Journal of Tropical Forest Science 1 (4): 383 - 389

A SHADING EXPERIMENT ON SOME TROPICAL RAIN FOREST TREE SEEDLINGS

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Received May 1989

TURNER, I. M. 1989. A shading experiment on some tropical rain forest tree seedlings. The growth of potted seedlings of *Shorea curtisii, Shorea macroptera* and *Gluta curtisii* was compared between three shade conditions. The treatments provided *circa* 1, 6 and 12% full sun photosynthetically active radiation (PAR) and altered the quality as well as the quantity of solar radiation reaching the plants, in order to simulate natural forest situations. All the species showed increased growth with increasing PAR. The two *Shorea* species grew better than *G. curtisii* in all the treatments. Whilst *S. curtisii* grew significantly better than *S. macroptera* in the 1 and 5% full sun treatments, the latter grew comparatively better in 12% full sun. This indicates that *S. curtisii* is more shade tolerant than *S. macroptera*.

Key words: Forest shade - red/far-red ratio - seedling-growth - *Gluta curtisii* - *Shorea curtisii* - *Shorea macroptera*.

Introduction

One of the few generalities to come out of forest ecology is the fact that the majority of canopy-top tree species in any forest require canopy gaps for their successful regeneration. This is widely accepted in the study of tropical rain forests and is the scientific basis of many silvicultural management systems used in such forests. Canopy thinning, like gap formation, increases the levels of solar radiation reaching the forest floor and thus allows growth by seedlings and saplings beyond the comparatively low rates achieved in the deep shade of the forest understorey. However there is relatively little data for tropical tree seedlings on either the quantitative relationship between the amount of photosynthetically active radiation (PAR) a plant receives and its growth rate or comparisons in performance between species growing under similar conditions.

Foresters frequently possess detailed knowledge of the comparative shade-tolerance of the species they work with, but this is usually based on casual field observations. This experiment was carried out to compare the growth of seedlings of three species of climax, canopy-top tree that coexist in Pantai Aceh Forest Reserve, Penang, Peninsular Malaysia, under different shade conditions in order to gain more evidence to consolidate and expand the empirical data we already have.

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Materials and methods

The experiment was performed at the Muka Head Field Station of Science University of Malaysia, which is adjacent to Pantai Aceh Forest Reserve. The species studied were:

1. *Shorea curtisii* Dyer ex King (Dipterocarpaceae), the canopy dominant at Pantai Aceh. It is the characteristic species of coastal hill dipterocarp forest (Symington 1943, Wyatt-Smith 1963), but is also found inland at higher altitudes on hill ridges and crests (Burgess 1975). It provides red meranti timber and is at present probably the most important hardwood timber tree in Peninsular Malaysia.

2. *Gluta curtisii* (Oliv.) Ding Hou (Anacardiaceae), another common canopy-top tree in the forest. A member of one of the genera of the Anacardiaceae known for their highly irritant black sap (the group known as "rengas" locally).

3. *Shorea macroptera* Dyer (Dipterocarpaceae), a large tree less frequent at Pantai Aceh than the other two species. Another member of the red meranti timber group.

Seeds of the three species were collected in Pantai Aceh Forest Reserve in August, 1986. The seeds were germinated and the seedlings grown in pots (*ca.* 1.5 *l*) of forest soil in shaded nurseries at Muka Head Field Station.

Groups of 15 five-month old individuals of each species were randomly and equally assigned to each of the three shade treatments used for the experiment.

Canopy shading does not just reduce the quantity of radiation that reaches the forest floor, its spectral composition is altered. This change in light quality is important in many plant responses to shade (Fitter & Hay 1981). The ratio of the irradiance in the red (655-665 *nm*) to far-red (725-735 *nm*) wavebands is a widely-used indicator of the morphogenetic effects of radiation because of its influence on the phytochrome system of plants (Smith 1981), and it has been shown to affect the morphology of seedlings of the tropical tree *Terminalia ivorensis* (Kwesiga & Grace 1986).

