PERFORMANCE OF TEN DIPTEROCARP SPECIES IN RESTOCKING LOGGED-OVER FOREST AREAS SUBJECTED TO SHIFTING CULTIVATION

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ÅDJERS, G., KUUSIPALO, J., HADENGGANAN, S., NURYANTO, K. & VESA, L. 1996. Performance on ten dipterocarp species in restocking logged-over forest areas subjected to shifting cultivation. The objective of this study was to test field performance of ten dipterocarp tree species line planted in a secondary forest previously subjected to intensive logging and shifting cultivation. The trial was arranged in a randomised complete block design with six replications and the data analysed using analyses of variance with aposteriori comparisons of means. Marked differences were identified among species for each individual variable. The best ranking species overall were *Shorea leprosula, S. johorensis, S. parvifolia* and *Hopea sangal*. Their survival varied from 48 to 78% with average mean annual height and diameter (DBH) increments from 1.27 to 0.84 m and from 1.14 to 0.56 cm respectively. These *Shorea* spp. have also performed well in other sites. *Hopea sangal* should be considered for the future. The *Dipterocarpus* spp. included in the trial performed poorly. Mortality leveled out after the second year stressing the importance of maintenance in the beginning. Dipterocarp species should be tested in multi-locational trials in order to acquire more information on site/species matching.

Key words: Dipterocarp - enrichment planting - line planting - restocking - rehabilitation - secondary forest - species trial

ÅDJERS, G., KUUSIPALO, J., HADENGGANAN, S., NURYANTO, K. & VESA, L. 1996. Prestasi sepuluh spesies dipterokap dalam penstokan semula kawasan hutan sudah kerja yang terdedah kepada pertanian pindah. Kajian ini bertujuan untuk menilai prestasi lapangan sepuluh spesies pokok-pokok dipterokap yang ditanam secara berbaris di hutan sekunder yang sebelumnya didedahkan kepada pembalakan secara intensif dan pertanian pindah. Percubaan tersebut disusun dalam reka bentuk blok lengkap rambang dengan enam ulangan dan data dianalisis menggunakan analisis varian dengan perbandingan aposteriori untuk purata. Perbezaan-perbezaan yang ketara dikenalpasti di kalangan spesies bagi setiap pembolehubah. Spesies terbaik secara keseluruhannya ialah *Shorea leprosula, S. johorensis, S. parvifolia* dan *Hopea sangal*. Kemandiriannya berjulat antara 40 hingga 78% dengan purata ketinggian tahunan dan pertambahan garispusat (DBH) masing-masing daripada 1.27 hingga 0.48 m dan 1.14 hingga 0.56 cm. Kumpulan *Shorea* spp. ini juga menunjukkan prestasi yang baik di tapak-tapak yang lain. *Hopea sangal* patut dipertimbangkan untuk masa hadapan. *Dipterokarpus* spp. yang termasuk di dalam percubaan menunjukkan prestasi yang teruk. Selepas tahun kedua, kematian menjadi kekal menandakan kepentingan

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penyelenggaraan di peringkat awal. Spesies dipterokap patut diuji di percubaan berbagai lokasi bagi memperoleh lebih maklumat mengenai pemadanan spesies/ tapak.

Introduction

Dipterocarp forests of Southeast Asia, due to repeated logging and subsequent shifting cultivation, have been depleted and are currently in need of rehabilitation. According to ITTO statistics (1990), there are at least 70 million hectares of seriously depleted forests in Southeast Asia. Deforestation in the Asia/Pacific region is continuing with the forest area decreasing at the estimated rate of *c.*1.8 million hectares per annuum (ITTO 1990). Without quick rehabilitation, many of these forests will be converted into low-productivity bushlands or grasslands.

