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POTASSIUM STATUS OF SOME COCONUT-GROWING SOILS OF SRI LANKA

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ABSTRACT

Shanmuganathan, R. T. and Loganathan, P., (1976). Potassium status of some coconut-growing soils of Sri Lanka. *Ceylon Cocon. Q.*, 27, 34-46.

Water soluble, exchangeable, difficultly exchangeable and total potassium contents of sixty-four profiles covering twenty soil series were correlated with percent clay, percent silt, percent sand, pH, percent organic carbon, cation exchange capacity and total exchangeable bases. All forms of potassium in the surface soil were negatively correlated with percent clay. Water soluble, exchangeable and difficultly exchangeable potassium contents were positively related to pH, cation exchange capacity and total exchangeable bases in both surface and sub-soils. The water soluble and exchangeable potassium significantly decreased with depth. The corresponding forms of potassium in surface soils and sub-soils were positively correlated.

Among total, difficultly exchangeable, exchangeable and water soluble potassium there was a positive correlation between two adjacent forms.

Coconut leaf samples collected from soils having wide range of exchangeable potassium showed that when the exchangeable potassium and difficultly exchangeable potassium $\geq$ 75 ppm, the potassium concentrations in the 14th leaf were higher than the critical level. Pot experiments carried out in these soils using an indicator plant (*Paspalum commersonii*) showed that the response to potassium was very low or nil in soils having exchangeable potassium $\geq$ 36 ppm.

The data indicate that most soils in the Intermediate and Wet zones are deficient in potassium.

INTRODUCTION

The coconut palm is a potassium (K) demanding crop, as large quantities are removed by the nuts of the palm. Insufficient K in the soils gives rise to poor growth with thin trunks, sparse canopy with fewer and smaller fronds and leaflets. The response to K is reflected not only in increased nut production, but also in improved setting of the flowers and in better copra out-turn.

The current fertilizer recommendation for coconut in Sri Lanka is based only on field trials. It is proposed to use soil and plant analyses as well, to determine fertilizer requirements. Before employing soil analysis for recommending K fertilization, it is useful to have information on the K status of the various coconut-growing soils. So far only limited data are available on this subject in Sri Lanka. The only information available is in some rubber growing districts which contain low levels of soil K (John, 1967). This study was initiated to assess the K status of the major coconut-growing soils and its relationship to soil properties and parent materials.

MATERIALS AND METHODS

Soil Sampling

Sixty-four sites belonging to twenty soil series in the coconut-growing areas of Sri Lanka were selected. The classification and the parent materials (Fraser, 1962; Fraser, 1963; Perera, 1964; Perera, 1968) are given in Table 1. The soils are sand to sandy clay loam in texture and the pH values range from 4.5 to 6.0 with the exception of Ronorewa, Gampura and Nagamadu which have pH values around 7.

Table 1. *Classification and parent material of the soils*

	*Soil Series**		*Zone***	*Parent material (or distinguishing features)*	*Great soil group*
1.	Boralu	(13)	I & W	Charnockite and Biotite Gneiss	Red Yellow Podzolic
2.	Kiriwana	(5)	I	Qartzite	Red Yellow Podzolic
3.	Kurunegala	(4)	I	Charnockite and Granitic Gneiss	Red Yellow Podzolic
4.	Maho	(4)	I	Hornblende Gneiss and Hornblende-Biotite Gneiss	Reddish Brown Earths and Non Calcic Brown
5.	Andigama	(4)	I	Undifferentiated Granitic Gneiss	Reddish Brown Earths and Non Calcic Brown
6.	Rathupasa	(3)	I	Sands of old beach ridges	Regosol
7.	Wilpattu	(3)	I	Sands of old beach ridges	Red Latasol
8.	Madampe	(3)	I	Old marine sands	Regosol
9.	Pallama	(3)	I & W	Colluvium	Red Yellow Podzolic
10.	Wariyapola	(2)	I	Charnockite and Biotite Granitic Gneiss	Reddish Brown Earths and Non Calcic Brown
11.	Aruvi	(3)	I	Alluvium	Alluvial
12.	Ranorewa	(2)	D	Granitic Gneiss	Reddish Brown Earth
13.	Gambura	(2)	D	Sands of old beach ridges	Red Latasol
14.	Soils of Rockknob Plain	(2)	I	Charnockite and Quartzite and Granitic Gneiss	Lithosolic Regosol
15.	Katunayake	(2)	W	Recent marine sands	Regosol
16.	Sudu	(2)	I & W	Old beach sands	Regosol
17.	Negombo	(4)	I & W	Recent marine sands	Regosol
18.	Bathalagoda	(1)	I	Alluvium	Alluvial
19.	Nagamadu	(1)	D	Sands of old beach ridges	Red Yellow Latasol
20.	Mattikotuwa	(1)	I	Alluvium	Alluvial

*Number of profiles in paranthesis

**W — Wet Zone. I — Intermediate Zone. D — Dry Zone.

Soil samples from profiles at the centre of square formed by four coconut palms were collected at two depths viz., 0 - 20 cm and 40 - 60 cm. The samples were air dried in the laboratory, crushed with a wooden pestle and sieved through a 2mm sieve.