The red:far-red (R/FR) ratio of bright sunlight is *circa* 1.2 but that of forest canopy shade is 0.15 - 0.77 (Hart 1988). Much of the early work on tropical tree seedling responses to radiation, especially that on dipterocarps, used neutral shade, that is, shading was provided by a material that reduces the fluence rate of the radiation without altering its spectral composition, for example, Nicholson (1960), Wadsworth and Lawton (1968), Gong (1981), and Sasaki and Mori (1981).

In the present study, the shading used approached R/FR ratio values, as well as PAR levels, found in natural forest situations. The treatments were designed to simulate the shade of a diffuse canopy, the edge of a small gap and the deep shade of a continuous and dense canopy.

Treatment 1

A shade house, sited on the edge of an open area in the Field Station grounds, with a roof consisting of two layers of clear polythene sheeting between which was a single layer of green plastic filter (Cinemoid Filter 21A Peagreen) which has a transmission curve similar to chlorophyll (P. L. Mitchell personal communication, M. D. Swaine personal communication). The internal radiation climate thus simulated the shade cast by a sparse natural canopy in spectral quality. The walls of the shade house were made with a single layer of shade cloth (green plastic mosquito netting) which casts neutral shade, but as there was relatively little side light, this may not greatly alter the R/FR ratio of the solar radiation reaching plants growing in the shade house. The plants were placed on a plastic sheet floor to prevent the roots of weeds entering the pots.

Treatment 2

A site at the edge of the forest under a large *Erythroxylum cuneatum* tree where the seedlings were shaded by a natural canopy most of the time, but did receive brief periods of direct sunshine in the early morning. Again, the pots stood on a plastic floor.

Treatment 3

A site inside the forest beneath a more-or-less continuous canopy. The pots were placed on benches beneath a transparent-plastic tarpaulin roof.

All the plants were placed at random within each site and well watered throughout the experiment. At the start, the plants were measured for height, basal stem diameter and their number of leaves counted. This was repeated at the end of the experiment, six months later, after which the seedlings were harvested for measurement of dry weight. The plants were divided into stem, leaf and root fractions, dried at 80°*C* for 48 *h* and then weighed.

The PAR in the shade treatments was measured with an instantaneous device [Li-Cor Incorporated Quantum Sensor (Model LI-192-SB) with Quantum-Radiometer-Photometer (Model LI-185-B)] on a uniformly overcast day (Table 1). The R/RF ratios in the treatments were measured on a clear, sunny day with an instantaneous device [Skye Instruments Measuring Unit (SKR 100) with 660/730 sensor (SKR 110), Skye Instruments, Llandidrod Wells, UK]. The R/FR ratio in Treatment 1 was 0.7 and in the other two treatments 0.4. Two of the sites had had their radiation regimes monitored previously using PAR integrating devices (Li-Cor Incorporated Model 1913B one-metre line quantum sensors with Li-Cor Incorporated Model LI-510BO PAR integrators). The PAR in Treatment 1 was found to average 3.72 mol m^2 d^1 over a 20 day period (Turner 1988) and 0.39 mol $m^2 d^1$ over a two month period in Treatment 3 (Raich 1987); or 12% and 1.2% full sun PAR respectively, when compared to the readings from a similar sensor on the top of the field station building. The less satisfactory, instantaneous measurements give higher estimates of full sun PAR for the three treatments. Therefore a lower estimate of 6% full sun PAR is taken as the mean for Treatment 2, with 12% and 1% for the other two treatments.

