VEGETATIVE PROPAGATION TO ASSURE A CONTINUOUS SUPPLY OF PLANT MATERIAL FOR FOREST REHABILITATION

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ABSTRACT

Species of the Dipterocarp family dominate the canopy of the tropical rain forests in the lowlands of Kalimantan, Indonesia. Many species are economically very important and, as a consequence, are threatened by logging activities. Enrichment planting after logging with dipterocarp species is feasible and ecologically acceptable. The species choice depends on the goals of the forest manager. A continuous supply of plant material is needed for plantation activities, forest rehabilitation and reforestation. Unfortunately, continuous availability of dipterocarp seeds is hampered by unpredictable fruiting seasons, irregular fruiting (only once in 4 to 13 years), recalcitrance of the seeds and fretting by insects and other animals. Collection of wildlings may help to solve the problem only during the first two years after the fruiting season.

The MoFEC-Tropenbos Kalimantan Project at the Wanariset Samboja Research Station has been developing methods for vegetative propagation of dipterocarp species since 1987. By using these methods, planting stock can now be produced continuously. In this paper, the main research results will be discussed.

Concession holders and other forest institutions have sent personnel to the Wanariset for training courses to learn these vegetative propagation methods for application in their forest concessions. This training programme has been running since 1993. An evaluation of the effects of the introduction of these vegetative propagation techniques and the training programme is recommended.

1. INTRODUCTION

Many dipterocarp species are economically important for their hardwood timber. The timber of these trees makes up about 25 percent of the total global tropical hardwood timber trade (Smits, 1987). Many dipterocarps (e.g. *Shorea javanica)* also yield other products, such as resin for the production of varnishes and turpentine. Fruits of several dipterocarps, called tengkawang, contain fat that is used in chocolate and the cosmetic industries (Sidiyasa, 1995).

The exploitation of the dipterocarp forests by logging operations however, has caused a sharp decrease in this resource. There is therefore a need to conserve, regenerate, protect and properly manage dipterocarp forest to ensure the sustainability of these forests. Planting activities for forest rehabilitation and reforestation need a continuous supply of plant material. Enrichment planting using dipterocarp species offers good economic prospects and is ecologically appropriate. Plant material normally used in these activities may originate from natural regeneration such as seeds, seedlings, wildlings and/or from vegetative propagation, like the stem cutting system. Whatever the source of the planting stock, its continuous supply is of the utmost importance to forest tree planting activities.

Since 1987 the International MoFEC-Tropenbos Kalimantan project, Wanariset Samboja, developed a technology for the vegetative propagation of dipterocarp species by means of stem cuttings that may meet the need for a continuous supply of planting stock. As a pioneer of this method, Wanariset Samboja is continuously searching for ways to improve the system. This paper discusses the research results of vegetative propagation and the introduction of the technology to concession holders and other forest institutions through training courses at Wanariset. The system is now well known and widely applied throughout Indonesia.

2. SELECTION OF PRIORITY SPECIES

The family of the Dipterocarpaceae is a very big family, consisting of 16 genera in 3 subfamilies making up about 515 species (Jacobs, 1981; Yasman et al., 1994). In the natural forests dipterocarps may comprise up to 80 percent of the trees in the upper canopy. Dipterocarp trees have long straight boles of large diameters, have rather homogenous timber of good quality and occur in large numbers. The timber of the Dipterocarpaceae has become a very important source of raw material from the forest. In addition, most of the species float on water, which makes the transport costs relatively low.

There is large variation in growth among the dipterocarps. Some species are very slow growing (e.g. *S. laevis*), while others can reach an average annual diameter increment of more than two centimetres (e.g. *S. leprosula*). It is therefore important to select the species with a specific growth rate. Provenance and progeny are also important criteria within the same species. Other decisive factors on which to base the choice of specific species are the site requirements, such as the suitability of the species for the local altitude, climate, soil type etc. Apart from the economic value, that has been mentioned already, there is the social acceptability (Smits, 1995). Poor species site matching will lead to poor growth and, therefore, economic loss. Poorly growing trees are also susceptible to pests and diseases.

The research group of the Wanariset Samboja selected 20 priority dipterocarp species for research and development based upon these criteria. The list of these species is given below in Table 1.