Soil Analysis

Total Potassium (Pratt, 1965): Half (0.5) g of finely ground soil was digested with 10 ml of 1 M hydrofluoric acid and 0.5 ml of 1 M perchloric acid in a platinum crucible and the excess hydrofluoric acid fumed off. The residue was dissolved in dilute hydrofluoric acid, filtered and the filtrate was made up to 500 ml.

Exchangeable Potassium (Pratt, 1965): Ten g of soil was agitated with 50 ml of 0.1 M neutral ammonium acetate, filtered and the filtrate was made up to 200 ml.

Difficultly Exchangeable Potassium (Pratt, 1965): One hundred ml of 1M cold nitric acid was added to 10 g of soil and left to stand overnight. This was then boiled for 10 minutes. After cooling for 15 minutes the digest was filtered and the residue leached with 0.1 M cold nitric acid to a total volume of 250 ml. The difficultly exchangeable K was determined from the difference between the amount of K extracted by nitric acid and exchangeable K.

Water Soluble Potassium: Twenty g of soil was agitated with 40 ml hot water. The supernatant was filtered and made up to 100 ml.

Potassium in the extracts was determined using an EEL flame photometer. pH was determined on 1 : 1 soil/water suspensions using a Beckman pH meter. Cation exchange capacity and total exchangeable bases were determined by 1 M ammonium acetate, pH 7 extraction (Jackson, 1964). Organic carbon was analysed by the wet combustion method of Walkley and Black (1934) and mechanical analysis by the pipette method (Piper, 1950).

Leaf Analyses

Leaf samples from the fourteenth frond of coconut palms in selected sites were collected in September, 1978 (3 palms per site) and K was estimated by extraction with 6 M hydrochloric acid.

Pot Experiment

A pot experiment to determine the yield response to K was carried out on five selected soils using an indicator plant—*Paspalum commersonii*. Three levels of K were tested, and each treatment was replicated thrice. The rates of K were zero, 225 mg and 450 mg of muriate of potash (60% K_2O) per pot (a pot containing 1500 g of soil). Height, dry matter weight and K concentrations in the plant were determined after 45 days of growth.

RESULTS AND DISCUSSION

The various K fractions in each soil series for the surface and sub-surface are shown in Table 2.

Analytical data for both depths showed that there were very highly significant differences between the different soil series and the content of total K (P = 0 001), difficulty exchangeable K (P = 0.001), exchangeable K (P = 0.001) and water soluble K (P = 0.001). Between parent materials too the trend was similar and highly significant (P = 0.01) at both depths except in the case of water soluble K at 40 — 60 cm depth (Figures 1 and 2).

Total Potassium

The soils can be grouped into three broad categories, based on their total K contents- Maho series (total K, 20,000 ppm), Wilpattu, Wariyaplola, Malikotuwa series and soils of Rocknob Plain (10,000 — 20,000 ppm) and the rest, less than 10,000 ppm. High total K in the Maho series is probably due to the presence of K rich minerals such as feldspars and micas in the parent material, hornblende and hornblende-biotite gneiss. This is supported by Figures 1 and 2, which show that soils derived from hornblende gneiss and hornblende-biotite gneiss had the highest content of total K.