Indonesia alone is estimated to have 36 million hectares of depleted forests requiring rehabilitation. In addition to 20 million hectares of *Imperata cylindrica* grasslands (alang-alang), there are 16 million hectares of logged-over forests with a remaining tree volume of less than 39 m^3 ha^{-1} (ITTO 1990). In areas where there are enough residual mother trees to give rise to sufficient supply of ephemeral seedling stock, liberation cuttings are suggested to ensure rapid regrowth of dipterocarp trees (Ådjers *et al.* 1995). Unfortunately, as a consequence of repeated selective logging, large areas are in extremely poor condition: mother trees are scarce and secondary forest species prevail.

Post-logging shifting cultivation makes rehabilitation of dipterocarp forests more difficult. Dipterocarp seedlings do not usually survive disturbance from fire, and natural regeneration from a distance is unlikely to happen due to the large size of the seed. Burned areas must therefore always be replanted (Riswan & Kartawinata 1991). In Indonesia alone, 11 million hectares of land are currently under shifting cultivation (Thangam 1989). In the rehabilitation of production forests, as well as conservation forests, techniques to reintroduce the original dipterocarp stock are consequently needed. Although the dipterocarps are of great commercial importance, in Indonesia there is little information on species/site matching, which is extremely important for planning restocking activities (e.g. Anonymous 1992).

In the present study, we tested the field performance of ten species of the Dipterocarpaceae family, collected as wildings from natural forest in the vicinity of the trial area. The aim of the trial was to test and recommend valuable timber tree species of local origin fit for restocking low-volume logged-over forests which have been previously subjected to shifting cultivation and which have consequently lost their natural regeneration capacity.

Materials and methods

Study area

The Kintap trial area is located on undulating terrain within an active timber concession area some 150 km southeast of Banjarmasin, the provincial capital of South Kalimantan (03°42'S, 115°09'E; elevation 100 m a.s.l.). The original forest was of mixed dipterocarp rain forest type typical of moist tropical lowland areas of the region. The average annual rainfall was 3725 mm during 1992-1993, i.e. during the time of our study. In 1993 there was a dry spell only in August, with 54 mm rainfall and 6 rainy days. The total number of rainy days was 174 in 1992 and 169 in 1993. The well-drained, clayish soil prevailing in the area is of the red-yellow podzolic/lateritic type (Anonymous 1985). No organic mor horizon between the litter and mineral horizons could be detected. The bedrock is mainly limestone.

The trial site was logged in 1979 and subsequently subjected to shifting cultivation until 1987. The experimental planting was carried out in December 1991, when the site had already reverted to secondary forest. A survey of the composition of the secondary forest in the area ten years after logging yielded a basal area of 22 m^2 of trees > 5 cm in DBH and an average height of 3 m. The most frequent families with their respective importance values were: Euphorbiaceae (101.7), Moraceae (72.4), Lauraceae (32.6), Verbenaceae (15.7) and Anacardiaceae (15.0) (Kuusipalo *et al.* 1996).

Inside the experimental plot, planting lines were opened so as to allow planted seedlings to receive overhead light (Ådjers *et al.* 1995). Some living residual trees had survived the shifting cultivation activities and these trees were left standing inside the experimental plot.

Species description

The trial included 10 different species of locally occurring dipterocarp species (Table 1), with *Shorea polyandra* as the only "non-local" dipterocarp. This species was brought in the form of seedlings from the Inhutani II nursery in Pulau Laut, South Kalimantan, 50 km from the trial area. All other seedlings were raised as potted wildings collected within the 1000-ha Kintap trial area. The species were identified in the field and the identifications confirmed by taxonomists of the Bogor Herbarium from collected specimens. The wildings were collected and potted into plastic tubes (250 cm^3) filled with top soil, kept in a greenhouse in high air humidity (>95%) for one month and moved out to the shaded area for an additional two months (Hadengganan *et al.* 1992, Ådjers *et al.* 1995).

