Journal of Tropical Forest Science 12(2):247–255 (2000)

LIGHT CONDITIONS, CANOPY CONDITIONS AND MICROTOPOGRAPHIES IN THE MICROSITES OF *SHOREA CURTISII* SAPLINGS IN A HILL DIPTEROCARP FOREST OF THE SEMANGKOK FOREST RESERVE, PENINSULAR MALAYSIA

Yohsuke Kominami,

Kyushu Research Center, Forestry and Forest Products Research Institute, Kurokami, Kumamoto 860-0862 Japan

Hiroyuki Tanouchi*,

Japan International Research Center for Agricultural Sciences, Owashi, Tsukuba, 305-0851 Japan

Hiroshi Tanaka,

Forestry and Forest Products Research Institute, Kukizaki, Ibaraki, 305-0903 Japan

Toshio Katsuki

Tama Forest Science Garden, Forestry and Forest Products Research Institute, Hachioji, Tokyo, 193-0843 Japan

&

Azman Hassan

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

Received June 1997

KOMINAMI, Y., TANOUCHI, H., TANAKA, H., KATSUKI, T. & AZMAN, H. 2000. Light conditions, canopy conditions and microtopographies in the microsites of *Shorea curtisii* saplings in a hill dipterocarp forest of the Semangkok Forest Reserve, Peninsular Malaysia. Light conditions, canopy conditions and microtopographies of natural habitats of *Shorea curtisii* saplings in a hill dipterocarp forest of Peninsular Malaysia were examined to determine the features of the sapling microsites. We estimated values of photosynthetic photon flux density (PPF) above 41 saplings of *S. curtisii* and at 301 points systematically positioned in a 2.6-ha study plot. A compu-

*Present address: *Hokkaido Research Center, Forestry and Forest Products Research Institute, Toyohira, Sapporo, 062-0045 Japan.*

terised technique for the analysis of hemispherical photographs was used for estimating the PPFs. The microsite types were classified from canopy conditions and microtopographies. Although PPFs on gentle slopes were significantly higher than on steep slopes, the densities of *S. curtisii* saplings were not different between the slopes. The density of *S. curtisii* saplings and the PPFs in canopy gaps were not significantly different from the values under closed canopy. Most of the PPFs at each microsite type were within the range of PPFs above the saplings of *S. curtisii*, and the sapling bank was maintained at all microsite types in the study plot. It is likely that most of the microsites receive sufficient light to maintain the sapling bank of *S. curtisii*.

Key words: Sapling - *Shorea curtisii* - light environment - PPF - canopy gap - topography - hemispherical photograph - hill dipterocarp forest - Semangkok Forest Reserve - Peninsular Malaysia

KOMINAMI, Y., TANOUCHI, H., TANAKA, H., KATSUKI, T. & AZMAN, H. 2000. **Keadaan cahaya, keadaan kanopi dan mikrotopografi dalam mikrosit anak pokok *Shorea curtisii* di hutan dipterokarpa bukit di Hutan Simpan Semangkok, Semenanjung Malaysia.** Keadaan cahaya, keadaan kanopi dan mikrotopografi bagi habitat semula jadi anak pokok *Shorea curtisii* di hutan dipterokarpa bukit di Semenanjung Malaysia diperiksa untuk menentukan sifat-sifat mikrosit anak pokok. Kami menganggarkan nilai ketumpatan fluks foton fotosintesis (KFF) di bawah 41 anak pokok *S. curtisii* dan pada point 301 yang ditempatkan secara sistematik di petak kajian seluas 2.6 hektar. Satu teknik berkomputer untuk menganalisis fotograf hemisfera digunakan untuk menganggarkan KFF. Jenis-jenis mikrosit dikelaskan mengikut keadaan kanopi dan mikrotofografi. Walaupun KFF di cerun yang landai adalah tinggi dengan bererti berbanding dengan cerun yang curam, kepadatan anak pokok *S. curtisii* adalah tidak berbeza di antara cerun tersebut. Kepadatan anak pokok *S. curtisii* dan KFF dalam jurang kanopi adalah tidak berbeza dengan bererti daripada nilai di bawah kanopi tertutup. Kebanyakan KFF di setiap jenis mikrosit berada antara julat KFF di bawah anak pokok *S. curtisii* dan bank anak pokok dikekalkan di semua jenis mikrosit dalam petak kajian. Mungkin juga kebanyakan mikrosit menerima cahaya yang mencukupi untuk mengekalkan bank anak pokok *S. curtisii*.

