EARLY PERFORMANCE OF 23 DIPTEROCARP SPECIES PLANTED IN LOGGED-OVER RAINFOREST

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INTRODUCTION

The tropical rainforest in Indonesia is known as one of the centres of biodiversity and the world’s second largest tropical forest in terms of biological diversity (60% of total land area or 10% of the world’s total tropical forest) (Rimbawanto 2006). One of the families dominating the tropical rainforest in Indonesia is Dipterocarpaceae, which plays a vital role in tropical timber market and hence influences the economy of many South-East Asian countries (Appanah 1998). Dipterocarpaceae consists of 16 genera in 3 subfamilies, making up about 515 species. In Asia, there are 13 genera and 470 species (Bawa 1998). Dipterocarps are major climax and dominant tree species which make up the rainforest in South-East Asia. They have essentially supported biodiversity and the carbon sink component in tropical rainforests. Dipterocarpaceae is not only harvested as wood but also produces resin and illepe nut. Bischoff et al. (2005) reported that the average volume of trees in the primary forest of tropical rainforest was estimated at 211.75 m³ ha⁻¹ where dipterocarps made up 86.9%.

Tropical rainforest in Indonesian is managed by many silviculture systems such as Indonesian selective cutting and replanting (tebang pilih tanam Indonesia, TPTI), selective cutting and line replanting (tebang pilih tanam jalur, TPTJ), and gap cutting (MOF 2009). For the past few decades, exploitation of tropical rainforest resulted in decreasing natural forest, forest productivity, biodiversity, genetics as well as increasing secondary forest (logged-over forest) and carbon emission. Exploitation of tropical rainforest results in genetic erosion of trees or unsuited genetic material. This is because mature trees have practically disappeared from local forests and seeds have to be collected from the remaining resources, i.e. poorly-shaped trees (Langenberger et al. 2005).

The residual stand of secondary forests recovering from logging and large natural disturbance is considerably different from the primary forests with respect to species composition, structure, dynamics and stability (Ng 1996, Bischoff et al. 2005). Sustainability of tropical forests is vital especially through the enrichment of secondary forests. Enrichment planting programme/large-scale plantation to rehabilitate tropical rainforest rarely uses dipterocarps as a source of land rehabilitation or reforestation, although dipterocarps have predominant role in forest exploitation (Langenberger 2006). On the other hand,
little is known about systematic species trial of Dipterocarpaceae involving a wide range of species tested in different sites (Hardiyanto 2006). Future research is needed to support the rehabilitation of tropical rainforest: species selection, well adapted genetic resources, site management and productivity, ecology and conservation, integrated pest management and silviculture (Soekotjo 2006). Species trial or species selection is a method that is applied to obtain information on species suitable to be developed at a certain location and on superior species prior to subsequent improvement programme on species screening test. The objective of the present study was to evaluate the growth of 23 species of dipterocarps and to study the reforestation potential of indigenous species with fast growth. These species of dipterocarps which were found suitable on degraded forest would be recommended for rehabilitation programme to conserve and increase the productivity of tropical rainforest.

MATERIALS AND METHODS

Study sites

This study was conducted in the natural forest at Sei Seruan block of PT Sari Bumi Kusuma (SBK) concession, central Borneo (00° 36’– 01° 10’ S and 111° 39’–112° 25’ E) (Figure 1). PT SBK received the concession in 1978. The total area of PT SBK is 147,600 ha, managed under two silviculture systems, namely, TPTI and TPTJ (MOF 2009).

The climate is type A (Schmidt and Ferguson). Mean annual temperature in the night is 22–28° C and in the afternoon 30–33 ° C; mean annual rainfall is 3376 mm/year and the number of rainy days varies from 89 to 189 days (Figure 2). Even though August is the month with the least rainfall (96.6 mm), it is still wet. Therefore, the soil under the surface always remains moist. The soil is Ordo Ultisol. However, this Ordo is the most weathered soil and shows ultimate effects of leaching. Ultisol is characterised by mineral soils that has B₂ horizon, 20% more clay compared with the upper B₁. Vegetation of the forest area is dominated by Dipterocarpaceae.

