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CHARACTERIZATION OF SOILS IN THE TEA GROWING REGIONS OF SRI LANKA IN RELATION TO POTASSIUM DYNAMICS

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Soils from the six tea growing regions of Sri Lanka namely Ratnapura, Hantane, Talawakelle, Kottawa, Deniyaya and Passara under different agro ecological regions were collected for this study, and quantity (Q) and intensity (I) measurements have been used as a tool for characterization.

Tea soils used could be characterized into two main groups according to their Potential Buffering Capacities of K (PBC^k). First group consisting of higher PBC^k values having constant availability of K over a longer period and second group having lower PBC^k values which need frequent fertilizations. Sub-divisions of soils were also suggested related to presence of K-specific-sites, available K as well.

Q/I isotherms indicated the presence of some specific sites for K ions in Ratnapura, Hantane and Talawakelle as against the other 3 soils.

Finally soils in the tea growing regions were characterized into five groups according to their K dynamics. It is worthy to consider these groupings also in arriving at K-recommendations for tea in Sri Lanka.

INTRODUCTION

Nutrient availability depends on the nutrients concentration of the soil solution at any given time, but also on the ability of the soil to maintain its nutrient concentration. This capability of a soil to buffer the nutrient concentration of the soil solution is an important factor, as far as nutrient availability is concerned. Therefore, two nutrient components in the soil can be distinguished. The quantity factor (Q) represents the amount of available nutrients, whereas the intensity factor (I) reflects the strength of retention by which the nutrient is held in the soil. Simply, the intensity factor is the concentration of the nutrients in the solution.

The concept of nutrient intensity and quantity was first proposed by Schofield and Tayler (1955). Beckett (1964a, b) suggested that the intensity of a nutrient in soil at equilibrium with its soil solution should be considered as the activity ratio (AR). Where, AR^k is the activity ratio of K and $a_K{}^+$, $a_{Ca}{}^{2+}$, $a_{Mg}{}^{2+}$ are activities of K^+, Ca^{2+} and Mg^{2+} respectively.

$$AR^k = \frac{a_K{}^+}{(a_{Ca}{}^{2+} + a_{Mg}{}^{2+})^{1/2}}$$

This, AR^k has often been used as a measure of K^+ availability. Tinker (1964) pointed out for acid soils, Al^{3+} should also be considered instead of Ca^{2+} and Mg^{2+}, as Al^{3+} is a dominant ion in acid soils. Hence, activity ratio is expressed as follows, where $a_{Al}{}^{3+}$ is the activity of Al^{3+}.

$$AR^k = \frac{a_K{}^+}{(a_{Al}{}^{3+})^{1/3}}$$

However, for acid soils that have received dolomitic limestone for a long period, combination of the activities of Ca^{2+}, Mg^{2+} and Al^{3+} is more appropriate (Tinker, 1964).

$$AR^k = \frac{a_K{}^+}{(a_{Ca}{}^{2+} + a_{Mg}{}^{2+})^{1/2} + (a_{Al}{}^{3+})^{1/3}}$$

For construction of a typical Q/I curve, a soil should be equilibrated with solutions containing a constant amounts of $AlCl_3$ and increasing amounts of KCl (Tinker, 1964). Soil gains and losses of K to achieve its characteristic AR^k value, or remains unchanged if its AR^k values are same as the equilibrating solution. The AR^k values should then be plotted viz. the gain or loss of K (ΔK) to form the characteristic Q/I curve (Fig. 1). From the Q/I plot, several parameters can be obtained in order to characterize the K status of the soil.

The AR^k value, when the Q factor or ΔK equals to zero is a measure of the degree of K^+ availability at equilibrium, or AR^k_e. Successive cropping decreases AR^k_e values until a constant value is reached (Le Roux, 1966). AR^k_e does not show capacity of a soil to release K^+ to plants, as soils can have the same AR^k_e value but contain different amount of labile K.