Table 1. Instantaneous irradiances in the three shade treatments and an open site on a uniformly overcast day

Site	Irradiance (μ mol $m^2 s^1$)	Percentage full sun PAR
Open	310	100
Treatment 1	70	23
Treatment 2	25	8.1
Treatment 3	8.5	2.7

Results

The results, summarised in Table 2, were analysed using a two-way analysis of variance with shading and species as the two factors. Several plants in each treatment died during the course of the experiment, largely due to macaques. Therefore the statistical analysis of the results is based upon a balanced analysis of variance with the cell size at ten, it being the minimum number of survivors for a treatment group. In treatments where there were more than ten survivors, the ten replicates for the analysis were chosen at random.

An analysis of covariance showed that height increment was significant]y correlated with initial height ($F = 4.1$, $p < 0.05$, d.f. = 1, 81). Therefore the adjusted height growth data were used in the analysis (Table 3). Negative height growth occurred in some treatments when seedlings sufferred die-back of the leading shoot. Basal stem diameter growth was not significantly correlated with initial stem diameter.

Clearly, shading had a highly significant effect on all of the parameters of growth investigated (column 1 in Table 3). The seedlings of all three species grew most in the least shaded treatment (Treatment 1) and least in the most shaded (Treatment 3). Morphologically, the plants showed changes with degree of shading: as the total PAR level was reduced, the root to shoot ratio tended to decrease and the leaf weight ratio, the ratio of the dry weight of leaves to total plant dry weight, tended to increase. There were also effects at the species level, largely because *G. curtisii* did less well than the two dipterocarp species. Height growth appears to be the only parameter with a strong interaction between shading and species. This is because *S. macroptera* performs relatively much better in Treatment 1, its height growth is not significantly different from *S. curtisii* in this treatment but it is significantly lower in Treatment 2.

Table 2. Summary of the results: mean ± standard error, n = 10 in all cases; A = Total dry weight (*g*), B = Height increment (*cm*), C = Basal stem diameter increment (*mm*), D = Change in leaf number, E = Root to shoot ratio, F = Leaf weight ratio

Species		Shading treatment		
		1	2	3
Shorea curtisii	A	12.6 ± 5.6	4.9 ± 2.0	2.5 ± 0.9
	B	30.8 ± 16.2	17.9 ± 6.	1.7 ± 1.3
	C	4.1 ± 1.5	1.6 ± 0.7	0.3 ± 0.4
	D	16.7 ± 9.4	8.2 ± 3.2	0.1 ± 1.8
	E	0.51 ± 0.39	0.22 ± 0.04	0.19 ± 0.06
	F	0.36 ± 0.10	0.56 ± 0.06	0.56 ± 0.04
Gluta curtisii	A	8.2 ± 3.8	2.2 ± 1.2	1.5 ± 0.7
	B	17.4 ± 4.8	2.6 ± 2.2	0.5 ± 0.8
	C	3.0 ± 0.7	0.6 ± 0.8	0.0 ± 0.4
	D	6.9 ± 4.3	-1.3 ± 7.5	-3.8 ± 3.7
	E	0.26 ± 0.04	0.27 ± 0.17	0.27 ± 0.07
	F	0.50 ± 0.08	0.45 ± 0.23	0.44 ± 0.07
Shorea macroptera	A	13.3 ± 4.6	2.6 ± 1.0	1.4 ± 0.6
	B	34.7 ± 7.5	10.2 ± 3.8	2.1 ± 2.3
	C	4.1 ± 0.9	1.0 ± 0.7	0.2 ± 0.4
	D	9.4 ± 3.7	3.9 ± 0.9	-0.3 ± 1.6
	E	0.32 ± 0.11	0.19 ± 0.04	0.23 ± 0.05
	F	0.42 ± 0.06	0.60 ± 0.03	0.53 ± 0.08

Table 3. F-statistics for the main factors and the interaction term from a 2-way ANOVA for the various parameters of growth

Parameter	Shading	Species	Interaction
Total dry weight	95.3**	7.0**	2.7*
Height increment (adjusted)	120.7**	20.9**	6.2**
Stem diameter increment	166.3**	8.1**	1.4
Change in leaf number	50.0**	19.4**	1.8
Shoot : root ratio	9.3**	0.3	2.6*
Leaf weight ratio	26.4**	7.0**	1.2

