THE NUTRIENT STATUS OF THE PLATEAU HEATH FOREST ON GUNUNG KERIONG, PAHANG, PENINSULAR MALAYSIA

G.L.S. Chua, B.L. Koh, S. Lau, S.C. Lee, M. Mathias, I. M. Turner*, J.W. H. Yong

Department of Botany, National University of Singapore, Singapore 119260

&

H. H. Heah

Malaysian German Forestry Research Project, Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur, Malaysia

Received November 1994

CHUA, G. L. S., KOH, B. L., LAU, S., LEE, S. C., MATHIAS, M., TURNER, I. M., YONG, J. W. H. & HEAH, H. H. 1995. The nutrient status of the plateau heath forest on Gunung Keriong, Pahang, Peninsular Malaysia. Foliage from six species (*Dacrydium beccarii, Eugenia caudata, Eugenia stapfiana, Eurycoma longifolia, Ficus deltoidea* and *Podocarpus neriifolius*, leaf litter and mineral soil (0 - 20 cm) samples were collected for elemental analysis from the heath forest growing on the summit plateau of Gunung Keriong on the southern border of Pahang, Peninsular Malaysia. The leaves of the trees (*Ficus deltoidea* being an epiphytic shrub) were generally small in size and sclerophyllous with a notably low foliar nitrogen concentration. The mineral soil was strongly acidic (pH in water of 4.04) and low in total N, P and K, but not extremely so. These analyses were similar to other published data for heath forests in Southeast Asia.

Key words: Foliar analysis - leaf litter - nitrogen - phosphorus - potassium - soil acidity - tropical forest

CHUA, G. L. S., KOH, B. L., LAU, S., LEE, S. C., MATHIAS, M., TURNER, I. M., YONG, J. W. H. & HEAH, H. H. 1995. Status nutrien bagi hutan rawa dataran tinggi di Gunung Keriong, Pahang, Semenanjung Malaysia. Dedaun daripada enam spesies (*Dacrydium beccarii, Eugenia caudata, Eugenia stapfiana, Eurycoma longifolia, Ficus deltoidea* dan *Podocarpus neriifolius*) sarap daun dan sampel tanah mineral (0 - 20 cm) telah diambil untuk analisis unsur daripada hutan rawa yang tumbuh pada kemuncak dataran tinggi Gunung Keriong di sempadan selatan Pahang, Semenanjung Malaysia. Dedaun pokok-pokok (*Ficus deltoidea* sebagai pokok renik epifit) secara amnya bersaiz kecil, tebal serta keras dengan kepekatan nitrogen dedaun yang agak rendah. Tanah mineral adalah sangat berasid (pH dalam air adalah 4.04) dan rendah dalam jumlah N, P dan K, tetapi tidak begitu melampau. Analisis-analisis berikut adalah sama dengan data-data lain yang telah diterbitkan untuk hutan-hutan rawa di Asia Tenggara.

Introduction

Heath forest is a floristically and physiognomically distinct formation of tropical rain forest (Richards 1952, Whitmore 1984) characterized by strongly scleromorphic

**Author for correspondence*

foliage and frequent domination by pole-sized trees (Brünig 1974). Edaphic conditions are believed to be the cause of the distinctive nature of the heath forest community but the specific controlling factor in the soil that leads to the presence of heath forest rather than mesomorphic lowland forest remains unclear. Soil nutrient poverty, exacerbated by extreme acidity and the presence of substances toxic to many plants such as free protons, aluminium ions and polyphenols, has been put forward as the most likely factor governing the distribution of heath forest (Proctor *et al.* 1983a, Turner 1994). However, others have argued that the freely-draining sands that often support heath forest are subjected to regular periods of drought which select for a more xeromorphic community than typical rain forest (Brünig 1974).

The Malay Peninsula has relatively little natural heath forest (Symington 1943, Wyatt-Smith 1963), especially in comparison to nearby Borneo, and it has received scant scientific attention. One of the types of sites where heath forest is found in Peninsular Malaysia is on the tops of sandstone plateaux in southern Pahang and Johore (Wong *et al.* 1987). This study was undertaken to make a preliminary assessment of the nutrient status of the vegetation at Gunung Keriong, at the southern border of Pahang.

