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Full Length Research Article

Potassium Quantity / Intensity Relationship of Soils in Manimutha Nadhi Watershed, India

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ABSTRACT

This work was aimed to study the potassium quantity/intensity potential of the Manimuktha Nadhi watershed, Kallakurichi district, Tamil Nadu. A total 14 samples were collected randomly and it spread over the study area. For studying Q/I relationship of the soil, 0, 50, 100, 200, 300, 400, and 500 ppm K solution is prepared by using 0.01 M $CaCl_2$ solution. The results revealed that the equilibrium activity ratio of potassium ranged from 0.59×10^{-3} to 21.31(mol $L^{-1})^{0.5}$. Most of the soil sample, $AR_e k$ is less than 2×10^{-3}(mol $L^{-1})^{0.5}$ indicating that K depletion was occur due to continuous and injudicious mining of K in the study area. The potassium buffering capacity of the soil ranged between 7.99 and 38.31 cmol kg^{-1}/ (mol $L^{-1})^{0.5}$ the Labile K (KL) values ranged from 0.14 to 0.625 cmol kg^{-1}. The results indicated that the soil in the study area needed the continuous K application for sustainable crop field.

***Key words*:** K quantity –intensity relationship, PBC, Equilibrium activity ratio, Labile K

Potassium is an essential element to crop along with N and P. In the last four decades, agricultural production in India has risen four times. A high-intensity cropping system can cause soil K pool depletion. The adoption of high-yielding modern crop varieties extracted more K from the soil than conventional crops, followed by the green revolution [1]. Every year, negative K balance results in depleted soil K status in all Asian soils [2]. The Q/I relation of soil describes the relation between K^+ availability or intensity (I) in the soil to the amount (Q) present in the soil, that is, changes of K sorbed to changes of K+ in solution concentration [3]. The potassium content in soil depends mainly on the type and degree of soil weathering and the forms in which it exists in the soil [4]. Hence the K^+ availability in the soil solution (intensity) and the inherent capacity of the soil to buffer this concentration against changes are among the important parameters that determine the effective availability of K to plants [5-6]. In some cases, even though the soil contains a considerable amount of total K, the availability to plants is negligible. This is because the availability of K^+ to plants depends not only on its availability but also on its dynamics viz., intensity, capacity, and renewal rate in soils. At this junction, the equilibrium constants are vital for predicting the status and supply of K for plants [7]. Potassium potential is one of the intensive characteristics of soil potassium dynamics which describes the intensity of potassium release from the soil solid phase into the soil solution [8].

Methods for evaluating the availability of K^+ in agricultural soil are of increasing importance for the development of sound guidelines for K-based management strategies [9]. Potassium Q/I relationships can be used to forecast K^+ for higher yield as well as recognize, characterize, and assess the K^+ status in soil [10]. Potassium Q/I relationships explain the availability, reserve, and replenishment of K in the soil in terms of intensity factor, quantity factor, and buffering capacity [11]. In light of this, the present study planned to find out the potassium quantity and intensity relationship of soils of Manimutha Nadhi watershed of Kallakurichi district, Tamil Nadu.

MATERIALS AND METHODS

The study area Manimutha Nadhi watershed is situated in the eastern part of Tamil Nadu and it lies with the latitude of 11° 28' to 11° 42' N and 79° 14' to 79° 27'E and it occupies an area of 263.74 km^2 (Fig 1). The study area receives high rainfall during the northeast monsoon (50%) followed by southwest monsoon (39%), remaining was occupied by the summer shower. The study area is covered with basic and ultrabasic intrusive and extrusive igneous rocks and metamorphic crystalline rocks.

Soil sampling and analysis

A total of 14 surface soils (0-15cm) were taken from each location, soil samples were air-dried, ground, and passed through a 2mm sieve. Soil pH as determined by soil: water ratio at 1:2.5 and soil: Available K content was analyzed using

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Neutral normal ammonium acetate method [12] EC was analyzed by conductivity bridge method at 1:2.5 soil: water ratio [13]. The cation exchange capacity of the soil was determined by the 1N neutral ammonium acetate method [14]. Organic carbon was determined by the wet oxidation method [15]. The particle size of the soil was determined by the hydrometer method [16].

