# SOIL AND FOLIAR NUTRIENT RELATIONSHIP IN SELECTED *SHOREA* AND *KOOMPASSIA* SPECIES IN TWO FOREST RESERVES, PENINSULAR MALAYSIA

**Amir Husni Mohd. Shariff & Mona Zakaria**

*Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur*

*Received May 1990*

**AMIR HUSNI MOHD SHARIFF & MONA ZAKARIA. 1990. Soil and foliar nutrient relationships in selected *Shorea* and *Koompassia* species in two forest reserves, Peninsular Malaysia.** We analysed the soil and foliar nutrient relationships of two lowland tropical rain forest trees. *Koompassia* spp. contain higher foliage nutrient concentrations for N, K, Ca and Zn than *Shorea* spp. Significance differences between soil and foliar K is established for both species. Foliage in trees growing on fertile soils had higher nutrient concentration compared to those on less fertile soils. *Koompassia* spp. accumulated a higher concentration of nutrients than *Shorea* spp.

Key words: Tropical forest - Malaysia - *Shorea* spp. - *Koompassia* spp.- soil - foliar nutrients

## Introduction

The nutrient status in dipterocarp and legume tree species grown on different soil types has not been intensively investigated. One of the factors that governs the rate of nutrient accumulation in the leaves is the soil pool (Miller 1984). In this study, two groups of common genera were chosen, namely *Shorea* and *Koompassia*, which represent dipterocarp and legume species, respectively. The two forests chosen were Tekam Forest Reserve (TFR), which has volcanic derived soils and Pasoh Forest Reserve (PFR) with soils derived from sedimentary and alluvial deposits. Both areas have contrasting soil fertility status (H.M.S. Amir & H.G. Miller unpublished).

Soil and foliar from the reserves were analysed together. Foliar nutrient concentrations of crops between the reserves were compared using analysis of variance (ANOVA). In addition, correlation analysis was adopted to establish soil-foliar nutrient relationships.

## Materials and methods

### *Study sites*

I. Pasoh Forest Reserve (PFR) covering 1360 *ha*, is located in the southwest of Negeri Sembilan (lat. 2° 58.4' N; longtd. 102° 16.9' E). The climate in the area is the west coast type (Lipis type) characterised by the lowest average annual rainfall in Peninsular Malaysia (Morgan 1971);

annual precipitation 1800 *mm* $y^1$ (Dale 1959); air temperature ranges 24.5°*C* to 27.2°*C* (Sani 1983).

The geology was described by Khoo (1976) and Loganathan (1980). The area is underlain by sedimentary rocks in the east and igneous in the west. Alluvial deposits from weathered granite are found in depression areas. The vegetation is described as red meranti-keruing type (*Shorea-Dipterocarpus* association) (Wyatt-Smith 1961) mixed red meranti forest turning to red meranti forest (Salleh 1968).

II. Tekam Forest Reserve (TFR) covering 12400 *ha* is approximately 170 *km* northeast of Kuala Lumpur (lat. 4° 15' N; longtd. 102° 37' E). Average annual precipitation ranges between 2765 to 2980 *mm* $y^1$, whilst average air temperature is between 24°*C* and 29°*C* (Dale 1963).

Rocks in the area are from upper Triassic to lower Cretaceous, associated with volcanism (Khoo 1977), and rich in tuffaceous materials (A. Ibrahim unpublished). The area can be described as undulating to rolling to hilly with slope ranging from 2° to 35° and elevation between 80 and 325 *m* above sea level.

A prevalence of the genera *Dipterocarpus* and *Shorea* of the red meranti group dominates the floristic composition (Poore 1968). The Tekam hydrological basin study area, 56.6 *ha* within the TFR was the study area.

## *Soil sampling*

TFR and PFR soils were described according to the field legend for soil surveyors in Malaysia (Paramananthan 1986). Five dominant series, each 2-*ha* in size, were chosen for each reserve.

The soils of TFR were: Tajau (TJU) (Typic Paleudult), Jempol (JPL) (Typic Paleudult), Bungor (BGR) (Typic Paleudult), Jengka (JKA) (Rhodic Paleudult) and Jeram (JRM) (Typic Paleudult); while for PFR the soil are: Padang Besar (PBR) (Orthoxic Tropudult), Bukit Tuku (BTU) (Aquic Paleudult), Ulu Dong (UDG) (Typic Paleudult), Awang (AWG) (Aquic Paleudult) and Chat series (Typic Paleudult).

