Journal of Tropical Forest Science 7(4): 541 - 557 (1995)

SURVIVAL AND EARLY GROWTH OF *SHOREA PLATYCLADOS*, *SHOREA MACROPTERA*, *SHOREA ASSAMICA* AND *HOPEA NERVOSA* IN OPEN PLANTING

L.H. Ang & Y. Maruyama*

Forest Research Institute Malaysia, 52190 Kepong, Malaysia

Received June 1993

ANG, L. H. & MARUYAMA, Y. 1995. Survival and early growth of *Shorea platyclados*, *Shorea macroptera*, *Shorea assamica* and *Hopea nervosa* in open planting. In view of the potential of domesticating commercially important dipterocarps as plantation species, a study was conducted to assess the effects of open planting at 2 × 2 m spacing on early growth and survival of four selected commercial dipterocarps, *Shorea platyclados* (meranti bukit), *Shorea assamica* (meranti pipit), *Shorea macroptera* (meranti melantai) and *Hopea nervosa* (merawan jangkang). A 4 × 4 Latin Square Design was employed to establish a 50 × 50 m plot on a gentle slope at Field 30F, Forest Research Institute Malaysia, Selangor. Prior to planting, the secondary vegetation on the site was clear felled and removed from the plot. No burning was carried out in the plot. Thus, the litter layer was not disturbed. At 26 months after planting, the survival of the four open planted dipterocarps was 92.2%, 85.9%, 64.0% and 57.6% for *S. platyclados*, *S. assamica*, *S. macroptera* and *H. nervosa* respectively. *S. platyclados* had the highest collar diameter increment (at 10 cm above ground level) and top height increment of 35.0 ± 4.3 mm and 2.51 ± 1.27 m respectively. This was followed by *S. assamica* with 1.23 ± 0.20 m and 21.5 ± 2.8 mm for top height increment and collar diameter increment respectively. *S. macroptera* and *H. nervosa* had slower growth rates and poorer survival compared to the other two dipterocarps. *S. platyclados*, which is a high value hill dipterocarp, had significantly the best survival ($p<0.05$), diameter increment ($p<0.01$) and top height increment ($p<0.01$) amongst the open planted dipterocarps. Higher efficiency of photosynthesis for *S. platyclados* found in open planting could be the main factor contributing to its good establishment. The study concluded that *S. platyclados* establishes well in open planting and has great potential as a future forest plantation species.

Key words: Dipterocarps - open planting - growth - survival - photosynthesis

ANG, L.H., & MARUYAMA, Y. 1995. Kemandirian dan pertumbuhan awal *Shorea platyclados*, *Shorea macroptera*, *Shorea assamica* dan *Hopea nervosa* di kawasan penanaman terbuka. Melihat kepada potensi mendomestikasikan dipterokarpa-dipterokarpa yang penting secara dagang sebagai spesies ladang, satu kajian telah dijalankan untuk menilai kesan-kesan penanaman terbuka pada jarak 2 × 2 m pada pertumbuhan awal dan kemandirian bagi empat dipterokarpa dagangan yang dipilih, *Shorea platyclados* (meranti bukit), *Shorea assamica* (meranti pipit), *Shorea macroptera* (meranti melantai) dan *Hopea nervosa* (merawan jangkang). Satu Rekabentuk Empat Segi Latin 4 × 4 telah digunakan untuk mendirikan satu plot 50 × 50 m di atas satu lereng landai di Ladang 30F, Institut Penyelidikan Perhutanan Malaysia, Selangor. Sebelum penanaman, tumbuh-tumbuhan sekunder di tapak tersebut ditebangbersih dan dipindahkan. Pembakaran tidak dilakukan di plot tersebut. Oleh itu, lapisan sarap tidak terusik.

*Present address: *Hokkaido Centre, FFPRI, 7 - Hitsujigaoka, Toyohida, Sapporo, - 062 Hokkaido, Japan*

Dua puluh enam bulan selepas penanaman, kemandirian bagi empat penanaman terbuka dipterokarpa adalah masing-masing 92.2%, 85.9%, 64.0% dan 57.6% bagi *S. platyclados, S. assamica, S. macroptera* dan *H. nervosa*. *S. platyclados* mempunyai pertambahan garis pusat kolar yang paling tinggi (pada 10 cm di bawah aras bumi) dan pertambahan ketinggian dominan masing-masing sebanyak 35.0 ± 4.3 mm dan 2.51 ± 1.27 m. Ini diikuti dengan *S. assamica* dengan 1.23 ± 0.20 m dan 21.5 ± 2.8 mm masing-masing bagi pertambahan ketinggian dominan dan pertambahan garispusat kolar. *S. macroptera* dan *H. nervosa* mempunyai kadar pertumbuhan lebih perlahan dan kemandirian yang lebih lemah berbanding dengan kedua-dua dipterokarpa iaitu *S. platyclados* dan *S. assamica*. *S. platyclados*, dipterokarpa bukit yang bernilai tinggi, mempunyai kemandirian terbaik ($p< 0.05$), pertambahan garispusat terbaik ($p<0.01$) dan pertambahan ketinggian dominan terbaik ($p<0.01$) di antara tanaman terbuka dipterokarpa. Kecekapan fotosintisis lebih tinggi bagi *S. platyclados* yang ditemui di kawasan penanaman terbuka mungkin merupakan faktor utama yang menyebabkan pertumbuhan yang baik ini. Kesimpulan dari kajian ini ialah *S. platyclados* dapat tumbuh dengan baik di kawasan penanaman terbuka dan berpotensi sebagai spesies hutan ladang di masa hadapan.