Introduction

The distribution of saplings shows microsites where the seedlings have passed the stage of high risk of death. If seedlings have a preference for certain microsites, the distribution of saplings will show a concentrative pattern at these microsites.

The seedling growth and survivorship of *Shorea curtisii* Dyer *ex* King, a commercial tree species of Peninsular Malaysia, are affected by light conditions of the forest microsites. Seedlings of *S. curtisii* grow faster when in higher light conditions (Turner 1989, 1990), and survive better in canopy gaps than under closed canopy (Turner 1990). This suggests that the saplings are more abundant in canopy gaps with high light regimes than closed canopy habitats. However, the shade tolerance of *S. curtisii* seedlings (Turner 1989) also suggests that the sapling bank is maintained in closed canopy habitats. Hence, it is unclear whether the formation of canopy gaps and the improvement of light conditions are essential for successful sapling establishment.

In this study, the features of *S. curtisii* microsites were determined by examining the light conditions, canopy conditions and microtopographies of natural habitats of *S. curtisii* saplings in a hill dipterocarp forest. For light conditions, we examined whether the distribution of *S. curtisii* saplings is related to the heterogeneous distribution of photosynthetic photon flux (PPF) on the forest floor. The microsite types were classified by canopy conditions and microtopographies. Canopy gaps and topography often correlate with the heterogeneity in PPF on the forest floor (Lawton 1990, Ashton *et al.* 1995). If *S. curtisii* is restricted to a given microsite at the seed or seedling stage, the evidence will be observed in the distribution of saplings. Particularly, it is important to examine the relationship between microsites on crests and the distribution of *S. curtisii* sapling, because such relationship could provide possible explanations for the restriction of *S. curtisii* trees in hill dipterocarp forests to ridge crests (Whitmore & Burnham 1984).

To estimate PPFs on the forest floor and above *S. curtisii* saplings, a computerised technique for the analysis of hemispherical photographs was used. Although quantum sensors are usually used to measure light conditions (Chazdon & Fetcher 1984, Lee 1989, Pearcy 1989), it is difficult to use many quantum sensors for measuring light conditions in a large area. Recently, computerised techniques have enabled easy and inexpensive estimation of photosynthetically active radiation from hemispherical photographs (Mitchell & Whitmore 1993, Whitmore *et al.* 1993, Easter & Spies 1994). These techniques are considered useful for the analysis of light conditions at many points over a large area.

Materials and methods

Study site

The study was conducted at the Semangkok Forest Reserve (33° 6' N, 101° 44' E) located 60 km north of Kuala Lumpur, Peninsular Malaysia. The area consists of a hill dipterocarp forest (Putz 1978). *Shorea curtisii* was the most abundant canopy species, followed by *Lithocarpus wallichianus*, *Teijsmanniodendron coriaceum*, *Antidesma cuspidatum*, *Scaphium macropodum*, *Diospyros latisepala* and *Eurycoma longifolia*. Bertam palm (*Eugeissona tristis*), whose fronds grow up to 6 m long (Whitmore & Burnham 1984), was abundant in the understorey habitat. According to the climatic data from 1976 to 1986 taken at Kuala Kubu Baru, the nearest meteorological station (15 km southwest of the Semangkok Forest Reserve), the average yearly maximum and minimum temperatures were 33 °C and 22 °C respectively, and the average annual rainfall was 2414 mm (Saifuddin *et al.* 1991).

Methods

A study plot of 2.6 ha was positioned with an elevation ranging from 360 to 520 m (Figure 1). The study plot included all types of microtopographies and three large canopy gaps of sizes 900, 400, and 250 m². Hemispherical photographs were taken at 301 observation points systematically positioned at 10-m intervals at 1 m above the ground. Hemispherical photographs were also taken from random samples of 41 saplings of *S. curtisii*, lower than 1 m in height. All the hemispherical photographs were taken with a Nikon Fisheye-NIKKOR 8 mm lens on a Nikon F601M body using Kodak Ektachrome Professional ISO 100 film. The top of each photograph was oriented to the north with the camera mounted horizontally.

