Seed Handling and Propagation of Papua New Guinea's Tree Species

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Acronyms

ACIAR	Australian Centre for International Agricultural Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
dbh	Diameter at breast height
mc	Moisture content
NTSC	National Tree Seed Centre (Papua New Guinea)
PNG	Papua New Guinea
PNGFA	Papua New Guinea Forest Authority
PNGFRI	Papua New Guinea Forest Research Institute
PNGNFS	Papua New Guinea National Forest Service

Preface

This booklet has been prepared as part of the project 'Domestication of Papua New Guinea's Indigenous Forest Species'. The project focused on the domestication and conservation of Papua New Guinea's forest species through the Papua New Guinea Forest Research Institute (PNGFRI). The project received financial support from the Australian Centre for International Agricultural Research (ACIAR). The Commonwealth Scientific Industrial Research Organisation (CSIRO) was the commissioned agent and implemented the project.

The PNGFRI is frequently called upon to provide information relating to the use of PNG forest species. Many of these requests come from the desire to propagate native trees to satisfy commercial and social needs. There has been an obvious lack of information on the cultivation of PNG tree species. As part of the four-year project, staff from the PNGFRI and the National Tree Seed Centre (NTSC) were engaged in various activities in order to gain information on seed handling, germination and vegetative propagation of PNG forest species. The work involved monitoring phenological activity of over 30 forest species from the time of flower initiation to the time of seed shed. Mature seed was then collected and used to determine optimum methods for processing the seed, to conduct germination tests and to assess the ability of seed to retain viability under differing storage conditions. Separate studies were carried out to assess the potential for striking cuttings from a similar range of species. The results of these studies are contained in this booklet.

The booklet is divided into six main sections. The first four sections deal with seed collection, processing and storage, and provide the reader with background information on how to collect seed and process it prior to sowing or storage. Information is also presented on the behaviour of seed in storage, and how to apply this knowledge to determine the most appropriate methods of storing seed of PNG species. Section 5 provides brief information on nursery techniques for raising seedlings and techniques for striking cuttings. Section 6 provides information on 27 PNG tree species, with a focus on seed handling and propagation. It is envisaged that these species descriptions will be reproduced in a series of 'Species Seed Leaflets' and at the same time will encourage others to write up more species. Information in the species descriptions is derived from reference material and from the results of research conducted by the Papua New Guinea Forest Research Institute and the National Tree Seed Centre. The booklet also provides a table of flowering and fruiting times for more than 150 species, based on observations from various sources. In most species there is great variation from year to year, from location to location and from tree to tree, so this information can be used only as a guide. Further monitoring over an extended period is required. Examples of forms used to record phenological activity and seed collected are provided. The great range of forest species, and morphological variation that occurs within species, sometimes makes identification to the species level very difficult. Information has therefore been provided on how to collect herbarium specimens and preserve them in order to assist with identification. A plan of a simple vegetative propagation unit is contained in the Appendices.

It is hoped that this publication will energise others in PNG and other parts of the region who are interested in growing trees. There are huge gaps in our knowledge and there is an on-going need to conduct research and expand the current knowledge of seed handling and propagation of tropical tree species.

Acknowledgements

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1. Background

Papua New Guinea (PNG) has a rich and diverse forest flora comprising over 2500 species and ranging from mangrove swamps through dense lowland rainforest to the wet mossy forests at altitudes of 3000 m. Even though there are extensive tracts of relatively undisturbed forests in PNG, it is now recognised that there is a need to better manage harvesting of the forest to enable the forest to regenerate naturally or to replant. This is necessary to meet community needs, address environmental degradation and to ensure the supply of raw material for forest-based industries.

Natural forests have the capacity to regenerate themselves if logged using reduced-impact logging guidelines, but deforested areas will require planting using plants raised from either seed or by vegetative propagation, or transplanted wildings. For this to occur, there is a need for increased knowledge on seed collection, processing, storage, propagation and planting. Seed, or other form of planting material, is a fundamental requirement in any agroforestry, plantation and reforestation program. An imperative to provide planting material has often led to the sacrifice of quality, suitability and overall sustainability in favour of whatever germplasm is available at the time and at the cheapest price. It must be remembered that the genetic quality of germplasm can contribute greatly to the success or failure of the planting, through its influence on tree form, tree vigour and quality of timber.

Despite the great range of valuable forest species for wood and non-wood forest products in PNG, only a very few have been planted on a large scale. A limited number have been cultivated in commercial plantations, including *Araucaria hunsteinii, A. cunninghamii, Acacia mangium, Eucalyptus deglupta and E. pellita. Casuarina oligodon* is widely planted for improved fallow by communities in the highlands. Other species have been grown as a food source, e.g. *Canarium indicum* (galip nut), *Pometia pinnata* (taun) and *Terminalia kaernbachii* (okari nut). However, for most PNG tree species there is no information on growth rates, flowering and fruiting times or methods of propagation.

This booklet is designed to provide the user with information on how to undertake seed collections including planning, removal of seed from the tree, processing, seed testing, storage and recording important information relating to the seed. For those species which are difficult to propagate from seed or where seed is difficult to obtain, alternative methods of producing plants need to be found. A separate section provides information on vegetative propagation, focusing on cutting techniques.

Vegetative propagation has the added advantage of providing mass-produced plants which may be genetically identical if they are derived from the same parent. This enables the grower to reproduce trees with superior desirable traits by taking cuttings from selected parents.

An important part of the booklet is the descriptions on 27 PNG forest tree species. Species descriptions focus on phenology, seed handling and propagation. The selection of species is based on recommendations made at the inception meeting, held in March 2000, for the 'Domestication of PNG's Indigenous Forest Species Project'. At that meeting, about 60 species were listed as having potential for commercial and community use. From this list, project staff selected species for which they could conduct phenological studies and subseq uently undertake seed research. The results from this work have been incorporated into the species descriptions given here.

2. Seed collection

2.1. Planning

Seed collections are frequently associated with planting programs and therefore the needs of nurseries. Given the great number of forest species and difficulties often associated with storing seed, it is important that careful planning precedes seed collection and the processes that follow. Planning of seed collection relates directly to the following questions:

- Which species to collect (species selection)?
- How much seed to collect (quantity)?
- Where to collect (seed source)?
- When to collect (harvest time)?
- How to collect (collection method)?
- Temporary storage and transport to store (organise containers and transport).

2.1.1. Which species to collect and how much?

Which species to target and how much seed to collect is frequently dictated by the user, be it a nursery, reforestation program or community activity. The amount of seed required usually relates to the number of seedlings needed, seed viability and the extent to which the seed will remain viable in storage. For species the seed of which can be stored for extended periods, seed additional to immediate requirements can be collected in order to meet future demand.

2.1.2. Where to collect?

The distribution of the species in relation to issues of access may dictate where it is possible to collect seed. For naturally occurring species, the local seed source, found closest to the planting area, is often the safest choice unless there is field trial information to indicate that an alternative seed source will provide more desirable genetic material. Seed from exotic species is frequently collected from local street trees or planted stands. In many situations it may be necessary to provide seed at the lowest possible cost in order to effectively compete with other suppliers, but this may be to the detriment of genetic and physiological quality of the seed. For exotic species, seed should be requested and collected from proven better-performing native provenances or from localities with environments similar to that where the material is to be planted, or from seed production stands.

2.1.3. When to harvest?

It is important to harvest fruit only when the maturation process is complete. The observable process by which trees produce seed starts with initiation of flower buds and progresses through to flowering, fruit development and finally fruit or seed shed. An understanding of reproductive behaviour for each species is important to determine when a species will set seed. If, for example, the time from flowering to seed set is known, once flowering is observed the seed collector can determine fairly accurately when seed must be collected.

Information on flowering and fruiting times of PNG forest species is scant and often conflicting, making it difficult to know when to collect seed, particularly for rainforest species that do not necessarily fruit on a regular annual basis. **Appendix I** provides phenological data for over 150 tree species native to PNG. The information is a collation of data gathered in Gogol forest, Madang between 1986 and 1988 by Emerick Davige of the PNG National Forest Service, and phenological studies conducted by NTSC. The table is a guide only, but it is a useful base on which to build up more accurate and locally relevant information. Data are listed by species and include flowering and fruiting information for different parts of PNG where observations have been made. The timing of phenological development varies within species over relatively short distances if altitude changes, as for example between Aseki (1850 m asl) and Bulolo (850 m asl).

In preliminary studies by Bulolo staff of NTSC, considerable differences were observed in fruiting times for particular species occurring in different parts of the country. In the case of *Calophyllum euryphyllum,* seed matures during January and March. However, *Pometia pinnata* fruiting is less precise and trees appears to fruit during the months of September to April. Planning seed collection from species which do not set seed at a consistent time each year is difficult, and often collection has to be undertaken at fairly short notice. Some species shed their fruit and/or seed immediately on maturity, whilst others may hold onto their fruit or seed for some months. These characteristics will affect the timing of collection and in turn planting programs, and may often be the reason why particular species are not propagated and planted.

It is important that phenological studies be carried out to improve understanding of the times of flowering and fruiting of PNG's forest species. For a detailed account of floral biology together with fruit structure, development and ripening refer to Vozzo (2002). This reference provides excellent diagrams and photographs of the structure of flowers and fruit.

It is essential to use binoculars (x8 or x10 with a 25 or 30 mm aperture) and to monitor not only the presence or absence of flowers and fruit but also the stage of development and size of crop. **Appendix II**

provides an example of a data form that can be used when monitoring phenological activity in the field.

For many species there is considerable variation in the timing of flowering and fruiting over the species distribution, between trees within populations and between different years. When monitoring these events, select at least 5 trees, but preferably 10–20 at each location and record observations against each tree rather than summarise in the field at the population level. If the species of interest has edible fruit, the presence of ripe fruit in the marketplace is a useful indicator that the seed is ready to collect. **Appendix III** is a summary of seed collection times, together with data on fruit and seed characteristics.

The time from flowering to seed maturity varies enormously between species, ranging from 2 weeks up to 2 years, with 6 to 16 weeks being common. The time between flowering and fruiting is related to the type of fruit. Species with large woody cones like klinki pine will take about 9–10 months to mature while *Acacia simsii* may take only 1–2 months.

The features which determine whether a seed crop is mature vary considerably from species to species. One of the key factors is the colour of fruit and seed, but there are also other aids as indicated below:

Colour change — fruit often change colour from green to another colour such as yellow, orange, brown, blue, purple or black. Seed also change colour from pale to darker colours.

Seed or fruit hardness — many fleshy fruit tend to go soft at maturity, although they may become dry and wrinkled as they dry out after being shed from the tree. In contrast, woody dry fruit become hard and dry at the time of maturity.

Dryness of the fruit — pods and papery capsules become dry and brittle as they reach maturity.

Ease of removal — mature fruit often tend to be easier to detach from the tree and may tend to shed by themselves.

Fruit shedding — some fruit will open on maturity, shedding their seed, as in the case of eucalypts and *Toona.*

The method of fruit or seed shed can be used to assist in determining when to collect the seed. Some species shed their fruit, as in the case of *Pometia* and other fleshy-fruited species. Other species like *Toona, Eucalyptus, Acacia* and *Flindersia* shed the seed while the fruit is still attached to the tree.

The length of time that the seed remains on the plant (seed retention) after maturing is a very important factor in the timing of seed collection. Depending on species, this can vary from immediate release once ripe (*Toona, Flindersia*) to several months or even years. For species which release their seed immediately on maturity, precise timing of collection is essential.

Most seed collections start with the collection of fruit. Fruit refers to the seeds' outer covering. Various types of fruit are illustrated and described in **Figure 1.**

2.1.4. Temporary storage and transport

Considerable care must be taken to ensure seed viability is maintained during transport and processing. This is particularly important with many PNG species which have fleshy (recalcitrant) seed. Fruit must be loosely packed in open-weave bags which allow adequate aeration. Onion or jute bags are good for this purpose, whereas plastic bags allow limited gas exchange and no moisture exchange, and can therefore cause overheating.

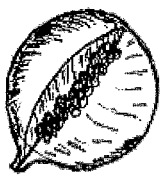
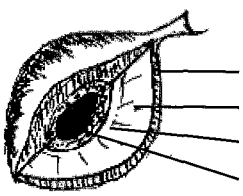
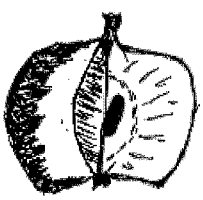
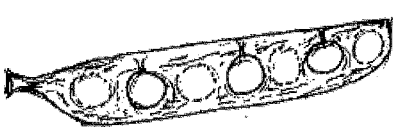
Fleshy fruit must be kept cool throughout the period from collection to sowing. At the time of collection, fruit should be kept in a shady spot. Once ready for transport, the fruit must be kept out of direct sunlight and taken to its destination as soon as possible. Even a delay of a couple of days can be critical to the survival of seed of some species. Vehicles should be equipped with a cover to protect the fruit from sunlight while travelling while allowing fee air movement to minimise heating.

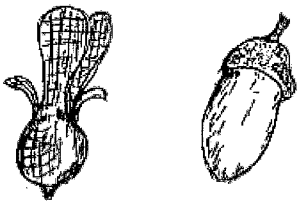
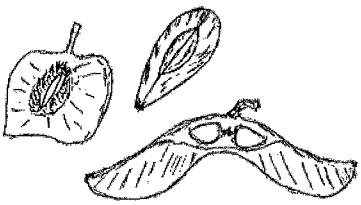
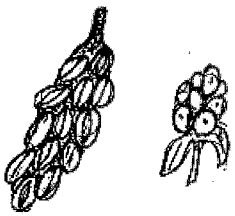
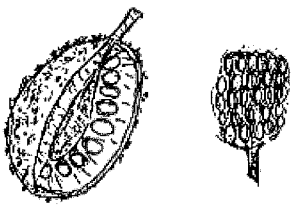
Dry seed (orthodox) can withstand much higher temperatures without deterioration of viability. In such cases, where drying is part of the process of seed extraction, it may be beneficial to spread out the seed on a sheet in sunlight.

Careful planning should go into deciding how best to transport the fruit to its destination. In addition to giving consideration to the mode of transport, it is also important to know what is planned for the seed. Is it going to be stored or sown directly? If the seed is to be stored, then plans must be in place for processing the fruit or seed, and facilities must be available for storing the seed under optimum conditions. If, on the other hand, it is intended to sow the seed immediately on arrival, plans must be in place for any necessary processing. The nursery must also be prepared for the seed to be sown as soon as it arrives.

Figure 1. Illustration and descriptions of fruit types within angiosperms.

Adapted from Schmidt (2000)

I. Berry 	A berry is a fleshy fruit with no hard layers and is usually many-seeded. e.g. *Manikara, Diospyros, Nephilium*
2. Drupe  	A drupe is an indehiscent fruit with an outer skin (exocarp), a middle fleshy layer (mesocarp) and a hard stony layer (endocarp). The seed coat is usually thin. With a single or few seeds (kernel). e.g. single kernel — *Santalum macgregorii* e.g. multi-seeded kernel — *Vitex cofassus*
3. Pome 	A pome is a fruit derived from a compound pistil embedded in a fleshy hypanthium. Many seeds. e.g. *Pyrus* (apple)
4. Follicle 	A follicle is a fruit derived from one carpel, splitting open along one side only. e.g. *Grevillea*
5. Debiscent pod 	This is a fruit formed by one carpel, opening along both sides of the pod. e.g. *Acacia, Albizia*

6. Capsule 	Derived from 2 or more fused carpels. May have one or more locules. Usually many-seeded. e.g. *Eucalyptus, Toona*
7. Nut 	Fruit derived from more than one carpel but in which all but one or a few ovules abort, leaving the fruit one- or few-seeded. Nuts have a hard pericarp and the seed has a very thin coat. e.g. *Dipterocarpus, Fagus* (oaks)
8. Samara 	A samara is a fruit similar to a nut except that it is flattened at the edge to form a wing. Samaras may contain one or more seed. e.g. *Pterocarpus, Terminalia*
9. Agregate fruit 	Pistils of one flower that form individual simple fruit, e.g. samaras, drupes or nuts, that may be separated or fused together with each other and the receptacle. e.g. *Elmerrillia*, *Magnolia*
10. Multiple fruit 	Fruit made up of individuals, and fruit of an inflorescence that may be either fused or separate but close together. e.g. *Artocarpus* (kapiak), *Casuarina* (yar)

2.2. How to collect seed

Which trees to collect from

It is important that as much genetic variation as possible is obtained in the sample of seed collected from each species. To ensure the capture of genetic variation in natural stands of trees seed collectors should:

- Collect from as many trees as possible at each site, preferably from at least 10, but from more if they are available.
- Collect from stands of trees rather than single, isolated trees, even if the latter are carrying large amounts of seed.
- Where possible collect from trees that are at least 100 m apart or, at least, several trees away from the previously-collected tree. Neighbouring plants are likely to be closely related, and hence genetically similar. Seed should not be collected from trees that are close to each other.
- When collecting from planted trees, it is not possible to assess how closely related one tree is to another, but genetic worth may be better reflected in the appearance of the tree than would be usual in natural forest. Therefore collect seed from the best trees that contain sufficient seed.
- If possible, collect approximately equal amounts of seed from each tree, and try to ensure that mixed samples are not predominately from one or two trees.
- It is important to record information relating to the location where the seed was collected, ecological information, date of collection etcetera. **Appendix IVa & b** provides examples of forms which can be used to gather botanical and seed collection data in the field. A GPS can be used to provide latitude, longitude and altitude data (**Figure 2**).

Collection methods

Numerous methods are used to collect seed from trees. Most are fairly straight forward and simple.

From seed fall — Many trees shed their mature fruit, which falls to the ground. This technique is best suited to large fruit or seed which can be readily seen amongst litter on the ground. A tarpaulin can be placed on the ground under the tree crown to catch fruit. Fruit collected off the ground is preferably gathered within a day or so of shedding. Collecting fruit and seed from the ground following natural shedding is generally not recommended for the following reasons (Thomson 1995):

- Uncertainty regarding their source
- The risk of contamination by morphologically similar seed of related species nearby
- Their possible low physiological quality, compared with those obtained direct from the crown, due to collecting a higher portion of immature, empty or unsound seed; insect damage; and the possible early onset of deterioration or germination
- Greater risk of contamination of fruit or seed with soil-borne pathogenic fungi
- Impractical for the collection of fine seed.

Climbing —Climbing into the crown of the tree may enable the climber to dislodge single fruit or to cut a seed-bearing branch which then falls to the ground. Home-made ladders using bamboo poles provide access to a height of about 12 m. More sophisticated ladders made from aluminium (**Figure 3**) are also available. The NTSC uses tree-climbing spurs (**Figure 4**) and rope techniques (**Figure 5**). These methods allow the climber safe access to much larger trees compared with climbing unaided. Once in the tree crown, the climber can then access and dislodge the seed crop (**Figure 6**). A simple bamboo hook (**Figure 7**) attached to a bamboo pole can be used to dislodge fruit while standing on the ladder or in the tree crown. Climbers should use a safety harness and rope to minimise the risk of falling from the tree and consequent injury.

Advance line using a catapult or bow and arrow — A catapult or sling shot (**Figures 8 & 9**) (or a bow with blunt-pointed arrow) can be used to shoot a (fishing) line over a suitable branch in the tree crown. The end of the line is first attached to a weight (**Figure 9**) which is fired over a suitable branch, the weight then bringing the line to the ground. The line is next attached to a heavy rope which is then drawn over the branch. By pulling on the heavy rope, branches can be broken off. Alternatively, climbing techniques may be used to ascend the rope.

Hand picking — Fruit accessible from the ground is stripped by hand into a container or onto a sheet spread out on the ground. Species such as acacias and *Leucaena,* with short stature and which produce dry pods, are well suited to this technique.

Bagging the fruit

Once the fruit is at ground level, remove stalks (**Figure 10**) and place it in a container. For ease of cleaning later, remove as many impurities as possible. Fruit should be stored in a loose-weave

bag (**Figure 11**) to prevent fungal development which can adversely affect seed viability.

