

Characterization and Categorization of Bench-Marked Soil Series In The Tea Growing Areas Of Sri Lanka, In Relation To Potassium (K) Dynamics

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Abstract

This research was focused on characterization and categorizations of the bench-marked soil series in the tea growing areas of Sri Lanka based on the Potassium (K) dynamics of the selected soil series. Twenty bench-marked soil series were selected representing thirteen tea growing Agro Ecological Regions (AER) in Sri Lanka. The Quantity- Intensity (QI) Isotherms of Soil K were plotted as the characterization tool. Results showed a variation among the selected soil series based on their K dynamics. Finally selected soil series were categorized in to six groups based on their Potential Buffering Capacities of K (PBC^K), Specific K Sites and Exchangeable K (ΔK_0) presented in soil. Also the Exchangeable K (ΔK_0) of soils showed a significant difference depending on the rainfall and elevation zones while Cation Exchangeable Capacities (CEC) of the soil showed a significant difference only depending on the elevation zone. Therefore it is important considering of this categorization when fine tuning the existing K fertilizer recommendations for tea growing soils in Sri Lanka.

Keywords: Quantity- Intensity (QI) Isotherms, Potential Buffering Capacities of K (PBC^K), Specific K Sites, Exchangeable or labile K (ΔK_0)

1. INTRODUCTION

Potassium (K) is an essential plant nutrient involved in many metabolic processes such as enzyme activation, osmotic control, carbohydrate production and metabolism and the anion/cation balance in plants. There is no argument on replenishing the amount of soil K content which removes as the tea flush or vegetative pruning parts as well as due to losses such as leaching, runoff and soil erosion. Though most of soils have the ability to buffer the slight changes take place in the exchangeable sites through exchangeable, non-exchangeable or fixed (mineral) phases, attention should be given to control the critical under-supplies or over-supplies which derive negative effects on the economics and environment.

Though tea industry was introduced in Sri Lanka in the 1860s, application of fertilizer for tea soils in Sri Lanka was initiated by T. Eden in 1931 in regular and organized basis. Bhavananda and Manipura (1969) proved by their various experiments that the optimum levels of K that should be applied vary from 40 to 120 kg ha⁻¹ yr⁻¹. The variation depends on the spatial variability of soils, topographic characteristics and climatic conditions prevailing in different regions. Sometimes these variations may observe even in different sites of a same region. Therefore, most of the researchers now think of formulating Site Specific Fertilizer Recommendation (SSFR) to improve the efficiency of applied soil K, as soil K dynamics is also changing spatially depending on the dominated soil series of a given location.

Nutrient availability depends on the nutrient concentrations of the soil solution of any given time, but also on the ability of the soil to maintain the nutrient concentration. Buffering ability of 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 intensity factor, (I) represents the amount of available nutrients, whereas the quantity factor (Q) reflects the strength of retention by the nutrients, held in the soil. Simply, the intensity factor is the concentration of the nutrients in the solution. The Quantity-Intensity (QI) isotherms of soil K will help to make prediction on Soil K dynamics of tea growing soils. The concept of nutrient intensity and quantity was first proposed by Schofield and Taylor in 1955.

Soils in Wet and Intermediate zone of Sri Lanka have been classified in to series by using their well-defined characteristics (Mapa et al, 1999, Mapa et al, 2005). Six tea growing soil series in different Agro Ecological Regions have been characterized in relation to soil K behavior and plant K uptake (Gunaratne, 2002). It is very important to further characterize the other tea growing bench-marked soil series in the tea growing areas in relation to K dynamics. This will results many advantages for researchers to fine tune the present SSFR. Therefore the objectives of this study were to:

Specific objectives

- 1) Characterization of bench-marked soil series in the tea growing areas of Sri Lanka, in relation to K dynamics.
- 2) Categorize the tea growing soils based on K dynamics.

General Objectives

- 3) Fine tune the Site Specific Fertilizer Recommendations (SSFR) considering soil K dynamics in those areas.

2. LITERATURE REVIEW

2.1. Tea Growing Soils and Agro Ecological Regions in Sri Lanka

Tea (*Camellia sinensis. L.*) is one of the economically important plantation crop in Sri Lanka. Tea prefers an acidic soil ranging from 4.5 to 5.5 pH values. Medium to light loamy soils are best while it can generally be cultivated in lateritic, alluvial, podzolic and peaty soils.

Sri Lanka is divided in to three major rainfall zones, namely, wet, intermediate and dry zones. These zones are sub divided in to seven major agro ecological zones based on the altitude. Both wet and intermediate zones consist of low country (0-300m AMSL), mid country (300-900m AMSL) and up country (>900m AMSL). The dry zone has only the low country. Thus the seven agro ecological zones are low country wet zone, low country intermediate zone, low country dry zone, mid country wet zone, mid country intermediate zone, up country wet zone and up country intermediate zone. These seven zones are further sub divided in to 24 well defined agro ecological regions each with its unique combination of rain fall pattern, elevation, landform, temperature range and type of soil (Mapa et al, 1999).

Out of 24 agro ecological regions about sixteen regions are suitable for tea cultivation in where the tea growing bench-marked soil series have been distributed.

2.2. Mineralogical Properties and K Dynamics of Tea Soils in Sri Lanka

Sri Lankan acid tea soils can be divided in to 3 groups in relation to their mineralogy (Wimaladasa, 1989). Accordingly the first category is soils in the up country (1200 AMSL) which have predominantly Kaolinite, Al-Chlorite, Gibbsite and Goethite with subsidiary amount of K-feldspar, Anatase and Plagioclase feldspars. The second category, the mid-country wet zone (between 600-1200m AMSL) soils consist of highest Kaolinite contents with considerable amount of Mica, Interstratified Mica/Vermiculite and Vermiculite. The Uva (mid-country dry zone, between 600-1800m AMSL) soils were classified similar to the mid-country wet zone soil group. The third category which is termed low-country (below 600m AMSL) soils, found in Deniyaya, Ratnapura and Galle have highest amounts of Kaolinite and small amounts of Gibbsite and Goethite. All these soils contain considerable quantities of Gibbsite. Goethite is found in all the acid tea soils except in Galle where Halloysites are found (Wimaladasa, 1989).

In general, the K fixing minerals such as Smectite and Vermiculite are not found in above soils. However substantial amounts of Vermiculite are found in above soils of Hantana area (Wimaladasa, 1989). As far as total K content in the soils are concerned, up- and mid-country soils have greater amounts of total K ranging from about 0.40-0.70% compared to low-country soils having 0.20-0.25% (Wimaladasa, 1989).

The K potentially available to plants includes the exchangeable, non-exchangeable and mineral K forms. The exchangeable K is readily available, since it is in direct equilibrium with soil solution. In soils containing little specifically adsorbed (wedge zone), or non exchangeable K, the exchangeable K may be the predominant phase with respect to K availability. The chemical equilibrium between the non exchangeable K and exchangeable K forms are very complex and depend on the overall K status of each phases. By a rapid depletion of solution and exchangeable phase K, the release of K from non exchangeable or fixed forms may frequently occur. Soils with a good texture may buffer insufficient K status

replenishing solution K with K from the non-exchangeable or slowly available reserves. But with continuous soil K mining, the soils exhaust on K reserves. Unbalanced nutrition as widely practiced mines the soil, it deprives the soil's capacity to buffer adverse conditions and ultimately it is a threat to the environment. The declining replenishment from K reserves of course restricts yield formation as well (Krauss, 2000).

Evidences for the utilization of fixed or non exchangeable K by plants are ample. In many instances, the K^+ removed by plants exceed the exchangeable K levels by considerable amounts (Ayers et al, 1945; Reitemeir et al, 1951; Hemingway, 1963). Because of the complexity of the dynamic equilibrium between the various soil phases, predicting available soil K is difficult. However several investigations have established good relationships between NH_4OAC extractable K or K extracted by other procedures and plant uptake.

Potassium concentrations measured in extracts of soils with water also show very good relationships with plant uptake (Nemath, 1975). In addition the K extracted by this method appeared to extract loosely held exchangeable K ions particularly in the tea soils, probably by displacement with H_3O^+ ions (Nemath.1975; Wimaladasa, 1989). Lysimeters have been widely used in field experiments to extract soil solutions, despite the wide variations in results. More recently the application of centrifugation techniques has overcome many of the problems uncounted with the extraction of soil solutions (Barrachlough, 1986; Linehan and Sinclair, 1988).

There is no commonly agreed method for assessing the non exchangeable K resources. The methods employed by researchers include leaching with dilute acids and salts, boiling with dilute or strong acids, repeated extractions with oxalic acid and Sodium Teteraphenyleboron ($NaTPB$) and hot $MgCl_2$ etc (Mclean and Watson, 1985;Goulding, 1988).

2.3. QUANTITY / INTENSITY (Q/I) RELATIONSHIP

Nutrient availability depends on the nutrient concentrations of the soil solution of any given time, but also on the ability of the soil to maintain the nutrient concentration. This capability of 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 intensity factor, (I) represents the amount of available nutrients, whereas the quantity factor (Q) reflects the strength of retention by which the nutrients 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 Taylor in 1955. Also Beckett (1964a) suggested that the intensity of a nutrient in soil at equilibrium with its soil solution should be considered as the activity ratio (AR), as given below.

