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報 文

マレーシア国サラワクにおける熱帯雨林生態系の回復*

――マレーシア農科大学および横浜国立大学の4年間の共同科学研究成果――

The Rehabilitation of the Tropical Rainforest Ecosystems in Sarawak, Malaysia — Four-year Results of a Scientific Study by Universiti Pertanian Malaysia and Yokohama National University Japan* —

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Synopsis

A study was conducted on the application of the Miyawaki forest rehabilitation technique toward creating a stand of native Malaysian primary forest trees (Dipterocarps and Non Dipterocarps) in degraded sites on the Universiti Pertanian Malaysia, Bintulu campus in Sarawak. This project was sponsored by the Mitsubishi Corporation, Japan. This report is a complete description of a four-year project for rehabilitation of tropical rainforest in Sarawak, Malaysia. From the results, planting of indigenous species in open areas especially abandoned shifting-cultivation areas, can be very successful. Species recommended for planting in open areas are *Dryobalanops aromatica, Shorea leprosula, S. macrophylla, S. ovata, Hopea kerangasensis, Whiteodendron moultianum, Vatica nitens and Pentaspodon motleyi.*

Species of *Eugenia* sp. and *Calophyllum ferrugenium* are not recommended because of their slow growth. *Shorea mecistopteryx* can grow well in open areas but needs a site where a strong wind does not occur. *Shorea mecistopteryx* has a big leaves which are easily blow off in strong wind, and if this happens, the seedlings can die easily.

Shorea mecistopteryx can be found in Mixed Dipterocarp Forest on gently undulating low hills throughout Sarawak. For planting of indigenous species under shade or under trees, the species recommended are *Shorea ovata, S. macrophylla, S. mecistopteryx, S. leprosula, S. gibbosa, Hopea kerangasensis, H. beccariana, Dryobalanops aromatica, D. beccarii, Pentaspodon motleyi, Eusideroxylon zwageri, Durio zybethinus* and *Garcinia* sp. This paper also describes several problems which have been encounted.

1. Introduction

Rehabilitation of forests with indigenous main tree species, especially potential natural vegetation has recently become an important aspect of forest conservation (Miyawaki, 1992; Miyawaki et al., 1980 -1990). Rehabilitation is a man-facilitated recovery process according to natural regeneration and succession (Lim, 1992).

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The concern over depletion of the tropical rain forests has resulted an increasing emphasis towards the programs of rehabilitation in an effort to maintain the ecological balance within the ecosystem. In Malaysia, the loss of the natural tropical forest is due to harvesting for its timbers and conversion into lands for the purpose of agriculture, mining, industries and urban development.

A joint research project entitled "Rehabilitation of Tropical Rainforest Ecosystems" was initiated and implemented by Universiti Pertanian Malaysia (University of Agricultural, Malaysia) and Yokohama National University. The purpose of the project is to conduct experimental planting of indigenous tree species on degraded sites as abandoned shifting-cultivation areas, secondary forests, degraded industrial and urban lands. The project was funded by Mitsubishi Corporation of Japan through its subsidiary company, Daiya Malaysia Sdn. Bhd. A sum of five million Malaysian ringgit has been allocated for a four-year period. A 50 hectare research site has been set aside for the joint project.

The first meeting on the project was held in Bintulu on May 2, 1990 between officials of Universiti Pertanian Malaysia, Yokohama National University and Mitsubishi Corporation. The agreement between Universiti Pertanian Malaysia and Yokohama National University was signed on December 27, 1990. Associate Professor Dr. Khalid Mohd Noor, Deputy Vice Chancellor (Development), signed on behalf of Universiti Pertanian Malaysia. Professor Dr. Akira Miyawaki, Director Institute of Environmental Science and Technology, signed on behalf of Yokohama National University in 1990.

An international symposium on "Rehabilitation of Tropical Rainforest Ecosystems: Research and Development Priorities" in Kuching, Sarawak was held from September 2 - 7 1992. This symposium was jointly organized by Universiti Pertanian Malaysia, Yokohama National University and Ministry of Resource Planning, Sarawak with 204 participants from ten countries.

Afterward,this project is continued by joint project between Universiti Pertanian Malaysia (UPM), Universiti Malaysia Sarawak (UNIMAS) and Japanese Center for International Studies in Ecology (JISE).

2. Objectives

The objectives of study include: 1) to restore disturbed tropical rain forest areas with native main tree species. 2) to rehabilitate and improve the natural forests environmental condition within those areas. 3) to rebuild the natural at least quasi natural forest landscape of those areas. 4) to understand the nature, tree - environmental relationships of those native species and to make clear which kind of species should be planted for rehabilitation of tropical rainforests.

3. Study area

The campus of Universiti Pertanian Malaysia, Bintulu branch is located in Bintulu Division, in the state of Sarawak about 600km north - east of Kuching, latitude 3° 12' N, longitude 113° 05'E. 2993. 9mm of annual rainfall for 1990 and 3221.7mm for 1991 in Bintulu, are rather lower than 3643.4 mm from 1980 to 1992 for annual rainfall. The rainy season occurs in the months of November, December and January during "Landas Season" of north-east monsoon. In 1990-1991 there was a prominent drought from May until August. The mean daily temperature recorded is 26.7℃ and relatively consistent throughout the year. The mean monthly relative humidity of the area is usually above 80% and slightly lower during the rainy seasons. The study is conducted on a 47.5ha. area within the campus premise, set aside for the purpose of this research. Peli , et. al. (1984) describes the soil of University of Agriculture Malaysia, Bintulu branch as belonging to Nyalau and Bekenu series, which is

well drained. The Nyalau series is characterized by coarse loam, light yellowish brown top soil of 9cm deep; with a brownish yellow subsoil. The Bekenu series is characterized by mix fine loam, light yellowish brown top soil of 4-15cm deep and brownish yellow subsoil.

The project conducted at four phases:

Phase	*Year*	*Area*
1	1990-1991	3.4ha
2	1991-1992	3.7ha
3	1992-1993	7.0ha
4	1993-1994	33.4ha

4. Production of planting stocks

Planting stocks were obtained from two sources, i.e. germinated seeds or collection of seedlings from the forest floor. Seed and seedlings were mainly collected from forest areas around Bintulu. Some seeds were purchased from the fringe of the primary forest. Purchased seeds were for the species *Shorea* spp., *Dipterocarpus* spp., *Dryobalanops* spp., and *Eusideroxylon zwageri*.

Two problems encountered are the irregular fruiting of dipterocarp tree species and increasingly disturbed forests. Fresh seeds could be collected during the fruiting season. The fruiting period of Dipterocarpaceae, however, is irregular and has no definite seasons. In addition, accessibility to tree seed source is becoming more difficult since most lowland forested land have been harvested or converted into agricultural plantation and other land development. Most undisturbed forests are located very far and difficult to reach. Therefore, the selection of Dipterocarpaceae species for research is indeed limited.

5. Germination of seeds

Huge fruiting of Dipterocarpaceae in 1990 and 1991 in Similajau Forest Reserve made the collection of seeds easier. From the fruiting season, seeds from 10 families of indigenous tree species were collected. Seeds-species consist of 14 species from Dipterocarpaceae family, 3 species from Anacardiaceae, 2 species Bombacaceae, and one species from Euphorbiaceae, Guttiferae, Lauraceae, Leguminaceae, Moraceae, Myrtaceae and Sterculiaceae. The highest number of seeds collection was from *Shorea ovata* with 61,669 following by *Shorea* sp. with 60,655. *Dryobalanops aromatica* was collected twice from different mother tree. The first collection of 13,000 seeds resulted in 0 % germination rate. This phenomenon is caused by inmatured seeds. In the second collection, 312 seeds gave 79.10% of germination rate. The highest germination rate was got from *Pentaspodon motleyi* with 98.67%. Total collection of seeds were 198,973 (Table 1).

After collection of the seeds from the forest, they were sown in the nursery. Sawdust was used for the sowing bed. Its capability for storing moisture is good for seeds and it gives good aeration for seeds for the germination period.

Young seedlings germinated in nursery were transfer into polythene bags or vinyl pots after the seedlings produced two or three young leaves. The seedlings were kept under 100% shade for two to four weeks before being exposed to 60% shade under netting. They will be kept under 60% shade for one to three months and then exposed to 40% shade for another one to three months before planting.

The other method of raising seedlings was by means of wilding collection using two different techniques. The first technique of wilding collection involved digging out seedlings with forest soil intact and then transferring the dug-out plants into pots. Seedlings were then kept under natural conditions for 3 weeks to 1 month. Later, these seedlings were transported to the nursery. Before planting the potted wildings will undergo further conditioning for one month to three months. The second method involved digging out the wildings (without adhering soil) and immediately transporting

them to the nursery. In order to minimize damage to the roots and dehydration, the seedlings were kept in plastic containers containing wet sawdust. At the nursery the seedlings were transplanted into pots. These pots were then kept in the shade for about 3 months and another month in the conditioning area. The numbers of potted wildings from natural forest area are shown in Table 2.

6. Selection of potential natural species of vegetation.

The climax species and/or present tree species in the area prior to disturbance were identified from vegetation sampling of the surrounding forest around Bintulu campus (Bojo. et al., 1990). It is important to choose species native to the site. The present specimens should be well adapted and suited to the local microclimate. Table 3 shows a list of indigenous species planted at the planting site for the project.

Table 1. The germination percentage from the sowing experiment.

	Species	Family	Sown	Germinated	% germination *
1	*Pentaspodon motleyi*	Anacardiaceae	1, 280	1, 263	98. 67
2	*Dracontomelon dao*	Anacardiaceae	100	53	53. 00
3	*Mangifera* sp.	Anacardiaceae	126	89	70. 63
4	*Durio zybethinus*	Bombacaceae	1, 198	827	69. 03
5	*Durio carinatus*	Bombacaceae	1, 386	1, 116	80. 52
6	*Shorea mecistopteryx*	Dipterocarpaceae	33, 158	19, 939	60. 93
7	*Shorea leprosula*	Dipterocarpaceae	370	170	45. 95
8	*Shorea macrophylla*	Dipterocarpaceae	672	659	96. 69
9	*Shorea materialis*	Dipterocarpaceae	54	27	50. 00
10	*Shorea gibbosa*	Dipterocarpaceae	1, 225	682	55. 70
11	*Shorea ovata*	Dipterocarpaceae	61, 669	41, 029	66. 53
12	*Shorea pauciflora*	Dipterocarpaceae	489	298	60. 94
13	*Shorea* sp.	Dipterocarpaceae	60, 655	30, 115	49. 60
14	*Hopea kerangasensis*	Dipterocarpaceae	49	25	51. 00
15	*Dryobalanops beccarii* *	Dipterocarpaceae	13, 000	-	0. 00
16	*Dryobalanops beccarii*	Dipterocarpaceae	312	181	79. 10
17	*Dryobalanops aromatica*	Dipterocarpaceae	452	386	85. 39
18	*Dipterocarpus lowii*	Dipterocarpaceae	75	48	64. 00
19	*Dipterocarpus crinitus*	Dipterocarpaceae	1, 560	1, 263	80. 96
20	*Vatica nitens*	Dipterocarpaceae	182	98	83. 85
21	*Elasteriospermum tapos*	Euphorbiaceae	43	8	18. 60
22	*Calophyllum ferrugineum*	Guttiferae	9, 494	6, 268	66. 15
23	*Eusideroxylon zwagerii*	Lauraceae	1, 071	473	44. 16
24	*Dialium* sp.	Leguminosae	1, 657	1, 489	89. 86
25	*Artocarpus rigidus*	Moraceae	92	71	77. 17
26	*Eugenia* sp.	Myrtaceae	7, 308	4, 960	66. 50
27	*Scaphium* sp.	Sterculiaceae	1, 296	896	68. 50

Note: * inmatured seed
no mark: matured seeds

Table 2. Number of wilding of indigenous tree species collected.

