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Potassium-supplying Power of Seven Soils Under Rubber

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In a glasshouse experiment, the inherent potassium-supplying power of seven soils which included an Entisol, an Inceptisol, three Ultisols and two Oxisols were estimated by measurements on growth parameters and potassium uptake by the plants. For soils of comparable texture, the Inceptisol (Selangor series) had the highest potassium-supplying power, followed by an Ultisol (Durian series). The other Ultisols (Serdang and Rengam series) and the Oxisols (Munchong and Segamat series) were estimated to have low potassium-supplying power; among them, the best potassium supplier was Serdang series. A fair comparison could not be made between the Entisol (Holyrood series), which is very coarse-textured, and the other six soils, which are clayey. However, it was seen that its potassium-supplying power was, nevertheless, very low and comparable to that of the Oxisols. Results obtained in the glasshouse related well to field experiments. Luxury uptake of potassium occurred in seedlings grown on Selangor series soil.

Potassium uptake by plants was a very good indicator for predicting the potassium-supplying power of the soils. Of the growth parameters, dry weight of seedlings of at least 192 days from transplanting was also a very good indicator.

The importance of potassium as a major element in *Hevea* nutrition is well appreciated. During the tree's life cycle, large amounts of potassium are continually immobilised, increasing from 7 kg per hectare of potassium (expressed as K) for a one-year-old stand of 445 trees per hectare to 1233 kg per hectare of potassium in a thirty-three-year-old stand of 267 trees per hectare[1]. The removal of potassium in latex depends on the yield obtained as well as on the nutritional status of the trees. A study on eight common clones, under normal exploitation (tapped on *Panels B* and *C*) showed that the potassium removal ranged from 6 kg to 16 kg per hectare, but the use of yield stimulants increased the potassium removal by more than 50%[2]. Although the rubber tree removes much less potassium than some other commercial crops[3], the inherently poor potassium status of most of the soils and the removal of the trees from the field at replanting result in the depletion of the potassium reserves in the soils. The replantings are deficient in potassium. Often the deficiency is incipient and visual deficiency symptoms are not seen on the leaves, but can be detected by foliar analysis. Moreover, when prices of fertilisers are high, or when rubber holdings are limited by budgetary constraints, managements often curtail the use of fertilisers. It was, therefore, deemed useful to test the inherent potassium-supplying power of seven common soils under rubber.

MATERIALS AND METHODS

The soils chosen for the study are Munchong, Segamat, Durian, Serdang, Rengam, Selangor and Holyrood series *(Table 1)*.

These seven soils constitute 1.1 million hectares or approximately 61% of the rubber-growing area in Peninsular Malaysia. Only soil from the Ap2 or the first B sub-horizon, whichever was shallower, was collected after the thin Ap horizon was removed.

The soils were analysed according to methods reported in the laboratory manual of Singh and Ratnasingam[5]; the results are presented in *Table 2*.

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TABLE 1. CLASSIFICATION AND PARENT MATERIAL OF SEVEN SOILS

Soil series	Soil taxonomy[4] (Sub group level)	Parent material
Munchong	Tropeptic Haplorthox	Argillaceous shale
Segamat	Haplic Acrorthox	Andesite
Durian	Orthoxic Tropudult	Argillaceous shale
Serdang	Typic Paleudult	Sandstone
Rengam	Typic Paleudult	Granite
Selangor	Sulfic Tropaquept	Marine alluvium
Holyrood	Orthoxic Quartzipsamment	Riverine alluvium

Tjir 1 selfed seedlings were grown in the glasshouse experiment which was a randomised complete block design consisting of the seven soils replicated four times.

For each of the series, 44 kg of air-dry soil, previously sieved through a 2 cm sieve, were filled into white poly-ethylene bags (also called polybags) measuring 25 cm broad and 60 cm high when laid flat. Three selected seven-week-old seedlings of uniform size and vigour were transplanted from the sand-beds, where they were initially grown, and then established in each polybag. Nutrient solution which did not contain any potassium was supplied once a week. The composition of this solution was 0.328 g calcium nitrate, 0.156 g sodium hydrogen phosphate, 0.307 g magnesium sulphate, 0.198 g ammonium sulphate, 0.085 g sodium nitrate, 2.230 mg manganese sulphate, 0.250 mg copper sulphate, 0.290 mg zinc sulphate, 0.680 mg boric acid and 0.035 mg ammonium molybdate made up to 1 litre with distilled water. The soil was kept at field capacity by watering with deionised water. Whenever necessary, prophylactic treatments were given to the plants to control leaf diseases.