Table 1. Dipterocarp species included in the trial

No.	Species	Timber group
1	*Shorea johorensis* Foxw.	Red meranti
2	*Shorea leprosula* Miq.	Red meranti
3	*Shorea parvifolia* Dyer	Red meranti
4	*Shorea faguetiana* Heim	Yellow meranti
5	*Shorea fallax* Meijer	Red meranti
6	*Shorea polyandra* Ashton	Yellow meranti
7	*Hopea sangal* Korth.	Cengal, sangal
8	*Dipterocarpus cornutus* Dyer	Keruing
9	*Dipterocarpus kunstleri* King	Keruing
10	*Shorea ovalis* Korth.	Red meranti

Experimental design

The trial was planted as a randomised complete block design with six replications. Each replicate included 10 wildings planted in a line. Each planting line was 2 m wide. Distance between lines was 10 m and the seedlings were planted at a 2 m spacing along the line. At the time of establishment the surrounding pioneer trees were about 3 m in height. The trial was maintained every third month: trees and branches closing the planting line were removed and competing herbs and ferns were slashed in the 2 m wide planting line. This tending method has proven successful (Ådjers *et al.* 1995).

Survival was recorded, and height and diameter D_{10} (10 cm above ground) were measured every sixth month for two years. During the three years of measurement after planting, DBH and crown diameter were also measured. Differences in survival, height, diameter and crown diameter were analysed using Model I ANOVA followed by the associated multiple range tests (LSD 0.01). The data met the assumptions for ANOVA (normality, equality of variances, etc.).

Importance values were calculated as composite ranking by adding up the rankings of each species in survival, height, DBH, D_{10} and crown diameter.

Results

Survival of the species three years after planting varied from 6 to 78% (Table 2). The patterns of mortality are shown in Figure 1. Highly significant differences in survival were established among the species ($F=4.429$; $p=0.0003$). *Hopea sangal*, a species which has received little attention in forestry literature, ranked first in survival. Four of the seven *Shorea* spp. yielded a survival exceeding 50%. *Dipterocarpus cornutus* and *D. kunstleri* had survival rates of 6 and 38% respectively. The survival of the only non-local species, *Shorea polyandra*, was only 24%, which must be considered unsatisfactory. *Shorea ovalis* showed surprisingly poor survival (41%). Virtually no mortality occurred during the last year of the study, with the exception of *S. parvifolia* whose survival dropped from 57 to 47% of the original stock during the third year.

Marked differences were also observed among the species for height, diameter (DBH and D_{10}) and crown diameter growth. Detailed information on growth and ANOVA calculations as well as a composite ranking of the included species is reported in Table 2. The mean annual height increment of *S. johorensis, S. leprosula, S. parvifolia*, and *H. sangal* exceeded 0.8 m y^{1}. This group of species out performed the other species ($p<0.01$). All other species had a mean annual increment (MAI) of height of less than 0.7 m (Figure 2). *Shorea leprosula, S. johorensis* and *S. parvifolia* performed best in diameter increment: MAI of diameter (DBH) exceeded 7.8 mm y^{1}. *Hopea sangal* and *S. fallax* ranked fourth and fifth with 5.6 and 5.1 mm y^{1}. With the remaining species, the diameter increment varied from 0.2 to 4.8 mm y^{1}.

Table 2. Survival, height, stem diameter, crown diameter and composite ranking of 10 dipterocarp species three years after planting

