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Preliminary Assessment on the Growth Performance of *Dryobalanops beccarii* Dyer Planted under Enrichment Planting Technique at Gunung Apeng Forest Reserve, Sarawak, Malaysia

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Abstract

Reforestation of degraded areas in Sarawak, Malaysia is vital in an effort to conserve the dynamic forest resources in Borneo. A preliminary assessment was conducted in providing the information on the growth performance and survival rate of planted indigenous Dipterocarp species (*Dryobalanops beccarii Dyer*) for reforestation purpose in Sarawak. In this study, reforestation areas which were planted with *Dryobalanops beccarii* under line planting technique were selected. Study sites were established in the reforestation areas (areas planted with *D. beccarii* in the year 2005; DB05 and 2008; DB08). The assessment on the growth performance of planted *D. beccarii* at different age stand was evaluated by measuring the stem diameter, height and survival rate from October 2010 to December 2012. Our findings showed that the survival rate of planted trees in DB05 and DB08 were at 88% and 86%, respectively. For the tree height and stem diameter, the results showed that the tree height and stem diameter in DB05 was 4.9 m and 3.6 cm, respectively. Meanwhile, the assessment on the tree height and stem diameter in DB08 was 1.9 m and 0.9 cm, respectively. The mean annual increment in height (MAIH) and diameter (MAID) of planted *D. beccarii* in DB05 was significantly higher than DB08. High survival rate and substantial growth performance of *D. beccarii* indicated that site edaphic condition such as competition between planted and existing pioneer species of the study area may have affected the survival rate and growth performance of planted *D. beccarii*. Therefore, further studies are required in order to find out the soil-plant relationship of *D. beccarii* as well as other edaphic factors which may affect the growth and survival of *D. beccarii* under line planting technique.

Key words: reforestation, line planting technique, *Dryobalanops beccarii Dyer*, Gunung Apeng Forest Reserve

Introduction

Tropical rainforests are considered as the most productive of all terrestrial ecosystems and they possess the functional roles for biodiversity conservation, world climate amelioration and soil conservation (Whitemore, 1998). In many parts of the tropics, vast forest areas have been impacted by overexploitation of forest resources such as excessive harvesting, shifting cultivation, repeated fire and other disturbances that damages the soil and vegetation. Such exploitation has reached to a degree that severely delays the establishment of forest structure after abandonment.

Reforestation is indispensable to prevent further loss of biodiversity under tropical rainforest ecosystem and restore soil fertility while increasing productivity of poor vegetation stock. As an option, reforestation through plantation forestry by planting high quality indigenous of Dipterocarp is considered as one of the effective way to accelerate recovery of the original ecosystem (Adjers *et al*., 1995; Appanah and Weiland, 1996). Dipterocarp species are the predominant tree species of the upper canopy of rainforests and suitable for reforestation under an artificial planting forestry (Okamura *et al*., 1999). Among the most common Dipterocarp species used for reforestation in Sarawak is *Dryobalanops beccarii* Dyer

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or locally known as *Kapur bukit* (Talip *et al*., 2011). Listed as Endangered under International Union for Conservation of Nature (IUCN) Red List of Threatened Species, *D. beccarii* is a large emergent, heavy hardwood tree which could rise up to 65 m tall and, is commonly found on shallow leached soils over both sandstone and shale of Mixed Dipterocarp Forests in Malaysia (Ashton, 1998; 2004). For humid tropics of Sarawak, Malaysia, *D. beccarii* are among the predominant tree species of the upper canopy of Hill Dipterocarp Forests which is suitable for reforestation under an artificial planting due to its importance as one of the climax tree species.

In Sarawak, the local authority, Forest Department, Sarawak in cooperation with several international agencies have implemented a reforestation activities by planting indigenous species (Dipterocarp species) for restoration of tropical rainforest at degraded areas (Talip *et al*., 2011). Among them, the implementation joint tree planting activities under the Friendship Forests Project involving the participation from Japan and Sarawak. This effort was initiated to enable the society, especially the local to appreciate the forests of Sarawak and at the same time, participate in the restoration of tropical rainforest through tree planting activities. Such efforts are especially significant in restoring small areas deforested by various activities such as illegal logging and shifting cultivation within the permanent forest estate and totally protected areas which would not be of economic size for big-scale plantation operators. At the same time, such reforestation activity was ecological in nature which aims in restoring the deforested areas through the establishment of vegetative cover while economic returns from the planting were not a major consideration.