	Species	Family	Number of wilding collection
1	*Mangifera* sp.	Anacardiaceae	196
2	*Durio carinatus*	Bombacaceae	3, 867
3	*Santiria* sp.	Burseraceae	167
4	*Casuarina sumatrana*	Casuarinaceae	167
5	*Shorea beccariana*	Dipterocarpaceae	227
6	*Shorea maxwelliana*	Dipterocarpaceae	3, 643
7	*Shorea ovata*	Dipterocarpaceae	41, 941
8	*Shorea* sp.	Dipterocarpaceae	19, 641
9	*Shorea andulensis*	Dipterocarpaceae	156
10	*Shorea leprosula*	Dipterocarpaceae	965
11	*Shorea gibbosa*	Dipterocarpaceae	297
12	*Dryobalanops beccarii*	Dipterocarpaceae	2, 195
13	*Dryobalanops aromatica*	Dipterocarpaceae	498
14	*Hopea kerangasensis*	Dipterocarpaceae	4, 844
15	*Hopea beccariana*	Dipterocarpaceae	695
16	*Hopea* sp.	Dipterocarpaceae	237
17	*Vatica nitens*	Dipterocarpaceae	1, 345
18	*Upuna borneensis*	Dipterocarpaceae	161
19	*Parashorea parvifolia*	Dipterocarpaceae	782
20	*Dipterocarpus crinitus*	Dipterocarpaceae	239
21	*Dipterocarpus* sp.	Dipterocarpaceae	264
22	*Cotylelobium burckii*	Dipterocarpaceae	2, 673
23	*Shorea scabrida*	Dipterocarpaceae	259
24	*Shorea pauciflora*	Dipterocarpaceae	324
25	*Shorea rubella*	Dipterocarpaceae	354
26	*Vatica* sp.	Dipterocarpaceae	2, 134
27	*Shorea dasphylla*	Dipterocarpaceae	451
28	*Shorea beccariana*	Dipterocarpaceae	624
29	*Baccaurea lanceolata*	Euphorbiaceae	256
30	*Garcinia* sp.	Guttiferae	275
31	*Calophyllum ferrugineum*	Guttiferae	2, 655
32	*Litsea* sp.	Lauraceae	286
33	*Dialium* sp.	Leguminosae	157
34	*Koompasia malaccensis*	Leguminosae	297
35	*Ashtonia angustifolia*	Melastomataceae	284
36	*Parartocarpus* sp.	Moraceae	132
37	*Artocarpus rigidus*	Moraceae	346
38	*Whiteodendron moultonianum*	Myrtaceae	1, 645
39	*Eugenia* sp.	Myrtaceae	4, 634
40	*Xanthophyllum amoenum*	Polygalaceae	134
41	*Anisophyllea ferruginea*	Rhizophoraceae	429
42	*Palaquium* sp.	Sapotaceae	1, 472
43	*Scaphium* sp.	Sterculiaceae	606
44	*Other species*		6, 974

Table 3. List of indigenous species planted at the site for the project.

	Species	Family	Local name
1	*Dracontomelon dao*	Anacardiaceae	Sengkuang
2	*Pentaspadon motleyi*	Anacardiaceae	Pelajau
3	*Mangifera* sp.	Anacardiaceae	Asam
4	*Ashtonia angustifolia*	Apocynaceae	Pulai
5	*Durio carinatus*	Bombacaceae	Durian burung
6	*Durio zybethinus*	Bombacaceae	Durian
7	*Santiria* sp.	Bursareceae	Seladah
8	*Casuarina sumatrana*	Casuarinaceae	Rhu
9	*Shorea mecistopteryx*	Dipterocarpaceae	Meranti kawang burung
10	*Shorea maxwelliana*	Dipterocarpaceae	Kumus hitam
11	*Shorea materialis*	Dipterocarpaceae	Selangan batu pasir
12	*Shorea macrophylla*	Dipterocarpaceae	Engkabang jantung
13	*Shorea leprosula*	Dipterocarpaceae	Meranti tembaga
14	*Shorea ovata*	Dipterocarpaceae	Meranti pitis
15	*Shorea pauciflora*	Dipterocarpaceae	Nemesu
16	*Shorea beccariana*	Dipterocarpaceae	Meranti langgai
17	*Shorea rubella*	Dipterocarpaceae	Meranti laut putih
18	*Shorea dasphylla*	Dipterocarpaceae	Meranti batu
19	*Shorea gibbosa*	Dipterocarpaceae	Meranti lun gajah
20	*Shorea andulensis*	Dipterocarpaceae	Meranti daun putih
21	*Shorea scabrida*	Dipterocarpaceae	Meranti lop
22	*Dipterocarpus crinitus*	Dipterocarpaceae	Keruing mempelas
23	*Dipterocarpus lowii*	Dipterocarpaceae	Keruing sol
24	*Dryobalanops beccarii*	Dipterocarpaceae	Kapur bukit
25	*Dryobalanops aromatica*	Dipterocarpaceae	Kapur peringi
26	*Hopea beccariana*	Dipterocarpaceae	Chengal pasir
27	*Hopea kerangasensis*	Dipterocarpaceae	Luis kerangas
28	*Cotylelobium burckii*	Dipterocarpaceae	Resak Durian
29	*Vatica nitens*	Dipterocarpaceae	Resak daun panjang
30	*Vatica* sp.	Dipterocarpaceae	Resak
31	*Parashorea parvifolia*	Dipterocarpaceae	Urat mata
32	*Upuna borneensis*	Dipterocarpaceae	Upuna
33	*Elateriospermum tapos*	Euphorbiaceae	Kelampai\Perah
34	*Baccaurea lanceolata*	Euphorbiaceae	Empaong
35	*Calophyllum ferrugineum*	Guttiferae	Bintangor
36	*Garcinia* sp.	Guttiferae	Kandis
37	*Eusideroxylon zwageri*	Lauraceae	Belian
38	*Litsea* sp.	Lauraceae	Medang
39	*Dialium* sp.	Leguminosae	Keranji
40	*Koompasia malaccensis*	Leguminosae	Kempas
41	*Parartocarpus* sp.	Moraceae	Minggi
42	*Eugenia* sp.	Myrtaceae	Ubah
43	*Artocarpus rigidus*	Myrtaceae	Terap
44	*Whiteodendron moultianum*	Myrtaceae	Kawi
45	*Xanthophyllum amoenum*	Polygalaceae	Langir
46	*Palaquium* sp.	Sapotaceae	Nyatoh
47	*Scaphium* sp.	Sterculiaceae	Kembang semangkuk

7. Method of planting

Planting of seedlings has been done in four phases (47.5ha) from March 26,1991, until the end of the project in March, 1994. Different methods of planting were applied according to site conditions.

7.1. Phase one: degraded area after shifting cultivation

Two different methods of planting were adopted for this 3.4 ha site. Plantings in the open area were clustered using three seedlings per square meter. The main species in the open area (abandoned shifting-cultivation area) were *Ischaemum magnum, Scleria sumatrensis, Trema orientalis, Melastoma malabathricum, Digitaria ciliaris, Fimbristylis globulosa* and *Ageratum conyzoides*.

Groundwork at this area included: 1) cutting and removing of grass, 2) lattice construction, 3) plowing of soil and 4) mulching after plantation.

The main purpose of lattice construction is to minimize soil erosion and improve the slope condition of site. Mulching, in addition to shading the young plant, also cools the soil so as to reduce the rate of evapotranspiration and loss of water from the soil surface. The lattice was constructed systematically 2 meters or 4 meters apart, depending on the slope.

A different technique of site preparation was used for minimal slopes with more stable soil. This technique includes only the clearing of undergrowth and grass for every one-meter-wide strip. Between each pair of cleared strips, a half-meter-width buffer of grass and undergrowth is maintained to provide shading to young plants.

7.2. Phase two: under secondary forest

Two techniques of planting were used in the Phase two area. For open areas, the same planting method as in Phase one was applied. The total area using this technique was 7759 square meters. The number of planted seedlings is shown in Table 4.

The second technique involved planting under the shade of secondary forest where the main species were *Macaranga gigantea, Vitex pubescens, Blechnum* sp. , *Alpina* sp., *Ficus* sp. and *Cyperus* sp. Two planting densities were applied, as follow: 1) 3 meters between seedlings or 1 seedling per 9 square meters, 2) 1 meter between seedlings or 1 seedling per square meter.

7.3. Phase three: open area and under forest

Three planting techniques were used in the Phase three area.

a. Pot hole planting method.

One seedling per 9 square meters was planted at random on a gentle to less steep slope area. The area is a secondary forest with big trees from the families Dipterocarpaceae, Burseraceae, Euphorbiaceae, Leguminoseae, Rubiaceae and Fagaceae.

b. Line planting method.

Seedlings were planted with a distance of 1 meter between individual seedlings, under secondary forest. Total area for this method was 0.42 ha.

c. Planting on small mound.

A small mound measuring 5 meters wide by 30 to 40 meters long was constructed on 0.35 ha of the open area. Planting was done on this mound at a density of 3 - 5 seedlings per square meter.

7.4. Phase four: open area and under forest

Five planting methods were applied at in Phase four; a) Planting on the open area, b) Line planting with a distance 1 to 1.5 meter between individuals, c) Pot-hole planting, d) Enrichment planting under shade of secondary forest (low species density), e) Gap planting in the secondary forest.

At the nursery area, two experimental plots, of 5 meters by 50 meters and 10 meters by 100 meters were established to study the potential growth of indigenous species. Both plots were on a small mound 1 meter high. Planting of seedlings was done on the mound at a density of 3 seedlings per square meter.

Table 4. Number of planted seedlings.

Time frame	Phase			
	One	Two	Three	Four
March 1991 to January 1994	67, 565	17, 869	75, 209	3, 597
Survival rate	62%	80%	80%	95%
Seedlings surviving	41, 890	14, 295	60, 167	3, 417
Replanted	26, 132	2, 895	6, 673	0
Total number of seedlings alive until April 1994	68, 022	17, 190	6, 673	3, 417
Total seedlings alive on sites	155, 469			
Total planted including replanted	199, 940			
Percentage of survival	77. 75%			

8. Results

8. 1. Planted at open area in Phase one

The plot growth was measured was 10 meters by 10 meters. The soil was improved before planting of seedlings in March 1991. Soil improvement included ploughing to 1 meter depth, lattice construction and mulching after plantation.

a. Number of planted seedlings and survival mortality rate.

14 indigenous species were chosen for Phase one, and the total number of seedlings planted was 450. Of these 14 species, *Eugenia* sp. shows the highest mortality rate with 94%, followed by *Shorea* sp. with 92%. *Dryobalanops aromatica* had the lowest mortality rate with 29% (Table 5).

b. Height increment of planted seedlings.

There was a significant difference in the height growth of the 14 species. *Dryobalanops aromatica* showed the greatest increment with 286.24 cm in 26 months, followed far behind by *Hopea kerangasensis* with 260.45cm. At the other extreme was *Eugenia* sp. with only 80.02cm increment. All *Shorea* sp. showed a height growth above 160cm (Table 6, Figure 1 and Figure 2)

c. Diameter increment of planted seedlings.

Table 7 shows the mean total diameter increment of different species. *Whiteodendron moultonianum* exhibited the fastest growth in diameter with 4.88 cm and left other species far behind. The nearest challenger was *Dryobalanops aromatica* with 3.63cm. Meanwhile, *Eugenia* sp. had the slowest growth with only 0.89cm. All *Shorea* spp. showed a diameter growth above 2.20cm (Figure 3 and Figure 4).

8. 2. Planted on flat area in the secondary forest in Phase two.

The size of the plot was 36 meters by 36 meters. The area was flat and near a small stream, under shade of secondary forest. *Macaranga gigantea* was the main pioneer species at this site. Distance between species was 3 meters.

a. Number of planted seedlings and survival mortality rate.

Only 4 species were chosen for planting under secondary forest due to their shade tolerance. A total of 119 seedlings were planted. *Pentaspodon motleyi* had the highest number of seedlings planted. *Eusideroxylon zwageri* and *Shorea macrophylla* both showed 4% mortality

rate 21 months after planting. *Pentaspodon motleyi* had the highest mortality rate with 16 % (Table 8).

b. Height increment of planted seedlings.

Table 9 shows the height increment of seedlings planted in a 36 meters x 36 meters plot at Phase two. *Pentaspodon motleyi* had the largest height increment with 262.16cm, followed by *Shorea mecistopteryx* with 164.41cm. *Eusideroxylon zwageri* had the lowest height increment with 108.65cm (Figure 5).

c. Diameter increment of planted seedlings.

Pentaspodon motleyi had the larger diameter increment at 2.36cm far ahead of other species. *Shorea mecistopteryx* was second highest with 1.63cm. *Eusideroxylon zwageri* had the lowest diameter increment with only 1.32cm (Table 10 and Figure 6).

8. 3. Planted on slope area in the secondary forest in the Phase two.

The plot was located under secondary forest at a slope area. Ten years before it was a shifting cultivation area. The main pioneer species were *Macaranga gigantea, Melastoma* sp. etc. Before planting was done at this site, undergrowth was limited to pioneer species less than 3 meter high. Dipterocarpaceae species were left to grow.

a. Number of planted seedlings and survival mortality rate.

Ten species were chosen for this plot. *Shorea leprosula* had the highest number of planted seedlings with 61, followed by *Shorea mecistopteryx* with 50 seedlings. Only 1 seedling of *Calophyllum ferrugineum* was included in this plot.

Calophyllum ferrugineum and *Cotylelobium burckii* both had the highest mortality rate with 100%. *Shorea* sp. responsed well with a low mortality rate. *Shorea mecistopteryx* only had 9% mortality rate, followed by *Shorea macrophylla* with 17% (Table 11).

b. Height increment of planted seedlings.

Shorea ovata had the highest increments with 212.39cm, followed by *Shorea mecistopteryx* with 190.52cm. *Eugenia* sp. had 47.10cm in height increment. Generally, all species except *Eugenia* sp. had height increment above 100cm (Table 12, Figure 7 and Figure 8).

c. Diameter increment of planted seedlings.

Table 13 shows the diameter increments of 10 species planted in this plot. *Shorea mecistopteryx* had the highest diameter increment with 2.627 cmc followed by *Shorea leprosula* with 2.560cm. *Eugenia* sp. had the lowest diameter increment with 0.593cm (Figure 9 and Figure 10).