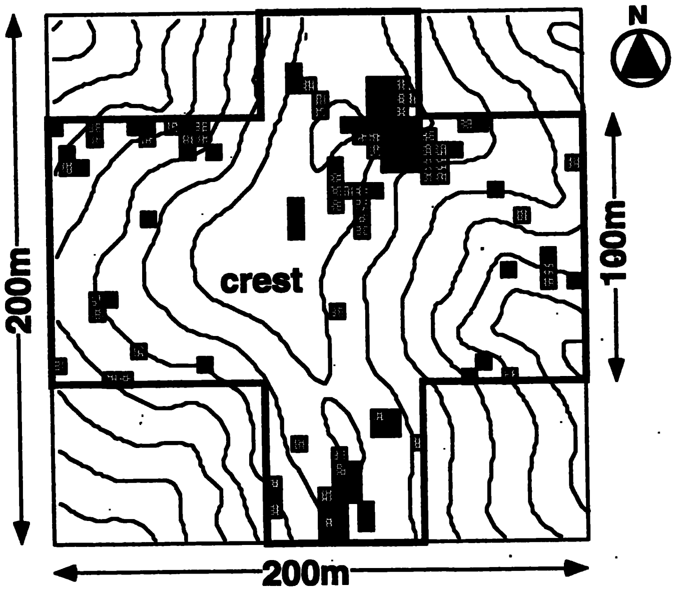

Figure 1. Topography and spatial distribution of canopy gaps of the study plot (cross enclosed by bold lines, 2.6 ha). Solid square indicates that the canopy height is lower than 5 m, gray square indicates that the canopy height is between 5 and 10 m, and open area is the site under closed canopy higher than 10 m. A main crest slope lies from north to south at the center of the plot. The interval of each contour line is 20 m.

The hemispherical photographs were digitised using a scanning digitiser at a resolution of 72 dpi. The sky was extracted from the digitised colour image using image processing and analysing software (Ultimage, Graftek France). In the resulting black and white binary image, the sky was white.

PPFs were estimated from the binary image of the hemispherical photograph using a computer program called HEMIPHOT (Steege 1994). In the computation of PPF using HEMIPHOT, the diffuse light was estimated as 15% of the direct light (Steege 1994). Parameters for the analysis of HEMIPHOT were as follows: latitude (3° 36' N), longitude (101° 44' E), and elevation (500 m) were the values at the centre of the study plot; standard overcast sky (SOC) was chosen as the sky type. Transmissivity of atmosphere was estimated at an open site near the

Semangkok Forest Reserve, by recording PPFs on four clear days using a quantum sensor (KOITO, IKS-25), and simultaneously taking a hemispherical photograph over the sensor. The PPFs for the days were computed from the hemispherical photograph with an allowance for different transmissivities of 0.5 to 0.9. At a transmissivity of 0.84, the difference between the mean value of sensor-PPFs (74.4 mol m^{-2} d^{-1}) and that of computed PPFs (73.4 mol m^{-2} d^{-1}) was minimal.

From every hemispherical photograph, relative PPF on the forest floor (rPPF) was computed as percentage of total annual PPF above canopy. The total annual PPF was calculated as the maximum potential PPF in year-round fine weather.

Fronds of bertam palm were frequently observed in the hemispherical photographs. To know the frequency of the palm fronds, we counted the number of observation points where the palm fronds covered a part of canopy openings in the hemispherical photograph. The coverage of palm fronds in hemisphere was not estimated, because the exact extraction of palm fronds from the digitised image of photograph was difficult.

Spatial distribution of canopy gaps in the study plot was mapped (Figure1). The study plot was divided into 1040 grids (5 × 5 m each) and the canopy height above the center of the grid was classified into three levels: lower than 5 m, from 5 to 10 m, and higher than 10 m (Niiyama & Iida unpublished data). A grid with canopy height lower than 10 m was defined as a canopy gap grid. Out of 301 observation points in the study plot, 84 points were classified as canopy gaps and 217 points under closed canopy; a point in a canopy gap had three or more canopy gap grids within 10 m of the point, while a point under closed canopy had less than three grids.

Further, out of the 301 observation points, 50 points were on gentle slopes and 251 points on steep slopes. The difference in land height within 10 m of a point on gentle slope was under 12 m, and over 12 m for a point on steep slope. Most points on gentle slopes were on the crest, which ran north to south along the centre of the study plot; steep slopes on the lower and upper side slopes, headmost wall, and foot slope.