Reforestation efforts require comprehensive understanding and assessment on the ecosystem involved as an attempt to provide proper techniques in reforestation efforts in the future. Various reports have stated that the progress of reforestation activities with various planting techniques for the purpose of rehabilitating degraded areas at tropical region (Nik Muhamad *et al*., 1994; Suhaili *et al*., 1998; McNamara *et al*., 2006) as well as assessment of planted trees under monoculture plantation of fast-growing exotic species (Tilki and Fisher, 1998; Norisada *et al*., 2005). Furthermore, several studies have been conducted in Sarawak to understand the ecological aspects for restoration of tropical rainforests from an experimental basis (Sakurai *et al*., 1999; Ninomiya *et al*., 2008; Hattori, 2009). These reports have focused on species selection for replanting in relation to the growth performance, various planting techniques and soil characteristics on areas after establishment of rehabilitation activities. In addition, several studies are available which concern with assessment of planted trees and the changes of the surrounding ecosystem under monoculture plantation of fast-growing exotic species (Tilki and Fisher, 1998; Norisada *et al*., 2005). However, still less information is available on the performance and survivability of planted indigenous tree species under reforestation as implemented by the local authorities in Sarawak.

Hence, this study will discuss preliminary information on the current state of the growth performance and survival rate of *D. beccarii* planted under line planting technique for forest rehabilitation purpose.

Materials and Methods

Brief information on Gunung Apeng Forest Reserve reforestation site

Gunung Apeng Forest Reserve reforestation sites (N00°55'24.7'', E110°38'32.2'') is located at Serian district which is approximately 100 km of southeast of Kuching city (Fig. 1). With an average annual precipitation of around 3,500 mm, the monthly minimum precipitation in the area exceeded 100 mm except for a period between mid-June to end of July (Department of Irrigation and Drainage, 2010). Annual temperatures ranged between 23 °C (73 °F) in the early hours of the morning and rises to around 33 °C (91 °F) during mid-afternoon with little monthly variation.

As part of the continuous efforts by the Forest Department, Sarawak in restoring the abandoned shifting cultivation area at various forest reserves in Sarawak, joint tree planting activities involving the participation of Japanese citizens and the people of Sarawak was initiated through the establishment of the Friendship Forests since 1995. In the year 2005, Forest Department of Sarawak, along with various international agencies had initiated a reforestation program to restore the tropical rainforest by planting various types of Dipterocarp species in Gunung Apeng FR. Since the implementation of this project, about 90,000 trees of various types of indigenous tree species were planted in an area of about 225.0 hectare

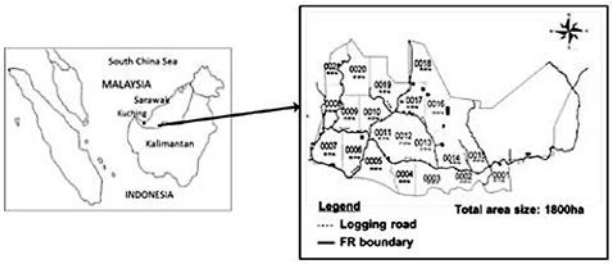

Fig. 1. Map and location of study area.

(Talip *et al*., 2011). Among the planted species were *Kapur bukit (Dryobalanops beccarii Dyer), Engkabang jantong (Shorea macrophylla), Selangan batu (Shorea falcifera), Meranti sarang punai (Shorea parvifolia) and Bintangor bukit (Calophyllum alboramulum). Moreover, as an effort to introduce agroforestry to the surrounding local communities, local fruit trees such as Petai (Parkia singularis) and Durian (Durio excelcus) were also planted*.

