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Vegetative Propagation of Tropical Tree Species by Stem Cuttings

Report Number 21

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Preface

The value of vegetative propagation in tree improvement work has been long recognized. There are numerous examples of impressive gains from clonal breeding programs throughout the tropics. When Darus and Aminah submitted this unsolicited report to F/FRED, we were honored to be considered by the authors as a venue for its publication.

This report presents the state of the art in a concise manner, with a useful and comprehensive bibliography that may be consulted by those wishing more information on the subject. It gives useful tips on "how to do it" and "what not to do". Of particular value are the plans for propagation beds. This publication makes it clear that vegetative propagation technology and methodology is available, "user friendly", and inexpensive for many MPT species. Perhaps this report will stimulate greater use of these methods at the nursery and farm level, so that small growers can benefit in the same way that tropical forestry industries have.

I would like to receive readers' thoughts on the advisability of following this report with a more in-depth user's manual that demonstrates vegetative propagation with illustrations and examples.

Rick J. Van Den Beldt
Team Leader, F/FRED

1. Introduction

In tropical countries, one of the most difficult problems in propagation of forest species is seed supply. According to Sasaki *et al* (1978) forest trees do not bear fruits regularly when subjected to certain conditions. When they do fruit they produce low quality seeds because of frequent insect and fungal attacks. It is, therefore, very difficult to predict the yield and quality of seeds for a reforestation program. Vegetative propagation of tropical species by stem cuttings is an important alternative for production of high quality and uniform planting stocks for a large scale reforestation. Stem cuttings offer several advantages over seeds. They save time and labor in seed collection and storage and produce uniform planting material reflecting the genetic purity of superior parent stock. Stem cutting is also inexpensive and easier to practice than other vegetative propagation methods, such as tissue culture. Finally, it can produce a continuous supply of planting stock throughout the year for reforestation activities.

In Malaysia and other ASEAN countries, there is increased interest in using vegetatively propagated clones of selected timber species for plantation establishment. This is further encouraged by the success of *Eucalyptus* forest plantations in Aracruz, Brazil using rooted cuttings. As a leading research and development institution in forestry, the Forest Research Institute of Malaysia (FRIM) has carried out studies on stem cuttings of selected timber species in order to better understand factors affecting the rooting process of cuttings and to develop proper techniques for mass vegetative production of these species.

This report documents factors which influence the rooting of stem cuttings and basic infrastucture and methods used for some commercially important timber species.

2. Important factors affecting rooting of stem cuttings

According to Girouard (1974) the success of rooting mainly depends on the species. Sometimes, cutting materials taken from different populations or individuals within a species also vary in their rooting capacity. It is recognised that physiological factors such as 1) juvenility and age of stock plants, 2) nutrition and carbohydrate reserves, 3) presence of buds and leaves, and 4) size of cuttings and node position all influence rooting. There are also several environmental factors, such as 1) rooting medium, 2) water relations, 3) light, 4) temperature and 5) plant growth substances which are considered very important for successful rooting of stem cuttings.

2.1 Physiological factors

2.1.1 Juvenility and age of stock plants

Generally, seedlings of woody plants pass through a juvenile stage before they become mature. These two stages are different in many ways. In some species, easily recognised morphological differences exist. For example, among heterophyllous trees such as *Acacia mangium*, juvenile compound leaves change to phyllodes at the mature stage. Juvenile plants, apart from their differences in morphological properties, are usually capable of exponential increase in size and have a higher ability to form adventitious roots but are unable to produce flowers (Dunberg, 1977; Borchert, 1976; Vieitez, 1976).

In general, cuttings taken from young seedlings of "difficult-to-root" tropical hardwood species root more easily than those of older plants. For example, Darus (1988) found that stem cuttings of 6-month-old and 24-month-old *A. mangium* seedlings gave 71.3 and 15.0% success rates respectively (Table 1). Aminah (unpublished) found that 6-12 month-old stem cuttings of *Hopea odorata* seedlings produced more than a 75% success rate whereas those from 18-21 month-old saplings produced less than 50%. Momose (1978) also reported that cuttings of *Agathis dammara*, *Podocarpus imbricatus* and

Vatica walichii from juvenile plants produced satisfactory rooting while those from mature trees failed to root. Apart from rooting percentages, it was also observed that the speed of rooting, the root length, the number of roots, survival and growth of rooted cuttings also decreased with increasing age of the parent material.

Table 1. Rooting percentage of *Acacia mangium* stem cuttings (n=80) in relation to the age of stock plants at time of cutting.

	Age of stock plants (months)			
	6	12	18	24
Total rooted cuttings	57	52	25	12
Total non-rooted cuttings	9	9	8	3
% rooted	71.3	65.0	31.3	15.0

Source: Darus, 1988

The difficulty in rooting of cuttings from mature trees may possibly be related to 1) increasing production of rooting inhibitors as plants grow older (Ooyama, 1962), 2) decreasing phenolic levels which act as an auxin cofactor or synergist in root initiation of stem cuttings (Hess, 1961), 3) lignification of the stem (Darus, 1988) and 4) anatomical barriers such as a sclerenchymatous sheath (Beakbane, 1961 and Darus, 1989).

The juvenile characteristics of stock plants can be maintained by regular pruning or hedging treatments. These treatments are very effective in propagating cuttings from mature trees. For example, Aminah (1991a) reported that regular pruning and hedging have been successfully used in *Hopea odorata* to prevent the decline in rootability of stem cuttings as stock plants increased in age. The second method to maintain a higher rooting percentage over a longer period is by serial propagating of the rooted cuttings. For example, serial cuttings of *Endospermum malaccense* produced a higher rooting percentage than cuttings from seedlings of the same age (Darus *et al.*, 1990a).

2.1.2 Nutrition and carbohydrate reserves

Nutrition is also considered an important factor in the rooting process of cuttings. During the time of root formation, the supply of carbohydrate reserves and nutrients in the cuttings must be adequate to satisfy metabolic requirements (Iktueren, 1971; Cameron, 1984; Hyuan and Hong, 1968).

Hartmann and Kester (1983) stated that cuttings should have an ample supply of stored carbohydrates to nourish the development of new roots and shoots until the new plant becomes self-sustaining. Generally, when leafy cuttings are grown in light, they root well because they contain more carbohydrates (Okoro and Grace, 1976). In *Triplochiton scleroxylon* cuttings collected from stock plants which contained higher carbohydrate and lower nitrogen levels normally rooted more easily than poorly nourished trees. (Leakey, 1983). Zakaria and Ong (1982) obtained a higher rooting percentage when using stem cuttings taken from the basal part of *Gmelina arborea* seedlings when compared to those taken from the terminal part. According to Hamsawi (1981), the basal part of the stem of *Gmelina arborea* seedlings had a higher carbohydrate to nitrogen ratio than cuttings from the terminal part.

2.1.3 Buds and leaves

Many scientists have reported that there is a positive relationship between the formation of adventitious roots and the presence of buds and leaves. Normally the presence of buds and leaves increases root formation. If the buds and leaves are removed, especially in stem cuttings of "difficult-to-root" species, it can delay root formation or cause a total failure in rooting (Komissarov, 1964; Kennedy *et al.*, 1980; Geary and Harding, 1984). This may be due to auxin production of buds and leaves and their nutritional effects (Wareing and Phillips, 1970). The function of leaves in the rooting process may also be to supply enough carbohydrate to the stem tissues involved in root formation and development. In most species, the presence of leaves on cuttings appears to be very important. Darus (1988) reported that single

node cuttings of *Acacia mangium* with one or half a phyllode increased rooting percentages. Without the phyllode, the rooting process was slow and a lower rooting percentage was obtained.

For some big leaf species which are indigenous to Malaysia such as *Endospermum malaccense* (Darus *et al.*, 1990a), *Shorea macrophylla* (Lo, 1985) and *S. bracteolata* (Aminah, 1990) trimming the leaves into half or one-third of their size produces a good rooting percentage. By trimming the leaves, loss of water is reduced and root initiation is stimulated. However, for timber species which have small leaves such as *Hopea odorata*, one whole leaf is recommended to be retained on each cutting (Aminah, 1991c). The recommended number of leaves which should be retained on stem cutting of various tree species is in Table 2.