Ten composite samples (from five sampling points) were randomly collected for each soil series; at 0 to 15 *cm* and 15 to 30 *cm*. Samples were oven dried for 48 to 72 *h* at 60°*C*; passed through the roller mill and sieved through a 2 *mm* sieve. For N determination, samples were sieved through 0.5 *mm* sieve.

Soil pH was determined using 1:2.5 (soil-water ratio). Kjedahl digestion procedure was adopted for total N determination (USDA 1972), followed by steam distillation. Available P by Bray and Kurtz's Number 2 extracts (Bray & Kurtz 1945), and measured colorimetrically. Exchangeable cations were determined after leaching with 1N $NH_4OAc$ at pH 7 (Chapman 1965).

Total elements were determined by digestion with perchloric: sulphuric acid mixture (1:1) for 2 *h* at 230°*C* (after Lim 1975) and measured using Jackson's procedures (1958). Fe, Al and P were precipitated, using ammonium hydroxide; prior to determination of K, Ca, Mg, Cu and Zn followed by destruction of ammonium salt by digestion with excess nitric acid on a hot plate. Exchangeable and total K were determined by flame photometer; Ca, Mg, Cu and Zn analysis was carried out using atomic absorption spectrophotometer; total P using ascorbic acid reduction (Watanabe & Olsen 1965).

### *Foliage sampling*

Foliar samples were taken from tree species on each soil series. The tree species were *Shorea leprosula, Shorea parvifolia, Shorea ovalis, Koompassia malaccensis* and *Koompassia excelsa.* All are common tree species in the study sites, except *K. excelsa.* This species was excluded for individual comparison except when combined. Trees sampled were at least 30 *cm* diameter at breast height (dbh) with their crowns in the canopy layer. Samples were collected from upper one third of the canopy; and confined to mature leaves of the outer-whorl and 15 *cm* from the shoot tip. Sampling was carried out in the morning and ceased during rain, commencing only after 24 *h.*

Samples were ground with a Christy and Norris grinding mill and passed through a 1 *mm* sieve.

Nitrogen was determined by Kjedahl method (Piper 1950). Dry ashing was used for P, K, Ca and Mg; while for Cu and Zn wet ashing was used. P was determined colorimetrically and measured using spectrophotometer; K by flame photometer; Ca, Mg, Cu and Zn by atomic absorption spectrophotometer.

### *Analysis of data*

Soil and foliar data from the two areas were analysed together. Confidence is gained from the fact that data on almost all parameters from the two reserves overlapped, with no significant gaps between the two groups. Furthermore, both reserves are classified as lowland dipterocarp rain forest of similar stature.

Significant level was set at 5% for t and F test and LSD (Least Significant Difference) calculated on that basis. LSD using 1 and 0.1% was also tried for some analyses where greater emphasis and examination was required.

To facilitate comparison and distinction, all *Shorea* spp. were classified as one and similarly as *Koompassia* spp.

## Results

### *Foliar nutrient concentrations*

Pasoh Forest Reserve:

Between *Koompassia* spp. and *Shorea* spp., only N differed significantly ($P<0.001$, Table 1), with foliage in the former having twice the concentration of the latter (Table 2). Among the *Shorea* spp., some degree of differences were observed with no consistent pattern.

**Table 1**. Foliar concentrations and results of analysis of variance (ANOVA) in *Shorea* spp. and *Koompassia* spp. in PFR and TFR

| Foliar nutrients | N | P | K | Ca | Mg | Cu | Zn |
|---|---|---|---|---|---|---|---|
| | | | (%) | | | (ppm) | |
| PFR: | | | | | | | |
| *Shorea* spp. *vs.* | 1.36 | 0.07 | 0.61 | 0.44 | 0.19 | 10.8 | 24.5 |
| *Koompassia* spp. | 2.68 | 0.08 | 0.72 | 0.60 | 0.24 | 11.8 | 24.9 |
| | *** | ns | ns | ns | ns | ns | ns |
| TFR: | | | | | | | |
| *Shorea* spp. *vs.* | 1.74 | 0.08 | 0.73 | 0.42 | 0.27 | 13.6 | 29.6 |
| *Koompassia* spp. | 2.45 | 0.10 | 1.21 | 0.42 | 0.57 | 11.9 | 24.6 |
| | * | ns | ** | ns | * | ns | * |
| *Shorea* spp. PFR. *vs.* | 1.36 | 0.07 | 0.61 | 0.44 | 0.19 | 10.8 | 24.5 |
| *Shorea* spp. TFR. | 1.74 | 0.08 | 0.73 | 0.42 | 0.27 | 13.6 | 29.6 |
| | ns | ns | ns | ns | ns | ns | * |
| *Koompassia* spp. PFR. *vs.* | 2.68 | 0.08 | 0.72 | 0.60 | 0.24 | 11.8 | 24.9 |
| *Koompassia* spp. TFR | 2.45 | 0.10 | 1.21 | 0.42 | 0.57 | 11.9 | 24.6 |
| | ns | ns | ** | ns | ** | ns | ns |
| *Shorea* + *Koompassia* spp. PFR. *vs.* | 2.02 | 0.07 | 0.67 | 0.52 | 0.22 | 11.4 | 24.7 |
| *Shorea* + *Koompassia* spp. TFR. | 2.09 | 0.09 | 0.97 | 0.42 | 0.42 | 12.7 | 27.1 |
| | ns | * | ** | ns | * | ns | ns |