Materials and methods

Study site

Gunung Keriong (441 m) is a flat-topped outcrop of sandstone (Che Aziz & Ibrahim 1989), the summit of which marks the Pahang-Johore state borders. The mountain lies within the boundaries of the proposed Endau-Rompin National Park and the Sungai Kinchin valley that lies below the scarp slope of Gunung Keriong was the site of a scientific expedition in 1989 (Davison 1990). The heath forest on the plateau of Gunung Keriong is of low stature (approximately 5 m canopy height), dominated by pole-sized trees, with abundant carnivorous (*Nepenthes* spp.) and myrmecophytic (*Hydnophytum formicarum*) plants. A thick litter layer (more than 20 cm deep in some places) overlays a uniformly pale grey mineral soil of a fine sandy texture.

Plant and soil analysis

Six plant species commonly found in the area of heath forest at Gunung Keriong were sampled for analysis. These consisted of five tree species, including the two gymnosperms *Dacrydium beccarii* Parl. and *Podocarpus neriifolius* D. Don; the two Myrtaceae *Eugenia caudata* King and *Eugenia stapfiana* King, and the simaroubaceous *Eurycoma longifolia* Jack; and the shrubby epiphytic fig *Ficus deltoidea* Jack. Foliage samples were collected from five individuals of each species for analysis. Leaf litter and mineral soil samples (0 - 20 cm) were collected from six randomly chosen sites. The samples were brought back to the camp where ten leaves (leaflets in the case of *Eurycoma*) from each foliage sample were measured for length and breadth and their outlines traced onto paper. The outlines were cut out and their area measured on an electronic area meter. The needle-like leaves of *Dacrydium beccarii* were too small to measure accurately in the field. The foliage and soil samples were transported to Singapore where they were dried at 80 °C and subsequently analysed chemically. Soil samples were passed through a 2-mm sieve before analysis. The total nitrogen, phosphorus and potassium concentrations in the leaves were determined on extracts after sulphuric acid-hydrogen peroxide digestion, as described by Allen (1989). Total nitrogen concentration was determined by the standard Kjeldahl method. Total phosphorus concentration was assayed colorimetrically using the molybdenum-blue method. Total potassium concentration was determined by flame emission using a flame photometer. Three foliage samples were analysed per species.

Soil pH measurements were obtained using an electronic meter by mixing the dry sample with distilled water in a ratio 1:2 (w/v) to form a slurry. Another pH reading was obtained using 0.01 M $CaCl_2$ solution in place of distilled water. Weight loss-on-ignition was determined by subjecting the dry leaf litter and soil samples to a combustion period of three hours at a temperature of 580 °C. The carbon/nitrogen (C/N) ratio was calculated by converting the weight loss-on-ignition to the total carbon content by multiplying the values by the widely used factor of 0.58 (Allen 1989), though this can only be viewed as a rough estimate because the actual carbon content of soil organic matter varies with soil type and the inaccuracy may be compounded by mineralogically-bound water (Howard & Howard 1990).

Voucher specimens of the plant species were deposited in the Herbarium (SINU) of the Department of Botany, National University of Singapore.

Results

The leaf area, length and width of the leaves were generally small (Table 1). Leaf surface area of all species, except *Eugenia stapfiana* and *Ficus deltoidea*, were grouped in the microphyll size class (Webb 1959). *Eugenia stapfiana* and *Ficus deltoidea* had leaves with surface area in the nanophyll and notophyll size classes respectively. Length of the leaves ranged from 2.4 cm in *Eugenia stapfiana* to 12.7 cm in *Podocarpus neriifolius*. Width of the leaves was between 1.3 cm in *Eugenia stapfiana* and 4.9 cm in *Ficus deltoidea*.