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

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.

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

However, for acid soils which have received dolomitic lime stones for a longer period, combination of the activities of Ca^{2+} , Mg^{2+} and Al^{3+} is more appropriate (Tinker, 1964). Thus it becomes;

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

For establishment of a typical Q/I curve, a soil is equilibrated with solutions containing constant amounts of $AlCl_3$ and increasing amount of KCl (Tinker, 1964). Soil's gains and losses K to achieve its characteristic AR^K values or remains unchanged if its AR^K values are same as the equilibrating solution. The AR^K values are then plotted vs the gain or loss of K (i.e. $K_i - K_e = \Delta K$) to form the characteristic Q/I curve (Fig 1). From Q/I plots, several parameters can be obtained in order to characterize the K status of the soil (Sparks and Huang, 1985).

The AR^K values, when the Q factor or K equals to zero is a measure of the degree of K^+ availability at equilibrium or AR_e^K . Successive cropping decrease AR_e^K values until a constant value is reached (Le Roux, 1960). AR_e^K does not show capacity of a soil to release K^+ to plants as soils can have the same AR_e^K values but contain different amount of labile K . The values of ΔK when $AR^K=0$ is a measure of labile or exchangeable K in soils (ΔK_0). Le Roux (1966) noted that ΔK_0 was a better estimate of soil labile K than normal exchangeable K . He found that higher values of labile K (ΔK_0) indicated a greater K^+ release in to soil solution.

The slope of the linear portion of the curve gives the Potential Buffering Capacity (PBC^K) and indicates the intensity of K^+ in the soil solution and is proportional to Cation Exchange Capacity (CEC) (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 longer period of time whereas a low (PBC^K) soil would suggest the need for frequent fertilizer application.

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

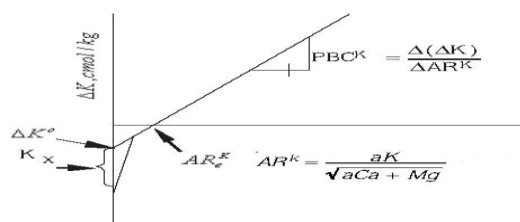


FIGURE 2.2. A TYPICAL QUANTITY / INTENSITY (Q/I) I (Moles / liter)^{1/2}

ΔK = quantity by which the soil gains or losses K in reaching equilibrium or the Quantity (Q) factor

PBC^K = potential buffering capacity.

AR^K = activity ratio for K or the Intensity (I) factor

K_x = specific K sites

ΔK^0 = labile or exchangeable K

AR_e^K = equilibrium activity ratio for K

The role of Al^{3+} in soils is of considerable interest in most investigation, exchangeable Al must be distinguished from other forms associated with the soil colloidal complex. Various methods have been used to measure exchangeable Al in soils. Out of those, neutral normal solutions of strong electrolytes are preferred for extraction by many workers (Yuan and Fiskell, 1959; Shen and Rich, 1962), and found that normal solutions of NaCl, KCl and $CaCl_2$ have removed comparable amounts of exchangeable Al when leaching was exhaustive, but KCl was more efficient for limited leaching. Skeen and Sumner (1967) showed that NH_4^+ and K^+ are most effective cations for the removal of exchangeable Al from acid soils. Al extracted by neutral 1N KCl is generally accepted as a measure of exchangeable Al^{3+} in clay mineral and soils (Sivasubramaniam,1970).

3. MATERIALS AND METHODS

3.1 SAMPLING LOCATIONS

Soil samples of top soil (0-15cm) were collected from sixteen Tea growing Agro Ecological Regions representing twenty locations giving priorities for prominent soil series dominated in those locations (Table.3.1). They were air dried, passed through 2mm sieve and analyzed. .

3.2. ANALYTICAL PROCEDURES

3.2.1. Determination of Soil pH

Soil pH was determined by ammonium saturation method. 10 g of soils from each soil series were taken and they were put in to 25 ml beakers. Then 25 ml of distilled water was added in to those beakers and they were stirred well and kept for about half and hour with intermittent stirring. After thirty minutes soil pH was measured using an electrically operated digital pH meter and above procedure was done for three replicates of each series.

3.2.2. Determination of Electrical Conductivity of soil

Soil solutions were extracted as shown in Table 3.2. Electrical conductivity of soil solutions were measured by using an electrically operated digital conductivity meter.

Table.3.1 Sampling Locations

AER	Location	Soil Series
WU1	Brunswick Estate, Maskeliya	Maskeliya Series
WU2	St. Coombs Estate, Mattakele	Mattakele Series
WU3	Courtclouge Estate, Kandapola, Nuwara Eliya	Nuwara Eliya Series
WM1	Sooriyakanda	Malaboda Series
WM2	Paranapattiya	Kandy Series
WM2	Bulathkohupitiya	Galigamuwa Series
WM3/IM2	Midlands, Ukuwela	Ukuwela Series.
WM3/IM3	Galagedara	Matale Series
WM3	Akurana	Akurana Series
WL1	Mathugama	Dodangoda Series
WM1	Kiriwanaganga Estate,	Pallegoda Series
WM1	Kalawana	Weddagala Series
IL1-2	Sittamgallena	Beliatta Series
IL1	Handurukanda, Kurunegala	Erosional Remnants
IM2	Lunugala, Hoptan	Mahawalatenna Series
IU1	Harepark	Hunnasgiriya series
IU2	Rahathangoda Estate	Rikillagaskada Series
IU2	Pannatawela	Ragala Series
IU3	Boralanda	Bandarawela Series
WM1	Neluwa	Weddagala/Malaboda Associate Series

3.2.3. Determination of Cation Exchange Capacity of soil

Cation Exchange Capacities of the soils were determined by Ammonium Saturation Method. Initially 12.5 g of soils were measured and they were washed with about four lots of 1N NH₄Cl (250ml for each) in a 542 filter paper. Then the soils were washed with four lots of 1/20 N NH₄Cl. After complete draining the soils were washed with four lots of 1N Na₂SO₄ solution (250ml). Then the leechates were taken and they were distilled in a Kjeldhal unit. The NH₄ presents in the distilled solution were determined by titrating them with 0.1N HCl and CEC of the sols were calculated thereby.

3.2.4. Q/I Isotherms

The Q/I isotherms were plotted with the data received by equilibrating 5.0 g of soils with 50.0 cm³ of 0.01 M AlCl₃ solution containing KCl from 0.0005 to 0.003 M, and with 0.01 M AlCl₃ solution containing no K at soil: solution ratios from 1:10 to 1:250 in an end-over-end shaker (40 r.p.m.) over night. After equilibration, the suspensions were centrifuged at 1600

r.p.m. for 15 minutes and filtered through whatman No. 542 filter paper to avoid contamination from fine clay material (Sinclair, 1979; Wimaladasa and Sinclair, 1988). The K concentration of the clear supernatant solutions and the non reacted solutions were determined by flame photometry. The changed in soil K(ΔK) was calculated. Concentrations of Ca^{2+} and Mg^{2+} were measured using Atomic Absorption Spectro Photo photometer. The K activity ratios (AR^K) for those soils were calculated by equation of Tinker (1964) as given below. Q/I isotherms of K in soil were plotted using collected data.

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

$$AR^K = \frac{\gamma_K^+}{(\gamma_{Ca^{2+}} \gamma_{Mg^{2+}})^{\frac{1}{2}} + (\gamma_{Al^{3+}})^{\frac{1}{3}}} \times \frac{C_K^+}{(C_{Ca^{2+}} + C_{Mg^{2+}}) + (C_{Al^{3+}})^{\frac{1}{3}}}$$

Where, a = Ionic activity

γ^i = Activity coefficient of the i^{th} ion

i = (K^+ , Mg^{2+} , Ca^{2+} and Al^{3+})

C_i = Concentration of the i^{th} ion in supernatant (mol dm⁻³)

$\log \gamma^i = -0.509 \times Z_i^2 \times \frac{(I^{1/2} - 0.3I)}{I + I^{1/2}}$

Where, I = 0.0131 λ $I + I^{1/2}$

Z_i = Valency of i^{th} ion

I = Ionic strength

λ = Electrical conductivity of Supernatant. (m. mhos cm²=ms)

Table 3.2. Soil extraction Procedure.