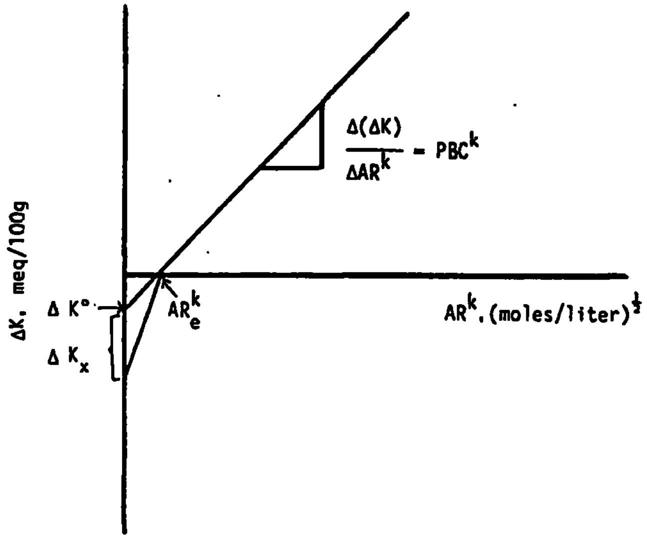


Fig. 1: *Typical quantity/intensity (Q/I) plot (Sparks and Liebhardt, 1981)*

The value of ΔK when $AR^k = 0$ is a measure of labile or exchangeable K in soils (ΔK°). Le Roux (1966) noted that ΔK° was a better estimate of soil labile K than normal exchangeable K. He found that higher values of labile K (ΔK °) indicated a greater K^+ release into soil solution. Sparks and Liebhardt (1981) found that the values of ΔK° compared favorably with NH_4OAC-extractable K in the Ap horizon of a Kalmia soil. ΔK° was poorly correlated with plant K uptake by the regression.

The slope of the linear portion of the curve gives the Potential Buffering Capacity (PBC^k), and indicates the ability of a soil to maintain the intensity of K^+ in the soil solution and is proportional to cation exchange capacity (C.E.C) (Lee, 1973). Le Roux (1966) noted that a high value of (PBC^k) is indicative of constant availability of K in the soil over a long period of time, whereas a low (PBC^k) soil would suggest the need for frequent fertilization.

The number of specific sites for K (K_x) is the difference between the intercept of curved and linear portion of the Q/I plot at $AR^k = 0$ (Beckett, 1964b). Sparks and Liebhardt (1981) found that K_x values in soils tend to increase with increasing K fertilization and liming.

The present fertilizer recommendation in the tea plantations in Sri Lanka is mainly based on crop removal but K dynamics of respective soils are not taken into account. (Anon, 2000). Thus regional specific fertilizer recommendations may be needed to improve the efficiency of soil applied K. For development of such procedure, it is absolutely necessary to understand the K dynamics of respective soils. Therefore, the main objective of this study was to characterize the soils in the tea growing areas in relation to K dynamics.

MATERIALS AND METHODS

Sampling procedure

Six tea growing regions were selected to represent a range of clay mineralogy expected to affect cation release and from each region one tea estate were selected randomly for sampling. The description related to the soils, are given in Table 1. From each estate one field were selected randomly for sampling and from each field 40 - 50 cores were collected from depth 0-15cm and 15-30cm separately by using post-hole auger. After compositing the collected soils from each field, small portion was taken to provide a sub sample of half kilogram. The soil sampling were done after a minimum period of six weeks following the last application of fertilizer. The moist soils were air dried and passed through a 2mm sieve prior to analysis.

Table 1: Description of the soil used

Location	Great soil group	Soil series	Clay mineralogy*	Clay %	Organic carbon %	Exch.K (mg/kg)	Exch. Al (mg/kg)
Hantane	R.B.L	Kandy	k/hl¶ m‡ gb†q†go†	33	1.69	88	241
Talawakelle	R.Y.P	Mattakelle	v/c¶ k/hl‡ gb†q†go† k-f† p-f†	28	3.58	116	407
Ratnapura	R.Y.P	Malaboda	k/hl¶ v/c‡ gh†q†go† p-f†	22	1.25	62	161
Kottawa	R.Y.P	Dodangoda	k/hl¶ v/c‡ gh‡q†	17	1.33	60	166
Deniyaya	R.Y.P	Weddagala	k/hl¶ v/c‡ gh†q†go†	34	1.50	68	101
Passara	R.Y.P	Mahawalatenna	k/hl¶ v/c‡ gh†q†go† k-f† p-f†	22	1.29	65	169