8. 4. Planted in line in Phase two.

Seedlings were planted under secondary forest, in a line with a distance 1 meter between seedlings. The method of site preparation included clearance of undergrowth in a radius of only 1 meter around the seedlings. The site was on a steep slope with rotten logs. *Macaranga gigantea* occurs together with *Ischaemum magnum, Trema orientalis, Melastoma malabathricum* and *Digitaria ciliaris*.

a. Number of planted seedlings and survival mortality rate.

Shorea mecistopteryx and *Shorea leprosula* had the most planted seedlings, both with 75 seedlings followed by *Durio zybethinus* (70 seedlings) and *Calophyllum ferrugineum* (67 seedlings). Total planted seedlings in this plot numbered 524 seedlings.

The highest mortality rate was for *Calophyllum ferrugineum* with 60%, followed by *Vatica nitens* with 53%. *Garcinia* sp., *Whiteodendron moultonianum, Dipterocarpus crinitus* and *Palaquium* sp. had 0% mortality after 15 months. *Shorea leprosula* only had 7% mortality compared with *Shorea mecistopteryx* and *Shorea ovata,* both with 12% mortality. Meanwhile, *Eusideroxylon zwageri* had 11% mortality (Table 14).

Table 5. Number of planted seedlings and Mortality Rate for Plot A in Phase One.

Species	Number of planted	3 month old		6 month old		9 month old		12 month old		15 month old		18 month old		21 month old		24 month old		27 month old	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Calophyllum ferrugineum	17	0	0	5	29	8	47	11	65	14	82	14	82	14	82	15	88	15	88
Durio carinatus	54	0	0	27	50	31	57	43	80	44	81	45	83	49	91	49	91	49	91
Whiteodendron moultonianum	16	0	0	2	13	2	13	4	25	4	25	4	25	6	38	6	38	6	38
Eugenia sp.	50	0	0	14	28	21	42	41	82	41	82	45	90	47	94	48	96	47	94
Cotylelobium burckii	11	0	0	6	55	7	64	8	73	8	73	8	73	8	73	9	82	9	82
Hopea kerangasensis	7	0	0	0	0	1	14	2	29	3	43	3	43	3	43	3	43	3	43
Parashorea parvifolia	48	0	0	34	71	34	71	39	81	39	81	41	85	41	85	41	85	41	85
Dryobalanops aromatica	38	0	0	2	5	4	11	11	29	11	29	11	29	11	29	11	29	11	29
Hopea beccariana	9	0	0	1	14	2	29	2	43	3	43	3	43	3	43	3	43	3	43
Shorea sp.	13	0	0	3	23	6	46	8	62	9	69	9	69	10	77	12	92	12	92
Shorea mecistopteryx	55	0	0	19	35	23	42	39	71	43	78	44	80	45	82	48	87	48	87
Shorea ovata	29	0	0	17	59	17	59	17	59	17	59	17	59	17	59	17	59	17	59
Shorea leprosula	82	0	0	25	30	25	30	25	30	25	30	35	43	35	43	35	43	35	43
Shorea metarialis	32	0	0	5	16	5	16	12	38	12	38	12	38	12	38	12	38	12	38

Table 6. Height Increment for Plot A in Phase One.

Species	Nov. 91	Dec. 91	Feb. 92	Mar. 92	Jun. 92	Aug. 92	Oct. 92	Dec. 92	Feb. 93	Apr. 93	Jun. 93	Aug. 93	Oct. 93	Dec. 93	Feb. 94
Calophyllum ferrugineum	19.17	19.22	20.72	20.97	27.44	36.64	46.47	47.80	52.17	60.67	63.33	93.00	107.50	146.50	168.00
Durio carinatus	22.02	26.33	33.59	36.30	43.93	56.17	56.96	60.20	63.61	65.20	69.20	80.55	86.00	86.44	96.92
Whiteodendron moultonianum	26.55	28.85	35.34	40.66	59.01	67.27	77.32	92.05	108.67	122.81	137.23	154.73	164.50	167.71	200.17
Eugenia sp.	15.20	17.18	19.49	19.87	24.96	38.72	43.53	44.78	50.35	52.60	52.66	69.20	74.19	77.10	80.02
Cotylelobium burckii	29.25	32.47	36.46	38.55	46.63	57.11	61.57	70.61	79.62	91.95	106.99	116.06	149.34	180.31	196.25
Hopea kerangasensis	44.51	49.01	50.35	57.15	74.59	99.24	121.79	147.07	148.33	156.45	167.85	182.56	194.56	200.50	260.45
Parashorea parvifolia	16.50	20.60	22.59	24.38	30.03	39.44	40.70	54.64	61.92	73.58	88.79	118.83	130.71	171.36	183.64
Dryobalanops aromatica	53.08	55.53	63.80	69.41	95.82	109.33	129.29	153.54	174.54	186.57	205.12	264.50	267.71	273.73	286.24
Hopea beccariana	27.04	33.34	36.18	37.29	44.87	55.14	59.29	70.34	81.56	91.85	111.54	119.00	149.36	176.16	195.53
Shorea sp.	24.10	31.28	35.12	38.41	44.19	65.64	85.34	89.56	100.57	108.47	119.05	138.60	144.20	172.65	223.14
Shorea mecistopteryx	35.50	36.38	37.01	39.00	42.05	58.16	60.34	70.86	82.73	94.21	100.67	131.14	132.15	150.74	162.08
Shorea ovata	29.40	30.01	33.08	34.29	35.80	56.18	65.56	79.35	90.36	122.81	131.14	150.74	162.08	166.32	172.04
Shorea leprosula	28.46	32.65	37.34	39.72	47.17	60.06	71.72	77.05	90.61	102.78	116.75	136.50	160.87	184.24	204.71
Shorea metarialis	40.67	46.09	46.63	48.67	55.40	69.36	73.82	83.03	89.07	97.90	110.25	133.09	146.48	174.90	184.37

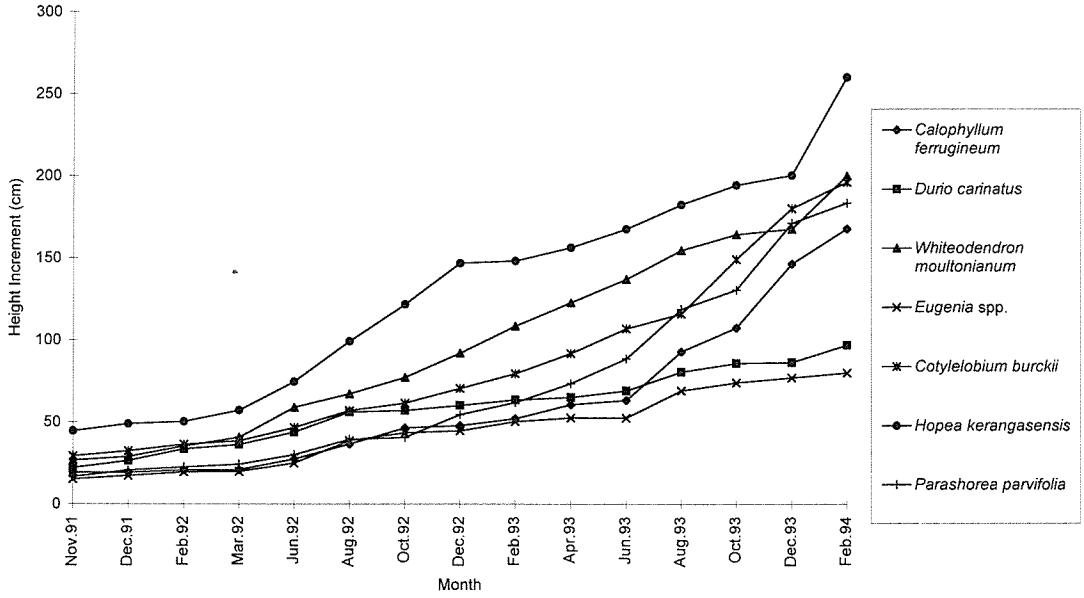

Figure 1. Height Increment for Plot A in Phase One.

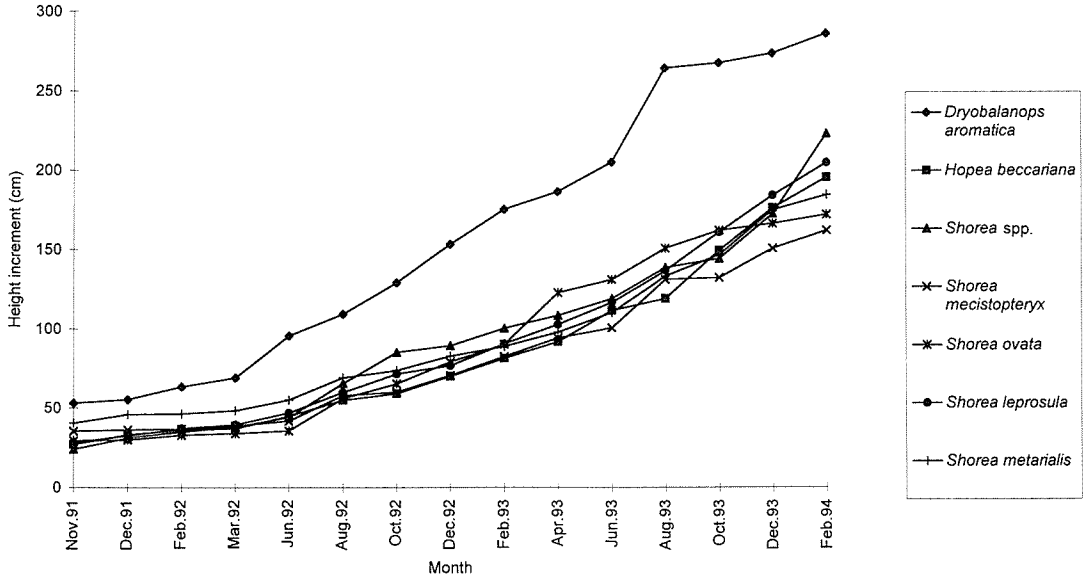

Figure 2. Height Increment for Plot A in Phase One.

Table 7. Diameter Increment for Plot A in Phase One.

Species	Nov. 91	Dec. 91	Feb. 92	Mar. 92	Jun. 92	Aug. 92	Oct. 92	Dec. 92	Feb. 93	Apr. 93	Jun. 93	Aug. 93	Oct. 93	Dec. 93	Feb. 94
Calophyllum ferrugineum	0.33	0.34	0.35	0.36	0.37	0.55	0.71	0.79	0.99	1.03	1.05	1.34	1.47	1.63	1.92
Durio carinatus	0.16	0.27	0.32	0.39	0.43	0.54	0.55	0.80	0.86	0.87	1.04	1.12	1.13	1.17	1.18
Whiteodendron moultonianum	0.46	0.53	0.64	0.67	0.96	1.27	1.67	1.92	2.19	2.32	2.68	2.95	3.47	4.13	4.88
Eugenia sp.	0.14	0.15	0.22	0.23	0.25	0.56	0.66	0.68	0.79	0.80	0.80	0.81	0.83	0.86	0.89
Cotylelobium burckii	0.25	0.25	0.38	0.42	0.51	0.78	0.87	0.98	1.04	1.15	1.29	1.57	1.63	1.96	1.99
Hopea kerangasensis	0.25	0.26	0.31	0.32	0.33	0.84	0.88	1.24	1.40	1.48	1.56	1.62	1.76	2.07	2.65
Parashorea parvifolia	0.12	0.26	0.32	0.39	0.39	0.67	0.90	1.02	1.20	1.52	1.62	1.80	2.02	2.32	2.55
Dryobalanops aromatica	0.78	0.85	0.90	0.90	1.03	1.53	1.95	2.26	2.40	2.55	2.70	2.91	3.35	3.55	3.63
Hopea beccariana	0.40	0.44	0.45	0.45	0.53	0.70	0.79	0.99	0.99	1.14	1.29	1.54	1.77	1.79	2.03
Shorea sp.	0.25	0.27	0.28	0.30	0.35	0.54	0.82	0.87	0.99	1.05	1.06	1.53	1.72	2.18	2.24
Shorea mecistopteryx	0.46	0.53	0.62	0.63	0.64	0.92	1.06	1.08	1.18	1.54	1.65	1.81	2.12	2.20	2.27
Shorea ovata	0.16	0.23	0.30	0.30	0.33	0.73	0.91	1.42	1.58	1.64	1.98	2.07	2.09	2.12	2.15
Shorea leprosula	0.17	0.29	0.41	0.42	0.52	0.80	0.89	1.07	1.22	1.46	1.55	2.42	2.47	3.01	3.58
Shorea metarialis	0.34	0.39	0.47	0.59	0.72	0.96	1.00	1.41	1.58	1.63	1.95	2.05	2.24	2.42	2.69

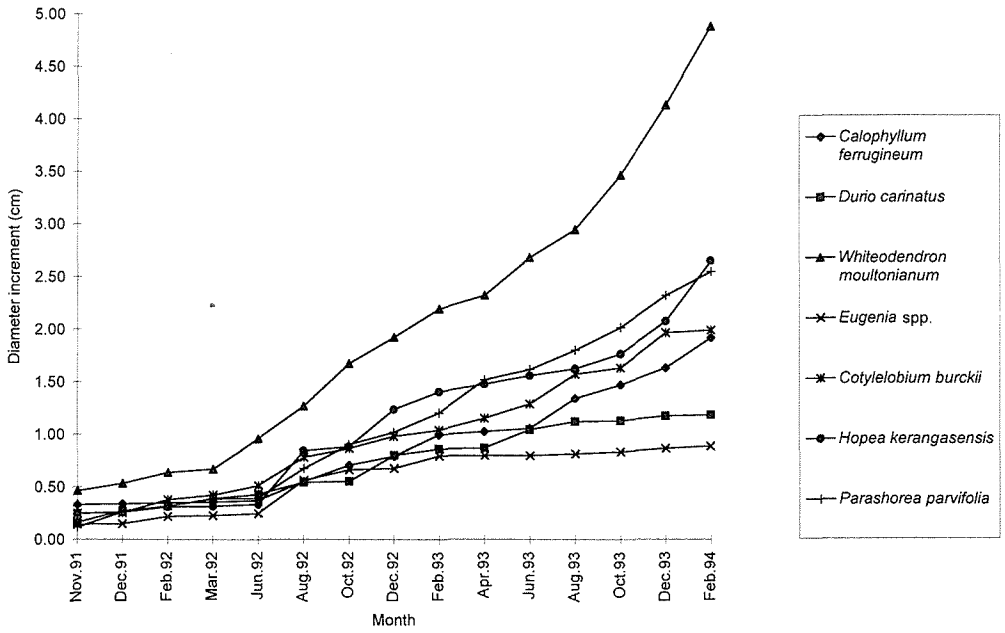

Figure 3. Diameter Increment for Plot A in Phase One.

