EFFECT OF NURSERY PRACTICES ON SEED GERMINATION OF SELECTED DIPTEROCARP SPECIES

R. Otsamo,

University of Helsinki, Department of Forest Ecology, P.O. Box 28 (Viikin koetila 20), SF-00014 University of Helsinki, Finland

G. Ådjers,

PT. Enso Forest Indonesia, S. Widjojo Centre, 5th Floor, Jl. Jenderal Sudirman 71, Jakarta Selatan 12190, Indonesia

J. Kuusipalo, A. Otsamo,

Enso Forest Development Ltd., Reforestation and Tropical Forest Management Project, c/o Balai Teknologi Reboisasi Banjarbaru, P.O. Box 65 (Jl. Sei Ulin 28 B), 70714 Banjarbaru, Kalimantan Selatan, Indonesia

N. Susilo

Balai Teknologi Reboisasi Banjarbaru, P.O. Box 65 (Jl. Sei Ulin 28 B), 70714 Banjarbaru, Kalimantan Selatan, Indonesia

&

K. Tuomela

University of Helsinki, Department of Forest Ecology, P.O. Box 28 (Viikin koetila 20), SF-00014 University of Helsinki, Finland

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OTSAMO, R., ÅDJERS, G., KUUSIPALO, J., OTSAMO, A., SUSILO, N. & TUOMELA, K. 1996. Effect of nursery practices on seed germination of selected dipterocarp species. Effect of nursery practices on germination of six commercially valuable dipterocarp species was studied in three separate experiments in South Kalimantan, Indonesia. Effect of substrate, germination site and sowing position of seed on germination of *Dipterocarpus grandiflorus, D. kunstleri, Hopea sangal, Shorea faguetiana, S. fallax* and *S. parvifolia* was tested. *Shorea parvifolia* showed the highest and most stable germination rates over all treatments with mean germination rate of 85%. *Hopea sangal* (45%) had the highest amount of germinated seeds in river sand or forest topsoil in greenhouse. *Shorea fallax* (19%) exhibited the highest germination rates in peat and rice husk substrate under shading net. *Dipterocarpus grandiflorus* and *D. kunstleri*, with mean germination rates of 13 and 8% respectively, had the lowest germination rates in river sand under shading net. Lying position and position with stalk pointing upwards resulted in the highest germination rates for *S. faguetiana* (89%). River sand and forest topsoil were the best substrates for lying and stalk pointing upwards positions and peat and rice husk the best substrate for position with stalk pointing downwards. Interaction between seed position and germination site showed that seed germination in greenhouse was stable over all seed positions, whereas seeds with stalk pointing downwards had clearly lower germination rates under shading net. Results of this study indicate that seedlings of many dipterocarp species can be raised from seeds. The required techniques are simple and appropriate for both small- and large-scale seedling production. However, there is no single procedure for seedling production of different dipterocarp species, but suitable methods have to be developed separately for each species.

Key words: Seedling production - sowing - substrate - seed position - *Shorea* - *Hopea* - *Dipterocarpus*

