POTASSIUM STATUS OF FOUR RICE GROWING SOILS
OF BANGLADESH

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Abstract

Soils of varying K status were selected at the BAU farm, Mymensingh and BADC farm, Madhupur for conducting laboratory, pot, and field experiments to see the dynamics of potassium in wet land rice soils. The soils were BAU-1(0.087 cmol/kg soil), BAU-2 (0.146 cmol/kg soil), Maddhupur-1 soil (0.097 cmol/kg soil), and Madhupur-2 soil (0.706 cmol/kg soil). Almost neutral silt loam soils (Sonatola series) of BAU firm developed on the recent alluvial deposits of Old Brahmaputra Flood Plain and the acidic clayey soils (Noadda and Kalma series) of BADC farm developed on Madhupur clay. The laboratory experiments were potassium release capacity of soils, Q/I relationships of potassium. Results of the experiments showed that BADC farm soils released more K than BAU farm soils. The Q/I relationship showed that the equilibrium exchangeable K (EK_0) and labile K (K_L) of Madhupur-2 soil were higher than other soils. The potential buffering capacity (PBC^K) was higher in BAU-2 (5.19±0.12 cmol/kg $(mol/L)^{1/2}$ soil followed by BAU-1 (4.07±0.09 cmol/kg $(mol/L)^{1/2}$) and then Madhupur-2 soil (2.23±0.04 cmol/kg $(mol/L)^{1/2}$). BAU farm soils adsorbed 55 to 60% of added K in non-exchangeable form, while it was 33 to 39% in BADC farm soils.

Keywords: K-release, soils, buffering capacity.

Introduction

The term potassium release refers to the replenishment of the readily available K removed either by crops or by chemical extractions (Zende, 1978). The release of potassium from the soil solution and its availability to plant has been studied in terms of activity ratio and Q/I relationships.

Potassium release behaviour of soils and establishing the relationships among various K release parameters would help draw appropriate K management strategy under intensive cropping. Soils with a texture from sandy loam to clay showed released rates approaching the net K out put, when not fertilized (Magnus *et al,* 2007). The threshold exchangeable potassium and the threshold K concentration become large when K content increases in the soil (Schneider, 2003). The K

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fixation and release were related to the composition of K-bearing minerals in soil. The K fixation in soils increased with increasing K application but the fixation rate decreased gradually. Illite was the main K-releasing mineral, whereas montmorillonite and vermiculite were the main K-fixing minerals (ShuXia *et al*., 2002). Mica dominates kaolinite and feldspars consequently release the highest quantities of K (Mittal *et al.,* 2000). Interlayer K release from silt and clay fractions are important for plant K nutrition and K fertilizer management (Rahmatullah and Mengel, 2000). Potassium release behaviour of untreated soils was strongly influenced by illite, vermiculite, and associated minor minerals but fixation of K in soil was negatively correlated with illite content and total potassium (Majumder and Datta, 1999). The K fixation and release behaviour of the soils could be related to their mineralogical make-up and 2:1 type of clays (vermiculite, hydrous mica, and smectite) fix K very readily and in large quantities (Brady and Ray, 2002). Accurate prediction of the available K supplied by soils of Bangladesh has long been a problem due to variable reserves of micaceous minerals (Moslehuddin and Egashira, 1999), which weather and release K at different rates. Q/I relationships is important to know the nature of K supply from sub surface soils, it also helps predict the buffering capacity of soil, which is important factor for crop production. Quantity factor, ΔK, and the intensity factor, AR^K, as proposed by Beckett (1964), give a better picture of the potash supplying power of the soil than either the so called 'available potassium or the ionic activity ratio of potassium'. Beckett (1964a) further proposed a new parameter, namely potential buffering capacity, PBC^K of soil with respect to potassium, combining in one parameter the quantity and intensity factors. The Q/I parameters provide useful information for understanding K^+ availability in calcareous soils and can be used for K^+ fertilizer recommendations (Mohsen, 2005).

Increased exchangeable K gives rise to increase in water soluble K, which would increase ARe^K but ARe^K had negative relation with PBC^K, pH, and Ca+Mg (Niranjana *et al.,* 2000). PBC^K and K potential showed significant positive correlation with clay, CEC, and available K (Basumatary, 1999). The soils rich in potassium exhibited higher equilibrium activity ratio (AR^K and potential buffering capacity but labile K ($-\Delta K°$) was less than NH_4OAC-K in soil. Higher available K, reserve K, and Q/I parameters in soil maintained adequate K supply to crops for longer periods and may not need K fertilization in future (Sharma *et al*., 1993). The equilibrium activity ratio (AR^K) in the soil solution can be used as a measure of K availability to plants and release of K increased with the decrease of activity ratio (AR^K) (Noor *et al.,* 1993).

The present experiment was conducted to determine the (i) K release capacity of soils and (ii) to know the Q/I relationship of K for soils.

Methodology

For this study, soils were collected from two locations, namely BAU farm, Mymensingh and BADC farm, Madhupur. Each location having two soils depending on their initial K status. These soils were BAU-1(0.087 cmol K/kg soil), BAU-2 (0.146 cmol K/kg soil), Madhupur-l (0.097 cmol K/kg soil), and Madhupur-2 (0.706 cmol K/kg soil) soils.