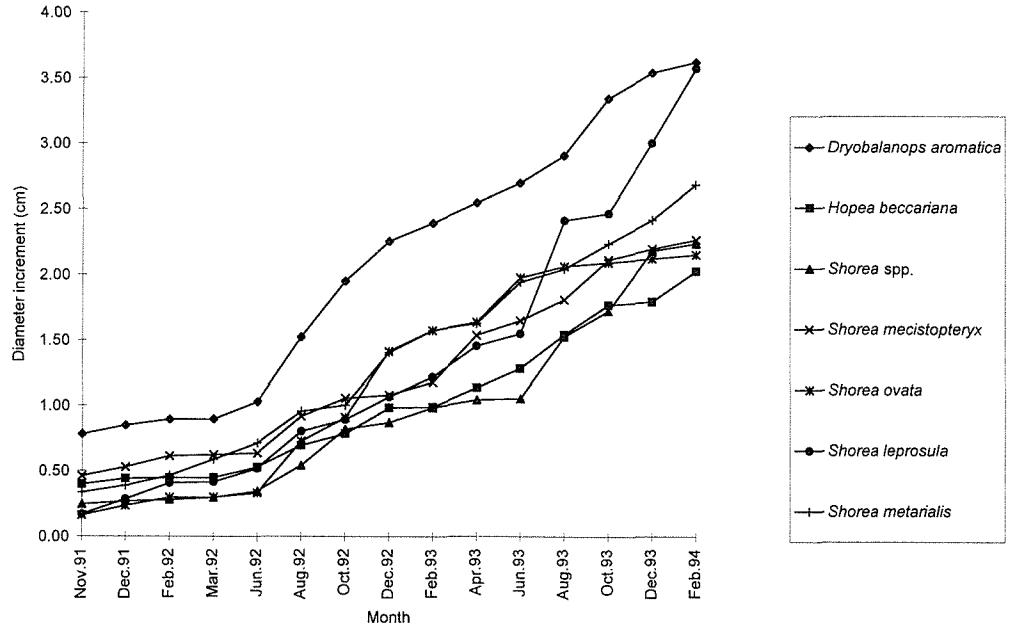

Figure 4. Diameter Increment for Plot A in Phase One.

Table 8. Number of Planted Seedlings and Mortality Rate for Plot on Flat Area in the Secondary Forest in Phase Two.

Species	Number of planted	3 month old		6 month old		9 month old		12 month old		15 month old		18 month old		21 month old	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Eusideroxylon zwageri	27	0	0	1	4	1	4	1	4	1	4	1	4	1	4
Shorea macrophylla	26	0	0	1	4	2	8	2	4	2	4	2	4	2	4
Shorea mecistopteryx	30	0	0	1	3	1	3	1	3	2	6	3	9	3	9
Pentaspodon motleyi	36	2	5	3	8	5	13	5	13	6	16	6	16	6	16

Table 9. Height Increment for Plot on Flat Area in the Secondary Forest in Phase Two.

Species	Dec. 91	Jan. 92	Feb. 92	Mar. 92	May. 92	Jun. 92	Aug. 92	Sep. 92	Oct. 92	Dec. 92	Feb. 93	Apr. 93	Jun. 93	Aug. 93	Oct. 93	Dec. 93	Feb. 94
Eusideroxylon zwageri	6. 28	61. 30	61. 81	63. 96	69. 90	74. 78	76. 87	78. 13	78. 56	86. 51	87. 89	93. 37	96. 33	101. 37	103. 80	106. 11	108. 65
Shorea macrophylla	52. 55	53. 85	54. 72	55. 67	60. 58	64. 57	65. 48	65. 93	65. 97	69. 60	73. 64	78. 84	83. 27	93. 51	99. 02	108. 72	113. 14
Shorea mecistopteryx	32. 14	36. 47	38. 61	39. 57	52. 54	61. 02	66. 56	68. 91	69. 23	79. 48	93. 31	106. 19	120. 25	126. 75	143. 26	162. 55	165. 41
Pentaspodon motleyi	23. 94	31. 90	37. 31	41. 99	62. 12	75. 71	88. 66	97. 82	98. 26	113. 61	128. 59	158. 74	182. 81	202. 27	213. 71	246. 74	262. 16

Table 10. Diameter Increment for Plot on Flat Area in the Secondary Forest in Phase Two.

Species	Dec. 91	Jan. 92	Feb. 92	Mar. 92	May. 92	Jun. 92	Aug. 92	Sep. 92	Oct. 92	Dec. 92	Feb. 93	Apr. 93	Jun. 93	Aug. 93	Oct. 93	Dec. 93	Feb. 94
Eusideroxylon zwageri	0. 73	0. 78	0. 80	0. 87	0. 94	0. 96	0. 98	1. 05	1. 07	1. 12	1. 12	1. 21	1. 24	1. 26	1. 27	1. 29	1. 32
Shorea macrophylla	0. 85	0. 88	0. 90	0. 94	0. 97	0. 99	0. 99	1. 02	1. 04	1. 12	1. 15	1. 28	1. 30	1. 34	1. 38	1. 42	1. 49
Shorea mecistopteryx	0. 63	0. 65	0. 68	0. 70	0. 76	0. 80	0. 81	0. 89	0. 92	0. 96	1. 04	1. 20	1. 25	1. 33	1. 44	1. 54	1. 63
Pentaspodon motleyi	0. 36	0. 42	0. 49	0. 56	0. 68	0. 77	0. 86	1. 00	1. 02	1. 18	1. 35	1. 62	1. 74	1. 95	2. 06	2. 27	2. 36

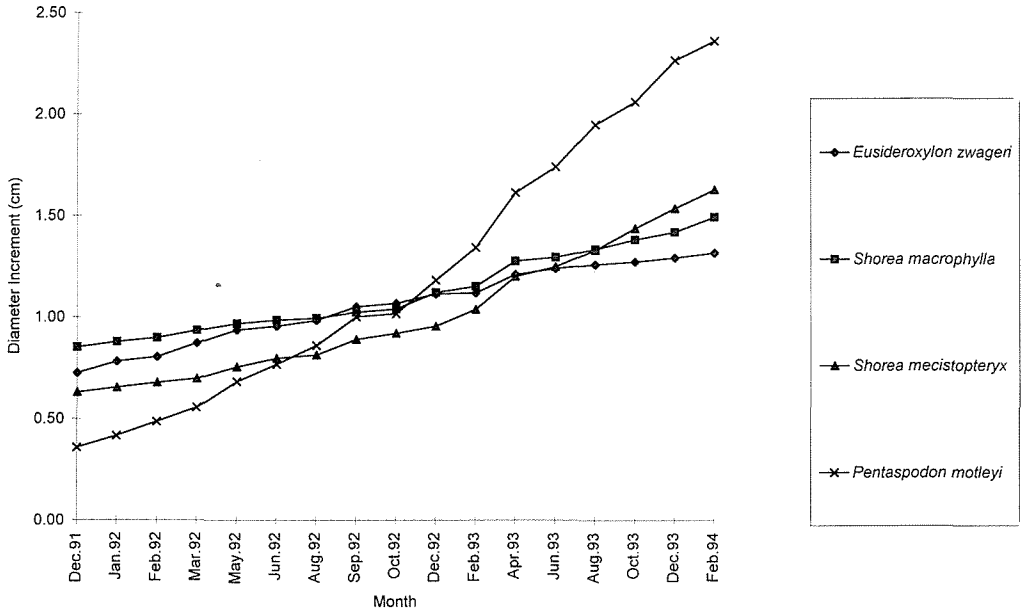

Figure 5. Diameter Increment for Plot on Flat Area in the Secondary Forest in Phase Two.

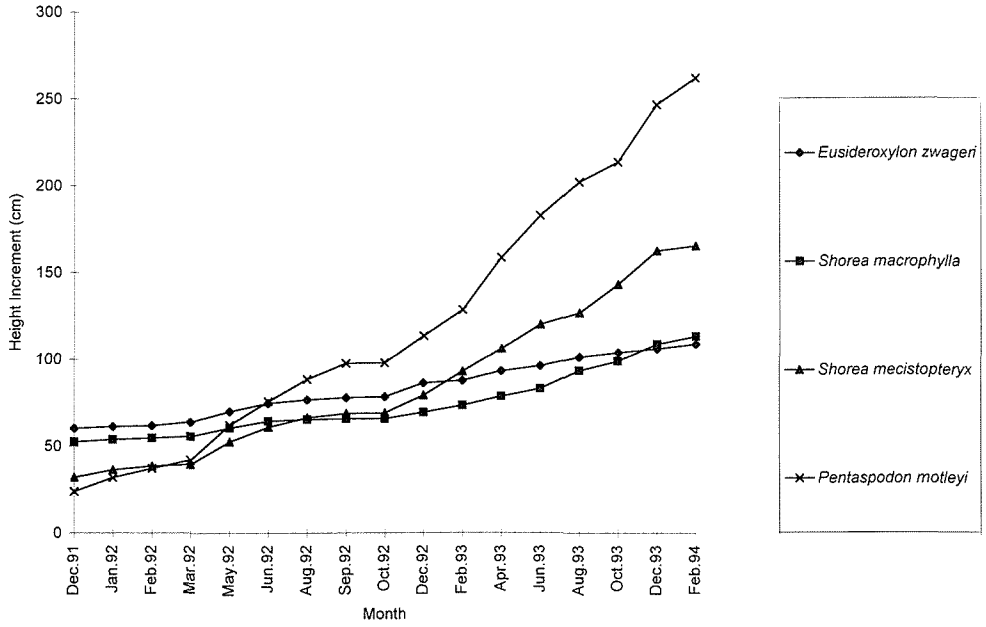

Figure 6. Height Increment for Plot on Flat Area in the Secondary Forest in Phase Two.

Table 11. Number of Planted Seedlings and Mortality Rate for Plot on Slope Area in the Secondary Forest in Phase Two.

Species	Number of planted	3 month old		6 month old		9 month old		12 month old		15 month old		18 month old		21 month old	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Calophyllum ferrugineum	1	0	0	1	100	1	100	1	100	1	100	1	100	1	100
Durio carinatus	15	2	13	4	27	7	47	12	80	12	80	12	80	12	80
Hopea kerangasensis	4	1	25	2	50	2	50	2	50	2	50	2	50	2	50
Cotylelobium burckii	6	0	0	1	17	2	33	4	67	5	83	6	100	6	100
Eugenia sp.	32	4	13	18	56	23	72	28	88	28	88	28	88	28	88
Shorea macrophylla	6	0	0	1	17	1	17	1	17	1	17	1	17	1	17
Shorea mecistopteryx	34	0	0	1	3	1	3	3	9	3	9	3	9	3	9
Shorea ovata	50	1	2	4	8	5	10	11	22	11	22	11	22	12	24
Shorea leprosula	61	10	16	13	21	14	23	15	24	17	28	17	28	17	28
Dryobalanops beccarii	14	0	0	2	14	3	21	4	28	4	28	4	28	4	28

Table 12. Height Increment for Plot on Slope Area in the Secondary Forest in Phase Two.