OTSAMO, R., ÅDJERS, G., KUUSIPALO, J., OTSAMO, A., SUSILO, N. & TUOMELA, K. 1996. Kesan amalan tapak semaian terhadap percambahan biji benih spesies dipterocarp terpilih. Kesan amalan tapak semaian terhadap percambahan enam spesies dipterocarp yang mempunyai nilai perdagangan telah dikaji di tiga tapak percubaan berasingan di Kalimantan Selatan, Indonesia. Kajian telah dilakukan untuk mengetahui kesan substrat, tapak percambahan dan kedudukan cambahan biji benih ke atas percambahan *Dipterocarpus grandiflorus, D. kunstleri, Hopea sangal, Shorea faguetiana, S. fallax* dan *S. parvifolia*. *Shorea parvifolia* telah menunjukkan kadar percambahan yang terstabil dan tertinggi dalam semua rawatan dengan purata kadar percambahan 85%. Di dalam rumah tanaman *Hopea sangal* (45%) mempunyai jumlah cambahan biji yang tertinggi di dalam pasir sungai dan bunga tanah hutan. *Shorea fallax* (19%) menunjukkan kadar percambahan yang tertinggi di dalam substrat gambut dan sekam padi di bawah naungan jaring. *Dipterocarpus grandiflorus* dan *D. kunstleri*, dengan purata kadar percambahan 13 and 8% masing-masing, mempunyai kadar percambahan terendah di dalam pasir sungai di bawah naungan jaring. Kedudukan berbaring dan kedudukan tangkai mengarah ke atas menghasilkan kadar percambahan tertinggi untuk *S. faguetiana* (89%). Pasir sungai dan bunga tanah hutan adalah substrat terbaik untuk kedudukan-kedudukan berbaring dan menghala ke atas sementara gambut dan sekam padi merupakan substrat terbaik untuk kedudukan tangkai menghala ke bawah. Interaksi diantara kedudukan biji benih dan tapak percambahan menunjukkan yang percambahan biji di dalam rumah tanaman adalah stabil untuk kesemua kedudukan biji benih, sementara biji dengan tangkai menghala ke bawah mempunyai kadar percambahan yang rendah di bawah naungan jaring. Keputusan dari kajian ini menunjukkan bahawa anak benih bagi kebanyakan spesies dipterokap boleh ditumbuhkan dari biji benih. Teknik-teknik yang diperlukan adalah mudah dan bersesuaian untuk kedua-dua pengeluaran anak benih berskala kecil dan besar. Walaubagaimanapun, tiada kaedah tunggal untuk pengeluaran anak benih bagi spesies-spesies dipterokap yang berlainan, tetapi kaedah yang bersesuaian perlu dikembangkan secara berasingan bagi setiap spesies.

Introduction

Forest resources of tropical Asia are declining at an alarming rate. Unsustainable large-scale commercial loggings and subsequent encroachment of shifting cultivation and illegal logging of the forests are serious threats to the dipterocarp rain forests. In Southeast Asia, there are about 70 million hectares of seriously depleted secondary forest in need of rehabilitation (ITTO 1990). Moreover, large areas of secondary forests are subjected to shifting cultivation, and subsequently converted to unproductive grasslands dominated by *Imperata cylindrica* (alang-alang) (Eussen

& Wirjahardja 1973).

Indonesia alone is estimated to have 36 million hectares of depleted forests requiring rehabilitation. Apart from 20 million hectares of *Imperata cylindrica* grasslands, there are 16 million hectares of logged-over forests with a remaining tree volume of less than 39 m^3 ha^{-1} (ITTO 1990). Without quick rehabilitation, many of these secondary forests will turn into useless bush- or grasslands.

Rehabilitation of logged-over secondary forests is possible through natural regeneration assisted by liberation of seedlings and saplings, provided that a sufficient ephemeral seedling stock exists (Leibundgut 1981). However, vast areas, where natural regeneration of dipterocarp species is insufficient and secondary species dominate, have to be restored by artificial regeneration.

Unpredictability of fruiting hampers planning of large-scale planting with seedling stock. The majority of dipterocarps flower and fruit gregariously at intervals of several years (Appanah & Weinland 1993). In addition to irregular seeding, seeds are recalcitrant and cannot be stored more than a few days without a rapid loss in viability (Tang & Tamari 1973, Yap 1981). Constant monitoring of seed maturation and careful timing of actual seed collection are crucial, since many seeds germinate in the tree and others within a few days after dispersal.

Possible alternatives for reforestation are direct sowing, planting of vegetatively produced seedlings and wildings collected from ephemeral seedling stock (Appanah & Weinland 1993). Direct sowing of dipterocarps is of limited use, since most of the seeds will be eaten by insects and rodents (Weidelt 1976a). Vegetative production needs advanced and expensive technology, although it may be a promising technique for the future (Appanah & Weinland 1993). Planting of wildings potted and raised in nursery conditions has shown good results (Weidelt 1976b, Appanah & Weinland 1993). Wildings have even performed better than seedlings raised from seeds, when planted in secondary pioneer forest (Ådjers *et al.* submitted).