Table 2. Suggested number of leaves per cutting of selected species

Species	Number of leaves per cutting
Acacia mangium	one half phyllode
Agathis dammara	three pairs of leaves
Alstonia angustiloba	four half leaves
Endospermum malaccense	one half leaf
Eucalyptus camaldulensis	four quarter leaves
Gmelina arborea	one half leaf
Anisoptera schapula	one leaf
Dipterocarpus charteceous	three half leaves
Shorea assamica	one half leaf
S. bracteolata	one third of the leaf
S. macrophylla	one third of the leaf
S. obtusa	two leaves
S. ovalis	one half leaf
S. parvifolia	one leaf
S. pauciflora	one half leaf
S. platyclados	one half leaf
S. singkawang	one third of the leaf
S. talura	one leaf
Vatica walichii	one leaf

2.1.4 Size of cuttings and node position

For stem cuttings, the suggested length of the cutting depends on the length of internodes. If the internode is long, the cutting can be one node and if they are short, each cutting may contain two or more internodes. In some species like *Eucalyptus camaldulensis*, long cuttings with four nodes root better than cuttings with three nodes or less (Geary and Hardings, 1984). In species such as *Hopea odorata* (Aminah, 1991c) and *Acacia mangium* (Darus, 1988), a single node cutting can be used. It is more efficient to root shorter cuttings as more plants can be propagated from one stem.

In many tree species the rooting ability of stem cuttings declined sequentially with distance from the apex. This has been observed in the species indicated in Table 3.

Table 3. Stem cuttings of species in which rooting declined with distance from the apex.

Species	References
Shorea bracteolata	Aminah, 1990
S. macrophylla	Lo, 1985
Eucalyptus deglupta	Davidson, 1974
Liquidambar styraciflua	Bilan, 1974
Olea sp.	Avidan and Lavee, 1978
Triplochiton scleroxylon	Leakey, 1983

Reasons for differences in rooting between node positions could be: 1) The length of internodes. The upper node cuttings have longer internodes compared to the basal nodes. Longer cuttings rooted better due to the influence of greater carbohydrate reserves and the presence of other essential substances for root formation (Hartmann and Kester, 1983). 2) The degree of lignification. The more lignified and woody cuttings of the lower nodes are unsuitable for rooting (Hartmann and Kester, 1983). 3) The age of leaves. Old leaves of cuttings from the basal nodes

readily dropped while on the rooting beds before rooting could take place (Leakey *et al.*, 1982). These cuttings will eventually die when their carbohydrate reserves become depleted.

2.2 Environmental factors

2.2.1 Rooting medium

Rooting medium is the substrate into which the cutting materials are inserted. The rooting medium has three main functions, 1) to hold the cuttings upright during the rooting period, 2) to provide moisture for the cuttings and 3) to maintain aerobic conditions at the base of the cuttings (Hartmann and Kester, 1983). Appropriate physical and chemical properties of a good rooting medium are 1) a high water-holding capacity, 2) good drainage 3) sufficient porosity to allow good aeration, 4) freedom from harmful pathogens and 5) a suitable pH level (Lamb *et al.*, 1975; Hartmann and Kester, 1983; Boeijink and Broekhuizen, 1974). The most commonly used rooting media are soil, sand, vermiculite, peat and perlite.

In Malaysia, most tree nurseries use sieved river sand as a rooting medium. Sand is often used because it is inexpensive, readily available and provides good drainage and aeration. However, sand has poor moisture-retaining properties and requires more frequent watering compared to other rooting media. If sand is used, it should not be too coarse so that some moisture could be retained around the cuttings. It was found that pure sand was the preferred medium for stem cuttings of most indigenous tree species such as *Endospermum malaccense*, *Shorea bracteolata* and *Hopea odorata*.

Other rooting media, such as peat moss, vermiculite and perlite are also widely used, particularly in Western countries. However, many reports show that these media are best when used in combination with other rooting medium, for example a mixture of equal parts of river sand and peat moss are suitable for *A. mangium* stem cuttings (Darus, 1988) (Table 4).

Besides the solid rooting medium, it was reported that aerated water has been successfully used to root several tropical timber tree species (Smits ie al., 1993).

Table 4. Rooting percentage of *A. mangium* stem cuttings in four different rooting media

Rooting medium	S	S:P	S:V	S:P:V
Total rooted cuttings	8	33	15	8
Total non-rooted cuttings	16	5	19	9
% rooted	16.0	66.0	30.0	16.0

Source: Darus, 1988

S = 100% river sand
S:P = A mixture of sand and Irish sphagnum peat in equal proportion.
S:V = A mixture of sand and vermiculite in equal proportion.
S:V:P = A mixture of sand, vermiculite and Irish sphagnum peat in equal proportion.

2.2.2 Water relations

Although the presence of leaves and buds on cuttings are important to stimulate root formation, the loss of water from the leaves due to transpiration can result in death before root formation can take place.

Nowadays intermittent mist spray systems are used to maintain high air humidity in rooting chambers. Covering the rooting beds with a plastic sheet will ensure higher humidity and reduce the frequency of spray. High humidity should always be maintained in the rooting chamber to avoid water stress in the cuttings. Several dipterocarp species such as *Hopea odorata, Shorea assamica, S. bracteolata, S. leprosula, S. ovalis, S. parvifolia* and *S. platyclados* have been successfully rooted with mist sprays in plastic enclosures (Aminah, 1991d).

2.2.3 Light

The effects of light on the rooting process depend on the quality, intensity (irradiance) and photoperiod (day-length) (Komissarov, 1964). Komissarov found that stem cuttings of light demanding species, such as *Lagerstroemia indica*, rooted well with high light intensity (5000-6000 lux at midday). Rooting percentage was greatly reduced at low light intensity (600-900 lux at midday). However, it should be noted that there are many light-loving plants, such as *Rhododendron* species which rooted well when planted under low light intensity.

The intensity of light needed by cuttings will depend on the species, their degree of lignification, their carbohydrate reserves and the age of stock plants. A greater light intensity is required for lignified and semi lignified cuttings of mature trees compared to little-lignified cuttings with less carbohydrate reserves (Komissarov, 1964). Very high light intensity is detrimental to newly planted cutting (Grange and Loach, 1983). In general, most tropical timber species require about fifty percent direct sunlight to produce an optimum rooting percentage.

Many workers reported that the length of photoperiod is also important for root formation. Nitrch (1957) reported that cuttings of *Salix* spp. exposed to an 18 hour-photoperiod, rooted faster and formed more and longer roots. For cuttings of tropical timber species, a 12 hour length day is normally sufficient.

Hartmann and Kester (1983) and Komissarov (1964) also reported that the photoperiod under which the stock plants were grown affected the rooting of cuttings. This may be related to carbohydrate accumulation in the cuttings. In most cases, when the stock plants, particularly light-loving plants, are held under long day or continuous illumination, they yield better rooting percentages.

There have been a number of studies on the influence of light quality. These suggest that the light spectrum under which the stock plants are grown has an impact on the subsequent rooting

performance of cuttings. Focus is given to the red (660 nm) and far-red (730 nm) wavelengths. This relates to the light regime on tropical rainforest floors which are characterised by the low red to far-red ratio (Richards, 1957 and Whitmore, 1975). Light quality may influence the growth, photosynthetic capacity and development of the plants as well as the subsequent rooting of cuttings taken from them. An experiment by Leakey and Storeton-West (1991) indicated that for light demanding species like *Triplochiton scleroxylon*, cuttings taken from stock plants planted under light with a lower red to far-red ratio (1.6) rooted better than cuttings obtained from stock plants grown under light with a high red to far-red ratio of 6.3. However, the shade tolerant species of *Lovoa trichiloides* did not show any significant improvement in rooting of cuttings taken from stock plants raised under low or high red to far-red ratios (Tchoundjeu, 1989).