Table 2. *Ranges and means* of the potassium fractions (ppm)*

Soil Series	Depth 0-20 cm				Depth 40-60 cm.			
	Water soluble K	*Exch. K*	*Diff. Exch. K*	*Total K*	*Water Soluble K*	*Exch. K*	*Diff. Exch. K.*	*Total K*
Boralu	1 - 15 (5)	8 - 28 (17)	1 - 21 (13)	500 - 18600 (4318)	1 - 7 (2)	4 - 32 (12)	1 - 20 (9)	1000 - 8600 (3073)
Kiriwana	1 - 18 (9)	10 - 75 (43)	20 - 125 (63)	1640 - 11800 (5120)	1 - 16 (5)	12 - 46 (26)	4 - 443 (100)	1120 - 12800 (6824)
Kurunegala ..	3 - 9 (7)	20 - 108 (56)	10 - 53 (30)	2650 - 5500 (4047)	2 - 6 (3)	24 - 58 (41)	4 - 50 (25)	1520 - 7300 (3915)
Maho	8 - 12 (10)	26 - 96 (73)	54 - 189 (125)	16500 - 22800 (21175)	4 - 10 (6)	12 - 82 (52)	13 - 218 (122)	9000 - 26000 (20950)
Andigama	4 - 8 (6)	9 - 56 (31)	15 - 69 (43)	3000 - 6700 (4162)	1 - 9 (5)	11 - 24 (17)	19 - 56 (33)	3050 - 6090 (5012)
Rathupasa	4 - 9 (7)	20 - 28 (23)	3 - 37 (25)	7300 - 12400 (9867)	1 - 2 (2)	10 - 12 (11)	10 - 48 (32)	8600 - 10200 (9366)
Wilpattu	13 - 20 (17)	26 - 32 (29)	13 - 28 (21)	8800 - 22000 (16000)	8 - 21 (15)	24 - 38 (33)	11 - 40 (24)	8800 - 14000 (11733)
Madampe	2 - 10 (6)	8 - 20 (15)	2 - 10 (5)	1700 - 4150 (3266)	2 - 10 (6)	7 - 14 (11)	1 - 36 (17)	1800 - 4850 (3650)
Pallama	2 - 4 (3)	6 - 16 (10)	7 - 12 (8)	900 - 4400 (2300)	2 - 7 (4)	6 - 10 (8)	7 - 8 (7)	1000 - 6000 (2933)
Aruvi	2 - 8 (5)	4 - 35 (18)	8 - 26 (17)	4300 - 11800 (8033)	6 - 11 (8)	6 - 15 (11)	9 - 22 (15)	6100 - 10500 (8266)
Wariyapola ..	5 - 10 (7)	12 - 28 (20)	6 - 137 (71)	12600 - 13000 (12800)	4 - 10 (7)	12 - 14 (13)	16 - 138 (77)	7000 - 12000 (9900)
Ranorewa	21 - 40 (30)	63 - 98 (80)	17 - 73 (45)	2500 - 3900 (3200)	20 - 27 (24)	56 - 110 (83)	45 - 129 (87)	3000 - 9800 (6400)
Gambura	15 - 37 (26)	24 - 128 (76)	17 - 44 (30)	6200 - 6600 (6400)	13 - 23 (18)	38 - 50 (44)	28 - 32 (30)	2200 - 2300 (2250)
Soils of Rockknob plain ..	1 - 12 (6)	18 - 70 (44)	22 - 90 (56)	12700 - 14300 (13500)	1 - 4 (2)	12 - 28 (20)	23 - 127 (75)	9750 - 12700 (12375)
Katunayake ..	6 - 10 (8)	6 - 20 (13)	8 - 14 (11)	300 - 1300 (800)	4 - 6 (5)	4 - 12 (8)	1 - 14 (7)	400 - 1000 (700)
Sudu	4 - 7 (6)	12 - 16 (14)	1 - 12 (6)	100 - 1200 (1100)	2 - 6 (4)	3 - 12 (8)	2 - 6 (4)	1800 - 3000 (2400)
Negombo	2 - 4 (3)	5 - 18 (11)	6 - 13 (10)	1950 - 8800 (6288)	2 - 4 (4)	2 - 16 (10)	1 - 7 (5)	1600 - 4900 (3550)
Nagamadu ..	28	62	44	2200	25	88	32	3000
Mattikottuwa ..	10	20	230	12600	2	18	30	16800
Bathalagoda ..	2	16	19	6100	5	12	18	8000