The reforestation sites were established at secondary forests which developed from previous history of selective logging and slash and burn activities. All tree seedlings were planted under line-planting technique with lines cut 5 m apart and trees planted at 5 m interval along the lines (Fig. 2). Arifin et al. (2008) reported that line planting technique is a suitable option for rehabilitation of degraded land as implementation of such planting technique is less complicated since only minimal number of tree seedlings are needed for rehabilitation purpose.

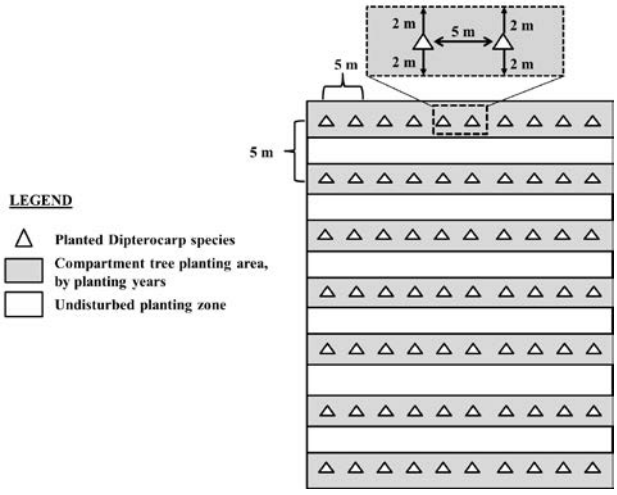

Fig. 2. Outline of study plot under line planting technique.

Since establishment, weeding activity in the reforestation area was conducted twice annually where all herbaceous species and seedlings of pioneer species were slashed at 2 m width along the planting line by manual slashing with bush knife. For larger pioneer tree species, they were left uncut at between the planting lines. According to Wasli and Sani (2011), a total of 18 species from 10 families which are mainly of secondary species were recorded in the study plots of DB05 and DB07 (Table 1). The tree crown of the existing pioneer species in the study plots provide natural shades for planted *D. beccarii* from strong light intensity. Among the common pioneer species which exist within the study plots are namely *Macaranga gigantea, Melanorrhoea* spp., *Sterculia spp*., *Antidesma* spp., *Eugienia* spp., and *Dioscorea* spp. Most of these species were commonly found in abandoned lands after shifting cultivation (Tanaka *et al*., 2007; Wasli *et al*., 2009).

Method for assessment of growth performance and survival rate of *D. beccarii*

In this assessment, study plots with the size of 100 x 75 m^2 were constructed within the compartment planted with *D. beccarii* at two different age tree stand (planted in year 2005 and 2008). Assessment on the growth performance and survival rate of planted *D. beccarii* was conducted from October 2010 to March 2012. It should be noted that abbreviation used to represent each study

Table 1. List of common tree species encountered in reforestation area.

No.	Vernacular name	Name	Family
1	*Ara*	*Ficus* spp.	Moraceae
2	*Biris laut*	*Sterculia* spp.	Sterculiaceae
3	*Entawah*	*Blumeodendron kurzii*	Euphorbiaceae
4	*Rengas*	*Melanorrhoea* spp.	Anacardiaceae
5	*Telinga gajah*	*Macaranga gigantea*	Euphorbiaceae
6	*Bernai*	*Antidesma* spp.	Euphorbiaceae
7	*Terbulan*	*Endospermum diadenum*	Euphorbiaceae
8	*Ubah*	*Eugienia* spp.	Myrtaceae
9	*Pling*	*Macaranga lowii*	Euphorbiaceae
10	*Meran*	*Ficus elastica*	Moraceae
11	*Ruban*	*Symplocos* spp.	Symplocaceae
12	*Kehet*	*Macaranga beccariana*	Euphorbiaceae
13	*Kayu bulus*	*Ixonanthes* spp.	Ixonanthaceae
14	*Kadamba*	*Neolarmarckia cadamba*	Rubiaceae
15	*Terap*	*Artocarpus sericicarpus*	Moraceae
16	*Pulai*	*Alstonia scholaris*	Apocynaceae
17	*Kroton*	*Croton* spp.	Euphorbiaceae
18	*Rambutan hutan*	*Nephelium subferruginuem*	Sapindaceae

plots are; DB05 (*D. beccarii* planted in year 2005) and DB08 (*D. beccarii* planted in year 2008).