R.B.L- Reddish Brown Latasolic soil
R.Y.P- Red Yellow Podzolic soil
v/c-Vermiculite/Chlorite, k/hl-Kaolinite/Hollosite, m-Mica, go-Goethite, q-Quartz, gh-gibbsite, k-f-Potassium feldspar, p-f-Plagioclase feldspar
¶-Dominant ‡- Abundant or co dominant †-Sub ordinate
* Wimaladasa (1989)

Analytical procedure

Q/I – relationship using 0.01M $AlCl_3$, as the equilibrate

The Q/I relationship were plotted with data received by equilibrating 5.0 g soils with 50.0cm^3 of 0.01 M $AlCl_3$ solution containing KCl from 0.0005 to 0.003 M, and with 0.01 M $AlCl_3$ solution containing no K at soil:solution ratios from 1:10 to 1:250 in an end-over-end shaker (40 r.p.m.) at 22°C ± 2. After equilibration the suspensions were centrifuged at 1600 r.p.m for 15 minutes and filtered through whatman No. 42 filter paper to avoid contamination from fine clay material (Sinclair, 1979; Wimaladasa and Sinclair, 1988). The K concentrations of the clear supernatant solutions and the unreacted solutions were determined by flame photometry and the change in soil K was calculated. Concentration of (Ca + Mg) were determined by EDTA titrametric method (Heald, 1965). Aluminium was determined colorimetrically (Jayman and Sivasubramanium, 1974). The electrical conductivity of the supernatants were also measured using a conductivity meter. The K activity ratios (AR^k) for these soils were calculated by equation of Tinker (1964) as given below.

Tinkers equation for Q/I relationship (Tinker, 1964)

$$AR^k = \frac{a_K^{+}}{(a_{Ca}^{2+} + a_{Mg}^{2+})^{1/2} + (a_{Al}^{3+})^{1/3}}$$

$$= \frac{\gamma_K^{+}}{(\gamma_{Ca}^{2+} + \gamma_{Mg}^{2+})^{1/2} + (\gamma_{Al}^{3+})^{1/3}} \quad X \quad \frac{C_K^{+}}{(C_{Ca}^{2+} + C_{Mg}^{2+})^{1/2} + (C_{Al}^{3+})^{1/3}}$$

Where a = Ionic activity
γI = activity coefficient of the ith ion
i = (K^+, Ca^{2+}, Mg^{2+} and Al^{3+})
C_i = Concentration of the ith ion in supernatant (mol dm^{-3})

$$Log\gamma i = \frac{-0.509 * Zi * (I^{1/2} - 0.3I)}{1 + I^{1/2}}$$

I = 0.0131λ
Where Zi = valency of the ith ion
I = ionic strength
λ = Electrical conductivity of the supernatant. (m.mhos cm^2 = ms)

The concentration of Ca and Mg in the 0.01M $AlCl_3$ solution were low and the desorption part Ca and Mg were undetectable. Therefore, $(a_{Ca}^{2+} + a_{Mg}^{2+})^{1/2}$ were lower when compared with the $(a_{Al}^{3+})^{1/3}$ and the units for AR^k were considered as $M^{2/3}$.

RESULTS AND DISCUSSION

Q/I relationship of soils in the different tea growing regions

The higher initial PBC^k values were observed in Deniyaya, Talawakelle and Hantane Soils as 6.66, 6.66, 6.15 x 10^4mg $kg^{-1}M^{-2/3}$ respectively, when compared the Passara, Ratnapura, Kottawa Soils which showed values of 4.50, 3.50, 3.80 x 10^4 mg kg^{-1} $M^{-2/3}$ respectively (Figs. 2-7 and Table 2). It can be attributed by the higher clay and organic carbon content as there is a close relationship between PBC^k and the nature of the colloidal complex (Sinclair, 1979). Lee (1973) also showed that PBC^k is directly proportional to C.E.C of soil. Therefore, soils in the tea growing regions can be characterized into 2 main groups according to their potential buffering capacities. First soil Group consisting of higher PBC^k values such as Hantane, Deniyaya and Talawakelle which showed constant availabilities of K^+ over a longer period of time. The 2nd group consisting of lower PBC^k values such as Passara, Ratnapura and Kottawa may need frequent fertilization.