Tube No.		Soil (g)	KCl ml 200ppm	AlCl ₃ 0.01M
1	2	5	5	45
3	4	5	10	40
5	6	5	20	30
7	8	5	30	20
9	10	5	40	10
11	12	5	45	5
13	14		0	50
15	16	2.5	0	50
17	18	2	0	50
19	20	1	0	50
21	22	0.5	0	50
23	24	0.25	0	50

3.3 STATISTICAL ANALYSIS

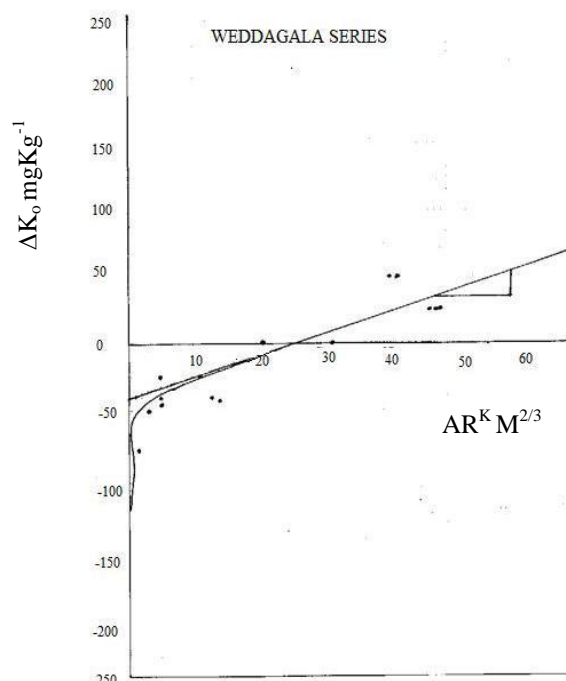
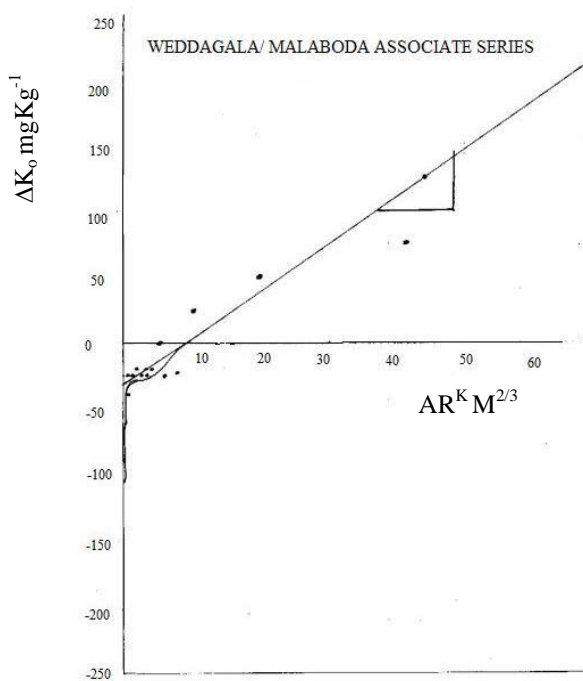
Statistical analysis was done to find the effect of elevation zone (mid, up and low country and uva zone) and main rain fall zones (wet and intermediate) on soil chemical properties including Q/I isotherm parameters as K potential buffering capacities of soil (PBC^K), K specific sites (K_x), available K (ΔK^0), equilibrium K activity ratio values (AR^K_e), cation exchange capacities (CEC) and soil pH by using SAS.

4. RESULTS AND DISCUSSION

4.1 Q/I ISOTHERMS OF SOILS OF DIFFERENT AGRO ECOLOGICAL REGIONS

The higher initial PBC^K values were observed in Kandy, Bandarawela, Beliatta, Mattakele, Rikillagaskada, Nuwara Eliya, Ragala, Maskeliya Ukuwela Hunnagiriya and Akurana soil series as 4.0, 4.37, 5.77, 5.88, 6.09, 6.34, 6.41, 6.79, 8.46, 9.67, and $20.83 \times 10^{-4} \text{ mgKg}^{-1} \text{ M}^{-2/3}$ respectively when compared with the Weddagala, Erosional Remnants, Dodangoda, Matale, Galigamuwa, Mahawalatenna, Weddagala/Malaboda Associate, Malaboda and Pallegoda Series which showed low PBC^K values as 1.67, 2.79, 2.85, 2.89, 2.94, 3.0, 3.4, 3.5 and $3.5 \times 10^{-4} \text{ mgKg}^{-1} \text{ M}^{-2/3}$ respectively (Table 4.1. and Fig 4.1-4.20)

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 CEC of soil. Therefore soil in the tea growing regions can be characterized in to two main groups according to their Potential Buffering Capacities. First soil group consisting of higher PBC^K values such as Kandy, Bandarawela, Beliatta, Mattakele, Rikillagaskada, Nuwara Eliya, Ragala, Maskeliya Ukuwela Hunnagiriya and Akurana soil series which showed constant availabilities of K^+ over a longer period of time. The second group consisting of lower PBC^K values such as Weddagala, Erosional Remnants, Dodangoda, Matale, Galigamuwa, Mahawalatenna, Weddagala/Malaboda Associate, Malaboda and Pallegoda Series may need frequent fertilizer application.



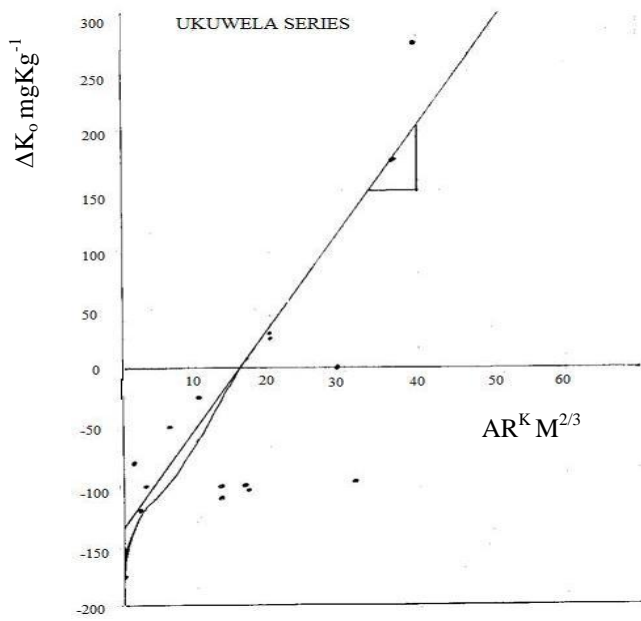


Fig.4.3. Quantity /Intensity Isotherm of Ukuwela Series.