Potassium releasing capacities of soils

A portion of 500 g of each soil was treated with K at the rate of 50 mg K/kg soils from KC1, while another portion of 500 g soil was kept as control. Ten g of treated soil sample (previous) was taken in centrifuge tube in triplicate. Thirty mL of 1.0 M NH_4OAC solution was added to the soil, shaken for 30 minutes and then centrifuged for 10 minutes. After centrifugation, the aliquot was collected for K determination (first sample). The whole process was repeated for 10 times.

Quantity-Intensity (Q/I) relationships for potassium of soils

Potassium Q/I isotherms were constructed according to the modified procedure of Beckett (1964) described by Wang *et al.* (2004). Soil samples of 2.5 g were placed in 30 ml. centrifuge tube (pre-weighed) containing 25 mL of 0.01M C_aCl_2 solutions with KNO_3 concentrations of 0.0, 0.5, 1.0, 2.0, 3.5, and 5.0 mM. The prepared soil suspensions were shaken for 30 minutes allowed to equilibrate for 18 hrs and centrifuged. The supernatant solutions were collected and analyzed for K, Ca, Mg, and Na. After collection of supernatant solutions, the weight of each centrifuge tube with the remaining soil was recorded. Twenty five milliliter of 1.0 M NH_4OAC was added to each centrifuge tube, again shaked (30 minutes), centrifuged (10 minutes), and filtered. The concentration of K, Ca, and Na in the filtrate was determined by flame photometer and the concentration of Mg was determined by atomic absorption spectrophotometer (AAS).

The final exchangeable K (EK_f) for each equilibrium point was calculated based on 1.0 M NH_4OAC extraction at the end of contact of $CaCl_2$ with correction of interstitial solutions remaining in centrifuge tubes from weight differences (Wang *et al.*, 2004). Other parameters were measured as follows:

$\Delta K = (CK_i - CK_f) (v/w)$ ....(1)

Where ΔK is the change of K in solution, CK_i and CK_f are the initial (K concentrated added) and final equilibrium concentration K in solution, whereas v and w are the solution volume and soil mass, respectively. Positive ΔK values indicate K adsorption by the soil solid phase whereas negative values indicate K release from the soil phase into solution.

Potassium concentration ratio (CR) was used to describe the intensity of K in the presence of Ca and Mg (Wang *et al.*, 1988) as follows:

$$CR = \frac{CK_f}{(Ca_f + Mg_f)^{1/2}} \text{ ....} (2)$$

Where Ca_f and Mg_f are concentrations of Ca and Mg in final equilibrium solutions, respectively (Wang *et al.*, 1988). For the dilute solution (0.0IM $CaCl_2$), the activity coefficient is closer to unity; therefore, the concentration of the equilibrium solution was assumed as activity of these ions. According to Wang *et al.* (2004), ΔK was partitioned into changes in K due to the exchangeable pool (ΔExch K) and non-exchangeable pool (ΔNon-Exch K). Calculations of ΔExch K and Δ Non-Exch K were as follows:

ΔExch K (EK_f — EK_0) ....(3)

and

ΔNon-Exch K = ΔK — (EK_f — EK_0) ....(4)

Where EKo was the exchangeable K corresponding to $\Delta K = 0$, which was estimated from the linear regression equation of EK_f vs. ΔK. The change due to non-exchangeable K was calculated by difference between total amount of K adsorbed and the amount of K re-extracted by NH_4OAC.

This change in non-exchangeable K is considered short-term fixed K and changes in the amount of K adsorption or release by soil solids depend not only on the nature of soil solids, but also on the initial disequilibrium of soil solution K applied to the soil. The initial disequilibrium of soil solution applied to the soil can be described by Φ an initial constraint (Schneider, 1997), which is calculated:

$\Phi = (CK_i$ — $CK_O) (v/w)$ ....(5)

Where CK_0 is the initial concentration corresponding to $\Delta K = 0$, and CK_i v, and w have been defined previously.

Least squares regression equations, based on quadratic model ($\Delta K = \alpha_1 + \alpha_2 CR + \alpha_3 CR^2$), were used to describe the Q/I relationships between ΔK and CR (Wang *et al.,* 1988).

Results and Discussion

Potassium release: Potassium release in the first extraction was the highest, decreased gradually with successive extractions and finally stabilized after 5 to 7 extractions in all the tested soils (Fig. 1). The amount of K release increased with increase of added K in all the soils. The result is supported by the findings of ShuXia *et al.* (2002). The highest release of K (219 mg/kg soil) was exhibited in