Plant identification and labelling

When collecting seed it is important to correctly identity the species. If unsure of the identity, take a botanical specimen of the plant to a herbarium, botanist or other experienced person for identification. The botanical specimen must comprise a branchlet containing at least the leaves but preferably include attached flowers and fruit from the same tree. After preparing a botanical specimen (**Figure 12**) it needs to be placed in a press between sheets of dry newspaper (**Figure 13**). The press and paper enables the specimen to dry out flat thus saving space and preventing the specimen from going mouldy and disintegrating. For more details on pressing specimens refer to **Appendix V**. Botanical specimens must be accompanied by a label providing the following information:

- Species name, if known
- Location of collection
- Latitude, longitude and altitude (if available or able to be determined with GPS)
- Date of collection
- Name of collector
- Description of tree including diameter and height
- Description of where the tree was growing (habitat) and associated species.

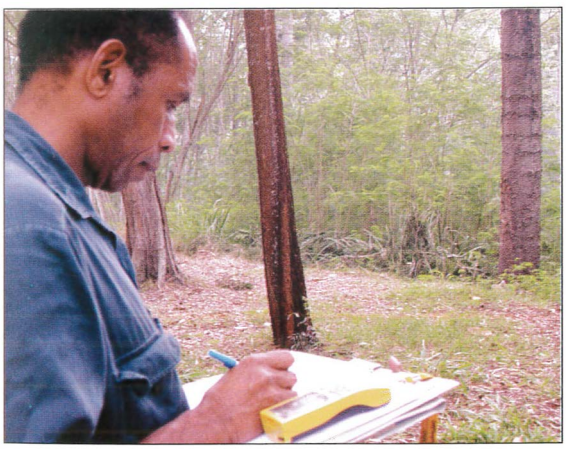


Figure 2. Information about the seed collection should be recorded to include description of location, latitude, longitude and altitude (using a GPS) and number of trees sampled.

Figure 3. Bamboo or aluminium ladders can be used to gain access to seed crops in the tree crown with the aid of a pole hook.

Figure 4. Specially designed metal tree-climbing spurs attached to the climber's boots enable a person to 'walk' up the bole of a tree.

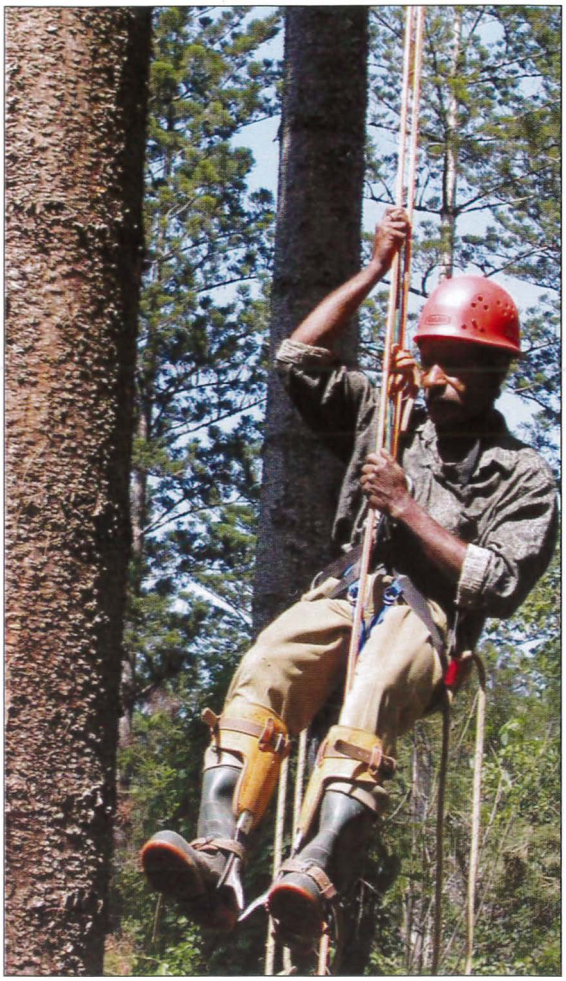


Figure 5. With the aid of an 'advance line', rope-climbing techniques enable a person to access the crown of a tree.

Figure 6. Rope-climbing techniques enable the collector to access seed crops on outer branches in safety.

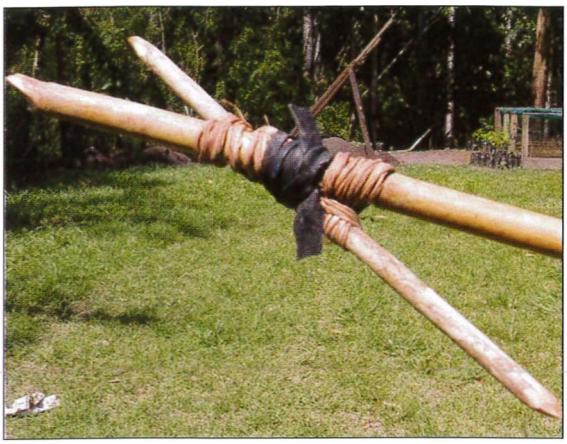


Figure 7. A hook on end of a bamboo pole may be used to remove fruit from the tree crown.

Figure 8. A specially designed catapult (called a Big Shot), can be used to shoot an advance line over a chosen branch. The line is then attached to a heavier rope which, when drawn over the branch, can be used to pull it down. Alternatively, the heavy line may be climbed.

Figure 9. A close-up of the catapult (Big Shot) with a red projectile, attached to a fishing line, placed in yellow sling.

Figure 11. Fruit should be placed in a loose-weave bag at the time of collection.

Figure 12. If you are not certain about the identity of the species you are collecting, take a complete botanical specimen comprising leaves, flowers and fruit where available.

Figure 10. Fruit being removed from the branch by hand.

Figure 13. Freshly collected botanical specimens are placed in a plant press between sheets of dry newspaper. A simple press can be made from strips of bamboo. The paper should be replaced daily to ensure the specimen is kept dry. A label providing details of where the specimen was collected should be included with the specimen.

3. Seed processing

Seed processing refers to the extraction of seed from the fruit and subsequent cleaning of seed. At all stages of seed handling, care must be taken to avoid damaging the seed as this can reduce seed viability and longevity.

3.1. Seed extraction and cleaning

Fruit is either stored or sown as it comes from the field, or is processed to separate the seed from the fruit. The method of processing depends on the type of fruit.

Fleshy rainforest fruit — Many rainforest fruit have a fleshy outer pulp which requires removal (e.g. taun, New Guinea walnut). If the pulp is very fleshy and soft it can be removed by hand immediately. Fruit with hard outer pulp can be kept moist under the shade of a tree to soften the pulp prior to removal (**Figure 14**). Alternatively, hard pulpy fruit can be immersed in water until the pulp becomes soft. The water should be changed daily. This softening process normally takes a few days to a week. Once the fruit is soft, the outer flesh is removed by hand and the seed cleaned. For fruit of a size similar to coffee beans, a manual coffee depulper can be used to depulp the fruit (**Figure 15**). Once the fruit has been depulped, it can be sown immediately. If, on the other hand, the seed is to be stored for any time, its surface must be dried under shade for up to a day before storage. Do not let the fruit dry out (dehydrate).

Drying fruit — Fruit of many species need to be dried before they will release their seed (e.g. *Araucaria, Toona, Acacia* and *Eucalyptus*). It is important to spread such fruit out on a sheet or tarpaulin, either in the shade for moist fruit or in the open sun for dry fruit. Once the fruit have lost moisture, they open to release the seed.

The seed can then be extracted and cleaned from the fruit and other impurities using sieves (**Figure 16**) or winnowing (**Figure 17**). Seed with hard coats, such as many legumes, can be cleaned by flotation in water. Good seed sinks to the bottom of the container while impurities and empty seed tend to float to the surface. The surface material can be discarded and good seed allowed to surface dry.

Dry seed stored as fruit — The seed of some species cannot be separated from the fruit, despite the drying process (*Terminalia, Pterocarpus*). For seed to be sown immediately, there is no need for any processing: simply sow the fruit. However, the fruit of seed which is to be stored must be allowed to dry for several days before storage.

Figure 14. Fruit with hard outer flesh can be placed on the ground under a shady tree and kept wet for several days. This softens the pulp, allowing it to be removed by hand.

Figure 15. A coffee depulper can be used to remove the pulp of fruit of a size similar to coffee beans.

Figure 16. Seed that sheds from the fruit after a period of drying (e.g. casuarina, eucalypts, erima) can be cleaned by sieving. Mosquito gauze works well as a sieve for very fine seed.

Figure 17. Electric fans or manual winnowing can be used to clean seed where there is a difference in density between the seed and waste material. Winnowing is a good technique for winged seed (e.g. *Toona, Flindersia*).

4. Seed storage

Seed that will not be sown immediately after processing must be stored under appropriate regimes. The storage life of a seed, in other words how long it can stay alive while in storage, depends on the species and the environment in which it is stored. Most tree species with moist seed (fleshy fruit) will store for only a very short time (i.e. from weeks to a few months). Most of PNG's rainforest species have fleshy seed. These moist seed, which do not store well, are often referred to as recalcitrant or moisture-sensitive seed. On the other hand, dry seed like those of acacias can be stored for some considerable time (i.e. many years) under the right conditions, and are often referred to as orthodox seed. Seed collectors cannot change the storage characteristics of the seed, but are able to influence the environment in which the seed is stored and thereby extend the life of the seed. The essential factors to consider when storing seed are:

- Ensuring that the seed is free of pests and diseases through good sanitation practices
- Where possible, control the temperature by reducing it to the minimum that the seed will tolerate
- Where possible, control the moisture content of the seed to the minimum that the seed will tolerate
- Avoid fluctuations in temperature and moisture content
- Be aware that fleshy seed and dry seed have to be stored in different conditions
- The decision on how to store the seed usually depends on what storage facilities are available and the expected duration of storage. Storage life is often broken down into three categories:
    1. Short-term storage (up to 2 years)
    2. Medium-term storage (2–8 years)
    3. Long-term storage (over 8 years).

No matter how well seed is stored, it will lose viability over time and eventually die. All that the seed handler can do is to minimise the rate of loss of viability. It is therefore important to know how long seed of different species will remain viable under various storage conditions, and plan the distribution and sowing of the seed before it loses viability and vigour.

No single factor can be used to predict seed storage behaviour (Vosso 2003); a combination of the following contribute to the outcome:

- Plant ecology
- Taxonomic classification
- Plant, fruit or seed characteristics
- Seed size
- Seed moisture content on shedding
- Seed shape

Vigour is the ability of the seed to germinate uniformly and develop a normal seedling under differing conditions. **Appendix III** provides information on recommended storage methods for the 27 species described in Section 6.

4.1. Controlling pests and diseases

As part of the cleaning process, any seed affected by insects or fungi should be removed. In most instances seed should already be free of pests at this stage. There should be few problems associated with pests and diseases of dry seed, which is stored in air-tight containers under appropriate conditions.

Moist seed, on the other hand, may still harbour pests and diseases requiring further treatment. This can include chemical insecticides or fungicides. Fleshy fruit can be soaked in water for a day to drown grubs contained in the seed. The cleaned seed is then dried out prior to storage.

Stored seed must be protected from pests such as rodents. Secure containers should be used for this purpose. Chemicals such as naphthalene balls (1 or 2 pieces per kilogram of seed) can be added to the container to minimise insect attack or act as a fumigant.

4.2. Control of temperature

The storage temperature should be kept as low as possible within the range tolerated by the species and, of special importance, be maintained without fluctuation.

- Dry seed, with a low moisture content (below 12%), will maintain viability for longer at lower temperatures. For short-term storage, seed can be kept in an air-conditioned room (20–24°C). For longer-term storage it is better to keep the seed under refrigeration (e.g. 3–5°C) or even in a freezer. For example, kamarere (*Eucalyptus deglupta*) seed stored at 20–24°C will lose more than 50% viability after 3 years. If, however, the same seed is stored at –15°C in an airtight container, it retains more than 60% viability after 5 years.
- In contrast, storage temperatures for moist seed are more critical, but information on optimal temperature regimes for individual species is not usually available. Seed of a number of tropical species is very sensitive to temperatures below about 15°C, below which viability is rapidly lost, but we do not know whether any PNG species behave in this way. Limited information suggests that seed of many of PNG's moist-seeded species stores well in a refrigerator (i.e. 3–5°C). Moist seed

of tropical tree species will not store in a freezer.

4.3. Control of moisture

Seed moisture content varies from species to species, and is also affected by the moisture content of surrounding air (humidity). For dry seed, the lower the moisture content (7–10%), the longer the storage life when combined with a suitable temperature. Dry seed (*Acacia, Casuarina, Eucalyptus*) can be dried further following collection without loss of viability.

However, fleshy moist seed is sensitive to drying and may rapidly lose viability if allowed to dry below a relatively high moisture content, e.g. 30–70%. Such seed must be prevented from drying right from the time of collection and throughout storage. In storage, the seed may need to be held in open containers packed in a moist medium such as sawdust or peat. Such a moist environment can result in fungal attack or even germination if the temperature is too high. Thus fleshy seed is very difficult to store for any length of time, and is normally sown soon after collection.

4.4. Storage containers

Dry seed is best stored in air-tight containers, if possible filled completely with seed to minimise the air space. This reduces the chance of the seed absorbing moisture from the air. The outside of the container should be labelled with details of the contents.

Moist seed is best stored in small batches inside plastic bags, ensuring that it receives air. Very moist seed is best mixed with a sterile, absorbent medium such as sawdust which has been pasteurised (see Section 5.1.3), charcoal or peat moss.

5. Nursery techniques

5.1. Raising seedlings

Most collected seed is used for raising seedlings in a nursery. Nurseries vary greatly in size, design and method, depending on the number of plants required, resources available, local materials and species to be raised. Different techniques may be needed for different species, but the choice is often constrained by local conditions. It is not the purpose of this booklet to provide details of nursery techniques for raising PNG forest species: many nurseries have already been established and are successfully producing plants. Nursery techniques appropriate for PNG conditions are described in 'Tree Nursery Manual for Sri Lankan Plantation Industry' by Quayle *et al.* (2001) and 'Setting up a Tree Nursery' by Liebregts and Keppel (1998). ATIK (1992) provides information on the establishment of a very simple nursery for villagers, using local materials and watered by hand.

5.1.1. Germination media

Make a decision whether to sow directly into individual containers, or into trays for pricking-out following germination. This choice will depend on the set-up in the nursery and the size of the seed. For very fine seed, seed trays are preferable as they can be moved to take advantage of the best environment, so maximising the percentage germination. Larger seed, with high viability, may be better sown directly into containers provided these can be properly tended and watered.

A good germination medium should be:

- Sterile (see pasteurisation method section 5.1.3.)
- Free draining (to reduce the likelihood of disease). This means that when water is applied, it should flow quickly through the medium, leaving it moist but not soaking wet.
- Free of particles more than 2 mm in diameter (which could impede the germination of small seedlings).
- Non-calcareous, with a neutral to slightly acid pH
- Friable with a fairly low organic content
- Examples of suitable germination media are:
    1. 1 part clean river sand:1 part sieved and sterilised loamy soil
    2. 3 parts clean river sand:1 part well-rotted, sieved and sterilised compost

The soil should have very little silt or clay. Some experimentation may be needed to determine the best mix for each location, type of medium available and species being germinated. Whether sowing the seed in a germination tray or directly into containers, the general rule of thumb is to cover the seed with a layer of medium which is the same thickness as the diameter of the seed (Liebregts and Keppel 1998).

5.1.2. Growing media

The physical, chemical and biological properties of the growing medium affect not only the seedlings but also the overall nursery hygiene. For nursery containers, a light-textured (e.g. sandy loam), permeable, non-calcareous soil or potting mixture that has adequate water-holding capacity whilst still allowing good drainage is generally recognised as the most suitable medium in which to grow most tree species. All potting mixes should be sieved to remove particles larger than 5 mm in diameter. A few pellets of slow-release fertiliser (e.g. Osmocote© or Nutricote©) can be placed at the surface of the medium or mixed directly into the potting mix at the rate of 1.5 kg/m^3. Alternatively, a soluble complete fertiliser (e.g. Aquasol©) can be applied weekly using a watering can.

Liebregts and Keppel (1998) recommend a potting medium of 3 parts topsoil:1 part humus-rich soil:1 part sand. Topsoil refers to the top 5-20 cm of soil which contains most of the nutrients available to plants. Humus-rich soil is the thin layer of topsoil — found under trees and in forests — which has great water-holding ability, thus helping to prevent excessive moisture loss and to improve nutrient absorption. Sand collected from riverbeds gives the potting medium adequate drainage. The mix is pasteurised to kill weed seed and pathogenic fungi prior to use.

5.1.3. Pasteurisation of soil

Soil-based media will normally contain organisms including fungi, bacteria and insects as well as weed seed. While some organisms are good for the seedling, many may cause diseases which will harm or even kill the plant. Weed seed, if allowed to germinate in the pots, will rob the seedling of moisture and nutrients. One method to control these harmful pests is to pasteurise the soil. A simple method is described as follows (Carter 1987):

1. Cut a large metal drum (200 litres) in half lengthwise. Ensure the inside is clean. Place the moist, but not wet, soil mix inside.
2. Heat (with fire) the metal drum from below to 60°C. Check the temperature with a thermometer pushed well into the heated soil.

3. Maintain the temperature of the soil for at least 30 minutes, then allow it to cool.

5.1.4. Transplanting

Germinants of seed sown in trays require pricking-out into containers before they get so large that root damage and severe set-back or death follows. Transplanting or pricking-out should be done once the seedlings have 1–2 pairs of leaves above the cotyledons, or — for large rainforest seedlings — even at the cotyledon stage. When transplanting, it is important to minimise any shock to the seedling by avoiding letting the radicle grow too long (e.g. more than 2–3 cm) to transplant without being damaged or distorted. The technique used is:

- Fill the pots with potting mix and wet thoroughly
- In each container make a hole in the medium large enough to take the seedling root without distorting it. This may require preparing a hole 1–2 cm in diameter and over 3 cm deep.
- Remove one seedling at a time from the tray, holding by the leaf and not the stem. If the radicle is too long (e.g. >6 cm) shorten it by cutting to a manageable length (e.g. 2–3 cm). Place the seedling in the prepared hole, ensuring that the radicle is not distorted, and bury the seedling slightly deeper than it was in the tray.
- Firm the soil around the seedling roots then gently water.

During the early stages of germination seedlings can be recognised as having epigeal or hypogeal germination, as illustrated in **Figures 18 and 19**. In epigeal germination, the hypocotyl expands and hence pushes the cotyledon above the ground, often together with the seed coat. In hypogeal germination, the hypocotyl does not expand and hence the cotyledon and thus the seed remain below ground during germination. Vozzo (2002) describes various types of germination and seedlings of tropical trees, as well as giving examples of species exhibiting epigeal and hypogeal germination. This can be an important diagnostic feature for species identification.

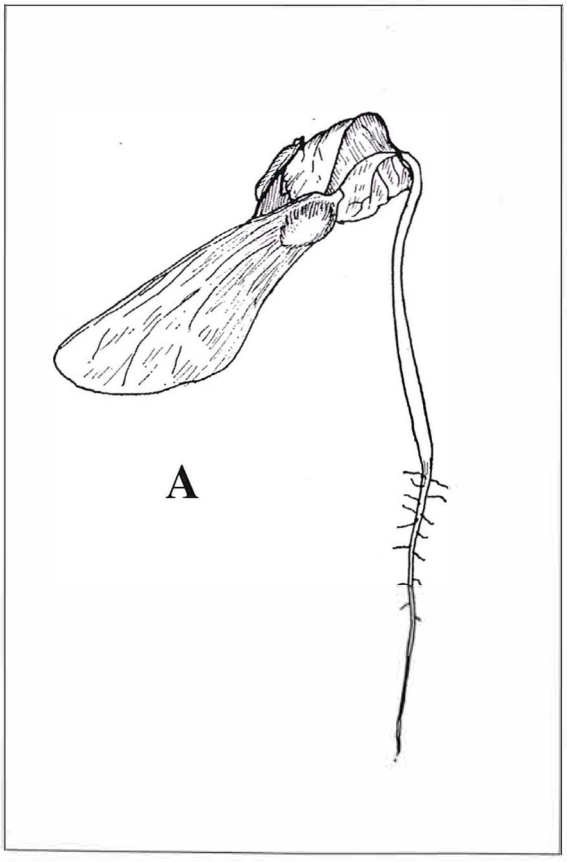


Figure 18. A. Epigeal germination, e.g. *Toona*
From Willan (1985).