The assessment on the growth performance involved measurements such as tree stem diameter and tree height. The diameter of the assessed trees was taken at 30 cm from the ground level using electronic caliper. The trees total height was measured using trigonometry principles from ground level to the point where the top part of the tree. For survival rate of the planted tree within the study plot, calculation was made using the following formula:

$$\text{Survival rate, } X = \frac{Z}{Y} \times 100\ \%$$

where, X = Survival rate of planted trees
Y = Total planted trees
Z = Total number of standing trees

For the mean annual increment in term of tree height (MAIH) and diameter (MAID), both values were estimated using the average values of tree height and stem diameter of assessed trees with the age stand of the study plot. Then, the MAIH and MAID of the study plots were compared using student's *t*-test.

Results and Discussion

General information on the soils in the studied area

Based on the Sarawak soil classification system, the soils in the area were classified into Nyalau family of the Red-Yellow Podzolic Soil group (Teng, 2004). The soils in the study area were derived from sedimentary rocks mainly of mixed shale and sandstone.

In Sarawak, soil of this group mainly consisted at low hills and dissected hills behind the coastal alluvium and coastal swamps which extended throughout the length of northeast-southwest axis of Sarawak region. At these areas, dominant landforms of this zone consist of low hills and dissected hills of 30-150m highly separated by narrow bottomland tracts along major tributary streams. The slopes in such area are gently rolling to moderately steep ranging from 6 to 25 degrees.

This soil group corresponds to soil group of Paleudults based on the USDA classification system (Soil Survey Staff, 2006). Such soil possess udic moisture regime that are characterized by brown to red colours with weak podzolic features. Soils of these features consist of friable to firm consistency, and weakly to moderately developed structure. The soils are well-drained to moderately well-drained and have variable soil depths. According to Soil Survey Staff (2006), such soils do not possess densic, lithic, paralithic, or petroferric contact within 150 cm of the mineral soil surface and do not have a clay decrease of 20 percent or more from the maximum clay content. In addition, the soils have 5 percent or more skeletans on faces of peds in the layer that has lower clay content and a clay increase of 3 percent or more in the fine-earth fractions.

Soils under such classification are generally acidic with poor natural fertility (Teng, 1994). Although commonly rated as marginally suitable for any agricultural activities, capability of the soils in accommodating wide range of tropical crops such as tree based crops namely rubber and fruit trees can be improved if implemented under careful land management practices i.e. construction of contour terraces.

Survival rate and growth performance of planted *D. beccarii* in DB05 and DB08

The survival rate of planted *D. beccarii* in DB05 and DB08 were shown in the Fig. 3. During the initial assessment conducted on October 2010, the survival rate of planted trees in the DB05 and DB08 were at 88% and 86%, respectively. The survival rate of planted trees in both plots was consistent since the initial assessment until March 2012. However, during the assessment in December 2012, the survival rate in both study plots decreased inevitably where the survival rate of *D. beccarii* in the DB05 and DB08 were at 79% and 65%, respectively. The sudden decrease in survival rate of *D. beccarii* during the assessment in December 2012 was due to the damage caused by fallen pioneer trees from severe winds and thunderstorms in the study area.

Fig. 4 shows the tree height and stem diameter of planted *D. beccarii* in DB05 and DB08 as observed during the period of assessment. In term of the tree height, the initial assessment on the tree height in both study plot revealed that the average tree height in DB05