Table 1 Priority list of Dipterocarps species in Wanariset Samboja

No.	Dipterocarps species	No.	Dipterocarps species
1.	*Shorea pauciflora*	11.	*Shorea pachyphylla*
2.	*Shorea parvifolia*	12.	*Shorea dasyphylla*
3.	*Shorea leprous*	13.	*Shorea selanica*
4.	*Shorea seminis*	14.	*Shorea platyclados*
5.	*Shorea johorensis*	15.	*Shorea albida*
6.	*Shorea smithiana*	16.	*Dryobalanops lanceolata*
7.	*Shorea ovalis*	17.	*Dryobalanops aromatica*
8.	*Shorea stenoptera*	18.	*Dryobalanops keithii*
9.	*Shorea polyandra*	19.	*Anisoptera costata*
10.	*Shorea macrophylla*	20.	*Anisoptera marginata*

Unfortunately, the tree selection programmes have not been as effective as they might have been because of lack of access to, or poor use of, species information. Too often, rehabilitation in the field followed trends and did not anticipate on future needs that were identified with vision and were based on wide insight as to what is available and suitable (Smits, 1995).

3. DIPTEROCARP PLANTING STOCK PRODUCTION

Several techniques are employed for the production of dipterocarp planting stock (Figure 1).

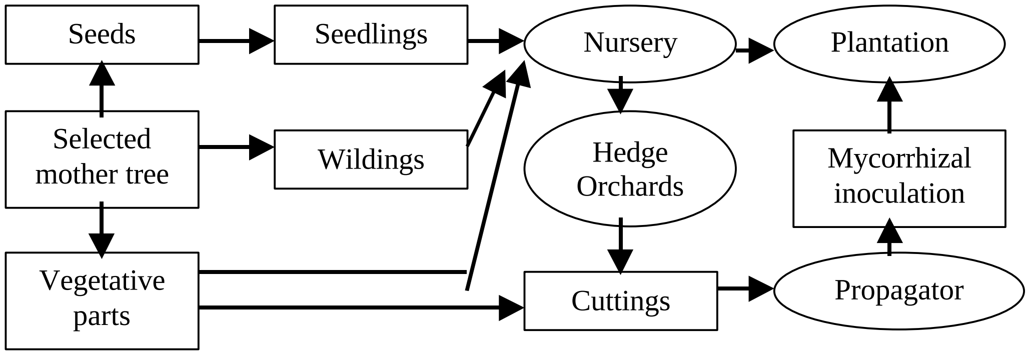

Figure 1 Dipterocarp planting stock production scheme

3.1 Seedlings

The production of dipterocarp planting stock through the controlled germination of seeds in nurseries is seldom practised. Seeds of species of the Dipterocarp family are produced in large quantities in periods of mass flowering once every 3 or 4 years. These periods are short, irregular and unpredictable. The seeds have a short viability period, a few weeks at the most, and are difficult to store (recalcitrant seed). In addition, insects and other animals eat many of the seeds. Accordingly, continuity of dipterocarp planting stock production originating from seeds cannot be guaranteed. Some research on seed technology has been conducted at Wanariset Samboja and has been published (Priadjati & Rayan, 1998).

3.2 Wildlings

A widely used method for the production of dipterocarp planting stock is by means of wildlings, collected underneath mother trees in the natural forest. In order to provide well identified wildlings, an area of high quality forest containing many commercial dipterocarps should be selected as a seed stand. It is also possible to collect the wildlings elsewhere, but the quality has to be taken into account.

Some important rules should be considered in the collection of dipterocarp wildlings. The collection should be done when the soil is very wet in order to reduce root damage. The species identification of young wildlings is difficult and only healthy and straight plants should be collected. The main problem in wildling collection is the condition during transport. If the wildlings are packed tightly and humid enough, the survival rate in the nursery is more than 95%, even for transport lasting up to one week (Smits and Leppe, 1991). High air humidity around the wildlings in the nursery is another important requirement. The technique for wildling production has been described in various publications (Giono *et al.*; 1996; Kusdadi and Priadjati, 1998; Leppe, 1995b) and in a simple manual (Smits, 1986).

Although very low in costs and technically simple to implement, the production of wildlings may still pose a problem if the aim is to obtain sufficiently large numbers of certain faster growing dipterocarp species. This is especially the case when natural mortality has significantly reduced the number of wildlings, as occurs two or more years after germination. Another consideration may be the need to select superior quality planting stock.