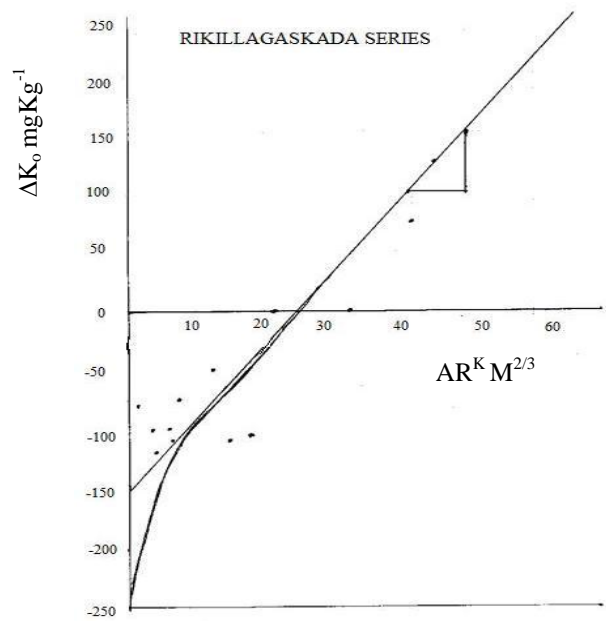


Fig. 4.4 Quantity /Intensity Isotherm of Rikillagaskada Series

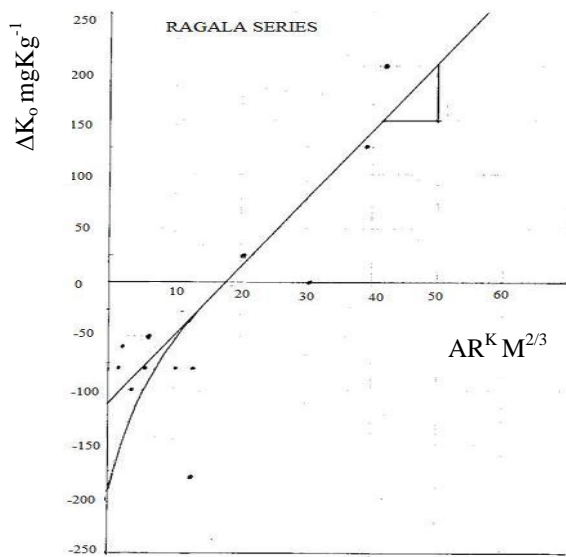


Fig.4.5 Quantity /Intensity Isotherm of Ragala Series

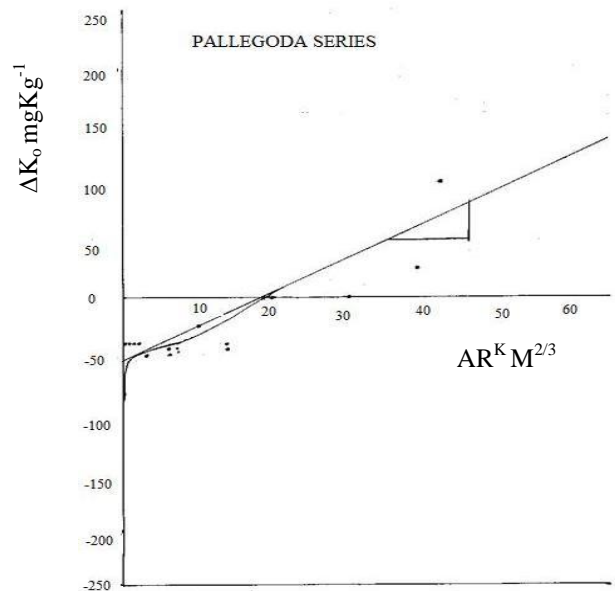


Fig.4.6 Quantity /Intensity Isotherm of Pallegoda Series

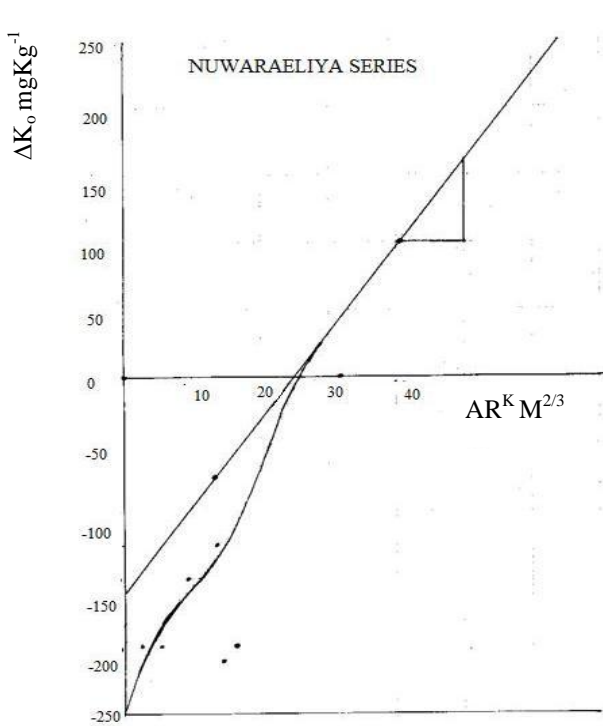


Fig. 4.7 Quantity /Intensity Isotherm of Nuwara Eliya Series

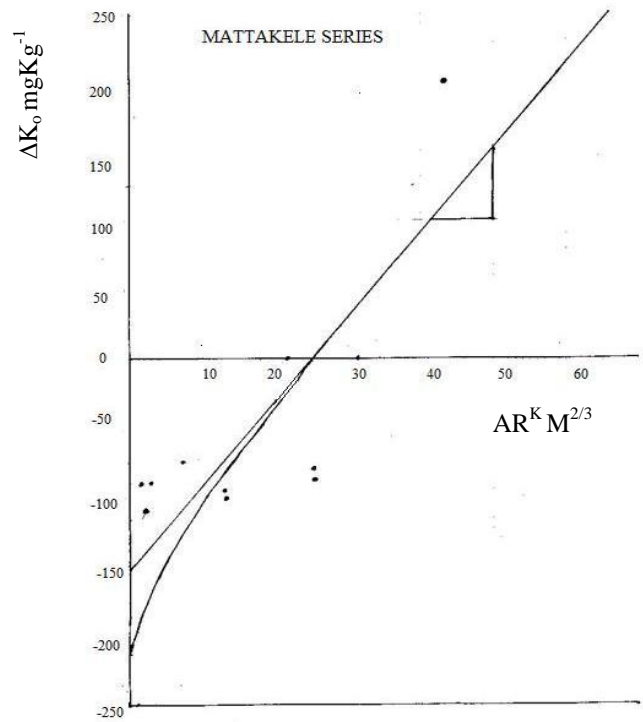


Fig. 4. 8 Quantity /Intensity Isotherm of Mattakele Series

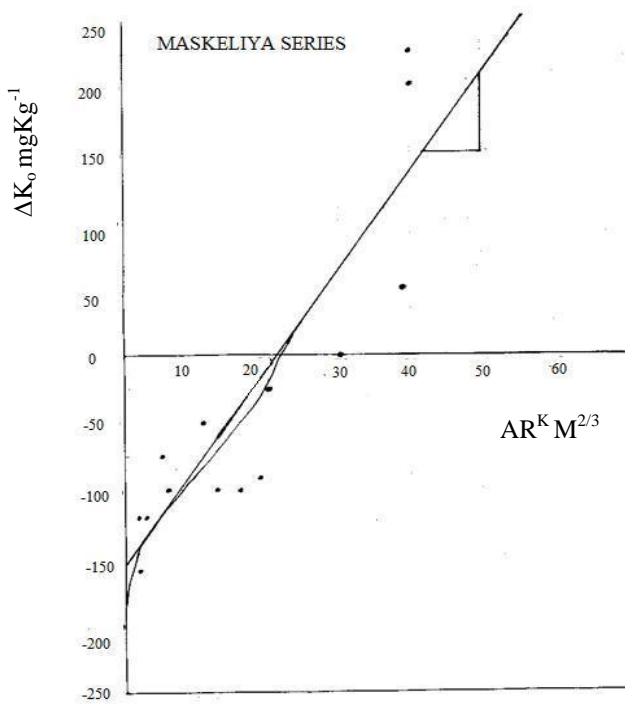


Fig. 4. 9 Quantity /Intensity Isotherm of Maskeliya Series

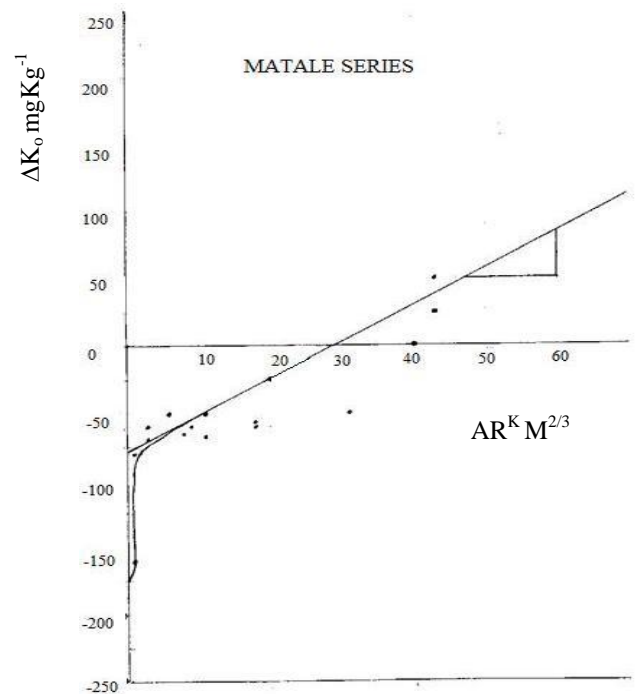


Fig.4.10 Quantity /Intensity Isotherm of Matala Series

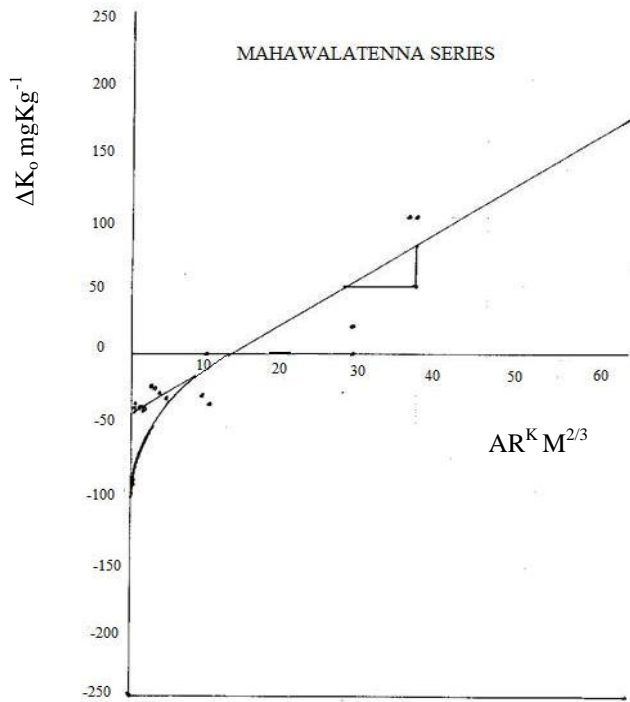


Fig. 4.11 Quantity /Intensity Isotherm of Mahawalatenna

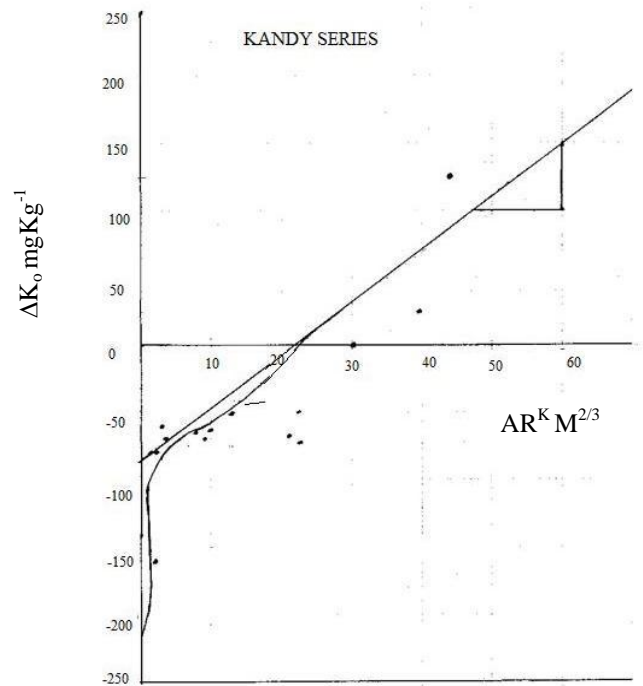


Fig. 4.12 Quantity /Intensity Isotherm of Kandy Series

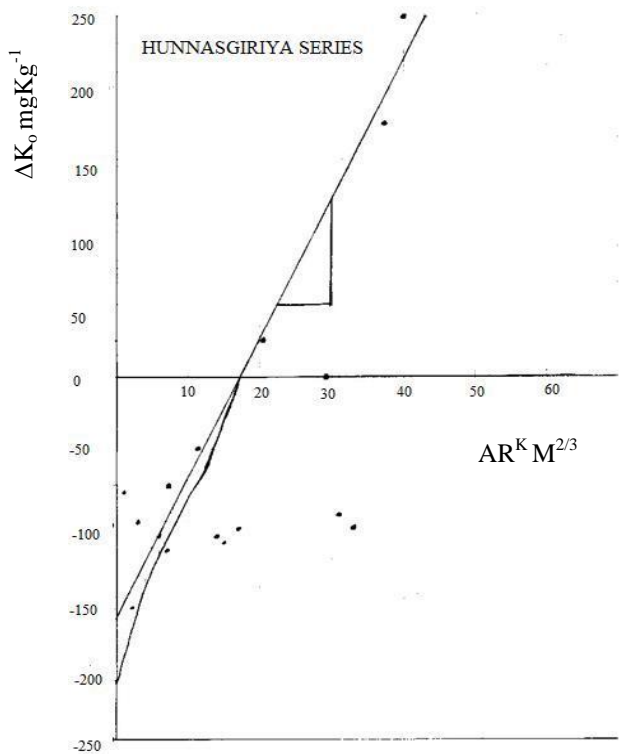


Fig. 4.13 Quantity /Intensity Isotherm of Hunnasingiriya Series

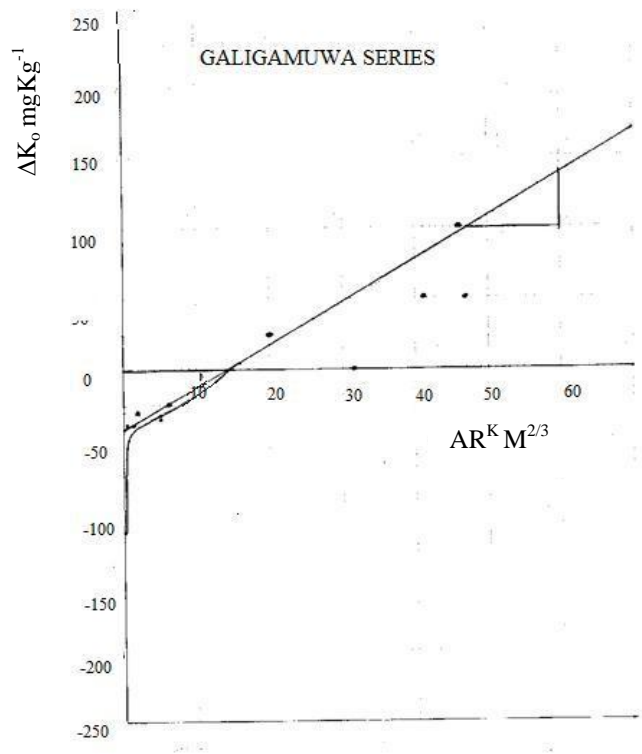


Fig. 4. 14 Quantity /Intensity Isotherm of Galigamuwa Series

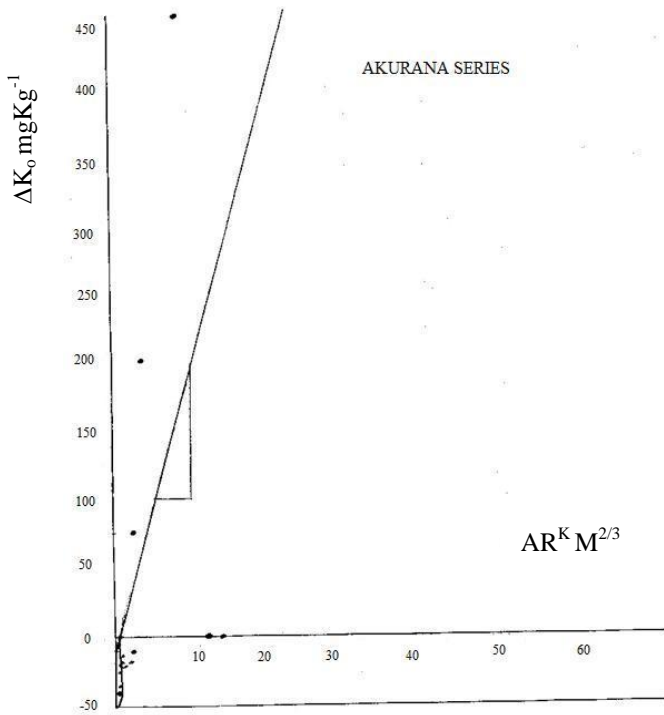


Fig. 4.16 Quantity /Intensity Isotherm of Akurana Series

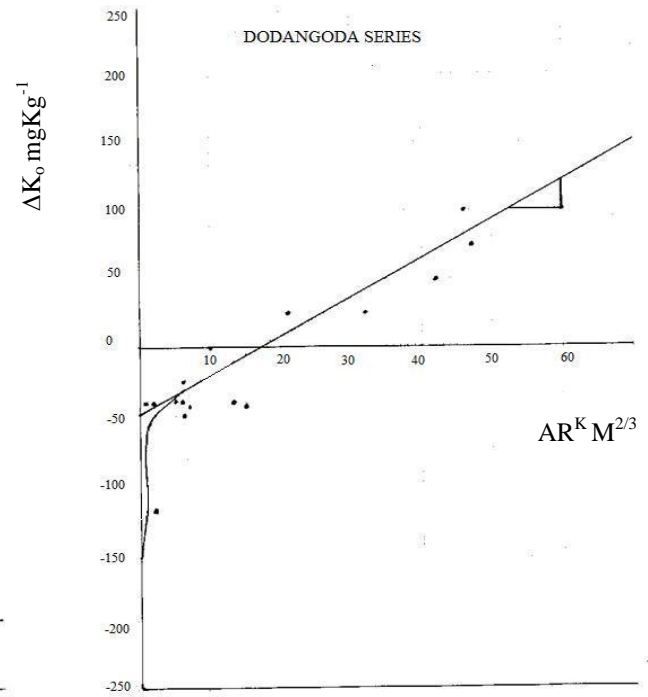


Fig. 4.15 Quantity /Intensity Isotherm of Dodangoda Series

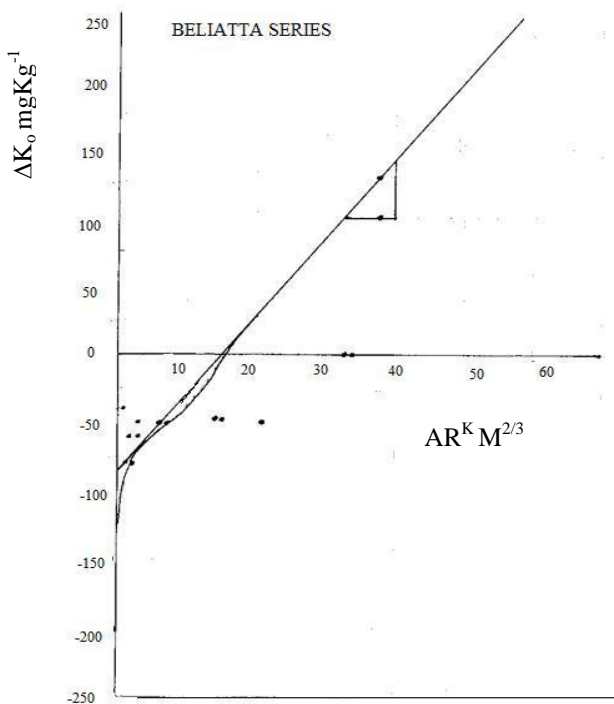


Fig. 4. 17 Quantity /Intensity Isotherm of Beliatta Series

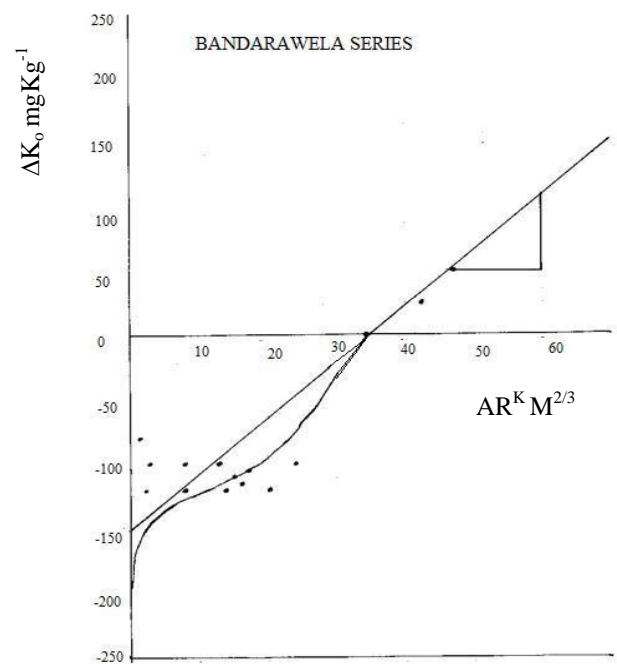


Fig. 4. 18 Quantity /Intensity Isotherm of Bandarawela Series

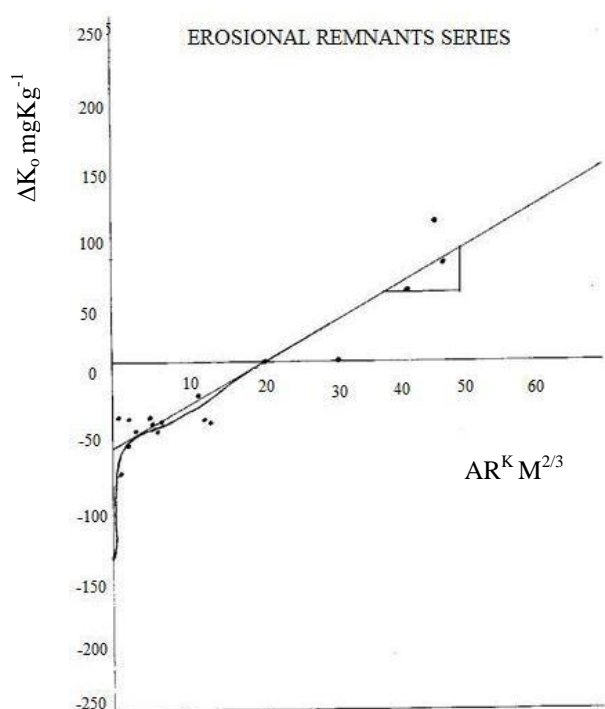


Fig. 4. 19 Quantity /Intensity Isotherm of Erosional Remnants

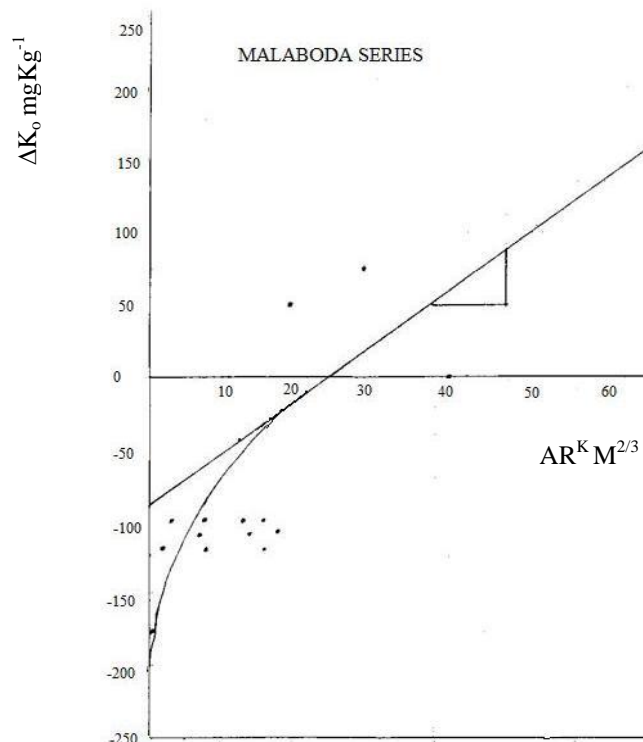


Fig. 4. 20 Quantity /Intensity Isotherm of Malaboda Series

Table 4.1 Q/I ISOTHERM PARAMETERS OF DIFFERENT SOIL SERIES.