*Means in parenthesis

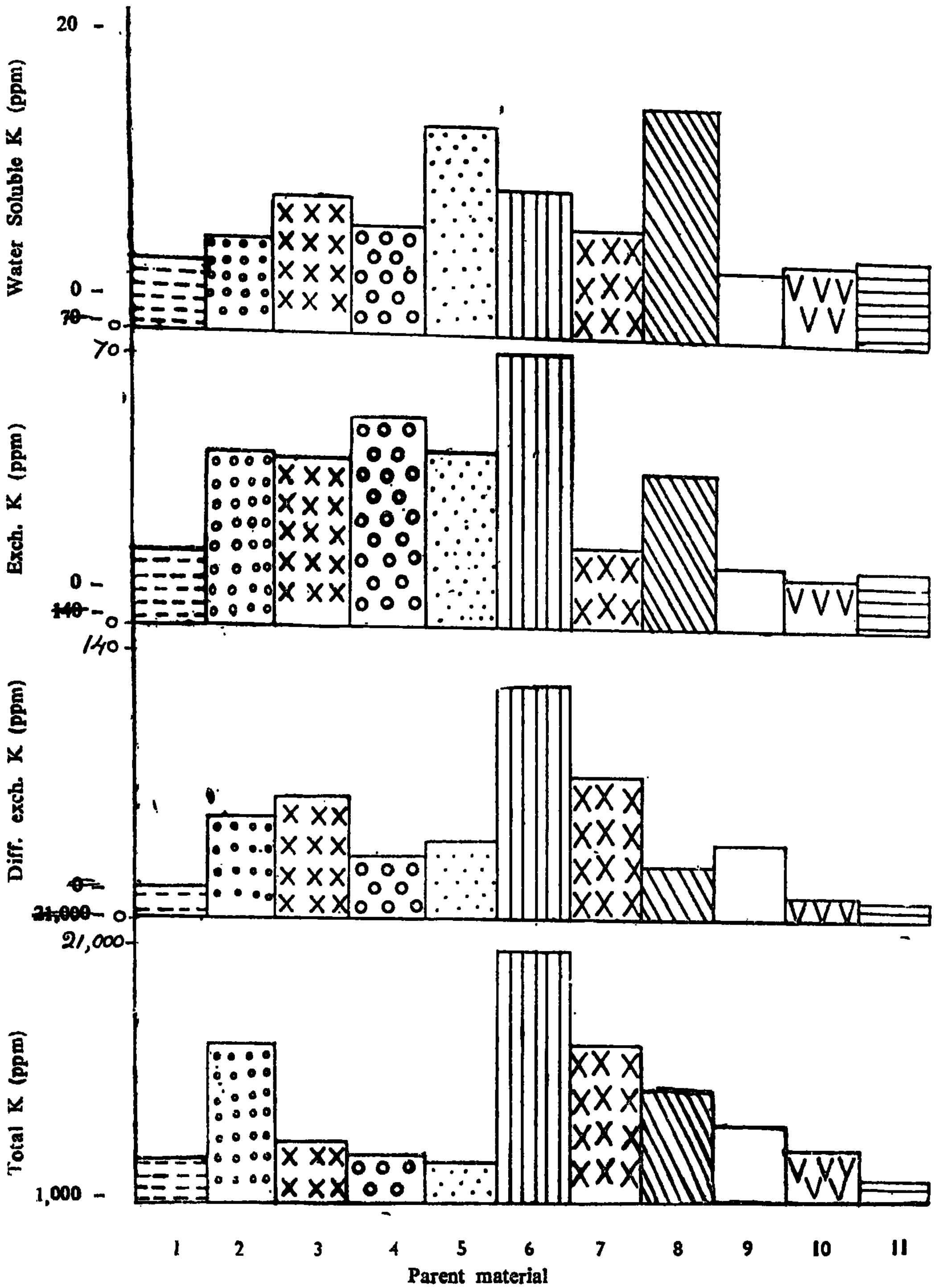

Fig. 1. Relationship between parent material and potassium contents of surface soil.

Legend
1. Charnockite and Quartzitic and Granitic Gneiss
2. Charnockite and Biotite Gneiss
3. Quartzite
4. Charnockite and Granitic Gneiss
5. Granitic Gneiss
6. Hornblende Gneiss and Hornblende—Biotite Gneiss
7. Alluvium
8. Charnockite and Biotite—Granite Gneiss
9. Sands of old beach ridges
10. Marine sands
11. Old beach sands.