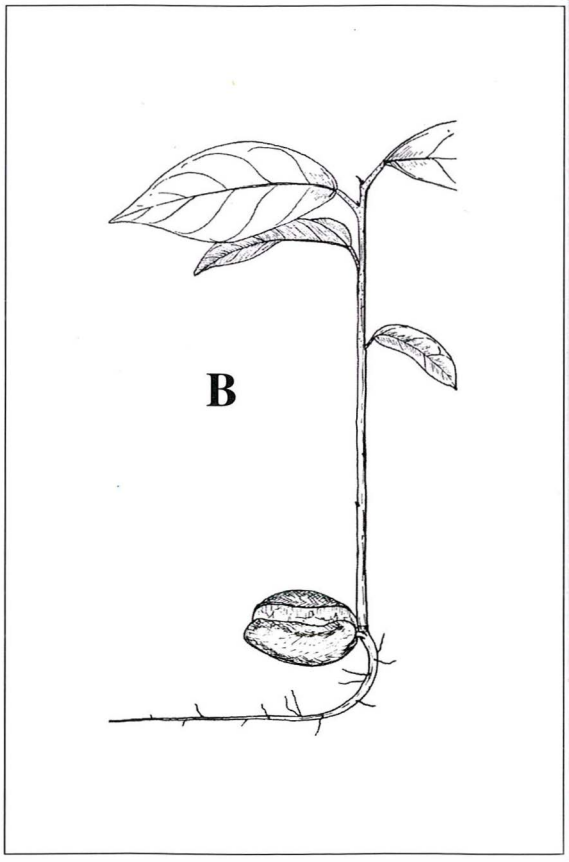


Figure 19. B. Hypogeal germination, e.g. *Artocarpus*.

5.1.5. Growing on

Seedlings should be encouraged to grow rapidly, through careful and regular maintenance in the nursery. The amount of watering desirable will depend on environmental conditions. As a general rule, pots should be kept moist but not saturated, and never allowed to dry out completely. Weed control should be ongoing, and carried out before the weeds reach a size at which they might compete with the growing stock. This is best carried out by hand. Insect and disease damage should be monitored and, when attacks occur, appropriate insecticides and/or fungicides or hand control should be used to avoid damage to and loss of plants.

Shade, and shelter against strong desiccating winds, are very important for seedlings of rainforest trees. Direct sun often causes serious leaf burn and loss of plants. Use of shade cloth is advisable, particularly in the early stages of growth. As the seedlings reach plantable size, shade should be progressively removed in order to harden the seedlings for planting out.

Seedlings about 20–25 cm tall are suitable for planting out. It is important to harden them in preparation for planting into the harsh conditions of the field. Reducing daily watering conditions the seedlings to water stress and makes them tougher. Avoid allowing the seedlings to become too tall ('leggy') as such plants will be vulnerable to bending over once planted.

5.2. Vegetative propagation

Vegetative propagation is the production of new plants without the use of seed, but using stem, leaf and root material from existing plants. There are many different methods of vegetative propagation including rooting cuttings, grafting, budding, marcotting or air layering, planting tubers, planting suckers, separating plants, and tissue culture. Tree species vary greatly in their ability to be propagated vegetatively. Poplars, for example, readily strike from cuttings, so this technique is preferred to propagation by seed. Many rainforest species, however, have not been able to be propagated vegetatively. In trying to develop vegetative propagation techniques for a species, it is important to commence with simple techniques, progressing to more sophisticated methods only if these prove to be essential. The simpler the method, the more likely the technique will be taken up and used, particularly in community situations where facilities may be very basic. The following discussion will focus only on the vegetative propagation method of rooting cuttings, but information on other methods are available in ATIK (1992). Very little work has been carried out on the ability of PNG tree species to be propagated vegetatively, but studies on tropical trees elsewhere indicate that many can be propagated using this method. A number of key processes need to be followed to produce rooted cuttings. Basic steps are outlined below.

5.2.1. Cutting hedges

To produce rooted cuttings you first need to collect shoot material from existing plants. These plants are known as mother plants, stock plants, hedges or ortets. Cutting material can be collected from naturally-grown trees in the bush or, for ease of continued collection and greater rooting success, from plants grown specifically for this purpose in the ground or in pots close to nurseries and villages. The latter are cut back regularly, and are generally referred to as hedges; this is the term that will be used throughout this discussion.

It is important that planted hedges are provided with moderate shade to reduce overheating, drying out and soil erosion. Shading can also improve rooting success (Longman 1993). Shade can be provided by inter-planting with other shrubs, planting in an area with sporadic existing trees, or providing artificial shade using large leaves, plastic or shade cloth material. When planted trees provide shade, it is important to maintain these at a modest size so they do not compete with the hedge plants for nutrients, water and sunlight, and to prune them periodically so they do not give too much shade.

The age of a mother plant can greatly affect the success of cuttings: material collected from younger plants is generally far better than that from mature trees. This often makes planted hedges better for the production of cuttings, as their age is known, and repeated trimming helps to retain juvenile characteristics. Thus the 'physiological' age of the hedge may be less than its actual age. It is important not to trim the hedge too severely, as some species do not regenerate or coppice quickly: it is best if at least a few leaves are left on the hedge. Ideal hedge size is species dependant, but generally they should be maintained at less than 1 metre high. Hedges of this height are easily accessible and they remain physiologically younger due to their reduced size and proximity of the foliage to the root system.

5.2.2. Rooting media for striking cuttings

The medium used for striking cuttings needs to fulfil a number of criteria. It needs to be aerated so that oxygen is able to diffuse along the length of the submerged stem portion of the cutting. It needs to have good moisture-holding capability to provide moisture for the cutting, but at the same time be

well drained so that waterlogging does not occur. It needs to be free of seed, pests and diseases, which can be ensured by sterilising it at high temperatures (on a hotplate over a fire for a number of hours) and/or by washing components prior to use.

The materials used in media for cuttings differ according to what is locally available. Sand and gravel, of differing grades, is used to provide drainage and structure, while coconut fibre, composted sawdust or soil provides moisture-holding characteristics. Peat, perlite and vermiculite can be used, but these components are often not readily available and are expensive. Generally nutrients are not added to the medium as this may inhibit root production. Nutrients are added via a soluble fertiliser once roots have formed.

It is important to test different media for suitability to local conditions and species. A medium of 50% river sand and 50% river soil, layered on top of small pebbles to improve the drainage of the mix, has been used in cuttings experiments carried out by the Forest Research Institute (FRI) in Lae. The methods tested have been suitable for species such as *Pometia pinnata, Dracontomelon dao* and *Casuarina oligodon*, but have not suited *Santalum macgregorii* (J. Beko, *pers. comm.* 2002), which may require better drainage of the medium by increasing the proportion of sand.

5.2.3. Propagation conditions

To produce rooted cuttings via vegetative propagation it is necessary to set up and maintain certain conditions. High humidity, reduced direct sunlight, reasonably constant temperatures and protection from wind, rain, pests and diseases are all required to attain rooting (Longman 1993).

High humidity, greater than 90%, is required to reduce evaporation from leaves and stems while the cutting is producing roots. Simple propagation facilities can be constructed relatively cheaply using materials locally available. The South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) project developed a portable propagator suitable for use in the tropics (Robson 2001), the construction of which is outlined in **Appendix VI**. In more established nurseries, a propagation house may be set up using mains water and electricity to provide high humidity via a mist irrigation system controlled by a timer or leaf balance (**Figure 20**).

To prevent over-heating within propagation units, it is often necessary to reduce the direct sunlight radiating through the roof of the unit. However, minimising radiant heat from the sun also means reducing light. Loss of light can have detrimental effects on the development of cuttings by causing undesirable leaf shed, particularly in pioneer species. Lower light intensity, however, does not have the same detrimental effect on shade-tolerant rainforest species. This would need to be determined for each species. Necessary shade may be obtained by placing matting, large leaves or shade cloth over the roof of the structure. It is important to extend the cover sufficiently beyond the area of the cuttings to protect the material from direct sunlight from all sides.

Figure 20. Mist house at PNG FRI used to propagate PNG forest species from cuttings. Cuttings are containerised and placed on free-draining benches under an electronic misting system which ensures the leaves are kept moist.

The air temperature within the propagator should ideally be 22–28°C. It is also reported that there should be a temperature differential between the root zone (medium) and the leaf (atmosphere), with the root zone being about 5°C above that of the atmosphere. Thus, if species do not readily develop roots using simpler techniques, bottom heat may be required. Shorter day lengths also affect rooting ability of species, so there may be pronounced differences in rooting at certain times of the year.

It is necessary to protect cuttings from outside factors such as wind and rain: the latter can cause stem dislodgment or erosion of the medium. Protection may be provided by shade cloth, matting or timber.

It is necessary to check the cuttings on a daily basis for signs of pests and diseases. The occasional pest can be removed manually, but if an infestation is present it may be necessary to use a pesticide to control the outbreak. Fungi and bacteria thrive in high humidity and warm/hot environments so it is best to maintain the cleanliness of the cuttings and media by removing dead leaves and stems regularly, reducing the chances of healthy cuttings contracting an infection. If the cuttings or media are seriously infected it may be necessary to use a fungicide to control the problem.

If fungal problems are significant and a suitable fungicide is available, it is often useful to soak the cuttings in a fungicide solution prior to setting the stems into the medium. When using a fungicide it is important to follow recommended dilution rates and all safety instructions.

5.2.4. The use of containers

Cuttings may be set in two ways: into a propagation bed or into containers or pots filled with a suitable medium. When producing small numbers of cuttings and to reduce costs, cuttings may be set straight into the bed of medium. For larger operations it is more economic, for species with high strike rates, to set the cuttings into pots as they can then go directly into the field without being potted on, which may disturb their root development.

Narrow deep containers are best, especially where root trainers are present inside the pot to guide the roots down the pot rather than circling inside the pot and resulting in a pot-bound plant. Such pots are often expensive to buy and difficult to obtain. Another option is to use poly-bags, which are usually far less expensive and easier to find, but they do not contain root trainers. The choice of container affects the physical characteristics required in the medium: when using a variety of containers it is important to ensure that the medium has the correct physical properties (drainage, aeration) in each type of container.

5.2.5. Rooting hormones

Hormones can be used to stimulate root development. The hormones commonly used for rooting cuttings are indole-3-butyric acid (IBA) or 1-naphtalenacetic acid (NAA), or a combination of both. Hormones can be purchased as a prepared powder or gel. The powder can be dissolved in alcohol, applied to the stem and allowed to dry prior to setting, or used directly by dipping the stem into the powder or gel and prior to setting. Hormones can also be prepared on site if the correct ingredients are available. It is important to store rooting hormones in the refrigerator or other cool environment with as little temperature fluctuation, as possible as this prolongs their shelf life.

The strength of rooting hormone used is species dependent. Generally, softer material roots with lower-strength hormones, whereas woodier material requires higher strengths. Tests at the Forest Research Institute in Lae showed that *Pometia pinnata* had a higher rooting ability with the lower strength 3 g/L active ingredient IBA, whereas *Dracontomelon dao* had better rooting with the higher strength 8 g/L active ingredient (J. Beko, *pers. comm.* 2002).

5.2.6. Cutting material

The type of cutting material used is critical to rooting success. The most suitable material varies between species and needs to be tested carefully. Some species root better using soft stems and tips, whereas other species will root only from woody stems. The length and diameter of the cutting also affects success. The cutting must be of sufficient size to maintain itself until effective roots develop. Liebregts and Keppel (1998) suggest starting with material 10–30 cm in length with a diameter of 0.3–2 cm.

It is necessary to reduce the leaf area (by leaf removal and trimming individual leaves) of cuttings to limit transpiration. If the leaf area is too large, the cutting dries out quickly and will wilt and die before rooting occurs. The complete removal of lower leaves facilitates setting the stem in the medium and reduces the chances of fungal attack from the soil to buried leaves (**Figure 21**). The rooting ability of a species may also be increased if leaves are removed from the stem before being placed in the medium: some species have a greater chance of producing roots from the area from which leaves are removed.

There can be large differences between the rooting ability of individual plants within a species, so it is important to collect cutting material from a number of unrelated hedges. The FRI found that the rooting of *Calophyllum euryphyllum* cuttings taken from nine families (27 hedges) varied from 0% to 34% (Singadan 2003).

Figure 21. Rooted cuttings.

5.2.7. General methodology and equipment

1. Purchase/obtain required components (sand, gravel, coconut fibre, composted sawdust, soil) to make up the medium for the cuttings, and sterilise/clean as necessary.
2. Make up suitable media, taking into account water-holding and drainage characteristics. A medium of 50% sand and 50% coconut fibre or composted sawdust is a good starting point.
3. Place the medium into a cuttings bed or containers as appropriate, and wet thoroughly.
4. Equipment required:
   - secateurs, scissors, knife — sharpened
   - rooting hormone and clean container
   - fungicide and clean container
   - labels
   - pencil/waterproof marker
   - dibble stick
   - bucket and water or plastic bags
   - spray bottle
   - clean, shaded working environment
   - propagation environment
5. If fungicide is being mixed, make up about 1 litre using the rates recommended on the container. Care should be taken when using chemicals and all safety instructions followed. The use of gloves is important as fungicide can be absorbed through the skin.
6. Pour a small amount of rooting hormone into the clean container, making sure it does not get wet. (It is important not to dip stems directly into the original container of rooting hormone as contamination may occur.)
7. Half fill a bucket with water and take it to the hedge plants. Plastic bags with a small amount of water added are an alternative to the bucket.
8. Select a hedge and collect material suitable for cuttings from it. Place the material directly into the bucket of water or plastic bag and write a label indicating the identity of the hedge.
9. If a water spray bottle is available, use this to mist water onto the collected material.
10. Take the collected material to a suitable working environment as quickly as possible. If possible, make this work area inside the propagation environment.
11. Prepare cuttings by trimming the material to a suitable size (this is dependent on the species). Remove all but the top one or two leaves, and reduce the area of the remaining leaves to 1/3 of their original size.
12. Place the cuttings into the fungicide for about 10 seconds. If gloves are not available, use tweezers or some other alternative to remove the cutting from the fungicide.
13. Prepare a label to identify the original hedge.
14. Drain cuttings of excess fungicide so as not to make the rooting hormone wet.
15. Dip the base of the cuttings into the rooting hormone, making sure the stem is well covered.
16. Use the dibble stick to make a hole in the medium to place the cutting. This stops the cutting being damaged during setting.
17. Place about 1/3 of the stem into the medium and place the label next to it so that it clearly identifies the cutting.
18. Repeat steps 11 to 17 until all the material collected has been set.
19. Start the process again at step 8, selecting another hedge from which to collect material, and set the cuttings. This is done repeatedly until cuttings have had set from all hedges.
20. It is important that high humidity is maintained at all times. Mist irrigation systems may need to be adjusted according to time of year, ambient temperatures and humidity, and species requirements.

5.2.8. Potting-on rooted cuttings

The length of time required for a cutting to produce roots is highly variable (some species may take up to 6 months). It is necessary to monitor cuttings closely and remove them from the propagation environment soon after roots have been formed. It is important to be aware that in some environments cuttings need to be carefully weaned from the high humidity of the propagation facility to normal environmental conditions. This is done by slowly reducing the water to cuttings to harden them, as you would do for normal seedlings.

If the cuttings were set directly into the medium, they need to be removed and potted into their own containers to allow them to grow to a size suitable for planting. Care is needed when doing this so that there is minimal disturbance to the roots. It is best to gently loosen the soil around the cutting and lift the cutting out, with some of the medium still attached. This whole root mass is then replanted into a suitable container.

Cuttings should remain in the nursery for some time after roots have been produced so that they grow to a size suitable for planting. It is at this stage that fertiliser can be added to aid the growth of the plant.

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6. Species descriptions

Twenty-seven species are described below. The selection of species was based on an original list of target species from which the authors chose desirable species which they could study. A number of factors were considered when selecting the species, including access to trees, phenological activity and access to seed. Only scant information on phenology, seed and propagation is available for the great majority of tree species in PNG. As part of the project, staff from the NTSC were involved in monitoring phenological activity for one to three years, depending on the species. These data were then analysed for presentation in this booklet. From those target species which produced seed, the staff collected seed and undertook seed tests covering germination and moisture content. The information from this work was used to describe how to collect and process the seed, as well as providing data on germination and moisture content as presented in **Appendix III.** Seedlings from this work were used for studies of vegetative propagation and established in a species trial in the Lae Botanical Gardens.

It is proposed that the 27 species descriptions contained in this section will also be published as individual leaflets. This will then enable other authors to continue the leaflet series by adding new species

6.1. *Aleurites moluccana* (L.) Willd.

Family Euphoriaceae

Comon name Candle nut

Distribution and habitat *Aleurites* comprises six species indigenous to Thailand, Malaysia, the Philippines, Indonesia, Australia and Papua New Guinea (PNG) (Hyland and Whiffin 1993). Candle nut is found in Asia, Malesia and Pacific including PNG. In PNG the tree is mostly found in lowland and lower montane rainforests. It is often found in disturbed rainforest and gallery forest at elevations from sea level to 800 m.

Uses The wood is used for canoes in some coastal areas in PNG. The seed contains oil which can be used as a constituent of paints, varnishes and linoleum, in soap and for wood preservation. The juice from the nut is used as a de-wormer in the Philippines. Some parts of the plant are used to treat skin ulcers. In Indonesia, the nut, known as the kemiri nut, is an important food.

Botanical description *Aleurites moluccana* is a fast-growing tree up to 40 m tall and 1 m in diameter. Boles, under good growing conditions, are mostly straight and clear. The crown is wide and sparse, with a silvery white appearance. The bark is 1–3 cm thick; the outer bark light grey, middle bark variable red or green, and the inner bark light brown with orange brown fibre, weakly fibrous. Leaves are alternate, moderately thick, glabrous, dark green above, rusty brown and densely hairy underneath when young. The flowers are in large panicles. The male flowers have numerous stamens joined at the base, while female flowers have a broad ovary with two narrow stigmas. Fruit is brown or green, dry or woody, dehiscent. Candle nut has a large two-lobed drupe containing two large hard seed 2.5 cm in diameter with an oily endosperm.

Flowering, fruiting and seed set — Appendix I indicates that there are two flowering periods. In Bulolo, heavy flowering occurs from January to April each year (Wau and Aseki areas) and again between August and November. In Oomsis, which is at a lower elevation (134 m asl), flowering is recorded in December–February and again in July–September. In Bulolo, fruiting occurs mainly in May–July with records of fruiting also in November–December as opposed to March–May in Oomsis. Seed fall is recorded as July–August and again in February–April in Bulolo and June–July in Oomsis. This would indicate that there is about seven months between flower development and seed shed. According to Hong *et al.* (1998) there are about 345 seeds/kg. The hardness of the seed coat and possibly the large size of the seed protects it from predators. However, some animals (pigs and rats) do feed on fruit on the ground.

Seed collection and processing Fruit is collected from the forest floor soon after it has fallen. It is then processed in order to remove the seed from the remainder of the fruit (exocarp and mesocarp). This can be done by leaving the fruit outside on the ground to naturally decay for about 30 days. In that time the exocarp and mesocarp (pulp) disintegrates, making it easy to remove by washing under running water. An alternative method for rapid processing is to remove the pulp with the aid of a knife and/or by crushing with a stone. The seed, enclosed by the hard endocarp (which forms the functional 'seed'), is then washed under running water before being allowed to air dry. In Indonesia it is allowed to dry in the sun for a day or two (L. Thomson, *pers. comm.* 2003).