Series	K_x $mgKg^{-1}$	ΔK_0 $mgKg^{-1}$	AR^k $\times 10^4 M^{2/3}$	CEC $meq/100g$	pH	PBC ^k $\times 10^{-4} mgKg^{-1} M^{2/3}$
Weddagala	105.00	40.00	26.00	10.51	4.96	1.67
Dodangoda	105.00	50.00	17.50	12.15	5.31	2.85
Galigamuwa	72.50	42.50	14.50	17.80	4.57	2.94
Weddagala/Malaboda Associate	44.00	31.00	9.50	14.11	4.90	3.40
Malaboda	111.00	89.00	25.30	11.05	4.80	3.52
Pallegoda	35.00	55.00	21.90	12.15	5.00	3.55
Kandy	140.00	84.00	22.50	17.95	6.49	4.00
Akurana	30.00	20.00	0.50	19.05	6.13	20.83
Mattakele	75.00	152.50	25.10	11.52	4.68	5.88
Nuwaraeliya	89.00	161.00	25.50	21.01	4.54	6.34
Maskeliya	30.00	155.00	21.90	16.62	5.24	6.79
Beliatta	41.00	84.00	15.30	12.86	5.02	5.77
Erosional Remnants	78.50	62.50	22.00	15.37	4.75	2.79
Matale	99.82	75.80	29.10	14.82	5.60	2.89

Rikillagaskada	92.50	152.50	25.20	16.31	4.50	6.09
Ukuwela	41.00	135.00	16.00	18.74	5.09	8.46
Hunnasgiriya	56.00	164.00	17.20	16.31	4.98	9.67
Mahawalatenna	60.00	45.00	14.00	12.00	5.19	3.00
Bandarawela	47.50	150.50	34.90	11.29	4.68	4.37
Ragala	67.00	122.00	17.90	15.29	5.15	6.41

Initial AR_e^K values of Kandy, Bandarawela, Beliatta, Mattakele, Rikillagaskada, Nuwara Eliya, Ragala, Maskeliya, Ukuwela, Hunnasgiriya, Weddagala, Erosional Remnants, Dodangoda, Matale, Galigamuwa, Mahawalatenna, Malaboda and Pallegoda Series were 22.5, 34.9, 15.3, 25.1, 25.2, 25.9, 17.9, 21.9, 16, 17.2, 26, 22, 17.5, 29.1, 14.5, 14, 25.3 and $21.9 \times 10^{-4} M^{2/3}$ respectively. There were considerably higher AR_e^K values when compared with the other two soils namely Akurana and Weddagala/Malaboda Associate series which had values of 0.5 and $9.5 \times 10^{-4} M^{2/3}$ respectively. This could be attributed to higher initial labial K values of former eighteen soil series or lower initial K values of later two soils. Therefore, AR_e^K cannot be used as a tool for characterization of soils. Ie Roux (1966) showed that different soils having the same AR_e^K do not have the same capacity for maintaining the AR_e^K while K is being removed by plant roots.