1st extraction of Madhupur-2 soil and the lowest value was exerted (16 mg/kg) in BAU-l soil. In general, the amount of K release increased with increase of adsorbed K. In BAU- 1 soil, without K application, the amount of K decreased from 16 mg/kg soil, to 2 mg/kg soil at fourth extraction and then reached a value of I mg/kg soil but from sixth to tenth extractions, the release of K remained constant without K added. Receiving K application, the BAU-1 soil yielded 17 mg/kg soil which decreased to 2 mg/kg soil at sixth extraction and reached a value of I mg/kg soil in seventh extraction, but from eight to tenth extractions, release of K remained constant (0.6 mg/kg soil). The native K in BAU-2 soil was 23 mg/kg soil in the first extraction which decreased to 4 mg/kg soil at the fourth extraction and then reached a value of 2 mg/kg soil in fifth extraction but from sixth to seventh extractions, a stable value of 1 mg/kg soil was obtained. Application of K increased K release in BAU-2 soil to 27 mg/kg soil, which decreased to 6 mg/kg soil after sixth extraction and reached a value of 1 mg/kg soil in seventh extraction, but from eight to tenth extractions, the release of K remained constant with a value of 0.6 mg/kg soil. In Madhupur-I soil, the amount of released K gradually decreased up to fifth extraction but from sixth to tenth extractions, the release of K remained constant in no K receiving soil. Potassium application increased available K to 40 mg/kg soil in Madhupur-l soil, which decreased to 3 mg/kg soil at 5th extraction but from sixth to tenth extractions, the release of K remained constant (2 mg/kg soil). Madhupur-2 soil gave the highest K with I N NH_4OAC extraction, 156 mg/kg soil without K application and 219 mg/kg soil with K application. In case of K control treatment, Madhupur-2 soil gave 17 mg/kg soil up to fourth extraction but from sixth to eighth extractions, slow release occurred and then from ninth to tenth extractions the release of K remains almost constant. Receiving K fertilizer, Madhupur-2 soil released more K than K-control soil upto eighth extraction.

Quantity-Intensity (Q/l) relationships of potassium for soils: In BAU-1 soil (Fig. 2a), increase in total quantity of K (ΔKt) with the increase in K concentration ratio (CR) was explained by the equation ΔKt = -0.1087 + 1.9528 CR – 0.2262 CR^2 (R^2 = 0.99). Partitioning of the Q/I curve (Wang *et al.,* 2004; Jalali *et al.,* 2007) yielded changes in K due to exchange pool (ΔExch K) and non- exchange pool (ΔNon-Exch K). The relationship between ΔExch K and CR was explained by the polynomial equation, ΔK_{exch} = - 0.0736 + 0.9861 CR – 0.2088 CR^2 (R^2 = 0.998). The ΔExch K was related to CR as ΔK_{NE}= - 0.0351 + 0.9966 CR – 0.0174 CR^2 (R^2 = 0.975). Polynomial regression equation fitted well with the CR in exchangeable and non-exchangeable K pool as well as total change in K of the BAU-1 soil. Differentiation of the polynomial equations show that the increase in ΔK_t, $\Delta K_{exch,}$ and ΔK_{NE} would continue up to the CR value of 4.32, 2.36, and 27.78 (m Mol/L). Intercept of the Q/I relationship represent labile

K, which was 0.109 cmol/kg portion (0.074 cmol/kg) of which belong to the exchangeable pool and the rest (0.035 cmol/kg) in non-exchangeable pool.

In BAU-2 soil showed the regression equations of ΔK_t, ΔK_{exch}, and ΔK_{NE} with CR were as follows: $\Delta K_t = - 0.231 + 5.981\ CR – 0.704\ CR^2$ ($R^2 = 0.997$); $\Delta K_{exch} = - 0.049 + 1.167\ CR - 0.183\ CR^2$ ($R^2 = 0.997$) and $\Delta K_{NE} = -0.164 + 4.814\ CR – 0.520\ CR^2$ ($R^2 = 0.995$), respectively (Fig. 2b). The maximum CR value for adsorption of BAU-2 soil was 4.25, 3.19, and 4.63 $(mMol/L)^{1/2}$ for ΔK_t, ΔK_{exch}, and ΔK_{NE}, respectively. The labile K was 0.231 cmol/kg, a portion (0.049 cmol/kg) of which belongs to the exchangeable pool and the rest (0.164 cmol/kg) in non exchangeable pool (Fig. 3.l.3b). The proportion of labile K in exchangeable pool compared to non-exchangeable pool in BAU- 1 soil was higher than that of BAU-2 soil.
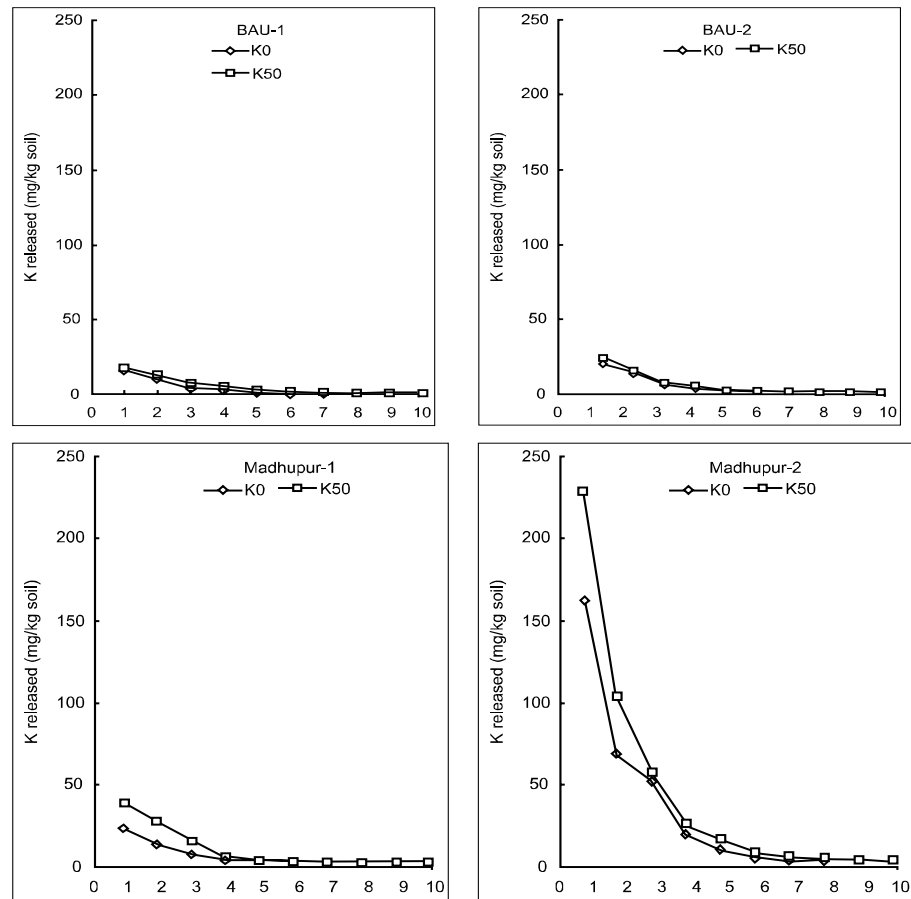