Seed collection

The mast fruiting of dipterocarps is infrequent, usually more than 3 years. However, sporadic fruiting occurs almost every year in some parts of the tropical rainforest (Appanah & Weinland 1993). The seed of dipterocarps is categorised as recalcitrant with less than one month seed viability after collection (Sasaki 1980, Otsamo et al. 1998). The seeds of 23 dipterocarp species were collected during a mass flowering event from January till February 2005 in the whole concession area. As fallen fruits were eaten by
animals, fresh fruits were collected everyday from the same collection sites. The fruits were taken to a nursery of SBK to be germinated in 15 cm × 20 cm polybags filled with top soil from the forest floor. The topsoil was collected from around mother trees of dipterocarps to ensure mycorrhizal infection of seedling roots. Seedlings were maintained in the nursery for 12 months.

Site preparation and planting

An experiment was carried out in a 4.97 ha artificial gap formed in a logged-over area of the tropical rainforest. The gap was created between January and March 2006. Site preparation was done by clear cutting the area to ensure all treatments had the same light and microclimate conditions. Clear cutting was also effective to control competitive vegetation. Planting hole was approximately 40 cm × 40 cm × 30 cm and spacing was 6 m × 3 m. Site preparation and planting time were between February and April 2006.

Experiment design

The design of species trial was randomised complete block design with four blocks used as replication. Twenty-three indigenous species (dipterocarps) were used as treatment. Each block consisted of 23 dipterocarp species and each species consisted of 3 × 10 tree plots (30 seedlings) with rectangular plot at a spacing of 6 m × 3 m. They were *Shorea leprosula*, *S. platyclados*, *S. johorensis*, *S. ovalis*, *S. parvifolia*, *S. macrophylla*, *S. pinanga*, *S. scaberima*, *S. smithiana*, *S. dasyphylla*, *S. leavis*, *S. fallax*, *S. macroptera*, *S. atrivervosa*, *S. seminis*, *S. guiso*, *S. virescens*, *S. singkawang*, *S. blumutensis*, *S. lamellate*, *Hopea mangerawan*, *Dipterocarpus retusus* and *D. caudiferus*.

The total number of seedlings planted was 2760. Land preparation in the research area was to open the land (land clearing so that sunlight could reach the forest floor). Therefore, each seedling received similar light. Data collected were survival rate, diameter at breast height (dbh) and height increment at 6.5 years after planting. Survival rate was assessed based on complete count of trees originally planted in each block. Dbh was taken at 1.3 m from the root collar using diameter callipers. The height of plants was measured from the root collar to the shoot tip using haga meter and the survival rate of each species was counted. Data collected was analysed using one-way analysis of variance (ANOVA) to determine the height and dbh increment variations between dipterocarp species and by Duncan’s multiple range test (DMRT) to detect significant differences of means between dipterocarp species. Analysis was performed using Statistical Analysis System version 9.0 and the significance level was set at 0.05.

RESULTS AND DISCUSSION

Survival rate

Survival rate of dipterocarps varied between species (Figure 3). At 6.5 years old, 7 species, had more than 70% survival rate. They were *S. leprosula*, *S. guiso*, *S. macrophylla*, *S. fallax*, *S. johorensis*, *S. leavis* and *S. ovalis*.
The study indicated that many species of dipterocarps had the potential to enrich a logged-over area of tropical rainforest. However, earlier studies involving enrichment planting of logged-over area had varied results. Affendi et al. (2009) reported that *S. leprosula* had poor survival rate of 20.7%. Adjers et al. (1996) reported that survival rate of 10 dipterocarps varied from 5 to 78% after 2 years of planting.

In this research, *S. platyclados* appeared to have lower survival rate (42.5 ± 3.2%) compared with *S. platyclados* planted by Ang and Maruyama (1995). The mortality of *S. platyclados* and other dipterocarp seedlings were mainly due to dehydration. Moreover, this species had not grown enough to tolerate direct sunlight. Land clearing in tropical rainforest also increases water stress of planted seedlings and relative light intensity (Kamo et al. 2009). Survival rate of dipterocarps decreased rapidly during the first 1.5 years and became stable after 3.5 years (Figure 3). It indicated that they had adapted to the site condition.