(+, *, **, *** and ns are significant at 10%, 5%, 1% 0.1% and non-significant respectively)

**Table 2**. Foliar concentrations in *Shorea ovalis*, *Shorea leprosula*, *Shorea parvifolia* and *Koompassia malaccensis* and results of analysis of variance (ANOVA) between means of nutrient concentrations in PFR and TFR

| | N | P | K | Ca | Mg | Cu | Zn |
|---|---|---|---|---|---|---|---|
| | | | (%) | | | ppm | |
| Tekam Forest Reserve: | | | | | | | |
| *S.ovalis* | 1.33a | 0.10a | 0.44a | 0.30a | 0.17a | 15.12a | 14.50a |
| *S.leprosula* | 1.64ab | 0.06a | 0.76b | 0.33a | 0.15a | 13.86a | 38.10b |
| *S.parvifolia* | 1.93b | 0.13b | 0.70ab | 0.44a | 0.31ab | 14.26a | 36.0b |
| *K.malaccensis* | 2.90c | 0.13b | 1.44c | 0.32a | 0.45b | 13.34a | 28.6ab |
| Pasoh Forest Reserve: | | | | | | | |
| *S. ovalis* | 1.19a | 0.07a | 0.63a | 0.63b | 0.14a | 13.39a | 27.30a |
| *S. leprosula* | 1.41a | 0.08a | 0.57a | 0.39a | 0.18a | 11.92a | 24.0a |
| *S. parvifolia* | 1.56a | 0.09a | 0.68a | 0.50ab | 0.28a | 13.24a | 28.0a |
| *K. malaccensis* | 2.61b | 0.09a | 0.74a | 0.62b | 0.26a | 12.75a | 25.5a |

Note: Values not sharing the same letter(s) are significantly different at $P<0.05$

### Tekam Forest Reserve:

Foliar levels of N, K, Mg and Zn in *Shorea* spp. and *Koompassia* spp. differed significantly ($P<0.05$-$0.01$) (Table 1). However, only K was more highly significantly. Foliar N and K were highly significant in *Koompassia* spp. compared to *Shorea* spp. Between the *Shorea* spp., some degree of significance were observed with no consistent pattern (Table 2).

TFR *versus* PFR

Foliar Zn in the shoreas of the two reserves differed significantly (P<0.05). Significant differences (P<0.01) in foliar K and Mg were observed in *Koompassia* spp. between the reserves. *Koompassia* spp. and *Shorea* spp. combined, differred in P, K and Mg levels (Table 1).

Comparison between individual species of both reserves revealed significant difference in K and Ca concentrations for *K. malaccensis*, Ca (P<0.01) for *S. ovalis*; and Mg (P<0.05) for *S. parvifolia* (Table 3).

**Table 3.** Foliar concentrations in *Shorea ovalis*, *Shorea leprosula*, *Shorea parvifolia* and *Koompassia malaccensis* between PFR and TFR, and results of analysis of variance (ANOVA) between means of nutrient concentrations

| | *S.parvifolia* TFR:PFR | *S.leprosula* TFR:PFR | *K.malaccensis* TFR:PFR | *S.ovalis* TFR:PFR |
|---|---|---|---|---|
| N | 1.93:1.56 | 1.64:1.41 | 2.90:2.61 | 1.33:1.19 |
| (%) | ns | ns | ns | ns |
| P | 0.13:0.09 | 0.06:0.08 | 0.13:0.09 | 0.10:0.07 |
| (ppm) | ns | ns | ns | ns |
| K | 0.70:0.68 | 0.76:0.57 | 1.44:0.76 | 0.44:0.63 |
| (%) | ns | ns | *** | ns |
| Ca | 0.44:0.50 | 0.33:0.39 | 0.32:0.62 | 0.30:0.63 |
| (%) | ns | ns | ** | ** |
| Mg | 0.45:0.28 | 0.17:0.14 | 0.33:0.26 | 0.15:0.18 |
| (%) | * | ns | ns | ns |
| Cu | 14.26:13.24 | 13.86:11.92 | 13.34:12.75 | 15.12:13.39 |
| (ppm) | ns | ns | ns | ns |
| Zn | 36.00:28.00 | 38.10:24.00 | 28.60:25.50 | 14.50:27.30 |
| (ppm) | ns | ns | ns | ns |