Initial AR^k_e values of Talawakelle, Hantane, Deniyaya and Passara soils were 23, 17, 22 and 19 x 10^{-4} $M^{2/3}$ respectively. There were considerably higher AR^k_e values when compared with the other two soils namely Kottawa and Ratnapura soils which had values of 8 and 12 x 10^{-4} $M^{2/3}$ respectively. This could be attributed to higher initial labile K values of former 4 soils, or lower initial K values of latter 2 soils. Therefore, AR^k_e cannot be used as a tool for characterization of soils. le Roux (1966) showed that different soils having the same AR^k_e do not have the same capacity for maintaining the AR^k_e while K is being removed by plant roots.

The labile K (ΔK^o) values were higher in Passara, Hantane, Deniyaya and Talawakelle indicating 80, 100, 130 and 160, mg kg^{-1} respectively when compared to Ratnapura and Kottawa of 40 and 30 mg kg^{-1} respectively (Table 2). Wimaladasa (1989) showed that the calculated ΔK^o values were much lower than the neutral 1M NH_4OAC extractable K. However contradictory results were observed here as there is no consistent differences between ΔK^o and exchangeable K values.

The curve portion of the Q/I isotherms indicates the presence of some specific sites for K-ions. The significance of taking presence of specific sites for K for this characterization is, that the K held in the ion exchange complex would be dependent on content and type of clay, organic matter, and pH. Exchangeable Al^{3+} which in acid tropical and sub tropical soils can be present in higher concentration

Table 2: Quantity/Intensity (Q/I) Isotherms Parameters

Location	Depth	AR^{k}_{e} $M^{2/3}$ $(X10^{-4})$	ΔK^{o} mg kg^{-1}	PBC^{k} mg kg^{-1} $M^{-2/3}$ $(x10^{4})$	K_x mg kg^{-1}
Hantane	0-15cm	17	100	6.15	1200
	15-30cm	9	40	7.61	600
Ratnapura	0-15cm	12	40	3.52	1200
	15-30cm	8	30	3.72	530
Talawakelle	0-15cm	23	160	6.66	2020
	15-30cm	8	40	5.21	1040
Kottawa	0-15cm	9	30	3.80	630
	15-30cm	4.5	20	4.28	380
Deniyaya	0-15cm	22	130	6.66	530
	15-30cm	10	40	5.00	580
Passara	0-15cm	19	80	4.50	340
	15-30cm	16	70	4.61	530

than the other cations, compete with K^+ for non specific sites of exchangeable sites of exchange (Tinker, 1964; and Sivasubramanium and Talibudeen, 1972). Ratnapura, Hantane and Talawakelle soils had more K specific sites in the order of 1200, 1200 and 2020 mg kg $^{-1}$ respectively, when compared with the other 3 soils, Passara, Deniyaya and Kottawa soils had 340, 530 and 630 mg kg^{-1} respectively. This sites may be due to the extremely weathered minerals and traces of micaceous minerals that present in these soils (Arkoll *et al.*, 1985), but were not detected in the Sri Lankan soils by X-ray diffractrometry, except in Hantane. As this was further supported by mineralogical analyses reported by Wimaladasa (1989).

Finally, considering overall Q/I parameters, soils in the tea growing regions can be characterized into 2 groups, first group having higher PBC^k values *i.e.* Talawakelle, Hantane, Deniyaya and the second group having lower PBC^k values *i.e.* Ratnapura, Kottawa and Passara soils.

Considering all parameters used for characterization, the following key could be prepared.