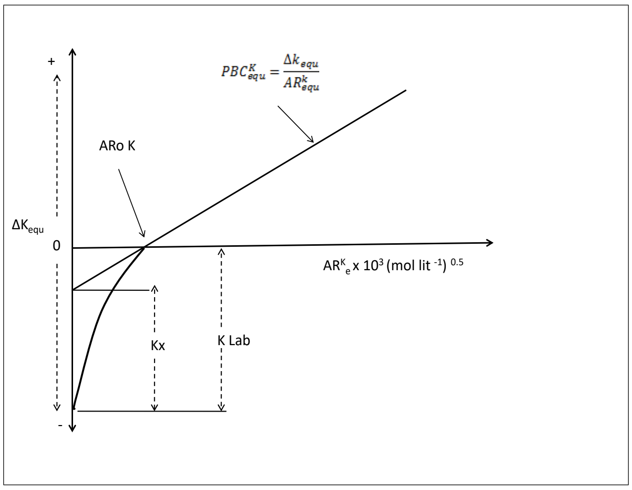

Fig 1 Typical quantity- Intensity isotherms – of potassium

Quantity of intensity relationship of potassium

The quantity intensity relationship of rice growing soils of Kallakurichi district was determined by the following procedure as outlined by Beckett [17]. Five grams of air-dried soil were placed in the 100 ml centrifuge tube containing 50 ml of 0.01M $CaCl_2$ with potassium dihydrogen phosphate (KH_2PO_4) of 0,50, 100, 200, 300, 400, and 500 mg ppm as K. The soil suspension was shaken for 1 h and allowed to 24 h for equilibrium. After collecting the supernatant solution was analyzed for K by flame photometer and Ca and Mg were analyzed by versanate titration method [13]. EC of the supernatant was determined by the conductivity bridge method for calculating the ionic strength [13]. The gain or loss of K+ (ΔK) by the solution during the equilibrium period was calculated from the difference between the concentration of K^+ in the initial (CKi) and final (CKf) in equilibrated solutions

$$\Delta K = (CK_i - CK_f) \times \frac{V}{W}$$

Where;
V and M are the solution volume and soil mass respectively.

Concentration ratio (CR_k) of potassium was determined by the following equation:

$$Concentration ratio(CRk) = \frac{CKf}{(CCaf + CMgf)^{\wedge}0.5}$$

Where;
CCaf and CMgf are the concentration of Ca^{2+} and Mg^{2+} in the field equilibrium solution respectively. The activity ratio was calculated as follows:

$$\text{Activity ratio } (AR_k) = CRk. \frac{fk}{\sqrt{f[Ca+Mg]}}$$

Where; $\frac{fk}{\sqrt{f[Ca+Mg]}}$ is the activity coefficient ratio. The activity coefficient ratio was obtained by the relationship

$$\text{Log } f = \frac{0.509Z^2 I^{\frac{1}{2}}}{1+1.5I^{\frac{1}{2}}}$$

Where Z and I are the valency and ionic strength of the particular cations respectively. The Ark values were plotted against the gain or loss of K (ΔK) to form a characteristic Q/I curve. Using the Q/I curve following parameters were calculated. ARek (activity ratio at equilibrium), ΔK° (K on nonspecific adding sites), PBCk (potential buffering capacity of potassium), KX (specific K sites), and KL (labile potassium by adding Kx and ΔK°). When the ΔK is equal to zero, ARek is called as equilibrium activity ratio (ARek). The values of ΔK, when the ARk =0 is called as exchangeable K in the soil (ΔK° or K on non-exchangeable sites). The slope of the curve at Δthe K=0 portion of the curve gives the potential buffering capacity (PBCk--). The number of specific sites for K (Kx) is the difference between the intercept of the curved and linear portion of the Q/I plot at ARk=0. A correlation coefficient was worked out between the Q/I parameter and soil properties.