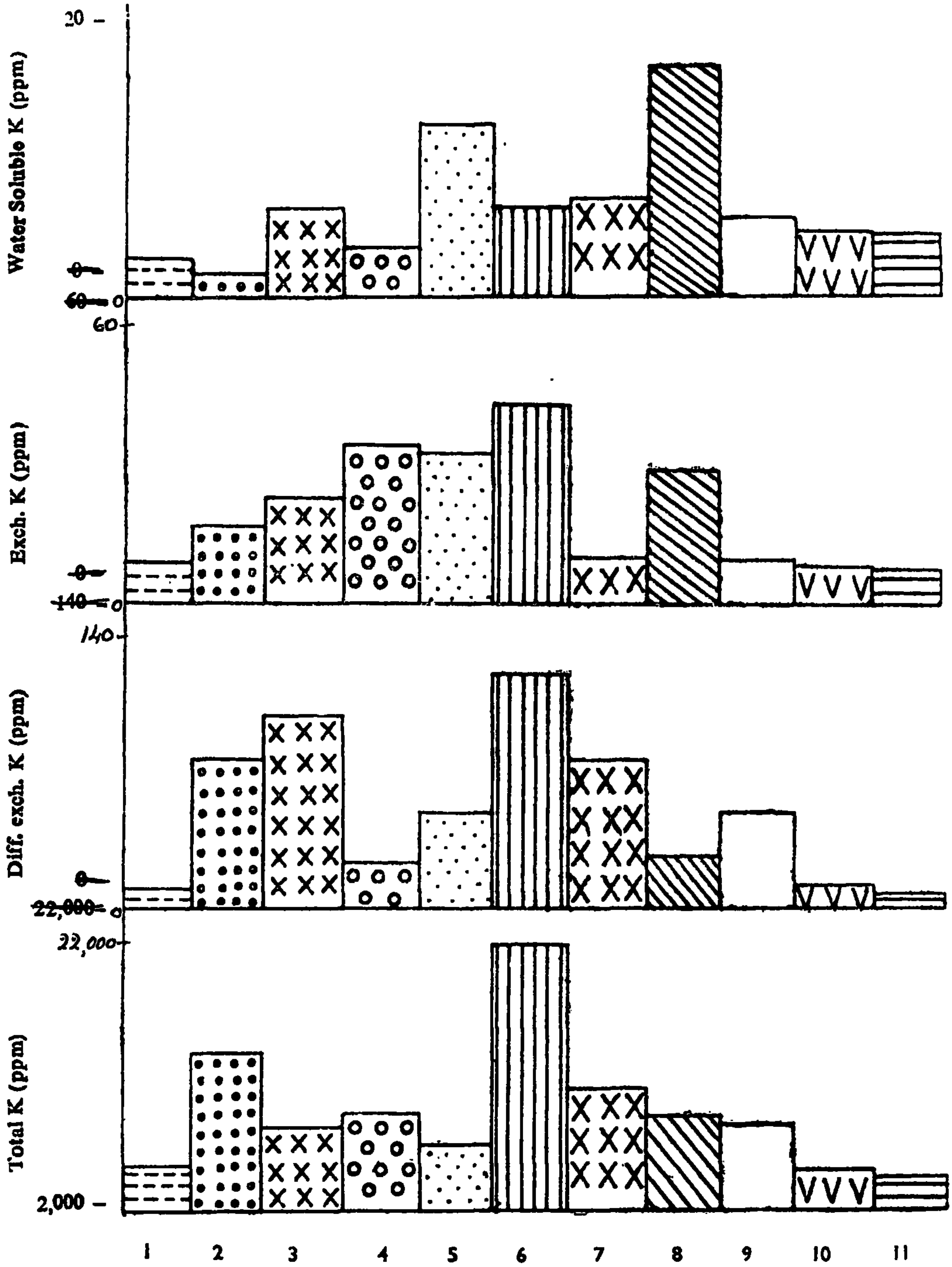

Fig. 2. Relationship between parent material and potassium contents of sub-soil.

Legend

1. Charnockite and Quartzitic and Granitic Gneiss
2. Charnockite and Biotite Gneiss
3. Quartzite
4. Charnockite and Granitic Gneiss
5. Granitic Gneiss
6. Hornblende Gneiss and Hornblende—Biotite Gneiss
7. Alluvium
8. Charnockite and Biotite—Granite Gneiss
9. Sands of old beach ridges
10. Marine sands
11. Old beach sands.

The medium K levels in the second group of soils were probably due to the presence of mica which was noted in localised pockets in the areas sampled.

The low K contents in the third group (Madampe, Katunayake, Negombo, and Sudu series) may be attributed to the very sandy nature of the soils. These were derived from transported parent materials such as marine sands and old beach sands containing mainly quartz (De Alwis and Panabokke, 1972 - 73) which has no K and lack of appreciable quantities of weatherable minerals containing K.

The total K content (mean 7116 ppm) in the soils range from 350 to 24,400 ppm. John (1967) reported that the potassium content of some of the rubber soils in Sri Lanka ranged from 400 to 16,000 ppm with a mean value of 3,100 ppm. Rubber soils are generally more weathered; therefore, one would expect lower contents of K. With the exception of Boralu, all the residual soils had higher total K compared to rubber soils. In Ghana soils the values ranged from 400 to 48,000 ppm with a mean of 7,000 ppm (Acquaye, 1973) and in the West Indian volcanic soils, from 550 to 40,000 ppm with a mean of 6,200 ppm (Moss and Coulter, 1964).

Difficultly Exchangeable Potassium

The difficultly exchangeable K content was highest in Maho series (124 ppm) and Matikotuwa series (130 ppm) as in the case of total K. This is not surprising as these two forms of K are related to each other and total K is the precursor for the release of difficultly exchangeable K. In fact statistical analyses of the data showed a strong positive relation between total and difficultly exchangeable K ($P = 0.001$). John (1967) also reported strong relation between these two forms of K in rubber-growing soils. The reasons for the differences in the difficultly exchangeable K among the soils are same as those given for total K differences.

The difficultly exchangeable K levels in coconut growing soils ranged from 1 to 230 ppm in the surface soils with a mean of 44 ppm and 1 to 143 ppm in the sub-soils with a mean of 38 ppm. These values are lower than those reported for rubber-growing soils (John, 1967)—surface soils having a range of 1 to 271 ppm with a mean of 72 ppm and sub-soils having a range of 2 to 300 ppm with a mean of 75 ppm.

Exchangeable Potassium

The mean exchangeable K content was 34 ppm in the surface soils and 26 ppm in the sub-soils and the corresponding ranges are 4 to 128 ppm and 2 to 110 ppm respectively. In the rubber-growing soils these values ranged from 5 to 73 ppm with a mean of 25 ppm in the surface soils and 6 to 60 ppm with a mean of 22 ppm in the sub-soils. In Ghana (Acquaye, 1973) and the Kingdom of Tonga (Lee and Widdowson, 1977) the exchangeable K levels ranged from 20 to 200 ppm with a mean of 74 ppm and from 85 to 1045 ppm with a mean of 440 ppm respectively. The mean exchangeable K in the Malaysian soils was 78 ppm (Ng, 1965). Exchangeable K content is related to the total K, cation exchange capacity, pH, presence of other exchangeable cations and rainfall. As these conditions differ from country to country it is not surprising that different values of exchangeable K were obtained at different places.