2.2.4 Temperature

Air temperature is an important factor influencing root formation of stem cuttings. The optimum temperature for root formation differs between species. Usually cuttings of tropical and subtropical species require a higher temperature for rooting than those from temperate and cold countries (Komissarov, 1964).

Although it has been suggested that the air temperature surrounding cuttings should be about 5°C lower than the temperature of the medium in order to get a good rooting percentage, cuttings of most tropical timber species tested in FRIM such as *Shorea ovalis*, *S. assamica*, *S. platyclados*, *S. bracteolata*, *Hopea odorata*, (Aminah, 1991d); *Endospermum malaccense* and *Acacia mangium* (Darus *et al.*, 1990a) rooted well under normal air temperature (28° - 32°C).

2.2.5 Plant growth substances

The purpose of treating cuttings with synthetic growth substances is 1) to increase rooting percentage, 2) to hasten root initiation, 3) to increase the number and quality of roots produced per cutting and 4) to increase uniformity of root size.

Of the many synthetic substances which act as growth regulators, only a few effectively stimulate adventitious root formation. They are beta-indole acetic acid (IAA), indole-3-butyric acid (IBA) and alpha-naphthalene acetic acid (NAA) (Komissarov, 1964). For "difficult-to-root" species, the application of growth substances generally improves the rooting ability of cuttings. However, the effectiveness of these substances largely depends on their concentration, the species, the age of stock plants and the type of cuttings. Smits (1983) found that cuttings of one year old *Shorea obtusa* and *Agathis dammara* seedlings, treated with 100 ppm IBA solution gave 100% rooting after six weeks in rooting chambers. Similar results were obtained in stem cuttings of *S. bracteolata, S. leprosula, Anisoptera scaphula* and *Dipterocarpus charteceous* treated with 500 to 2000 ppm IBA (Srivastava and Penguang Manggil, 1981).

The most common methods of treating stem cuttings are 1) soaking or quick dipping of the base of the cuttings in growth substance solutions or 2) dipping into a mixture of growth substance and talcum powder. Table 5 indicates the growth hormone that is suggested for rooting stem cuttings of various species.

3. Infrastructure required for stem cuttings

3.1 Cutting shed

For large scale production of cuttings, it is advisable to build a permanent cutting shed with wooden/concrete rooting beds so that they can be continuously used. Normally, translucent plastic roofing with sarlon netting is used to reduce about 50% of the direct sunlight. The side walls of the cutting shed can be made of wire netting to avoid outside disturbance Additional net should be hanged at the sides of the cutting shed to shade the cuttings from direct sunlight whenever necessary. The size of the cutting shed depends on its usage and available capital. In FRIM, the size of the

cutting shed is 10 m x 30 m. Such a cutting shed, together with concrete rooting beds and an automatic mist sprinkler system, costs about RM80,000.00 (Appendix 1).

Table 5 Types of hormones and concentrations that can be used for rooting stem cuttings of selected species.

Species	Type of hormone used	Concentration
Acacia mangium	IBA	500 ppm(solution)
Agathis dammara	IBA	100 ppm(solution)
Alstonia angustiloba	no hormone	–
Endospermum malaccense	Seradix 3	0.8% IBA(powder)
Gmelina arborea	Trihormone	3% NAA(powder) or
	IBA	100 ppm (solution)
Anisoptera scaphula	IBA	2000 ppm (solution)
Dipterocarpus oblogifolia	IBA	1000 ppm (solution)
Hopea odorata	Seradix 3	0.8% IBA (powder) or
	IBA	1000 ppm (solution)
Shorea assamica	Seradix 3	0.8% IBA (powder)
S. bracteolata	Seradix 3	0.8% IBA (powder) or
	IBA	500 ppm (solution)
S. leprosula	IBA	2000 ppm(solution)
S. macrophylla	IBA	1200 pm (solution)
S. obtusa	IBA	100 ppm (solution)
S. ovalis	Seradix 3	0.8% IBA (powder)
S. parvifolia	Seradix 3	0.8% IBA (powder)
S. pauciflora	Seradix 3	0.8% IBA (powder)
S. platyclados	Seradix 3	0.8% IBA (powder)
S. singkawang	Seradix 3	0.8% IBA (powder)
Vatica pauciflora	IBA	2000 ppm (solution)

A simple and low cost propagator can also be constructed as described in Leakey *et al.* (1990). It consists of a wooden frame wrapped with plastic sheet. The plastic sheet is extended to the base of the propagator so that it is water tight. Water is added

through the hollow bamboo whenever necessary to maintain the water table (Appendix 2). This propagator is then shaded with palm leaves or plastic netting. This system has proven effective in propagating species such as *Albizia guachepele, Acacia tortilis, Eucalyptus deglupta, Gmelina arborea* and *Prosopis juliflora* (Leakey *et al.*, 1990).

In Cameroon, mass production of rooted cuttings of selected walnut has been carried out (Leakey *et al.*, 1990). This is conducted in simple wooden propagators containing 100% river sand as a rooting medium. A plastic sheet is wrapped around a wooden frame in order to increase air humidity and is placed under a palm leaf shade.

Another alternative is to use a plastic tray which is filled with water and rooting medium. After the cuttings have been planted, the tray is tightly covered with glass or plastic sheet to maintain high humidity inside it. This is placed under a plastic enclosure supported by a wooden frame to protect it from rain or other disturbance. The shade can either be from a commercial plastic net or natural shade of trees (Appendix 3). This propagator is simple and portable. It has been successfully used in FRIM to root tissue culture shoots of *Acacia mangium* and *Calamus* species.

3.2 Rooting beds

The size of the rooting bed is not important because it varies from one nursery to the next. In FRIM, a concrete rooting bed measuring 1 m x 0.2 m x 10 m is used. It is normally raised about 1 meter above the ground to facilitate working. Drainage holes are made around the rooting bed to remove excess water (Figure 1).

3.3 Sprinkler systems

The sprinkler system is important to keep the cuttings and rooting medium moist during the rooting process. Sprinklers should be fitted at equal distances along the centre of the rooting bed. Normally, in a three meter bed, three sprinkler nozzles should