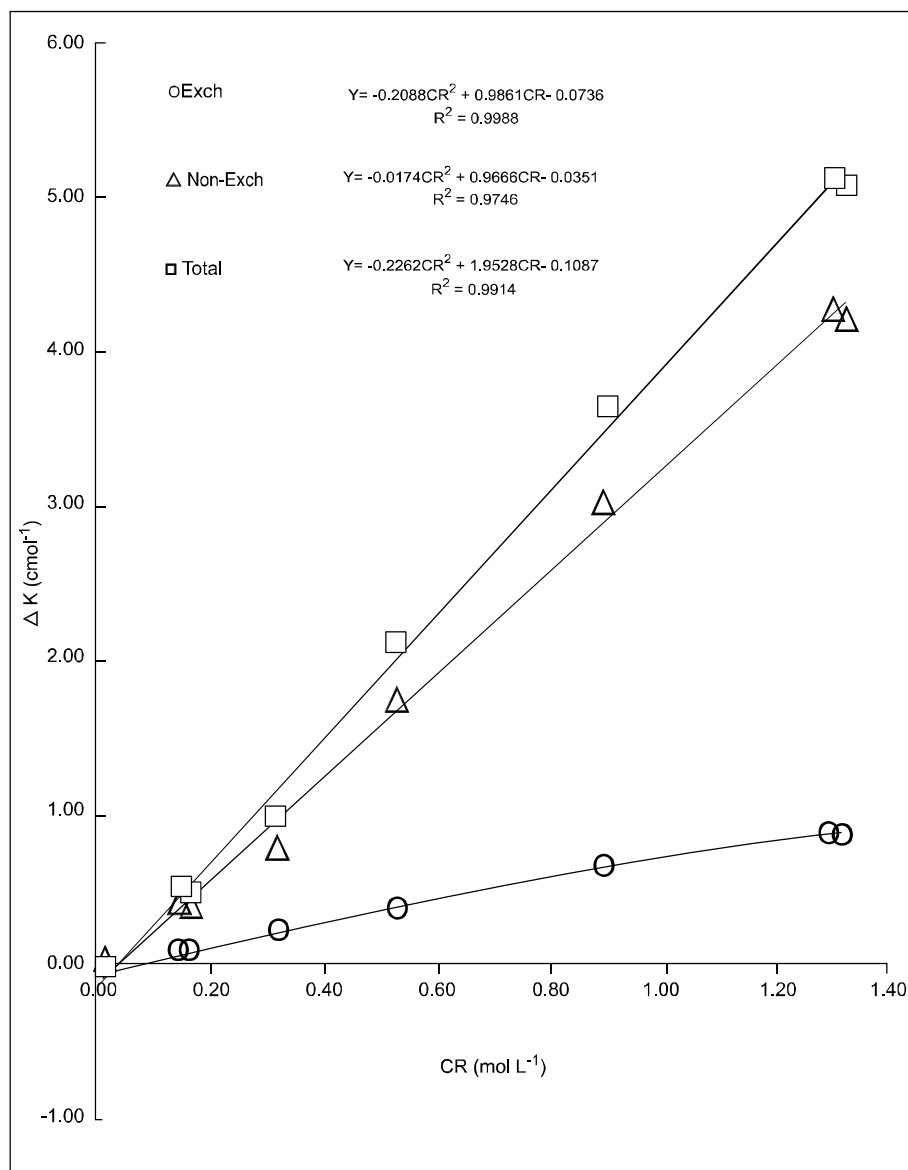Fig. 1. Potassium release from four soils by 1.0 M NH$_4$OAC extraction method.