3.3 Vegetative propagation

Another method of dipterocarp planting stock production is by means of vegetative propagation. Vegetative propagating dipterocarps can provide an uninterrupted supply of high quality planting stock at times when wildlings may be scarce because of the time lapse since the last mass flowering. The techniques for vegetative propagation have long been considered as expensive, both in terms of investment as well as production costs. This was based on the high skills required for the production of cuttings and the treatment and handling of the cuttings in the nursery for rooting. Special technical provisions in the nursery and special biochemicals and fertilizers increased the costs. Moreover, the rooted cuttings needed to be inoculated with suitable mycorrhizal fungi in the nursery during the transplanting process.

4. WANARISET DIPTEROCARP PROPAGATION

As we stated above, vegetative propagation combined with mycorrhizae research started at the Wanariset Research Station in Samboja near Balikpapan as long ago as 1987. The MoFEC Tropenbos Kalimantan moved into the station in November of that year and started its programme of propagation and mycorrhizae research as its main activity. In a personal communication, Smits, the long-term team leader of the project, reports that vegetative parts of adult trees were tested in Wanariset Samboja using direct cuttings, air layering, grafting, spheroblastic shoots, with the results varying from complete failure to fairly positive. Direct cuttings from adult trees were tried for *S. lamellata, S. laevis, S. leprosula, S. ovalis, S. smithiana, S. seminis, S. pauciflora, S. parvifolia, S. johorensis and Dryobalanops lanceolata*. Pruning of adult trees followed by collecting cuttings from the sprouts had negative results, but subsequent grafting resulted in some success. Pruning of young dipterocarp trees (diameter less than 10 cm) followed by taking stem cuttings from shoots had a positive result. Other research by Omon (1997) on stumps of *S. balangeran* with 5 mm root collar diameter, combined with 15 mg Rotoone F showed a 97 percent survival rate.

The technique developed at the International MoFEC Tropenbos Kalimantan project involves rooting orthotropic stem cuttings of juvenile dipterocarps with auxine hormone in both solid or water media. The water medium is aerated by means of a small air compressor as normally used in aquaria. The air humidity is kept high during the rooting process and the light intensity is somewhat reduced. The method of cutting production has been described in various publications (Leppe, 1995a; Smits *et al*, 1990) and in a manual by Yasman and Smits (1988).

Some studies have indicated that plants yielding faster rooted cuttings also grow faster. There are some differences in root system development when cuttings are rooted in water or in a solid medium such as washed river sand or vermiculite. In water, fewer roots tend to develop and they become much longer and less branched, as compared with roots of cuttings in a solid medium (Tolkamp and Priadjati, 1996). The overall survival of rooted cuttings from a solid medium is slightly higher than that of cuttings rooted in water. Rooting percentages do differ slightly between the two methods, depending upon the species considered. Some species developed roots faster in water (e.g., *Hopea rudiformis, S. ovalis*), others faster in sand (e.g., *S. lamellata*) or vermiculite (e.g. *Dryobalanops lanceolata, S. smithiana, S. parvifolia, S. pauciflora, S. seminis*) and *S. leprosula* in both water and vermiculite media (Tolkamp and Priadjati, 1996). Another difference between rooting in water and in a solid medium is the number of roots developed from lenticels and those from wound calluses. Some species, like *D. lanceolata,* develop more roots from lenticels in water. Other species, like *S. ovalis,* develop more roots from lenticels in sands. Again other species, like *S. leprosula,* show no differences.

Table 2 The internal and external factors influenced the rooting ability of cuttings

Internal factor (cutting)	**External factor (propagator)**
Species	Humidity
Age/Juvenility	Light intensity
Hormone	Temperature
Physiological condition	Media
Resting period	Fertilization
Provenance	Day length
Technique	Aeration

There is large variation in rooting ability amongst the provenances within one dipterocarp species. *D. lanceolata*, originating from Longnah, East Kalimantan, had a lower rooting percentage compared with the same species originating from Wanariset Samboja, East Kalimantan. *S. smithiana* originating from Longnah, East Kalimantan, had a higher rooting percentage compared with the same species originating from Wanariset Samboja, East Kalimantan (Leppe and Juliaty, 1996). During the many years of research, a number of factors have been identified that influenced the rooting ability of dipterocarp cuttings. The main internal and external factors are listed in Table 2.

The development of a hedge orchard is needed to provide a sufficient regular supply of cutting material. The method for the establishment and maintenance of hedge orchards is described in various publications (Tolkamp and Priadjati, 1997a), in a detailed manual by Leppe and Smits (1989) and in a simple manual by Leppe (1995c). Experience has shown that, the older the age of a hedge orchard, the higher the production of cuttings, but these cuttings have a lower rooting ability.