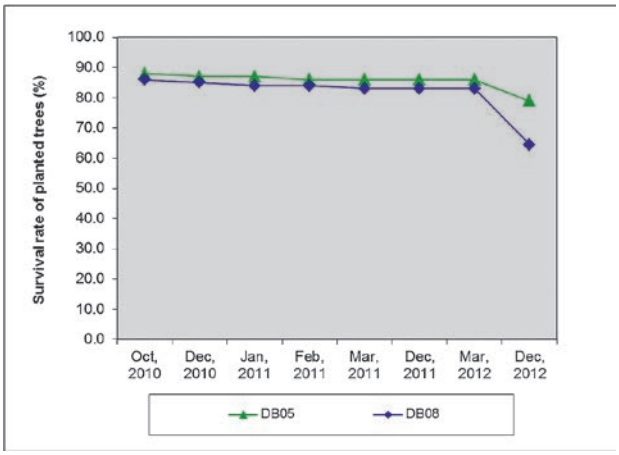

Fig. 3. Survival rate of planted *Dryobalanops beccarii* in DB05 and DB08 plots.

and DB08 was at 3.6 m and 1.3 m, respectively. The trend in term of tree height in DB05 and DBB08 showed gradual increment since the initial measurement. For the measurement in December 2012, the average tree height of trees in DB05 and DB08 were 4.9 m and 1.9 m, respectively. On the other hand, the initial assessment on the stem diameter of planted *D. beccarii* in DB05 and DB08 plot was at 2.5 cm and 0.8 cm, respectively. Similar to the trend in term of tree height, the trend for stem diameter of planted *D. beccarii* since the initial measurement showed positive increment. However, the measurement taken in December 2012 revealed that the stem diameter of planted trees of DB08 decreased to 0.9 cm while for stem diameter of trees in DB05, it increased abruptly to 3.8 cm. One of the possible reasons to the decrement of the stem diameter value in DB08 was due to the high mortality rate of bigger sized planted trees in the study plot. Out of 200 planted *D. beccarii* in DB08, 37 trees which were affected due to high mortality rate possessed stem diameter ranging from 1.5 – 2.0 cm (data not shown).

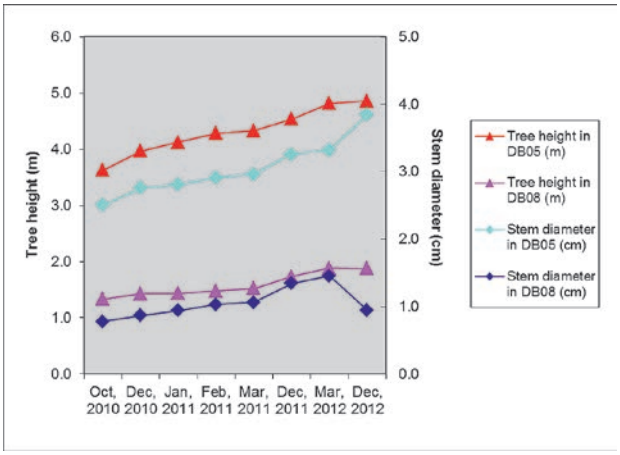

Fig. 4. The tree height and stem diameter of *D. beccarii* in DB05 and DB08 as observed from October 2010 – December 2012.

Fig. 5 shows the tree height and diameter class of planted *D. beccarii* in DB05 and DB08. It is noted that the tree height and diameter class were constructed using the data obtained in December 2012. For DB05, most of the trees were at the tree height class of 5–6 m, while some trees possess the tree height exceeding 7 m. As for the tree height in DB08, most of the planted trees were classified at the range of below 2 m. For the stem diameter, diameter sizes of planted trees in DB05 were fairly distributed with some trees possess stem diameter exceeding 6 cm. In addition, the stem diameter classes for planted trees in DB08 showed that most of the stem diameter of the trees was with size of less than 1 cm. The results indicated that without taking into consideration of the age stand of the study plots, trees in DB05 showed promising growth rate as compared to trees planted in DB08.

The mean annual increment of height (MAIH) and stem diameter (MAID) of planted *D. beccarii* in DB05 and DB08 are shown in Fig. 6. The results showed that the MAIH of DB05 (0.69 m year^{-1}) was significantly higher as compared to the MAIH of DB08 (0.47 m year^{-1}) (p<0.05). In addition, MAID of planted trees in DB05 (0.55 cm year^{-1}) was significantly higher than MAID of planted trees in DB08 (0.24 cm year^{-1}) (p<0.05). Our field observation suggested that factors such as topographical features and competition between the existing pioneer species in both study sites may have contributed to differences in terms of the MAIH and MAID in DB05 and DB08. It was observed that the degree of slope in DB08 (overall slope degree at 28°) was much higher as compared to DB05 (slope degree at 10°). Itoh et al. (2003) explained that the soil texture and topographical features largely effect the spatial distribution of *Dryobalanops* species under natural tropical rainforests.