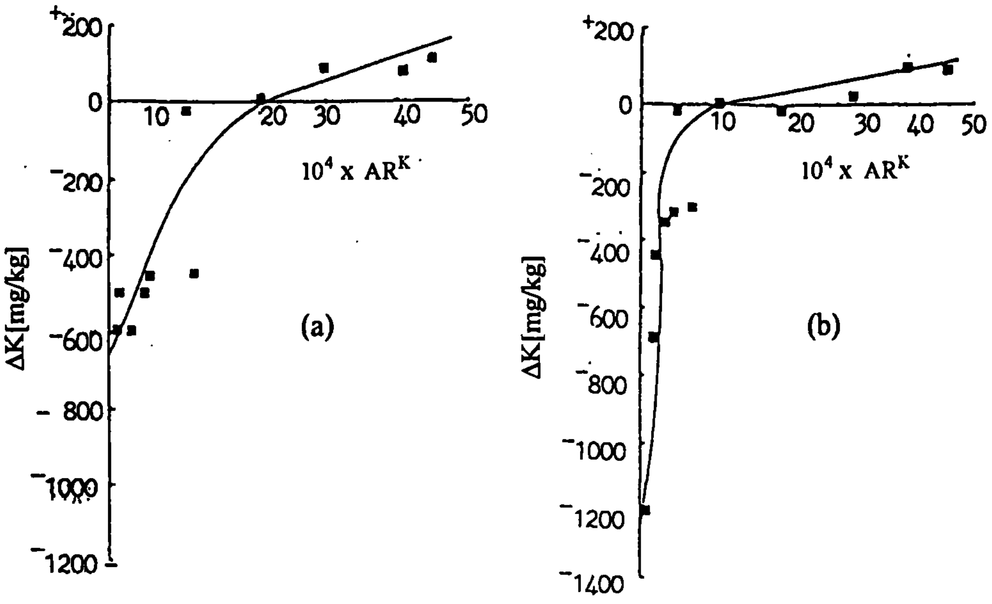


Fig. 2: *Quantity/Intensity Isotherm of Deniyaya Soil*
a. from 0-15 cm soil
b. from 15-30 cm soil

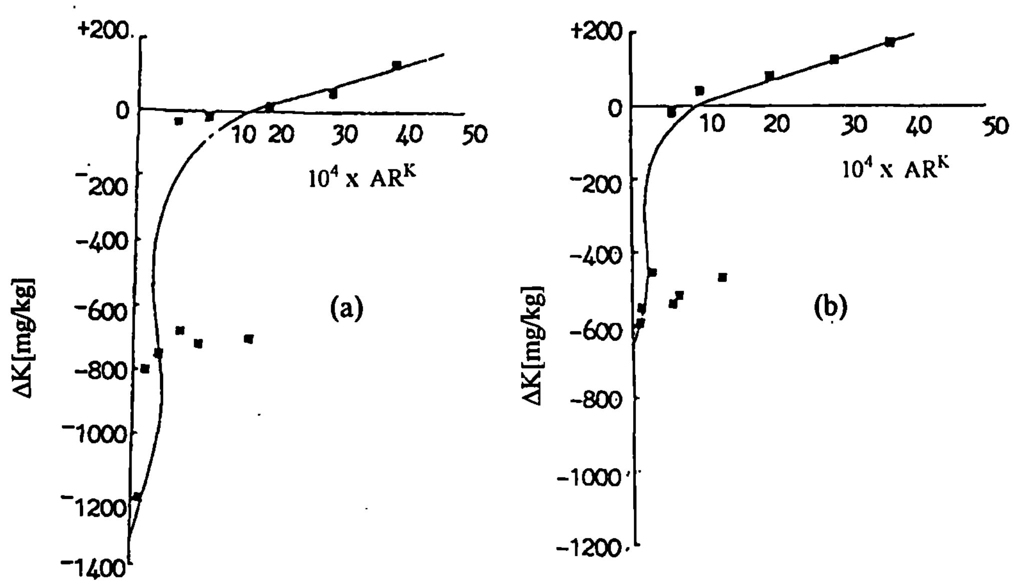


Fig. 3: *Quantity/Intensity Isotherm of Hantane Soil*
a. from 0-15 cm soil
b. from 15-30 cm soil