Fig. 2(a). Partitioned quantity/intensity (Q/I) relationships for BAU 1 soil.

In Madhupur-1 soil (Fig. 2c), the regression equations of ΔK_t, ΔK_{exch} and ΔK_{NE} with CR were as follows: $\Delta K_t = -0.0075 + 0.6901$ CR -0.1322 CR^2 ($R^2 =$

0.974); ΔK_{exch} = - 0.0032 + 0.6421 CR – 0.0821 CR^2 (R^2 = 0.9676) and ΔK_{NE} = - 0.0043 + 0.0481 CR – 0.0501 CR^2 (R^2 = 0.956), respectively. The maximum CR value for adsorption of Madhupur-1 soil was 2.61, 3.91 and 0.48 $(mMol/L)^{1/2}$ for ΔK_{exch} and ΔK_{NE}, respectively. The labile K was 0.007 cmol/kg, a portion (0.003 cmol/kg) of which belongs to the exchangeable pool and the rest (0.004 cmol/kg) in non-exchangeable pool, respectively (Fig 3.1.3c). Results showed polynomial regression equation fitted well with the CR in exchangeable K and total change in K but not with non-exchangeable pool.
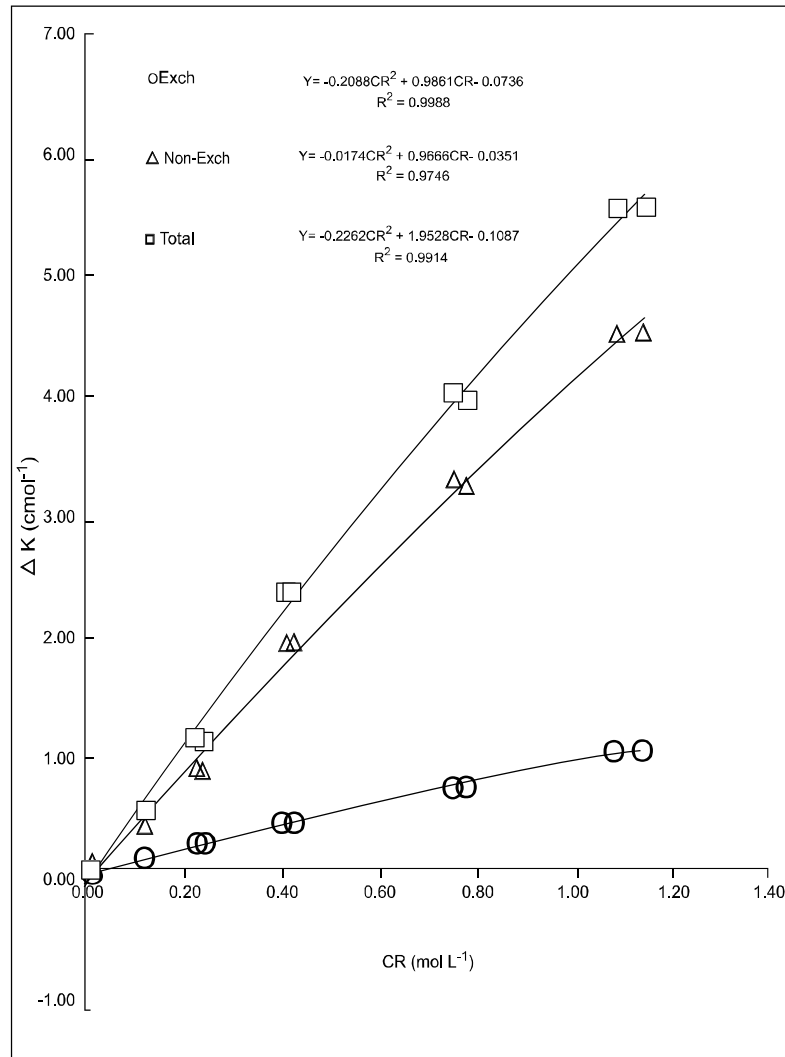