From the above classifications of canopy condition and microtopography, the 301 observation points of the study plot were divided into four microsites: canopy gaps on gentle slopes (14 points), closed canopy on gentle slopes (36 points), canopy gaps on steep slopes (70 points), and closed canopy on steep slopes (181 points). To assess the effect of canopy gaps and microtopographies on light conditions, the differences in rPPFs within each of the four microsites were tested using a Mann-Whitney U-test. To examine whether the *S. curtisii* saplings distribute according to light availability on the forest floor, the rPPFs for the 41 saplings were also tested against those in the four microsites.

All saplings of *S. curtisii* from 30 to 100 cm in height were censused in a area of 100 × 200 m of the study plot. Canopy conditions and microtopographies at the saplings were identified with the microsite type of the nearest observation point classified as mentioned above.

Results

The spatial distribution of estimated rPPFs was heterogeneous in the study plot (Figure 2). Estimated rPPFs ranged from 2.7 to 12.3% (mean ± standard deviation: 8.1 ± 2.7%) in canopy gaps on gentle slopes, from 2.8 to 15.0% (7.4 ± 3.0%) under closed canopy on gentle slopes, from 1.3 to 18.6% (6.5 ± 3.4%) in canopy gaps on steep slopes, and from 1.1 to 19.6% (6.1 ± 3.3%) under closed canopy on steep slopes. The differences in rPPFs between the microsites are presented in Figure 3. It is clear from Figure 3 that the rPPFs in canopy gaps were not significantly different from those under closed canopy. The rPPFs on gentle slopes were significantly higher than those on steep slopes. Hence, the difference in light availability was greater at the microtopographical than the canopy condition.

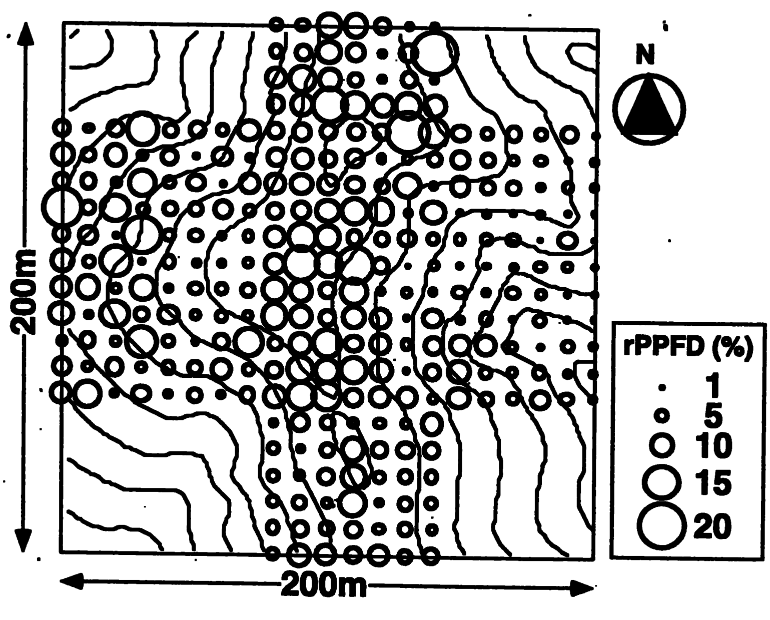

Figure 2. Spatial distribution of rPPFs in the study plot. The values at the 301 points are shown by diameters of circles.

Fronds of bertam palm were observed in the hemispherical photographs at 261 points (87%) of 301 observation points in the study plot. The proportions of observation points where the palm fronds covered a part of the canopy opening in the hemispherical photograph were 93% in canopy gaps on gentle slopes, 86% under closed canopy on gentle slopes, 93% in canopy gaps on steep slopes, and 84% under closed canopy on steep slopes. These proportions did not differ significantly (x^2 = 0.28, p= 0.96).

. The rPPFs above *S. curtisii* saplings were common at most of the areas within the study plot (Figure 3). The rPPFs above the saplings ranged from 3.2 to 11.5% (6.9 ± 2.0%), and were not significantly different from those in canopy gaps on gentle slopes, under closed canopy on gentle slopes, and in canopy gaps on steep slopes. Only rPPFs under closed canopy on steep slopes were significantly lower than those above *S. curtisii* saplings. However, 71% of rPPFs under closed canopy on steep slopes overlapped with the range of rPPFs above the saplings.