The rooting ability of a cutting is also influenced by the maintenance of hedge orchard (Tolkamp, 1995). It is important to discover the optimal age of a hedge orchard for each individual species. The pruning of hedge orchards can produce juvenile shoots and stimulate the higher rooting ability of cuttings from these shoots (Macdonald, 1976; Hartmann, *et al* 1990; Tolkamp, 1995). The older the source material, the higher the concentration of externally applied auxine needed, but there are no absolute concentrations of hormone needed, because the rooting of cuttings is influenced by many factors (Table 2). The highest rooting percentage for species grown in Longnah, East Kalimantan, was obtained from shoots taken from two year-old hedge orchard. The rooting percentage of the cuttings from a four year-old, well-maintained hedge orchard, can still be high (Bachtaruddin *et al*, 1994). Cuttings obtained from trees older than 10 years did not root successfully. A detailed overview of the rooting ability of 20 important timber species is given in Table 3.

The success of the method, from the moment the cutting is made until a rooted cutting is ready to be planted in the field, varies between species, but is about 60-70% on average. This figure is the overall result of different success percentages. Cutting survival and successful rooting in the greenhouse is 80%. Conditioning after transplanting in the nursery beds shows a survival rate of 95%, while the same figure of 95 % is recorded for survival in the further nursing period until the plantlets leave the nursery (Bachtaruddin *et al* 1994).

Smits (1994) describes nursery aspects of mycorrhizae in detail, whereas Noor (1995) describes them briefly. The method for mycorrhizal inoculation has also been described in various other publications (Omon, 1999; Yasman, 1995).

Table 3 Overview of rooting ability of dipterocarp cuttings

No	Species	Hormone		Media	Period (weeks)	Rooting ability (%)	Hedge Orchard (age)	References
		Type	Conc. (time)					
1	*Anisoptera marginata*	IBA	10^{-4} (1 h.)	Peat:Sand (1:1)	5-9	100		Smits (1987)
2	*Cotylelobium spp.*	Rootone F	20 g/300 ml (20 minutes)	Water	16	0		Tolkamp & Priadjati (1996)
3	*Dipterocarpus cornutus*	Rootone F	20 g/300 ml (20 minutes)	Water	21	33		Tolkamp & Priadjati (1996)
4	*Dryobalanops lanceolata*	Rootone F	20 g/300 ml (20 minutes)	Vermiculite	16	69		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	67	3 years old	Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	43	6 years old	Tolkamp (1997)
		Without			21	17	3 years old	Priadjati & Prayitno (1998)
5	*S. assamicca*	Rootone F	20 g/300 ml (20 minutes)	Water	21	93		Tolkamp & Priadjati (1996)
6	*S. faguetiana*	Rootone F	20 g/300 ml (20 minutes)	Water	19	5		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	0	3 years old	Tolkamp (1995)
7	*S. johorensis*	Rootone F	20 g/300 ml (20 minutes)	Water	18	25		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	10	3 years old	Tolkamp (1995)
		Rootone F	100000 ppm (20 minutes)		21	21	3 years old	Priadjati & Prayitno (1998)
		Rootone F	Dipping	Vermiculite	48	0	6 years old	Tolkamp (1997)
8	*S. lamellata*	Without		Sand	4	90	8 months old	Omon & Smits (1989)
		IBA	200 ppm (1 hour)	Sand	4	100	8 months old	Omon & Smits (1989)
9	*S. leprous*	Rootone F	20 g/300 ml (20 minutes) & Dipping	Water & Vermiculite	11-26	51-75		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	32		Tolkamp (1995)
		Rotoone F	15 g/300 ml (20 minutes)	Water	22	50		Priadjati (1995)
		Rootone F	Dipping	Vermiculite	48	61	6 years old	Tolkamp (1997)
		Without			21	21	3 years old	Priadjati & Prayitno (1998)
		Without		Vermiculite	14	63	1 year old, wounding	Tolkamp & Priadjati (1997b)
10	*S. ovalis*	Rootone F	30 g/300 ml (20 minutes)	Water	21-26	63		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	17	3 years old	Tolkamp (1995)
		Without			21	31	3 years old	Priadjati & Prayitno (1998)
11	*S. parvifolia*	Rootone F	Dipping	Vermiculite	11-29	48		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	15		Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	0	6 years old	Tolkamp (1997)