In spite of the advantages of the wilding production or vegetative propagation, seedborn seedlings raised in nursery are required for sustaining wide genetic background and for ensuring availability of planting material after the mast fruiting years of dipterocarps.

Dipterocarp species tested in this study, *Dipterocarpus grandiflorus, D. kunstleri, Hopea sangal, Shorea fallax*, *S. faguetiana* and *S. parvifolia*, are valuable timber species used by local and large-scale industries (Martawijaya *et al.* 1986, Martawijaya *et al.* 1992, Appanah & Weinland 1993). They are all subjected to extensive logging operations in South Kalimantan. This has led to a situation where mother trees are few and scattered in too small groups to maintain the supply of ephemeral wilding stocks. In addition, poorly planned wildings collection reduces the existing stock.

In seedling production the critical factors affecting seed germination are related to the availability of moisture, e.g. substrate, shading and irrigation. Although air humidity is high in rain forest area, dipterocarp seedlings and wildings have proven to perform best in the constant humidity of greenhouse (Ådjers *et al.* submitted). The choice of suitable germination medium depends, for example, on the size, structure and viability of seed. The medium should have good aeration and infiltration capacity as well as rather small particle size (Pancel

1993). However, the overall production cycle has to be considered (Evans 1982). For transportation and planting operations, substrate should preferably be as light as possible and rootball compactness good enough for preventing the disintegration of roots (Evans 1982, Pancel 1993).

In addition to water availability in germination medium, water imbibition, which is the initial step in germination process, depends on seed position in the medium. In natural regeneration of dipterocarps, seeds are dispersed by their wings and land with the stalk of the fruit pointing downwards. In this position the radicle grows initially upwards, which according to earlier experiences, makes the radicle very sensitive to drying.

The aim of this study was to investigate different seed sowing methods of six dipterocarp species in nursery conditions, and specifically,

(a) to determine the germination period of six dipterocarp species,
(b) to test the effect of site (greenhouse vs. shaded area) on germination,
(c) to test the effect of substrate on germination,
(d) to test the effect of seed position on germination.

Materials and methods

Study area

The tree nursery is located in Kintap research area in South Kalimantan, Indonesia (03°42'S, 115° 09'E; 100-200 m a.s.l.; mean annual rainfall 3000 mm). The forest in Kintap area is of mixed secondary dipterocarp forest type and the trial area is situated inside an active logging concession. Soils in the trial area belong to the red-yellow podzolic/lateritic type (Anonymous 1985). A total of 13 species of Dipterocarpaceae family were identified during a permanent sample plot survey. Species distribution per genus was the following: 8 *Shorea* sp., 3 *Dipterocarpus* sp., 1 *Hopea* sp. and 1 *Vatica* sp.

Seed material

The seeds were collected in March 1994 from the ground under a group of mother trees (*Dipterocarpus grandiflorus* and *D. kunstleri*) or directly from single felled trees (*Hopea sangal* and *Shorea* species). The seeds were immediately transported to the nursery and stored overnight in a greenhouse. The wings of each seed were removed before sowing. The seeds were selected to be as uniform as possible with large size and brown color, which indicates the maturity of seeds (Appanah & Weinland 1993). Already germinated seeds were excluded.

In each experiment the seeds were sown in plastic boxes (20 × 30 cm with a depth of 10 cm). Following earlier experiences with dipterocarps, the big seeds of *Dipterocarpus* species were sown in a lying position (experiment II) and the smaller seeds of *Hopea sangal, Shorea fallax* and *S. parvifolia* (experiment I) in a position with the stalk of the fruit pointing upwards. Two-thirds of seeds were covered with the germination medium. Constant moisture was maintained by manual watering.

Experimental design and data analysis

The study consisted of three separate experiments (Table 1), because the species were seeding at different time and because the seeds cannot be stored.