(*, **, *** and ns are significant at 5, 1, 0.1% and not significant, respectively)

## *Soil-foliar relationships*

Highly significant correlations between foliar and soil K in the subsoil and topsoil (r=0.90 and 0.96, Table 4) were obtained in *S. leprosula*. Similar result was shown in *K. malaccensis* with r=0.78 from the subsoil but weakly expressed in the topsoil due to its absence in TJU and JRM series soils. For exchangeable soil cations the relationships with foliar nutrients are poor except for Mg (Table 4).

Table 5 shows that foliar K in shoreas are well correlated to topsoil and subsoil K (r=0.82 and 0.88). Similarly for *Koompassia* spp. (r=0.67 and 0.79).

Other soil-foliar relationships were also established particularly for total Mg, exchangeable Ca, extractable P and Zn (Table 4).

**Table 4.** Correlation coefficients (r) of foliar nutrient concentrations of *Shorea parvifolia, Shorea leprosula, Koompassia malaccensis* and *Shorea ovalis versus* total element concentrations, where n = 7, 9, 8 and 6, respectively, except *Koompassia malaccensis* - Zn is 7 (PFR and TFR combined)

| | | Foliage nutrients | | | |
|---|---|---|---|---|---|
| Species | | *S.parvifolia* | *S.leprosula* | *K.malaccensis* | *S.ovalis* |
| Soil nutrients: | | | | | |
| N | - topsoil | 0.02 | -0.37 | -0.71 | -0.74 |
| | - subsoil | 0.23 | -0.36 | -0.68 | -0.67 |
| P | - topsoil | 0.16 | 0.09 | 0.14 | 0.66 |
| | - subsoil | 0.12 | 0.14 | -0.05 | 0.59 |
| K | - topsoil | 0.08 | 0.90*** | 0.67+ | -0.45 |
| | - subsoil | 0.18 | 0.96*** | 0.78* | -0.50 |
| Ca | - topsoil | -0.56 | 0.30 | 0.21 | -0.27 |
| | - subsoil | -0.48 | 0.34 | 0.35 | 0.02 |
| Mg | - topsoil | 0.70+ | 0.64+ | -0.08 | 0.36 |
| | - subsoil | 0.75+ | 0.74* | -0.13 | 0.19 |
| Cu | - topsoil | -0.07 | 0.40 | -0.10 | 0.14 |
| | - subsoil | -0.35 | 0.02 | -0.14 | 0.49 |
| Zn | - topsoil | 0.43 | 0.06 | 0.15 | 0.44 |
| | - subsoil | 0.22 | -0.05 | 0.14 | 0.74+ |
| Av.P | - topsoil | -0.13 | 0.48 | -0.66 | 0.13 |
| | - subsoil | -0.19 | 0.16 | -0.44 | 0.81* |
| Ex.K | - topsoil | 0.61 | 0.29 | 0.54 | -0.32 |
| | - subsoil | 0.53 | 0.39 | 0.64+ | -0.40 |
| Ex.Ca | - topsoil | -0.33 | 0.06 | -0.14 | 0.81+ |
| | - subsoil | -0.28 | 0.28 | 0.54 | 0.86* |
| Ex.Mg | - topsoil | 0.75+ | 0.82** | -0.47 | 0.08 |
| | - subsoil | 0.67+ | 0.81** | -0.31 | -0.15 |

(+, *, ** and *** are significant at 10, 5, 1 and 0.1%, respectively; the abbreviations Ex. and Av. are for exchangeable and available, respectively)

**Table 5.** Correlation coefficients (r) of foliar nutrient concentrations in *Shorea* spp. and *Koompassia* spp. *versus* total soil element concentrations, where n=10 (PFR and TFR combined) unless otherwise stated