Introduction

The potential of planting commercially important dipterocarps in forest plantation must not be overlooked (Watson 1935, Symington 1943, Wan Razali 1988). However, the suitability of these dipterocarps for plantation development must first be determined. Studies have indicated that most of the dipterocarps require partial shading in their early growing stage (Watson 1935, Barnard 1954). Therefore, the majority of the dipterocarps are only suitable for underplanting. Never-theless, recent studies indicated that some dipterocarps can be open planted (Wan Razali & Ang 1990, Ang 1991a, 1991b). Due to the constraint of seed availability for dipterocarps, only four dipterocarps, namely *Shorea platyclados* (meranti bukit), *Shorea assamica* (meranti pipit), *Shorea macroptera* (meranti melantai) and *Hopea nervosa* (merawan jangkang) were selected for open planting to assess their early growth, survival and some of their physiological activities.

Materials and methods

Study site

A planting trial of the four dipterocarps was carried out at Field 30F, Forest Research Institute Malaysia (FRIM). The site was formerly a secondary forest with mean stand height of about 25 m. *Macaranga* sp., *Endospermum malaccense, Eleaocarpus* sp. and *Alstonia angustiloba* were the dominant vegetation. The altitude of the study site is about 90 m a.s.l. The soil is Harimau series which has relatively good properties and an average fertility (Amir 1984). The monthly total rainfall and mean daily temperature of the site were recorded (Figures 1a and 1b.)

Experimental plot

The secondary forest was clear felled and the trees were removed from the study plot. No burning was carried out. Seedlings of the four dipterocarps with average top height ranging from 0.31 to 0.72 m were open planted in December 1990. The lay-out of the planting were carried out according to Latin Square Design. A total of 100 seedlings of each species were randomly planted in four subplots on gentle slopes of about 10% gradient. Each subplot consisted of 25 seedlings and only the inner 16 seedlings were enumerated.

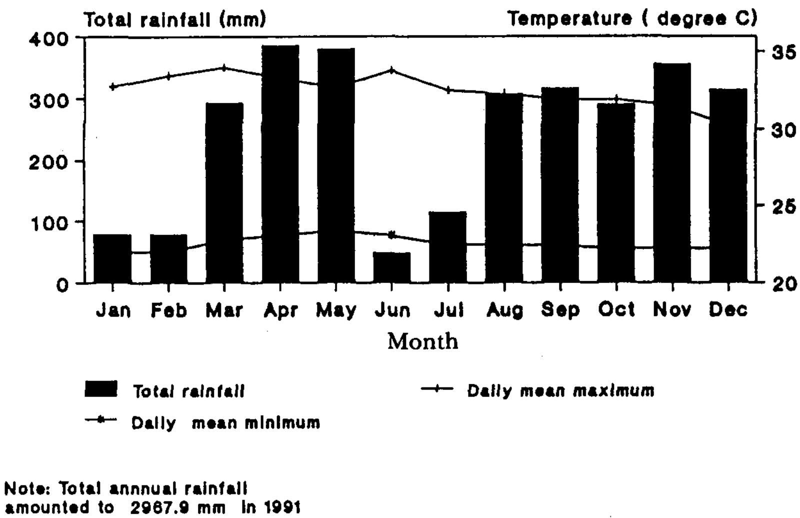


Figure 1a. Temperature and rainfall of the study site in 1991

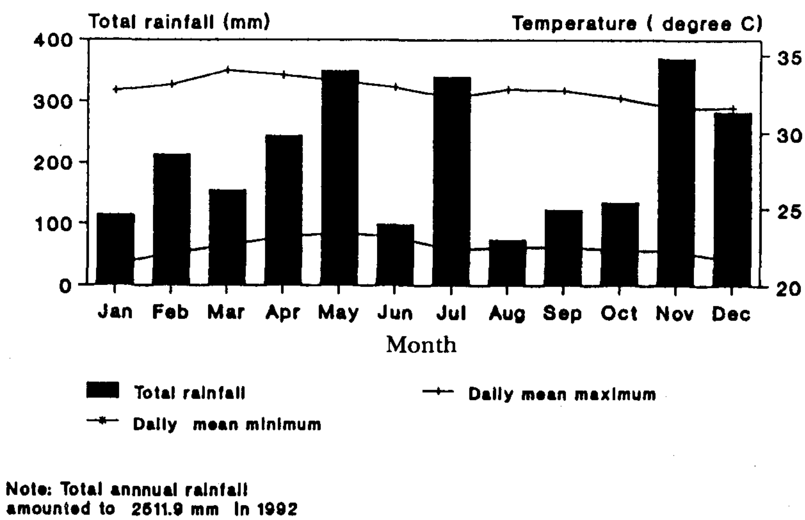


Figure 1b. Temperature and rainfall of the study site in 1992

Silviculture treatments

A summary of the silviculture activities carried out in the plots until stand age 26 months old is recorded in Table 1.

Parameters measured in this trial comprised top height, survival counts and collar diameter at 10 cm above ground level. The survival percentage of each species was calculated from the monthly survival count until 26 months after planting. Top height and root collar diameter (at 10 cm above soil level) measurements for the seedlings were carried out at the 4th, 12th, 15th and 26th months after planting. The data collected were statistically analysed. Analysis of variance for Latin Square Design and the Scheffe's test for determination of mean significance differences were conducted following Freese (1967).