Table 1. Description of experiments in the study

Experiment	Species	Experimental design	Factors
Experiment I	*Hopea sangal, Shorea fallax* and *S. parvifolia*	RCBD 5 replications 50 seeds/plot	1. Species 2. Germination site 3. Substrate
Experiment II	*Dipterocarpus grandiflorus* and *D. kunstleri*	RCBD 12 replications 20 seeds/plot	1. Species 2. Germination site 3. Substrate[1]
Experiment III	*Shorea faguetiana*	RCBD 4 replications 50 seeds/plot	1. Seed position 2. Germination site 3. Substrate

[1]River sand and forest topsoil included only.

In each experiment the objective was to test the effect of site and substrate on seed germination:

Site: (1) greenhouse (light, plastic construction),
(2) shaded area (sharlon net, 50% shade).

Substrate: (1) river sand,
(2) forest topsoil,
(3) mixture of peat and rice husk in portion of 70:30 (standard method for *Acacia mangium*).

In addition, sowing position of seed was studied in experiment III:

Position: (1) lying position,
(2) standing position with the stalk of the fruit pointing downwards (natural position after seed dispersal),
(3) standing position with the stalk of the fruit pointing upwards.

The number of germinated seeds was assessed every fourth day until germination had ceased.

Germination percentages were converted by an arcsin transformation to fulfill the normal distribution requirements of Anova. Experiments I and III were analysed by a factorial analysis of two-way Anova, and aposteriori comparisons of means were carried out using Tukey's HSD-test. In experiment I, which included three species, a treatment combination of substrate and germination site was constructed and its effect was tested separately for each species. This was done because the germination capacity varied remarkably between the species, and on the other hand, the species specific results were considered to be the most valuable in this study. Due to low germination percentages of *Dipterocarpus grandiflorus* and *D. kunstleri*, the mean values only were calculated in experiment II.

Results

Cumulative germination of species

Germination of the 6 dipterocarp species started within 4 days after sowing in all treatments (Figure 1). After 8 days, 89% of *Shorea parvifolia* and after 12 days, 85% of *S. faguetiana* had germinated. The shapes of cumulative germination curve of *Hopea sangal*, *S. faguetiana* and *S. parvifolia* were different from those of *Dipterocarpus* species, which had low germination rate and longer germination period.

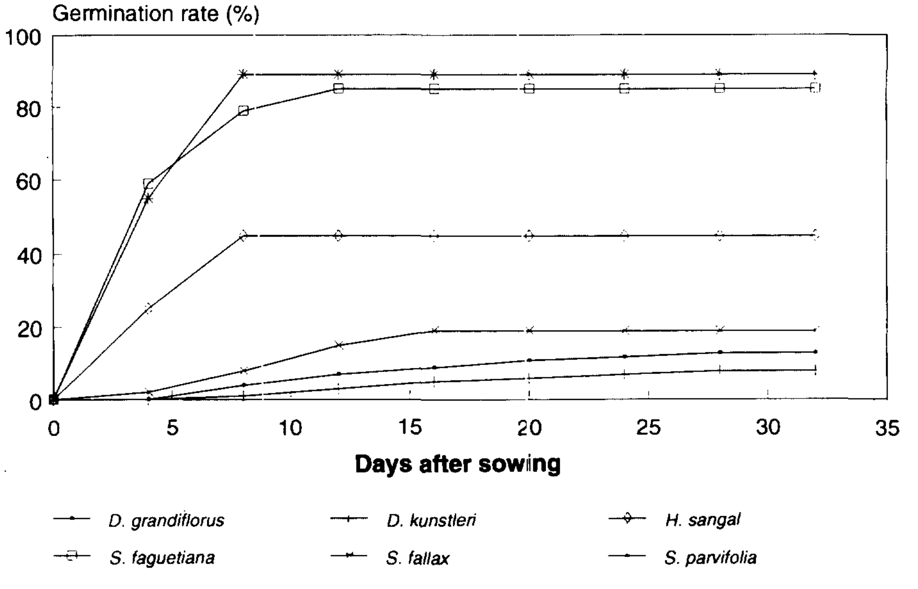

Figure 1. Pooled (treatments combined) cumulative germination of *Dipterocarpus grandiflorus*, *D. kunstleri*, *Hopea sangal*, *Shorea fallax*, *S. faguetiana* and *S. parvifolia*

Experiment I

Statistically significant differences were found in mean germination rate between species (F=14.04; p=0.003), substrate (F=6.95; p=0.002) and germination site (F=18.96; p<0.001). Significant interactions were detected between species and substrate (F=8.81; p<0.001), species and germination site (F=33.56; p<0.001) as well as substrate and germination site (F=5.57; p=0.006).