Asterisks represent significant results : * = $p < 0.05$, ** = $p < 0.01$

Discussion

The seedlings of the three primary forest species, *G. curtisii, S. curtisii* and *S. macroptera,* grew significantly faster when in relatively high PAR conditions. They could respond to increasing PAR and were not tied to a slow growth rate. There were differences between the species. *G. curtisii* grew slowest at all PAR levels used. *S. macroptera* grew faster than *S. curtisii* at higher irradiances but the latter was more shade-tolerant. Symington (1943) supports *S. macroptera* being a faster grower than *S. curtisii;* he stated that the former is the third fastest in terms of girth increment amongst the red meranti timber group of *Shorea* species of Peninsular Malaysia.

In the light of the results one might therefore predict that, of the two *Shorea* species studied, *S. macroptera* seedlings would grow better in a big gap, but *S. curtisii* would probably grow faster in a small gap or gap edge site. *G. curtisii* would appear to have a competitive disadvantage at all PAR levels.

This simple experiment shows some of the ecological and silvicultural differences between these species and may help explain their continued coexistence in Pantai Aceh Forest Reserve. It indicates that there may be some differentiation in the regeneration niches of these species. These differences may be exploitable in silvicultural terms, for example, to favour the regeneration of *S. macroptera* over *S. curtisii* one would have to open the forest canopy to a greater degree than to favour *S. curtisii* alone.

Acknowledgements

I thank the Malaysian Government for granting me permission to carry out research in Malaysia, and the Dean of the School of Biological Sciences, Science University of Malaysia, for allowing me use the facilities of Muka Head Field Station. I am very grateful to T. C. Whitmore, J. W. Raich, W. K. Gong and J. E. Ong for all their help with my research.

References

BURGESS, P.F. 1975. Studies on the regeneration of the hill forests of the Malay Peninsula. *Research Pamphlet,* No. 66. Forest Research Institute, Kepong.

FITTER, A. H. & HAY, R. K. 1981. *Environmental physiology of plants.* Academic Press, London.

GONG, W. K. 1981. Studies on the natural regeneration of a hill dipterocarp species, *Hopea pedicellata. Malaysian Forester* 44: 357 - 369.

HART, J. W. 1988. *Light and plant growth.* Unwin Hyman, London.

KWESIGA, F. & GRACE, J. 1986. The role of the Red/Far-red ratio in the response of tropical tree seedlings to shade. *Annals of Botany* 57: 283 - 290.

NICHOLSON, D. I. 1960. Light requirements of seedlings of five species of Dipterocarpaceae. *Malayan Forester* 23: 344 - 356.

RAICH, J. W. 1987. *Canopy openings, seed germination and tree regeneration in Malaysian coastal hill* *dipterocarp forest.* Ph. D. thesis. Duke University, North Carolina, United States of America.

SASAKI, S. & MORI, T. 1981. Growth responses of dipterocarp seedlings to light. *Malaysian Forester* 44: 319 - 345.

SMITH, H. 1981. Light quality as an ecological factor. Pp. 93 - 110 in Grace, J., Ford, E.D. & Jarvis, P.G. (eds.) *Plants and their atmospheric environment.* Blackwell Scientific Publications, Oxford.

SYMINGTON, C. F. 1943. Foresters' manual of dipterocarps. *Malayan Forest Record* No. 16.

TURNER, I. M. 1988. *The response of tree species to canopy gaps in a tropical forest.* D. Phil. thesis. University of Oxford, United Kingdom.

WADSWORTH, R. M. & LAWTON, J. R. S. 1968. The effect of light intensity on the growth of seedlings of some tropical tree species. *Journal of the west African Science Association* 13: 211 - 214.

WYATT-SMITH, J. 1963. Manual of Malayan silviculture for inland forests. *Malayan Forest Record* No. 23.