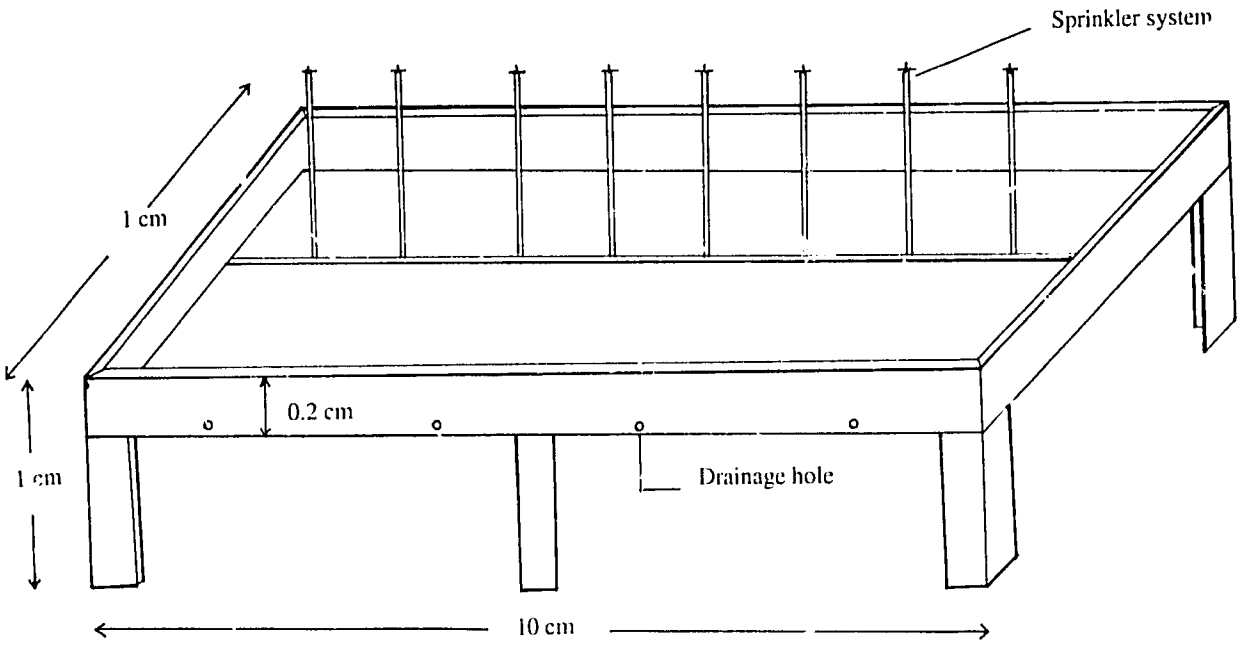


Figure 1. Rooting bed with sprinkler system

be installed (Figure 1). The system operates automatically and a timer is installed to regulate the frequency and duration of misting. The frequency of spray depends on the species used and should be tested for its suitability. In FRIM, the sprinkler system operates 24 hours at hourly intervals. Each duration of spray is one minute. This frequency is used when the rooting beds are covered with plastic sheet (Plate 1). The plastic enclosure ensures higher air humidity around the cuttings. Presence of mist or water droplets on the plastic sheet is an indication of a higher air humidity (90% to 100%), which is necessary for

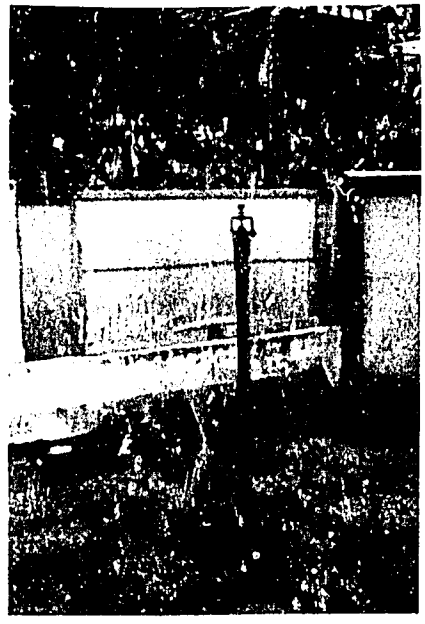


Plate 1. Rooting bed with plastic enclosure

successful rooting of cuttings of tropical timber species. If the rooting beds are not covered with plastic sheet, the sprinkler system should be operated more frequently (e.g. every five minutes). A higher mortality will result when the cuttings are under water stress.

3.4 Rooting medium

Pure river sand (60% with less than 2mm and 40% with about 2 mm to 5 mm diameter) is normally used for stem cuttings in FRIM. It is inexpensive, readily available and well drained. It has been successfully used for rooting cuttings of many timber species. Freshly collected river sand needs to be cleaned of debris, big stones, rubbish and mud before it is placed in the rooting beds. In FRIM the cleaned rooting beds are first layered with stones (2 to 3 cm diameter) to facilitate drainage. This followed by distribution of the rooting medium (Figure 2). Experience in FRIM indicates that there is no need for sand to be sterilised. However, it is advisable to change the upper 10 cm of the medium for each new batch of cuttings to avoid fungal contamination from dead cuttings of previous batches.

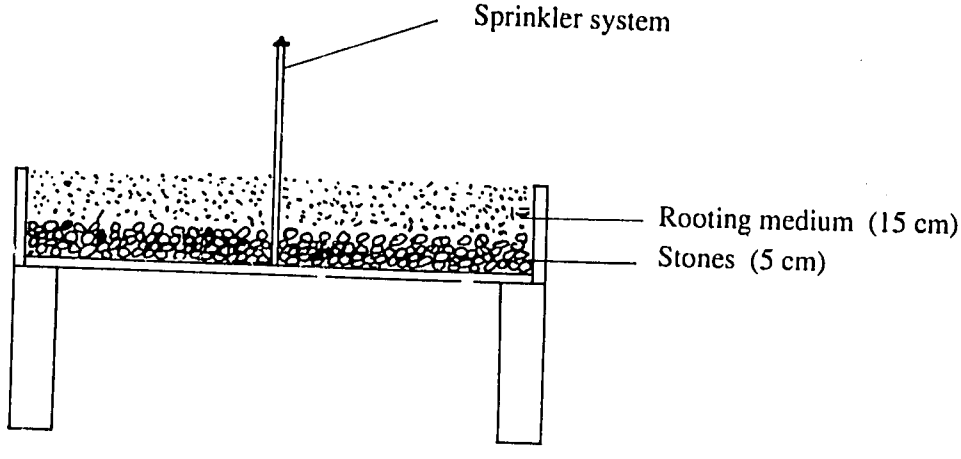


Figure 2. Cross section of the rooting bed

4. Methods and procedures

4.1 Stock plants

Stock plants are normally raised in black polythene bags. However, for continuous supply of cutting materials, it is recommended that the stock plants be permanently planted in a bush garden. The normal planting distance of these stock plants within and between rows is about 0.5 m and 1.0 m respectively. For dipterocarp species, 20% to 30% shade is necessary during the initial 3 to 4 months after planting for optimum growth. This is achieved by planting stock plants under temporary sarlon netting. Stock plants are regularly pruned to about 20 to 50 cm from ground level depending on the species. This can produce optimal coppices for cutting materials (Plate 2).

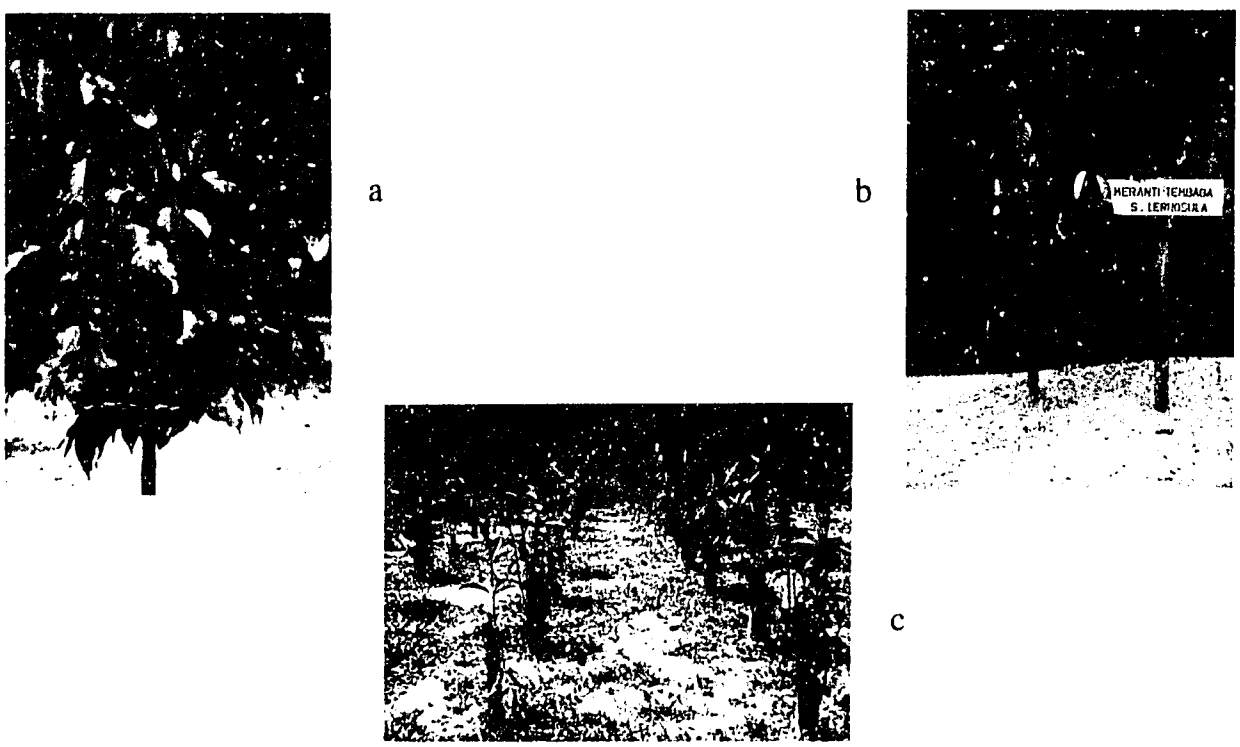


Plate 2. Stock plants of some timber species including a) *Shorea leprosula*, b) *Hopea odorata* and c) *Alstonia angustiloba* planted in the bush garden at the FRIM nursery