Hopea sangal and *Shorea parvifolia* exhibited the highest germination rates when sown in river sand or forest topsoil in greenhouse, although statistically significant differences were detected with *H. sangal* only (Table 2). *H. sangal* showed the lowest germination rates when sown under the shading net in topsoil or peat and rice husk substrate, which differed significantly from other treatment combinations. *S. fallax* had statistically higher germination rates in peat and rice husk substrate in shaded area compared to other treatments.

Table 2. Effect of substrate and germination site on germination of *Hopea sangal, Shorea fallax and S. parvifolia.* Standard errors of mean are presented in parentheses. Means indicated with the same letter within each column (species) are not significantly different.

Treatment	*Hopea sangal*	*Shorea fallax*	*Shorea parvifolia*
Greenhouse - sand	81.2 (3.0) a	11.2 (3.8) b	95.6 (1.2) a
Greenhouse - topsoil	61.6 (7.4) ab	6.8 (1.7) b	91.6 (2.5) a
Greenhouse - peat	44.4 (8.7) b	17.2 (2.9) b	86.8 (3.0) a
Shading net - sand	34.4 (4.6) b	19.2 (4.5) b	91.2 (2.3) a
Shading net - topsoil	24.8 (8.0) c	13.6 (1.5) b	85.2 (1.7) a
Shading net - peat	22.8 (6.7) c	46.0 (1.1) a	84.0 (3.9) a
Pooled mean	44.9 (4.6)	19.0 (2.6)	89.1 (1.2)
df	20	20	20
F-value	12.166	21.365	2.696
p-value	<0.001	<0.001	0.051

Experiment II

Germination rates of *Dipterocarpus grandiflorus* and *D. kunstleri* were low (Table 3). Highest germination rate for *D. grandiflorus* was achieved by forest topsoil as substrate and shaded area as site and for *D. kunstleri* by forest topsoil and greenhouse or shaded area respectively.

Table 3. Effect of substrate and germination site on germination of *Dipterocarpus grandiflorus* and *D. kunstleri*

Treatment	*Dipterocarpus grandiflorus*	*Dipterocarpus kunstleri*
Greenhouse - sand	15.0 (3.4)	7.1 (2.9)
Greenhouse - topsoil	8.3 (2.9)	10.8 (3.4)
Shading net - sand	4.6 (1.4)	2.1 (0.7)
Shading net - topsoil	25.0 (3.7)	10.4 (3.1)
Pooled mean	13.2 (1.8)	7.6 (1.4)

Experiment III

Statistically significant differences were found in mean germination rate between seed positions ($F=8.04$; $p=0.001$) of *Shorea faguetiana*. Lying position and position with the stalk pointing upwards resulted in the highest germination rates, and differed significantly from position with the stalk pointing downwards.

Significant interactions were detected between seed position and substrate ($F=3.98$; $p=0.006$) as well as seed position and germination site ($F=5.21$; $p=0.008$). Position with stalk pointing downwards was more sensitive to the effect of substrate and germination site than other positions (Figures 2 and 3). The best germination media for positions of lying and stalk pointing upwards were topsoil and sand, whereas for position with the stalk pointing downwards, peat and rice husk substrate gave the highest germination rates (Figure 2). Peat and rice husk substrate showed fairly stable germination rates over all positions, whereas river sand and forest topsoil exhibited lower rates with the stalk down position. Interaction between seed position and germination site showed that seed germination in greenhouse was stable over all seed positions, whereas seeds with stalk pointing downwards had clearly lower germination rates under shading net (Figure 3).