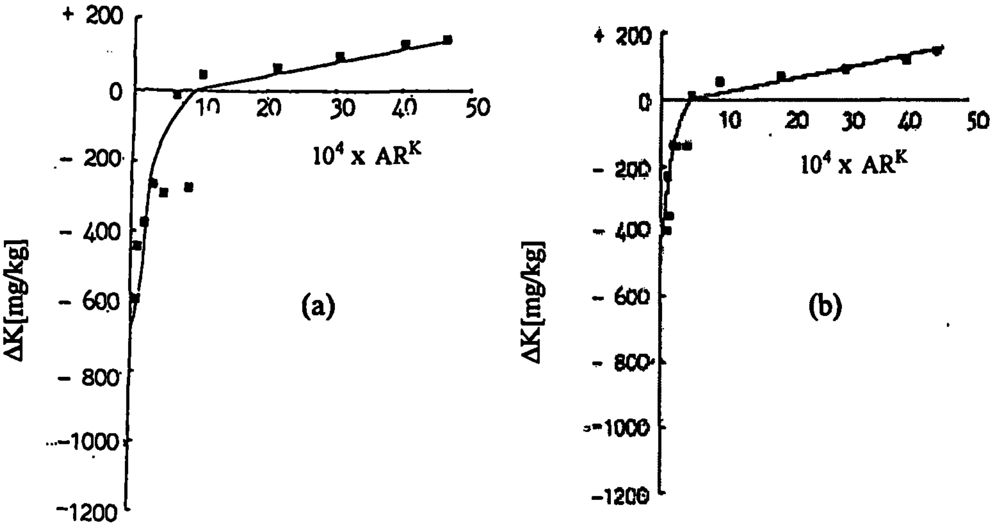


Fig. 4: *Quantity/Intensity Isotherm of Kottawa Soil*
a. from 0-15 cm soil
b. from 15-30 cm soil

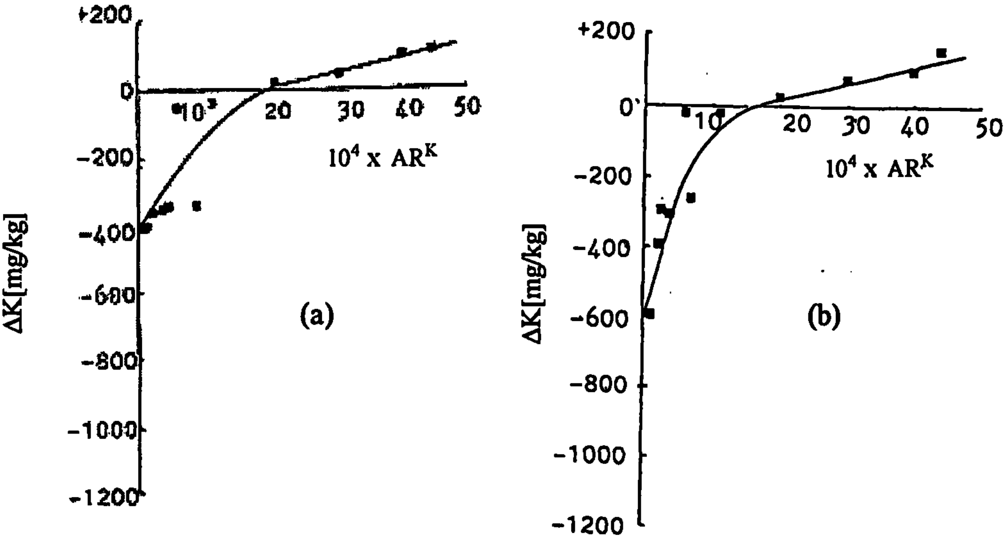


Fig. 5: *Quantity/Intensity Isotherm of Passara Soil*
a. from 0-15 cm soil
b. from 15-30 cm soil