RESULTS AND DISCUSSION

Soil properties

The selected chemical and physical properties of soil samples from the Manimutha Nadhi watershed are presented in (Table 1). The pH and EC varied from 6.7 to 8.7 and 0.3 to 0.5 (dSm^{-1}) respectively. The organic carbon content was low to medium and ranged between 2.4 and 7.7 with the mean value of 5.1 (g/ kg^{-1}). The CEC exchange capacity of the soil varied between 11 and 17 with the mean value of 13(cmol (P^+) kg^{-1}). Most of the Manimutha Nadhi watershed soils are texturally classified as sandy clay loam followed by sandy loam, sandy clay, and clay.

Table 1 Physico-chemical properties of soils of Manimutha Nadhi watershed

Sample No.	Village name	pH	EC (dS m^{-1})	OC (g kg^{-1})	CEC (cmol (P+) kg^{-1})	Sand	Silt	Clay	Textural class
S7	Arasampattu	6.7	0.5	0.38	15	54.4	6	39.6	Sandy clay
S9	Seshasamuthram	8.5	0.6	0.43	11	56.4	8	35.6	Sandy clay
S12	Cholampattu	8.7	0.8	0.61	12	53.2	16	30.2	Sandy clay loam
S13	Sankarapuram	7.7	0.7	0.77	16	65.8	20	14.2	Sandy loam
S14	Palayapalapattu	7.4	0.3	0.47	12	67.8	8	24.2	Sandy clay loam
S17	Kuchi kaadu	6.4	0.4	0.54	11	75.8	6	18.2	Sandy loam
S19	Paramanatham	6.8	0.5	0.77	14	64.4	12	23.6	Sandy clay loam
S21	Semapalayam	7.6	0.3	0.47	12	63.8	12	24.2	Sandy clay loam
S26	Semparampattu	6.7	0.4	0.49	11	45.8	20	34.2	Sandy clay loam
S28	Puttai	6.7	0.5	0.24	17	45.8	20	34.2	Sandy clay loam
S30	Puttai	6.4	0.3	0.29	16	75.8	12	12.2	Sandy Loam
S32	Murarpalayam	7.4	0.5	0.52	15	51	18.8	30.2	Sandy clay loam
S34	Puttai	6.8	0.3	0.61	12	43.8	16	40.2	Clay
S50	Vadasetiyandhal	6.9	0.3	0.61	11	49.8	16	34.2	Sandy clay loam
	Mean		0.4	0.51	13				