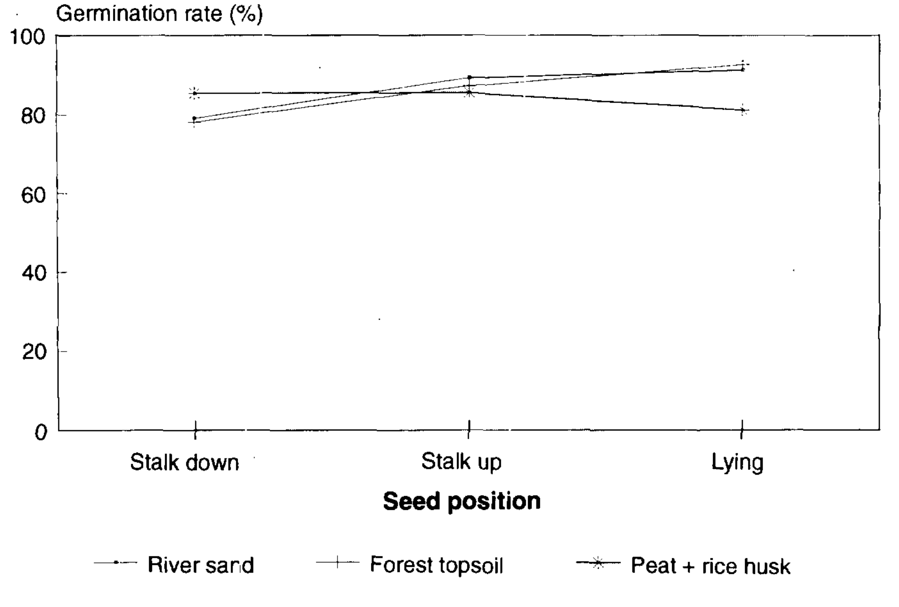

Figure 2. Effect of seed position and substrate on germination of *Shorea faguetiana*

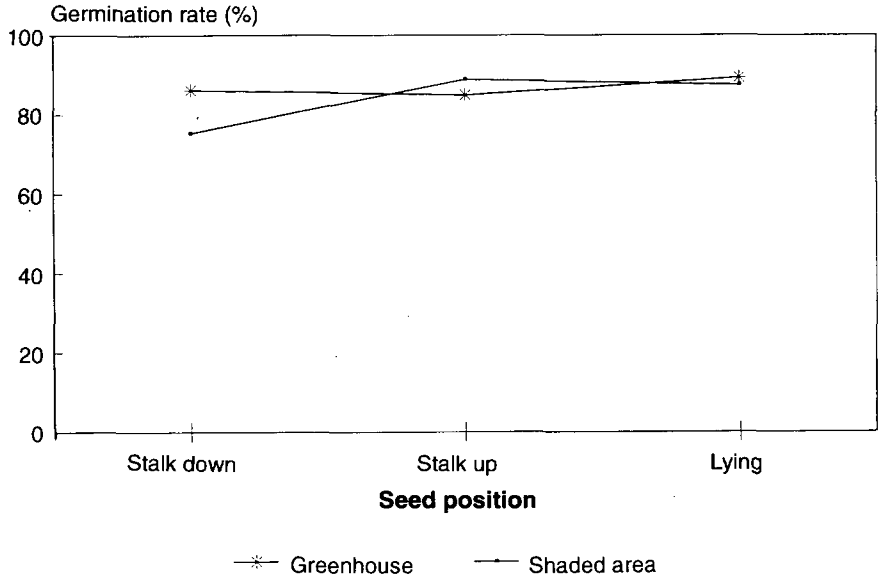

Figure 3. Effect of seed position and germination site on germination of *Shorea faguetiana*

Discussion

Duration and rate of germination differed widely between the six dipterocarp species. *Shorea faguetiana* and *S. parvifolia* germinated in less than two weeks and showed the highest and most stable germination rates over all treatments. Germination of *Hopea sangal* was clearly more sensitive to the effect of substrate and germination site. Species with large seeds, *Dipterocarpus grandiflorus, D. kunstleri* and *S. fallax,* exhibited extremely low germination rates, and compared to the above species, showed a different kind of relationship between the treatments and the success of germination.