The plant height, diameter of stem and the number of whorls of leaves per plant were recorded at various intervals during the growth of the seedlings.

Four harvests were made at 72, 136, 192 and 260 days from transplanting. At each harvest, the seedlings were separated into laminae and petioles of the different whorls (including fallen senescent leaves), stems and roots. After their dry weights were obtained, the plant materials were analysed for their potassium contents. Two grams of the 'dry ashed' plant material were treated with 8 ml of 20% nitric acid on a steam bath for 1 h and the filtrate analysed for its potassium content on the auto-analyser. Details of this method were reported earlier[7].

The total dry matter produced was calculated from the total weight of the laminae, petioles, stems and roots. Values presented here were adjusted for the initial weight of the seedlings, since at the time of transplant, each Tjir 1 seedling already weighed 1.26 grams.

Potassium-uptake values were calculated from dry weight of the different tissues and their respective potassium contents. Correction for the initial potassium contained in the plant at the time of transplanting was made by subtracting 21.67 mg potassium per plant from the values obtained since a determination on a batch of forty seedlings at the time of transplanting showed that, on an average, each plant contained that amount of potassium.

RESULTS

Height of Plant

The heights of the Tjir 1 seedlings in each polybag were measured at different times;

TABLE 2. PHYSICO-CHEMICAL ANALYSES OF SEVEN SOILS

Soil series[a]	Coarse sand (%) 2−0.2 mm	Fine sand (%) 0.2−0.02 mm	Silt (%) 0.02−0.002 mm	Clay (%) < 0.002 mm	pH 1:1		Org. C (%)	Total N (%)	Phosphorus (p.p.m.)		Potassium (p.p.m.)		Calcium (m.e.%)		Magnesium (m.e.%)		CEC (m.e./100 g soil)
					H_2O	KCl			Total	Avail[a]	A.E.	Exch.	A.E.	Exch.	A.E.	Exch.	
Segamat	1.7	2.3	20.0	76.0	4.5	4.0	0.78	0.10	1 310	7	124	11	0.53	0.14	1.07	0.06	6.51
Munchong	11.3	8.7	17.2	62.8	4.8	4.3	0.96	0.10	624	5	109	19	0.37	0.21	0.62	0.06	5.51
Serdang	41.4	35.3	3.6	19.7	4.3	3.8	0.22	0.06	79	4	451	12	0.13	0.09	2.03	0.02	3.31
Rengam	33.7	6.8	6.5	53.0	4.5	3.9	0.45	0.06	125	3	76	8	0.74	0.04	0.47	0.02	3.18
Holyrood	55.2	30.3	5.7	8.8	4.9	4.4	0.35	0.04	75	14	86	4	0.04	0.02	0.43	0.01	2.11
Selangor	0.8	1.7	26.9	70.6	4.0	3.4	1.00	0.14	174	13	3 580	174	0.12	0.03	30.53	0.62	19.64
Durian	8.2	13.1	32.9	45.8	4.2	3.5	0.39	0.07	41	7	2 215	32	0.42	0.11	2.77	0.06	8.62

A.E. = 6*N* HCl acid extractable

[a] Avail P by Bray's Procedure modified by Arnold (1947)[6].

TABLE 3. HEIGHTS OF PLANTS AT DIFFERENT AGES ON SEVEN SOILS

Soil series	Height of plant (cm) at 30 days	62 days	91 days	128 days	156 days	184 days	218 days	248 days	Difference[a] in height (cm)
Holyrood	43.2	56.3	72.4	80.4	94.6	100.0	109.4	114.0	70.8
Segamat	44.0	59.9	77.1	89.7	94.9	98.9	103.0	109.0	65.0
Munchong	45.0	65.8	69.4	78.4	77.3	90.9	101.6	111.0	66.0
Rengam	47.8	66.2	75.6	91.3	97.4	104.2	107.3	116.0	68.2
Serdang	42.5	55.6	68.2	82.6	89.1	96.2	104.1	109.0	66.5
Durian	42.7	60.7	61.8	85.8	86.8	99.0	111.8	116.0	73.3
Selangor	45.8	64.4	72.4	88.6	90.8	102.2	111.3	117.0	71.2

[a]Between 30 days and 248 days

mean values are presented in *Table 3.* Plants grown on Durian, Selangor, Rengam and Holyrood series soils were taller than the rest.