Table 1. Leaf characteristics (mean ± one standard error) of five species collected from the heath forest on Gunung Keriong

Species	Leaf length (mm)	Leaf width (mm)	Leaf area (cm^2)
Eugenia caudata	55.5 ± 1.5	26.3 ± 0.7	7.3 ± 0.4
Eugenia stapfiana	24.0 ± 0.7	13.4 ± 0.4	1.7 ± 0.1
Eurycoma longifolia	80.8 ± 1.5	20.0 ± 0.6	9.7 ± 0.2
Ficus deltoidea	84.6 ± 3.0	49.2 ± 2.7	30.3 ± 2.7
Podocarpus neriifolius	127.5 ± 5.7	15.4 ± 0.3	13.3 ± 0.9

The total nitrogen, phosphorus and potassium concentrations in the leaf litter and soil were generally lower than in the foliage of the plant species (Table 2). The total nitrogen and phosphorus concentrations in the leaf litter were higher compared to the soil. However, the total potassium concentration in the soil was about 4.5 times greater than that in the leaf litter. *Ficus deltoidea* differed from the other species in having a slightly higher total nitrogen, lower total phosphorus and an unusually high total potassium concentration in its foliage. The mineral soil was highly acidic, with a mean (± one standard error) pH in distilled water of 4.04 (± 0.09), and 3.08 (± 0.05) in 0.01 M $CaCl_2$ solution. The latter lower value indicates the presence of exchangeable protons or Al^{3+} ions in the soil. The loss-on-ignition value of the mineral soil averaged 18.3 (± 3.1) %. The C/N ratios of the litter and mineral soil were 88 and 72 respectively.

Table 2. Mineral nutrient analyses for foliage, litter and mineral soil samples from the heath forest on Gunung Keriong

Species	Total N (mg g^{-1})	Total P (mg g^{-1})	Total K (mg g^{-1})
Dacrydium beccarii	8.9 ± 0.3	0.57 ± 0.09	3.7 ± 0.6
Eugenia caudata	6.5 ± 0.5	0.47 ± 0.03	5.1 ± 0.2
Eugenia stapfiana	8.6 ± 0.5	0.81 ± 0.24	7.4 ± 2.0
Eurycoma longifolia	nd	1.28 ± 0.18	8.2 ± 0.8
Ficus deltoidea	13.2 ± 0.6	0.18 ± 0.07	20.6 ± 1.1
Podocarpus neriifolius	6.9 ± 0.3	0.54 ± 0.06	5.4 ± 0.2
Mean foliage value	8.8	0.64	8.4
Leaf litter	6.4 ± 0.5	0.22 ± 0.02	0.17 ± 0.03
Mineral soil (0-20 cm)	1.5 ± 0.6	0.15 ± 0.03	0.79 ± 0.3

nd = not determined.

Discussion

The leaves of the heath forest species studied were generally small and sclerophyllous. The foliar nutrient analysis gave results similar to other published analyses for tropical sclerophyllous forests (see Bongers & Popma 1990 and Table 3), including those from Southeast Asia (Peace & MacDonald 1981, Riswan 1991, Turner *et al.* 1995), which are most notable for their low foliar nitrogen concentration in comparison with mesomorphic lowland forest. This probably reflects the high degree of sclerophylly of the vegetation, with a high fibre concentration diluting the nitrogen content of the foliage (Turner 1994). The epiphytic *Ficus deltoidea* was markedly different from the five tree species in its foliar nutrient profile, with higher nitrogen and potassium concentrations but considerably lower levels of phosphorus. This may indicate fundamental differences between the nutrient relationships of epiphytes and terrestrial species, but clearly the sample size was too small to infer any definite link to life form.

The leaf litter at Gunung Keriong was low in the concentration of the three important plant nutrients when compared to data of other tropical forest sites (Proctor *et al.* 1983b, Table 3), most notably in potassium. Compared to the heath forest studied by Proctor *et al.* (1983b) in Gunung Mulu National Park, Sarawak, Gunung Keriong showed a similar nitrogen, higher phosphorus but lower potassium concentrations in the litter.