Table 1. Silviculture treatments for the four open planted dipterocarps

Stand age (months)	Type of treatment
0-1	A dose of 30g of NPK green was applied to the planting hole prior to planting. The seedlings were watered for the first two weeks. Creepers and climbers were cut.
3-4	Circle weeding of 50 cm radius, cleaning, pruning and climber and creeper cuttings.
This operation was repeated at stand ages of 10-11, 13-14, 15-16, 17-19, 20-23 and 24-27 months	

At stand age of 24 months, the four dipterocarps were assessed for the net photosynthesis, transpiration rate and stomatal conductance. The physiological parameters were determined using a portable photosynthesis and transpiration measurement system, ADC-LAC2 (U.K.). The first fully expanded mature sun leaf was selected for infrared gas analysis. Only five or six samples were randomly selected for each dipterocarp. The data were collected from 10.11 am to 10.44 am on 16.11.1992. The photosynthetically active radiation and leaf temperature at that period were 1185 ± 138 μmol $m^{-2} s^{-1}$ and 33.4 ± 1.5 °C respectively. These important physiological parameters which are closely related to growth and survival would provide an insight into understanding the establishment of dipterocarps in open planting.

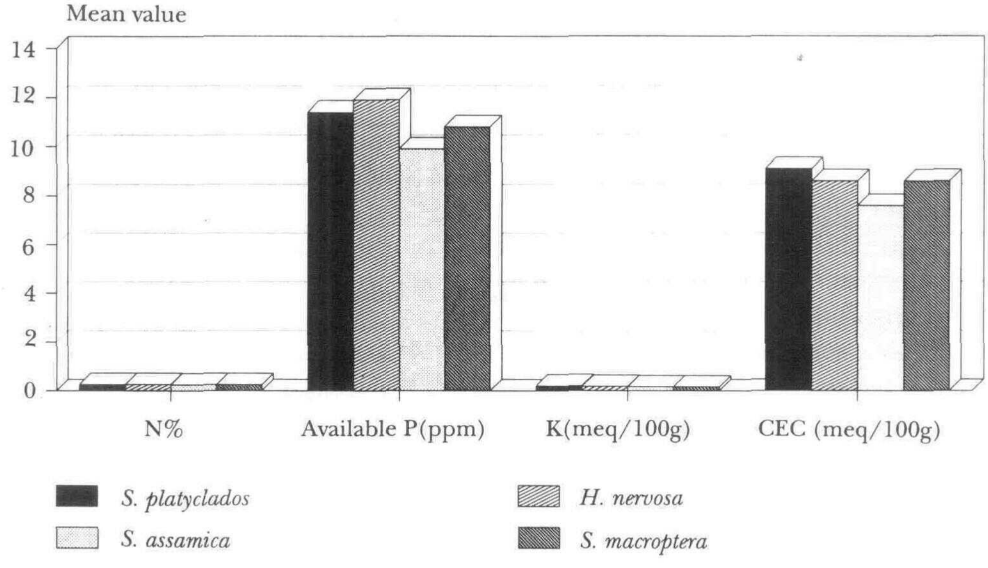
Soil analysis

Soil samples at 0-10 cm depth were collected from each subplot for analysis. Some important macronutrients, namely N, P, K and CEC, were determined. N was determined colorimetrically, P was measured using Shimadzu UV/VIS spectrometer after conversion to yellow vanadomolybdophosphate, and organic carbon was determined by Walkley and Black's method (1934). K was determined by leaching with 1 N NH_4OAc at pH 7 (Chapman 1965).

Results

Some soil chemical properties of the subplots

Figure 2 shows the distribution of mean N, P, K and CEC at 10 cm depth for the subplots planted with the four dipterocarps. The distribution of N, P, K and CEC at 10 cm depth was not significantly different in the 16 subplots according to the statistical analysis based on Latin Square Design (Appendix 1: Table I). This indicates that in terms of N, P, K and CEC distribution, the four dipterocarps were planted under similar site conditions.

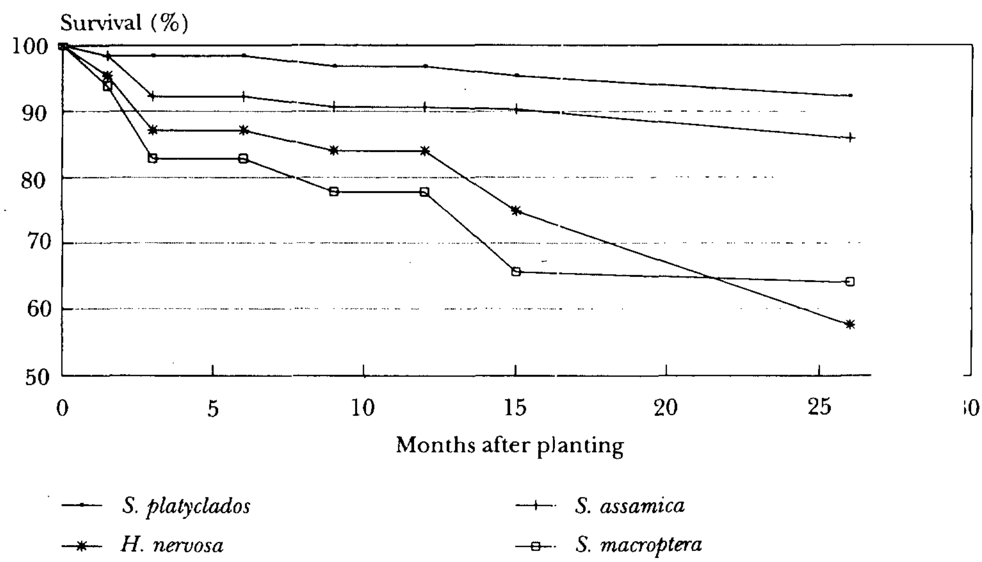


Note: No significant difference (p>0.05) was recorded for the parameters assessed

Figure 2. Distribution of N, P, K and CEC in subplots planted with the dipterocarps

Survival

At the end of 26 months after planting, the survivals recorded for *S. platyclados*, *S. assamica*, *S. macroptera* and *H. nervosa* were 92.2±4.5%, 85.9±5.4%, 64.0±10.6% and 57.6 ±7.3% respectively (Figure 3). The mortality of the seedlings was mainly due to dehydration in open conditions. Table 2 shows that the mortality of the dipterocarp seedlings increased in March 1991, September 1991 and March 1992 when mean monthly rainfalls in the period before each enumeration were 79.3 mm, 157.4 mm and 214.8 mm respectively. No mortality of seedlings was observed when the mean monthly rainfall was more than 320.4 mm for the four open planted dipterocarps.