Alternatively, collection may be delayed to allow the fruit to shed and lie on the forest floor where the pulp will decay naturally. This may take up to a month. The seed is then collected and washed by hand before being surface dried and stored or sown.

Storage and viability Storage behaviour is considered orthodox (Hong *et al.* 1998). Initial fruit moisture content is 82%. *A. moluccana* seed is sun

dried for 1–2 days and stored at room temperature (25°C) in calico bags or in airtight containers for 6–12 months. Improved shelf life may result from refrigerated storage. Germination is sporadic and can take over 80 days.

Nursery techniques Candlenut seed has a very thick and hard seedcoat, resulting in extremely protracted and uneven germination extending for months. This results in uneven seedling size and potential for damping off. Staff at the National Tree Seed Centre carefully crack the endocarp using a stone, hammer or other heavy instrument prior to sowing. This may damage the seed if the impact is too great. In the Philippines, seed is mixed in the proportions of two parts seed to one part mud and water to form a slurry. The seed is soaked for 30 days in this mix, in direct sunlight, before being sown (Eakle and Garcia 1977). Another option worth testing is abrasion by mixing the seed with coarse sand in a concrete mixer for about one hour. This mechanical process reduces the thickness of the endocarp, allowing moisture to access the seed and reducing physical barriers to germination. Alternatively, nick the seed on the side using a pair of secateurs. Germinants are pricked out 3–4 days after emerging.

Vegetative propagation: Unknown

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6.2. *Anisoptera thurifera* (Blanco) Blume

Family Dipterocarpaceae
Comon name Mersawa

Distribution and habitat *Anisoptera* consists of 11 species and is distributed from Bangladesh eastwards to Thailand, Vietnam and throughout Malesia to New Guinea (Johns *et al.* 1994). *A. thurifera* is distributed in Papua New Guinea (PNG), Philippines, Malaysia, India, Sabah, Burma, Thailand, Vietnam, Cambodia and possibly Sulawesi and the Moluccas in Indonesia. Major distribution areas in PNG are Bewani — Mos, West Sepik; Central Fly, and Aramia, Kikori and Kiunga in Western Province. It also occurs in Central, Milne Bay, Northern (Oro), along the coast of Morobe and to a lesser extent in East Sepik Provinces. *A. thurifera* grows in evergreen and semi-evergreen dipterocarp forests, especially on ridges, below 750 (–1000) m altitude, or scattered in small groups in lowland forests on flat and undulating ridges frequently associated with sedimentary rocks. The species usually occurs on well-drained soils but also in peat swamps and on podsols in heath forests.

Uses The timber is used for general light construction such as door and window frames, and decorative panels. In some areas of PNG the nuts of mersawa, which are rich in edible oils, are eaten after being cooked. The gum is traditionally used as chewing gum.

Botanical description *A. thurifera* is a medium-sized to very large tree up to 60 m tall. The bole is branchless for up to 25 m and reaches 2 m in diameter, and is prominently buttressed. The bark is 2 cm thick, the outer bark grey-brown to red-brown with some pustules on young trees, the middle bark green and brown mottled, and the inner bark light brown, hard, with clear resinous exudates. Leaves are 6–18 cm x 2.5–8.5 cm, elliptical to lanceolate or oblanceolate or obovate, greyish to brown lepidote beneath with (10–)12–18(–20) pairs of secondary veins. Flowers are bisexual in axillary and terminal panicles. Individual flowers are 4 mm in diameter, consisting of 5 downy yellow green sepals. The yellow stamens have hair-like tips. These surround the light green, ovoid, super ovary with a thin style. Fruit is a winged nut (dipterocarp) 1 cm in diameter, surrounded by persistent sepals of which two are enlarged into two wings, light brown in colour.

Flowering, fruiting and seed set Mersawa usually flowers and fruits annually, but if conditions are unfavourable flowering may not occur (Johns *et al.* 1994). The sweet-scented flowers appear in Oomsis from November to December, in Timini Guruko from December to January, and in Madang Province and planted trees in Bulolo from January to February. In PNG, seed falls from mid-May in Oomsis and from June/July in Timini and Bundun Gurako. There are about 1200 de-winged seeds/kg.

Seed collection and processing Mersawa fruit can be collected from the ground or by climbing. Once collected the fruit is stored with the wing attached. It is desirable to sow the fruit immediately following collection as stored seed does not retain viability for long.

Storage and viability Based on other *Anisoptera* species and NTSC data, the seed is likely to be recalcitrant. Moisture content (mc) of fresh seed is 51%. The best temperature for storing mersawa seed is 3–6°C. The mc should be reduced to 20–25% by air drying, and the seed should be packed in polyethylene bags (Johns *et al.* 1994). In PNG, seed is stored in wet sawdust or wet paper tissues in unsealed containers at 3–6°C or 18°C for 1–2 weeks. In Laos, seed of *Anisoptera costata* is stored for 15–90 days in well-ventilated bags in a humid environment at room temperature (Phongoudome, unpublished). Seed loses viability quickly; after 2–3 weeks the germination rate is often almost zero. Viability is significantly reduced

when the mc of the seed falls below 14% (Johns *et al.* 1994).

Nursery techniques Seed often geminates while the fruit is still on the tree (i.e., it is viviparous). Fresh seed tested at the NTSC had a germination of 89%. Seed is sown either with or without wings and takes 18–35 days to germinate. Mersawa seed is best direct sown (L. Thomson, *pers. comm.* 2003). The radicle breaks through the upper section of the globose nut. When sown in germination trays the germinants are pricked out 3–4 days after germination (when cotyledons are clear of the soil surface). The germination of *A. thurifera* is epigeal, with the radicle emerging first and the cotyledons appearing 3–4 days later. Seedlings reach plantable size 25–35 days from pricking out.

Vegetative propagation Vegetative propagation has shown some success. Trials on air laying branches of mersawa in the Philippines resulted in 25% of the branches developing roots. Grafting had a 10% success rate (Johns *et al.* 1994).

Other information The trees need mycorrhizal infection for optimal growth. A variety of ectomycorrhizae may be associated with *A. thurifera* in PNG.

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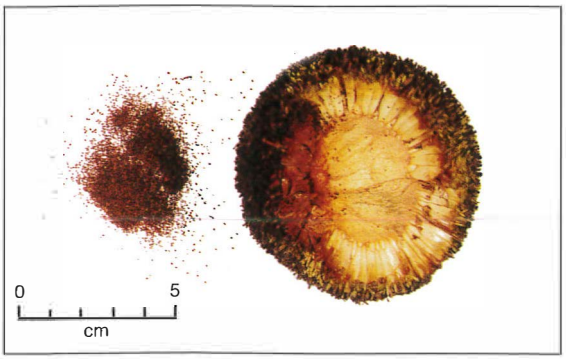
6.3. *Anthocephalus chinensis* (Lamk.) Rich. syn. *Neolamarckia cadamba* (Roxb.)

Family Rubiaceae
Comon name Labula



Distribution and habitat *Anthocephalus* consists of two species distributed in Asia, Malesia and Australia (Hyland and Whiffin 1993). The natural range of *A. chinensis* covers Sri Lanka, India, Nepal, Bangladesh, India, Burma, Indochina, southern China, Thailand, through Malaysia, Laos, Indonesia to New Guinea and Australia. In Papua New Guinea (PNG), the species is recorded in New Britain, New Ireland, Central and Gulf Provinces. It is mostly found growing in montane lowland forests with *Araucaria, Cryptocarya, Endiandra* and *Octomeles* from about sea level to 250 m altitude.

Uses Its most important use is for the manufacture of low- and medium-quality paper. Other uses of the wood include fuelwood, plywood, fibreboards, matches, chopsticks, canoes, carving and kitchen furniture. The tree is also suitable as an ornamental and shade tree for other crops, and is used in reforestation and agroforestry, especially due to its tolerance of periodic flooding (Greijmans unpublished). Leaves and bark are used in traditional medicine. Labula is regarded as having fodder potential, while the inflorescences and fruit are reported to be edible.

Botanical description *Anthocephalus chinensis* has had a name change and is now referred to as *Neolamarckia cadamba* (Roxb.) (Smith 1988). It is a fast-growing tree to 40 m tall and 90 cm in diameter, with slender buttresses. The dense crown of young trees becomes flat — almost umbrella shaped — with many horizontal branches in mature trees. In open-grown situations it has poor form with a rapidly tapering bole and heavy low branching. The outer bark is very light and smooth when young and grey to grey-brown when old. Leaves are simple, opposite, 13–32 cm x 7–15 cm with an acute to acuminate apex, distinctly petiolate with a 2.5–6 cm petiole. Stalked flower heads are 3–5 cm wide; the upper part of the ovary is distinctly 4-loculed with 4 hollow artilaginous structures. Calyx white, cream, yellow or orange. Corolla yellow or orange. Fruit green, yellow or orange, fleshy, indehiscent.

Flowering, fruiting and seed set Flowering occurs mainly from September to December with peak fruiting between January and April. Fruit shed is expected between May and August. The (multiple) fruit contains numerous tiny seed in a fleshy fruit which does not split open. The fleshy, indehiscent round mature fruit turn yellow to orange when ripe and are shed between May and June in the Bulolo area. Green immature fruit and fully mature shedding fruit can be observed at the same time. Fully mature spherical fruit weigh an average of 120 g and are 6–7 cm in diameter. The ripe fruit are eaten by flying foxes, pigs and bandicoots. The seed is tiny (1 mm long), averaging 8 million seeds/kg.

Seed collection and processing Labula fruit is collected either from standing trees using tree climbers with the aid of bamboo poles to dislodge individual fruit or else following natural shedding. Fully mature fruit with soft flesh can be immediately depulped by hand with the aid of water. Fruit with firm flesh is spread out under shade and kept moist until the flesh is soft enough to depulp. This normally takes about a week. The macerated pulp is soaked in water to separate the pulp from the seed. Flotation is used to separate seed from pulp. Further sieving is required to clean the seed. Once clean the seed is air dried for 1–2 days before storage and/or sowing.

Storage and viability Storage behaviour is orthodox (Hong *et al.* 1998). Moisture content of seed is 8–10%. Dried seed is placed in airtight plastic screw-top containers and kept refrigerated at temperatures of 3–5°C. Hong *et al.* (1998) reported

that seed tolerates desiccation to 5% mc. Under these conditions seed has been stored successfully for 6–12 months. However, seed stored at room temperature (20–26°C) loses viability within 6 months. Campbell (1980) reported that fresh seed in Nepal produced 90% germination, tapering off after 4 months and diminishing to 5% after 12 months. Viability can be maintained for 1 year in hermetic storage at room temperature with 13±2% mc (Hong *et al.* 1998)

Nursery techniques The fine seed is sprinkled lightly on the top of seed trays, or can be mixed with fine sand to aid distribution when sprinkled (Greijmans, unpublished) and kept moist. The alternative is to sow the seed on moist tissue paper. Germination starts after 8 days and continues for a period of 14 days. Seedlings about 3 weeks old and 3 cm in height with two pairs of leaves are pricked out into pots and hardened off under 30% shade.

Vegetative propagation *A. chinensis* has been propagated using stumps about 1 cm thick, but there has been little success with cuttings in Sabah (Fox 1971).

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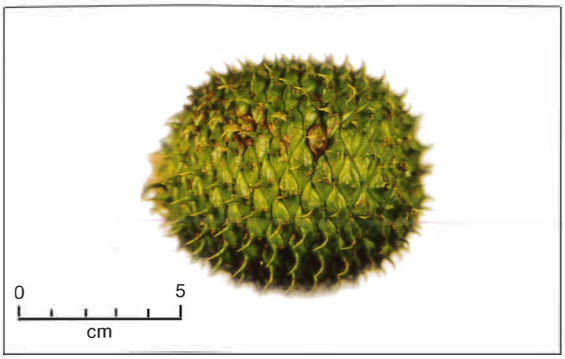
6.4. *Araucaria cunninghamii* Aiton ex D. Don.

Family Araucariaceae
Comon name Hoop pine



Distribution and habitat The genus *Araucaria* consists of 19 species that are distributed along the eastern coast of Australia, New Guinea, New Caledonia, Norfolk Island, southern and central Chile, Argentina and southern Brazil. Papua New Guinea (PNG) has two species, *A. cunninghamii* and *A. hunsteinii*. *A. cunninghamii* has a scattered distribution along the eastern coast of Australia from northern New South Wales to north-eastern Queensland and north into New Guinea. In PNG, the species is found in the east, especially Bulolo, Wau, Waria, Watut, Waghai, and Jimi Valleys in the Central Highlands. The species occurs most often in sub-montane *Fagaceae* forest on leached soils. The altitudinal range is 600–1500 m in areas with high rainfall. It occurs on a variety of rainforest soils and may grow on very low nutrient, leached and podsolised soils with a pH of less than 5. In PNG, it is commonly associated with *Castanopsis acuminatissima*, *Cinnamomum* species, *Podocarpus neriifolius, Prumnopitys amara and Schiomeria* species.

Uses The timber is used for various purposes. Young trees are extensively used for temporary house building material, fencing and firewood. It is grown in plantations for use in plywood manufacture. The tree is cultivated as an ornamental.

Botanical description *A. cunninghamii* is a tall tree up to 60 m in height and 2 m diameter, with a straight cylindrical bole. The crown is mostly irregular in outline. The bark is reddish-brown to coppery, peeling in horizontal strips. Leaves are lanceolate to triangular, curved with the pointed apices directed slightly inwards, green or glaucous. Male flowers are on thin hanging branches in the low part of the crown and are 5 cm long. Female flowers are in the upper crown in small scales (2 cm). Flowers turn dark yellow when mature. Fruit is a cone 5–10 cm in diameter, green or brown in colour, dry and woody comprising flattened, wedge-shaped woody scales with lateral wings with sharp points that contain the seed. Each scale is 20–30 mm x 9–10 mm excluding the membranous wings.

Flowering, fruiting and seed set Flowering occurs regularly each year between March and June. Fruit is a single cone, ready for collection from October to December. When mature, the fruit weighs about 200 g and holds an average of 260 seed in each cone. There are about 4000–5000 seeds/kg.

Seed collection and processing Cones are collected before they open on the trees. Cone collection is done with an extended pole fitted with a hook to dislodge the cones. Maturity may be determined by the following:

1. A slight cut is made on the tip of a sample cone with a bush knife. If a dark grey-brown colour is evident, the cone is ready for collection;
2. Full-size dark green cones are also considered mature.

At Bulolo the collected cones are air dried by spreading them on trays under heavy shade for 2–3 weeks. The wings are removed by hand using gloves and a wire screen. Further cleaning is done by winnowing, using a domestic electric fan to separate light material from the heavier seed.

Storage and viability The seed of *A. cunninghamii* is orthodox. The seed can be dried to 2% moisture content without damage from an initial mc of 23%. Stored seed should be kept in a freezer (–18°C) where it will keep for up to 6 years. In PNG, seed is placed in copra sack bags or in containers and stored at –10°C for up to 3 years. Fresh seed takes 12–20 days to germinate with viability of 75–80%.

Nursery techniques The seed is sown in beds of well-sieved forest topsoil. Pricking out is done two days after germination and seedlings are ready for planting (at the age of 18–22 months) when they are 20–25 cm tall.

Vegetative propagation *Araucaria cunninghamii* is easily propagated vegetatively. The Department of Primary Industries, Queensland, produced cuttings in a mix of 50% bark, 25% sand and 25% peat media.

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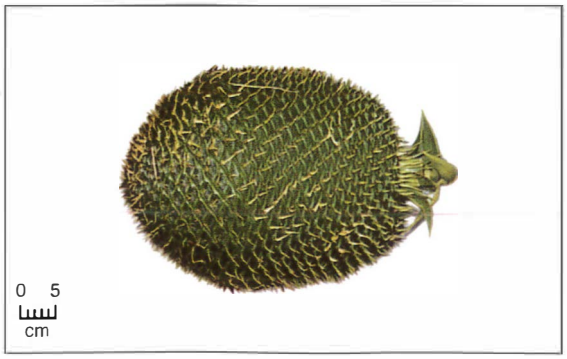
6.5. *Araucaria hunsteinii* K. Schum.

Family Araucariaceae
Comon name Klinki pine



Distribution and habitat The genus *Araucaria* consists of 19 species that are distributed along the eastern coast of Australia, New Guinea, New Caledonia, Norfolk Island, southern and central Chile, Argentina and southern Brazil. Papua New Guinea (PNG) has two species, *A. hunsteinii* and *A. cunninghamii*. In PNG, klinki pine occurs in Morobe Province near Bulolo, Wau, Watut, Waria Waghi and Jimi Valleys, as well as in the Central and Western Highlands. *A. hunsteinii* grows in primary forests at altitudes between 500 and 2100 m.

Uses *A. hunsteinii*, as well as *A. cunninghamii*, has been established in commercial plantations in the Bulolo and Wau districts for use in the plywood mill at Bulolo. The species is used for interior work including domestic flooring, panelling, furniture and general joinery. The tree is also used as an ornamental.

Botanical description *A. hunsteinii* is a very tall tree up to 90 m in height and 2 m in diameter, with a characteristic straight cylindrical bole. Branches are whorled, horizontal, slender and long with leaf-bearing twigs crowded at the ends. Crowns are pyramidal early but develop into flat or rounded tops in older trees. The bark is about 3 cm thick, dark brown outside with large pustules and fissures. Inside bark is red to pink in colour and fibrous near the wood. Leaves are lanceolate or ovate, rather sharply pointed with the tip curved, green or glaucous; juvenile leaves flattened. Male flowers are on lower branches in pendulous spikes up to 15 cm long with papery scales, and light green in colour. Female flowers are on upper branches in short spikes; pointed scales cover the ovules. *A. hunsteinii* is wind pollinated. Fruit is a cone up to 20 cm long and 12 cm diameter with spiny, winged cone scales; seed oblong; 30–40 mm x 8–10 mm excluding the membrane wing (Arentz *et al.* 1994).

Flowering, fruiting and seed set Flowers appear from January to March in Bulolo and Wau. Cones mature at the end of the dry season in September–October each year with occasional cones found throughout the year. A single cone weighs about 850 g. There are on average about 117 viable seed in each cone with about 5000 to 6000 seeds per kg.

Seed collection and processing The time between cones reaching maturity and seed shed is short. It is therefore critical to determine when the seed crop is mature and to undertake collections immediately. A number of methods are used to determine cone maturity:

1. The length of the embryo. Embryos should be at least 16 mm long and the endosperm must be well developed and hard.
2. The scales at the tip of the cone need to be brown in colour. This is determined by cutting the tip of a cone.
3. Experienced seed collectors can determine whether the cone is mature by its weight. Mature cones are lighter than immature cones.

Cones are collected as soon as they are mature by dislodging them from the tree. This is done by tree climbers using hooks attached to bamboo poles. Ladders are used to collect cones from orchards and seed production areas in Bulolo.

After collection, klinki pine cones are transported in copra bags to the extraction shed where they are dried for 2–3 weeks on open racks. If rack space is not available at the time, the cones can be stored in bags for up to a week. Longer periods in the bag will result in fungal development and destruction of the seed. As the cone dries it fragments into individual scales, enabling the seed to be hand separated from other cone segments. The seed is de-winged by hand, then dried for a further

week before storage.

Storage and viability Storage behaviour is recalcitrant, with seed having a moisture content (mc) of >53% at maturity. According to Tompsett (1982), seed will tolerate desiccation down to 32% mc. Viability of klinki seed drops to zero after 4 months when stored at 25°C, but when stored in airtight containers at a constant temperature of 3–6°C viability can be maintained for at least 6 months and sometimes up to 18 months. Havel (1965) reported that 50% of seed survived moist storage in a sealed container at 3–5°C for 18 months.