The labile K (ΔK^0) values were higher in Bandarawela, Mattakele, Rikillagaskada, Nuwara Eliya, Ragala, Maskeliya Ukuwela and Hunnasgiriya series indicating 150.5, 152.5, 152.5, 161, 122, 155, 135 and 164 mg Kg⁻¹ respectively when compared to Kandy, Beliatta, Weddagala, Erosional Remnants, Dodangoda, Matale, Galigamuwa, Akurana, Weddagala/Malaboda Associate, Mahawalatenna, Malaboda and Pallegoda Series of 84, 84, 40, 62.5, 50, 75.8, 42.5, 20, 31, 45, 89 and 55 mg Kg⁻¹ respectively (Table 5.1)

Wimaladasa (1989) showed that the calculated (ΔK^0) values were much lower than the neutral IM NH₄OAC extractable K. However contradictory results were observed here as there is no consistent difference between (ΔK^0) and exchangeable K values.

The curve position of the QI isotherms indicates the presence of some specific sites for K ions. The significance of 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 Al³⁺ which in acid tropical and sub tropical soils can be present in higher concentration than the other cations, compete with K⁺ for non specific sites of exchangeable sites of exchange complex (Tinker,1964; and Sivasubramaniam and Talibudeen, 1972).

Kandy, Mattakele, Rikillagaskada, Nuwara Eliya, Weddagala, Erosional Remnants, Dodangoda, Matale and Malaboda Series had more K specific sites in the order of 140, 70, 92.5, 89, 105, 78.5, 105, 99.2 and 111 mg Kg⁻¹ respectively when compared with the other eleven soils such as Bandarawela, Beliatta, Ragala, Maskeliya Ukuwela Hunnasgiriya Galigamuwa, Mahawalatenna, Akurana, Weddagala/Malaboda Associate and Pallegoda Series had 47.5, 41, 67, 30, 41, 56, 72.5, 60, 30, 44, and 35 mg Kg⁻¹ respectively.