Note: Details of statistical analysis are in Appendix 1: Table II.

Figure 3. Survivals of the four open planted dipterocarps in FRIM, Selangor

S. platyclados and *S. assamica* appear to have lower mortality than *S. macroptera* and *H. nervosa* in lower total rainfall months. This indicates that *S. platycaldos* and *S.assamica* may possess better drought tolerance. The high mortality of *S. assamica* seedlings at 3 months after planting was mainly caused by dehydration due to uprooting by rodents.

There was no significant difference amongst the dipterocarps in survival at the first 15 months after planting but *S. platyclados* and *S. assamica* were observed to have significantly ($F= 23.7$, significant at $p<0.01$ level in Scheffe's test) higher survival than the other two dipterocarps at 26 months after planting (Appendix 1:

Table II). The result indicated that *S. platyclados* and *S. assamica* were more suitable for open planting than *S. macroptera* and *H. nervosa.*

Table 2. Relationship between the mean monthly rainfall and mortality of the dipterocarps in open planting

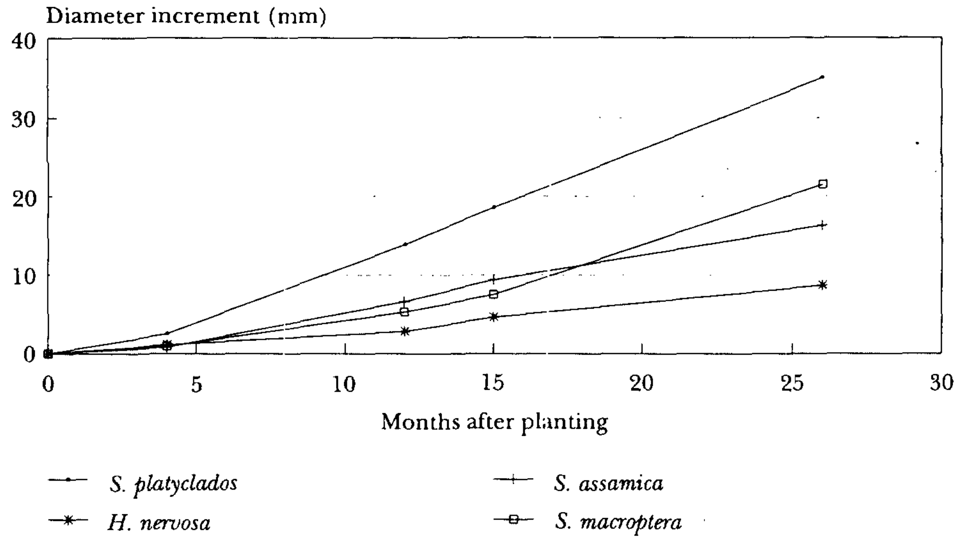
Enumeration date (stand age: mth)	Mean monthly rainfall* (mm)	Mortality							
		Freq. (*Shorea platyclados*)	Cumulative (*Shorea platyclados*)	Freq. (*Shorea assamica*)	Cumulative (*Shorea assamica*)	Freq. (*Shorea macroptera*)	Cumulative (*Shorea macroptera*)	Freq. (*Hopea nervosa*)	Cumulative (*Hopea nervosa*)
March 1991(3)	79.3	0.6	0.6	7.8	7.8	17.8	17.8	12.9	12.9
June 1991(6)	353.7	0.0	0.6	0.0	7.8	0.0	17.8	0.0	12.9
Sept. 1991(9)	157.4	2.6	3.2	1.6	9.4	4.4	22.2	3.1	16.0
Dec. 1991(12)	320.4	0.0	3.2	0.0	9.4	0.0	22.2	0.0	16.0
March 1992(15)	214.8	1.5	4.7	0.3	9.7	2.9	25.1	19.0	35.0

*Calculated from the total rainfall in the period before each enumeration date based on Figures 1a and 1b.

At the stand age of 26 months, the collar diameter increments at 10 cm above ground level for *S. platyclados, S. assamica, S. macroptera* and *H. nervosa* were 35 ± 4.3 mm, 21.5 ± 2.8mm, 16.4 ± 2.2 mm and 8.7 ± 0.8 mm respectively (Figure 4). There was significant difference amongst the dipterocarps in the collar diameter increment at 4 ($p<0.01$), 12 ($p<0.05$), 15 ($p<0.05$) and 26($p<0.01$) months after planting (Appendix 1: Table III). *S. platyclados* had the highest significant collar diameter increments amongst the dipterocarps throughout the assessment period.

