

Chapter 3.6

EARLY ESTABLISHMENT OF DIPTEROCARP SEEDLINGS IN BERKELAH FOREST RESERVE, PAHANG

by

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Introduction

This study, “The Early Establishment of Dipterocarp Seedlings in a Malaysian Logged-over Hill Forest”, was part of the project entitled “Dipterocarp Domestication in Malaysia”. The project was funded by the Commission of the European Community (CEC) through the Centre National de la Recherche Scientifique (CNRS), France, as the main contractor and jointly conducted by the Forest Research Institute Malaysia (FRIM), the University of Stirling and the University of Aberdeen in Scotland. The implementing agency for the project was FRIM. The project was conducted from early 1991 to 1994 in a 5.6-ha plot at Berkelah Forest Reserve (FR), Jengka, State of Pahang. The plot is about 234 km to the northeast of Kuala Lumpur and 218 km to the northeast of FRIM. The project site was located in Compartment 37 (TT 04/86 KP) which was within the C72 logging block. The forest reserve has been identified as a red meranti forest

(Wyatt-Smith 1961). It is a selectively logged mixed hill dipterocarp forest stand and the area was tractor-logged once in 1986–1987 (Temerloh District Forest Office, pers. comm.).

Due to logging activities, there were gaps created in the logged-over forest such as logging roads, skid trails, and log-decking sites or matau. After four years, the area was still void with no vegetation although a few *Macaranga* spp. were found growing at the study site. The soil of the study site was heavily compacted by heavy machinery used during logging activities. The study site was covered mainly with the light-demanding tree species such as *Macaranga* spp. and was also heavily colonized with the rhizomatous fern *Dicranopteris linearis* (Gleicheniaceae). This area was selected to be planted with two dipterocarp species for investigating the growth performance under different light intensities, soil conditions and the effects of triple superphosphate (TSP) application in the field. The two species used for planting were *Hopea odorata* and *Dryobalanops oblongifolia*. The techniques of planting used in the study were similar to those used in normal practice by the Forest Department Peninsular Malaysia. The main objectives of the study were:

- to investigate different light intensities and soil conditions in influencing growth performance of seedlings in the field;
- to investigate the effect of phosphorus fertilizer (TSP) on seedling growth.

Materials and methods

Study site

To accommodate the study of the early establishment of dipterocarp seedlings and the light level trial in a logged hill forest, a study plot of 5.6 ha was established in November 1991 (Raja Barizan 1997). The plot was divided into 140 subplots, each of which was of size 20 × 20 m. All trees ≥ 10 cm dbh were tagged and measured. Based on the light levels at subplot establishment, the subplots were categorized into A, B, C, D and E (Figure 3.6.1). Subplots A and B were categorized as open, C as partial shade and D and E as closed categories. The light category of each subplot was defined according to the percentage of exposure of the ground and mean percentage of relative light intensity (RLI) received by the seedlings within the subplot. The mean percentages of RLI in the open-category subplots were A (20–25%) and B (≥ 55%), partial shade subplots C (8–9%), and closed subplots D and E (2–3%). Each category was randomly replicated at six locations within the plot. Category B was formed from log landings and secondary decking sites within the logged forest whereby all vegetation, litter and topsoil had been removed during the logging operations. Within the 5.6-ha plot, all subplots were classified and categorized. From the 140 subplots established, 30 subplots were selected consisting of six random replicates of each of the five subplot categories for field planting trials.