Table 3. Comparison of the nutrient concentration data (mean values reported) from Gunung Keriong with those from other forest sites in Southeast Asia

Material	Forest type	Total N (mg g^{-1})	Total P (mg g^{-1})	Total K (mg g^{-1})
Foliage	Heath[1]	**7.7**	**0.73**	**6.0**
Foliage	Heath[2]	9.8	1.5	6.4
Foliage	Heath[3]	8.7	0.22	3.5
Foliage	Heath[4]	8.1	0.28	5.6
Foliage	Lowland dipterocarp[5]	19	0.78	12
Foliage	Lowland dipterocarp[6]	15	0.71	10
Foliage	Lowland dipterocarp[7]	15	1.5	8.1
Litter	Heath[1]	**6.4**	**0.22**	**0.17**
Litter	Heath[8]	5.7	0.14	2.3
Litter	Lowland dipterocarp[8]	9.5	0.10	4.5
Litter	Lowland dipterocarp[5]	14	0.23	5.9
Soil (0-20 cm)	Heath[1]	**1.5**	**0.15**	**0.79**
Soil (0-10 cm)	Heath[8]	9.1	0.28	0.21
Soil (0-10 cm)	Heath[9]	1.0	0.006	nd
Soil (0-10 cm)	Heath[9]	1.0	0.008	nd
Soil (0-5 cm)	Heath[4]	2.1	0.17	32
Soil (0-10 cm)	Lowland dipterocarp[8]	5.1	0.12	0.10
Soil (0-10 cm)	Lowland dipterocarp[9]	4.0	0.14	nd

1 = **this study**, 2 = Riswan 1991, 3 = Peace & MacDonald 1981, 4 = Turner *et al.* 1995, 5 = Grubb *et al.* 1994, 6 = Grubb 1977 as modified in Grubb *et al.* 1994, 7 = Riswan 1988, 8 = Proctor *et al.* 1983b, 9 = Riswan 1989, nd = not determined.

Soil values for nitrogen and total phosphorus were low, but not extremely so (see Sim *et al.* 1992 and Table 3). Most Southeast Asian forests occur on soils of pH less than 5.0, but the soil pH at Gunung Keriong was still at the low end, although heath forest soils of under pH 4 when measured in water have been recorded (Proctor *et al.* 1983a, Riswan 1989). The C/N ratio of the soil was high incomparison with other sites in Southeast Asia (Yamakura & Sahunalu 1990).

Conclusion

The heath forest of the Gunung Keriong plateau appears similar in nutrient status with other heath forests in Southeast Asia. It occurs on extremely acidic soils that are low in major plant nutrients. It is possible that the concentrations of these nutrients, available to the plant roots are considerably lower than the total extractable values. Soil infertility leads to relatively low foliar nutrient concentrations, particularly nitrogen. The poor soils of the plateau must result from a low concentration of the important elements in the parent material and a tendency for nutrients to be leached out of the system.

Acknowledgements

Our stay at Ulu Kinchin and visit to Gunung Keriong would not have been possible without the assistance of the Orang Asli boatmen and guides from Kampung Peta. Financial support from the National University of Singapore is gratefully acknowledged.

References

ALLEN, S. E. 1989. Analysis of vegetation and other organic materials. Pp. 46 - 61 in Allen, S. E. (Ed.) *Chemical Analysis of Ecological Materials*. 2nd edition. Blackwell Scientific Publications, Oxford.

BONGERS, F. & POPMA, J. 1990. Leaf characteristics of the rain forest flora at Los Tuxtlas, Mexico. *Botanical Gazette* 151 : 354 - 365.

BRÜNIG, E. F. 1974. *Ecological Studies in the Kerangas forests of Sarawak and Brunei*. Borneo Literature Bureau, Kuching.

CHE AZIZ, A. & IBRAHIM, K. 1989. A brief description of the Tebak Formation in the Ulu Kinchin Area, Pahang, Malaysia. *Malayan Nature Journal* 43 : 220 - 227.

DAVISON, G. W. H. 1990. The Malayan Nature Society Rompin-Endau Expedition: 1989. *Malayan Nature Journal* 43 : 212 - 219.