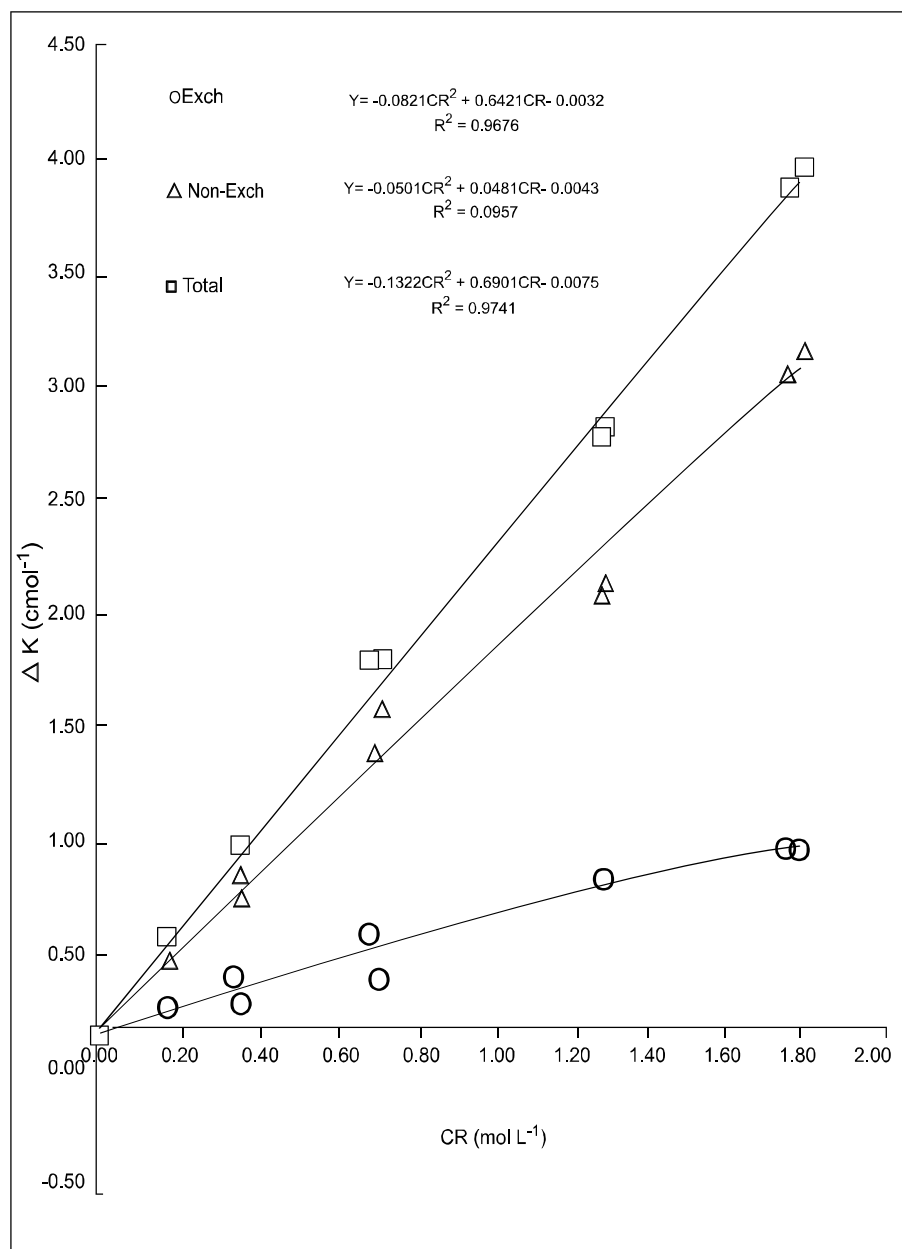Fig. 2(b). Partitioned quantity/intensity (Q/I) relationships for BAU 2 soil.

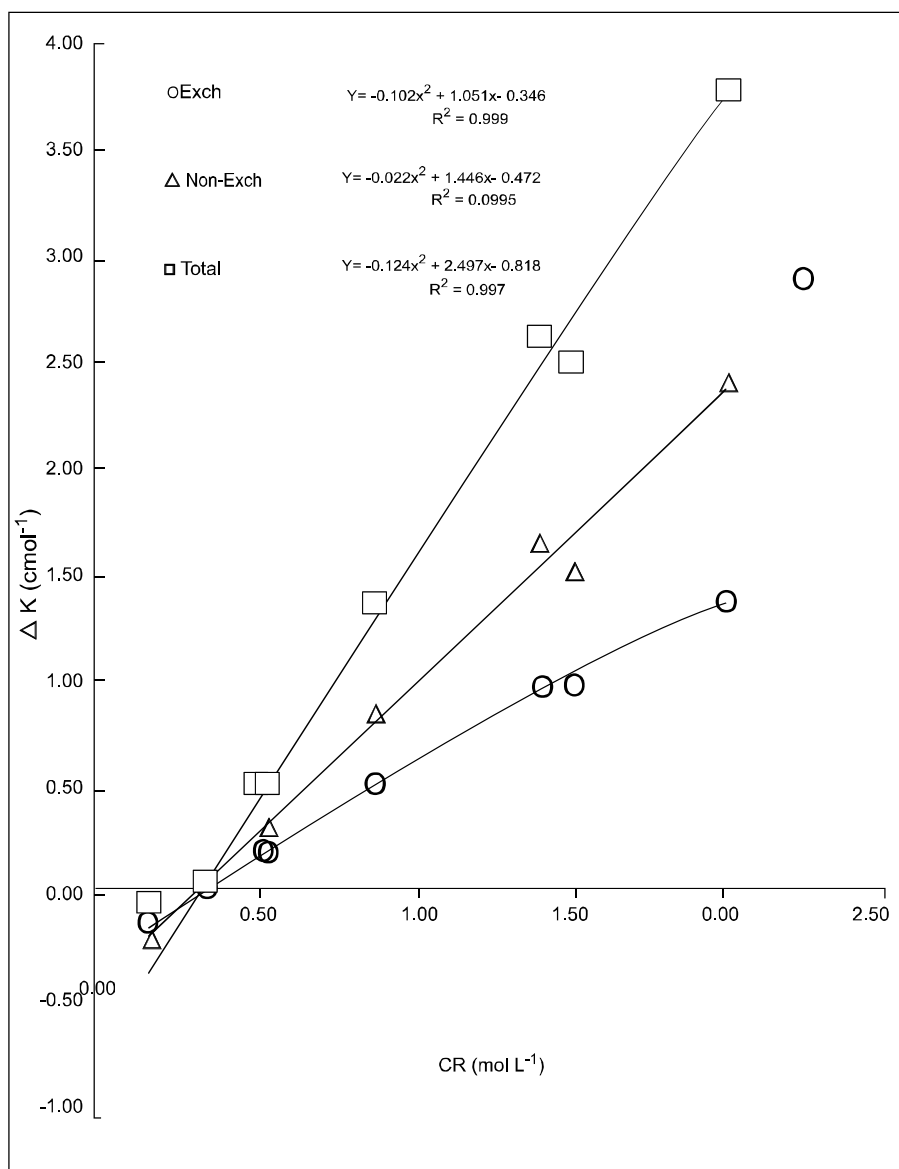Fig. 2(c). Partitioned quantity/intensity (Q/I) relationships for Madhupur 1 soil.