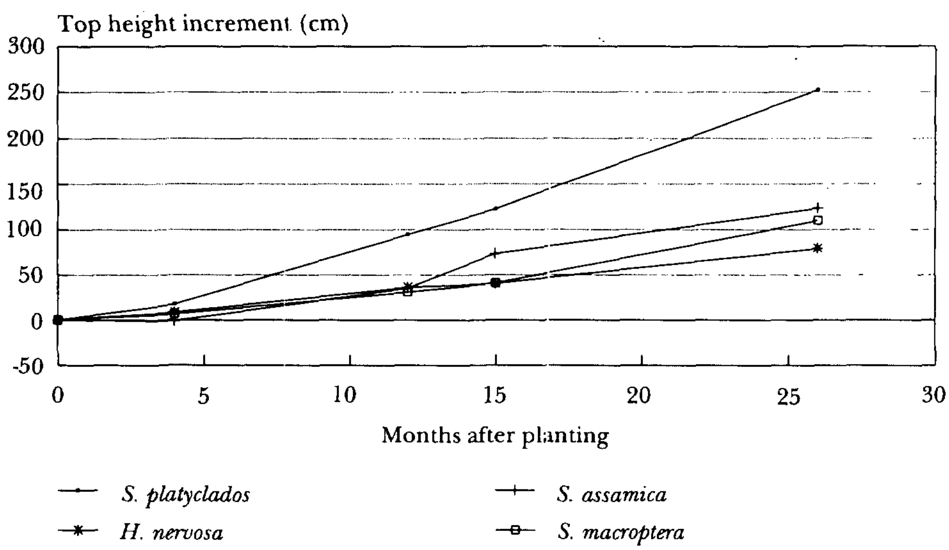
Top height increment

The top height increments at the stand age of 26 months for *S.platyclados, S. assamica, S. macroptera* and *H. nervosa* were 2.51 ± 1.27 m, 1.23 ± 0.20 m, 1.10 ± 0.17 m and 0.79 ± 0.05 m respectively (Figure 5). A negative height increment was observed for *S. assamica* at 3 months after planting because of drying of the shoots caused by planting shock. There was no significant difference ($p<0.05$) amongst the dipterocarps in top height increment at 15 months after planting (Appendix 1: Table IV). However, *S. platyclados* had the highest significant top height increment at the stand age of 26 months .



Note: Details of statistical analysis
are in Appendix 1: Table III.

Figure 4. Root collar diameter increment of the four open planted dipterocarps



Note: Details of statistical analysis
are in Appendix 1: Table IV.

Figure 5. Mean top height increment of the four open planted dipterocarps

Net photosynthesis, transpiration rate and stomatal conductance

The relationship between net photosynthesis and transpiration (Pn/Ev) indicated that *S. platycaldos* and *S. assamica* had higher net photosynthesis than *H. nervosa* and *S. macroptera. S. assamica,* especially, maintained a high net photosynthesis rate despite its higher transpiration rate (Figure 6). A similar trend was also observed in the net photosynthesis and stomatal conductance relationship (Figure 7). Hence, it was found that the efficiency of photosynthesis of the open planted dipterocarps was of the following order: *S. platyclados* > *S. assamica* > *S. macroptera* > *H. nervosa* (Table 3).

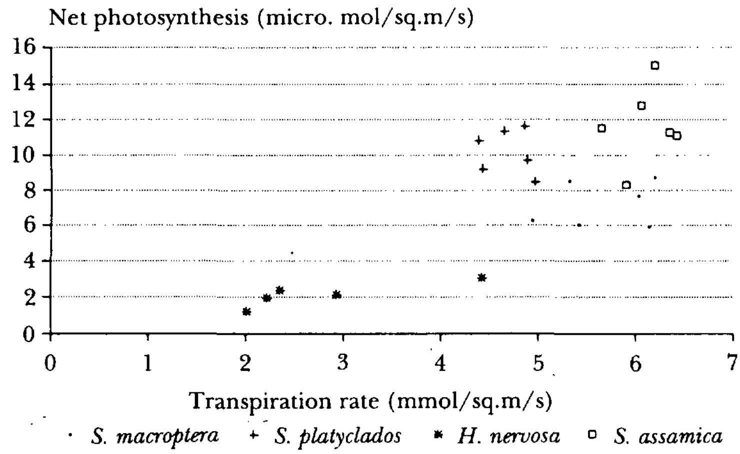


Figure 6. Photosynthesis vs. transpiration of the four open planted dipterocarps

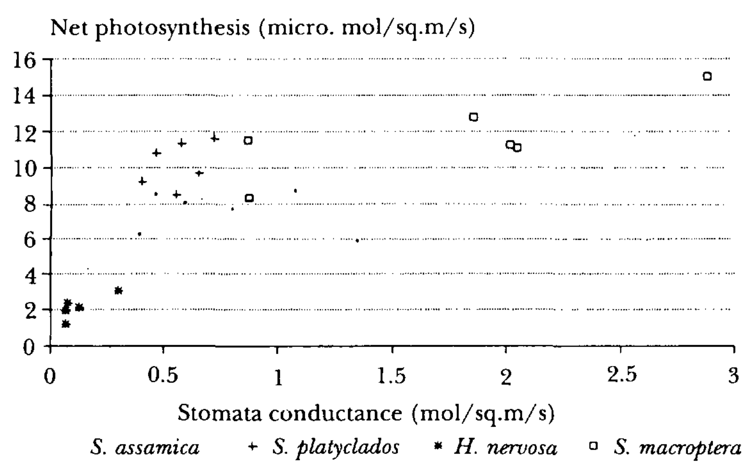


Figure 7. Photosynthesis vs. stomatal conductance of the four open planted dipterocarps

Table 3. Mean photosynthesis (Pn) /transpiration (Ev) ratio of the four open planted dipterocarps

Species	Sample size(n)	Net photo-synthesis (Pn) $\mu mol\ m^{-2}\ s^{-1}$	Transpiration (Ev) $mmol\ m^{-2}\ s^{-1}$	Pn/Ev ratio($\times 10^{-3}$)
Shorea platyclados	6	10.19 ± 0.45	4.69 ± 0.10	2.191 ± 0.125
Shorea assamica	6	11.66 ± 0.90	6.10 ± 0.12	1.908 ± 0.143
Shorea macroptera	6	7.15 ± 0.52	5.68 ± 0.21	1.262 ± 0.090
Hopea nervosa	5	2.15 ± 0.41	2.79 ± 0.43	0.780 ± 0.071