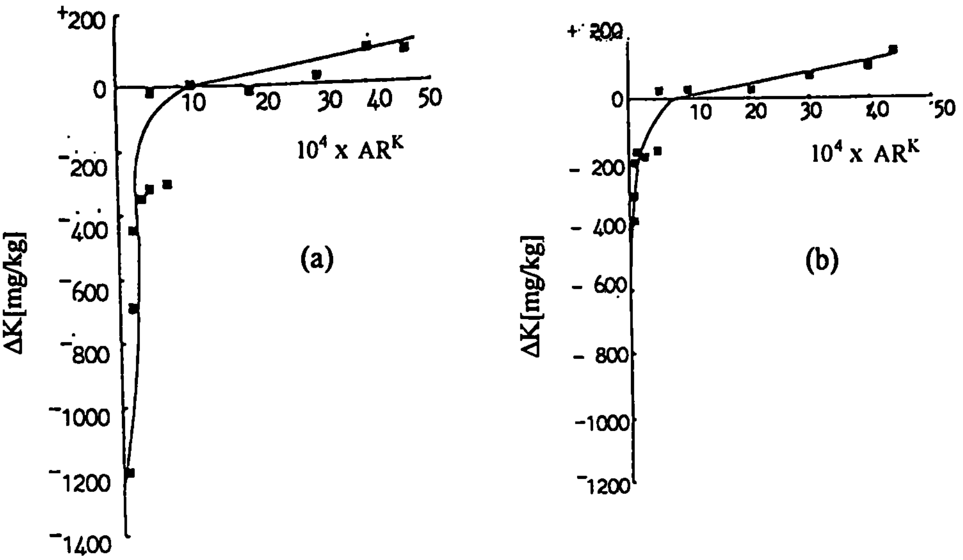


Fig. 6: *Quantity/Intensity Isotherm of Ratnapura Soil*
a. from 0-15 cm soil
b. from 15-30 cm soil

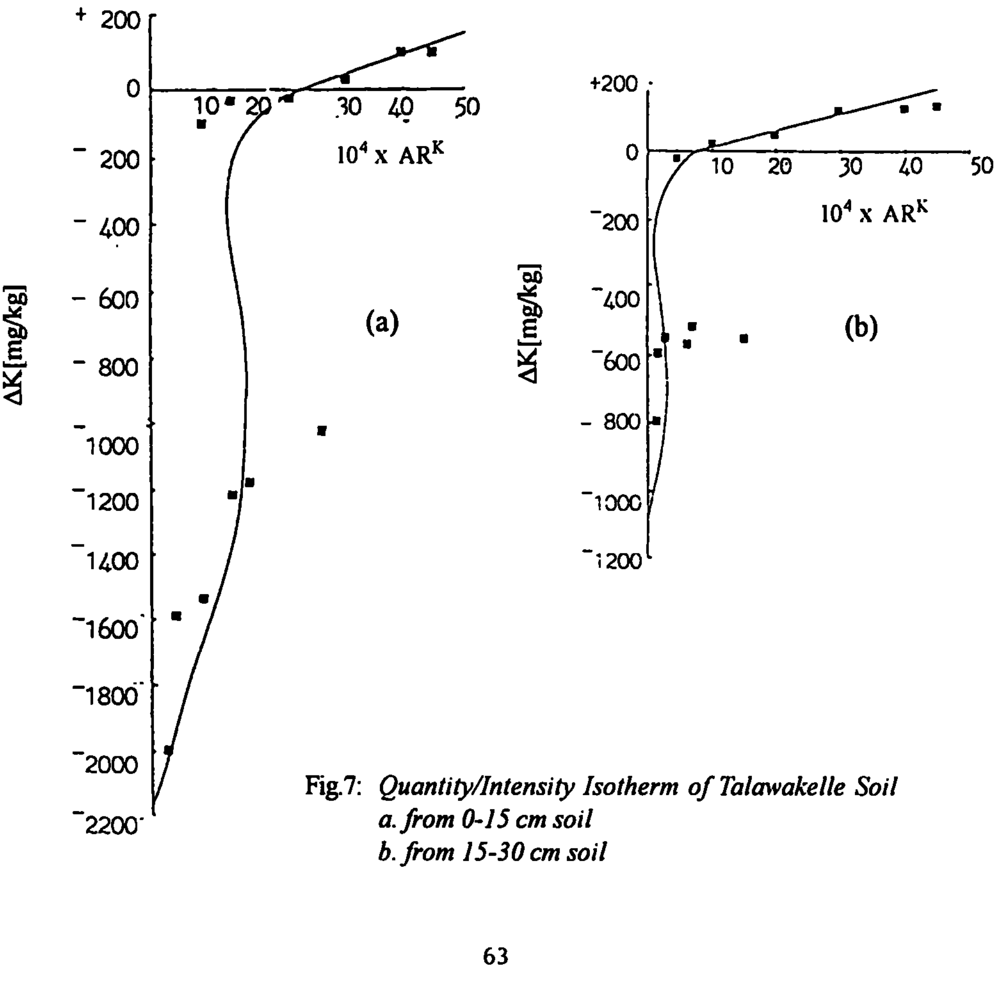
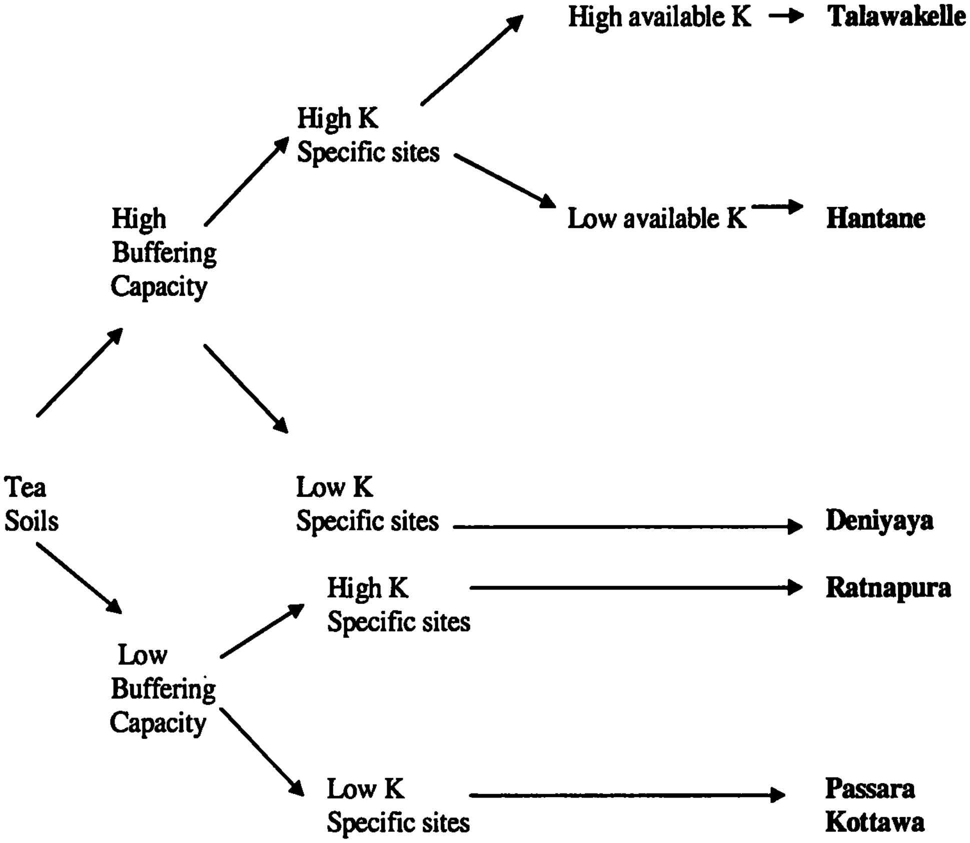