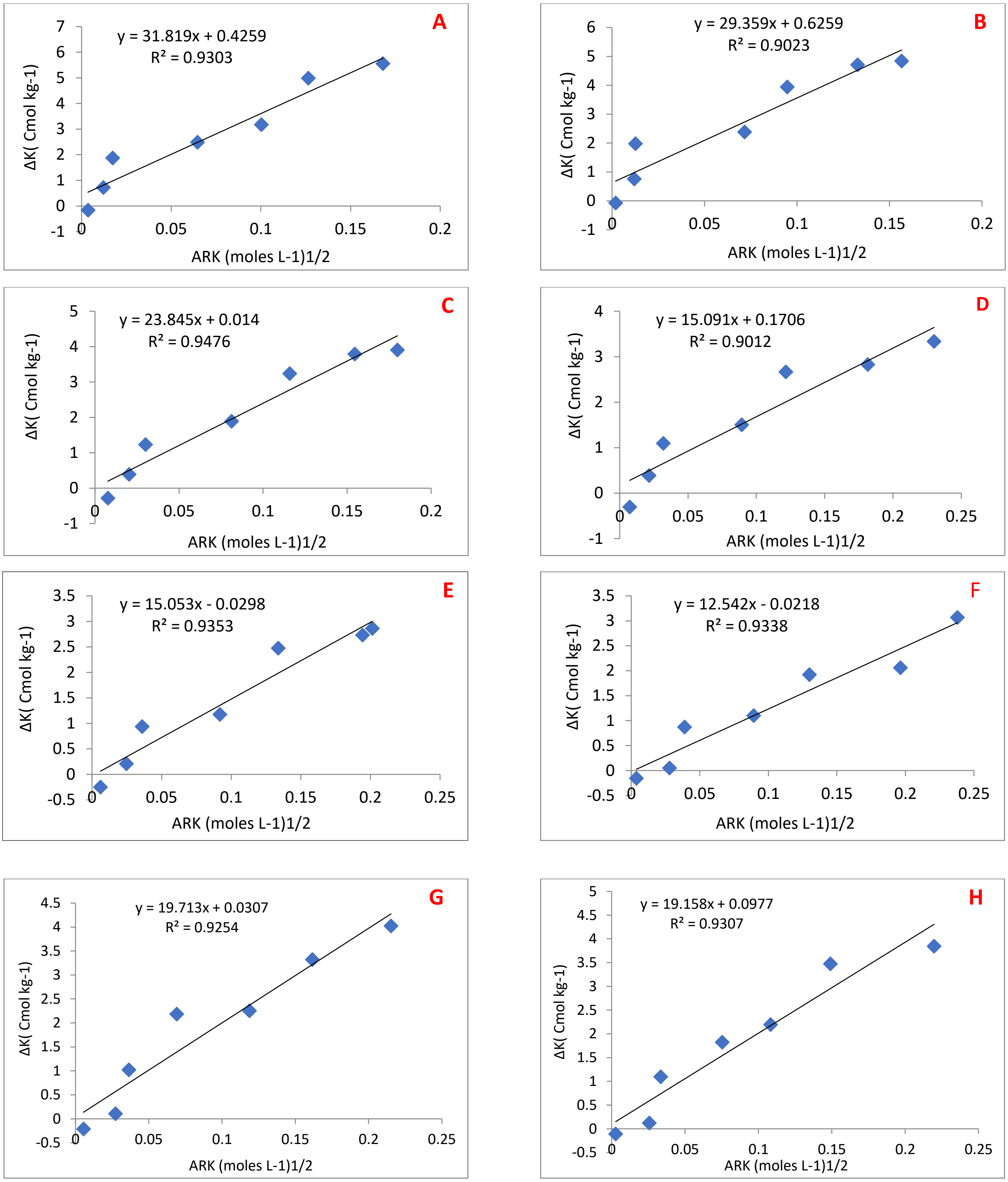

Fig 2 Q/I Isotherms of soils of Manimutha Nadhi watershed (A-H)

Potassium Q/I Relationship

Potassium Q/I relationship parameters were calculated from Q/I curves and presented in (Table 3).

Equilibrium activity ratio of K (AR_{eK})

The ARek values are the status of immediately available K [18]. The potassium equilibrium activity ratio (AReK) in the Manimutha Nadhi watershed ranged from 0.59 and 21.31 (cmol kg^{-1}/mol L^{-1}) with the mean value of 7.9.(cmol kg^{-1}/mol L^{-1}) the Cholampattu (S12) recorded the greatest value of the lowest value was recorded at Seshasamuthram (S9). In general, about 35% of the soil samples in the study area had less AReK value (< 2× 10-3 $molL^{-1}$) 0.5. This could indicate potassium depletion occurs due to continuous K mining in the study area, about 35% of the soil were high AReK value may be attributed by recent K fertilization or soil under frightful weathering. Ferges *et al.* [19] suggested that AReK of (< 2× 10-3 $molL^{-7}$) 0.5 only will give a satisfactory yield of 90% of the maximum value of AReK explains the greater potassium ion strength in the solution could attribute the instant higher K availability [20] presence of illite and smectite reduced the magnitude of equilibrium concentration ratio, whereas in soil dominated with kaolin, it would be increased [21].