| Species | | | *Shorea* spp. | *Koompassia* spp. |
|---|---|---|---|---|
| Soil nutrients: | N | - topsoil | 0.27 (0.60+) | -0.89*** |
| | | - subsoil | 0.24 (0.51) | -0.85** |
| | P | - topsoil | 0.31 | 0.11 |
| | | - subsoil | 0.24 | 0.06 |
| | K | - topsoil | 0.82** | 0.67* |
| | | - subsoil | 0.88*** | 0.79** |
| | Ca | - topsoil | -0.39 | 0.09 |
| | | - subsoil | -0.29 | 0.17 |
| | Mg | - topsoil | 0.42 | 0.50 |
| | | - subsoil | 0.61+ | 0.63+ |
| | Cu | - topsoil | 0.41 | -0.21 |
| | | - subsoil | 0.27 | -0.20 |
| | Zn | - topsoil | 0.38 | (0.21) |
| | | - subsoil | 0.28 | (0.33) |
| | Av.P | - topsoil | 0.16 | -0.29 |
| | | - subsoil | 0.06 | -0.08 |
| | Ex.K | - topsoil | 0.44 | 0.33 |
| | | - subsoil | 0.55 | 0.44 |
| | Ex.Ca | - topsoil | 0.38 | -0.22 |
| | | - subsoil | 0.49 | 0.32 |
| | Ex.Mg | - topsoil | 0.84** | 0.62+ |
| | | - subsoil | 0.70* | 0.68* |

(Number in parenthesis are those where n=9; +, *, ** and *** are significant at 10, 5, 1 and 0.1, respectively; the abbreviations Ex. and Av. are for exchangeable and available, respectively)

## *Soil fertility status between TFR and PFR*

Nutrients in the topsoil and subsoil of TFR were higher than the corresponding depths in PFR. Exceptions were noted for exchangeable Ca, extractable Zn, and to a lesser extent total Ca (Table 6).

From the 13 parameters analysed, ten differed appreciably between reserves in the topsoil. For subsoil, all the exchangeable and total nutrients, including available P and pH differ significantly, except total Ca. High concentration of exchangeable bases in TFR corresponded to the total amount of cations and is well supported by high pH values.

**Table 6.** Results of chemical analyses of soil sample; and analysis of variance (ANOVA) between means of chemical soil properties of bulk samples between PFR and TFR in topsoils and subsoils, where n=50 for each horizon

Topsoil: Available and exchangeable nutrients plus pH

| Site | Av.P | Ex. K | Ex. Ca | Ex. Mg | pH |
|---|---|---|---|---|---|
| | (ppm) | (*meq*/100 *g* soils) | | | ($H_2O$) |
| TFR | 6.73 | 0.18 | 0.34 | 0.38 | 4.40 |
| PFR | 5.29 | 0.10 | 0.34 | 0.26 | 4.24 |
| Significant levels | *** | *** | ns | *** | * |

Topsoils: Total soil nutrients

| Site | N | P | K | Ca | Mg | $Fe_2O_3$ | Cu | Zn |
|---|---|---|---|---|---|---|---|---|
| | (%) | (ppm) | (*meq*/100 *g* soils) | | | (%) | (ppm) | |
| TFR | 0.094 | 294 | 5.05 | 3.03 | 3.08 | 2.07 | 12.17 | 28.70 |
| PFR | 0.077 | 143 | 2.47 | 2.68 | 1.84 | 0.97 | 7.42 | 33.20 |
| Significant levels | *** | *** | *** | ns | *** | *** | *** | ns |

Subsoils: Available and exchangeable nutrients plus pH

| Site | Av. P | Ex. K | Ex. Ca | Ex. Mg | pH |
|---|---|---|---|---|---|
| | (ppm) | (*meq*/100 *g* soil) | | | ($H_2O$) |
| TFR | 4.34 | 0.14 | 0.17 | 0.33 | 4.57 |
| PFR | 3.17 | 0.07 | 0.23 | 0.14 | 4.39 |
| Significant levels | *** | *** | *** | *** | * |

Subsoils: Total soil nutrients

| Site | N | P | K | Ca | Mg | $Fe_2O_3$ | Cu | Zn |
|---|---|---|---|---|---|---|---|---|
| | (%) | (ppm) | (*meq*/100 *g* soil) | | | (%) | (ppm) | |
| TFR | 0.056 | 207 | 8.41 | 1.70 | 4.55 | 2.79 | 9.38 | 13.80 |
| PFR | 0.047 | 122 | 2.29 | 1.63 | 1.91 | 1.54 | 5.85 | 23.50 |
| Significant levels | ** | *** | *** | ns | *** | *** | *** | *** |

(+, *, **, *** and ns are significant at 10, 5, 1, 0.1% and not significant at P< 0.05, respectively)

## Discussion

### *Foliar nutrient status in PFR and TFR*

Selected *Shorea* and *Koompassia* spp. in TFR contained higher foliar nutrient concentrations than in PFR, for all elements except Ca (Table 1). The same was found when comparison between the mean of foliar nutrient concentrations of TFR and PFR were made (Table 3). This is not surprising since TFR soils are of volcanic origin and hence fertile (Table 6). This phenomenon has also been observed elsewhere (Miller 1984, Riswan 1989). TFR soils have more efficient decomposition rate and organic matter mineralization; where C:N ratio is <15, compared to 15 to 26 in PFR (H.M.S. Amir & H.G. Miller unpublished). Foliar N content in TFR is surprisingly not significantly different from that of PFR.