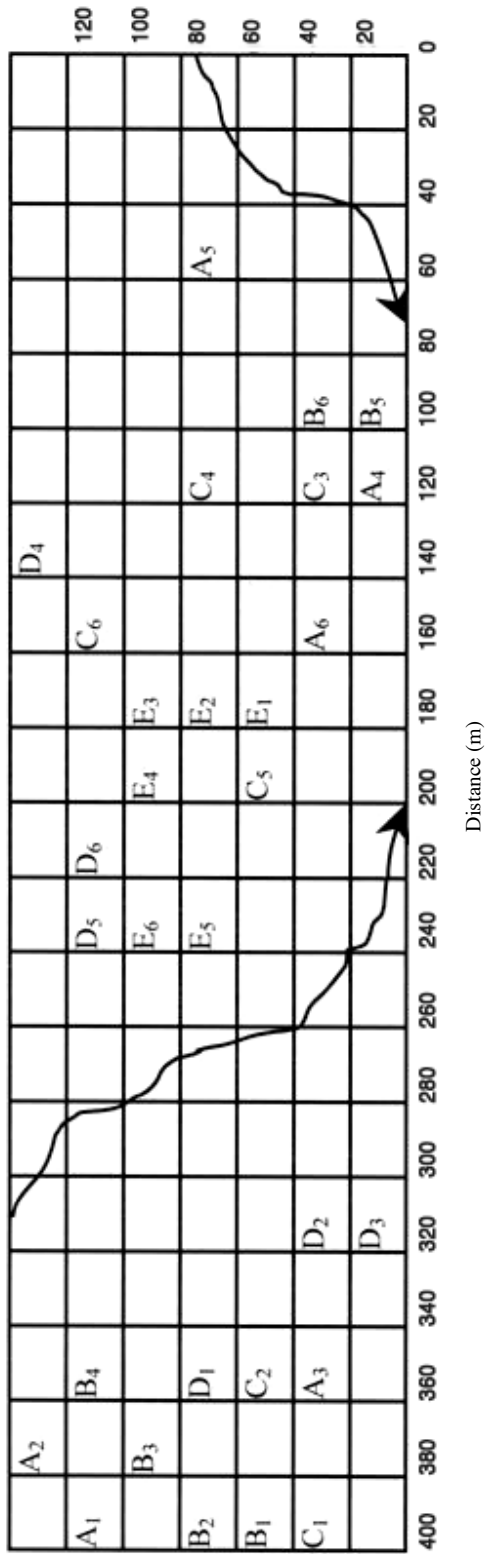


Figure 3.6.1 The 5.6-ha plot in a logged forest at Berkelah FR, Pahang. Subplot categories: A=large gap and less compacted soil, B=large gap and compacted soil, C=partially shaded and less compacted soil, D=closed canopy with many dipterocarps, and E=closed canopy with few dipterocarps. The subscripted numbers indicate the subplot replicates. Two streams cross the study plot.

Categories A and C were skid trails whereby all vegetation, litter and topsoil had been removed but some canopy cover from the surrounding trees remained. Categories D and E were left intact for closed-canopy planting. Both of these two closed-canopy types were mainly covered with the residual trees after logging and subcanopy of secondary species which had emerged after logging and these were mainly *Macaranga* spp. (Euphorbiaceae). For the purpose of planting trials, subplots A, B and C were given silvicultural treatments. Categories A and B were opened up to 80–100% for open planting. Subplot C was opened up to 30–70% by felling all non-dipterocarp trees < 9.6 cm dbh to create partially shaded category. All stumps and logs left behind at the planting points were cut and removed to the edges of subplots and left to rot. The percentage of the exposure of the ground was maintained throughout the study period by weeding in categories A and B and by thinning in category C. Closed canopy of category D was defined as “many dipterocarps” in which the number of dipterocarps (seedlings, saplings and poles; dbh < 9.6 cm) found growing naturally in the subplots was between 67 and 146, whilst closed category E was defined as “few dipterocarps” with 13–33 dipterocarps found in the subplots.

The topographical survey of the plot showed that the plot had a gentle slope and lay at an altitude of 204–236 m asl. It was located at the lower part of the hill forest area. The nearest climatological station is the Research Station of FRIM in Jengka, Pahang. The station is approximately 30 km away from the research plot and the climatological data collected were assumed to be representative of the climatological data of the study site. The wet period in the year is usually from September to December and the dry period from April to July. The highest total monthly rainfall recorded during the study period was 523 mm in November, the minimum monthly temperature 19 °C and maximum temperature 34 °C. The soil profiles in Berkelah FR can be categorized as belonging to the Durian Series in ultisols order (Kamaruzaman 1988). The texture of the soil was reported as sandy loam (Kamaruzaman 1992). The chemical and physical properties of the soil in the plot are as reported in Tables 3.6.1 and 3.6.2 respectively.

Planting materials

Two species of dipterocarps were chosen for field planting trials: *H. odorata*, locally known as merawan siput jantan, and *D. oblongifolia*, locally known as keladan. The seedlings were potted in 12.5 × 20 cm black polythene bags with a standard nursery soil mixture of three parts of soil to one part of sand. Seeds of *H. odorata* were collected from trees growing in FRIM compound and the seedlings were raised in the nursery in FRIM. A total of 1200 seedlings, ranging 6–10 cm in size, were potted. Due to the different initial sizes of the seedlings used for potting, this resulted in two distinct ranges of size in terms of seedling height, six

months after potting. Thus the seedlings were grouped into two size classes, i.e. small seedlings ranging 10–15 cm in height and large seedlings ranging 20–30 cm in height. A total of 1200 seedlings of *D. oblongifolia* were raised and potted in the same size polythene bags and with the same type of soil as for *H. odorata*. However, the size of *D. oblongifolia* seedlings prior to planting was quite uniform (4–5 number of leaves; 17–22 cm in height); therefore only one size class treatment was considered.

Fertilizer application in the nursery

A phosphorus fertilizer, triple super phosphate (TSP), was applied to both species in the nursery. For the purpose of fertilizer effect study, however, only half of the total seedlings (600 seedlings) were treated with TSP and no TSP was applied to the other half. The amount of 0.33 g (144 mg P) per pot of TSP was applied to *H. odorata* seedlings at monthly intervals over five months. As *D. oblongifolia* seedlings were bigger than *H. odorata* seedlings, 0.40 g of TSP (175 mg P) per pot of TSP was applied on the former at monthly intervals in the nursery.

Transplanting in the field

The seedlings were transported from FRIM to the study site. Three weeks after hardening, 32 seedlings at the age of eight months, 16 fertilized and 16 non-fertilized, were randomly planted in each subplot (Figure 3.6.2). For each fertilizer level, out of 16 seedlings, 6 were small and 10 were large seedlings. The size of planting hole used in this study was 20 × 20 × 30 cm. *Hopea odorata* was planted at a spacing of 3.4 × 3.4 m. The root collar of each seedling was placed level with the ground or slightly below it. The hole was refilled with soil from the planting hole and the soil around the roots was pressed in by hand and then stamped down by foot to ensure the seedling was steadily placed in the planting hole. In all planting categories, the only disturbance to the soil was due to the preparation of planting hole. No fertilizer was applied in the field. The total number of seedlings planted in the plot was: 5 categories × 6 subplots × 2 harvests × 2 P levels × (3 replicates for small size + 5 replicates for large size) = 960.