Species	Jul. 92	Sep. 92	Oct. 92	Nov. 92	Dec. 92	Jan. 93	Feb. 93	Mar. 93	Apr. 93	May. 93	Jun. 93	Jul. 93	Sep. 93	Nov. 93	Jan. 94	Mar. 94
Calophyllum ferrugineum	13.50	13.60	13.90	14.00	Dead											
Durio carinatus	41.41	44.30	44.61	44.80	45.59	49.90	54.50	55.68	58.37	65.60	69.33	76.00	81.13	88.67	103.00	115.63
Hopea kerangasensis	17.94	22.43	22.56	22.84	38.31	41.25	72.05	75.77	91.94	102.20	114.50	125.85	133.42	151.62	169.65	185.49
Cotylelobium burckii	46.40	48.40	48.60	48.80	57.50	58.60	59.20	61.51	62.84	63.04	63.80	63.80	dead			
Eugenia sp.	19.21	19.45	19.57	20.05	20.14	21.62	22.35	23.42	25.83	26.17	37.00	41.00	46.00	46.10	46.50	47.10
Shorea macrophylla	43.17	44.40	44.73	45.12	44.38	53.90	55.42	56.51	55.15	62.18	65.80	71.67	75.10	85.03	101.53	113.87
Shorea mecistopteryx	69.79	74.40	74.66	75.48	87.93	95.37	97.75	98.67	105.20	106.29	109.36	113.28	131.06	149.58	167.51	190.52
Shorea ovata	41.61	51.79	51.99	52.68	65.69	80.46	84.14	86.48	99.70	103.72	118.17	121.00	145.78	176.02	199.82	212.39
Shorea leprosula	43.62	47.65	47.85	48.48	59.26	70.88	75.65	82.32	94.22	97.71	95.45	100.50	126.84	145.38	165.80	182.10
Dryobalanops beccarii	42.17	47.81	47.86	48.28	59.12	68.50	72.05	75.77	91.94	102.20	114.50	125.85	133.42	151.62	169.65	185.49

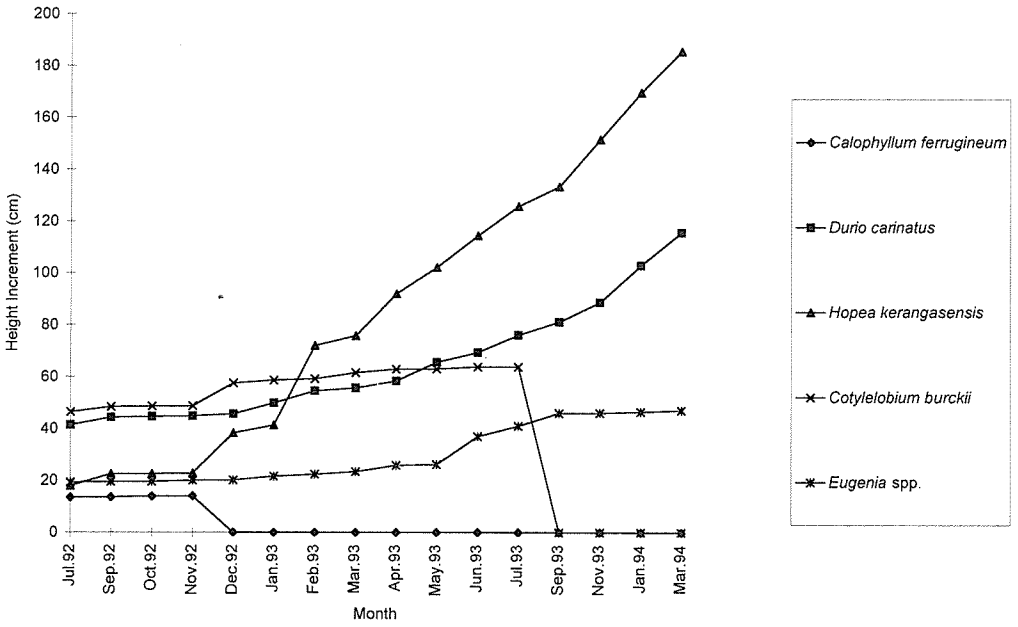

Figure 7. Height Increment for Plot on Slope Area in the Secondary Forest in Phase Two.

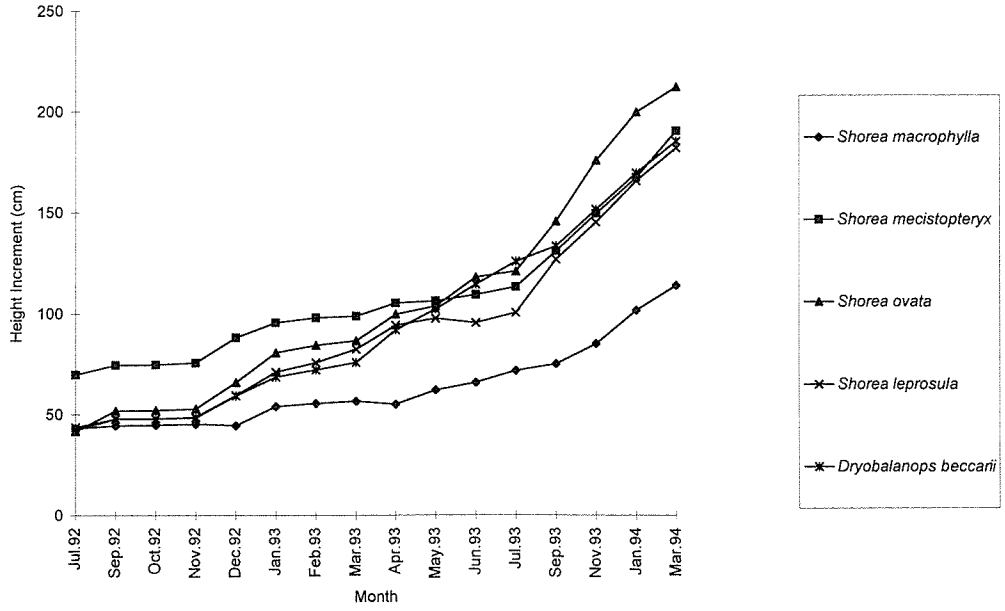

Figure 8. Height Increment for Plot on Slope Area in the Secondary Forest in Phase Two.

Table 13. Diameter Increment for Plot on Slope Area in the Secondary Forest in Phase Two.

Species	Jul. 92	Sep. 92	Oct. 92	Nov. 92	Dec. 92	Jan. 93	Feb. 93	Mar. 93	Apr. 93	May. 93	Jun. 93	Jul. 93	Sep. 93	Nov. 93	Jan. 94	Mar. 94
Calophyllum ferrugineum	0. 210	0. 211	0. 215	0. 220	dead											
Durio carinatus	0. 381	0. 446	0. 463	0. 472	0. 537	0. 548	0. 558	0. 582	0. 696	0. 704	0. 740	0. 744	0. 809	0. 963	1. 057	1. 213
Hopea kerangasensis	0. 452	0. 542	0. 547	0. 552	0. 744	0. 871	0. 050	1. 141	1. 283	1. 274	1. 342	1. 346	1. 561	1. 726	1. 919	2. 177
Cotylelobium burckii	0. 400	0. 417	0. 419	0. 423	0. 452	0. 458	0. 495	0. 507	0. 508	0. 509	0. 511	0. 513	dead			
Eugenia sp.	0. 221	0. 234	0. 228	0. 237	0. 238	0. 272	0. 277	0. 348	0. 374	0. 381	0. 449	0. 451	0. 467	0. 515	0. 583	0. 593
Shorea macrophylla	0. 591	0. 640	0. 669	0. 698	0. 866	0. 996	1. 005	1. 041	1. 090	1. 105	1. 154	1. 158	1. 374	1. 458	1. 587	1. 764
Shorea mecistopteryx	0. 942	1. 143	1. 146	1. 163	1. 330	1. 450	1. 494	1. 562	1. 674	1. 748	1. 768	1. 773	1. 943	2. 193	2. 390	2. 627
Shorea ovata	0. 538	0. 655	0. 660	0. 666	0. 787	0. 882	0. 965	1. 047	1. 120	1. 120	1. 168	1. 173	1. 390	1. 563	1. 672	1. 833
Shorea leprosula	0. 446	0. 607	0. 611	0. 627	0. 795	0. 971	1. 063	1. 108	1. 217	1. 268	1. 378	1. 387	1. 654	2. 123	2. 378	2. 560
Dryobalanops beccarii	0. 492	0. 604	0. 618	0. 624	0. 806	0. 951	1. 025	1. 150	1. 297	1. 299	1. 397	1. 402	1. 751	1. 901	2. 125	2. 341

Table 14. Number of Planted Seedlings and Mortality Rate for Line Planting Plot in Phase Two.

Species	Number of planted	3 month old		6 month old		9 month old		12 month old		15 month old	
		Number	%	Number	%	Number	%	Number	%	Number	%
Eusideraxylon zwageri	36	0	0	0	0	4	11	4	11	4	11
Calophyllum ferrugineum	67	4	6	24	36	33	49	40	60	40	60
Durio carinatus	47	2	4	8	17	11	23	11	23	11	23
Durio zybethinus	70	1	1	1	1	1	1	1	1	1	1
Garcinia sp.	2	0	0	0	0	0	0	0	0	0	0
Whiteodendron moultonianum	2	0	0	0	0	0	0	0	0	0	0
Dipterocarpus crinitus	2	0	0	0	0	0	0	0	0	0	0
Shorea mecistopteryx	75	0	0	6	8	9	12	9	12	9	12
Shorea ovata	66	2	3	5	8	8	12	8	12	8	12
Shorea leprosula	75	0	0	1	1	5	7	5	7	5	7
Palaquium sp.	2	0	0	0	0	0	0	0	0	0	0
Vatica nitens	17	1	6	5	29	6	35	9	53	9	53
Shorea materialis	21	5	24	7	33	8	38	9	43	9	43
Eugenia sp.	7	0	0	0	0	1	14	2	29	2	29
Upuna borneensis	22	0	0	1	5	1	5	4	18	4	18
Parashorea parvifolia	13	0	0	1	8	1	8	2	15	2	15

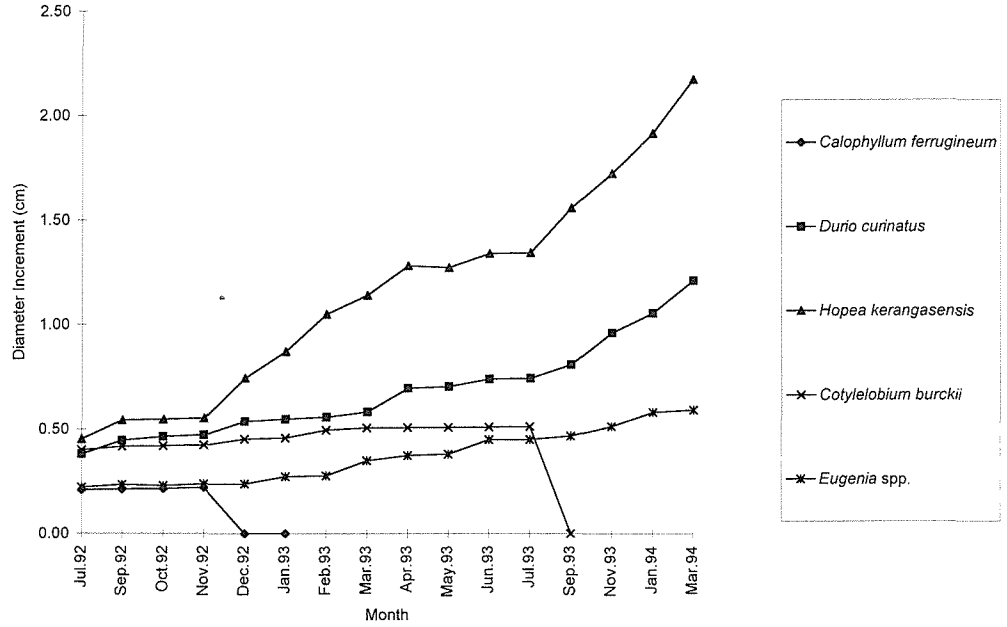

Figure 9. Diameter Increment for Plot on Slope Area in the Secondary Forest in Phase Two.

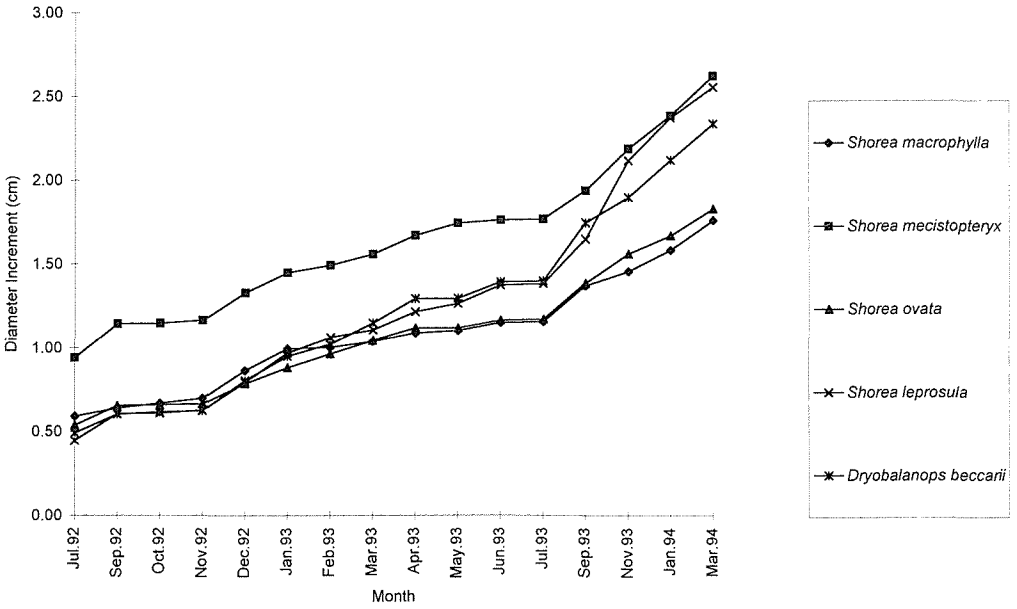

Figure 10. Diameter Increment for Plot on Slope Area in the Secondary Forest in Phase Two.

b. Height increment of planted seedlings.