Foliar K and Mg were higher at TFR for *Koompassia* spp. (Table 1). This is reflected by high levels of total and exchangeable K and Mg in the soils (Table 6).

Foliar P was higher in TFR than in PFR (Table 1). The difference is significant after combining foliar values of *Koompassia* spp. and *Shorea* spp. The fact that the difference is not clearcut is believed to be due to P fixation by free Fe, despite high amounts of total P (H.M.S. Amir & H.G. Miller unpublished). P from the soil reserve is considered to be the primary source of foliar P (Walker & Syers 1976), and retranslocation prior to leaf abscission as secondary (Herrera *et al.* 1978, Vitousek 1984, Katainen & Valtonen 1986). The relative high foliar P levels at TFR suggest that the crops are capable of extracting soil P despite high potential for fixing phosphate in the soil. It is hypothesized that the acid nature of the soils, (Sanchez 1976), nitrification processes (Delwiche 1977), by product of ammonium uptake (Nilsson *et al.* 1982) and microorganism interactions (Stevenson 1964, Graustein *et al.* 1977), may have chelated the Al and Fe phosphate complexes rendering P available for plant uptake.

High foliage level of nutrients in legumes compared to dipterocarps have been documented by Riswan (1982, 1989) and Araujo and Haridasan (1988). The ability of legumes to increase nutrient uptake has been documented by Sprent (1983) and Harley and Smith (1983). This is a direct consequence of atmospheric N fixation by bacteria in the root nodules. K is particularly important for strengthening cell wall (Perrenoud 1977, Beringer & Nothdurft 1985). *K. malaccensis* is shade tolerant (Newbery *et al.* 1986) and known to emerge from the canopy layer (Whitmore 1972). According to Hubbell & Foster (1986), this particular species tends to occupy the post-emergent layers, therefore, its crown is exposed to strong wind and highly likely to break. It is absolutely necessary for this species to acquire high amounts of K to strengthen its crown.

Some degree of fluctuations were observed between individual species, within and between reserves (Tables 2 & 3). This observation accords with the work of Riswan (1989) on the vegetation of karangas forest in Indonesia. These differences reflect the capability of some species to absorb more nutrients than others, especially on fertile sites. It may also reflect different development stages at the time of sampling (Miller 1984).

### *Relationship between foliar and soil nutrients*

Soil and foliar relationships are well expressed by total K for *S. leprosula* and *K. malaccensis* (Table 4 ), and also by *Shorea* spp. and *Koompassia* spp. (Table 5). Interestingly, no relationship was recorded with exchangeable soil K. This may be due to its low concentration compared to the total, and the ability of perennial tree roots to obtain nutrients from intractable soil sources (Nilsson *et al.* 1982).

The poor relationship between foliar and soil N in *Shorea* spp. could be due to one outlying point in JPL series. N value (0.07%) is based on bulk sample taken to a depth of 15 *cm*. The soils contained 0.14 % N based on soil profile sample in the upper 5 *cm* of the soil (H.M.S. Amir & H.G. Miller unpublished). It is suggested that because samples were taken to a depth of 15 *cm*, the high N content in the thin layer of the topsoil is obscured. This depth being a horizon of intense mineralisation and N availability. Furthermore, ten composite samples based on five sampling points each in 2-*ha* size plot is inadequate for sedimentary derived soils as they are highly heterogenous even over short distances (Ng & Ratnasingam 1970, Singh & Norhayati 1978, Baillie & Ahmad 1984).

Significant relationships of soil-foliar Mg were observed in *S. parvifolia* and *S. leprosula* (Table 4), but less significant for *Shorea* spp. and *Koompassia* spp. (Table 5). These relationships suggest that as the levels of total and exchangeable Mg in the soil increase, the uptake by plant increases, thus indicating higher affinity for Mg in individual species than genera composition.

## Conclusion

It is clear that trees growing on fertile soils tend to absorb more nutrients than those in less fertile soils. High amounts of K uptake were recorded in *Shorea* spp. and *Koompassia* spp.; and to a lesser degree for Mg, parallel to their availability in the soil pool. Legumes like *Koompassia* absorbed more nutrients than dipterocarps for most of the nutrients, particularly N, K, Mg and Zn.