Discussion

Specific performance

S. platyclados, which produces high quality dark red meranti timber, is confined to the upper dipterocarp forest zone, having a higher altitudinal distribution than any other *Shorea.* The optimum range is between 800 m and 1200 m a.s.l., but the species has been recorded at elevations as low as 350 m a.s.l. and as high as 1400 m a.s.l. along the Main Range of Peninsular Malaysia (Symington 1943, Ashton 1982). However, poor regeneration of dipterocarps on hill forests was observed (Symington 1943, Burgess 1968). In addition, extensive logging activities carried out in the hill forest have further aggravated the poor regeneration of the dipterocarps. Hence, domestication of this species for conservation purpose is timely. *S. platycaldos* was observed to be successfully planted under legume tree species and arboretum conditions at low elevations of about 90 m a.s.l. It also had high diameter growth rate of 2.4 cm y^{-1} (Symington 1943). The present study shows that this species establishes well in the open and confirms the finding of Symington (1943) that it can be successfully grown at low elevation.

S. assamica is a lowland dipterocarp and distributed in northern Peninsular Malaysia. It produces the less valuable white meranti wood. It favours low-lying land, occurring often in the vicinity of streams and has been observed in valleys up to 500 m a.s.l. (Symington 1943). This dipterocarp is adapted to seasonal drought found in the northern peninsula. The study indicates that it has better survival, collar diameter increment and top height increment than *S. macroptera* and *H. nervosa* in open planting.

S. macroptera inhabits low lying, but usually well drained sites from sea level to 900 m a.s.l. It is more abundant in hilly forests than on the plains. A density of 34 stems ha^{-1} for *S. macroptera* has been recorded in the 50-ha plot at a lowland dipterocarp forest reserve in Pasoh, Negeri Sembilan (Manokaran *et al.* 1991). In a primary lowland forest at Sungai Menyala Forest Reserve, a *S. macroptera* tree was recorded to have the highest long-term diameter increment of 0.8 cm y^{-1} and reached a diameter of just under 50 cm in 38 years (Manokaran & Kochmmen 1994). It also established well in underplanting of secondary forest with 0.8 cm y^{-1} in diameter increment at stand age of 7 years (Symington 1943). However, the present study shows that *S. macroptera* does not respond favourably in open planting.

H. nervosa produces the merawan group timber. It prefers valleys and can be found up to 600 m a.s.l. The study indicates that this species is not suitable for open planting because of its high mortality rate, slow collar diameter and top height increments.

Higher net photosynthetic rates (Figure 6) and higher Pn/Ev ratios (Table 3) in *S. platyclados* and *S. assamica* could contribute to their higher survival and better growth. The superiority in photosynthetic efficiency of *S. platyclados* could be the main factor that contributes to its successful establishment in open conditions. Hence, this finding indicates that *S. platyclados* is a potential species for plantation development in the peninsula.

The Pn/Ev ratio of *S.macroptera* was lower compared to those of *S. platyclados* and *S. assamica.* This indicates a lower water use efficiency in *S. macroptera.* In addititon, *H. nervosa* was observed to have the lowest stomatal conductance and net photosynthesis (Figure 7), which suggests that *H. nervosa* might have difficulty maintaining its physiological processes when open planted. Thus, it was not surprising to observe the higher mortality rate and poor growth of this species in open planting.

Silviculture treatments

Site preparation

A higher survival of open planted *S. platyclados* and *S. macroptera* was noted in this study compared to those trees of the same species open planted at compacted (decking) sites in a logged-overhill forest where the survivals were only 58% and 16% respectively at 14 months after planting (Ang *et al.* 1992). This was mainly due to a lack of a litter layer, poor nutrient content of the soil and compaction at the decking sites. In contrast, site preparation without burning in this study could have contributed to the better establishment of the dipterocarps due to the litter layer which remained intact after clearing, thus maintaining its moisture retention properties and also reducing excessive dehydration of the soil surface.

Spacing

The initial spacing of 2 × 2 m was employed instead of the 3 × 3 m spacing of the normal plantation practice for sawn timber production. Thinning would be employed to remove the anticipated future excessive competition within the stand.

Watering

Based on the results obtained for the relationship between the mean monthly rainfall and mortality of the dipterocarps in the open planting, a higher mortality was observed in the drier months, and would have been more serious especially, in the first three months immediately after planting, if watering had not been carried out. In addition, the seedlings were watered before planting to reduce water stress on the seedling. Planting should be carried out before 10.00 am or after 4.30 pm. As watering of dipterocarp seedlings in the field after planting can be very costly, planting in the raining season is highly recommended.

Pruning

Pruning of new orthotropic leaders is needed for *S. platyclados* to ensure single leader development for the species. These orthotropic leaders from dormant accessory buds were observed to replace damaged orthotropic leader shoots (Ashton 1982). The orthotropic leaders were only observed in those open planted seedlings that had damaged leader shoots caused either by climbers, insects or desiccation.

Conclusion

S. platyclados and *S. assamica* were found to establish better than *S. macroptera* and *H. nervosa* in open planting. *S. platyclados,* which is a high value dipterocarp, had the best survival, diameter and top height increments amongst the dipterocarps studied. Hence, *S. platyclados* has great potential to be domesticated as a forest plantation species. However, a pilot plantation trial of *S. platyclados* ought to be established before any large scale operational planting is initiated.

Acknowledgements

The authors also would like to express their gratitude to Md Gazali Hasan and Rozita Ahmad for soil sampling and analysis, and N. Manokaran, Zakaria Ibrahim and K.L. Ng for their constructive criticisms.