Species	Survival (%)	Height (cm)	DBH (cm)	D_{10} (cm)	Crown diameter (m)	Composite ranking
Dipterocarpus cornutus	5.9 (3.4) a	82.6 (47.5) a	0.49 (0.31) a	1.04 (0.60) a	0.28 (0.28) a	10
Shorea polyandra	23.7 (17.5) ab	192.1 (50.8) abcd	1.16 (0.34) abc	1.50 (0.36) ab	1.35 (0.27) bc	8
Dipterocarpus kunstleri	38.3 (8.0) abc	102.2 (36.5) ab	0.77 (0.27) ab	0.96 (0.33) a	0.57 (0.21) ab	9
Shorea faguetiana	54.7 (9.9) bcd	160.7 (41.5) abc	1.25 (0.13) abc	1.54 (0.17) ab	0.96 (0.10) abc	7
Shorea ovalis	40.8 (15.5) abc	190.2 (44.6) abcd	1.45 (0.39) abc	1.63 (0.41) ab	1.04 (0.26) abc	6
Shorea fallax	66.9 (13.3) cd	152.6 (24.0) abc	1.45 (0.21) abc	2.02 (0.25) ab	1.47 (0.18) c	5
Shorea parvifolia	48.2 (10.7) abcd	266.6 (56.4) cde	2.33 (0.56) bc	2.71 (0.62) bc	1.78 (0.38) cd	3
Hopea sangal	77.9 (9.6) d	251.7 (26.6) bcde	1.68 (0.22) cd	2.03 (0.22) ab	1.45 (0.14) c	3
Shorea johorensis	55.8 (12.1) bcd	382.2 (38.6) e	3.29 (0.36) d	3.56 (0.36) c	2.32 (0.18) d	2
Shorea leprosula	67.2 (7.5) cd	342.9 (35.9) de	3.42 (0.41) d	3.87 (0.47) c	2.47 (0.21) d	1
F-value	4.429	5.736	9.985	7.410	10.492	
p-value	0.0003	< 0.001	< 0.001	< 0.001	< 0.001	

Note: Standard errors of means are in parentheses. Within the columns, means followed by the same letter(s) do not differ significantly ($p < 0.01$).

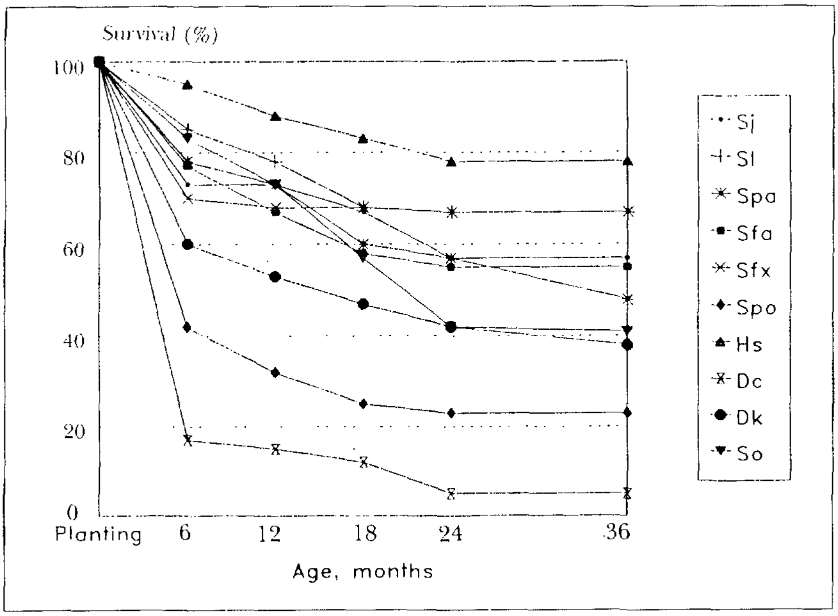

Figure 1. Survival curves for eight dipterocarp species until three years from transplanting. Sj = *Shorea johorensis*, Sl = *S. leprosula*, Spa = *S. parvifolia*, Sfa = *S. faguetiana*, Sfx = *S. fallax*, Spo = *S. polyandra*, Hs = *Hopea sanggal*, Dc = *Dipterocarpus cornutus* Dk = *D. kunstleri*, So = *S. ovalis*