**Dbh growth**

ANOVA showed that there were significant differences between species (F = 6.27, p < 0.001) in dbh variable (Table 1). The five fast-growing species of dipterocarps based on DMRT analysis—*S. platyclados, S. leprosula, S. macrophylla, S. parvifolia* and *S. dasyphylla* showed dominant growth and performance where mean annual increment (MAI) of dbh was more than 1.90 cm year\(^{-1}\) (Table 2). The best two species based on MAI of dbh was achieved by *S. platyclados* and *S. leprosula*, i.e. 2.56 and 2.20 cm year\(^{-1}\) respectively. Species with moderate growth based on MAI of dbh were *S. ovalis, S. johorensis, S. scaberima, S. smithiana, S. virescens* and *S. pinanga* (1.48–1.71 cm year\(^{-1}\)). The two species that had the lowest growth of MAI dbh were *S. macroptera* and *D. caudiferus* (1.01 and 0.87 cm year\(^{-1}\) respectively). The dbh growth trend of Dipterocarpaceae in the early stage was linear with *S. platyclados* and *D. caudiferus* showing y = 2.47x + 0.10 (r\(^2\) = 0.99) and y = 0.77x + 0.67 (r\(^2\) = 0.99) respectively (Figure 4).

**Height growth**

Height growth showed relative similar pattern to dbh growth where *S. platyclados* and *S. leprosula* had the highest growth (Table 2). However, *S. johorensis* had height growth better than *S. parvifolia* and *S. macrophylla*. At 6.5 years old, the best two species based on MAI of height growth were *S. platyclados* and *S. leprosula*, i.e. 1.33 and
respectively. ANOVA showed significant difference in height (F = 5.54) (Table 1). Some species classified as moderate growth were S. parvifolia, S. macrophylla, S. dasyphylla, S. scaberima and S. smithiana (1.02–1.10 m year\(^{-1}\)) (Table 2).

The species with lowest height was S. macroptera where the MAI of height was 0.67 m year\(^{-1}\). Some saplings of dipterocarps were sensitive to light during the initial establishment stage but later responded to light to support their growth. The height growth trend in the early stage was linear for S. platyclados and D. caudiferus (y = 1.22x + 0.89 (r\(^2\) = 0.99) and y = 0.57x + 1.07 (r\(^2\) = 0.92) respectively) (Figure 5).

**Species evaluation**

Dipterocarp species have different requirements during their early survival and growth. When they were established on degraded tropical rainforest initially their growth was under shade. Some species of dipterocarps prefer to grow in shade condition while others can grow well in gaps of different widths (Appanah & Weinland 1996). The main constraint for some dipterocarps to survive is high air temperature. The average air temperature in the morning, afternoon and evening were 23.98, 33.16 and 30.29 °C respectively. On the other hand, the average relative humidity in the morning, afternoon and evening were 60.98, 53.16 and 45.29% respectively. Some species showed significant difference in height (F = 5.54) (Table 1). Some species classified as moderate growth were S. parvifolia, S. macrophylla, S. dasyphylla, S. scaberima and S. smithiana (1.02–1.10 m year\(^{-1}\)) (Table 2).

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### Table 1

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Df</th>
<th>Mean square</th>
<th>F value</th>
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** = significant at 0.01 level of probability; Df = degree of freedom; Dbh = diameter at breast height

### Table 2

The average of dbh and height of 23 dipterocarp species at 6.5 years old

<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Dbh (cm)</th>
<th>Standard deviation</th>
<th>No.</th>
<th>Species</th>
<th>Height (m)</th>
<th>Standard deviation</th>
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<td>2</td>
<td>S. leprosula</td>
<td>14.32</td>
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<td>S. dasyphylla</td>
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<td>5</td>
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<td>2.37</td>
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</table>

1.28 m year\(^{-1}\) respectively. ANOVA showed significant difference in height (F = 5.54) (Table 1). Some species classified as moderate growth were S. parvifolia, S. macrophylla, S. dasyphylla, S. scaberima and S. smithiana (1.02–1.10 m year\(^{-1}\)) (Table 2).
evening were 99.9, 78.6 and 87.6% respectively. The high air temperature and low relative temperature will increase water loss from the leaf and cause stomata closure. On the other hand, the rate of net photosynthesis will be reduced and the tree will have low survival (Ang 2005).