The Ranorewa and Nagamadu series had the greatest contents of the exchangeable K (82 ppm and 75 ppm respectively) followed by Maho series (62 ppm), Gambura series (60 ppm) and Kurunegala series (50 ppm). The rest had less than 44 ppm. These soils are in the Dry zone, where leaching losses would be minimum and the base saturation high. Therefore, the fraction of exchangeable K in these soils were higher than that of the other soils in more wet environment.

Statistical analysis showed that exchangeable Kwas very highly correlated with difficultly exchangeable K ($P = 0.001$).

Water Soluble Potassium

Soils of the Ranorewa, Gambura and Nagamadu series had water soluble K content of 20 to 30 ppm while other soils had lower values. Low water soluble K content of other soils is due to the low exchangeable K contents and heavy leaching in these soils.

Data showed that water soluble K is very highly correlated with exchangeable K (P = 0.001) as one would expect from the mass action principle.

Soil Potassium Relationship with Depth

Table 3 shows that each of the four forms of K in the surface soils was significantly related to the corresponding forms of K in sub-soils, i.e., a high K content in surface soils was an indication of high K content in the sub-soils and vice versa. Therefore, one could analyse the surface soil alone and infer the value in the sub-soil. For tree crops like coconut, K in the sub-soil is also important. Therefore in determining the availability of K for tree crops one would expect to analyse the sub-soil too. But the results in Table 3 show that this is not necessary. This would lead to a reduction in the volume of analytical work.

Table 3. *Relation between the surface and subsurface K*

Forms of K (ppm)		*n*	*r*	*Significant Level*
Water Soluble K	..	64	0.65	***
Exch. K	..	64	0.61	***
Diff. exch. K	..	64	0.81	***
Total K	..	64	0.66	***

*** Significant at P = 0.001

Although Table 3 indicates that there was a positive relationship between surface and sub-soils in K content, Table 4 shows that exchangeble K and water soluble K were higher in surface soils compared to that of the sub-soils. A similar trend was also reported for exchangeable K in rubber-growing soils (John, 1967). The higher exchangeable and water soluble K in surface soils is probably due to phytocycling. Further, the presence of organic acids coupled with intense weathering in the surface layers may have released K from soil minerals.

Table 4. *Variation of soil properties and K forms with depth*

Soil Parameter	*Gradient with Depth*	*Significant Level*
pH (1 : 1 H_2O)	Increasing	N.S.
Organic C %	Decreasing	***
Sand %	Decreasing	***
Silt %	Decreasing	N.S.
Clay %	Increasing	***
Cation Exchange Capacity (me/100 g)	Decreasing	N.S.
Total Exchangeable Bases (me/100 g)	Decreasing	N.S.
Water Soluble K (ppm)	Decreasing	***
Exch. K (ppm)	Decreasing	***
Diff. exch. K (ppm)	Decreasing	N.S.
Total K (ppm)	Increasing	N.S.

*** Significant at P = 0.001

Soil Potassium Relationship with Soil Properties

Table 5 shows that total K in the top soil was negatively correlated with the clay content. This is because the clay fractions contain a predominance of kaolinite and hydrous oxide minerals (De Alwis and Panabokke, 1972–1973) which are poor in K. During the process of weathering, K in the original parent materials has largely distributed itself with the sand and silt fractions leaving very little K if any in the clay fraction.

At both depths, the exchangeable and difficultly exchangeable K were positively correlated with pH, silt, cation exchange capacity and total exchangeable bases. The effect of cation exchange capacity is to increase the negative charges in the soil colloids which therefore increased the retention of exchangeable K and to some extent difficultly exchangeable K. The increase of these forms of K with increase of percent silt was perhaps due to the presence of K containing weatherable minerals in the silt fraction. The effect of pH is to increase base saturation, which gives rise to higher exchangeable and water soluble K.

Leaf Potassium Concentrations of Coconut

The critical concentration of K in the 14th leaf has been shown to be around 0.8 to 1.0% (Fremond *et al.*, 1966; Kanapathy, 1972), above which response to K application is expected to be very low. Table 6 shows the K concentrations in the 14th leaf of palms selected from five soils which had wide range of exchangeable and difficultly exchangeable K values. For short term and annual crops, generally, exchangeable K is considered to be the form of K available to plants. But for perennials like coconut, difficultly exchangeable K may also be important as this form of K acts as a K reserve in the soil and continues to supply exchangeable K when the latter gets used up by the plant. Table 6 indicates that the two soils—Gambura and Ranorewa with both exchangeable and difficultly exchangeable K $\geq$ 75 ppm had leaf K concentrations very much above the critical range, suggesting that soils having these two forms of K $\geq$ 75 ppm, could be considered to have sufficient available soil K. Similarly soils having exchangeable K $\leq$ 36 ppm and difficultly exchangeable K $\leq$ 69 are deficient in K. It should be noted that these values are very broad and tentative as large number of data points are required to arrive at more accurate limits.