Diameter of Stem

The growth as measured by diameter was best in Durian, Selangor and Serdang series and poorest in Segamat series soil *(Table 4).*

Number of Existing Whorls of Leaves

The number of existing whorls of leaves per plant was counted for the different polybags on three occasions, mean values are in *Table 5.*

Seedlings grown on Selangor, Durian and Serdang series soil generally had more whorls than seedlings grown on the other four soils.

Total Dry Matter Production

The analysis of variance is presented in *Table 6.* There were significant differences between the different soil series on the dry matter production of Tjir 1 selfed seedlings.

A Duncan multiple range test (below) at the 5% protection level is used to compare the dry matter yield on the different soils. Values are expressed in grams per plant.

Generally, plants grown on Durian, Serdang and Selangor series soils had larger dry matter yield than plants grown on the other soils.

Potassium Uptake

The total potassium uptake of Tjir 1 seedling is shown in *Figure 1* while the analysis of variance is in *Table 7.* There were significant differences in potassium uptake by the seedlings due to different abilities of the soils to supply potassium.

A Duncan multiple range test at the 5% protection level is used to allow an easy compa-

72 days:	Durian	Rengam	Serdang	Holyrood	Segamat	Selangor	Munchong
	11.0	10.0	8.8	8.2	8.1	7.9	7.6
136 days:	Durian	Selangor	Munchong	Serdang	Holyrood	Segamat	Rengam
	24.0	23.1	22.4	19.9	18.8	18.7	16.2
192 days:	Selangor	Durian	Serdang	Rengam	Munchong	Holyrood	Segamat
	38.9	38.1	36.0	33.1	31.2	30.4	27.2
260 days:	Selangor	Durian	Serdang	Rengam	Holyrood	Munchong	Segamat
	63.6	61.6	58.7	53.8	52.2	47.7	40.0

TABLE 4. DIAMETERS OF STEMS AT DIFFERENT AGES ON SEVEN SOILS

Soil series	Diameter of stem (cm) at		
	130 days	184 days	259 days
Holyrood	0.75	0.94	1.06
Segamat	0.78	0.82	1.03
Munchong	0.85	0.96	1.11
Rengam	0.67	0.98	1.17
Serdang	0.84	1.01	1.19
Durian	0.86	1.01	1.22
Selangor	0.83	1.04	1.19

TABLE 5. NUMBER OF WHORLS PER PLANT AT DIFFERENT AGES ON SEVEN SOILS

Soil series	Number of whorls at		
	135 days	191 days	259 days
Holyrood	4	3	3
Segamat	3	4	3
Munchong	3	3	3
Rengam	3	3	3
Serdang	4	4	4
Durian	4	5	4
Selangor	4	4	4

rison of the total potassium uptake per seedling and shown below. Values are expressed in milligrams per plant.

Selangor series soil is seen to supply the highest amount of potassium, followed next by Durian soil. The other five soils have poor potassium-supplying power; among them, Serdang series is the best.

72 days:	Holyrood	Segamat	Serdang	Rengam	Munchong	Durian	Selangor
	3.95	4.39	12.06	12.91	17.41	41.44	72.44
136 days:	Holyrood	Segamat	Rengam	Munchong	Serdang	Durian	Selangor
	10.41	14.06	24.62	24.66	29.61	91.63	208.31
192 days:	Holyrood	Munchong	Segamat	Rengam	Serdang	Durian	Selangor
	72.07	74.42	77.63	86.22	110.93	226.42	335.36
260 days:	Segamat	Munchong	Holyrood	Rengam	Serdang	Durian	Selangor
	63.01	87.82	98.27	101.56	147.34	274.79	588.52

DISCUSSION

Growth parameters as heights, diameter, number of whorls per plant and total dry

TABLE 6. ANOVA OF TOTAL DRY WEIGHT
(Mean of Means)

Source of variation	df	Mean squares			
		72 days	136 days	192 days	260 days
Replicate	3	0.78 NS	3.02*	16.13**	249.72 NS
Between soils	6	6.12*	31.60*	74.26**	275.03***
Error	18	3.43	4.82	3.43	47.29
Mean		8.8	20.5	33.6	53.9
S.D.		1.9	2.2	3.5	6.9
C.V. (%)		21.0	10.7	10.4	12.8

*P<0.05 **P<0.01 ***P<0.001
NS = not significant

TABLE 7. ANOVA OF TOTAL POTASSIUM UPTAKE (Mean of Means)

Source of variation	df	Mean square			
		72 days	136 days	192 days	260 days
Replicate	3	91	365	11 157	2 388
Between soils	6	2 496***	20 632***	364 101***	140 328***
Error	18	116	87	2 321	1 889
Mean		23.5	57.6	403.2	194.5
S.D.		10.8	9.3	48.2	43.5
C.V. (%)		46.0	16.2	12.0	22.4

***P<0.001

weight of the plants were measured to see which could be used to predict the potassium-supplying power of the seven soils.