Fig.7: *Quantity/Intensity Isotherm of Talawakelle Soil*
a. from 0-15 cm soil
b. from 15-30 cm soil

Key to characterization of tea soils



According to the key prepared a first group is categorized as those soils having higher K buffering capacity, K specific sites, Available K, and Al concentration (Table 1). As a result of higher buffering capacities and K specific sites, the K absorption and desorption should be relatively high in this group. eg. **Talawakelle.**

The second group is those having higher K buffering capacities and K specific sites but having lower available K and Al concentration (Table 1). Though absorption and desorption are greater, the available K is relatively low compared with the first group. eg. **Hantane.**

Third group is those having higher K buffering capacities but with low K specific sites. eg. **Deniyaya.**

Fourth group is those having lower K buffering capacities but with higher K specific sites. eg. **Ratnapura.**

Fifth group is those having lower K buffering capacities and K specific sites. eg. **Passara, Kottawa.**

CONCLUSIONS

Soils in the tea growing regions could be divided into two main groups according to their Potential Buffering Capacities of K (PBC^k). First group consisting of higher PBC^K values and second group having lower PBC^k values. Sub-divisions of soils were also suggested related to presence of K-specific-sites, available K and exchangeable Al as well. Q/I isotherms indicated the presence of some specific sites for K ions in Ratnapura, Hantane and Talawakelle as against the other 3 soils. Finally, soils in the tea growing regions were characterized into 5 groups according to their K dynamics. It is worthy to consider these groupings also in arriving at K-recommendations for tea in Sri Lanka.

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