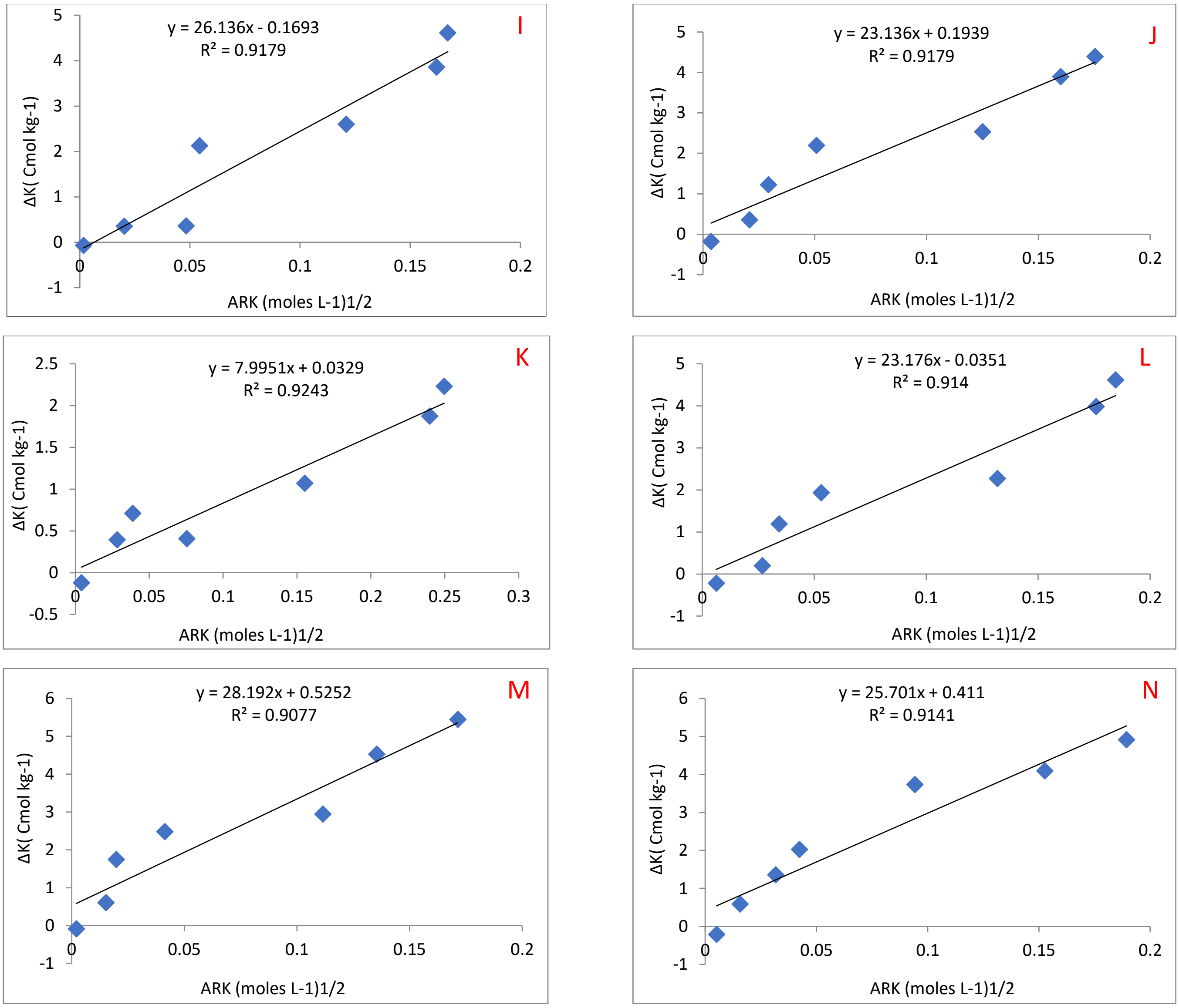

Fig 3 Q/I Isotherms of soils of Manimutha Nadhi watershed (I-N)