Despite P fixation in soils, forest trees are able to absorb P in the undisturbed forest ecosystem. Under this condition, the process of nutrient cycling remains open allowing free flow of minerals.

*K. malaccensis* accumulated higher nutrient concentrations, especially N, than *S. ovalis*, S. *parvifolia* and *S. leprosula*. Among the shoreas, nutrient uptake fluctuation was observed with no particular trend. Some species were able to absorb more nutrients than others.

## Acknowledgements

We thank the Soil Chemistry Laboratory staff for their services, the Botany staff for retrieving the foliage, and Y.P. Tho for his comments on the manuscript.

# References

ARAUJO & HARIDASAN. 1988. A comparison of the nutritional status of two forest communities on mesotrophic and dystrophic soils in Central Brazil. *Soil Science Plant Analytical* 19: 1075-1089.

BAILLIE, I.C. & AHMAD, M.I. 1984. The variability of red yellow podzolic soils under mixed dipterocarp forest in Sarawak, Malaysia. *Malaysian Journal of Tropical Geography* 9: 1-13.

BRAY, R.H. & KURTZ, L.T. 1945. Determination of total organic matter and available forms of phosphorus in soils. *Soil Science* 59 : 39-45.

BERINGER, H. & NOTHDURFT, F. 1985. Effects of potassium on plant and cellular structures. Pp. 352-567 in *Potassium in agriculture.* American Society of Agronomy, Crop Science Society of America and Soil Science Society of America.

CHAPMAN, H.D. 1965. Cation exchange capacity. Pp. 891-901 in [Black, C.A. *et al.* (Eds.)] *Methods of soil analysis. Agronomy 9.* American Society of Agronomy Inc., Madison, Wisconsin.

DALE, W.L. 1959. Rainfall of Malaya, Part 1. *Journal of Tropical Geography* 13:23-37.

DALE, W.L. 1963. Surface temperature in Malaya. *Journal of Tropical Geography* 17:57-71.

DELWICHE, C.C. 1977. Energy relations in the global nitrogen cycle. *Ambio* 6: 106-111.

FLORENCE, R.G. & CHUONG, P.H. 1974. The influence of soil types on foliar nutrients in *Pinus radiata* plantations. *Australian Forestry Research* 6(3): 1-8.

GRAUSTEIN, W.C., CROMACK, K. & SOLLINS, P. 1977. Calcium oxalate occurence in the soils and effect on nutrients and geochemical cycles. *Science* 198 : 1252-1254.

HARLEY, J.L. & SMITH, S.E. 1983. *Mychorrhizal symbiosis.* Academic Press, London.

HERRERA, R., JORDAN, C.F., KLINGE, H. & MEDINA, E. 1978. Amazon ecosystems. Their structure and functioning with particular emphasis on nutrients. *Interciencia* 3: 223-232.

HUBBELL, S.P. & FOSTER, R.B. 1986. Biology, chance and history and the structure of tropical rain forest tree communities. Pp. 314-329 in [Diamond, J. & Case, T.J. (Eds)]. *Community ecology.* Harpers and Row, New York.

JACKSON, M.L. 1956. Soil Chemical Analysis. Sodium carbonate fusion of silicates. *Handbook of Chemistry and Physics 302.*Department of Soil Science, University of Wisconsin, Madison, Wisconsin.

KATAINEN, H.S. & VALTONEN, E. 1986. Nutrient retranslocation in relation to growth and senescence of Scots pine needles. *Crop physiology of forest tree. Proceedings of the International Seminar on Managing forest trees as cultivated plants.* July 23-28, 1984. Helsinki, Finland.

KHOO, H.P. 1976. Geology of the Jelai- Gemas forest reserve area Sheet 104, Kuala Pilah. Pp. 101-102 in *Annual Report for 1975.* Geological Survey of Malaysia, Ministry of Primary Industries, Malaysia.

KHOO, H.P. 1977. The geology of Sungai Tekai area, Pahang. Pp. 93-103 in *Annual Report for 1976.* Geological Survey of Malaysia, Ministry of Primary Industries, Malaysia.

LIM, H.K. 1975. Working manual for soil analysis. Soil and Analytical Services. *Manual Number 6.* Division of Agriculture. Ministry of Agriculture and Rural Development, Malaysia.

LOGANATHAN, P. 1980. The geology of south-western part of the Durian Tepus area (Sheet No. 96), Negeri Sembilan. Geology survey. Pp. 147-158 in *Annual Report for 1979.* Geological Survey of Malaysia, Ministry of Primary Industries.