Commercial compound fertilizers such as NPK Blue (12:12:17:2 -N: P_2O: K_2O: MgO: TE - trace element) is applied every two months to ensure healthy growth of stock plants. The rate of application is about 50 gm per plant. Regular spray of fungicides and insecticides is necessary to protect these plants from disease and insect attack. The planting site is regularly tilled to avoid soil compaction around the stock plants. Compost or rotted cowdung is applied when the planting site is sandy to improve the texture of the soil.

4.2 Preparation of the cuttings

Cutting scions should be taken from healthy stock plants which are free from disease and insect attack. A sharp blade is necessary when preparing cutting scions. The base should be cut at a right angle and it is important to ensure that the cut is smooth to prevent rotting. The length of the cutting depends on whether it is single node or two node. It is normally between 3 to 8 cm long. The diameter of the cutting material is between 1 and 6 mm depending on the node position, species and age of stock plants. Normally cuttings from the middle part of the stem are used for rooting (Figure 3). The soft terminal shoot/apex and the woody basal part of the seedlings or coppicing shoots are not used because they are not suitable for rooting.

Normally, the stem is preferable as a source for cuttings to ensure that the new plants obtained grow othotropically. Branch cuttings of some tree species retain their plagiotropic growth as observed in *Araucaria hunsteinii* (Darus, 1982) and *Agathis dammara* (Smits, 1983). The branch cuttings of dipterocarp species such as *Hopea odorata* also grew plagiotropically even after having been planted one year on the ground (Aminah, 1991b).

The presence of a leaf or leaves on the cutting is important for root formation and development. For species which have big leaves such as *Endospermum malaccense, Shorea bracteolata* and *Acacia mangium* the leaf needs to be cut transversely to half or one third of its size in order to reduce water loss through transpiration. The

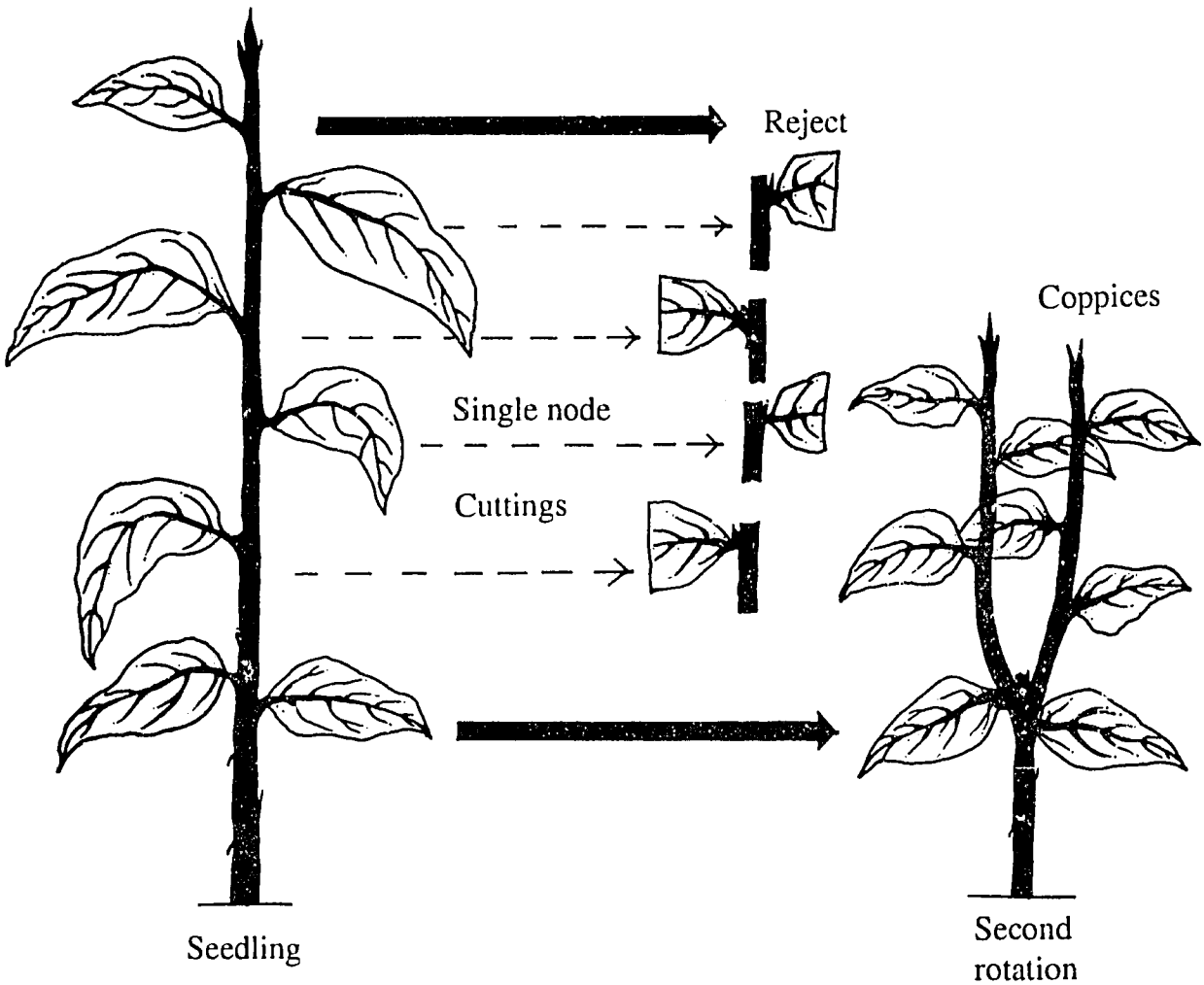


Figure 3. Schematic drawing of stock plant and cutting scions

optimum size of leaf is also necessary for the process of photosynthesis which is reported to occur while cuttings are on the rooting beds (Leakey *et al.*, 1982).

4.3 Planting of cuttings

Before planting the cuttings the medium is first watered to keep it moist. The base of the cuttings are treated with a suitable growth hormone and planted into the rooting medium at 1 to 2 cm deep depending on the size of the cuttings. The cuttings are planted in rows and distributed in the rooting beds so that no overlapping occurs between them (Plate 3).