Nursery techniques Seed germinates 7–21 days after sowing. The germination of *A. hunsteinii* seed is epigeous (cotyledons are forced above the ground by the hypocotyl). Where necessary, seed is pricked out two days after germination. Seed is sown into beds or tubes. Seed sown in the nursery needs to be covered by a layer of mulch or sawdust and kept shaded until after germination. This is to ensure the germinants do not get damaged, causing loss of geotropism, withering of the radicle or breaking of the hypocotyls. Care needs to be taken to control damage in the nursery from snails in the early stages of growth, and from grasshoppers, termites and white ants in older seedlings. Seedlings are ready for planting out at 18–20 months.

Vegetative propagation Cuttings 6–7 cm long (with a whorl of branches) taken from leaders of 3-year-old seedlings exhibited up to 90% rooting (Arentz *et al.* 1994). Lateral shoots root well but remain plagiotropic (i.e. grow sideways). Rooted cuttings outgrow seedlings of a similar age.

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Authors: Lawrence Jarua and Annonciata

6.6. *Artocarpus altilis* (Parkinson) Fosberg

Family Moraceae
Comon name Breadfruit, kapiak

Description and habitat It is thought that the natural source of breadfruit is New Guinea, Moluccas, western Melanesia, and Micronesia. Seedless forms, and to a lesser extent the seeded forms, are now cultivated throughout the tropics. *Artocarpus altilis* is a tree of hot humid tropical lowlands associated with moist, deep, humus-rich and well-drained soils, frequently occurring on forest edges in flood-plains and swamps. It occurs at altitudes below 600 m, with temperatures of 20-40°C and an annual rainfall of 2000–3000 mm. Young plants grow better under shade, but later require full sun.

Uses Breadfruit provides nutritious fruit for human consumption, being an excellent source of carbohydrates and vitamins. Fruit and seed are eaten after boiling, baking, roasting or frying. The wood is used for light construction and canoes. The latex is used as glue. Leaves as well as fruit are a good animal feed. In Pacific islands, the leaves are also used to wrap food, such as palusami in Samoa. The latex is massaged into the skin to treat broken bones and sprains, while the bark extract is used to treat headaches in several Pacific islands. The trees are used for ornament, windbreaks or shade for crops such as coffee.

Botanical description *A. altilis* is a tree reaching heights of 15–25 m, and the trunk may be as large as 1.2 m in diameter and often buttressed. The tree has a smooth, light-coloured bark. Twigs are very thick. Leaves are broadly obovate to broadly ovate, 20–60 cm x 20–40 cm, at first undivided, later — on young trees — deeply divided into 5-lobed juvenile leaves. Leaves on new shoots of mature trees are usually larger, more dissected and more hirsute. Flowers are very numerous (1500–2000 per head, male and female on the same tree (monoecious) in separate thick fleshy clusters (heads) borne singly at leaf bases on stalks of about 5 cm. The male cluster is a cylindrical or club-shaped soft mass 13–30 cm long and 2.5 cm in diameter; yellowish and turning brown; each flower is about 1.5 mm long. Female flowers form elliptical or round clusters, 6 cm long and 4 cm in diameter or larger; light green. Female flowers are 10 mm long (Little and Skolmen 1989). Multiple fruit, globular to ellipsoid in shape, 12–20 cm wide and 12 cm long; the outer surface is light green, yellowish-green or yellow when mature and the flesh is creamy-white or pale yellow. Seed is 1–2 cm thick, thin-walled, sub-globose or obovoid, irregularly compressed, and embedded in the pulp. Seed has little or no endosperm.

Flowering, fruiting and seed set In the humid tropics the flowering times appears to depend on the cultivar rather than the climate. Some cultivars flower irregularly throughout the year and cultivars can be selected to provide fruit throughout the entire year (Rajendran 1991). This is confirmed by data from the phenological studies carried out in PNG, although there is a tendency for peak flowering in April–June. Peak fruiting time is July–September, with fruit available year round. In seeded forms, each fruit may contain 20–60 edible seed although some forms have only 2–5 seed per fruit. Average fruit weight is 9.6 kg, while the seed weight is 5 g. There are about 200 seeds/kg.

Seed collection and processing Mature fruit is harvested when yellowish. A good indicator of fruit availability and maturity is to check the markets. Fruit harvested green should be handled with care to avoid a flow of latex. The fruit stalk is cut with a sharp knife, or twisted using a sharp hook attached to a long pole. The fruit drops to the ground or is caught in a net as it falls. In order to stop the flow of latex, the fruit is first submerged in water or the end of the stalk immediately covered. Harvested fruit is collected in baskets and kept in a cool,

shaded place. Seed is extracted from ripe fruit by splitting this open — with a bush knife, or by dropping it on the ground several times — and removing the seed manually.

Storage and viability Seed storage behaviour is recalcitrant, with seed having a moisture content (mc) of about 60%. The seed has no dormant period, germinating immediately, and is unable to withstand desiccation. The seed loses viability within a few weeks and cannot be stored in a refrigerator. Hong *et al.* (1998) reported that imbibed seed of another *Artocarpus* species, viz. jackfruit (*A. heterophyllus*), can be maintained for 8–9 months if stored at a mc above 48% in polythene bags at 15°C with aeration.

Nursery techniques Fresh seed germinates readily, giving 90–95% germination. Seed is planted 5 cm apart and 1 cm deep, and germinates 2 weeks after sowing. Seedlings can be transplanted into individual containers as soon as they sprout. They grow quickly and are ready for planting in the field when they are about 1 year old.

Vegetative propagation Breadfruit is traditionally vegetatively propagated from root segments/suckers. Ragone (1997) describes the different vegetative techniques used to propagate breadfruit including damaging roots to promote suckering, budding, air-layering, root cuttings and stem cuttings. Leafless stem cuttings were treated with rooting hormone and placed into mist; 95% of the cuttings produced roots after 10 weeks. Rajendran (1991) describes the importance of setting sections of root, 2.5 cm in diameter and 20–25 cm in length, at an angle rather than upright in a shaded nursery bed.

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Authors: Lawrence Jarua and Annonciata Uwamariya

6.7. *Calophyllum euryphyllum* Laut.

Family Guttiferae
Comon name Kalophilum (or kalopilum)

Description and habitat There are about 190 species of *Calophyllum* from East Africa, Madagascar, the East Indies, tropical America, Indonesia and New Guinea (Stevens 1995). In New Guinea, the genus is represented by almost 50 species. *Calophyllum euryphyllum* is widely distributed throughout northern New Guinea, including the Bismarck Archipelago and the Aru Islands. In PNG, kalophilum grows in East and West Sepik, Central, Milne Bay, East and West New Britain and New Ireland Provinces including Umboi Island in the Morobe Province. Almost 50% of forest cover on Manus Island is *Calophyllum*, mostly *C. euryphyllum*, growing on all types of soil. The species grows on well drained primary or secondary lowland closed forest over coral to 650 m asl.

Uses *C. euryphyllum* is often used for general construction including flooring, moulding, panelling, shelving, interior finish, furniture, veneer, plywood, joinery, weatherboards, cladding, decking and turnery.

Botanical description A medium-sized to large tree up to 20–30 m (–50 m) tall with a bole often up to 100 cm diameter, buttress is absent or is very short. Flowers are in single inflorescences or in pairs, borne in upper branch axils, unbranched with 5–15 flowers per inflorescence. Actual flowers are hermaphroditic, with 4 tepals; the outer pair ovate 8–9.5 x 6–7.5 mm covered in short soft hairs on the back, the inner pair elliptic-ovate 8–10 x 7–8 mm and sometimes hairy. The fruit is sub-spherical, 2.8–6.0 cm in diameter, rounded at the apex, green in colour turning darker at maturity at which stage the endocarp develops shallow wrinkles. The single seed is spherical, 2.5–5.0 cm in diameter with a coat 0.5–1.4 mm thick.

Stevens (1995) reported that most New Guinea species have bluish-blackish fruit, and/or angled stones, and those species that do not have angled stones quite often have basal plugs that are pushed out during germination. There is considerable variation in the method of germination, the number of seedling leaves, the colour and arrangement of the leaves on the stem, and how the axis of the young plant is held (erect, or declined to one side). This means that even young plants of *Calophyllum* can often be readily identified to species. According to Stevens (1995), *C. euryphyllum* fruit lack a basal plug. However, this is refuted by the authors who germinated large numbers as part of a field trial.

Flowering, fruiting and seed set The species flowers twice a year, July–September, and again towards the end of the year (Poesi 2002). Good seed crops generally occur only every second year. Seed is shed around 4 months later. The heaviest crop normally follows the July–September flowering, with seed ready for collection in January–April.

On maturity, the fruit readily detaches from the tree. The fruit has a compact outer layer and a thick-walled stone. Flying foxes, cuscus and parrots are known to eat the endocarp. . There are 25–35 fruit (including endocarp) per kg.

Seed collection and processing Seed crops mature in late January to March depending on the location (Manus and Mussau – January/February, Open Bay and East/West Kaut – February/March and Siassi – March/April). It is recommended wherever possible to collect fruit from the crown rather than from the ground. If collecting from the ground, try to collect on a daily basis as seed loses viability rapidly on the ground. Fruit is collected and placed in well-aerated containers, e.g. hessian or copra sacks or onion bags. Bags need to be sturdy, as the fruit is heavy. Fruit should then be kept in the shade to ensure it does not overheat. Given that the seed is likely to be recalcitrant, it is important that time in transit, from collection to

sowing, is kept to a minimum.

Apart from extraneous matter that should be removed at the time of collection, a decision has to be made on whether to remove the endocarp or leave it intact to protect the single seed inside. When sowing the seed immediately, there is no need to remove the endocarp. Studies are required to determine whether it is better to retain or remove the endocarp prior to storage.

The method of removing the compact 2–5 mm thick endocarp depends on its condition. If the endocarp has softened and turned brown, it is simply a matter of depulping using water and manually removing the endocarp, followed by surface drying of the seed under shade.

Storage and viability On the basis that kalophilum seed has a mc of 68%, it can be assumed that it is recalcitrant. There are about 60 seeds/kg (excluding endocarp). Investigations are needed into the storage life of seed. In the absence of reliable information, it is recommended that seed be stored in a moist state (buried in moist sawdust) at temperatures of 3–6°C — not below freezing.

Nursery techniques Seed is sown with the endocarp intact. The radical breaks the stone wall to one side of the base, through a plug, allowing the cotyledons and one leaf pair to emerge, separated by an internode of 0.5–2 cm. Subsequent internodes are much longer while the plant grows erect. Germination can be very rapid, taking only 5 days to commence in ambient temperatures up to 35°C. Fresh seed can germinate during transportation between collection and reaching the nursery. Direct sowing can be done in either polybags or prepared germination beds. Seedlings take 3–4 months from germination to reach planting size. Within this period they develop 2–4 pairs of leaves and are ready to plant after hardening off in the sun. Avoid planting out soft-leaved seedlings as there is a high chance of leaf damage and sun scorch.

Vegetative propagation Tests by the PNG Forest Research Institute resulted in a 15% strike rate. Best results were obtained using woody material treated with 8 g/L a.i. indol-3-butyric acid.

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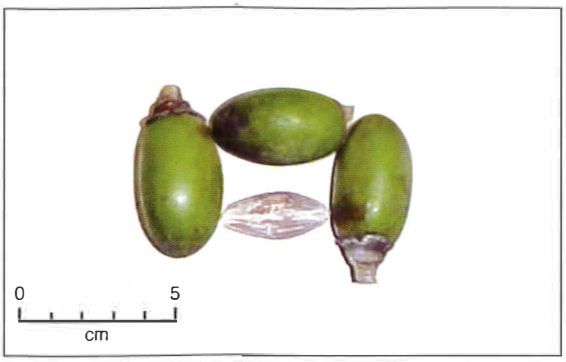
Authors: Michael Poesi, Derek Bosimbi

6.8. *Canarium indicum* L.

Family Burseraceae
Comon name Red canarium, galip



Distribution and habit *Canarium* contains about 100 species in Africa, Asia, Malesia, Australia and the Pacific islands. There are about 20 species of Canarium in New Guinea. *C. indicum* is distributed from Indonesia (Sulawesi, Moluccas and West Papua), through Papua New Guinea (PNG) and the Solomon Islands to Vanuatu.

Canarium indicum grows well in lowland rainforests and is particularly common under cultivation in old garden sites and around villages in New Britain, where it is highly valued for its edible fruit. Although a low-altitude species, it can be cultivated at elevations up to 1000 m. The species common in the Bulolo valley, at 700–1800 m asl, is *Canarium macadamii*. The fruit of *C. macadamii* is only half the size of that of *C. indicum*, and is more rounded in cross section.

Uses In PNG the seed kernel is used as a food and the oil from the seed is often used instead of coconut oil. The timber is used in general construction, moulding, interior finish, veneer, boxes, utility furniture, joinery and cabinet work. The wood is also used as firewood.

Botanical description *C. indicum* is a medium-sized to large tree up to 40 m tall. The bole is usually short and branchless for up to 10 m, with a diameter 60–100 cm and fluted buttress up to 1 m high, with a moderately broad crown. Flowers are either terminal or in axillary panicles. They can be either unisexual or bisexual. Large individual flowers (>1.0 cm) consist of a concave hairy receptacle, 3 yellow-green hairy sepals, 3 white hairy petals, 6 stamens, a disc and an ovary. In male flowers the ovary is reduced, while in female flowers the anthers are reduced. The fruit is an ovoid drupe, slightly triangular in cross section, about 5 cm long and 2–2.5 cm in diameter. It contains a large stone with three chambers of which one is usually enlarged to contain the equally large oily edible kernel. Fruit turns purple/black when fully ripened.

Flowering, fruiting and seed set Recent phenological observations have revealed considerable variation in flowering and fruiting. Peak flowering was observed in June–August and November, while fruiting was prominent in January–March. In contrast, Verheij and Coronel (1991) reported that flowering begins around October to December, followed by fruiting from July to December.

Seed collection and processing Seed can be collected from the ground following natural shedding, or by climbing the tree and using a hook to detach seed, or by shaking seed off the tree. The optimum time for collection is when the fruit is fully mature. A good indicator of maturity is that villagers begin to sell the fruit at the market. The outer skin is removed manually by hand. Avoid exposing the stones to direct sunlight as the heat may kill the seed kernel. There are on average 50 (35–100) seed per kilogram.

Storage and viability Storage characteristics of galip seed is unknown, and need investigation. Cleaned seed can be stored either in calico bags or in airtight containers in a cool room at 3–5°C. Seed may remain viable for up to 6 months, thereafter losing viability rapidly. The seed coat is carefully cracked with a hammer prior to sowing.

Nursery technique Galip seed can be either directly sown into medium-sized or large soil-filled polybags, or sown into a prepared seedbed. Seed is sown about 3–4 cm below the surface. If seed is sown in beds, the seedlings require transplanting when they have two pairs of leaves.

Vegetative propagation Staff at the Forest Research Institute in Lae have twice attempted to root cuttings of *C. indicum*, with little success (<10% produced roots; J. Beko, *pers. comm.* 2002).

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Authors: Derek Bosimbi and Annonciata Uwamariya

6.9. *Casuarina oligodon* L. Johnson

Family Casuarinaceae
Comon name Yar, sheoak

Distribution and habitat Casuarinaceae, which comprises the four genera *Allocasuarina, Casuarina, Ceuthostoma and Gymnostoma,* includes 90 species which occur in SE Asia, Malesia, Australia, Pacific islands and Papua New Guinea (PNG). *Casuarina* and *Gymnostoma* are represented in PNG. *C. oligodon* occurs in the highlands of New Guinea at altitudes of 1400–2500 (560–2700) m, but is recorded at sites as low as 250 m along the Ramu River. In PNG, *C. oligodon* occurs from near Aiyura in the Eastern Highlands, and from the Finisterre Range in the Madang District, extending at least as far west as the upper Strickland River. It occurs commonly on stream banks, ridge tops, and in old garden and village sites. The rainfall is 1900–2600 mm (–5000 mm) per annum, with high humidity throughout the year. The species grows well on sandy soils associated with drainage lines, and on alluvial soils.

Uses In the PNG highlands, the species is planted extensively as a tree fallow to improve fertility and reduce fallow periods to e.g. 10–20 years. Yar is suitable for fuelwood, traditional house construction, windbreaks, soil improvement and shade for coffee trees.

Botanical description *C. oligodon* is a tree growing to 30 m tall with a diameter of about 60 cm. The crown tapers to a point. The bark is grey-brown, fissured and peels off in irregular flakes with red inner bark. Leaves are arranged in whorls at the internodes of the thin green branchlets, with six leaf scales in each whorl. The species is dioecious or rarely monoecious. Male spikes are 1.5–4.5 cm long on the end of branchlets, and each flower consists of one anther surrounded by four scales. Red female flowers are shaped as short cylindrical or sub-cylindrical cones. The fruit, a cone 4–10 mm long, green to brown in colour, contains over 20 grey or yellow-brown winged seed (Suhardi 1998) enclosed in woody bracteoles.

Flowering, fruiting and seed set Flowering times are not recorded for yar. However, it has been suggested that flowering commences in about June, with seed crops available for collection from August. There is also a suggestion that flowering may occur almost year round. There are about 675 000 seeds per kilogram.

Seed collection and processing The cones are ready for collection once their bracteoles have fully formed, but the cone itself may still be green or turning brown just prior to seed shed. To determine the maturity of the seed, remove a branchlet containing cones and leave it in a sunny dry place for one day. If mature, the cones will release pale-coloured winged seed. If immature, the scales will not open. Alternatively, cut open a cone to see if the seed is firm and mature. Seed is usually collected by climbing the trees and, with the aid of a pole pruner or bamboo hook, removing fruit-bearing branchlets. Once on the ground, the cones are removed from the branches by hand and placed in calico bags. Avoid mixing branchlets with the cones, as broken branch segments may later be difficult to separate from seed. After collection, the cones need to be left in sunlight to dry for one or two days in order for the bracteoles to open and release the seed. The shed seed can then be sieved to separate seed from impurities including the cones.

Storage and viability Storage behaviour is orthodox. Seed should be stored in a refrigerator (3–5°C) or, for a longer term, in a freezer. Under these conditions seed should retain viability for at least several years.

Nursery techniques Germination is rapid and commences about 10 days from sowing. Seedlings may be pricked out into polythene bags when 2–3 cm high. They are ready for planting out after 3–4 months.

Vegetative propagation Trials by the Forest Research Institute in Lae gave 60% rooting (J. Beko, *pers. comm.* 2002), indicating that *C. oligodon* can be readily propagated vegetatively. Very thin tips, up to 5 cm in length, from the main stem (not side branches) are used. The lower needles are removed and upper needles trimmed to reduce surface area. The rooting hormone gel Clonex purple (0.3% a.i. IBA) was used.

Other *Casuarina* species can be propagated vegetatively. *C. equisetifolia* has been successfully grown from stem cuttings taken from epicormic shoots as well as from trees 25 years old (Kha 1996). Parthiban *et. al.* (1996) reported successful propagation by air-layering and suckering, as well as by rooted cuttings, although some material expressed plagiotropism (showing a branching habit rather than straight stems). *C. junghuhniana* is also propagated vegetatively, with 50–55% rooting using 100 ppm IBA (Surendran *et. al.* 1996).

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Authors: Alex Agiwa and Annonciata Uwamariya

6.10. *Dracontomelon dao* (Blanco) Merr. & Rolfe

Family Anacardiaceae
Comon name New Guinea walnut, mon

Distribution and habitat *Dracontomelon* comprises about 8 species distributed across Asia, Malesia and parts of the Pacific. The natural distribution of *Dracontomelon dao* covers India, Myanmar, Thailand, Cambodia, southern China, Brunei, Indonesia, Philippines, Malaysia, Vietnam, Papua New Guinea (PNG), and the Solomon Islands (Louman *et al.* 1995). The species occurs in most PNG provinces in lowland rainforests up to 1200 m. It occurs in primary or secondary evergreen forest in areas of high rainfall, or less commonly in areas with a short dry spell where it is deciduous, or partly so, shedding its leaves shortly before the wet season. *D. dao* regenerates well in abandoned garden sites and tolerates shade.