MILLER, H.G. 1984. Dynamics of nutrient cycling in plantation ecosystems. Pp. 53-78 in [Bowen, G.D. and Nambiar, E.K.S. (Eds.)] *Nutrition of plantation forest.* Academic Press, London.

MORGAN, R.P.C 1971. Rainfall of West Malaysia. A preliminary regionalization using principle component analysis. *Area* 3:222-227.

NEWBERY, D. McC, RENSHAW, E. & BRUENIG, E.F. 1986. Spatial pattern of trees in karangas forest, Sarawak. *Vegetatio* 65: 77-89.

NILSSON, S.I., MILLER, H.G. & MILLER, J.D. 1982. Fast growth as a possible cause of soil and water acidification. An examination of the concepts. *Oikos* 39: 40-49.

NG, S.K. & RATNASINGAM, K. 1970. Soil heterogeneity and field sampling for chemical analysis of Malaysian soils. *Proceedings of first ASEAN Soil Conference* (Compiled by the Malaysian Society of Soil Science). January 6 - 17, 1969. Bangkok.

PARAMANATHAN, S. 1986. *Field legend for soil surveys in Malaysia.* Universiti Pertanian Malaysia and Malaysian Society of Soil Science, Kuala Lumpur, Malaysia.

PERRENOUD, S. 1977. Potassium and plant health. Bern-worblaujen, Switzerland. *International Potash Institute of Research. Topic number 3.*

PIPER, C.S. 1950. *Soil and plant analysis.* University of Adelaide, Adelaide, Australia.

POORE, M.E.D. 1968. Studies in Malaysian rain forest. I. The forest on triassic sediments in Jengka forest reserve. *Journal of Ecology* 56: 143-196.

RISWAN, S. 1982. *Ecological studies on primary and secondary and experimentally cleared mixed dipterocarp forests and kerangas forests in East Kalimantan, Indonesia.* Ph.D. Thesis, University of Aberdeen. Volumes I and II. 342 pp.

RISWAN, S. 1989. Kerangas forest at Gunung Pasir, Samboja, East Kalimantan. II. Nutrient status in the leaves. Paper presented at the *Fourth Round-Table Conference on Dipterocarps.* December 12 - 15, 1989. Bogor, Indonesia.

SALLEH, M.N. 1968. Forest resources reconnaissance survey of Malaya. Jelebu district, Negeri Sembilan. *Report Number 21,* Department of Forestry, Malaysia.

SANCHEZ, P.A. 1976. *Properties and management of soils in the tropics.* Wiley, New York.

SANI, S. 1983. *Microclimate aspects of a lowland dipterocarp forest in Pasoh Forest Reserve, Negeri Sembilan, Malaysia.* Department of Geography, Universiti Kebangsaan Malaysia. 41pp.

SINGH, M.M. & NORHAYATI, M. 1978. Precision of soil and leaf data analysis in Malaysian laboratories. Pp. 23-41 in *Proceedings of Seminar on Soil and Leaf Analytical Methods. Their techniques and Interpretations.* Malaysian Society of Soil Science and Universiti Pertanian Malaysia.

SPRENT, J.I. 1983. Agricultural and horticultural systems: Implications for forestry. Pp. 23-41 in [Gordon, J.C. and Wheeler, C.T. (Eds)] *Biological nitrogen fixation in forest ecosystems; foundations and applications.* Martinus Nijhoff/W. Junk, Publishers.

STEVENSON, I.L. 1964. Biochemistry of soil. Pp. 242-291 in [Bear, F.E.( Ed.)] *Chemistry of the soil.* Reinhold, New York.

USDA. 1972. Soil survey laboratory methods and procedures for collecting soil samples. *Soil survey investigations report number 1.* United States Department of Agriculture and Conservation Services, Washington, D.C.

VITOUSEK, P.M. 1984. Litter fall, nutrient cycling and nutrient limitation in tropical rain forests. *Ecology* 65: 285-298.

WALKER, T.W. & SYERS, J.K. 1976. The fate of phosphorus during pedogenesis. *Geoderma* 15: 1-15.

WATANABE, F.S. & OLSEN, S.R. 1965. Test of ascorbic acid method for determining phosphorus in water and NaHCO extracts from the soil. *Soil Science Society of America Proceedings* 29 : 677-678.

WHITMORE, T.C. 1972. Leguminosae. Pp. 237 - 304 in *Tree flora of Malaya. Volume I.* Longman, Kuala Lumpur, Malaysia.

WYATT-SMITH, J. 1961. A note on the fresh water swamps, lowland and hill forests of Malaya. *Malayan Forester* 24: 110 - 121.