No	Species	Hormone		Media	Period (weeks)	Rooting ability (%)	Hedge Orchard (age)	References
		Type	Conc. (time)					
12	*S. pauciflora*	Rootone F	Dipping	Vermiculite	20-29	59		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	17		Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	55	6 years old	Tolkamp (1997)
13	*S. selanica*	Rootone F	30 g/300 ml (20 minutes)	Water	16	67		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	20	3 years old	Tolkamp (1995)
14	*S. seminis*	Rootone F	Dipping	Vermiculite	19-29	78		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	64	3 years old	Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	45	6 years old	Tolkamp (1997)
		IBA	100 mg/l (24 hours)	Water	72 days	27-34	Wounding	Erwinsyah (1994)
15	*S. smithiana*	Rootone F	20 g/300 ml (20 minutes)	Vermiculite	17	21		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	11	3 years old	Tolkamp (1995)
		Rootone F	Dipping	Vermiculite	48	0	6 years old	Tolkamp (1997)
						100		Smits (1987)
16	*S. stenoptera*	Rootone F	20 g/300 ml (20 minutes)	Water	26	0		Tolkamp & Priadjati (1996)
		Rootone F	20 g/300 ml (20 minutes)	Water	24	0	3 years old	Tolkamp (1995)
17	*S. laevis*					100		Smits (1987)
18	*S. blanco*					100		Smits (1987)
19	*Shorea spp.*	Rootone F	100000 ppm (20 minutes)		21	61	3 years old	Priadjati & Prayitno (1998)
1	*Diospyros borneensis*	Atonik	20 ppm (5 minutes)	Water	3-7 months	60-93		Omon (1997)

5. PRACTICAL ASPECTS

The most commonly heard concerns about the risks associated with vegetative propagation are the risks of pests and diseases caused by genetic narrowing of the trees produced, poor root architecture and poor wood quality. No serious pests and diseases problems associated with large dipterocarps have been experienced so far. Some species even showed the presence of insecticides and fungicides in their resins (Messer, 1991). From root observations of both naturally grown and plantation grown trees, it has become clear that trees grown from cuttings developed a root system similar to that of natural regeneration (Bachtaruddin *et.al.*, 1994; Smits, 1995). Studies on the wood anatomy of some very fast grown individual dipterocarp trees have shown that, although the wood is lighter and somewhat less strong and durable (Bosman, 1992), it is still within the natural variation of the species and within the product specifications used in the markets. Moreover, no signs of problems such as brittle heart and cell collapse were encountered. These facts indicate therefore that the vegetatively propagated trees of the Dipterocarpaceae family present no problems of product quality and they do offer very favorable economic prospects in terms of growth.

Vegetative propagation techniques have been developed both to enable dipterocarps to be used for large-scale production and to make these techniques more cost efficient. The choice between wildling or cutting production, in terms of economics of production, depends on the time lapse between the last dipterocarp mass flowering and the time the planting stock is needed. The cost of wildling production increases exponentially with time, while the cost of cutting production increases more slowly in time. The cost comparison model, a software program developed for cost comparisons in nursery and stand establishment operations, can assist in deciding when it becomes more advantageous to produce wildlings and when it is better to produce cuttings. For the most common situation, at a certain point in time after the occurrence of the last mass flowering, the production cost of one cutting becomes less than that of one wildling.

Training courses on propagation through stem cuttings have been given in Wanariset Samboja since 1993. There have so far been more than three hundred participants from concession holders, forestry institutions and also from mining companies. The Wanariset dipterocarp propagation method was first applied on a production scale by PT Inhutani I in Longnah, East Kalimantan, where a nursery was established capable of producing more than half a million cuttings per year (Bachtaruddin et.al. 1994). In 1994, a total of 328 forest concession holders in Indonesia had already established hedge orchards to support the vegetative propagation of dipterocarps (Leppe and Smits, 1996).

6. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions which can be drawn from the propagation research are:

- The Wanariset research has resulted in the development of a successful rooting and mycorrhizal inoculation technology making possible the efficient production of planting stock for forest rehabilitation and reforestation with dipterocarp species, independent of the availability of seeds and wildlings.
- The vegetative propagation of dipterocarps through stem cuttings, as developed at the Wanariset Research Station, is feasible and generally accepted and applied by forest concession holders throughout Indonesia

In order to improve the propagation technology and contribute further to the conservation, rehabilitation and sustainable management of the dipterocarp forest in Indonesia we recommend:

- further integrated research, including genetic improvement
- increased research input; in terms of both personnel and resources
- updated manuals
- evaluation, updating and increase in training courses
- monitoring of participants of training courses
- monitoring the introduction and application of the technology in the forestry sector
- improved co-operation between institutions

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