Uses The species is used extensively for furniture, panelling and flooring, and for construction of traditional dwellings. The fruit is edible, while flowers and leaves are cooked and eaten as vegetables or food flavouring. Bark is occasionally used in traditional medicine. The tree is planted as an ornamental.

Botanical description A large tree up to 45 (–50) m tall with a 20 m clear bole 100 (–150) cm in diameter, with narrow buttress up to 6 m. Bark is irregularly scaly, greyish-brown with brown or greenish patches. Leaves are compound, 35–40 cm long, each with 5–9 pairs of sub-opposite or alternately arranged leaflets plus a terminal leaflet. Flowers are arranged in axillary panicles, individual flowers consisting of a calyx with 5 lobes, 5 petals and 10 stamens, and a superior ovary divided into 5 segments. Inflorescences are produced at the base of new shoots and the tree flowers just before all the old leaves have fallen. New Guinea walnut appears to be pollinated by insects. The fruit is a round, fleshy, edible drupe, 2 cm in diameter. The colour changes from green to yellow when ripe. Inside the fruit is a lens-shaped woody nut (endocarp), having up to 5 locules, normally with 1–2 viable seed.

Flowering, fruiting and seed set In PNG, flowers appear sporadically, but in Bulolo, Rabaul and Milne Bay most trees start flowering September–October. Observations in Lae indicate flowering occurs February–March, with fruit maturing three months later in June. According to fruiting records, there is a tendency for walnut to set seed between February and June. The species is regarded as having fruit adapted for dispersal by bats as it is duller in colour than that of bird-dispersed fruit, and has a strong musky odour. The fruit ripens on the tree and is held at some distance from the foliage to facilitate visits by bats. There are about 100 fruit per kg and 400–700 seeds per kg.

Seed collection and processing Seed is collected by climbing, but ripe mature fruit can also be picked from the ground. The exocarp (outer skin) is initially fractured or removed using a knife or by crushing with a flat instrument such as a piece of wood. The fruit is then soaked in water for 2–6 days, exchanging the water daily, to soften the outer pulp before removing the flesh by hand. The depulped fruit is washed in running water and air-dried. Fermentation of the fruit should be avoided as this may result in lower seed viability.

Storage and viability Storage behaviour is considered recalcitrant, but this assumption requires confirmation. The seed is stored in the woody nut, as it is very difficult to separate it from the nut (endocarp). The storage life of seed is unknown but is likely to be relatively short (<6 months). Seed should be stored in unsealed containers at 3–5°C (cool room).

Nursery techniques Germination is slow and sporadic, taking 28–56 days or longer. Seed is pre-treated in order to hasten germination. This is done either by carefully cracking the hard seed coat

or by abrasion using a file, grinding machine or sandpaper and then soaking in water overnight. The seed is sown near the surface in forest topsoil.

Vegetative propagation The PNG Forest Research Institute (FRI) obtained a 93% strike rate from 18-month-old hedge plants (J. Beko, *pers. comm.* 2002). Material 3–5 cm in length, including the tip, is most suitable. Two leaves were kept on the stems and reduced to one third of their original surface area. Clonex red gel (0.8% a.i. IBA) rooting hormone was used. Oporto and Garcia (1998) also reported that *D. dao* can be successfully propagated from shoot tips and leaf cuttings.

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Author: Annonciata Uwamariya

6.11. *Elmerrillia papuana* (Schltr) Dandy.

Family Magnoliaceae

Comon name Wau beech

Distribution and habitat *Elmerrillia* comprises 7 species from Malesia, Kalimantan, Philippines and Papua New Guinea (PNG). *E. papuana* is restricted to PNG and the eastern Moluccas (Indonesia). In PNG the species is locally common from the Vogelkop to the Milne Bay district and New Britain (Croft 1978). Wau beech is mostly found growing from sea level to above 1600 (–2600?) m asl. It occurs in lowlands to sub-montane rainforests and occasionally in regrowth. Common in localised areas, often in association with *Castanopsis* and *Lithocarpus*.

Uses Wau beech timber is durable and is suitable for veneer, high-grade furniture, boat building, moulding and light construction.

Botanical description *E. papuana* is a large tree up to 40 m tall with a straight or crooked bole to 20 m with a diameter to 1.2 m, and a large spreading crown. Slight, low buttresses may be present. Bark is 2 cm thick, with the outer bark light grey with brown blotches, peeling off in large flakes, and the inner bark green with brown patches. Leaves are elliptic, oblong, slightly ovate or slightly obovate, 8–31 x 3.5–11.5 cm; apex acute to slightly attenuate, or obtusely acuminate. Flowers are axillary, solitary or occasionally in pairs with one much more developed than the other. Prior to anthesis the flower buds are enclosed in 2–3 spathulate caduceus bracts. Fruit 4–10 cm long, a syncarp of 1-seeded follicles, dehiscing along dorsal suture to expose pink, red or orange seed 5 mm in diameter.

Flowering, fruiting and seed set In PNG, flowering occurs throughout the year with the major flowering period reported to be November–January in the Bulolo and Wau areas. Seed fall is recorded from April to June. There are about 30 000 seeds/kg.

Seed collection and processing The presence of fructiferous birds on the tree and falling of mature seed are indicators of seed maturity. Mature fruit is collected by climbing. Freshly-fallen seed may also be collected from the ground. Unripe fruit is separated to allow an extra 1–2 days of ripening before extraction. Following collection, mature fruit is spread under shade for 1–3 days to allow further ripening before the fruit is manually removed from the stalk by hand. The fruit is then soaked in water for 1–2 days to remove the flesh. Seed is washed again in clean water and air dried before sowing or storage.

Storage and viability The moisture content of Wau beech fruit is 63% and of seed 37%, so the seed is likely to have recalcitrant storage behaviour. The seed can be stored moist under refrigeration (3–5°C) for 4 months, while seed stored at 25°C (room temperature) in calico bags can maintain viability for only about 6 weeks.

Nursery techniques The seed is soaked in cold water for 1–2 days prior to sowing in order to increase the rate and uniformity of germination. Within one week of germination, the seedlings are ready for pricking out.

Vegetative propagation No studies of vegetative propagation for Wau beech are known.

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6.12. *Endospermum medullosum* (L.S.Smith)

Family Euphorbiaceae
Comon name Basswood, whitewood (in the Pacific)

Distribution and habitat *Endospermum* comprises 12–14 species from Asia, Malesia, Australia and the Pacific islands. Endospermum medullosum occurs in New Guinea, the Solomon Islands, and in the Santa Cruz Islands to Vanuatu. In Papua New Guinea (PNG) the species is widespread in West and East Sepik, Madang, Morobe, Gulf, Northern (Oro) and Milne Bay Provinces. Also in the Bismarck Archipelago (Manus and New Britain) and Bougainville. *E. medullosum* grows predominately in lowland, humid tropical climates. Rainfall is high, typically 2500–4500 mm per annum, with no pronounced dry season. The species grows on a very wide range of soil types including clays, gravely alluvials, sandy clays, grey sandy loams of considerable depth and seasonally inundated soils.

Uses Basswood is well suited for use in moulding, veneer, sawn timber, lining, joinery, interior finish, match splints, match boxes, shutting, turnery, dowels, pattern making, packing cases, furniture, cabinet work, weatherboards and shingles. In PNG the species is marketed with two other species, *E. myrmecophilum* and *E. moluccanum,* under the tradename of basswood, and is sometimes confused with these species (L. Thomson, *pers. comm.* 2003). Community uses include firewood and canoe making. The young leaves are reported to be sometimes eaten as a vegetable but this possibly refers to another *Endospermum* species. The bark and leaves are used as medicine, including the treatment of rheumatism.

Botanical description *E. medullosum* is a large tree up to 45 m tall. The crown is monopodial, with a single leader and branches in whorls. The bole is usually twisted, sometimes with steep buttresses. Diameter above the buttress may reach >1 m but more commonly is 50–80 cm. The bark may be hard or somewhat corky, fairly smooth but scaly or marked with longitudinal lines near the base and with scattered pustules or lenticels. Leaves are simple/entire, large 8–25 (–33) cm long x 5.5–20 (25) cm across, cordate or peltate. The leaf is mid-dark green, sub-shiny with fine soft hairs above, light silvery-green and densely hairy below. Flowers are small and arranged in axillary spikes, greenish white behind the leaves; bisexual flowers are rarely present, calyx indistinctly 4-lobed, and petals absent.

Flowering, fruiting and seed set The species starts flowering at the age of 3–4 years. In PNG flowering of basswood appears to be sporadic, with records showing flowering February–March and again July–September. Fruiting is sporadic with a peak September–October. Seed set is also recorded in January, May and June. Fruit is fleshly ovoid drupe, 6–9 mm in diameter, light greyish-green turning yellowish-green and covered in fine hairs when mature. Fruit does not split and encases one hard black seed 5 mm in diameter. There are about 9000 fruit per kg and 30 000 to 35 000 seed per kg. Ripe fruit is eaten by birds. Pigeons eat fruit that has fallen to the ground, and parrots eat immature fruit.

Seed collection and processing Seed collections are made by accessing the crown and removing seed-bearing branches. Following collection, fruit is placed in hessian bags and taken back to base for processing. While waiting for extraction, it is spread out in the open under shade. The seed is then soaked overnight in water after which the outer flesh is removed by hand. Further cleaning is done by water flotation. The seed is rewashed under running water and air-dried for 2 days prior to sowing or storage. In Vanuatu, fruit bearing branches are removed from the crown by breaking using a strong rope (which may be

positioned using various techniques such as the big-shot catapult). The fruit is immediately immersed in water where fruit infested by wasp larvae float and are discarded. The fruit is allowed to soften for 1–3 days before the fleshy pulp is removed. Whole fruit can be sown immediately (L. Thomson, *pers. comm.* 2003).

Storage and viability Seed storage behaviour has yet to be fully determined; it is normal for seed to be sown as soon as possible after collection. Seed is reported to have a moisture content of about 51% and fruit, 79%. If storage is unavoidable, seed should be kept in the refrigerator at 3–5°C. In the case of related species, seed of *E. malaccense* can be stored for only 3 months, whilst seed of *E. sinensis* is reported to be orthodox and able to be stored for a long time. Fresh seed normally has low viability — below 35%. Factors contributing to this are the high incidence of insect damage and the collection of immature seed. Similarly, *E. malaccense* is also reported to have very low initial viability (<30%) due to a lack of embryo development and insect damage.

Nursery technique Seedlings may be raised in rigid tapering plastic pots (12 cm deep, 250 cm^3). They are ready for planting out when around 25 cm tall.

Vegetative propagation Basswood is readily propagated by cuttings, taken from young hedges, when set in a high-humidity poly-propagator or preferably under mist. It is possible to grow plants suitable for field planting by setting terminal cuttings 20–25 cm long directly into containers (Walker *et al.* 1994); the growth rate of cuttings is comparable to that of seedlings (Aru and Collins 1999).

An experiment at the Forest Research Institute (FRI) in Lae tested E. medullosum stem cuttings taken from hedges ~80 cm in height. All leaves were removed except the top one or two, and these were reduced in size to an area ~2–4 cm across. The rooting hormone gel Clonex red (0.8% a.i. IBA) was used. The cuttings were set in small narrow polybags. Of the 14 cuttings taken, 5 produced roots (36%) after three weeks (Brammall *et al. 2000).*

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6.13. *Gnetum gnemon* L.

Family Gnetaceae
Comon name Tulip

Distribution and habit *Gnetum* comprises 28 species of tropical lianas, less often trees and shrubs (Mabberley 1987). *Gnetum gnemon* occurs throughout Papua New Guinea (PNG) in lowland and lower montane rainforests, mostly in the understorey on well drained sites. It also occurs throughout South East Asia and the Pacific islands to Fiji and is reported up to altitudes of 1200 m in areas with a distinct dry season (Hong *et al.* 1998). The species is often cultivated near villages and on old garden sites.

Uses Traditionally, tulip is cultivated for its fruit and edible leaves. Young leaves, the inflorescence and the ovoid drupe are cooked in vegetable dishes (Verheij and Coronel 1991). The inner bark is used in making twine and rope for string bags or billums, and for nets of various sizes for trapping and catching pigs, wallabies and bandicoots. The round timber is used as post and poles for house construction.

Botanical description *Gnetum gnemon* is a small to medium-sized tree up to 25 m tall, sometimes reaching 50 cm in diameter. The main trunk usually continues into the crown, which is deep and narrow. The bole itself is normally not buttressed and is characterised by raised horizontal ridges. Branches are usually present low down on the bole. Leaves are alternate, simple, deciduous, broadly cordate or ovate, up to 20 cm x 16 cm, base oblique, apex acute to acuminate, margins coarsely toothed, 5 principal nerves palmate, petiole up to 1.5 cm long. Flower inflorescences are in axillary spikes, creamy yellow in colour, flowers grouped in whorls. Male flowers consist of an anther and a simple perianth, whilst the female flowers consist of an ovule surrounded by a fleshy tube. Fruit is an ovoid drupe, 1.8–2.2 cm in diameter, indistinctly lobed, red or purple. Flesh soft, fibrous, greenish-white, stained with purplish-red, tasting pleasantly acid, with a pointed apex, turning yellow to red when ripe. The seed has two coats, an outer fleshy mesocarp and an inner hard endocarp.

Flowering, fruiting and seed set Flowering times for tulip vary between locations. Not all trees in any one location flower at the same time — individual trees flower sporadically. The ripe seed or drupe is eaten by cassowaries and soft-beaked birds such as 'gwawi'.

Seed collection and processing The interval between flowering and fruit maturity is three months. Ripe seed can be collected either from the tree or from the ground. Mature fruit falls to the ground where rats, mice and bandicoots eat the mesocarp and effectively 'depulp' it to leave 1–2, hemispherical, 5 mm wide seed. Cleaning is done manually by hand. The depulped mesocarp is often cooked and eaten with other vegetables.

Storage and viability Storage behaviour is orthodox (Hong *et al.* 1998). Fresh fruit has a mc of 60%. Store seed in an appropriately-sealed container or — preferably — in calico bags. Storage trials have not been undertaken. Seed germinates in 15–20 days (Verheij and Coronel 1991). The juvenile leaf stage lasts for 15–18 months.

Nursery technique Propagation is mostly by seed which does not require any pre-sowing treatment (Verheij and Coronel 1991). However, the PNG National Tree Seed Centre has found that tulip takes a considerable time to germinate (L. Jarua, *pers. comm.* 2003). The question of whether the seed requires a pre-treatment to speed up germination needs further study. Seedlings are ready for planting out within 3–4 months.

Vegetative propagation Vegetative propagation by cuttings, layers and budding is feasible (Verheij and Coronel 1991).

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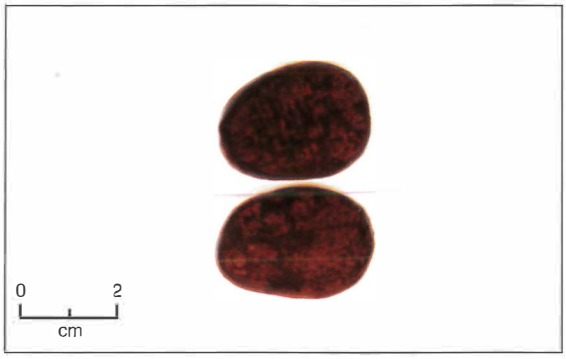
6.14. *Intsia bijuga* (Colebr.) Kuntze

Family Caesalpiniaceae
Comon name Kwila



Distribution and habitat *Intsia* comprises three species with a distribution in Madagascar, Asia, Malesia, Australia and the Pacific islands. *Intsia bijuga* is widely distributed from Madagascar, the islands of the Indian Ocean, through Papua New Guinea (PNG), Australia (Hyland and Whiffin 1993) and the Pacific (Melanesia, Micronesia and Polynesia). In PNG, kwila occurs in the lowlands on steep slopes of raised coral reefs almost without soil, but it is also found in swampy, even brackish habitats. The species is a common component of the lowland ridge flora in association with *Anisoptera* and *Hopea*. Kwila prefers a rainfall of more than 2000 mm a year and grows in primary or old secondary forests on a wide variety of soils, but not usually on peat.

Uses Kwila is an important commercial timber species, and is sometimes known as merbau in the PNG timber industry. The timber has a wide range of uses, both indoors and outdoors. It is particularly suited to outdoor furniture, being able to resist deterioration well. Occasionally it is used for canoes and carving. Commercially it is used in heavy construction, boat building and furniture. Bark and leaves are used medicinally, and the seed can be eaten after careful preparation.

Botanical description *I. bijuga* is a medium-sized tree 20–30 m high and up to 160 (–250) cm in diameter. It is straight boled or crooked, with thick buttress. Bark is reddish brown, smooth, torugulose with small lenticels. The inner bark is light brown and the heartwood yellow-brown or red-brown. Leaves are spiral, pinnate, and have one or, infrequently, 2 leaflet pairs. Flowers have white petals and red stamens, and are arranged in small terminal panicles. Insects such as bees are likely pollinators. The seed is held in a wide, dark brown, dry, leathery, dehiscent pod or legume.

Flowering, fruiting and seed set Flowers have been observed year round, peaking in August in Madang. Fruit has also been observed year round, with a peak in February. Pods are oblong, compressed, 8.5–23 x 4–8 cm, green turning to dark brown to black when ripe. Each fruit contains 3–10 dull reddish-brown compressed hard seed about 3 x 2 cm. There are about 160 seeds per kg.

Seed collection and processing Kwila produces copious amounts of seed on an almost annual basis. Collections can either be made from the trees or of pods the ground. After collection, the fruit/pods are dried in the sun for up to 3 days to facilitate their opening. The pods are spread thinly on a dry surface. Once they split open, the seed can be separated from the impurities by sieving, winnowing or flotation.

Storage and viability Storage behaviour is orthodox. Mature seed has a moisture content of less than 10%. *I. bijuga* seed should be stored in airtight containers, preferably at 3–5°C (refrigerator), otherwise in an air-conditioned room where they will remain viable for over 1 year.

Nursery techniques It takes 9–11 days for the seed to germinate, but if the seed is pre-treated (nicked) this time is reduced to less than a week (2–5 days). To promote rapid and simultaneous germination, scarification followed by soaking in water is necessary. Seed must be sown vertically with the hilum downward, so that the seedcoat is shed as the hypocotyl emerges from the soil. Seed may also be sown directly into the field. Seedlings can reach a height of 50 cm within 2–3 months. Form in open-grown plantings is very poor, with no definite main leader. This species should preferably be planted in gaps or in situations of filtered light.

Vegetative propagation Tests have been carried out in the Philippines using long cuttings (60 cm). Six weeks after setting these in a sandy clay-loam

medium, the mortality rate was 62% (Johns *et al.* 1994). The South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) project conducted an experiment to assess the rooting ability of kwila. The average strike was 35%, the greatest success being with cuttings taken from the second and third nodal positions (Collins *et al.* 2000).

An experiment at the PNG Forest Research Institute (FRI) obtained good results (90% rooting) (M. Singadan, *pers. comm.* 2003). Woody and semi-woody material 4–5 cm long was used, with leaves reduced to one third their original size. Both Clonex© red and purple rooting hormone gel (0.3 % and 0.8 % a.i. IBA) were applied.