Among the two forms of K, exchangeable K appeared to be a better measure of K availability as this form correlated better with leaf K values ($r = 0.764$ for diff. exch. K and $r = 0.912^*$ for exch. K). Table 6 also shows that total K had no relation to leaf K indicating that the inert K (total K — diff. exch. K — exch. K) in the minerals do not become available even for a long-lived crop like coconut.

Nethsinghe (1963) reported that in soils having more than 66 ppm exchangeable K in the surface soils, coconut did not respond to K fertilizers whereas on soils having less than 6.6 ppm exchangeable K, coconut responded to K. The upper limit of 66 ppm is in close agreement with the value of 75 ppm suggested in this study. Based on these soil values, it could be concluded that most coconut soils except some of the soils in the dry areas such as Ranorewa. Nagamadu, Gambura and Maho series, are deficient in K. This agreed with the observation that almost all fertilizer experiments on coconut carried out in the Intermediate and Wet zones of Sri Lanka showed response to K fertilizer applications.

Based on the above results the soils are classified into three groups according to the exchangeable K values as shown in Figure 3.

Yield Responses to K applications

Yield responses of *Paspalum commersonii* to K applications were very high in Negombo and Boralu series, very low in Kiriwana series and almost nil in Gambura and Ranorewa series (Figures 4 and 5). It appears that a level of exchangeable K (little over 36 ppm) lower than that suggested for coconut (based on leaf analysis) is sufficient for short term crops. This difference is due to the differences in the nature of the crops as well as on the difference in the techniques used. In the case of coconut, field determinations were made whereas with *Paspalum commersonii*, soil samples were collected from fields down to an arbitrary depth and plants were grown in pots having restricted volume under greenhouse conditions.

Table 5. *Correlation coefficients of potassium contents and selected soil properties*

Forms of potassium (ppm)	Depth 0 - 20 cm							Depth 40 - 60 cm						
	pH (1 : 1)	C %	Sand %	Silt %	Clay %	C.E.C.[1] me/100g	T.E.B.[2] me/100g	pH (1 : 1)	C %	Sand %	Silt %	Clay %	C.E.C.[1] me/100g	T.E.B.[2] me/100g
Water Soluble K ..	0.58***	—0.10	0.10	0.01	—0.76***	0.52***	0.61***	0.54***	0.02	0.11	0.03	0.13	0.46***	0.49***
Exch. K. ..	0.62***	—0.01	—0.15	0.28**	—0.73***	0.65***	0.59***	0.71***	0.03	—0.11	0.26*	0.06	0.75***	0.73***
Diff. Exch. K ..	0.33**	0.19	—0.05	0.25*	—0.51***	0.24	0.26*	0.33**	0.01	—0.12	0.31*	0.05	0.43***	0.42***
Total K ..	0.18	—0.22	0.20	0.06	—0.83***	0.01	0.03	0.20	—0.18	0.05	0.15	—0.12	0.20	0.16

1. Cation exchange capacity
2. Total exchangeable bases

*, **, *** Significant at $P = 0.05, 0.01, 0.001$ respectively

Table 6. *Potassium concentration in the 14th leaf of palms selected from five sites*

Soil Series	*Soil Site*	*Total K (ppm)*	*Diff. exch. K (ppm)*	*Exch. K (ppm)*	*Leaf K (%)*
Gambura	Vanathivillu	6200	75.0	75.0	1.6
Ranorewa	Kalladi ..	9800	101.0	78.0	2.0
Kiriwana	Kobeigana ..	11800	69.0	36.0	0.5
Negombo	Negombo ..	4900	9.5	13.0	0.6
Boralu	Halpototu	1040	3.0	7.0	0.6