Fig. 2(d). Partitioned quantity/intensity (Q/I) relationships for Madhupur 2 soil.
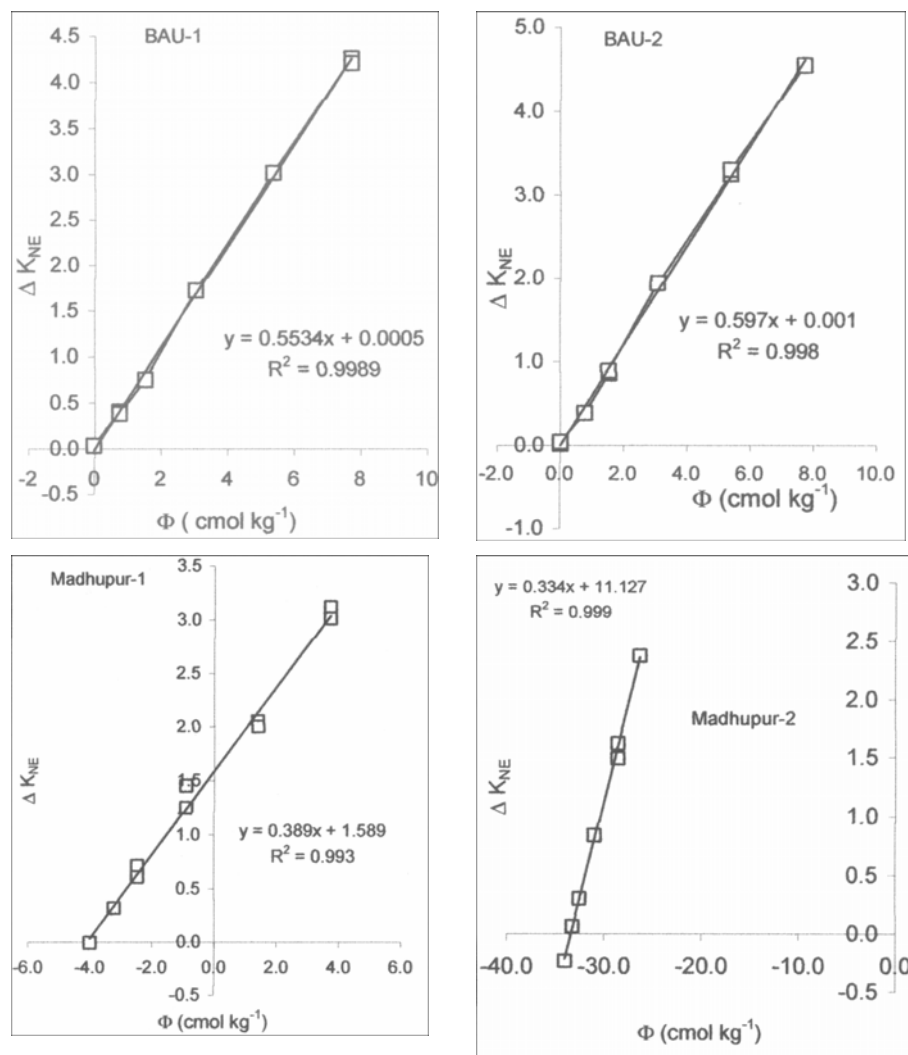
Fig. 3. Relationship between Φ and ΔK_{NE} for BAU and BADC farm soils.