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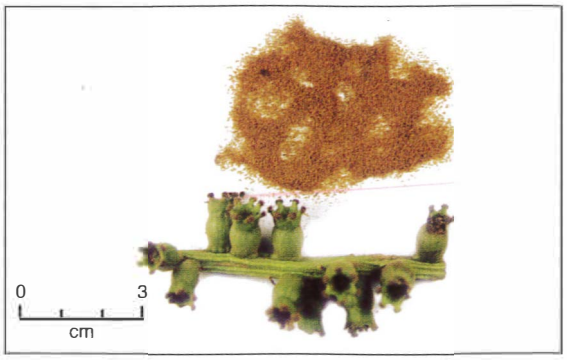
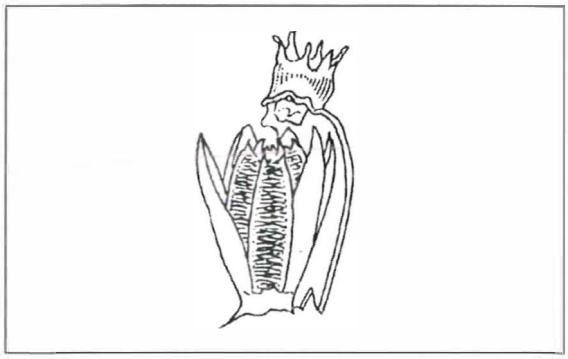
6.15. *Octomeles sumatrana* Miquel

Family Datiscaceae

Comon name Erima, irima, ilima





Distribution and habitat *Octomeles* is represented by a single species, Octomeles sumatrana. It extends from northern Sumatra, through Borneo, Sulawesi, the Moluccas, the Philippines, Lesser Sunda Islands, Vogelkop Peninsula , throughout much of New Guinea, eastwards as far as Santa Isabel Island in the Solomon Islands (Croft 1978). The species grows in lowland evergreen rainforest up to an altitude of 1000 m. In Papua New Guinea (PNG) the species occurs in even-aged pure stands along rivers, or sometimes in association with *Eucalyptus deglupta*. The most important condition for growth of erima seems to be an evenly distributed rainfall of at least 1500 mm annually. The species needs a fertile, deep soil for best development, and in PNG it grows on recent volcanic ash deposits.

Uses A non-durable timber suitable for a wide range of interior joinery as well as for packing cases, coffins, veneer for backs and cores of plywood, and for match-boxes. Favoured for traditional canoe building. Erima merits attention as a plantation species, especially for the production of raw material for the manufacture of plywood and for pulp. It develops well in open areas and is used for enrichment planting in logged-over forest. It is a fast-growing species in low-lying *Imperata* grassland.

Botanical description *O. sumatrana* is a tree to 75 m tall with a diameter of 2 m above buttresses, with a clear straight cylindrical bole to 40 m. The crown is open and semi-globular when mature. Bark is grey to grey-brown, fissured, 2–4 cm thick, often with pustular outer bark. Under-bark is greyish in colour with the inner bark rapidly turning brown when cut, no exudates, and an unpleasant smell. Leaves are glabrous, round, broadly ovate to cordate, acuminate ± entire 12–30 x 6–23 cm. Male flowers are 4–5 mm, in spikes 20–60 cm long; female flowers 5 cm long, in spikes 8–12 cm. Fruit is a barrel-shaped capsule about 12 mm long, arranged on long, 15–40 cm, spikes on a peduncle 10–20 cm long. Seed is numerous, tiny, 1 x 0.2 mm, and spindle-shaped (Croft 1978).

Flowering, fruiting and seed set Erima may be found in flower and fruit more or less throughout the year. Records indicate fruiting mainly October–December and also in May, and seed shed in April–May and July–September. Hildebrand et al. (1995) report that erima produces abundant fruit every 3–4 years. There are 115 000–200 000 seeds per kg.

Seed collection and processing The fruit is collected off the tree when it begins to turn brown. Seed is susceptible to damage by fungi during transportation. Fruit must be stored loosely in open-weave bags and extracted as soon as possible. Fruit is laid out in the open to dry on a sheet or tarpaulin to prevent loss of seed. Once dry, the capsule splits open longitudinally, shedding the seed. The fruit is then shaken vigorously over a sheet to release the seed, which is then separated using a fine sieve.

Storage and viability Initial indications are that the fresh seed has a viability of about 40% and a moisture content of 7%. According to Kale (1999), the storage life of the seed is very short, so the it should be sown as soon as possible following collection. More work is required to determine optimum storage conditions.

Nursery techniques For sowing, seed is mixed with fine river sand and sown in trays that are kept moist under full shade. The seed should be sown thinly to prevent dense clumps of seedlings. Germination occurs 8–16 days after sowing. Damping-off can be prevented by providing good ventilation. Seedlings can be pricked out 5–6 weeks after sowing and are ready for planting after about

4 months. when they are 15–20 cm tall.

Vegetative propagation Vegetative propagation techniques using root cuttings have been developed in Malaysia to fulfil industrial plantation programs.

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Author: Annonciata Uwamariya

6.16. *Pangium edule* Reinwardt

Family Flacourtiaceae
Comon name Seis, pangi

Distribution and habitat In Papua New Guinea (PNG) *Pangium edule* grows in lowlands, mid-mountain rainforests and often near creeks at altitudes ranging between sea level and 1000 m. It is a lesser-known timber species and it is scarce throughout the country.

Uses Seis produces a poisonous fruit which can be made edible through a leaching process. The leached fruit is served at special feasts. The seed contains prussic acid which must be leached out by soaking in running water for 24–48 hours before eating. In PNG, young leaves are used to treat tropical ulcers or any large sores. Hard shells (rattles) are strung together by villagers and used as a musical instrument. It grows rapidly in the initial stages (Tinggal 1992).

Botanical description *P. edule* is a medium-sized tree, usually about 20–40 m tall and 75 cm in diameter, with buttresses, often crooked, and a broad crown. The bark is 1.3–2.0 cm thick, the outer bark greenish-brown, middle bark creamy-yellow, and inner bark creamy-yellow with orange stone cells and very hard. Leaves are alternate, simple, large, cordiform (18–22 x 16–17 cm), the tip acuminate, margin entire, palmate, thin, dark green, glossy with a long petiole. Flowers are in separate inflorescences: each flower has 5–8 petals. Fruit is ovoid but somewhat asymmetrical with rough brown skin; seed is enveloped in yellow custard-like strong-smelling pulp. Fruit is 15–21 cm long and 12 cm wide. The flattened greyish-brown seed is about 5 cm long.

Flowering, fruiting and seed set Flowering occurs from September to October with seed shed likely to be in December–January. However, there are records of seed shed in April–May and July–September. Fruit comprise about 20 large red-brown seed. Pigs and tree rats feed on the seed. The tree is reported to start producing fruit after 10–15 years.

Seed collection and processing Seed is collected from the ground and held in containers until ready for processing. The pulp is removed as soon as possible by hand. The seed is washed in running water and then air dried prior to storage.

Storage and viability The seed of seis is known to have a high moisture content (72%) thus it is likely that the seed has a recalcitrant storage character. There is no information on storage life.

Nursery techniques No specific nursery techniques for seis have been described in the literature.

Vegetative propagation There is no information on vegetative propagation of seis.

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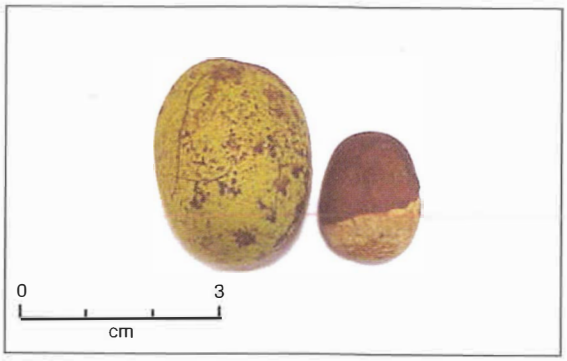
New Guinea walnut (*Dracontomelon dao*), is widespread in PNG associated with lowland rainforest. It is widely used in furniture manufacture and traditional dwellings. The fruit is edible. (see description under Section 6.10).

6.17. *Pometia pinnata* J.R. Forster & J.G. Forster

Family Sapindaceae
Comon name Taun



Distribution and habitat *Pometia* is widely distributed from Sri Lanka and the Andaman Islands, throughout South East Asia extending into southern China and Vietnam. From Malesia it occurs throughout the Pacific as far as Samoa and Niue. Within Papua New Guinea (PNG) *Pometia pinnata* exists in at least three distinctive forms, viz. *pinnata*, glabra and repanda. The type form of *P. pinnata* is the most important for timber production, although this form has often been incorrectly referred to as form *tomentosa* (or *P. tomentosa*) in PNG (Thomson and Damas 2000). In PNG, the species occurs along coastal areas in Madang, Morobe, East and West New Britain, New Ireland and Bougainville Provinces. *P. pinnata* occurs in a variety of soil and vegetation types ranging from coastal limestone to primary lowland rain forests on alluvial floodplains and foothills. *P. pinnata* is often the dominant species in the forest, with its canopy emerging above those of other forest tree species.

Uses *P. pinnata* timber is used as a general construction material, and for panelling, domestic flooring, veneer, joinery, furniture, cabinet-work, boat building, mouldings, dowels, window frames, interior finish, turnery, doors, billiard tables and tool handles. The fleshy mesocarp is edible.

Botanical description *P. pinnata* is a medium-sized to large tree, often growing up to 50 m tall and 1.5 m in diameter. The crown is deep and dense, of untidy outline, always with some young red leaves. Buttresses are variable, steep to spreading. The bark is grey to pinkish/orange-brown, smooth to mottled, peeling off in thin scale-like flakes. The inner bark is thin, fibrous, pink-brown (with slight to abundant exudation of thin red to clear gum following wounding). Leaves are pari-pinnate, 3–8 pairs of leaflets, rachis up to 1 m long, lowest pair often reduced, midrib hairy or glabrous above, margin toothed. Flowers are unisexual, calyx 5–lobed, petals 5, disc ring-like, stamens 5, filaments needle-shaped, ovaries 2-celled, hairy. Flowers occur in highly variable clusters of terminal or sub-terminal inflorescences or rarely as axillary panicles conspicuously projecting beyond the foliage, 15–70 cm long. The main branches are simple or with secondary branching sometimes subtended by auricle-like leaflets. Pollinators include small insects such as bees, bugs and beetles. The fruit is a sub-globose to ovoid, 2.5--4.5 cm x 2--4.5 cm, the skin or pericarp is smooth and occurs in various colours from greenish-yellow, yellow, red, purple or blackish with a gelatinous sweet white translucent pulp (mesocarp) partially encasing a single large seed. Seed is globular to ovoid, 2.0 x 3--4 cm.

There is considerable confusion concerning the taxonomy of *Pometia* due to its complex and highly variable nature (Thomson 2000). Three forms of *P. pinnata* are recognised in PNG: *pinnata, glabra* and *repanda* (Jacobs 1962). A better understanding of the morphological and genetic variation in *Pometia* in PNG is required.

Flowering, fruiting and seed set Flowering times for taun vary both geographically and between years. Kale (1999) reported flowers appearing from September to October in Lae and Oomsis. In Kavieng, New Ireland Province, taun has been observed flowering in January/February and at Gogal, Madang Province, peak flowering occurs in April with seed set in July. However, there are records of flowering throughout the year. Fruit maturity varies from year to year with a tendency towards December–March when the various colorations take on a darker hue. There are about 300–500 seeds per kg.

Seed collection & processing Taun seed can be collected from either the crown, which is the

preferred option, or following natural shed. The seed is sensitive to moisture reduction and is readily damaged by insects or fungi. Seed collected from the ground must be harvested within a day of seed fall, ensuring that immature fruit is not collected. Collected seed is placed in calico or cloth bags and taken for processing immediately. Removal of pericarp and arillode promotes seed gemination. It is recommended that seed be sown as soon as possible after collection.

Storage and viability Storage behaviour is recalcitrant. Seed moisture content is about 35–55%. Under suitable conditions the seed can be stored for up to 6 weeks with the skin intact. Fresh seed has a high initial viability but this falls rapidly in storage.

Nursery techniques It takes 7—10 days for taun seed to germinate. Seed is sown directly into pots. Pricking out is best done as soon as the seed has germinated. Young seedlings grow very quickly during the first month or so and the species may be best established through direct seeding into the final field location.

Vegetative propagation Trials at the Forest Research Institute (FRI) in Lae indicate that *P. pinnata* can be vegetatively propagated. Initial trials resulted in 50% rooting (Brammall *et al.* 2000) but this was increased to 100% by using 20-month-old hedge plants (J. Beko, *pers. comm.* 2002). The most successful results were achieved by using cutting material 3–5 cm in length. The leaf area was reduced to one third its original size. The rooting hormone gel Clonex purple (0.3 % a.i. IBA) was used.

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Author: Annonciata Uwamariya

6.18. *Pterocarpus indicus* Willd

Family Leguminosae
Comon name Rosewood, nar

Distribution and habitat *Pterocarpus* includes about 20 species, 5 of which occur in the Indo-Pacific region and 11 in tropical Africa. *Pterocarpus indicus* has a wide distribution from southern Burma to the Philippines and throughout the Malay Archipelago to New Guinea including New Britain, New Ireland and Manus, the Solomon Islands and Vanuatu. In Papua New Guinea (PNG), the species occurs in inland forests and is common as a canopy tree in valleys below 100 m altitude, but is known to occur at altitudes up to 800 m. *P. indicus* is best-suited to moist sandy loam or clay-loam soil.

Uses Rosewood timber is one of the most valuable timbers in the region and highly preferred for cabinet and furniture making. The tree is also planted for its beautiful canopy and fragrant flowers. Boiled shredded bark is used as medicine for dysentery. The bark is also used to treat tuberculosis, headaches, sores and as a purgative.

Botanical description *Pterocarpus indicus* is a big tree, growing to 33 m in height and 1 m in diameter. The bole is usually poorly formed, gnarled and variously fluted. Buttresses are numerous. The crown is dense, domed, the leafy twigs drooping. Bark is cream and brown, finely streaked, finely scaly, fissured, with thin adherent rather fibrous scales. Leaves are pinnate, 2–3 pairs with a terminal leaflet; leaflets are large, 7 x 3.5 to 11 x 5.5 cm and alternate, ovate, rounded at base, rather suddenly tipped, thin. Flowers are in axillary racemes, long; showy, bright yellow, and very fragrant. The fruit of rosewood is a samara (indehiscent pod), about 5 cm across, corky-woody and flattened into a wing around the periphery. Internally the fruit is divided by cross walls into 4 or 5 seed chambers of which 1–2 (–3) may contain developed seed.

Flowering, fruiting and seed set Flowers appear May–October with fruit ripening from early December to March. Some pods fall or disperse while others remain on the tree up to the end of May. The seed has a leathery brittle coat. There are about 1300 seeds per kg.

Seed collection and processing The pods can be collected from trees or the ground from December to May. Since the fruit is indehiscent, it is normal to store the entire fruit following drying rather than to extract the seed.

Storage and viability Storage behaviour is orthodox with seed able to be dried down to 4% moisture content (mc). Initial mc of seed was found to be around 16–17% on a fresh weight basis. Percentage of viable seed is often as low as 10–20%.

Nursery techniques Seed begin to germinate 3–4 days after sowing. The pods or seed can be sown direct into containers or sown into trays and pricked out following germination. Germination rate is improved if seed is extracted from the pod before sowing. Seedlings take 4–6 months to reach a plantable size (20–25 cm).

Vegetative propagation Stem cuttings can be taken from trees of any age and size; but cuttings of diameter 6 mm or larger will root better than cuttings of small diameter. In the Philippines, cuttings 30 cm long from trees about 20 years old were planted in plastic bags and placed under shade. They developed shoots and roots, and grew (Zabala 1977). Grafting is also possible. Buds on scions were noticed to develop five days after grafting, at which time callus formation at the point of stock-scion union was also obvious (Zabala 1977).

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6.19. *Santalum macgregorii* F.v. Muell

Family Santalaceae
Comon name Sandalwood

Distribution and habitat The genus *Santalum* comprises about 16 species naturally occurring in India, Indonesia, Papua New Guinea (PNG), Australia, Hawaii and the South Pacific, including Vanuatu, Fiji, Tonga, Cook Islands and French Polynesia. *Santalum macgregorii* is endemic to PNG, occurring in Central, Gulf and Western Provinces. The altitudinal range is from near sea level to 750 m. Average rainfall is about 1000 mm per annum, mainly falling during a short wet season December–March. The species grows mainly in relatively dry savannah forests and grasslands in association with *Eucalyptus, Nauclea, Neonauclea, Pittosporum, Melaleuca, Pandanus,* cycads and various species of palms. It grows on various soil types from almost pure sand at sea level through clay loam to rocky outcrops.

Uses Sandalwood is extensively harvested and sold to buyers who export it for the fragrant heartwood. Oil is extracted from the heartwood for the manufacture of perfumes, scented soaps and joss sticks used in Asian temples. Large billets are also sought-after for furniture and carvings.

Botanical description Small to medium-sized tree mostly less that 8 m but may grow up to 20 m tall and 25 cm in diameter. The bole is usually crooked and short, with an open crown. Leaves are simple, entire, glabrous and light green, and arranged in opposite pairs. Flowers are small (4-4.5 mm long); yellow-green at the base to red with 4 lobes, 2–2.5 mm long x 1.5 mm across. The fruit is an ovoid drupe about 8–10 mm; immature fruit is green changing to red then purple to black when fully ripe.

Flowering, fruiting and seed set Flowering is sporadic and may occur at any time of the year. During peak flowering periods, it is possible to find all stages from flower buds through to mature fruit on the one tree. Fruit may be produced at any time of the year but is often very sparse and on only a few trees. The ripe fruit is attractive to soft-beaked birds, bats and rodents. Clean seed, free of juicy flesh and skin, under mature trees is a clear evidence of bat and bird activity. There are about 4000 seeds per kg.

Seed collection and processing The optimum collection time is still to be determined and may vary from year to year, or be sporadic throughout the year. Collections should be made from standing trees only and not from the ground, as fallen fruit may have already lost viability. Following collection the pulp should be removed as soon as possible. This can be done by chewing off the flesh, by hand or with the aid of a modified coffee grinder. If it is not convenient to remove the pulp immediately, wrap the fruit in a damp cloth or similar material to ensure the pulp remains moist, because if the pulp dries it will become very difficult to remove. To soften the pulp, fruit may need soaking in water for 2 days, with water being changed every 12–24 hours. Failure to remove the pulp can result in a more rapid loss of viability. The seed is then cleaned in water before being dried under shade.

Storage and viability The behaviour of sandalwood seed in storage is uncertain, but it may be orthodox. It is advisable to sow the seed immediately after processing. Storage life is unknown but anticipated to be about one year in a refrigerator (2–5°C).

Nursery techniques In order to enhance germination, the seed can be nicked on the side or the pointed end of the seed coat and soaked in a 2% solution of gibberellic acid overnight (12 hours).

Seed can be sown either directly into prepared medium or sown in a seedling tray. Sow the seed in a mixture of 2 parts sand : 1 part soil (preferably compost). Germination should begin 2-4 weeks

from the date of sowing and continue for up to 6 months, depending on pre-treatment and age of the seed. Seed germinated in trays must be transplanted when the seedlings have 2–4 leaves.

Sandalwood is a hemi-parasitic species and therefore requires special root associations with other plants in order to grow. Seedlings will therefore benefit from the addition of a pot host plant such as *Ruellia tuberosa* or *Alternanthera sessilis* when the seedlings are 4–6 weeks old.

Vegetative propagation Cuttings of *S. macgregorii* have been set by PNG Forest Research Institute (FRI) Lae, with up to 27% rooting (J. Beko, *pers. comm.* 2002). Soft shoot material including the tip, and the rooting hormone gel Clonex purple (3g/L a.i IBA), in a medium of 50% sand and 50% peat was used. An experiment carried out by the South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) in a cooler climate produced 7% rooting (Collins *et al.* 2000).

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Authors: Derek Bosimbi and Annonciata Uwamariya

6.20. *Schleinitzia novo-guineensis* (Warb.) Verdc

Family Leguminosae, subfamily Mimosoideae
Comon name Maringe

Distribution and habitat *Schleinitzia* is a genus of three species, found near coastal localities in the lowland humid tropics of the western Pacific basin (including New Guinea, Melanesia, Micronesia and Polynesia): *S. novo-guineensis* extends from the Moluccas in the west, through New Guinea and the Solomon Islands to northern islands of Vanuatu. Rainfall is high throughout the range, typically 2000–5000 mm per annum and distributed rather evenly throughout the year. Temperatures are high throughout the year, with little seasonal or diurnal variation. The mean annual temperature is 23–28°C, the maximum for the hottest month is 28–34°C and mean minimum for the coolest month 20–24°C. The absolute minimum temperature experienced is 15–21°C.