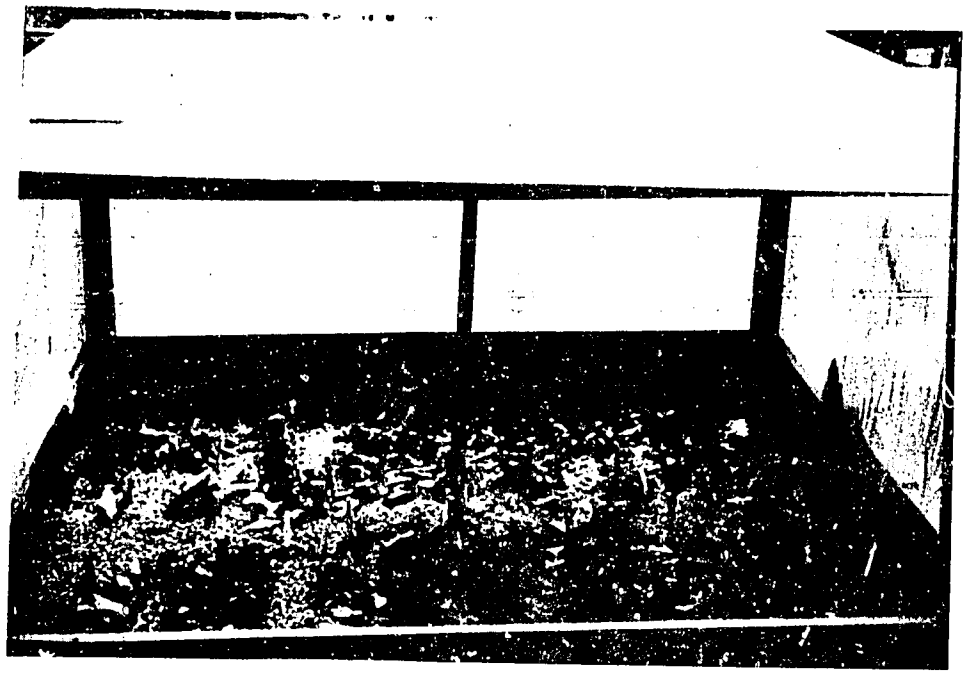
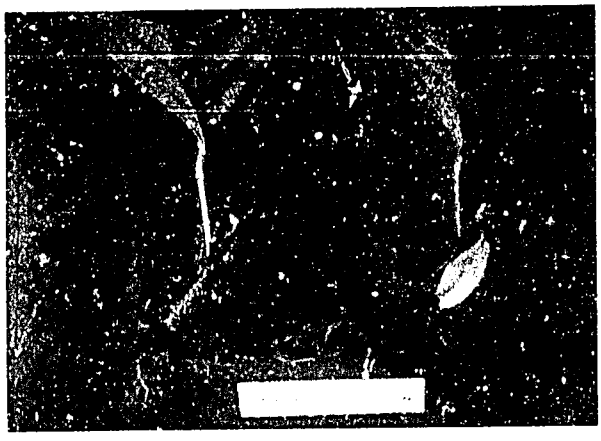


Plate 3. Cuttings on the rooting bed

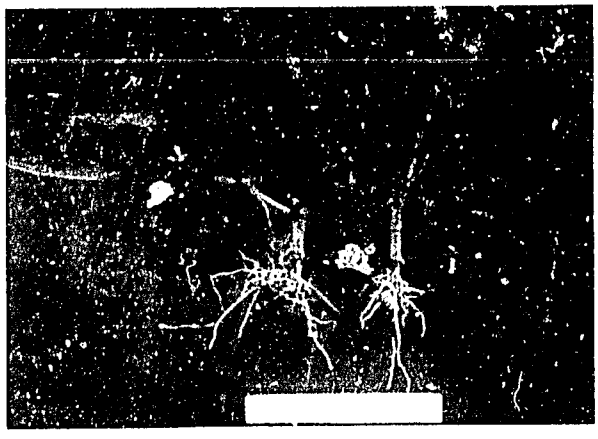
4.5 Harvesting and potting of rooted cuttings

Cuttings on the rooting bed should be regularly inspected. Dead cuttings and dried leaves should be removed from the bed to avoid spread of diseases. Insecticides and fungicides are sprayed on the cuttings when there is a sign of insect or fungus attack. The time at which cuttings should be harvested from the rooting beds varies between species. For many dipterocarp species, cuttings can be harvested at about ten to twelve weeks after planting. On the other hand, harvesting the stem cuttings of *Acacia mangium*, *Endospermum malaccense* and *Alstonia angustiloba* can be carried out only four to five weeks after planting. Examples of the rooted cuttings are shown in Plate 4.

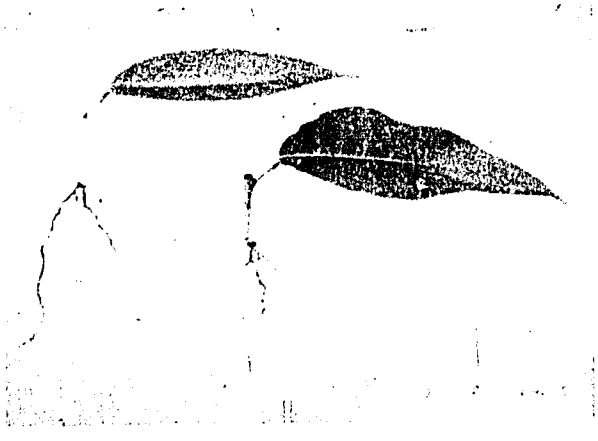
Rooted cuttings are immediately transplanted into polythene bags when the roots show some lignification. This is because the fragile roots of cuttings are easily broken and this will cause death of cuttings after transplanting. In FRIM the potting mixture for rooted cuttings is sand and forest top soil in the ratio of 1:3. Ground magnesium limestone and triple superphosphate (46% P_2O_5) are added to the mixture at the rate of 1.6 kg/m^3 and 1.2 kg/m^3 respectively.



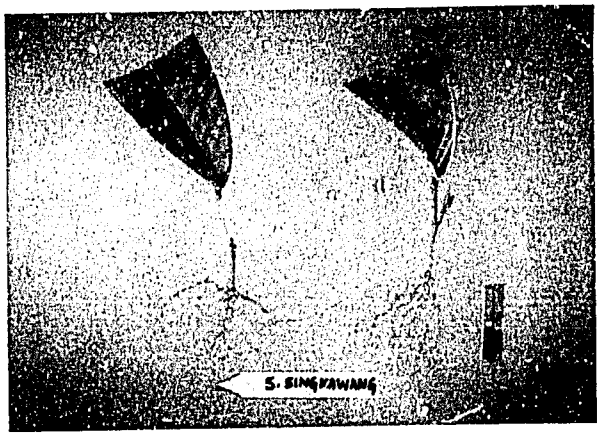
Shorea bracteolata



Shorea parvifolia

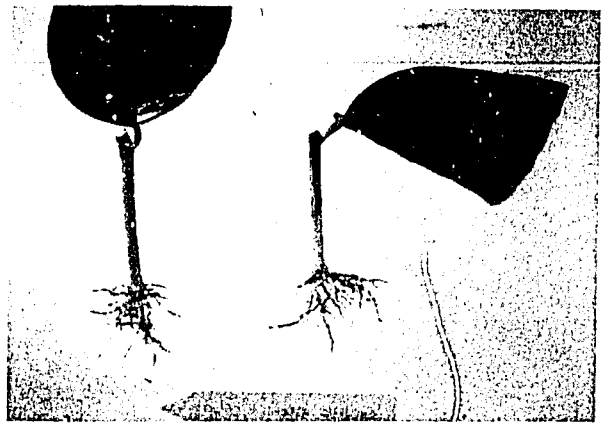


Shorea platyclados



Shorea singkawang

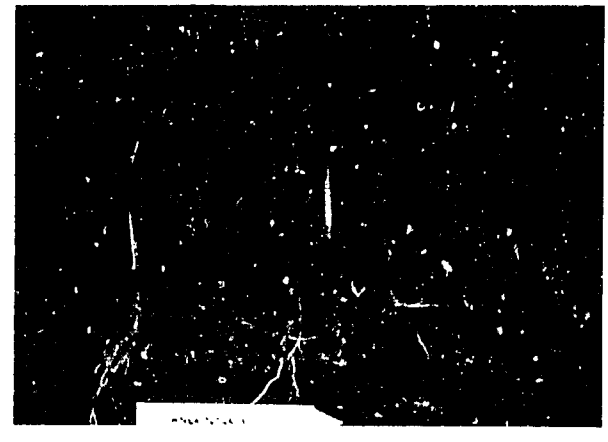
Plate 4a. Examples of rooted cuttings



Shorea leprosula

Shorea ovalis

Shorea assamica



Hopea odorata

Plate 4b. Examples of rooted cuttings

4.6 Maintenance of rooted cuttings

The potted cuttings are weaned in the shade for one month before being transfered to transplanting beds with 50 to 60% light intensity. The dipterocarp species will remain under this light intensity until they are sent to the field. Rooted cuttings of other species like *Endospermum malaccense, Alstonia angustiloba* and *Acacia mangium* are fully exposed to the sun when they are three to four months old.