River sand and forest topsoil were the best substrates for germination of *Hopea sangal, Shorea faguetiana* and *S. parvifolia.* They are the most widely used media for germination beds and have given good results in other experiments with *Shorea* species (Ådjers *et al.* submitted). Peat and rice husk substrate gave slightly lower germination rates than river sand and forest topsoil and appeared to respond more to the effect of germination site. The effect of germination site was significant with *H. sangal* only, which can probably be explained by higher and more constant moisture levels inside the greenhouse than under the shading net.

Shorea fallax exhibited the highest germination rate in peat and rice husk substrate. This might be a result from moister conditions in the germination bed, since peat has good water holding capacity (Pancel 1993). Compared to other *Shorea* species, it seems that *S. fallax* has greater water requirements for successful germination. This might have also been the case with *Dipterocarpus* species, which indicated better results in forest topsoil than in the more coarse river sand.

According to the results from the seed position experiment of *Shorea faguetiana,* lying position and position with the stalk pointing upwards were more tolerant to the effect of substrate and germination site than position with stalk pointing downwards. This natural position, contradictory to other positions, exhibited the best germination in the combination of peat and rice husk substrate and greenhouse. This can be at least partly explained by the initial upwards growth of radicle, which makes it sensitive to drought. In natural regeneration the wings might promote the success of germination: they are still connected to the seed after dispersal and ensure moisture for the radicle by collecting water drops between the wings. Position is likely to be even more important with big seeds, and it should be studied with other species as well.

Low germination rates of *Dipterocarpus* species and *Shorea fallax* might be due to the poor quality of seeds, although the cutting test (see Willan 1985) was applied for some seeds before sowing. Generally, the genus *Dipterocarpus* is notorious for low viability; apparently sound and fresh fruit are not germinating at all (Appanah & Weinland 1993).

Seeds of *Hopea sangal, Shorea faguetiana* and *S. parvifolia* were collected from single cut trees. This was considered to be suitable for the purpose of this study, although it led to a narrow genetic base of the seedlot. Collection of good quality seeds of these species is difficult to organise, since a remarkable proportion of seeds germinate already in the tree or immediately after dispersal. If collection is delayed for one or two days germination will occur prematurely or seeds will deteriorate. Evidently, collecting from single seed trees is not a preferable collection method, and the actual planting operations should be carried out with seedlings raised from a number of mother trees.

Conclusion

Use of *Shorea faguetiana* and *S. parvifolia* seedling stock can be recommended already with the present knowledge. They can be sown in sand in germination beds or directly into pots with a suitable, beforehand tested, mixture of other substrates. Even peat and rice husk substrate, which is preferred due to its light weight, can be used. These species can be raised both in greenhouse and in shaded area, which widens the possibilities to use small nurseries without high technology. Seed positions of lying and stalk pointing upwards should be preferred, if irrigation system is not secure enough to maintain permanent moisture. In the case of *Hopea sangal,* seeds should be sown preferably in the combination of sand and greenhouse, transplanting plantlets later to pots.

The problem of low germination rate of *Dipterocarpus* species and *Shorea fallax* can be partly solved by sowing seeds into germination beds. However, germination ecology of these species is evidently more complex than that of the other species examined in this study, and more research is needed on germination ecology as well as its practical implications.

Results of this study indicate that seedlings of many dipterocarp species can be raised from seeds. In addition, the required techniques are simple and appropriate for both small- and large-scale seedling production. Seedling production and planting should be promoted during the mast fruiting years of dipterocarps. This is especially the case with *Hopea sangal, Shorea faguetiana* and *S. parvifolia*, which have plenty of high quality seeds. In addition, *H. sangal* and *S. parvifolia* are reported to be among the most suitable species for reforestation due to their ability to withstand harsh environmental conditions (Appanah & Weinland 1993).

There is no single procedure for seedling production of different dipterocarp species. The technique used depends on the size and viability of the seed and the overall production cycle used in the nursery. Before mass production of dipterocarp seedling stock is started, suitable methods have to be developed separately for each species.

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