Madhupur-2 soil exhibited the regression equations of ΔK_t, ΔK_{exch} and ΔK_{NE} with CR were as follows:

ΔK_t = - 0.818 + 2.497 CR – 0.124 CR^2 (R^2 = 0.997); ΔK_{exch} = - 0.346 + 1.051 CR – 0.102 CR^2 (R^2 = 0.999) and ΔK_{NE} = -0.472 + 1.446 CR – 0.022 CR^2 (R^2 = 0.995), respectively (Fig. 2d). The maximum CR value for adsorption of Madhupur-2 soil was 10.04, 5.15, and 32.86 (mMol/L)$^{1/2}$ for ΔK_t, ΔK_{exch} and ΔK_{NE}, respectively. Intercept of the Q/I relationship represent labile K, which

was 0.8 18 cmol/kg, a portion (0.346 cmol/kg) of which belong to the exchangeable pool and the rest (0.472 cmol/kg) in non-exchangeable pool. Result showed the polynomial equation fitted well with CR in exchangeable pool, non-exchangeable pool as well as total change in K of Madhupur-2 soil. (Fig. 2d). Madhupur-2 soil showed much strong total adsorption K than that of BAU-1, BAU-2, and Madhupur-1 soil as CR increased (Table 1). The maximum CR value to adsorb K for Madhupur-2 soil was 10.04 (mM/L, while it was 2.61 (mM/L$)^{1/2}$ in Madhupur-l, 4.25 (mM/L$)^{1/2}$ in BAU-2 and 4.32 (mM/L$)^{1/2}$ in BAU-1 soil. The quantity of ΔK in all soils due to exchangeable pools was less than due to non-exchangeable pools.

The critical CR when K desorption starts in BAU-l, BAU-2, Madhupur-1, and Madhupur-2 soil was 0.03, 0.019,0.01, and 0.33 (mM/L$)^{1/2}$, respectively.

The partitioning of Q/I curve was allowed to explicitly assess K changes associated with slowly available or non-exchangeable K. The amount of total K adsorbed or released (ΔK) during the experiment was partitioned into changes due to exchangeable K and non-exchangeable K. The changes due to exchangeable K were measured by reextracting the amount of K at end $CaCl_2$ contact of soil with 1 M NH_4OAC. One important parameter is potential buffering capacity (PBC^K), an indicator of soils buffering ability, was estimated from least square regression equations that described partitioning Q/I curves.

Table 1. Equilibrium exchangeable K (EK_0) and potential buffering capacity (PBC^K) of BAU and BADC farm soils.

Soils	EKo (cmol/kg)	PBC^K cmol/kg (mM/L$)^{1/2}$	Labile K cmol/kg	Maximum CR (mM/L)		
				ΔKt	ΔK_{exch}	ΔK_{NE}
BAU-1	0.113	4.07±0.09	0.109	4.32	2.36	27.78
BAU-2	0.145	5.19±0.12	0.213	4.25	3.19	4.63
Madhupur-1	0.07 1	2.22 ± 0.04	0.008	2.61	3.91	0.48
Madhupur-2	0.563	2.23 ± 0.04	0.818	10.04	5.15	32.86

Potential buffering capacity (PBC^K): The results of calculated buffering capacities of four soils are presented in the Table 1. The PBC^K were 4.07 ± 0.09, 5.19 ± 0.12, 2.22± 0.04, and 2.23 ± 0.04 cmol/kg (mM/L$)^{1/2}$ in BAU-1, BAU-2, Madhupur-l and Madhupur-2 soil, respectively. BAU-2 soil showed higher buffering capacity than that of other soils. High buffering capacity indicates low exchangeable K saturation and slow release of K.

Equilibrium exchangeable potassium (EK_0): The higher EKo value (0.563 emol/kg) was exhibited in Madhupur-2 soil and the lowest value was 0.071 cmol/kg in Madhupur-1 soil. The second highest (0.145 cmol/kg) was found in BAU-2 soil followed by BAU-1 soil (0.113 cmol/kg). The result indicates Madhupur-2 soil had high power of K release compared to other soils (Table 1).

Labile potassium (K_L): Table 1 illustrates the results of labile K of four soils obtained from partitioning Q/I curves through regression equations. The concentrations of labile K were 0.109, 0.213, 0.008, and 0.818 cmol/kg in BAU-1, BAU-2, Madhupur-1 and Madhupur-2 soil, respectively. The higher labile K (0.818 cmol/kg) was exhibited in Madhupur-2 soil. The higher levels of labile K indicate that higher loose bonded K^+ present in exchangeable site. The Madhupur-2 soil holds more exchangeable K than others.

Conversion of added potassium to non-exchangeable pool: Proportion of added K converted to the non-exchangeable K (NEK) was calculated from the linear relationship between initial disequilibrium of soil solution Φ and the change in ΔK_{NE} (Fig. 3). The slope (β) of the linear regression between Φ and ΔK_{NE} is the fraction of added K converted to the NEK pool (Schneider, 1997a). The value of slope (β) or soil ability for K^+ release or fixation were 0.55 ± 0.01, 0.60 ± 0.01, 0.39 ± 0.01, and 0.33 ± 00 in BAU-l, BAU-2, Madhupur-l and Madhupur-2 soil, respectively. These indicate that 55, 60, 39, and 33% of added K was converted to NEK for BAU-l, BAU-2, Madhupur-l and Madhupur-2 soil, respectively. The highest percentage (60%) of added K was converted to NEK in BAU-2 soil and the lowest was 33% in Madhupur-2 soil. Our results are in agreement with the fmdings of Sharma and Mishra (1989) and Noor *et al.* (1993).

Conclusion

BADC farm soil released more K than BAU farm soil. In BAU farm, 55-60% added K converted in non-exchangeable form, while it was 33-39% in BADC farm. BAU farm soil exhibited more buffering capacity than BADC farm soil. So, BADC farm soils need more fertilization than BAU farm.

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