Table 2 Quantity –intensity relationship of soils in Manimutha Nadhi watershed

Sample No.	Activity ratio at equilibrium (AR_e^k) × 10^{-3} cmol kg^{-1}/mol L^{-1}	Labile potassium (K_L) cmol kg^{-1}	K on nonspecific adding sites (ΔK_O) (cmol kg^{-1})	Specific K sites (K_x) cmol kg^{-1}	Potential buffering capacity (PBC_K) cmol kg^{-1} /mol L^{-1}
S7	13.38	0.86	0.43	0.43	31.82
S9	21.31	0.86	0.63	0.23	29.36
S12	0.59	0.45	0.14	0.31	23.85
S13	11.3	0.34	0.17	0.17	15.1
S14	1.98	0.24	0.03	0.21	15.1
S17	1.73	0.25	0.02	0.23	12.54
S19	1.56	0.31	0.03	0.28	19.71
S21	5	0.46	0.10	0.36	19.16
S26	6.47	0.34	0.17	0.17	26.13
S28	8.38	0.51	0.19	0.32	23.14
S30	4.1	0.24	0.03	0.21	7.99
S32	1.51	0.27	0.04	0.23	23.18
S34	18.6	0.25	0.05	0.20	28.19
S50	15.99	0.31	0.04	0.27	25.7
Mean	7.90	0.406	0.147	0.43	21.49

Potential buffering capacity of potassium (PBC_K)

Potential buffering capacity is a measure of the ability of a soil to maintain a given K and this suggests that in a higher range the soils would be able to maintain a relatively higher activity ratio of the soil K when there is any K stress, whereas the lower value would be susceptible to rapid changes in the AReK, signifying frequent K fertilization [22]. The potential buffering capacity of potassium of the soil is the ability of the soil to maintain a given AReK when increased or decreased ΔK. The PBCK of Manimutha Nadhi watershed soil ranged from 7.99 to 31.82 cmol kg^{-1}/ mol L^{-1} with the mean value of 21.49 cmol kg^{-1}/ mol L^{-1}. The least PBC K value was observed at

Puttai (S30), whereas a high value was recorded at Arasampattu (S7). But all the soil has no greater values (C> 100 cmol kg^{-1}/ mol L^{-1}) which indicate low K depletion or low specific and non-specific sites are found in the soil. Arnold [23] explained the soils with greater PBCK value having low K saturation level indicate greater potential to replenish K concentration in soil solution.

Potassium on nonspecific sites (ΔK_0)

The linear portion of the curve has been described to non-specific sites for K [21], and these non-specific sites have been attributed to planer surfaces [22], The ΔK0 values for Manimutha Nadhi watershed ranged from 0.02 to 0.63 with the mean value of 0.147 cmol kg^{-1}, About 50% of the Manimutha Nadhi watershed soils had less than 0.1 cmol kg^{-1}, 50% of the Manimutha Nadhi watershed soils had ΔK0 values of less than 0.1 cmol kg^{-1} Leroux and Samner [23] noted that ΔK0 was the better estimate of soil exchangeable K than normal exchange K. This will indicate most of the soils had low K release capacity into the soil solution, which result in a less pool of labile K. The lower value in (0.02 cmol kg^{-1}) indicates it had a strong ability to absorb K. The contents of both easily exchangeable and labile potassium (ΔK0 and –KL, respectively) are also high in soil properties.

Labile K (K_L)

The labile K (KL) of soils in Manimutha Nadhi watershed 0.24 to 0.86 cmol Kg^{-1}. The labile K represents the amount of K that is capable of ion-exchange during the period of equilibration between soil solids and soil solution. Most of the samples in the study area have high KL values which indicate the greater value of K^+ released in the soil solution. This may be due to similar size of K^+ and $NH4^+$ ions leading to extraction of K^+ ions, which are in specific sites [24]. The labile K represents the amount of K capable of ion-exchange during the equilibrium between soil solids and solution. The total amount of K in the labile pool ranged from 0.0062 to 0.348 cmol (p^+) kg-1in soil. The higher levels of labile K indicate a higher amount of loosely bonded K^+ ions present in the exchangeable site. The lower amount of labile K in soils is due to the more retention of K because of the presence of the nature of clay minerals.