Based on survival rate, dbh and height growth, dipterocarp species that could be selected for rehabilitation of degraded tropical rainforest were *S. leprosula*, *S. parvifolia*, *S. macrophylla* and *S. johorensis*. These species showed the highest dbh growth and height as well as high survival rate. Besides they are known as less tolerant to shade in their initial growth and benefit from open area condition (Appanah & Weinland 1993). The four species have potential to rehabilitate logged-over area of tropical rainforest that has low volume or species composition compared with fast-growing exotic tree species (Adjers et al. 1996).

*Shorea leprosula* showed higher dbh growth in the present study compared with those of Affendi et al. (2009) and Symington (1974) who reported...
MAI of dbh 1.03 and 1.2 cm year\(^{-1}\) respectively. *Shorea leprosula* has been known as a dipterocarp species tolerant to water stress and a light demander in the early stage of growth (Appanah & Weinland 1993). This species is also adapted to a wide range of site distribution (Newman et al. 1996).

*Shorea parvifolia* is one of the light demanders of dipterocarps. It grows in clay soil on lowland and hill forest up to 800 m above sea level (Appanah & Weinland 1993, Newman et al. 1996). The MAI of dbh and height of *S. parvifolia* in Sampadi and Balai Ringin, Malaysia were 0.48–1.06 and 0.24–0.85 m year\(^{-1}\) respectively (Vincent & Davies 2003).

*Shorea johorensis* has natural distribution in Peninsular Malaysia, Sumatra and Borneo. It needs sites with well-drained alluvium and undulating soil that can be found up to 600 m above sea level (Newman et al. 1996). *Shorea johorensis* reported slow growth in line planting (3 m in line width) system where the survival rate and MAI of dbh at 2 years old were less than 70% and 0.6 cm year\(^{-1}\) (Adjers et al. 1995). Their results contradicted our results where MAI of dbh and height of *S. johorensis* were 1.91 cm year\(^{-1}\) and 1.45 m year\(^{-1}\).

*Shorea macrophylla* can produce wood and illepe nut. It is naturally distributed in Borneo especially in West Kalimantan, East Kalimantan, Brunei as well as central and western Sarawak (Appanah & Weinland 1993, Newman et al. 1996). It can be found below 600 m above sea level and uncommon on hillsides (Newman et al. 1996). Our study showed that MAI of dbh and height of *S. macrophylla* were 2.11 cm year\(^{-1}\) and 1.09 m year\(^{-1}\), Azani et al. (2001) reported that *S. macrophylla* had MAI of dbh and height of 0.44–0.80 cm year\(^{-1}\) and 0.4–0.71 m year\(^{-1}\) respectively. *Shorea macrophylla* is mainly found in riparian site but does not occur on flat or slightly undulating land that is well watered with small stream (Appanah & Weinlad 1993). This species will be recommended for planting in sites prone to flooding (Appanah & Weinland 1996).

The evaluation of dipterocarp species to rehabilitate degraded tropical rainforest is not only based on their growth but also their survival rate to achieve successful rehabilitation. Thus, the choice of tree species to be planted in degraded tropical rainforest is not only from their tolerance to available light but also the ability to adapt to their microclimate. On the other hand, species–site matching of dipterocarp species is needed in large-scale plantation because each species requires different site conditions. For example, *S. leprosula* needs sites with sufficient soil water, only occasional water stress and no perched water tables (Ashton 1982); *S. macrophylla* can be planted in impeded drainage or riparian site (Appanah & Weinland 1996).

High variation in growth rates (dbh and height) between species provides us opportunity to select fast-growing and valuable wood of dipterocarps in large-scale dipterocarp plantation. This will conserve dipterocarp species from extinction and improve productivity of tropical rainforest. Collection of seeds from plus trees of selected dipterocarp species should be conducted to establish progeny test so that suitable plus tree can be propagated by generative or vegetative technique to support future large-scale dipterocarp plantation (Zaki et al. 2002).

**CONCLUSIONS**

*Shorea platyclados* had the highest MAI both in dbh and height, i.e. 2.56 cm year\(^{-1}\) and 1.33 m year\(^{-1}\) respectively but had low survival rate (42.5%). The species recommended for rehabilitation of degraded area of tropical rainforest were *S. leprosula, S. parvifolia, S. macrophylla* and *S. johorensis*. These species had high survival rate as well as growth of dbh and height. These species not only can produce valuable wood in 20–30 years time but they are also considered to protect and conserve indigenous species in tropical rainforests.

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