Only *Shorea mecistopteryx* reached 125.97cm in height and left *Shorea leprosula* behind with 97.26cm. *Whiteodendron moultonianum* only had 22.66cm in height after 15 months (Table 15, Figure 11 and Figure 12).

c. Diameter increment of planted seedlings.

Table 16 shows the diameter increment for 16 species selected for this plot. *Shorea mecistopteryx* had the fastest diameter growth with 1.40cm, followed by *Durio zybethinus* with 1.32cm. *Calophyllum ferrugineum* had the smallest diameter with 0.28cm (Figure 13 and Figure 14).

8.5. Planted on the mound in the open area.

All seedlings were planted on a mound with a size of 5 meters by 50 meters. The mound was built to a height of 1 meter using topsoil. Soil ploughing was done before adding the topsoil to the planting area. Planting density of 3 seedlings per 1 square meter with mix species was applied.

a. Number of planted seedlings and survival mortality rate.

15 species were chose to be planted at this experimental plot. *Calophyllum ferrugineum* had the highest number of planted seedlings with 107 seedlings, followed by *Shorea mecistopteryx* with 105 seedlings. Seven species were planted at fewer than 10 seedlings per species, according to their availability at the time of planting.

Calophyllum ferrugineum had the highest mortality rate with 64%, followed by *Hopea kerangasensis* with 55%. *Durio carinatus, Whiteodendron moultonianum, Pentaspodon motleyi, Vatica* sp. and *Shorea macrophylla* had the lowest mortality rate with 0% (Table 17).

b. Height increment of planted seedlings.

Table 18 shows the height increment for 15 species. *Pentaspodon motleyi* was the highest increment in height with 435.00cm follow by *Vatica* sp. with 430.00cm. Amongst *Shorea* spp., *Shorea leprosula* has the highest height with 299.18cm. *Calophyllum ferrugineum* only reach 125.92cm after 27 months of planting (Table 18, Figure 15 and Figure 16).

c. Diameter increment of planted seedlings.

Pentaspodon motleyi had the highest diameter increment at 11.88cm, followed by *Vatica* sp. with 9.99cm. *Calophyllum ferrugineum* only has 1.39cm in diameter increment. Amongst *Shorea* spp., *Shorea leprosula* has the biggest diameter with at 4.97cm followed by *Shorea macrophylla* with 4.65cm (Table 19, Figure 17 and Figure 18).

9. Discussion

From the results, it appears that planting of indigenous species on open areas especially abandoned shifting-cultivation areas can be very successful. Species recommended for planting on open area are *Dryobalanops aromatica, Shorea leprosula, S. macrophylla, S. ovata, Hopea kerangasensis, Whiteodendron moultonianum, Vatica nitens* and *Pentaspodon motleyi*. These species are belong to the coastal forest (see pp. xx - xx: Fujiwara et al. 1995). Species of *Eugenia* and *Calophyllum ferrugenium* are not well recommended because of their slow growth. *Shorea mecistopteryx* can grow in open areas but needs a site where strong wind does not occur. *Shorea mecistopteryx* has big leaves which easily blow off in strong wind and if this happens, the seedlings can die easily. *Shorea mecistopteryx* can be found in Mixed Dipterocarp Forest on gently undulating low hills throughout Sarawak.

For plantation of indigenous species under shade or under trees, recommended species are *Shorea ovata, S. macrophylla, S. mecistopteryx, S. leprosula, S. gibbosa, Hopea kerangasensis, H. beccariana, Dryobalanops aromatica, D. beccarii, Pentaspodon motleyi, Eusideroxylon zwageri, Durio zybethinus* and *Garcinia* sp.

Table 15. Height Increment for Line Planting Plot in Phase Two.

Species	Jul. 92	Aug. 92	Sep. 92	Oct. 92	Nov. 92	Dec. 92	Jan. 93	Mar. 93	Apr. 93	May. 93	Jun. 93	Jul. 93
Eusideroxylon zwageri	62. 96	63. 46	64. 21	68. 93	70. 15	72. 92	74. 45	78. 62	80. 00	82. 05	84. 06	87. 16
Calophyllum ferrugineum	8. 41	8. 89	10. 02	10. 08	10. 29	12. 96	13. 16	14. 96	15. 97	17. 09	20. 69	25. 34
Durio carinatus	29. 18	29. 80	30. 28	32. 55	32. 84	35. 27	35. 76	36. 45	37. 80	40. 40	42. 39	44. 76
Durio zybethinus	52. 39	53. 46	54. 08	57. 78	58. 15	65. 04	68. 26	72. 24	75. 28	77. 06	81. 25	85. 16
Garcinia sp.	50. 82	51. 93	52. 61	56. 35	56. 71	63. 51	66. 57	69. 34	72. 40	72. 65	76. 93	80. 16
Whiteodendron moultonianum	15. 40	16. 00	16. 33	17. 10	17. 44	18. 26	18. 95	19. 26	20. 43	20. 79	21. 22	22. 66
Dipterocarpus crinitus	46. 15	47. 04	47. 53	51. 39	51. 81	57. 24	58. 53	59. 31	62. 14	62. 76	66. 41	76. 32
Shorea mecistopteryx	68. 96	69. 71	70. 45	80. 31	80. 66	92. 69	92. 78	107. 97	110. 13	118. 80	122. 39	125. 97
Shorea ovata	32. 32	33. 72	35. 92	47. 25	47. 53	55. 25	61. 93	69. 91	72. 33	83. 57	88. 35	90. 85
Shorea leprosula	30. 77	30. 81	32. 62	44. 34	44. 59	51. 26	59. 48	70. 99	73. 42	89. 96	93. 98	97. 26
Palaquium spp.	29. 55	30. 62	31. 51	43. 57	45. 30	49. 29	56. 67	68. 33	70. 75	83. 63	87. 69	90. 07
Vatica nitens	27. 13	27. 46	27. 76	28. 20	30. 12	31. 26	31. 56	35. 62	41. 86	43. 68	44. 98	45. 57
Shorea metarialis	45. 59	45. 82	45. 96	46. 09	46. 21	52. 54	53. 23	57. 28	60. 07	63. 92	66. 83	69. 97
Eugenia sp.	43. 60	44. 55	45. 82	45. 90	46. 16	48. 92	49. 91	53. 23	56. 00	58. 28	60. 84	63. 56
Upuna borneensis	37. 57	38. 04	38. 40	40. 44	40. 85	41. 35	41. 87	42. 98	44. 83	46. 04	46. 72	48. 94
Parashorea parvifolia	32. 90	33. 38	33. 39	36. 96	37. 34	39. 02	39. 88	41. 42	42. 87	45. 57	56. 62	58. 93

Table 16. Diameter Increment for Line Planting Plot in Phase Two.

Species	Jul. 92	Aug. 92	Sep. 92	Oct. 92	Nov. 92	Dec. 92	Jan. 93	Mar. 93	Apr. 93	May. 93	Jun. 93	Jul. 93
Eusideroxylon zwageri	0. 86	0. 88	0. 88	0. 96	0. 99	1. 00	1. 02	1. 07	1. 07	1. 09	1. 10	1. 13
Calophyllum ferrugineum	0. 16	0. 17	0. 18	0. 20	0. 21	0. 22	0. 24	0. 27	0. 28	0. 28	0. 28	0. 28
Durio carinatus	0. 30	0. 31	0. 33	0. 36	0. 37	0. 38	0. 43	0. 45	0. 45	0. 46	0. 46	0. 46
Durio zybethinus	0. 94	0. 98	1. 00	1. 16	1. 16	1. 17	1. 22	1. 27	1. 27	1. 28	1. 30	1. 32
Garcinia sp.	0. 90	0. 95	0. 97	1. 12	1. 13	1. 14	1. 18	1. 23	1. 23	1. 24	1. 27	1. 27
Whiteodendron moultonianum	0. 22	0. 23	0. 23	0. 24	0. 25	0. 25	0. 26	0. 27	0. 27	0. 27	0. 28	0. 29
Dipterocarpus crinitus	0. 85	0. 88	0. 90	1. 06	1. 07	1. 08	1. 09	1. 13	1. 13	1. 14	1. 16	1. 16
Shorea mecistopteryx	0. 88	0. 90	0. 93	1. 00	1. 01	1. 13	1. 14	1. 34	1. 35	1. 35	1. 40	1. 40
Shorea ovata	0. 37	0. 39	0. 40	0. 50	0. 50	0. 54	0. 61	0. 68	0. 68	0. 74	0. 74	0. 75
Shorea leprosula	0. 38	0. 40	0. 41	0. 52	0. 71	0. 72	0. 72	0. 81	0. 81	0. 89	0. 89	0. 90
Palaquium spp.	0. 39	0. 40	0. 42	0. 52	0. 54	0. 58	0. 71	0. 79	0. 79	0. 86	0. 86	0. 87
Vatica nitens	0. 29	0. 30	0. 31	0. 39	0. 39	0. 39	0. 42	0. 46	0. 47	0. 49	0. 49	0. 50
Shorea metarialis	0. 40	0. 41	0. 44	0. 45	0. 46	0. 51	0. 52	0. 56	0. 56	0. 58	0. 58	0. 59
Eugenia sp.	0. 41	0. 43	0. 43	0. 47	0. 48	0. 49	0. 51	0. 53	0. 54	0. 56	0. 56	0. 56
Upuna borneensis	0. 62	0. 63	0. 64	0. 71	0. 72	0. 73	0. 74	0. 77	0. 78	0. 79	0. 79	0. 80
Parashorea parvifolia	0. 55	0. 56	0. 57	0. 65	0. 66	0. 66	0. 68	0. 69	0. 71	0. 73	0. 73	0. 74

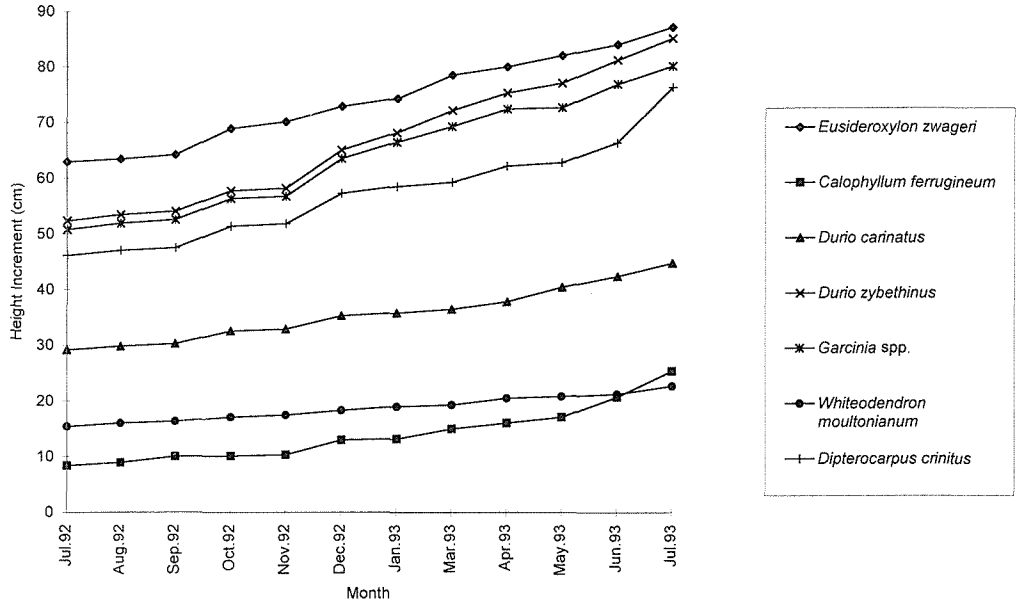

Figure 11. Height Increment for Line Planting Plot Phase Two.