Table 3 Correlation coefficient between soil physic chemical properties and Q/I parameters of Manimutha Nadhi watershed

	pH	EC	OC	CEC	Sand	Silt	Clay
ARek	0.092	-0.040	-0.040	-0.151	-0.442*	-0.01	0.545
KL	0.364*	0.395	-0.352*	0.0351*	-0.245*	-0.345	0.493*
ΔK°	0.420*	0.429*	-0.295	-0.030	-0.236	-0.273	0.443*
Kx	0.030	0.096	-0.293*	0.170	-0.129	-0.325*	0.340*
PBCK	0.232*	0.203	-0.017	-0.238	-0.843	0.105	0.951

K-Labile K; PBC- Potential buffering capacity; K_X- K adsorbed on specific sites; ARk- Activity ratio at equilibrium and (K_L) - Labile Potassium
*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

K held at specific sites (Kx)

Potassium held on specific sites (Kx) in the soil of the Manimutha Nadhi watershed ranged from 0.17 c mol kg^{-1} to 0.43 c mol kg^{-1} with the mean value of 0.43 c mol kg^{-1}, least value was recorded at Sankarapuram (S13) and Semparampattu (S26) samples value depends on the type of the clay minerals present in the soil sample. In soils having clay minerals with more specific K sites, the amount of Kx is high, indicating that a significant amount of K was absorbed on the high-energy sites [25]. The curved portion of the Q/I curve has been attributed to specific sites with high K affinity [26]. Potassium held on K-specific sites (KX) in soils ranged from 0.002 to 0.712cmol kg^{-1} of soil with a mean value of 0.19 cmol kg^{-1} of soil (Table 2). Rich [27] has ascribed the specific sites to edges of clay crystal sand to wedge sites of weathered mica. The variation in K held on specific sites (KX) in soils may be due to the nature and quantity of clay minerals present in these soils [28].

Correlation

There was a positive correlation was observed between pH having KL (0.364*) and ΔK0 (0.420**). It is because increased available potassium saturation gives rise to an increase in pH. The EC value of soil had a positive correlation with KL (0.395*) and ΔK0 (0.429). The sand content negatively correlated with PBCK (-0.843*). The clay content positively correlates with KL (0.493*) and ΔK0 (0.443*) Soils with higher clay content have higher exchange surface offered selective or specific binding sites for K compared to other soils which were light in texture [29].

Table 4 Correlation coefficient between Q/I parameters

Q/I Parameters	AReK	K_L	K_0	K_X	PBC
AReK	1.000				
KL	0.503	1.000			
K0	0.605*	0.940**	1.000		
KX	-0.014	0.590*	0.279	1.000	
PBC	0.599*	0.621*	0.582*	0.370	1.000

K-Labile K; PBC- Potential buffering capacity; K_X- K adsorbed on specific sites; ARk- Activity ratio at equilibrium and (K_L) - Labile Potassium
*Correlation is significant at the 0.05 level (2-tailed); **Correlation is significant at the 0.01 level (2-tailed)

CONCLUSION

In the current study, soils of the Manuimutha Nadhi watershed displayed medium PBCk, high labile k and Low ΔK° according to Q/I studies. The present investigation revealed that soils had a limited efficiency to fix K, a greater capability to buffer implemented K fertilizer and release K fertilizer in a manner that was appropriate for the soil. The findings also suggest that rather than K fixation, the reduced k fertility status of these soils is due to nutrient mining as a result of overuse of the soil. As a result, external implementation of K fertilizer would be necessary to keep these soils efficient and productive. From this study, we can plan the K-fertility management strategies of Manuimutha Nadhi watershed.

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