A total of 1200 seedlings of *D. oblongifolia* were transported to the plot in April 1993. After hardening, 30 seedlings at age of 8.5 months, 15 fertilized and 15 non-fertilized seedlings, were randomly planted in the subplots. The total number of seedlings planted in the plot was: 5 categories × 6 subplots × 2 P levels × (8 replicates for first harvest + 7 replicates for second harvests) = 900. *Dryobalanops oblongifolia* seedlings were planted in between the *H. odorata* at a spacing of 1.7 × 3.4 m, but the spacing in between the *D. oblongifolia* was 3.4 × 3.4 m (Figure 3.6.2).

Table 3.6.1 Soil chemical characteristics of the subplots at different depths prior to planting; Subplot categories: A, large gap and less compacted soil; B, large gap and compacted soil; C, partially shaded; D, closed canopy with many dipterocarps; and E, closed canopy with few dipterocarps (mean \pm SE, n = 3)

Subplot category	Depth (cm)	N (%)	Organic carbon (%)	Fe (%)	P available (ppm)	Exchangeable (meq. 100 g ⁻¹)		
						Mg	Ca	K
A	10	0.17 \pm 0.02	1.89 \pm 0.27	0.94 \pm 0.03	4.21 \pm 0.94	0.40 \pm 0.10	0.18 \pm 0.07	0.18 \pm 0.03
	30	0.13 \pm 0.02	1.26 \pm 0.30	1.04 \pm 0.01	2.22 \pm 0.75	0.23 \pm 0.03	0.10 \pm 0.03	0.16 \pm 0.03
B	10	0.10 \pm 0.01	1.13 \pm 0.17	1.00 \pm 0.08	1.75 \pm 0.50	0.14 \pm 0.02	0.15 \pm 0.04	0.11 \pm 0.01
	30	0.09 \pm 0.01	0.88 \pm 0.13	0.99 \pm 0.08	0.97 \pm 0.31	0.09 \pm 0.02	0.10 \pm 0.03	0.10 \pm 0.03
C	10	0.13 \pm 0.01	1.49 \pm 0.21	0.81 \pm 0.05	3.17 \pm 0.38	0.25 \pm 0.08	0.16 \pm 0.09	0.10 \pm 0.01
	30	0.12 \pm 0.01	1.34 \pm 0.22	0.92 \pm 0.06	2.19 \pm 0.57	0.20 \pm 0.10	0.10 \pm 0.05	0.08 \pm 0.007
D	10	0.14 \pm 0.01	1.54 \pm 0.13	0.99 \pm 0.06	2.20 \pm 0.12	0.48 \pm 0.05	0.09 \pm 0.01	0.17 \pm 0.01
	30	0.10 \pm 0.001	1.00 \pm 0.10	1.10 \pm 0.06	1.13 \pm 0.23	0.33 \pm 0.05	0.06 \pm 0.01	0.13 \pm 0.01
E	10	0.14 \pm 0.003	1.85 \pm 0.17	0.88 \pm 0.05	4.48 \pm 1.11	0.30 \pm 0.07	0.18 \pm 0.12	0.14 \pm 0.01
	30	0.12 \pm 0.01	1.48 \pm 0.06	0.99 \pm 0.07	3.01 \pm 0.38	0.36 \pm 0.21	0.07 \pm 0.03	0.09 \pm 0.003

Source: (Raja Barizan 1997)

Table 3.6.2 Soil physical properties in the subplots at different depths prior to planting. Subplot categories: A, large gap and less compacted soil; B, large gap and compacted soil; C, partially shaded; D, closed canopy with many dipterocarps; and E, closed canopy with few dipterocarps (mean \pm SE, n=3)

Subplot category	Depth (cm)	CEC (%)	Fine sand (%)	Coarse sand (%)	Silt (%)	Clay (%)	Bulk density (g cm ⁻³)	pH
A	10	5.89 \pm 0.46	40.67 \pm 1.76	17.00 \pm 10.54	12.67 \pm 4.10	12.67 \pm 4.10	1.06	4.31 \pm 0.04
	30	6.81 \pm 0.86	44.67 \pm 0.88	15.33 \pm 10.48	11.67 \pm 3.84	11.67 \pm 3.84	-	4.34 \pm 0.12
B	10	6.50 \pm 2.62	36.67 \pm 7.13	27.00 \pm 11.37	9.00 \pm 7.00	9.00 \pm 7.00	1.13	4.41 \pm 0.07
	30	6.58 \pm 3.11	36.67 \pm 8.45	26.33 \pm 12.73	10.33 \pm 6.36	10.33 \pm 6.36	-	4.43 \pm 0.08
C	10	4.21 \pm 0.09	38.33 \pm 2.60	43.33 \pm 2.96	2.67 \pm 0.67	2.67 \pm 0.67	0.94	4.40 \pm 0.13
	30	3.66 \pm 0.04	39.33 \pm 1.76	43.33 \pm 2.33	2.67 \pm 0.67	2.67 \pm 0.67	-	4.48 \pm 0.07
D	10	6.81 \pm 0.90	45.00 \pm 4.73	7.67 \pm 1.76	15.00 \pm 2.65	15.00 \pm 2.65	0.91	4.44 \pm 0.04
	30	5.64 \pm 0.49	43.67 \pm 5.24	8.00 \pm 1.52	16.00 \pm 3.21	16.00 \pm 3.21	-	4.52 \pm 0.07
E	10	6.36 \pm 1.20	39.67 \pm 1.45	39.67 \pm 0.67	2.67 \pm 0.67	2.67 \pm 0.67	0.89	4.28 \pm 0.13
	30	5.42 \pm 0.37	50.00 \pm 8.50	29.33 \pm 8.41	3.00 \pm 1.00	3.00 \pm 1.00	-	4.34 \pm 0.04