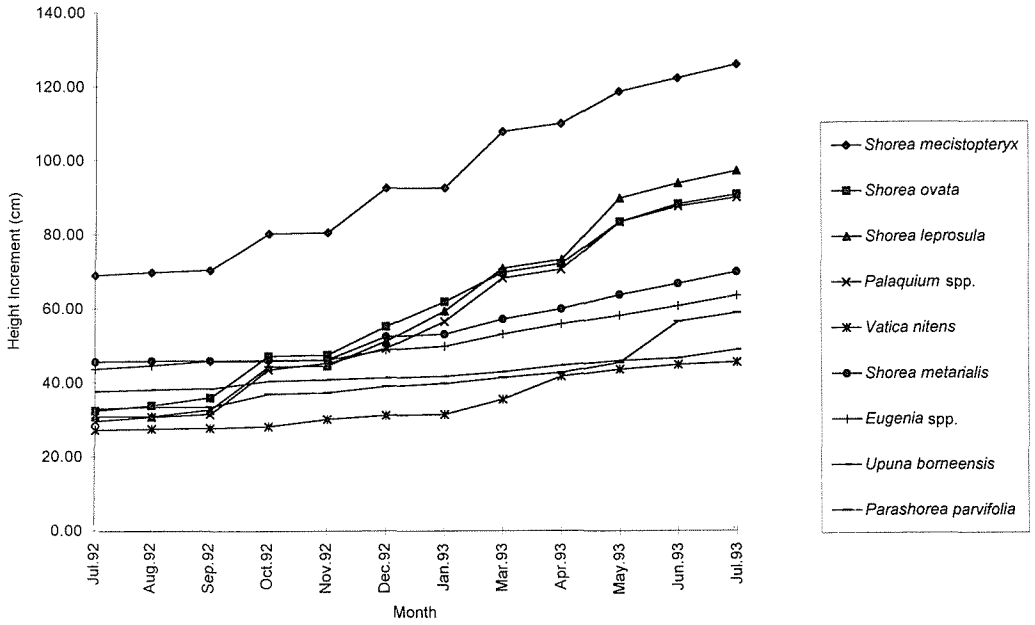

Figure 12. Height Increment for Line Planting Plot Phase Two.

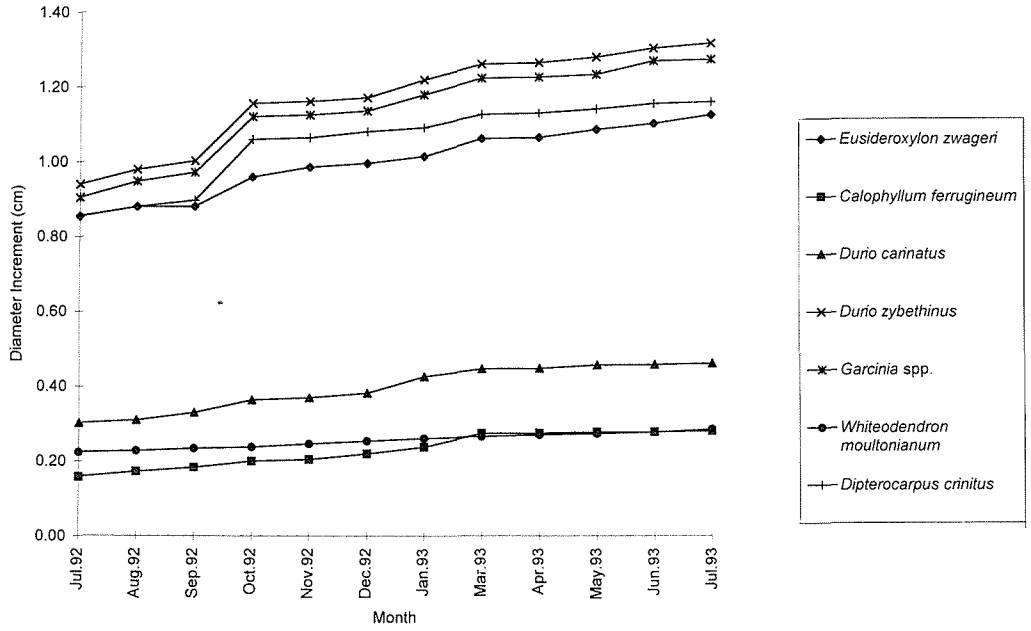

Figure 13. Diameter Increment for Line Planting Plot in Phase Two.

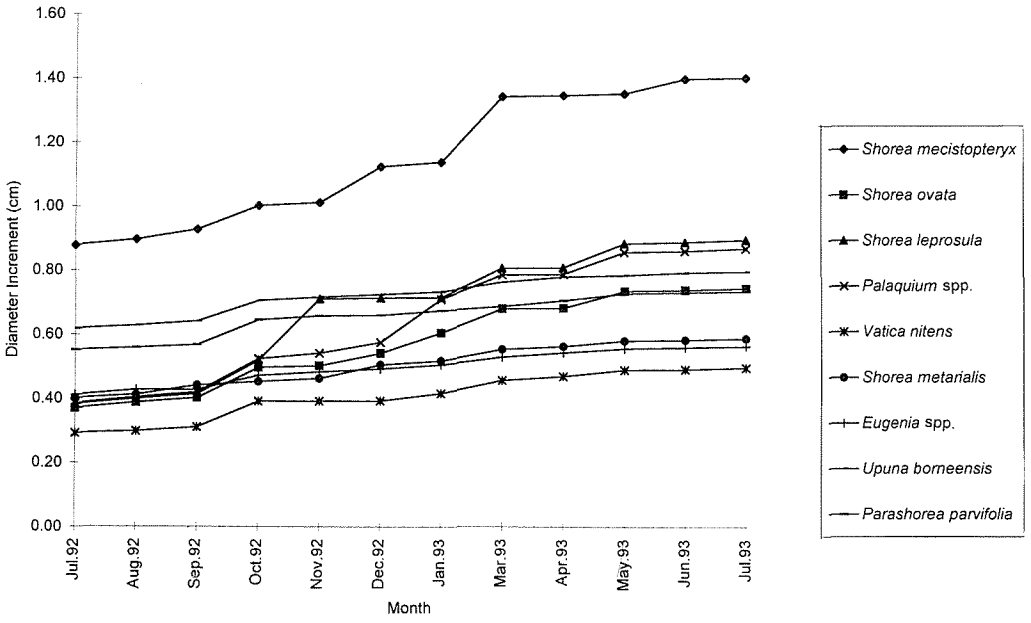

Figure 14. Diameter Increment for Line Planting Plot in Phase Two.

Table 17. Number of planted seedlings and Mortality Rate for Mound Plot.

Species	Number of planted	3 month old		6 month old		9 month old		12 month old		15 month old		18 month old		21 month old		24 month old		27 month old	
		Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Calophyllum ferrugineum	107	0	0	8	7	15	14	15	14	23	21	47	44	62	58	66	62	68	64
Durio carinatus	3	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whiteodendron moultonianum	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hopea kerangasensis	60	0	0	16	27	16	27	16	27	23	38	29	48	31	52	31	52	33	55
Pentaspodon motleyi	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vatica sp.	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eugenia sp.	3	0	0	0	0	1	33	1	33	1	33	1	33	1	33	1	33	1	33
Hopea beccariana	51	0	0	6	12	8	16	8	16	12	24	12	24	14	27	17	33	17	33
Dryobalanops beccarii	94	0	0	2	2	5	5	5	5	8	9	8	9	10	11	10	11	12	13
Shorea mecistopteryx	105	1	1	27	26	27	26	27	26	29	28	32	30	36	34	38	36	38	36
Shorea gibbosa	6	0	0	1	17	3	50	3	50	3	50	3	50	3	50	3	50	3	50
Shorea ovata	20	0	0	2	10	2	10	4	20	5	25	5	25	6	30	6	30	6	30
Shorea leprosula	88	0	0	3	3	6	7	7	8	9	10	10	11	10	11	10	11	10	11
Shorea macrophylla	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shorea materialis	103	0	0	8	8	23	22	23	22	28	27	36	35	44	43	44	43	44	43

Table 18. Height Increment for Mound Plot.

Species	Aug. 91	Sept. 91	Nov. 91	Mar. 92	May. 92	Jul. 92	Aug. 92	Oct. 92	Dec. 92	Feb. 93	Apr. 93	Jun. 93	Aug. 93	Oct. 93	Dec. 93	Feb. 94
Calophyllum ferrugineum	17. 59	19. 18	23. 57	26. 99	31. 41	33. 83	36. 94	41. 91	47. 56	56. 97	63. 57	80. 94	106. 60	112. 60	114. 98	125. 92
Durio carinatus	35. 40	43. 10	44. 20	46. 70	47. 65	48. 10	49. 56	52. 31	54. 40	68. 30	83. 40	112. 00	135. 00	144. 00	150. 00	177. 00
Whiteodendron moultonianum	35. 67	40. 17	53. 83	87. 70	98. 27	105. 83	111. 23	125. 64	135. 07	156. 03	172. 43	190. 00	194. 33	225. 33	241. 67	261. 00
Hopea kerangasensis	15. 45	18. 83	23. 42	27. 82	37. 56	42. 95	53. 38	63. 65	75. 67	85. 16	97. 62	115. 40	139. 04	149. 24	176. 74	215. 64
Pentaspodon motleyi	24. 70	27. 10	32. 60	62. 30	79. 70	93. 30	121. 70	149. 50	172. 40	189. 10	214. 20	255. 00	300. 00	358. 00	370. 00	435. 00
Vatica sp.	28. 50	38. 10	38. 30	58. 60	67. 90	77. 80	103. 50	146. 50	187. 20	231. 50	266. 10	308. 00	338. 50	360. 00	372. 00	430. 00
Eugenia sp.	35. 83	37. 73	46. 77	58. 73	63. 43	64. 73	84. 00	102. 75	118. 35	132. 45	144. 45	151. 80	160. 00	174. 50	190. 50	215. 00
Hopea beccariana	27. 60	32. 59	40. 12	54. 42	62. 13	66. 00	67. 29	81. 06	87. 93	98. 19	107. 34	122. 69	141. 57	151. 99	175. 81	194. 00
Dryobalanops beccarii	34. 34	37. 74	46. 53	63. 41	80. 63	88. 23	93. 18	103. 52	123. 24	135. 60	147. 11	164. 08	182. 42	193. 36	214. 39	236. 12
Shorea mecistopteryx	35. 04	36. 93	42. 30	47. 42	50. 35	54. 49	58. 31	70. 10	86. 22	101. 02	114. 48	128. 33	141. 44	161. 60	180. 52	215. 31
Shorea gibbosa	30. 93	35. 63	41. 92	53. 27	58. 47	58. 97	60. 43	69. 78	78. 08	83. 43	118. 10	135. 97	156. 00	185. 00	199. 67	244. 00
Shorea ovata	24. 85	25. 66	32. 00	46. 87	55. 07	61. 90	70. 62	80. 68	91. 61	113. 79	128. 85	149. 97	165. 83	196. 93	226. 21	254. 93
Shorea leprosula	29. 01	34. 75	48. 99	73. 70	88. 72	99. 44	102. 21	121. 02	151. 70	168. 71	181. 62	199. 03	212. 10	242. 46	264. 60	299. 18
Shorea macrophylla	50. 40	53. 57	61. 43	85. 20	95. 20	95. 80	107. 20	132. 46	156. 17	180. 43	185. 53	203. 00	211. 67	223. 67	252. 67	286. 67
Shorea materialis	36. 26	40. 98	48. 76	57. 34	69. 72	71. 21	76. 13	91. 84	112. 67	128. 33	141. 41	160. 31	174. 63	193. 81	212. 83	240. 81

Table 19. Diameter Increment for Mound Plot.