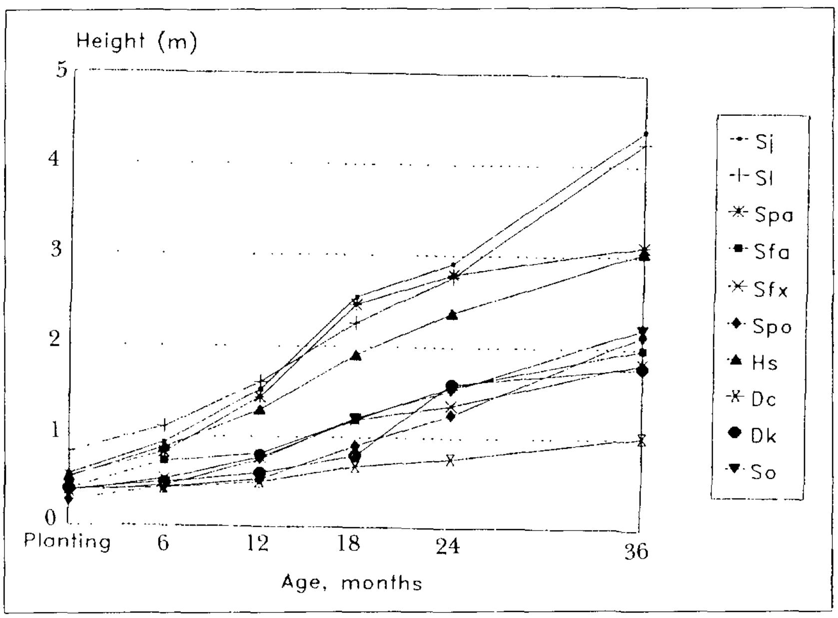

Figure 2. Height increment for eight dipterocarps until three years from transplanting. For species codes, see Figure 1.

With respect to the composite ranking, the best meranti species were *Shorea leprosula*, *S. johorensis* and *S. parvifolia*, followed by *H. sangal*. The red meranti group of species performed well also in previous pilot plantations of the trial area and they can be easily obtained as wildings. The high scoring of *Hopea sangal* was a surprise. The next group of species following in ranking was *S. fallax*, *S. ovalis* and *S. faguetiana*. The two *Dipterocarpus* species, together with *S. polyandra*, showed the poorest performance in our experiment.

Discussion

Our trial shows that the two first years are the most important for securing good performance. Mortality rates leveled out after the second year, with one exception (*S. parvifolia*). The implication of this is that intensive maintenance is needed after planting for at least two years (cf. Lamprecht 1989).

Crown diameter was still relatively small after three years. Suppression of weeds under the tree crowns is thus limited and weeding is needed. According to results by Ådjers *et al.* (1995), the slashing of undergrowth has an insignificant effect on growth when the crown development is good.

Shorea leprosula is a favorite species for planting (Appanah & Weinland 1993) and its fast initial growth has been documented, e.g. by Symington (1943). It requires only minimal maintenance in the secondary forest and benefits from open conditions. Although mother trees occur abundantly in the area, wildings of *S. leprosula* have been difficult to find. In 1994, however, this species was fruiting profusely and the situation might change. *Shorea johorensis* ranked second in our trial. Good performance of this species is in accordance with our previous experience from Kintap area.

Shorea parvifolia is frequently associated with *S. leprosula*. According to Walton (1939, cited by Symington 1943), it grows more slowly and is more tolerant to shade than *S. leprosula*. However, from about the 25th year of age, growth exceeds that of *S. leprosula* (Appanah & Weinland 1993).

Hopea sangal had the best survival rate (78%) of all species and its height as well as diameter ranked fourth. *Hopea sangal* is a reasonable species for consideration in future replanting operations. According to Symington (1943), young *H. sangal* individuals have shown ability to survive even when planted in *Imperata cylindrica* infested sites.