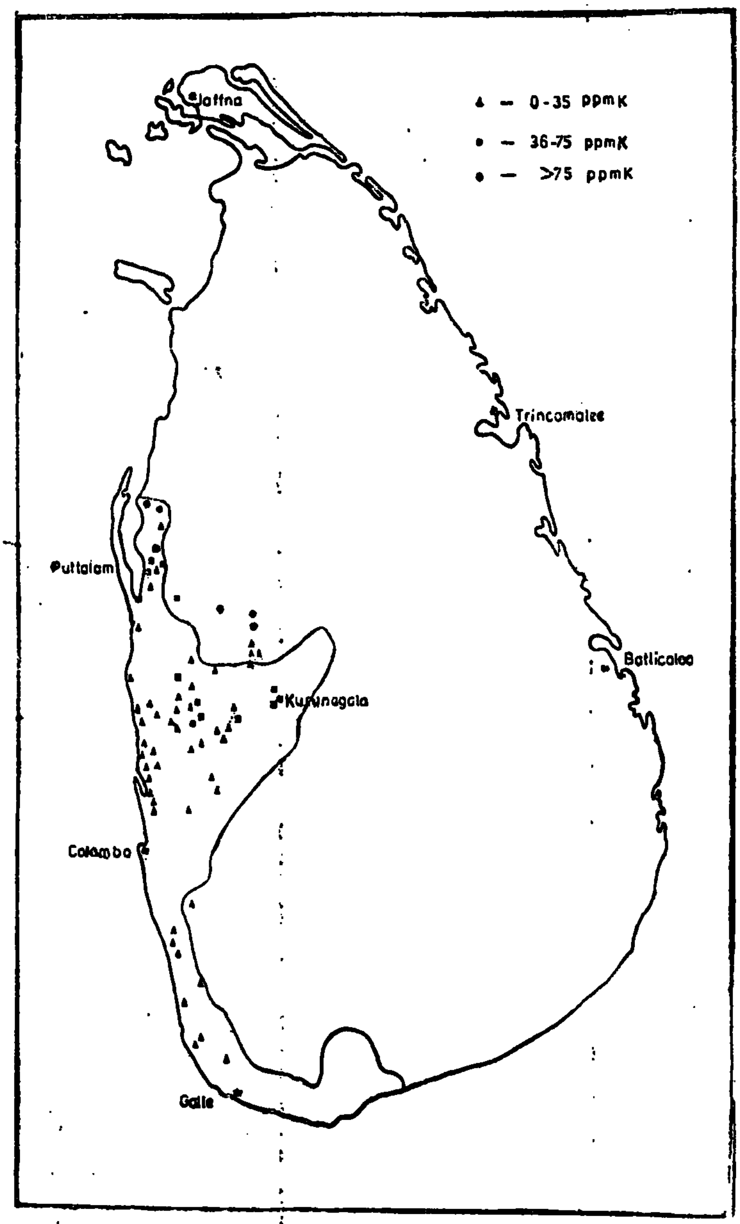

Fig. 3. Exchangeable K status of the surface soils

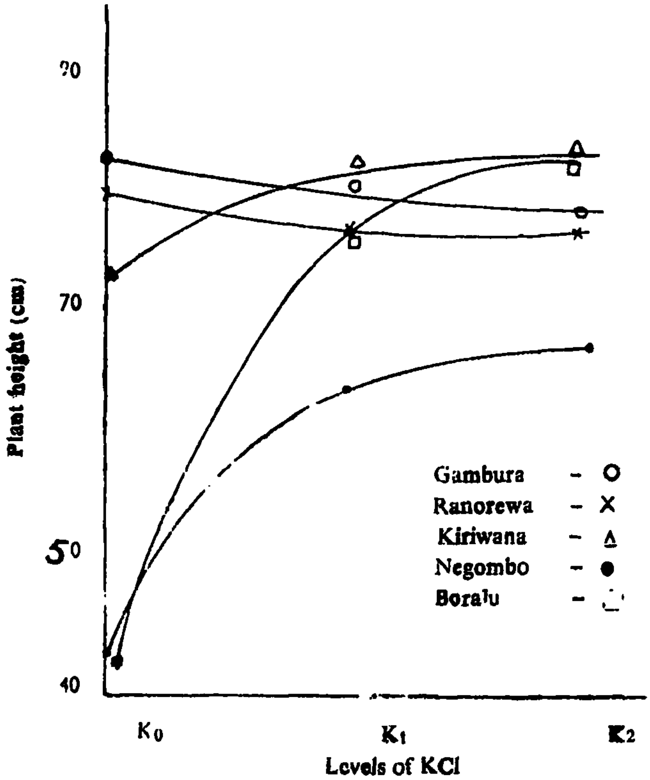

Fig. 4. Plant height response to potassium

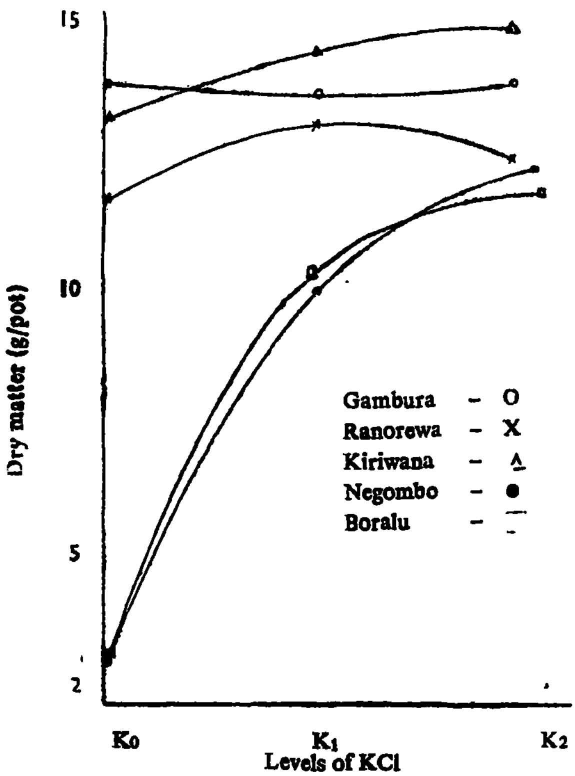

Fig. 5. Dry matter response to potassium