Species	Aug. 91	Sept. 91	Nov. 91	Mar. 92	May. 92	Jul. 92	Aug. 92	Oct. 92	Dec. 92	Feb. 93	Apr. 93	Jun. 93	Aug. 93	Oct. 93	Dec. 93	Feb. 94
Calophyllum ferrugineum	0. 30	0. 34	0. 38	0. 46	0. 49	0. 51	0. 58	0. 59	0. 65	0. 75	0. 83	0. 96	1. 17	1. 24	1. 31	1. 39
Durio carinatus	0. 33	0. 49	0. 53	0. 67	0. 71	0. 75	0. 76	0. 94	1. 24	1. 48	1. 63	1. 88	2. 31	2. 32	2. 72	2. 81
Whiteodendron moultonianum	0. 38	0. 42	0. 55	0. 87	1. 37	1. 51	1. 68	1. 95	2. 15	2. 26	2. 40	2. 75	2. 94	2. 99	3. 18	3. 39
Hopea kerangasensis	0. 19	0. 22	0. 27	0. 34	0. 51	0. 62	0. 68	0. 89	1. 08	1. 24	1. 51	1. 69	2. 05	2. 38	2. 80	3. 14
Pentaspodon motleyi	0. 32	0. 35	0. 41	0. 45	0. 52	0. 54	2. 00	2. 98	4. 36	5. 32	6. 86	8. 31	9. 14	10. 19	11. 09	11. 88
Vatica sp.	0. 21	0. 24	1. 01	1. 33	1. 44	1. 48	1. 77	2. 47	3. 15	3. 77	4. 07	4. 26	6. 33	7. 40	8. 32	9. 99
Eugenia sp.	0. 29	0. 36	0. 42	0. 74	1. 02	1. 13	1. 26	1. 45	1. 62	1. 86	1. 95	2. 09	2. 24	2. 25	2. 43	2. 61
Hopea beccariana	0. 32	0. 37	0. 46	0. 65	0. 72	0. 79	0. 87	1. 06	1. 19	1. 30	1. 36	1. 49	1. 64	2. 03	2. 20	2. 45
Dryobalanops beccarii	0. 34	0. 40	0. 55	0. 83	1. 07	1. 23	1. 38	1. 64	1. 86	2. 08	2. 25	2. 39	2. 64	2. 84	3. 10	3. 38
Shorea mecistopteryx	0. 63	0. 67	0. 75	0. 82	0. 87	0. 90	0. 91	1. 12	1. 35	1. 59	1. 78	1. 93	2. 23	2. 42	2. 73	2. 94
Shorea gibbosa	0. 54	0. 57	0. 61	0. 74	0. 87	0. 97	1. 09	1. 28	1. 40	1. 53	2. 02	2. 27	2. 46	2. 90	3. 02	3. 50
Shorea ovata	0. 26	0. 29	0. 38	0. 56	0. 69	0. 80	0. 90	0. 97	1. 08	1. 32	1. 44	1. 54	1. 58	1. 95	2. 17	2. 44
Shorea leprosula	0. 36	0. 44	0. 74	1. 13	1. 44	1. 62	1. 73	2. 04	2. 54	2. 92	3. 12	3. 35	3. 53	4. 01	4. 52	4. 97
Shorea macrophylla	0. 66	0. 68	0. 93	1. 58	1. 60	2. 07	2. 07	2. 68	2. 79	2. 98	3. 15	3. 40	3. 87	4. 30	4. 41	4. 65
Shorea materialis	0. 28	0. 31	0. 48	0. 51	0. 64	0. 73	0. 79	0. 96	1. 12	1. 31	1. 49	1. 64	2. 03	2. 04	2. 25	2. 50

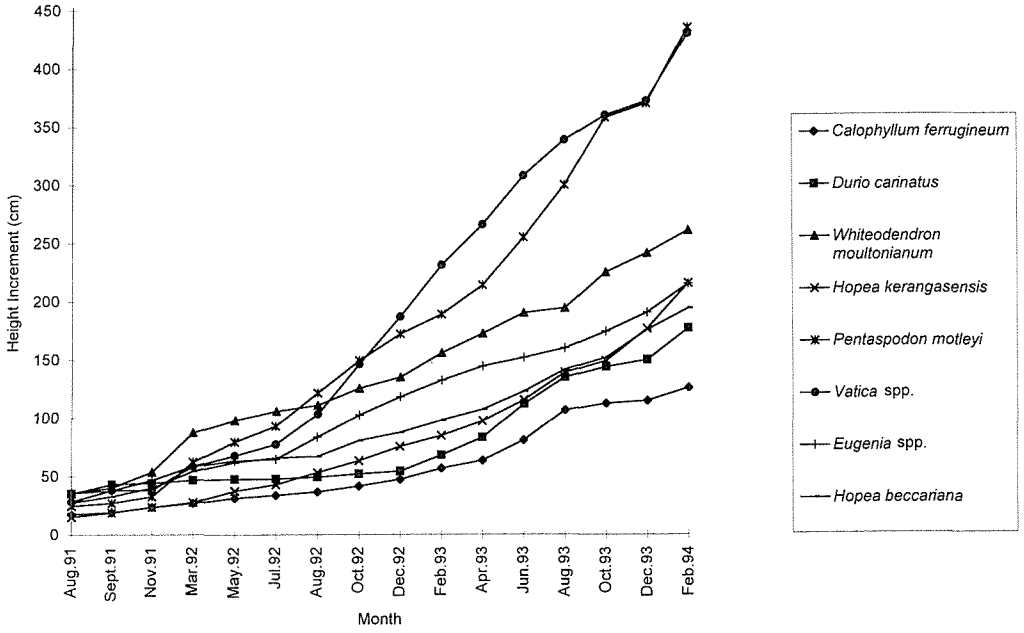

Figure 15. Height Increment for Mound Plot.

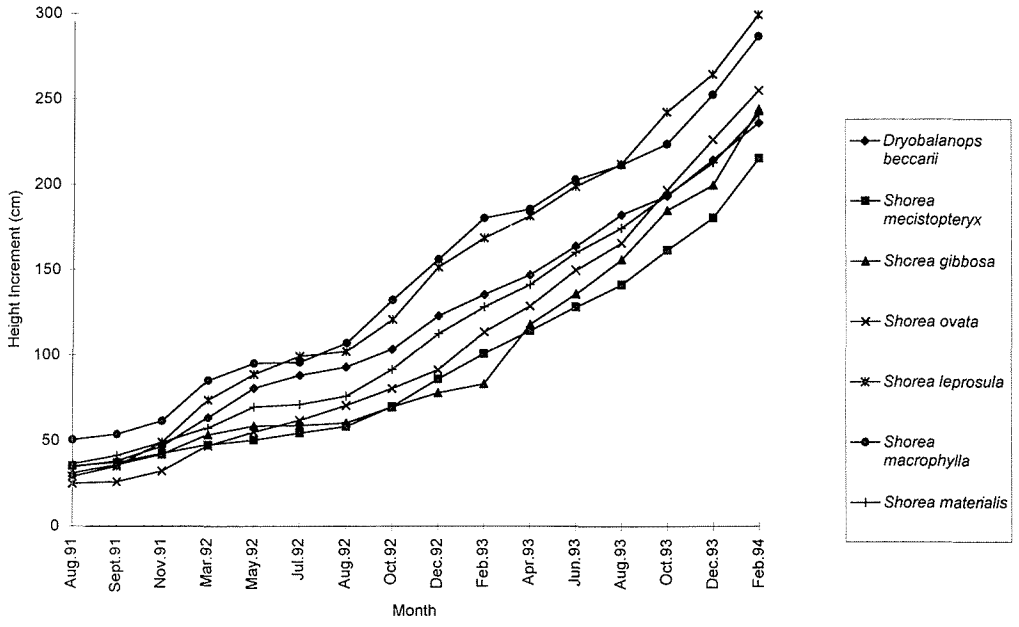

Figure 16. Height Increment for Mound Plot.

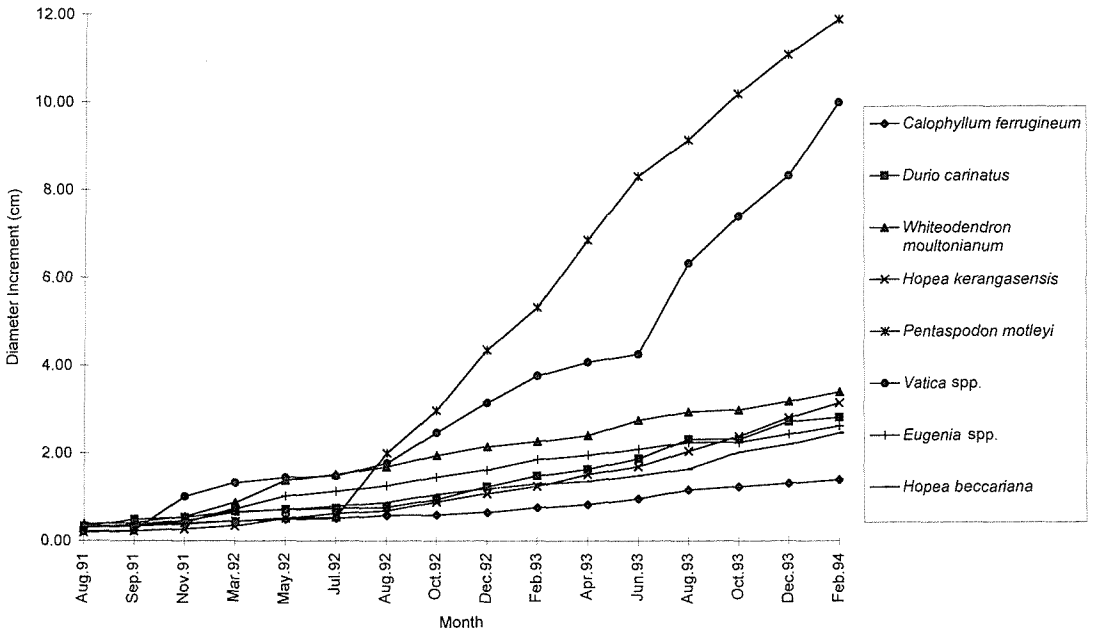

Figure 17. Diameter Increment for Mound Plot.

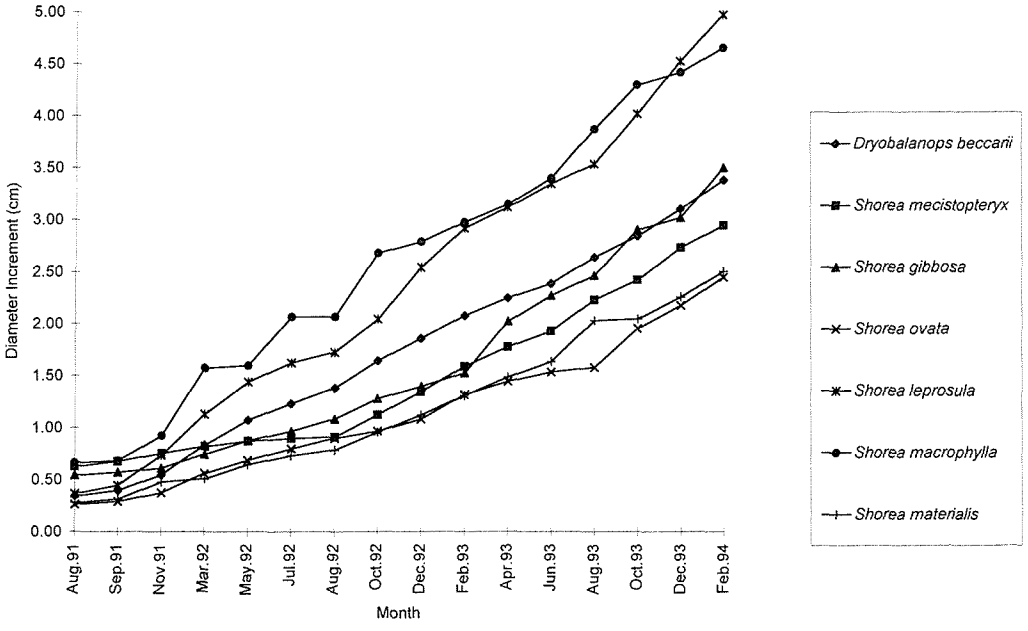

Figure 18. Diameter Increment for Mound Plot.

Problems encountered

During the project implementation, several problems were encountered including the following:

1. The planting stock is substantial considering the problems faced during the project, namely irregular fruiting of dipterocarp tree species and the increasing inaccessibility of virgin forests. Fresh seeds could only be collected during the fruiting seasons. The fruiting of *Dipterocarpaceae* is irregular and has no definite seasons: Unpredictable flowering and fruiting of *Dipterocarpaceae* has made it difficult to plan the production of sufficient planting stock. In addition, accessibility to tree seed sources is becoming more difficult since most lowland forested land has been harvested or converted into agricultural plantations and other land development. Most undisturbed forests are located further inland and are more difficult to reach. Unpredictable flowering and fruiting of *Dipterocarpaceae* has made it difficult to plan for the production of sufficient planting stocks. Therefore, the choice of dipterocarp species for research is indeed limited.
2. In 1990-1991, the prolonged drought was the major cause of concern. Drought affected the planting program and mortality of the seedlings, both in the field and in the nursery.
3. Wildings have been unreliable as collected wildings have shown higher rates of mortality.
4. Weeding after planting requires a lot of effort as the climate is conductive to weed growth. After three years, weeding is already not neccessary.
5. The quality of the seedlings was not homogenous. Some seedlings were good (well maintaned under shade), but some seedlings were planted too early under direct sunlight. Therefore, survival rate became lower especially *Calophylum* spp. *Calophyllum* spp. grow slower than other species.
6. Some species were not potential natural species in Universiti Pertanian Malaysia campus, such as *Eusideroxylon zwageri* and *Shorea mecistopteryx*. Therefore, their survival rate is very low.
7. Wild seedlings: only small wildings had good survival rates as potted seedlings. The maximum height of wild potted seedlings was 40 to 50 cm or up to two or three young leaves.
8. Some plantation areas have bad drainage, soil erosion occurs easily after a heavy rain. Because of bad drainage, areas unsuitable for planting the seedlings occured on undulating areas where the areas were too moist. A good drainage system should be prepared. Therefore, planting on mounds were recommended because of the better growth rate.
9. Mulching material: experience from Abas Plot which used a coconut fiber for mulching material suggested that coconut fiber was not a good mulching material. Coconut fiber store lots of water and cannot give enough air for seedlings. When this happen for a long period, survival rate of planted seedlings are down.

Important things choosing a good seedlings.

1) Size of seedlings: for the small wildings under 40 or 50 cm with a well developed root system were good for potting and planting.
2) Enough hardening in the nursery: seedlings, after 6 months hardening in the nursery under shade, grow very well and due to their good root systems are succesful when planted.

Acknowledgement

We wish to express our sincerely thank to Professor Elgene O. Box, University of Georgia (USA) for correction manuscripts.

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