References

AMIR HUSNI, M. S. 1984. *Detailed Reconnaissance Soil Survey of Part of Bukit Perangan Forest Reserve and Semi Detailed Soil Survey of Bukit Malut Forest Reserve Pulau Langkawi, Kedah, for Teak Crop.* Forest Research Institute Malaysia Research Pamphlet No. 95. 60 pp.

ANG, L.H. 1991a. Effects of open planting and underplanting on survival and growth of *Endospermum malaccense* (sesendok), *Alstonia angustiloba* (pulai) and *Shorea parvifolia* (meranti sarang punai). *Journal of Tropical Forest Science* 3(4): 380 - 384.

ANG, L.H. 1991b. Effects of nurse tree and topography on survival and growth of four dipterocarps in open planting. *Malaysian Forester* 52. (In press).

ANG, L.H. MARUYAMA, Y., WAN RAZALI, W. M. & ABD RAHMAN, K. 1992. Early growth and survival of three commercial dipterocarps planted on decking sites of a logged-over hill forest. Pp. 147-156 in Nik Muhamad, M. *et al.* (Eds.) *Preproceedings of International Symposium on Rehabilitation of Tropical Rainforest Ecosystems: Research and Development Priorities.* 2-4 Sept 1992. Kuching. Malaysia.

ASHTON, P.C. 1982. Dipterocarpaceae. *Flora Malesiana* Ser. 1. 9 : 238 - 600.

BARNARD, R.C. 1954. *A Manual of Malayan Silviculture for Inland Lowland Forests.* Research Pamphlet No. 14. Forest Research Institute Malaysia, Kepong. 199 pp.

BURGESS, P.F. 1968. An ecological study of the hill forest of the Malay peninsula: An assessment after nine months' preliminary investigation. *Malaysian Forester* 31: 314 - 325.

CHAPMAN, H. D. 1965. Cation exchangeable capacity. Pp. 891 - 901 in Black, C.A. *et al.* (Eds.) *Methods of Soil Analysis.* Agronomy 9. American Society of Agronomy Incorporated Madison, Wisconsin.

FREESE, F. 1967. *Elementary Statistical Methods for Foresters.* Agriculture Handbook 317. Washington D.C. 87 pp.

MANOKARAN, N. & KOCHUMMEN, K.M. 1993. Tree growth in primary lowland and hill diptero-carps forests. *Journal of Tropical Forest Science* 6(3): 323 - 345.

MANOKARAN, N., LAFRANKIE, J.V. & ROSLAN, I. 1991. Pp. 317-331 in Soerianegara, I. Tjitrosomo, S.S., Umaly, R. C. & Umboh, I. (Eds.) *Proceedings of the Fourth Round-Table Conference on Dipterocarps.* 12-15 December 1989. Bogor, Indonesia. Biotrop Special Publication No. 41. SEAMEO BIOTROP, Bogor, Indonesia.

SYMINGTON, C.F. 1943. *Foresters' Manual of Dipterocarps.* Malayan Forest Records No.16. Universiti Malaya. 244 pp.

WALKLEY, A. & BLACK, I.A. 1934. An examination of the Degtjorett method for determining soil organic matter and a proposal for modification of the chromic acid titration method. *Soil Science* 37 : 29 - 38.

WAN RAZALI, W. M. 1988. Level of productivity in plantation of fast growing indigenous species in Malaysia : Problems and prospects. Pp. 117 - 123 in Heuveldop, J., Homola, M., Maydell, K.J.V. & Van Tuyll, C. (Eds.) *Proceedings of the GTZ Regional Forestry Seminar.* 3 - 14 October 1988. Fiji.

WAN RAZALI W. M. & ANG, L. H. 1990. The early growth of two indigenous commercial tree species planted on degraded sites of logged-over forest Pp. 22 - 29 in Appanah, S., Ng. F.S.P & Roslan , I. (Eds.) *Proceedings of the Conference: Malaysian Forestry and Forest Products Research.* 3 - 4 October, 1990. Forest Reaserch Institute Malaysia, Kepong.

WATSON, J. G. 1935. Plantation experiments at Kepong. *Malaysian Forester* 4 : 110 - 119.

Appendix 1. Summary of data and statistical results of ANOVA for nutrient distribution, survival, top height and diameter increment

Table I. The distribution of some macronutrients of subplots planted with the four dipterocarps

N(%)	Column				
	1	2	3	4	Mean
S. platyclados	0.28	0.25	0.24	0.28	0.26
H. nervosa	0.27	0.28	0.26	0.25	0.26
S. macroptera	0.22	0.27	0.24	0.26	0.25
S. assamica	0.23	0.23	0.26	0.25	0.24
F-value=0.66 ns					

P (ppm)	Column				
	1	2	3	4	Mean
H. nervosa	12.0	12.6	11.8	11.6	11.9
S. platyclados	9.7	11.1	10.3	14.6	11.4
S. macroptera	10.9	10.5	11.7	10.3	10.8
S. assamica	11.0	8.7	8.4	11.6	9.9
F-value= 1.07 ns					

K (meq $100g^{-1}$)	Column				
	1	2	3	4	Mean
S. macroptera	0.21	0.26	0.19	0.14	0.20
H. nervosa	0.17	0.13	0.21	0.17	0.17
S. platyclados	0.11	0.14	0.19	0.18	0.16
S. assamica	0.12	0.12	0.16	0.25	0.16
F-value= 0.380 ns					

CEC (meq $100g^{-1}$)	Column				
	1	2	3	4	Mean
S. platyclados	10.3	7.8	8.4	9.8	9.1
S. macroptera	7.9	10.4	7.9	8.4	8.6
H. nervosa	8.7	8.9	8.4	8.2	8.6
S. assamica	7.5	7.5	7.3	8.1	7.6
F-value= 1.34 ns					

Note: ns denotes not significant at p = 0.05 level.