Application of fertilizer is monthly, starting one month after potting to maintain healthy growth of rooted cuttings. Compound fertiliser such as NPK Blue can be applied at a rate of 1g/plant as practised in the FRIM nursery.

Watering of the potted cuttings is carried out twice a day, in the morning and late afternoon. Weeding, insecticide and fungicide applications are carried out whenever necessary.

5. Discussion and Conclusions

Important factors which influence rooting of stem cuttings are species, age of stock plants (juvenility), nutrition, plant growth substances, presence of buds and foliage, rooting medium, temperature, light quality and intensity and water supply. We believe that stem cuttings of commercial indigenous species in Malaysia can be rooted easily. In fact, some tropical hardwood species which are considered as "difficult-to-root" have been successfully propagated by FRIM scientists and scientists from other research institutions in South East Asia (see Appendix 4).

The concept of using rooted cuttings for large scale planting is not new. For example, in Aracruz, Brazil rooted cuttings of *Eucalyptus grandis* and *E. urophylla* are mass produced for large scale planting programmes (Spears, 1985). Similarly, in Thailand thousands of *Casuarina junguliana* rooted cuttings are propagated annually for agroforestry activities.

The gains of using selected clonal materials are spectacular. It is reported that the mean annual increment (MAI) of *Eucalyptus* rooted cuttings in Aracruz, Brazil is increased to about 130 m^3/ha/year and they are very resistant to major diseases such as trunk canker, and rust and other foliage diseases.

In FRIM, efficient techniques for production of rooted cuttings of some indigenous tree species such as *Endospermum malaccense* and *Hopea odorata* have been developed. About one thousand rooted cuttings of these particular species have been produced and they are planted on the FRIM grounds to test their anchorage stability and growth performance.

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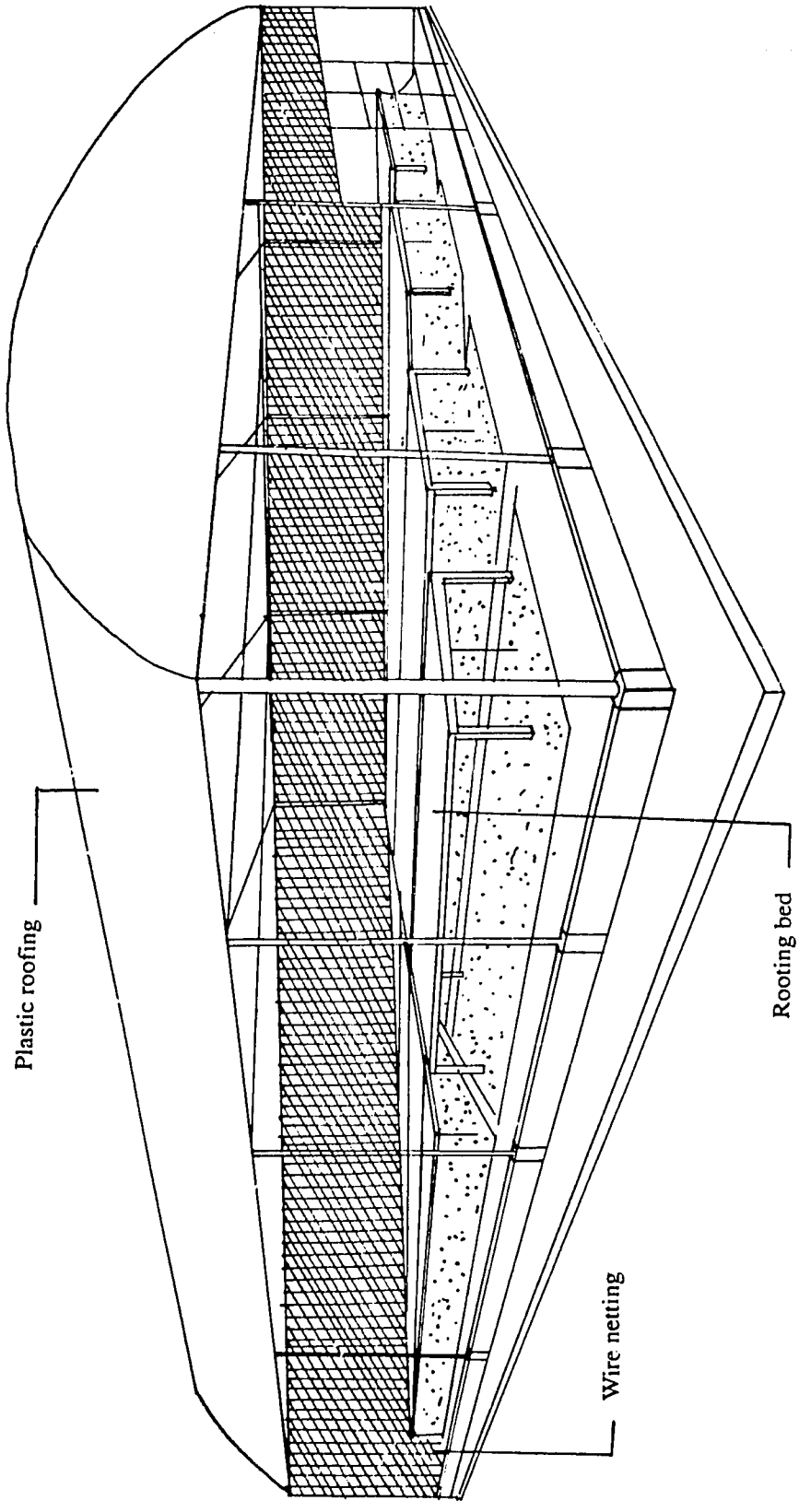
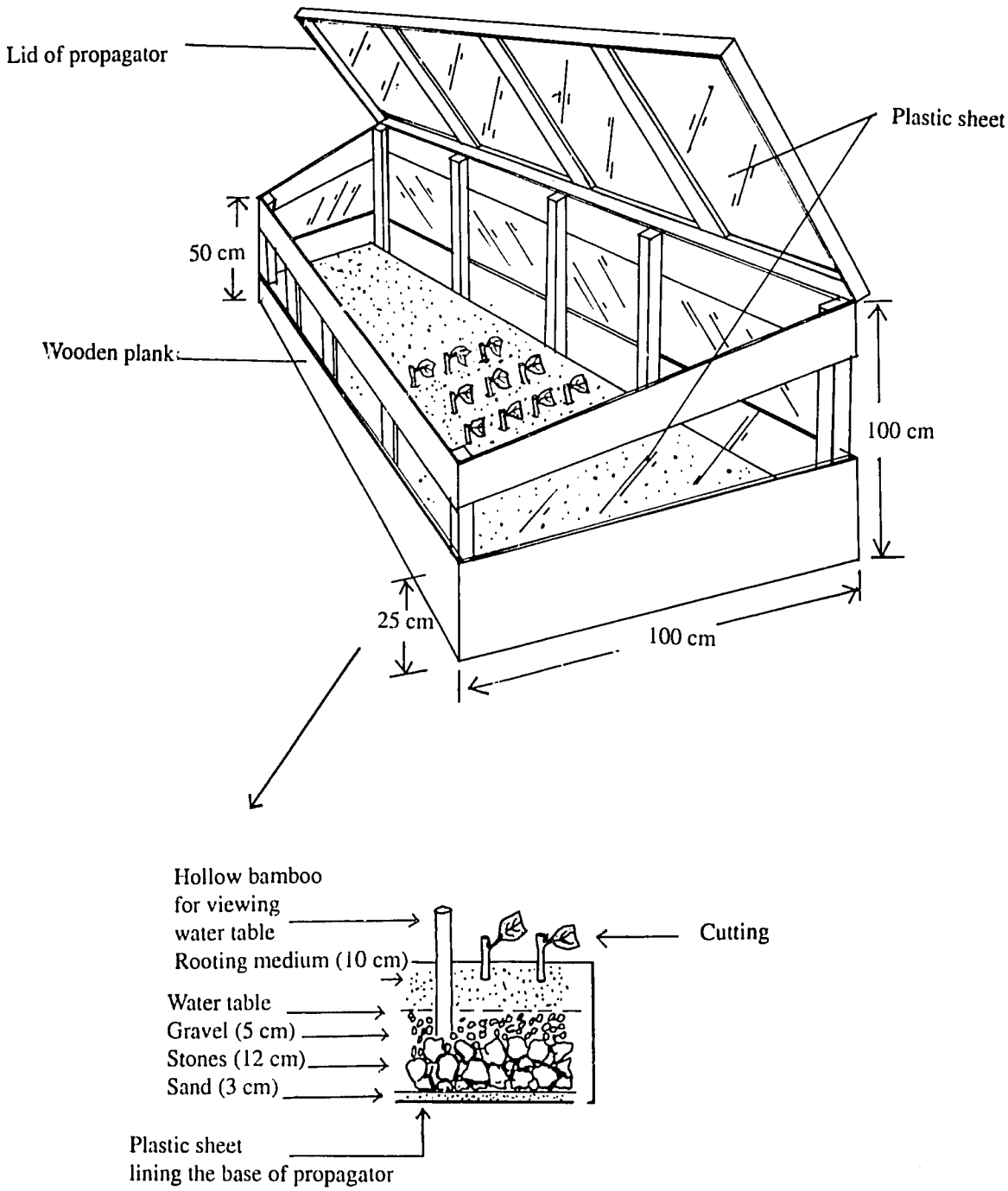
Appendices