Source: (Raja Barizan 1997)

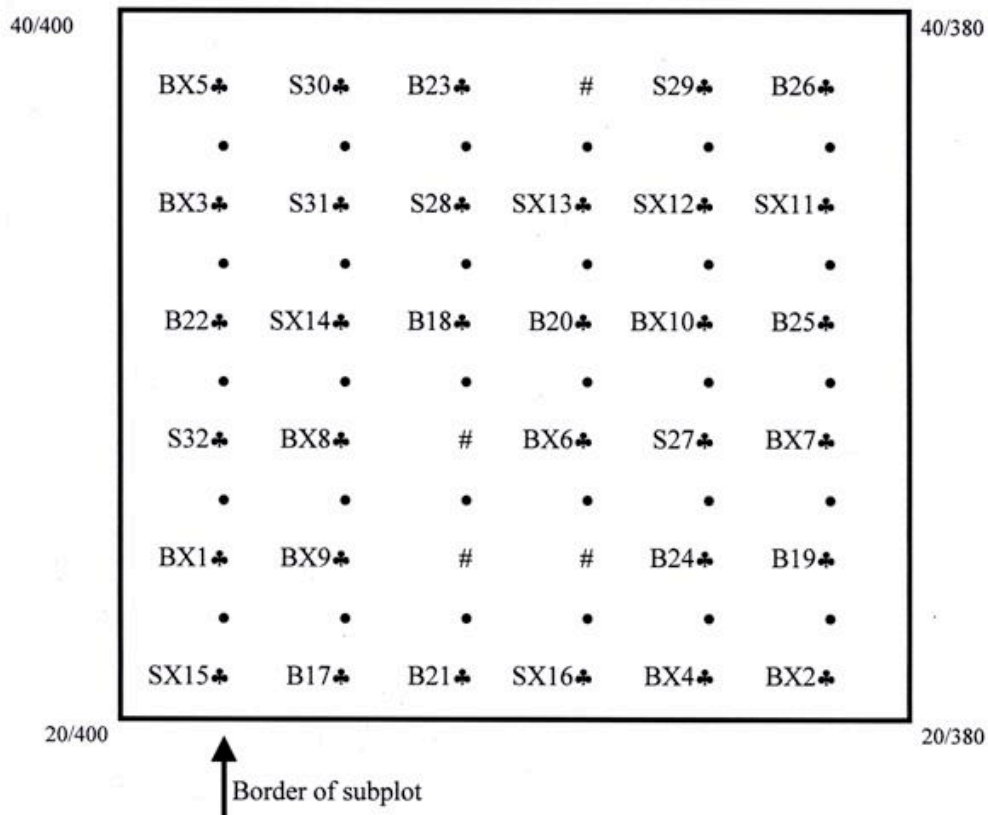


Figure 3.6.2 Layout of planting in subplot C_1 . The subplot is located at 380 to 400 m from the base point and 20 to 40 m from the baseline in the 5.6-ha plot at Berkelah FR, Pahang

Abbreviations:

BX = Large size and fertilized seedlings of *Hopea odorata*

SX = Small size and fertilized seedlings of *H. odorata*

B = Large non-fertilized seedlings of *H. odorata*

S = Small non-fertilized seedlings of *H. odorata*

= No plant

□ = Planting position for *H. odorata*

• = Planting position for *Dryobalanops oblongifolia*

1–32 = Tag numbers of *H. odorata* in subplot C_1

Relative light intensity (RLI)

In this study the determination of light was only on the quantity of light received by the seedlings in the field. This was determined using a LI-COR quantum sensor radiophotometer. Only one radiophotometer was used for the measurements; therefore the photosynthetic active radiation (PAR, $\mu\text{E m}^{-2} \text{s}^{-1}$) of the seedlings in

the open was measured immediately after completing the reading in the shade house or in the plot. The calculation for relative light intensity (RLI) is as shown:

$$\text{RLI (\%)} = \frac{\text{PAR (in the shade house or in the plot)} \times 100 \%}{\text{PAR (in the open)}}$$

Destructive measurements of growth

The survivals of the seedlings, the growths and the dry weights for both species were determined yearly for two years after planting. The sample sizes of *H. odorata* and *D. oblongifolia* within and between the subplot categories varied due to the death of seedlings as the experiment progressed. Destructive measurements of growth for seedlings in the field were made at 12-month intervals. The height (cm) and stem basal diameter (mm) were measured and the total number of green leaves was counted. Each harvested seedling was divided into different parts, i.e. leaves, stem and roots. The plant parts were stored in paper bags, labelled by species, treatment and harvesting date and dried in an oven at 75 °C for 24 h. Before measuring the dry weights, samples were cooled in a desiccator for 1 h to prevent them from gaining weight from the humid air.