This sites may be due to the extremely weathered minerals and traces of micaceous minerals that presence in this soils (Arkoll et al., 1985) but were not detected by X-ray diffractometry. This was further supported by mineralogical analysis reported by Wimaladasa(1989).

Finally considering overall QI parameters soils in the tea growing regions can be characterized in to two groups. First group having higher PBC^K values i.e. Kandy, Bandarawela, Beliatta, Mattakele, Rikillagaskada, Nuwara Eliya, Ragala, Maskeliya Ukuwela Hunnagiriya and Akurana soil series and the second group having lower PBC^K values i.e. Weddagala, Erosional Remnants, Dodangoda, Matale, Galigamuwa, Mahawalatenna, Weddagala/Malaboda Associate, Malaboda and Pallegoda Series soils.

Considering all parameters used for characterization the following key (Fig 5.21) could be prepared. The key was based on the critical values established by Tea Research Institute of Sri Lanka for such a categorization.

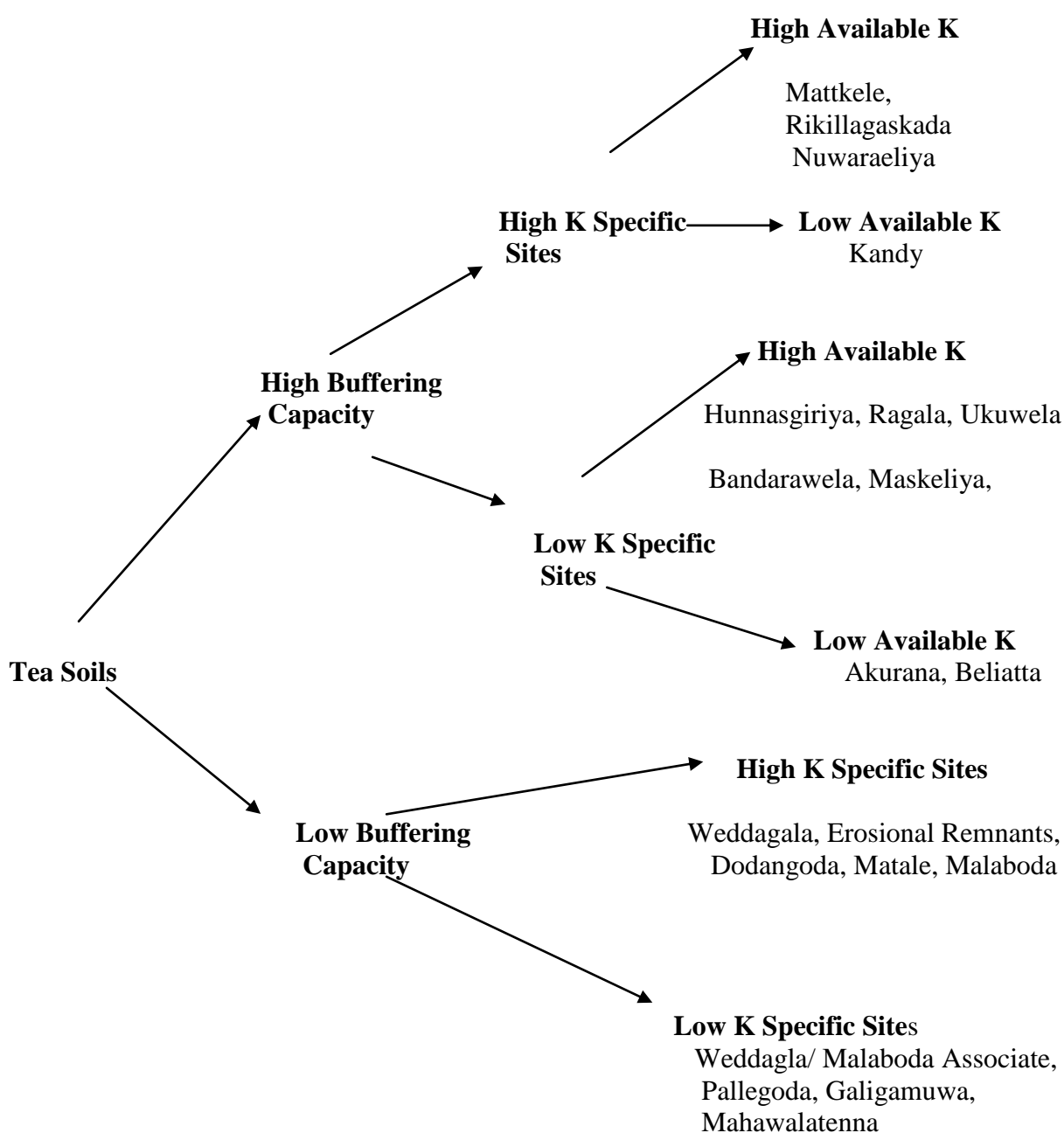


Fig. 4. 21 Key for characterization of tea soils

4.2. EFFECT OF RAINFALL ZONES ON SOIL CHEMICAL PROPERTIES.

According to the least square means of soil chemical properties including Q/I isotherm parameters as K potential buffering capacities of soil (PBC^K), K specific sites (K_x), available K (ΔK^0), equilibrium K activity ratio values (AR_e^K), cation exchange capacities (CEC) and soil pH, only available K (ΔK^0) showed a significant difference depending on rainfall zone as wet and intermediate zone.

Table 4.2. Least Square means of soil chemical properties depending on rainfall zone.

RF Zone	PBC^K $Mg\ Kg^{-1} M^{2/3}$	K_x $Mg\ Kg^{-1}$	ΔK^0 $Mg\ Kg^{-1}$	AR_e^K $10^{-4}M^{2/3}$	CEC meq/100g	pH
Wet	6.98	68.20	89.70	18.17	15.29	5.32
Intermediate	4.35	44.55	140.7	24.23	13.94	4.55
Significancy	NS	NS	*	NS	NS	NS

NS- Not Significant

* - Significant

4.3. EFFECT OF ELEVATION ZONE ON SOIL CHEMICAL PROPERTIES.

According to the least square means of soil chemical properties including Q/I isotherm parameters as K potential buffering capacities of soil (PBC^K), K specific sites (K_x), available K (ΔK^0), equilibrium K activity ratio values (AR_e^K), cation exchange capacities (CEC) and soil pH, available K (ΔK^0) shows a highly significant difference depending on elevation regions as low, mid, up country and uva zone while cation exchange capacities of soil (CEC) is also shows a significant difference depending on same elevation category.

Table 4.3. Least Square means of soil chemical properties depending on elevation zone.

Elevation Category	PBC^K $mgKg^{-1} M^{2/3}$	K_x $Mg\ Kg^{-1}$	ΔK^0 $Mg\ Kg^{-1}$	AR_e^K $10^{-4}M^{2/3}$	CEC Meq/100g	pH
Low	2.7	61.54	78.08	20.70	12.65	4.63
Mid	8.43	71.26	94.54	17.94	17.19	5.47
Up	5.33	37.77	194.76	27.04	15.40	4.35
Uva	6.21	54.92	93.43	19.08	13.223	5.30
Significancy	NS	NS	**	NS	*	NS

NS- Not Significant

* - Significant ** - Highly Significant

4.4. RELATIONSHIP BETWEEN POTENTIAL BUFFERING CAPACITIES OF K (PBC^K) AND CATION EXCHANGE CAPACITY (CEC) OF SOILS.

According to the Fig. 5.22 the potential buffering capacities of K and Cation Exchange Capacities of soil show a liener relationship which means soils with low PBC^K values show low CEC values while soils with high PBC^K values show high CEC values.

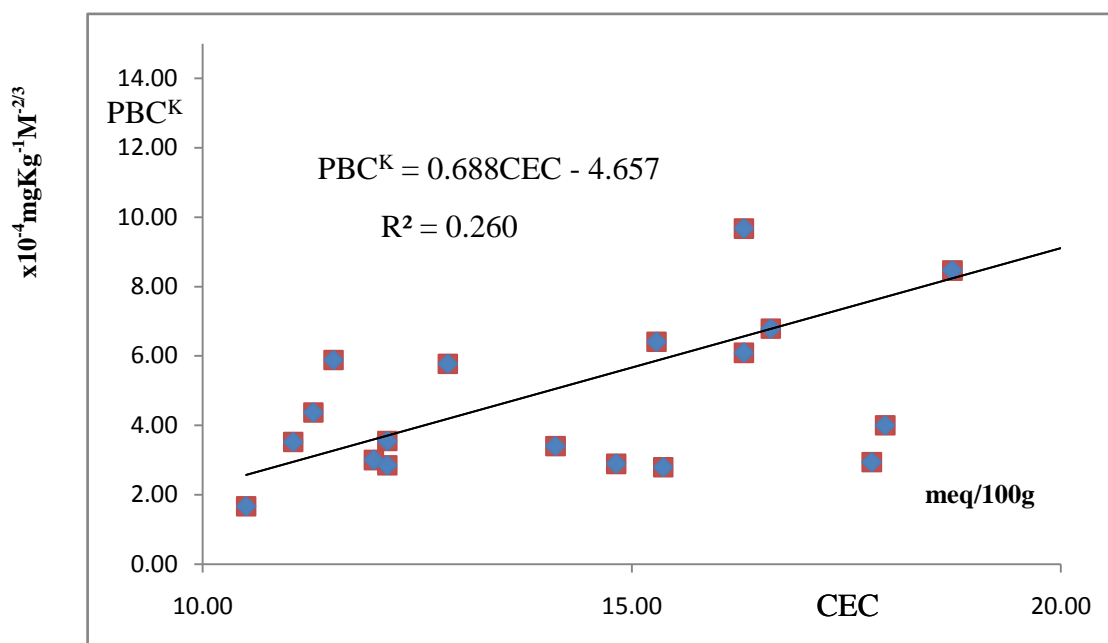


Fig. 4.22 .Relationship between PBC^K and CEC of soils.