Appendix 1. Cutting shed

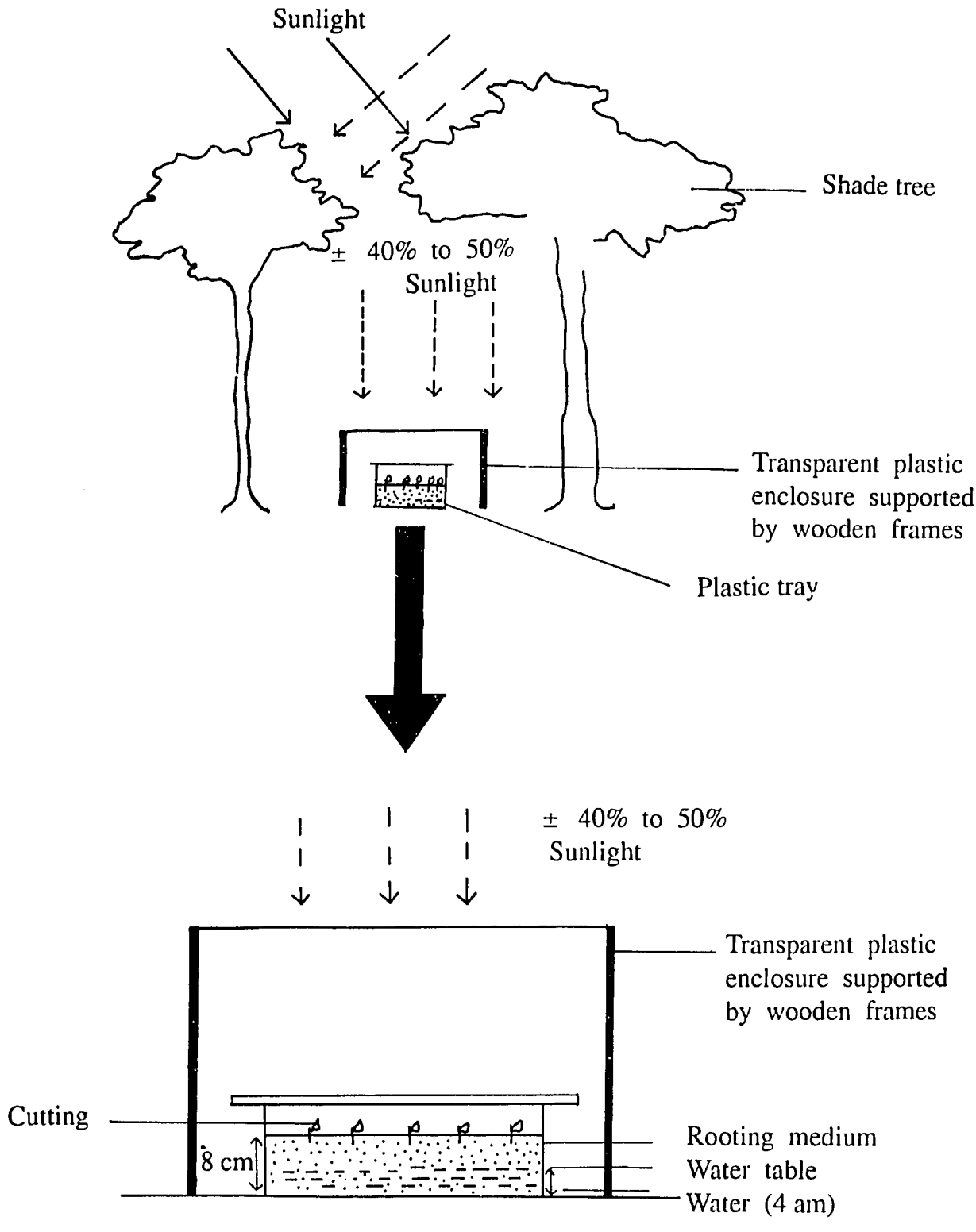


Appendix 2. Simple, low technology propagator

(Source: Leakey *et al.*, 1990)



Appendix 3. Simple portable propagator



Appendix 4. List of tree species which are successfully propagated by stem cuttings

Species	Referenes
Acacia mangium Willd.	Darus 1988
Agathis dammara	Momose 1978 and Smits 1983
Alstonia angustiloba Miq.	Aminah 1991a
Araucaria hunsteinii	Darus 1981
Gmelina arborea Roxb.	Zakaria and Ong 1982; Wong and Jones 1986
Endospermum malaccense M.A.	Darus *et al.* 1990
Podocarpus imbricatus	Momose 1978
Dryobalanops keithii Sym.	Muckadell and Malim 1978
D. lanceolata Burck.	Muckadell and Malim 1978
Parashorea tomentella Meijer.	Muckadell and Malim 1978
Shorea acuminatissima Sym.	Muckadell and Malim 1978
S. argentifolia Sym.	Muckadell and Malim 1978
S. faguetiana Heim.	Muckadell and Malim 1978
S. gysbertsiana Burck	Muckadell and Malim 1978
S. leavis Ridl.	Muckadell and Malim 1978
S. leprosula Miq.	Muckadell and Malim 1978
S. macroptera Dyer.	Muckadell and Malim 1978
S. oleosa Meijer.	Muckadell and Malim 1978
S. parvifolia Dyer.	Muckadell and Malim 1978
Anisoptera scaphula (Roxb) Pierre.	Momose 1978; Srivastava and Manggil 1981
Dipterocarpus charteceous Sym.	Momose 1978; Srivastava and Manggil 1981
Dipterocarpus oblogifolia Bl.	Alias 1984
Hopea odorata Roxb.	Aminah 1991d and Alias 1984.
Shorea assamica Dyer.	Aminah 1991d
S. bracteolata Dyer.	Aminah 1991d; Srivastava and Manggil 1981; Alias 1984
S. macrophylla (De Vr) Ashton	Lo 1985
S. obtusa CF.	Smits 1983
S. platyclados V. Sl. ex Foxw.	Aminah 1991d
S. singkawang (Miq) Burck.	Aminah unpublished
S. talura Roxb.	Momose 1978
Vatica pauciflora	Halle and Kamil, 1981
Vatica walichii Dyer.	Momose 1978