Data analysis

The analysis was only carried out on the surviving seedlings. The survival and some treatment combinations of the growth data were naturally “missing” and the replication was unequal, therefore a split-plot unbalanced design was used for the analysis. The different categories were replicated at the subplot levels and fertilizer, size and harvest factors were all nested within six subplot replicates using Statistical Analysis System (SAS 1993). The least significant difference (LSD) test was used to test the significant differences between levels of factors.

The survival and growth data of *H. odorata* for each harvest (at one and two years) and each size class (small and large) combinations were analysed separately. The analysis of *D. oblongifolia* was divided into two parts, at one and two years of harvest after planting. The survival of each species under the different plot categories was examined. The mean percentage seedling survivals were derived after calculating the percentage values at each harvest for each subplot category. The survival data for both species were arcsine transformed prior to analysis (Zar 1984).

Results and discussion

Seedling survival

There were no significant differences in survival of *H. odorata* seedlings between categories A, B and C, although survival in these three categories was significantly different from those in categories D and E, one year after planting (Table 3.6.3). After two years, the survival of seedlings was found to decrease to 78% in categories A and B and 86% in category C, while the survival of seedlings in the closed subplots, categories D and E, was greatly reduced to 35 and 45% respectively. However, there was no significant difference in survival found between categories D and E after two years in the field.

Table 3.6.3 Effect of subplot category (regardless of fertilizer levels) on the mean survival % (calculated from the detransformed arcsine data used in the ANOVA) of *Hopea odorata*, one and two years after planting

Subplot category	1 year (%)	2 years (%)
A	100 a	78a
B	100 a	78a
C	100 a	86a
D	96 b	35b
E	96 b	45b

Means not sharing the same letter(s) are significantly different at $p < 0.05$.
Source: (Raja Barizan 1997)

Table 3.6.4 shows that the survival of *D. oblongifolia* seedlings in the open (A and B) and in the partial shade (C) were significantly higher than in the closed categories (D and E) at both harvests. However, in all categories, the mean percentage survivals of the seedlings were reduced in the second year's harvest by 24% in category A, 14% in category B, 68% in category D and 42% in category E. But there was not much change of survival for category C (2%). In the first year, no significant difference in survival was found between categories D and E but in the second year, the survival of seedlings in category D was significantly lower than that in category E.

Table 3.6.4 Effect of subplot category (regardless of fertilizer levels) on the mean survivals (calculated from the detransformed arcsine data used in ANOVA) of *Dryobalanops oblongifolia* at two harvests

Subplot category	1 year	2 years	% change of harvest*
A	91a	69a	-24
B	91a	78a	-14
C	81a	79a	-2
D	40b	13c	-68
E	48b	28b	-42

Means not sharing the same letter(s) are significantly different at $p < 0.05$.

*% change from 1 to 2 y; i.e. $[(2\text{ y} - 1\text{ y})/1\text{ y}] \times 100$.

Source: (Raja Barizan 1997)

Application of fertilizer in the nursery did not affect the survival of *H. odorata* at one year in the field; however, it significantly increased the survival of the seedlings after two years. Fertilizing *D. oblongifolia* significantly reduced the survival of the seedlings at one year and no effect was seen after two years. The death of seedlings in category D was probably due to the extremely low light level which subsequently weakened the growth of the seedlings and subjected them to disease attack. In general both species survived better in the open and partial shade than in the closed categories regardless of the fertilizer level and size class. This showed that light plays an important role in determining the survival of seedlings and adding fertilizer had no consistent effect in increasing the survival.

The compaction of soil in categories A (less compacted; 1.06 g cm^{-3}) and B (compacted soil; 1.13 g cm^{-3}) did not affect the survival of both species. The results in the closed categories (D and E) showed no significant difference in survival for both species after one year in the field. After two years, the survival of *H. odorata* (large seedlings) again showed no significant difference in both categories (D and E) but the survival of *D. oblongifolia* in category D (closed canopy with many dipterocarps) was significantly lower than that in category E. Although no root interference or root competition study was done in categories D and E, probably the significantly lower survival in category D was due to root competition between the planted *D. oblongifolia* and the existing seedlings and saplings of dipterocarps in the subplots.