5. CONCLUSIONS

A key could be prepared to characterize the soils under study pertaining to K availability and K dynamics. This key may help in deciding the K needs of the soils in form of fertilizers. Potassium fertilizer adjustments could be suggested as improvements based on the key.

According to the key prepared a first group is categorized as those soil series having higher K buffering capacity, K specific sites and available K. As a result of higher buffering capacities and K specific sites, the K absorption and desorption should be relatively high in this group. Therefore the present recommendation for tea based on yield potential could be continued in such soils in Sri Lanka. Besides when needed higher K application could also be considered.

Eg. Mattakele, Rikillagaskada and Nuwara Eliya Series.

The second group is those having higher K buffering capacities, K specific sites and lower available K. Though adsorption and desorption are greater the available K is relatively low compared with the first group. The present recommendation for tea could be adopted in this region. However at higher yield categories over application of fertilizer could occur. To

avoid such a situation site specific fertilizer recommendation for higher yield categories is recommended.

Eg. Kandy Series.

Third group is those having higher K buffering capacities but with low K specific sites and high available K. Nitrogen and Phosphorous application should be done by yield potential but total K should be splitted among main fertilizer application to avoid losses due to low K specific sites. As this would lead to low retention of K in such soils.

Eg. Hunnagiriya, Ragala, Bandarawela, Maskeliya and Ukuwela Series.

Fourth group is those having higher K buffering capacities, low K specific sites and lower available K. Usual K applications and frequencies can be adopted. How ever cation exchange capacities should be improved by cultural practices such as adding of compost, lopping shade trees and burying of pruning etc. if possible.

Eg. Akurana and Beliatta Series

These Akurana series is differently behaves compared to other series as it is consisting of Immature Brown Loam soil that is rich in micaceous minerals. Also it is in a primary stage of soil formation with comparison to other series. Once soil is deficit in K, it will be subsidized by the K rich micaceous minerals present in the soil but not from the available K.

Fifth group is those having lower K buffering capacities but high K specific sites and low available K. Due to low adsorption and desorption properties of these soils the possibility of losing of applied K is very high. Split applications of fertilizer may be the solution and also the introduction of appropriate new fertilizer recommendations should be developed. New fertilizer trials should be initiated to investigate the responses under field conditions where frequent dry spells are also experienced.

Eg. Weddagala, Erosional Remnants, Dodangoda, Matale and Malaboda Series.

The sixth group is those having lower K buffering capacities, K specific sites and available K. In this group due to low adsorption and desorption properties the possibility to loss of applied K is very high compare to other five groups. Therefore split application of fertilizer may be the solution. The introduction of appropriate new field trials should be initiated to investigate the responses under field conditions where frequent dry spells are practiced.

Eg. Weddagala/Malaboda Associate, Pallegoda, Galigamuwa and Mahawalatenna Series

The available K present in soil is significantly differs than the other soil chemical properties (i.e. potential buffering capacity of K, equilibrium activity ratio of K, K specific sites, cation exchange capacity and pH etc.) depending on the rainfall zone as wet and intermediate.

The available K present in soil shows highly significant difference than that of the other soil chemical properties (i.e. potential buffering capacity of K, equilibrium activity ratio of K, K specific sites, cation exchange capacity and pH etc.) while cation exchange capacities of soil

show a significant difference depending on the elevation zone such as up, mid, low country and uva zone.

The Ca and Mg content in soil of Beliatta, Akurana, Kandy, and Matale series were high compare to other series.

It is worthy to concentrate on these categorization of soils based on K dynamics, when fine tuning the TRI recommended Site specific Fertilizer Recommendations for tea soils in Sri Lanka in the future.

REFERENCES

Abbas, SAMADI. (2005), Potassium Exchange Isotherms as Plant Availability Index in Selected Calcareous Soils of Western Azarbaijan Province, Iran, Soil Science Department, Urmia University, IRAN

Barrachlough, P.B. (1986), The growth and activity of winter wheat roots in the field: nutrients inflows of high yielding crops. *J. Agric Sci. Camb.*, **15**: 1-8

Bavanada, V.P. and Manipura, W.P. (1969), Fertilizer response of tea in the up country districts. *Tea Q.*, **40**: 135 to 144.

Beckett, P.H.T. (1964), Studies on soil potassium, Confirmation of ratio low, Measurement of Potassium in the soil. *J. Soil. sci.*, **15**: 1-8

Gath, S. (1992): Dynamik der Kaliumanlieferung im Boden. Report of the Institut für Landeskultur, Justus-Liebig-University Giessen, Germany.

Goulding, K.W.T. (1988), Potassium fixation and release. In: Methodology in soil K research, Proc. 20th colloquium., International Research Institute, Switzerland, pp. 125-142

Guneratne, G.P. (2000), Characterization of Sri Lankan acid tea soils in relation to soil K dynamics and K uptake by tea (*Camellia sinensis. L*), M Phil's theses, University of Peradeniya, Sri Lanka.

Gunarathne, G.P., Hettiarachchi, L.S.K. and Jayakody, A.N. (2002), Characterization of soils in the tea growing regions of Sri Lanka in relation to Potassium dynamics. *SI J Tea Sci* **67(1/2)** 54-66

Hemingway, R.G. (1963), Soil and herbage potassium levels in relation to yield. *J. Food. Agric*, **14**: 188-195

Lee Roux, J. (1966), Studies on ionic equilibria in Natal soils. Ph. D. diss., University of Natal, Pietermaritzburg, Republic of South Africa.

Krauss, A. (2000), Potassium, integral part for sustained soil fertility, International Potash Institute, Switzerland.

Mapa, R.B., Dasanayake, A.R. and Nayakakorale, H.B. (2005), Soils of intermediate zone of Sri Lanka. Special publication 4. SSS of Sri Lanka.

Mapa, R.B., Somasiri, S. and Nagaragah, S. (1999), Soils of wet zone of Sri Lanka. Special publication no 1, SSS of Sri Lanka.

Macleane, E.O. and Watson, M.E. (1985), Soil measurements of plant available potassium. In: Munson, R.D. (Ed.), Potassium in agriculture, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, U.S.A., pp. 278-308.

Nemath, K. (1975), The effect of K fertilization and K removal by rye grass in pot experiments on the K concentration of the soil solution of various soils. *Plant and soil*, 42: 97-107

Reitmeier, R.F., Brown, I.C. and Holms, R.S. (1951), Release of native and fixed non exchangeable Potassium of soils containing hydrous mica. USDA Tech bull. 1029

Sivasubramanian, S. (1970), The role of aluminium ions in 1. The release of Potassium from mineral soils, its modification by soil organic matter 2. Its effect on the nutrient composition of tea. Ph. D. Thesis. Rothamsted experimental station, Harpenden, Herts.

Skeen, J. B. and Summer, M.E. (1967), Exchangeable aluminium: part 1. The efficiency of various electrolytes for extracting aluminum from acid soils. *S. Afric. J.* **45**: 786-790

Sparks, D.L. and Liebhaf, W.C. (1981), Effect of long term lime and potassium applications on quantity intensity (Q/I) relationship in sandy soils. *Soil Sci. Soc. Am. J.* **45**: 786-790

Spark, D.L. and Hung, P.M. (1985), Physical chemistry of soil Potassium., In: Munson, R.D. (Ed.), Potassium in agriculture, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin, U.S.A., pp. 21-265

Tinker, P.B. (1964) Studies on soil Potassium: Cation activity ratios in acid Nigerian soils. *J. Soil Sci.* **15**:24-34

Wimaladasa, G.D. and Sinclair, A.H. (1988), Assessment of soil Potassium and its uptake by ryegrass. *S.L. J. Tea. Sci.* **57**(2), 73-82.

Wimaladasa, G.D. (1989), Some aspects of the chemistry and mineralogy of soil potassium in Sri Lankan acid tea soils under a range of crops. Ph. D. Thesis. University of Aberdeen, Scotland, United Kingdom.

Yuan, T.L. and Fskell, J.G.A. (1959), The extraction of aluminium from some Florida soils. *Soil Sci. Soc. Am. Proc.*, **23**: 202-205