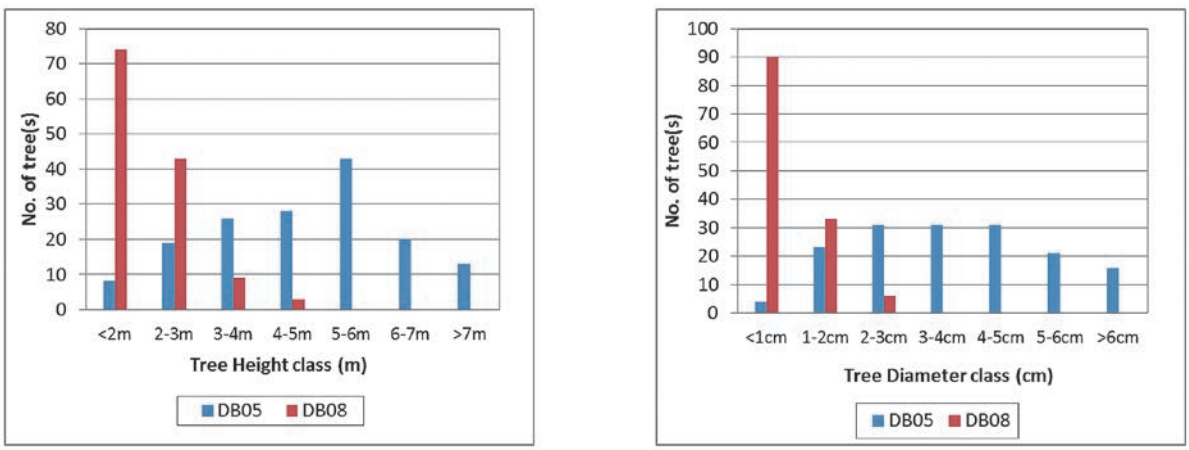

Fig. 5. The tree height and stem diameter class of *D. beccarii* in DB05 and DB08 as observed in December 2012.

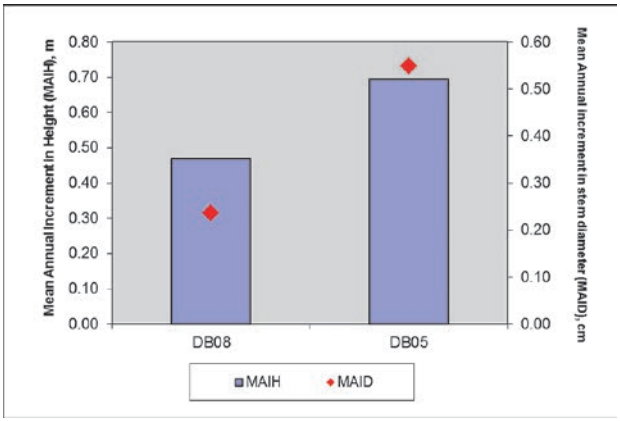

Fig. 6. Mean annual increment in term of tree height (MAIH) and stem diameter (MAID) in DB05 and DB08.

In order to find out the fundamental information on the suitability of *D. beccarii* for reforestation purpose, we compared our findings with previous studies on experimental reforestation effort to rehabilitate degraded lands by using Dipterocarp species trees under various forms of planting techniques in Malaysia (Table 2). It should be noted that although various edaphic factors may influence over speculation when comparing the performance of planted trees for rehabilitation purpose in this study with previous studies, the discussion from this comparisons is mainly to determine whether the planted *D. beccarii* in this study is suitable to be used as planting seedlings for future rehabilitation purpose in the study area.