Table II. Survival (%) of the four open planted dipterocarps

1.5-month-old	Column					
	1	2	3	4	Mean	
S. platyclados	93.8	100	100	100	98.4	
S. macroptera	100	93.8	100	100	98.4	
S. assamica	100	100	81.2	100	95.3	
H. nervosa	100	100	87.5	87.5	93.8	F-value= 0.847 ns
3-month-old						
	1	2	3	4	Mean	
S. platyclados	93.8	100	100	100	98.4	
S. assamica	93.8	100	87.5	87.5	92.2	
H. nervosa	93.8	100	75.0	79.9	87.1	
S. macroptera	75.0	75.0	87.5	93.8	82.8	F-value= 2.853 ns
6-month-old						
	1	2	3	4	Mean	
S. platyclados	93.8	100	100	100	98.4	
S. assamica	93.8	100	81.2	100	92.2	
H. nervosa	93.8	100	75.0	79.9	87.1	
S. macroptera	75.0	75.0	87.5	93.8	82.8	F-value=2.853 ns
9-month-old						
	1	2	3	4	Mean	
S. platyclados	87.5	100	100	100	96.8	
S. assamica	87.5	93.8	81.2	100	90.6	
H. nervosa	93.8	87.5	75.0	79.9	84.0	
S. macroptera	62.3	75.0	79.9	93.8	77.8	F-value=4.05 ns
12-month-old						
	1	2	3	4	Mean	
S. platyclados	87.5	100	100	100	96.8	
S. assamica	87.5	93.8	79.9	100	90.6	
H. nervosa	93.8	87.5	68.7	79.9	84.0	
S. macroptera	62.3	75.0	79.9	93.8	77.8	F-value=4.15 ns
15-month-old						
	1	2	3	4	Mean	
S. platyclados	87.5	93.8	100	100	95.3	
S. assamica	87.5	93.8	79.9	100	90.3	
S. macroptera	62.3	68.7	75.0	93.8	74.9	
H. nervosa	68.7	75.0	56.2	62.5	65.6	F-value= 4.17 ns
26-month-old						
	1	2	3	4	Mean	
S. platyclados	87.5	81.2	100	100	92.2	
S. assamica	87.5	81.2	75.0	100	85.9	
S. macroptera	62.3	43.8	56.2	93.8	64.0	
H. nervosa	68.2	68.8	37.5	56.2	57.6	F-value=6.06*

Note: ns denotes not significant at p=0.05 level, *denotes significant at p = 0.05 level.

Journal of Tropical Forest Science 7(4): 541 - 557 (1995)

Table III. Collar diameter increment (mm) of the four open planted dipterocarps

4-month-old	Column				
	1	2	3	4	Mean
S. platyclados	2.2	2.1	2.7	3.0	2.5
S. macroptera	0.9	1.2	0.6	1.1	0.9
H. nervosa	1.0	1.1	1.0	1.4	1.1
S. assamica	0.2	0.4	0.2	1.1	0.8
F-value=14.4 **					
12-month-old	Column				
	1	2	3	4	Mean
S. platyclados	9.0	12.9	16.0	17.7	13.9
S. assamica	4.9	4.9	5.0	11.7	6.6
S. macroptera	2.0	4.8	5.9	8.6	5.3
H. nervosa	2.5	4.0	2.2	2.5	2.8
F-value=7.56*					
15-month-old	Column				
	1	2	3	4	Mean
S. platyclados	12.6	16.2	21.4	24.1	18.6
S. assamica	6.9	7.7	7.6	15.6	9.4
S. macroptera	3.9	4.9	9.4	11.8	7.5
H. nervosa	4.1	5.5	4.1	4.8	4.6
F-value= 6.54*					
26-month-old	Column				
	1	2	3	4	Mean
S. platyclados	44.6	38.4	32.8	24.3	35.0
S. macroptera	29.8	19.1	19.9	17.2	21.5
S. assamica	22.1	16.0	16.1	11.4	16.3
H. nervosa	8.1	7.3	10.9	8.4	8.7
F-value= 9.40**					

Note: * and ** denote significant at p = 0.05 and 0.01 levels respectively.

Table IV. Top height increment (cm) of the four open planted dipterocarps

4-month-old			Column		
	1	2	3	4	Mean
S. platyclados	7.4	13.1	22.5	27.5	17.6
H. nervosa	7.7	9.9	7.2	9.6	8.6
S. macroptera	3.8	4.6	7.2	10.6	6.6
S. assamica	-1.1	-8.0	-4.9	9.0	-1.2
F-value = 3.91 ns					
12-month-old			Column		
	1	2	3	4	Mean
S. platyclados	67.4	72.0	120.1	118.7	94.5
H nervosa	31.7	67.9	19.0	26.3	36.2
S. assamica	25.7	18.2	25.5	74.3	35.9
S. macroptera	4.8	14.4	37.2	67.2	30.9
F-value = 4.34 ns					
15-month-old			Column		
	1	2	3	4	Mean
S. platyclados	89.8	102.7	145.9	151.6	122.5
S. assamica	69.0	47.4	40.9	135.5	73.2
S. macroptera	6.2	18.4	55.8	83.3	40.9
H. nervosa	45.2	28.4	35.4	52.6	40.4
F-value = 3.90 ns					
26-month-old			Column		
	1	2	3	4	Mean
S. platyclados	309	291	231	179	252.5
S. assamica	184	113	98	99	123.5
S. macroptera	151	94	121	74	110.0
H. nervosa	89	73	87	68	79.3
F-value = 8.18**					

Note: ** denotes significant at p=0.01 level and ns denotes not significant at p=0.05 level.