Seedlings grown on Durian, Selangor, Rengam and Holyrood series soils were taller than seedlings grown on the other soils.

Seedlings grown on Durian, Selangor and Serdang series soils had larger stem diameters than the seedlings on the other four soils. Also, seedlings grown on the three soils had more whorls existing on the plant than seedlings grown on the other soils.

The results showed that the ranking of the soils on their influence on the plants to produce dry matter varied somewhat during different harvest dates, the ranking of the soils being more consistent and about similar for harvests made on both the 192nd and 260th days after transplanting. The seedlings grown on Selangor series soil produced the largest amount of dry matter, followed next by Durian and Serdang series soil.

Since the seedlings were regularly supplied with a nutrient solution which did not contain any potassium, potassium uptake by the seedlings could only be from native potassium in the soils; the differences in the growth of the seedlings indicate the potassium-supplying power of these soils. Selangor, Durian and Serdang series soils have higher inherent

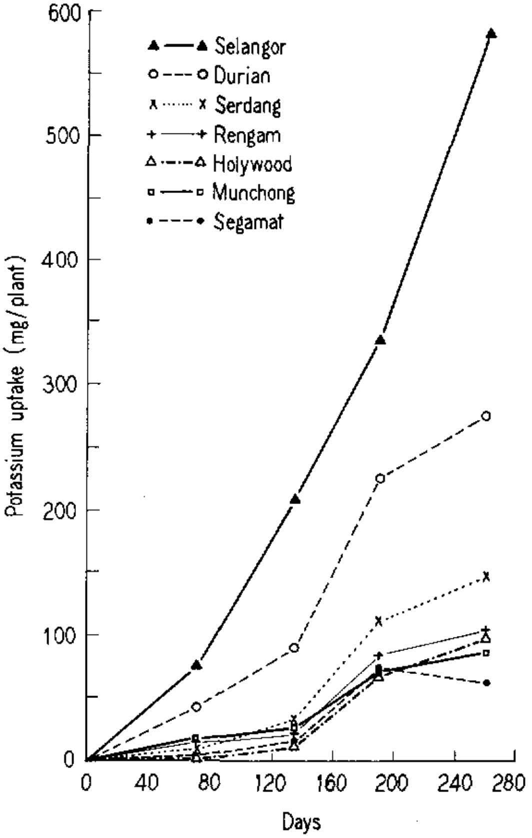

Figure 1. Total plant potassium uptake on different soils.

potassium-supplying power compared to the other soils. Of these three soils, Selangor series is estimated to have the highest potassium-supplying power, followed next by Durian series.

The method of evaluating the potassium-supplying power of the soils by measuring potassium uptake by the plants has often been used[8,9,10]. The potassium uptake from Selangor series (Tropaquept) was the highest, followed next by Durian series (Tropudult). The potassium uptake from the other five soils which included two Paleudults (Serdang and Rengam series soil), an Acrorthox (Segamat series), a Haplorthox (Munchong series) and a Quartzipsamment (Holyrood series) were lower and the differences between these soils were not statistically significant. In fact, on the 260th day from transplanting, the potassium uptake by Tjir 1 seedlings on Selangor series soil was about twice that from Durian series and nine times the uptake from Segamat series soil.

The graph in *Figure 1* shows that on about the 260th day from transplanting, the potassium uptake by the seedlings was almost approaching the 'plateau' or peak of uptake on all the soils except in Selangor series where the 'plateau' was still not reached. The seedlings grown on the last soil showed a 'luxury uptake' of potassium, the uptake being greater than was essential to the growth of the plants. When performance on two soils, Selangor and Durian series was compared, dry matter production in Selangor series was only 3.3% higher than that on Durian series despite the fact that the potassium uptake on the former soil on the 260th day from transplanting was about twice that on the latter soil.

The potassium-supplying power of Selangor series is, therefore, estimated to be very high, that of Durian series high while the remainder of the soils are low in native potassium supply. These results support results obtained from field experiments on response to potassium manuring reported by Pushparajah[11] which showed that yield response to potassium was very low in Durian series. With the present yield levels and exploitation system, yield response to potassium is unlikely on Durian series soil. For Selangor series, there was no response to potassium, while responses were obtained on the other soils. The use of potassium fertilisers on these five soils, excluding Durian and Selangor series soils, is, therefore, very necessary.

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