Irrespective of the difference in stand age after planting, planting techniques and types of planted tree species, overall observation suggested that the survival rate of the planted *D. beccarii* in this study was higher than that reported by other studies. Moreover, the MAIH value of *D. beccarii* planted in this study was higher as compared to the Dipterocarp species planted under open planting (OP) and Island Corridor planting scheme (ICPS). It should be noted that at the age stand of 7 years after planting, the survival rate of *Dryobalanops beccarii* was higher than that of *Dryobalanops aromatica* (8%) planted under open planting technique by Hamzah et al. (2009). The effect of over exposure of light to the planted seedlings under open planting could be the main reason behind the low survival rate of planted *Dryobalanops aromatica*. Although the survival rate of the *D. beccarii* planted in Gunung Apeng Forest Reserve were substantial, it is expected that the survival rate of *D. beccarii* will slightly decrease when the planted trees reached its maturity due to competition for space, nutrients in soil and light requirement for the planted trees after a certain period of time. According to Lavelle (1987), under an open area after forest clearing, dramatic changes will occur in the temperature and moisture at surface soils which later will create large diurnal range and drier and hot surface soils. Under such scheme, nutrients will be lost rapidly through erosion and leaching and, high water evaporation could lead to soil drying quickly (Lu *et al*., 2002).

Dipterocarp species shows relatively slow growth rate but it is adapting well to sufficient amount of sunlight when planted in land with poor soil properties (Adjers *et al*., 1995; Appanah and Weiland, 1996; Vincent and Davies, 2003). The differences in growth rate and survival rate of Dipterocarp species largely affected by several environmental factors such as planting technique, drought season, weed competition and sunlight intensity. Line planting technique as adapted in this study enables undisturbed pioneer species which has grown naturally before establishment of planting lines to provide shades for the planted seedlings to reduce over exposure to sunlight. Adjers et al. (1995) reported that line planting technique is suitable to be adapted for reforestation activities under homogenous secondary forests or fallow forests after shifting cultivation where stratification of canopy

Table 2. The growth rates of planted species in this study and other previous study on reforestation in Malaysia.

Studied species	Stand age (yrs)	Survival rate (%)	MAIH (m yr^{-1})	MAID (cm yr^{-1})	Planting technique [a)]	Source
Dryobalanops beccarii	4	84	0.47	0.24	LP	Present study
Dryobalanops beccarii	7	86	0.69	0.55	LP	Present study
Dryobalanops aromatica	6	8	0.43	0.41	OP	Hamzah et al. 2009
Dryobalanops beccarii	7	58	0.50	0.29	ICPS	Hattori, 2009
Dryobalanops beccarii	7	50	0.52	0.30	ICPS	Hattori, 2009
Shorea pauciflora	11	34	0.67	0.74	LP	Abdu *et al*., 2008
Shorea macroptera	11	47	0.61	0.67	LP	Abdu *et al*., 2008

[a)] Planting techniques: LP, line planting; OP, open planting; ICPS, Island Corridor Planting Scheme

layers has not been fully developed. Besides that, in such planting technique, conducting silvicultural activities will become easier as the spaces between the planted seedlings are uniform. Notwithstanding, proper silvicultural practice in the reforestation area under line planting techniques should be considered as dominant pioneer tree species in DB05 and DB08 would create a competition for the planted *D. beccarii*.

Conclusion

As a conclusion, the preliminary assessment on planted *D. beccarii* tree under line planting technique at reforestation site in Gunung Apeng Forest Reserve showed positive progress in terms of its survival rate and growth performance. Our findings implied that *D. beccarii* is suitable for forest rehabilitation purpose in the study area and positive outcome could be achieved from this reforestation effort on a long run. Other than the suitability of adapted planting techniques, other possible reason behind the substantial growth rate in term of diameter and height associated with high survival rate of *D. beccarii* could be due to the adaptability of planted trees to grow under certain soil condition or competition for light between planted trees and naturally grown trees which was undisturbed with the planting line. Therefore, further studies are required in order to find out the soil-plant relationship of *D. beccarii* as well as other edaphic factors which could affect the growth and survival of *D. beccarii* under line planting technique.

Acknowledgments

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