GRUBB, P. J. 1977. Control of forest growth and distribution on wet tropical mountains. *Annual Review of Ecology and Systematics* 8 : 83 - 107.

GRUBB, P. J., TURNER, I. M. & BURSLEM, D. F. R. P. 1994. Mineral nutrient status of coastal hill dipterocarp forest and adinandra belukar in Singapore: analysis of soil, leaves and litter. *Journal of Tropical Ecology* 10 : 559 - 577.

HOWARD, P. J. A. & HOWARD, D. M. 1990. Use of organic carbon and loss-on-ignition to estimate soil organic matter in different soil types and horizons. *Biology and Fertility of Soils* 9 : 306 - 310.

PEACE, W. J. H. & MACDONALD, F. D. 1981. An investigation of the leaf anatomy, foliar mineral levels, and water relations of trees of a Sarawak forest. *Biotropica* 13: 100 - 109.

PROCTOR, J., ANDERSON, J. M., CHAI, P. & VALLACK, H.W. 1983a. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. I. Forest environment, structure and floristics. *Journal of Ecology* 71: 237 - 260.

PROCTOR, J., ANDERSON, J. M., FOGDEN, S. C. L. & VALLACK, H.W. 1983b. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. II. Litterfall, litter standing crop and preliminary observations on herbivory. *Journal of Ecology* 71: 261 - 283.

RICHARDS, P. W. 1952. *Tropical Rain Forest - An Ecological Study*. Cambridge University Press, Cambridge. 450 pp.

RISWAN, S. 1988. Leaf nutrient status in the lowland dipterocarp forest. *Reinwardtia* 10 : 425 - 437.

RISWAN, S. 1989. Trend of soil nutrient movements in two different soil types after clear-cut with or without burnt [*sic*] in Kalimantan, Indonesia. Pp. 261-270 in van der Heide, J. (Ed.) *Nutrient Management for Food Crop Production in Tropical Farming Systems*. Institute for Soil Fertility, Haren, Netherlands.

RISWAN, S. 1991. Kerangas forest at Gunung Pasir, Samboja, East Kalimantan: status of nutrient in the leaves. Pp. 279 - 294 in Soerianegara, I., Tjitrosomo, S.S., Umaly, R.C. & Umboh, I. (Eds.) *Proceedings of the Fourth Round-Table Conference on Dipterocarps*. SEAMEO BIOTROP, Bogor.

SIM, J. W. S., TAN, H. T. W. & TURNER, I. M. 1992. Adinandra belukar: an anthropogenic heath forest in Singapore. *Vegetatio* 102 : 125 - 137.

SYMINGTON, C. F. 1943. *A Foresters' Manual of Dipterocarps*. Malayan Forest Records No. 16. Kuala Lumpur. 244 pp.

TURNER, I. M. 1994. Sclerophylly : primarily protective? *Functional Ecology* 8 : 669 - 675.

TURNER, I. M., ONG, B. L. & TAN, H. T. W. 1995. Vegetation analysis, leaf structure and nutrient status of a Malaysian heath community. *Biotropica* 27 : 2 - 12.

WEBB, L. J. 1959. A physiognomic classification of Australian rain forests. *Journal of Ecology* 47 : 551 - 570.

WHITMORE, T. C. 1984. *Tropical Rain Forests of the Far East*. Second edition. Clarendon Press, Oxford.

WONG, K. M., SAW, L. G. & KOCHUMMEN, K. M. 1987. A survey of the forests of the Endau Rompin Area, Peninsular Malaysia: principal forest types and floristic notes. *Malayan Nature Journal* 41 : 125 - 144.

WYATT-SMITH, J. 1963. *Manual of Malayan Silviculture for Inland Forests*. Malayan Forest Records No. 23. Kuala Lumpur.

YAMAKURA, T. & SAHUNALU, P. 1990. Soil carbon/nitrogen ratio as a site quality index for some South-east Asian forests. *Journal of Tropical Ecology* 6 : 371 - 378.