Seedling growth

Table 3.6.5 shows that all growth parameters and dry weights of stems and roots for small and large seedlings of *H. odorata* were not significantly different between the two open categories (A and B), except that the dry weight of leaves in category B was significantly higher than that in category A. All growth parameters and dry weights of the seedlings in the closed categories (D and E) were also not significantly different from each other for both size classes. All growth variables and dry weights of small seedlings in partial shade (C) showed no significant differences from those in the closed categories but their growth was significantly different from that in the open categories. All the growth variables and the dry weights of seedlings

in either size class were significantly higher in the open categories (A and B) than in the partial shade (C) and closed categories (D and E). Large seedlings had a better growth compared with small seedlings, regardless of planting category. Regardless of the size of the seedlings and of the subplot categories, fertilizer increased the growth and the dry weight of seedlings, two years after planting. The mean growth values and the mean dry weights of seedlings in either size class showed that seedlings in the open categories (A and B) were significantly higher than those seedlings in the partial shade category (C) and in the closed categories (D and E). The diameters of small seedlings in category C were significantly lower than those in categories A and B but higher than those in categories D and E. As for small seedlings, the height and the diameter growths of large seedlings in category C were significantly lower than in categories A and B but significantly higher than in categories D and E. However, the percentage of size effects showed that the growth values and the dry weights of large seedlings were higher than those of small seedlings, irrespective of planting category.

Table 3.6.5 Effect of subplot category (regardless of fertilizer levels) on the mean growth variables and dry weights of *Hopea odorata* in two size classes, one and two years after planting

Harvest	Size	Subplot category	No. of leaves	Height (cm)	Diameter (mm)	Dry weight (g)		
						Leaf	Stem	Root
1 year	Small	A	50a	38.8a	6.00a	4.25b	4.08a	4.05a
		B	60a	43.7a	7.00a	7.12a	6.12a	6.02a
		C	23ab	21.3b	3.24b	1.67bc	1.39b	1.28b
		D	6c	14.5bc	2.29bc	0.19c	0.20b	0.29b
		E	5c	12.9c	1.98c	0.16c	0.13b	0.22b
		Mean	29.0	26.2	4.1	3.5	2.4	2.4
	Large	A	89a	60.5a	8.97a	12.93a	14.07a	11.01a
		B	104a	64.7a	9.65a	13.99a	16.46a	13.79a
		C	40b	37.8b	5.48b	3.29b	3.15b	3.40b
		D	8c	21.5c	2.91c	0.50b	0.42b	0.48b
		E	8c	19.8c	2.78c	0.36b	0.34b	0.32b
		Mean	50.0	40.9	6.0	6.2	6.9	5.8
		% effect of size*	72	56	45	76	189	145
	2 years	Small	A	55ab	54.6ab	8.23a	6.79ab	6.79ab
B			80a	63.6a	9.42a	9.96a	9.96a	20.51a
C			39b	34.0bc	5.46b	2.70bc	2.70b	3.50b
D			7c	15.5c	2.10c	0.22c	0.22b	0.19b
E			7c	15.4c	1.96c	0.17c	0.17b	0.15b
Mean			38.0	36.6	5.4	4.0	4.0	8.2
Large		A	103a	79.3a	11.03b	18.65a	40.40a	35.30a
		B	129a	89.0a	12.67a	20.15a	49.17a	34.71a
		C	52b	44.1b	6.31c	4.11bc	6.29bc	5.34bc
		D	11b	21.1c	3.16d	0.57c	0.66c	0.47c
		E	10b	19.7c	2.64d	0.38c	0.44c	0.35c
		Mean	61.0	50.6	7.2	8.8	19.4	15.2
		% effect of size*	61	38	32	121	388	86

Means not sharing the same letter(s) are significantly different at $p < 0.05$.

* % increase of large size over small seedlings; i.e. $([large-small]/small) \times 100$.

Source: (Raja Barizan 1997)

Fertilizing the seedlings significantly improved the growth of seedlings in either size class (Table 3.6.6). The effect of fertilizer on the size of planted seedlings has shown that smaller seedlings benefited more from the application of fertilizer. Table 3.6.7 shows that the growth of *D. oblongifolia* seedlings was significantly better in the open and partial shade categories than in the closed categories (D and E) in either year of harvest. Despite this, the mean percentages of the growth variables and the dry weights of seedlings increased in the second harvest, regardless of fertilizer levels (Table 3.6.8). Fertilizing the seedlings increased the growth and the dry weight of seedlings at both years of harvest. However, the effect of fertilizer, fertilized over non-fertilized seedlings, was in the slight increase in the number of leaves, and the dry weights of leaves and stems after two years.

Table 3.6.6 Effect of fertilization (regardless of subplot category) on the mean growth variables and dry weights of *Hopea odorata* seedlings within size classes at one and two years after planting

Harvest	Size	Fertilizer level	No. of leaves	Height (cm)	Diameter (mm)	Dry weight (g)		
						Leaf	Stem	Roots
1 year	Small	P0	25b	24.6b	3.82b	1.87b	1.80b	1.74b
		P1	40a	31.1a	4.90a	4.21a	3.52a	3.61a
		Mean	33	28	4.36	3.04	2.66	2.68
	% effect of fertilizer*		60.0	26.4	28.3	125.1	95.6	107.5
	Large	P0	39b	35.6b	5.23b	3.79b	3.91b	3.53b
		P1	62a	46.6a	6.77a	8.75a	9.88a	8.14a
Mean		51	41.1	6	6.27	6.9	5.84	
% effect of fertilizer*		59.0	30.9	29.4	130.9	152.7	130.6	
2 year	Small	P0	26b	31.1b	4.90b	2.67b	4.84b	5.38b
		P1	65a	53.2a	7.78a	7.23a	17.62a	15.45a
		Mean	46	42.2	6.34	4.95	11.23	10.42
	% effect of fertilizer*		150.0	71.1	58.8	170.8	264.0	187.0
	Large	P0	50b	46.6b	6.60b	6.87b	13.88b	10.08b
		P1	87a	63.8a	9.00a	12.87a	29.62a	23.84a
Mean		69	55	7.8	9.87	21.75	16.96	
% effect of fertilizer*		74.0	36.9	36.4	87.3	113.4	136.5	

Means not sharing the same letter(s) are significantly different at $p < 0.05$.