Hopea sangal yielded high survival rate and reasonable height growth also in the Haurbentes trial area in West Java. At the age of 26 years the survival since planting was 91% and the mean annual height and diameter increments were 62 cm y^{-1} and 9.5 mm y^{-1} respectively. Other *Hopea* species tried in the same experiment had even faster growth (Masano *et al.* 1987). *Hopea* species require vertical and horizontal crown opening to perform well (Appanah & Weinland 1993). This species is therefore suitable for line planting, as in our trial.

At a young age *S. ovalis* fails to grow satisfactorily if exposed to full light. It tends to develop galls in full sunlight during early growth (Appanah & Weinland

1993). Despite its slow growth at young age, *S. ovalis* was ranked as the fastest growing red meranti in Malaysia (Symington 1943).

In a species trial conducted in East Kalimantan by Priasukmana (1991), two species were common with our trial. Two-year growth data were adjusted to permit comparison with our results. The East Kalimantan results are reported in brackets.

Species	Survival (%)	Height (m)	Diameter (cm)
Shorea leprosula	67 (38)	1.29 (1.78)	1.55 (1.27)
Shorea ovalis	42 (51)	0.61 (1.88)	0.55 (1.20)

Compared to our results, the height and diameter growths in the East Kalimantan trial were better for both species. Survival of *S. ovalis* was better in East Kalimantan. The relatively high mortality in the East Kalimantan trial was attributed to weeds, climbers and falling litter. Our trial was maintained intensively every third month and the mortality was due to other reasons.

The two species of the genus *Dipterocarpus* showed unsatisfactory performance. In the Haurbentes trial plantations, *D. reusus* and *D. tempehes* yielded a poor and a high survival (39 vs. 92% respectively). Mean annual height growth was less than 1 m and diameter growth less than 1 cm (Masano *et al.* 1987). According to the results of our trial, we recommend better performing species instead.

Young individuals of *S. faguetiana* require shelter from direct sunlight (Martawijaya *et al.* 1986). Line planted seedlings, as in our trial, received full overhead light. The relatively poor performance of *S. faguetiana* could perhaps be attributed to too high light intensity. If this is the case, the species reacts completely differently compared to *S. johorensis*, *S. leprosula* and *S. parvifolia*.

Shorea fallax grew relatively slowly but had the second best survival (67%). *Shorea polyandra* is a valuable timber tree species but showed a poor survival (24%) and slow growth in this trial. In Pulau Laut this species is predominant. We could not find any previous test results on the performance of these two species.

The performance of *S. polyandra* emphasises the importance of locally established dipterocarp species. Although the distance from Pulau Laut and Kintap is only 50 km it seems that site conditions differ and influence the performance. An additional reason for local trial and development activities is the variation in species composition. Species performing poorly in this trial should not be forgotten. Instead, it is recommended that multilocational species trials be established to acquire more information on species/site matching.

Even though the results of this trial were obtained up to the age of three years only, they provide strong support to our view that selected *Shorea* species, together with *Hopea sangal*, should be planted in logged-over secondary forests lacking natural seedling stock. Growth figures obtained in our experiment are still expected to be exceeded as the stock ages but they coincide rather well with those found in the literature (e.g. Evans 1982, Korpelainen *et al.* in print). Volume increment as high as of 10-15 m^3 ha^{-1} y^1 ought to be achieved easily. According to Evans (1982), the growth rate of a managed Southeast Asian dipterocarp forest can be as high as 17 m^3 ha^{-1} y^1.

The results of this trial give some light to the question of which dipterocarp species should be preferred in restocking the abundant secondary forests in Kalimantan. By planting dipterocarps in former shifting cultivation areas an additional source of valuable timber could be obtained. Dipterocarp timber prices are rising continuously as the remaining natural forests become scarce and less easily accessible. With an estimated annual volume increment of 10 m^3 ha^{-1} y^1, the profit would be worth of USD 6 000 - 10 000 per hectare (Korpelainen *et al.* in print). Economical prospects of restocking the logged-over forests with dipterocarps seem therefore promising.

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