Saplings of *S. curtisii* were observed at all microsites, and no large difference of sapling density between microsites was found (Table 1). The proportion of *S. curtisii* saplings among four microsites was similar to the proportion of points systematically positioned at 10-m intervals, and these proportions did not differ significantly (x^2 = 3.8, p = 0.28).

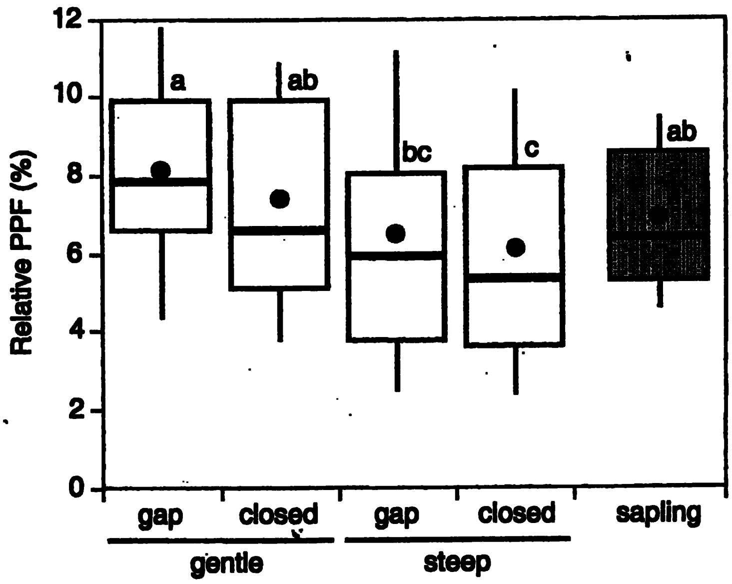

Figure 3. Distributions of rPPFs above *Shorea curtisii* saplings and at four different microsite types: in canopy gaps on gentle slopes, under closed canopy on gentle slopes, in canopy gaps on steep slopes, and under closed canopy on steep slopes. The upper and lower bars represent the 90th and 10th percentiles respectively. The box plot shows the 25th, 50th (median) and 75th percentiles; the dot indicates the mean value. The groups followed by the same letters are not significantly different (p = 0.05) as determined by Mann-Whitney U-test.

Table 1. Distribution of *Shorea curtisii* saplings among four different microsite types

	Gentle slope		Steep slope		Total
	Gap	Closed	Gap	Closed	
Sapling					
Number	5	38	123	281	447
Percentage	1.1	8.5	27.5	62.9	100.0
Density (m^{-2})	0.010	0.022	0.027	0.021	0.022
Points*					
Number	6	20	52	153	231
Percentage	2.6	8.7	22.5	66.2	100.0
Area (m^2)**	519	1732	4502	13247	20000

* Points systematically positioned at 10-m intervals.
** Ratio of points at the microsite × 20000.

Discussion

The heterogeneous distribution of light conditions found in the study plot was not related to the natural distribution of *S. curtisii* saplings. Although the light availability on gentle slopes was better than on steep slopes, the densities of *S. curtisii* saplings were not different between the slopes. The light availability above *S. curtisii* saplings was common irrespective of the microsite. The traits of *S. curtisii* seedlings, shown by Turner (1989), such as tolerance under shade light (1% full sun) and better growth under bright light (12% full sun), may have widened the possible range of light availability for maintaining the sapling bank observed in the present study (3.2–11.5% rPPF).

The density of *S. curtisii* saplings in the canopy gaps was not different from that under closed canopy. Turner (1990) reports that gaps with high light regimes are favourable for the survival and growth of *S. curtisii* saplings. However, canopy gaps in the study plot could not be regarded as specific microsites of high light regimes for *S. curtisii* saplings, as would be evident from non-significant differences in PPFs for canopy gaps and closed canopy habitats. The shading by fronds of bertam palm is most likely the cause of the indistinct effect of canopy gaps on the light regime at 1 m above the ground in the study plot. Fronds of bertam palm reduced canopy openings in hemisphere at most observation points in the study plot. If the diminution of canopy opening by the palm is larger in canopy gaps than under closed canopy, the light availability in canopy gaps will be less different from that under closed canopy.