* % effect of fertilized over non-fertilized; i.e. $[(P1 - P0)/P0] \times 100$.

Source: (Raja Barizan 1997)

Table 3.6.7 Effect of subplot category on the mean growth variables and dry weights of *Dryobalanops oblongifolia* at one and two years after planting irrespective of fertilizer level

Harvest	Plot category	No. of leaves	Height (cm)	Diameter (mm)	Dry weight (g)		
					Leaf	Stem	Root
1 year	A	46a	67.6ab	8.25a	8.30a	10.18a	4.12a
	B	50a	72.4a	7.90a	9.47a	11.84a	5.04a
	C	31b	56.8b	5.96b	3.97b	4.60b	2.11b
	D	12c	43.7bc	4.93bc	1.06c	2.10b	1.39bc
	E	13c	43.6bc	4.94bc	1.16c	2.15b	0.97c
2 years	A	117a	113.2a	14.51a	30.79ab	36.45b	13.94a
	B	106a	111.1a	12.40a	36.71a	66.13a	16.82a
	C	48b	70.1b	7.57b	13.40bc	16.20bc	5.95b
	D	18b	42.6c	5.02b	1.90bc	3.22c	2.53b
	E	21b	43.1c	5.28b	1.94c	2.30c	1.25b

Means not sharing the same letter(s) are significantly different at $p < 0.05$
Source: (Raja Barizan 1997)

Table 3.6.8 Effect of fertilization (regardless of subplot category) on the mean growth variables and dry weights of *Dryobalanops oblongifolia* at one and two years after planting

Harvest	Fertilizer level	No. of leaves	Height (cm)	Diameter (mm)	Dry weight (g)		
					Leaf	Stem	Root
1 year	P0	29b	56.2b	6.64a	4.38b	5.77b	2.85a
	P1	41a	64.6a	6.91a	7.30a	8.87a	3.41a
	Mean	35	60.4	6.78	5.84	7.32	3.13
2 years	P0	60b	74.7b	9.6a	15.5a	22.7a	7.3a
	P1	93a	100.0a	10.8a	28.8a	42.8a	13.1a
	Mean	77	87.4	10.2	22.2	32.8	10.2
% effect of fertilizer		120	45	50	280	348	226

Means not sharing the same letter(s) are significantly different at $p < 0.05$
Source: (Raja Barizan 1997)

Response of seedling growth to light and soil

Categories of the subplots strongly affected the growth variables and the dry weights of seedlings for both species one year after planting. The open (A and B) and partial shade (C) categories had significantly improved growth of seedlings of both species compared with the closed categories (D and E). Seedlings grown in the open categories had better growth and more leaves than those in the partial shade and closed categories; however, the leaves were yellowish in colour. All growth parameters and total dry weights of the seedlings, regardless of the size

classes and fertilizer levels, increased with increase of light intensity in the plot. Compared with the seedlings grown in the open categories, seedlings grown in the partial shade condition had large dark green and thin leaves but when the seedlings were grown in the closed categories, with extremely low light intensities, the leaves became smaller and retained their dark green colour. Nicholson (1960) has also reported on the effect of light requirements of dipterocarp species.

The seedlings grown in the open categories (A and B) developed better root systems. For the first year of planting the roots grew within the planting hole but after one year the roots started penetrating beyond for water and mineral nutrients. Seedlings grown in the closed categories were relatively smaller in size, with a few small dark green leaves, and they also developed poor root systems. The seedlings were also unhardened and therefore were prone to pest attack, e.g. wild boars, squirrels and termites. Ashton and De Zoysa (1989) suggested that height of seedlings of the same age can be used to characterize the size of seedlings. Larger individuals show better and faster growth than smaller ones. This was also observed in this study: initially larger seedlings of *H. odorata* seedlings gave far better growth than the smaller ones. Leaves of seedlings were retained longer in the partially shaded condition. The size of seedlings had greater impact on the growth of the seedlings, thus larger seedlings had better growth in all subplot categories than the smaller ones.

Soils in categories A, B and C were relatively compacted with higher bulk density and this reduced the number of large pores of soil. However, differences in soil compaction had little effect on the growth of seedlings of either species. The same results were also reported in other studies elsewhere (Wan Razali & Ang 1991, Ang *et al.* 1992, Nussbaum 1995, Nussbaum *et al.* 1995). The degree of compaction in this study ($0.89\text{--}1.13\text{ g cm}^{-3}$), however, was lower than the degree of compaction reported in other studies: $1.22\text{--}1.52\text{ g cm}^{-3}$, two years after logging (Kamaruzaman 1988) and $1.00\text{--}1.34\text{ g cm}^{-3}$, 18 months after logging (Nussbaum 1995, Nussbaum *et al.* 1995). However, this soil parameter does not necessarily affect uptake of mineral nutrients and their uptake might even be increased with compaction (Talha *et al.* 1979, Marschner 1995). The increment of mineral nutrients uptake is partly due to the increase in the buffer power for nutrients at higher bulk densities (Silberbush *et al.* 1983). Despite the relatively high bulk density and also poor fertility in categories A, B and C (Tables 3.6.1 and 3.6.2) in the study plot, they did not appear to significantly affect the early growth of the seedlings up to two years. This was probably because the roots of the seedlings were largely confined within the looser nursery (potting) soil in the planting hole at the early stage and the mineral nutrients were mainly supplied by the nursery soil.

Although both species (*H. odorata* and *D. oblongifolia*) were not found naturally growing in the plot, results from this study showed that they established well in the open categories regardless of soil fertility and soil compaction. No further analysis was done to test the effect of soil compaction in the different categories: open (A and B), partial shade (C), and closed canopy (D and E). The reason for this was because the light factor was a primary limiting factor, it might confound the effect of soil compaction on the growth of seedlings.

Effect of phosphorus fertilizer on total dry weight

Fertilizing *H. odorata* (144 mg P per plant) and *D. oblongifolia* (175 mg P per plant) at the nursery stage improved the growth of seedlings in all planting categories (Raja Barizan 1996, 1997). Fertilizer studies on dipterocarp species in logged forest were also been carried out by others (Sundralingam 1983, Wan Razali & Ang 1991, Ang *et al.* 1992, Turner *et al.* 1993, Nussbaum 1995, Nussbaum *et al.* 1995). In these studies, fertilizer was applied in the field and produced different results. Application of fertilizer on *Shorea curtisii* in small canopy openings (10 g N and 5 g P) and on *H. beccariana* under a closed canopy (10 g of NPK) showed no significant improvement in height and stem diameter growth (Turner *et al.* 1993). The absence of a clear response to fertilizer application by Ang *et al.* (1992) and by Turner *et al.* (1993) was probably due to the low rates of fertilizer addition, whereby the amounts applied did not exceed losses due to leaching, denitrification and immobilization. It was concluded that the available nutrients did not meet the plant requirements (Nussbaum 1995, Nussbaum *et al.* 1995). The absence of a clear response in growth was probably also due to the low light levels whereby the seedlings were unable to respond to the added nutrients. It is thus thought that fertilizing seedlings under closed canopy will not be of significant benefit to the growth of dipterocarp seedlings. However, results from the study conducted by Raja Barizan (1997) in Berkelah FR showed that application of TSP in the nursery and planted in the closed categories (D and E) significantly increased by 2 - 2.6 folds the dry weight of stems and roots of *H. odorata* after one year, and 2 - 3 folds after two years. Although fertilizing *D. oblongifolia* reduced the dry weight of stems and roots 1 - 2 folds at one year, it did significantly increase 1.5 - 2 folds the dry weight of stems and roots at two years. Fertilizing planted dipterocarp species in the logged forest improved the growth of the seedlings but this will increase the cost of planting. The amount of fertilizer applied may not be fully beneficial to the seedlings due to a proportion that might be lost through adsorption and leaching. The results from this study showed that fertilizing the seedlings in the nursery with 0.33– 0.40 g of TSP per pot (144–175 mg P) monthly up to five times gave an early promising growth up to two years in the field.

Plot establishment costing

Direct costs involved in establishing the plot in this study per hectare are comparable with the standard costs involved in enrichment planting in natural forest. The costs for establishing the plot are as shown in Table 3.6.9.

Table 3.6.9 Costs involved in enrichment planting using dipterocarp species in logged hill forest of Berkelah FR, Pahang, in 1992

Item	Cost per ha (RM)
1. Planting stocks (RM 2.20/plant; 865 plants)	1903
2. Fertilizer cost, TSP (fertilization only carried out in the nursery and no application in the field)	200
3. Transportation cost (from nursery to the planting site and within the planting site)	865
4. Ground preparation	
• Open and compacted (categories A & B conditions)	100
• Partially shaded (category C condition)	200
• Shaded (categories D & E conditions)	-
5. Planting (RM1.00/plant; 865 plants)	865
6. Maintenance (canopy opening and ground weeding)	
• Open and compacted (categories A & B conditions)	200
• Partially shaded (category C condition)	300
• Shaded (categories D & E conditions)	-
Total	4633

Conclusion and recommendations

Based on the study in Berkelah FR the following conclusion and recommendations could be made :

1. Both species showed better survival in the open and under partial shade conditions than in the closed conditions regardless of the application of fertilizer in the nursery and size of seedlings used.
2. The fertilized and non-fertilized seedlings planted in the open conditions (categories A & B) developed better root systems. This shows that light plays an important role in promoting root growth that will subsequently influence the survival of seedlings in the field. However, fertilized and non-fertilized seedlings under closed conditions (categories D & E) showed no significant results in the survival of seedlings.
3. The initial size of seedlings planted in the field had great impact on survival, diameter and height increments; thus it is recommended that larger seedlings should be used for planting in open degraded areas.
4. It is important to know the optimum amounts of fertilizer to be applied for different species and for different sizes and ages of the seedlings for better response to application. This study showed that the correct fertilizer and amounts to be applied in the nursery are crucial for inducing better height and diameter growth at least for a duration of two years after planting.