The distribution of *S. curtisii* saplings in the study plot does not explain the restriction of *S. curtisii* trees in hill dipterocarp forests to crests (Whitmore & Burnham 1984). The sapling bank of *S. curtisii* was maintained both on the gentle slopes (crest) and the steep slopes (side slope, headmost wall, and foot slope). Most (71–86%) of the rPPFs at each microsite type was within the range of rPPFs above the saplings (Figure 3), suggesting that most of the microsites had sufficient light to maintain the sapling bank of *S. curtisii*. Nevertheless, there is a possibility of the better light availability on gentle slopes being related to the restriction of *S. curtisii* trees to crests, because the available light regime for the growth of saplings into trees is still unknown. It is also necessary to examine the possibilities of other factors such as periodic drought on crests and higher probability of landslides on steep slopes affecting the regeneration process of *S. curtisii* (Whitmore & Burnham 1984). In any case, the wide distribution of *S. curtisii* saplings observed in this study suggests that the key factor of the restriction of the trees to crests is found in the regeneration process from saplings to trees.

Acknowledgements

We are grateful to Kaoru Niiyama and Shigeo Iida for allowing us to use their unpublished data of canopy gaps in the study site. We are indebted to Satoshi Saito and Simmathiri Appanah for their advice in preparing the manuscript and two anonymous referees for their comments. This study was supported in part by FRIM-JIRCAS and FRIM-NIES (Grant No. E-1) Collaborative Research Projects.

References

ASHTON, P. M. S., GUNATILLEKE, C. V. S. & GUNATILLEKE, I. A. U. N. 1995. Seedling survival and growth of four *Shorea* species in a Sri Lankan rainforest. *Journal of Tropical Ecology* 11:263–279.

CHAZDON, R. L. & FETCHER, N. 1984. Photosynthetic light environments in a lowland tropical rain forest in Costa Rica. *Journal of Ecology* 72:553–564.

EASTER, M. J. & SPIES, T. A. 1994. Using hemispherical photography for estimating photosynthetic photon flux density under canopies and in gaps in Douglas-fir forests of the Pacific Northwest. *Canadian Journal of Forest Research* 24:2050–2058.

LAWTON, R. O. 1990. Canopy gaps and light penetration into a wind-exposed tropical lower montane rain forest. *Canadian Journal of Forest Research* 20:659–667.

LEE, D. W. 1989. Canopy dynamics and light climates in a tropical moist deciduous forest in India. *Journal of Tropical Ecology* 5:65–79.

MITCHELL, P. L. & WHITMORE, T. C. 1993. *Use of Hemispherical Photographs in Forest Ecology: Calculation of Absolute Amount of Radiation beneath the Canopy.* OFI Occasional Papers No. 44. Oxford Forestry Institute, Oxford. 39 pp.

PEARCY, R. W. 1989. Radiation and light measurements. Pp. 97–116 in Pearcy, R. W., Ehleringer, J., Mooney, H. A. & Rundel, P. W. (Eds.) *Plant Physiological Ecology. Field Methods and Instrumentation.* Chapman and Hall, London.

PUTZ, F. E. 1978. *A Survey of Virgin Jungle Reserves in Peninsular Malaysia.* Research Pamphlet No. 73. Forest Research Institute Malaysia, Kuala Lumpur. 87 pp.

SAIFUDDIN, S., ABDUL RAHIM, N. & MUHAMMAD FARID, A. R. 1991. *Watershed Research in Forest Plantation: 1. Establishment and Physical Characteristics of Bukit Tarek Watershed.* Research Pamphlet No. 110. Forest Research Institute Malaysia, Kuala Lumpur. 51 pp.

STEEGE, H. TER. 1994. HEMIPHOT, *A Programme to Analyze Vegetation Indices, Light and Light Quality from Hemispherical Photographs.* Tropenbos Documents 3. Stichting Tropenbos, Wageningen. 44 pp.

TURNER, I. M. 1989. A shading experiment on some tropical rain forest tree seedlings. *Journal of Tropical Forest Science* 1:383–389.

TURNER, I. M. 1990. The seedling survivorship and growth of three *Shorea* species in a Malaysian tropical rain forest. *Journal of Tropical Ecology* 6:469–478.

WHITMORE, T. C., BROWN, N. D., SWAINE, M. D., KENNEDY, D., GOODWIN-BAILEY, C. I. & GONG, W.-K. 1993. Use of hemispherical photographs in forest ecology: measurement of gap size and radiation totals in a Bornean tropical rain forest. *Journal of Tropical Ecology* 9:131–151.

WHITMORE, T. C. & BURNHAM, C. P. 1984. *Tropical Rain Forests of the Far East.* Second edition. Oxford University Press, Oxford. 352 pp.