Uses *Schleinitzia novo-guineensis* is a nitrogen-fixing, multipurpose, small to medium-sized tree. The species has considerable potential for inclusion in agroforestry systems in lowland areas, both for improving soil fertility and producing wood (fuelwood and light construction wood) for community purposes. In the Solomon Islands the tree is widely used by local people for many purposes, including fuelwood, construction, handicrafts, food and traditional medicine, and is being evaluated in self-sustaining alley-cropping/agroforestry systems (Henderson and Hancock 1988). In New Ireland, *S. novo-guineensis* has been planted to provide shade for coffee and for fencing.

Botanical description Botanical descriptions are available in Nevling and Niezgoda (1978) and Henderson and Hancock (1988), and the following information is principally derived from these sources. *S. novo-guineensis* is a small to medium-sized, spreading tree, 4.5–20 (–25) m tall, with a trunk diameter up to about 30–40 cm at breast height. The bole is rather short (2.5–10 m) and straight, without buttresses. Branches are pubescent or glabrescent. Leaves bipinnate, typically with (10–) 14–22 (–30) pairs of pinnae, and each pinnae with 30–60 pairs of leaflets. Each leaflet is 2–6 mm long x 0.25–2 mm wide. Leaflet indumentum may be ciliate or pubescent. The leaf rachis or petiole bears one (rarely two) boat-shaped glands midway between the petiole base and the lower-most pinnae pair. There is also a cup-shaped gland between the pinnae of the upper five pairs, and additional glands may be scattered elsewhere on the rachis. Stipules are erect or recurved and 1–4.5 mm long. The inflorescences are globular heads, about 1 cm across, white, and consist of 80–120 tiny flowers. Individual flowers may be bi-sexual or male (staminate), with 5 petals and 10 filaments, and are subtended by a short peltate bract, 1.5 mm long. Fruit is a pod. There are typically 1–3 pods (maximum 5) per flower head. The pod(s) are borne on a thin peduncle. Pods are dark brown to black, with a narrowly winged edge, and covered with a conspicuous network of veins. Each pod is flat, oblong, 4–10 cm long x (1.2–) 1.4–2 (–2.5) cm wide and contains (8–) 14–20 blackish seed.

Schleinitzia species resemble and have sometimes been placed in the widespread genera *Leucaena, Piptadenia* and *Prosopis,* but differ in their pollen grains which are arranged in tetrahedral tetrads (Nevling and Niezgoda 1978).

The genus *Schleinitzia* was originally established by Warburg (1891), and has been re-established by Verdcourt (1977). *Schleinitzia novo-guineensis* is the type species for the genus.

Schleinitzia novo-guineensis is distinguished from *S. insularum* and *S. fosbergii* by its:

- Greater number of pinnae pairs on each bi-pin nate leaf (10–30 cf. 4–16 pairs),
- Leaflets which are smaller (2–6 mm long x

0.25–2 mm wide cf. 5.5–10 x 1–3 mm) and more numerous (30–60 cf. 20–35),
- Position of lower-most gland, which is located midway between lower-most pinnae pair and petiole base cf. at the junction of the lower-most pinnae pair,
- Boat-shaped lowermost foliar gland (cf. cup-shaped), and
- Thin fruiting peduncle (cf. stout).

Schleinitzia plants differ from *Leucaena* in their smaller flower balls, indehiscent (non-splitting) pods, anthers with glands and albuminous seed (cf. little albumen in *Leucaena*) (Nevling and Niezgoda 1978).

Flowering, fruiting and seed set In the Solomon Islands (Malaita Province) flowering has been recorded in January and fruiting in March (Lepping 2000).

Seed collection and processing Information is not available on seed collection and processing of maringe. However, given that it produces a pod much like *Acacia* and *Leucaena,* it should be fairly straight forward to collect and process. Prior to seed shed, pods should be collected off the tree and allowed to dry in the sun on a tarpaulin. The seed can then be extracted from the open pod by breaking and shaking. The seed is then sieved or winnowed to separate from pod material. Seed can be further processed using water flotation to separate heavy from light particles which include insect-attacked seed.

Storage and viability Storage behaviour is almost certainly orthodox. Seed can be stored either at room temperature for a short term, or in the refrigerator for longer periods.

Nursery techniques *S. novo-guineensis* is readily propagated following seed pre-treatment in which the seed is placed in a container and boiling water (not boiled) is poured over the seed until there is at least 10 x the volume of water to volume of seed. The seed is allowed to soak in the water until the water is cold, after which the seed is removed and sown.

Vegetative propagation Reference is made to the use of branch cuttings by Henderson and Hancock (1988).

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Author: Lex Thomson

6.21. *Serianthes hooglandii* (Fosberg) Kanis

Family Leguminosae
Comon name Unknown

Distribution and habitat The genus *Serianthes* comprises about 15 species distributed from the Malaya Peninsula through Malesia to the Pacific islands. According to botanical records in the Lae Herbarium, distribution of *S. hooglandii* in Papua New Guinea (PNG) is in the Momase Region, Central and Milne Bay Provinces. *S. hooglandii* is mainly found in open savannah from sea level to 100 (200) m altitude, but also sometimes occurs in closed forest. Soils are sometimes poorly drained.

Uses *S. hooglandii* can be used as a shade tree and as a multi-purpose nitrogen-fixing tree with potential for restoration of degraded sites.

Botanical description *S. hooglandii* is a tree up to 35 m tall with a 20 m clear bole and diameter up to 100 cm, and not buttressed. Bark is rather smooth to slightly rough with shallow vertical cracks, often blotched with brown and/or green patches. The bi-pinnate leaves are (10–) 15–30 (–40) cm long, and up to 50 cm long in juvenile plants. Flowers are paniculate, 3–5 cm long, rusty-tomentose. Calyx is cylindrical or slightly widened, 0.9–1 cm long, at length splitting around the base. Corolla is reddish or cream, the tube 1.6–1.8 cm long, the lobes 0.7–1.1 cm long, all woolly outside, stamens cream or brownish-grey, 5 cm long. Fruit is a dark brown pod, 16 cm long, 7 cm wide, with very woody walls 8 mm thick, and thickened margins. Seed is about 2 x 1 cm and rather flat.

Flowering, fruiting and seed set The flowering periods appears to be rather variable throughout its range. In north-eastern PNG, flowers are reported to occur October–March with fruit ripening July–September. In the south-eastern part of the country flowering occurs January–July with fruit ripening April–September (Kanis 1979). There are about 4200 seeds per kg.

Seed collection and processing When mature; the fruit turns brown to black in colour. Seed collection starts August–September. The pod, with its thick stalk, is retained on the tree until about January the following year at which time it sheds. The woody pods can be collected from the ground or by climbing. The seed is hard to extract because of the thick woody pods. A bush knife can be used to cut open the pod in order to release the seed.

Storage and viability Storage behaviour is orthodox. The seed can be stored at 25°C. Preliminary results indicate a storage life of >5 years.

Nursery techniques Seed starts to germinate 5 days after sowing.

Vegetative propagation There are no known vegetative propagation techniques for *S. hooglandii*.

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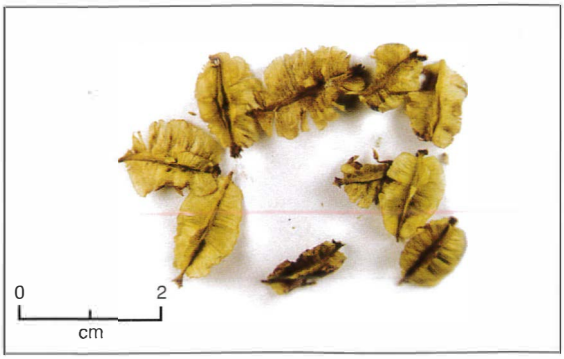
Taun (*Pometia pinnata*) occurs along the coastal areas of Madang, Morobe, New Britain, New Ireland and Bougainville Provinces. The timber is used for a wide range of structural uses and the fruit is edible. It has great potential as a community forestry species. (see description under Section 6.17).

6.22. *Terminalia brassii* Excell.

Family Combretaceae
Comon name Swamp terminalia, swamp talis, brown terminalia



Distribution and habitat *Terminalia* consists of about 200 species distributed throughout the tropics and subtropics. *Terminalia brassii* occurs in the Bismarck Archipelago, the Solomon Islands and in New Guinea. In Papua New Guinea (PNG) the species is found only in East New Britain, southern New Ireland and Bougainville in lowland forest up to altitudes of 250 m. The species occurs in fresh-water swamps where it can form large pure stands, or beside rivers as scattered trees. *T. brassii* may also be found in drier areas.

Uses Swamp terminalia is used mainly for light construction, plywood construction, moulding, joinery and veneer. A useful characteristic is its tolerance of water inundation where other timber species are unable to grow successfully.

Botanical description *T. brassii* is a large tree reaching 35–50 m tall with a diameter up to 150 (–250) cm. Huge flange buttresses, often with stilt roots, start to form in very young trees, eventually reaching up to 7 m high. The crown is broad, taking on a flat shape after 20–30 years. The bark is fawn coloured and fissured, with scales. Young branchlets are tomentose or nearly glabrous. Leaves are alternate to sub-opposite, narrowly oblong to elliptical, (7–) 10–15 (–18) cm x 3–6 cm, base rounded to subcordate, glabrous or hairy, with 20–35 pairs of secondary veins; petiole 5–12 mm long. Flowers are pale green, sessile in terminal and axillary panicles, 8–13 cm long. The species flowers throughout the year. The flowers are insect pollinated. The fruit of swamp terminalia is a samara, 9–14 x 5–11 mm, flat and papery with 2 well-developed papery wings supporting a single seed.

Flowering, fruiting and seed set Fruit set is sporadic throughout the year. Mature seed has been observed in April–May and July–September. The fruit turns from golden yellow to slightly brownish when mature. There are about 70 000 seeds per kg.

Seed collection and processing Mature fruit is readily shed from the tree, so it is important to ensure that collections are made as soon as the fruit matures but before shedding. Care should be taken to collect mature seed about 1 cm long, as smaller seed is often not viable. Prior to collection, cut open a number of fruit to determine the maturity of the seed. If the fruit has already started to be shed, it is best to collect in the early morning or when there is no wind so that the winged fruit will tend to fall straight down to the ground rather than be blown away. Following collection, twigs and other non-fruit materials are removed. The fruit is then spread out to dry under shade in order to reduce the moisture content. Swamp terminalia seed is stored as a fruit as it is impractical to extract the seed from the fruit.

Storage and viability Storage behaviour is orthodox. The seed is reported to be able to be dried down to 5% mc. For long-term storage, seed should be dried down to about 5% mc and stored at sub-zero temperatures (Sosef *et al.* 1995; Tompsett 1986).

Nursery techniques Seed is broadcast-sown thickly on a sandy seed bed and is covered with decomposed sawdust or loose sandy soil (Fenton *et al.* 1977). *T. brassii* seed start to germinate about a week after sowing and continue for about 3 weeks. Seedlings are pricked out into pots before the cotyledons are fully expanded and while the seed coat is still in place, or after the first true leaf has developed.

Vegetative propagation No specific vegetative propagation tests were conducted by the PNG Forest Research Institute (FRI) on *T. brassii*. Initial testing of the related *Terminalia, T. kaernbachii,* showed some potential with low rooting per cent (<10%) (J. Beko, *pers. comm.* 2002). Research on

T. richii by the South Pacific Regional Initiative on Forest Genetic Resourced (SPRIG) gave good results, with up to 78% of cuttings (soft tip and woody material) producing roots using 0.8% IBA (Alatimu 1998; Collins *et al.* 2000), indicating that this species has potential for vegetative propagation.

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Authors: Alex Agiwa and Annonciata Uwamariya

6.23. *Terminalia catappa* Linn.

Family Combretaceae
Comon name Sea almond

Distribution and habitat *Terminalia* is found throughout the tropics and subtropics. There are about 200 species. *Terminalia catappa* extends from the Seychelles, through India, the Andamans and adjacent islands, throughout South East Asia (Myanmar, Thailand, the Malay Peninsula, Vietnam, the Philippines, Indonesia) to Papua New Guinea (PNG) and northern Australia. The species is also found in the Pacific including the Solomon Islands, Vanuatu, and Fiji; and is present on nearly all the high archipelagos of Polynesia and Micronesia. Rainfall is generally 1000–3500 mm per annum. In PNG, the species is widespread in most coastal regions of the mainland and islands. It occurs along sandy or rocky beaches or on tidal river banks, often with *Barringtonia asiatica* and *Calophyllum inophyllum*. It is occasionally found at altitudes up to 400 m.

Uses The timber is used for furniture, house and boat-building, and cabinet making. Cultivated trees provide shade. The kernel of the fruit is occasionally eaten by children, and large-fruited varieties are a valued food source in parts of PNG, the Solomon Islands and Vanuatu. Fatty oil, similar to that of almond oil, is produced from the kernel. In traditional medicinal practice, crushed flowers are mixed with water and the mixture is drunk to induce sterility.

Botanical description *T. catappa* is a tree 25–40 m in height with a diameter up to about 1 m. The bole is more or less cylindrical, sometimes crooked and/or leaning. The crown is tiered with stiff horizontal branches, especially conspicuous in young trees. Buttresses are big, equal, and sometimes branching. The bark surface is shallowly fissured and slightly flaky, grey to dark grey-brown. The inner bark is firmly fibrous, homogeneous and pinkish-brown. Leaves are short, broadly obovate; 8–25 (–38) cm x 5–14 (–19) cm and arranged in close spirals. The flowers are small (4–6 mm across), white or creamish, arranged on long (8–25 cm) axillary spikes with a somewhat unpleasant smell. The flowers are pollinated by insects. The fruit, a drupe, is sessile, laterally compressed, ovoid to ovate, and smooth-skinned. Fruit size varies considerably: 3.5–7 cm x 2–5.5 cm, with Walter and Sam (1993) reporting an exceptional range in length of 2.5–10 cm.

Flowering, fruiting and seed set The flowering/fruiting period is poorly defined, with records showing flowering November–March and fruit development December–February. They are about 500–2000 seeds/kg.

Seed collection and processing The seed is collected by climbing the tree, or sometimes from the ground. The fruit is heaped together under shade or packed in a container and allowed to rot until the pulp has softened sufficiently to be removed by hand or with the aid of a sharp instrument.

Storage and viability Storage behaviour is most probably orthodox, with seed reported to remain viable for several months. However, seed is normally sown fresh within a few weeks of collection. Longer-term storage will result in greatly reduced viability.

Nursery techniques *T. catappa* seed commences germination 3–8 days after sowing. Fruit may be sown without pre–treatment. Adequate covering of seed or fruit in the seed bed is very important to increase the germination percentage. Pricking out should be undertaken sufficiently early to avoid disturbing the rapidly developing taproot. Young seedlings are potted into containers, and seedlings can be transported into the field at the age of 3 months.

Vegetative propagation No specific vegetative propagation trials were conducted by the PNG Forest Research Institute on *T. catappa*, but initial

testing of *T. kaernbachii* showed some potential (<10% root strike) (J. Beko, *pers. comm.* 2002). Research on *T. richii* by the South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) gave good results, with up to 78% of soft tip and woody material producing roots using 0.8% IBA (Alatimu 1998; Collins *et al.* 2000), indicating that this species has potential for vegetative propagation.

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Author: Annonciata Uwamariya

6.24. *Terminalia complanata* K.Schum

Family Combretaceae
Comon name Talis, pale yellow terminalia

Distribution and habitat *Terminalia* is found throughout the tropics and subtropics. There are about 200 species. *Terminalia complanata* is distributed in New Guinea, the Bismarck Archipelago, Solomon Islands as well as in the Moluccas and northern Queensland (Australia). In western Papua New Guinea (PNG) the species is known from the Vogelkop, Geelvink Bay and Jayapura districts, in north-eastern PNG from the East Sepik and Madang districts and from the Morobe district where it seems particularly common. It is also found in the Southern Highlands, Western and Milne Bay Provinces. Found in lowland forest, often in swampy areas and also at higher altitudes to 1500 m asl.

Uses Talis is used for light framing, veneer, plywood, interior trim, moulding, wall panelling, joinery, cabinet-work, cladding, shelving flooring and furniture. The wood is said to be tough and fibrous and to contain a yellow dye. The wood is among the more useful of the *Terminalia* species. The species is also very useful because of its ability to grow in swampland.

Botanical description *T. complanata* is a large tree up to 50 m in height and 100 cm diameter, with a straight buttressed bole. The crown becomes large; spreading and umbrella-shaped, with dense foliage. Bark is grey to brown, smooth to finely fissured. The inner bark is firmly fibrous, red-brown or fawn coloured, and yellow near the cambium. Leaves are sparsely hairy or ±glabrous, with yellow, greyish or brownish hairs at first, with generally fewer nerves scattered along slender twigs; petioles 7–15 mm long. Flowers are in axillary spikes, 7–14 cm long, hairy outside; calyx lobes less hairy or glabrous. The flowers are pollinated by insects. The fruit is a pink, red or purple, fleshy indehiscent drupe, with juicy flesh and a hard stone, somewhat flattened, irregularly triangular in cross section when fully ripe. Fruit is 1.4–2.1 cm long x 1.1–1.9 cm wide.

Flowering, fruiting and seed set Flowering time varies within PNG and between years. At lower altitudes (Markham Bridge, Lae, Morobe Province) flowering tends to occur around December–January and at higher altitudes (Bulolo, Morobe Province) in February–March. Flowering occurs from September–October at Gogol (Madang Province). Fruit shed is reported to occur from March to late April in lowlands and June–August in highlands. Further phenological studies are required to more accurately determine flowering and fruiting times. Grubs are frequently found within the fruit. There are about 1100 seeds/kg.

Seed collection and processing *T. complanata* fruit turns reddish in colour when mature. Special care must be taken in handling the fruit from the collection site to the seed store. Transport fruit in calico bags with free air circulation and avoid exposure to direct sunlight. Seed processing entails the removal of impurities, leaving the fruit intact as the unit for storage.

Storage and viability The behaviour of talis seed in storage is unknown, but in view of the behaviour of seed of other *Terminalia* species it is likely to be orthodox (Hong *et al.* 1998). The PNG National Tree Seed Centre reported that when storing the fruit in the cool room it developed mould, implying that there was considerable moisture in the fruit. Research is needed to determine whether it would be preferable to store the seed rather than fruit.

Nursery techniques Seed is sown with the fleshy outer layer intact. Germination occurs within about 50 days of sowing.

Vegetative propagation No specific vegetative propagation tests were conducted by the Forest Research Institute (FRI) on *T. complanata*, but

initial testing of *T. kaernbachii* showed some potential, with low rooting (<10%) (J. Beko, *pers. comm.* 2002). Research on *T. richii* by the South Pacific Regional Initiative on Forest Genetic Resourced (SPRIG) gave good results, with up to 78% of soft tip and woody material producing roots using 0.8% IBA (Alatimu 1998; Collins *et al.* 2000); indicating that this species has potential for vegetative propagation.

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Authors: Alex Agiwa and Annonciata Uwamariya

6.25. *Terminalia kaernbachii* Warb

Family Combretaceae
Comon name Okari nut, talis, red brown terminalia

Distribution and habitat *Terminalia* is found throughout the tropics and subtropics. There are about 200 species. *Terminalia kaernbachii* is native to rainforest in Aru and Papuasia from sea level to 1000 m altitude. In Papua New Guinea (PNG) it is very common from the West Papua border in the west to Mt Dayman in the east, at altitudes of up to 1000 m. It also occurs in a few inland locations on the northern side of the main ranges and in West New Britain between the Aria River and Cape Gloucester. *T. kaernbachii* is known from the Morobe district (south of the Markham Valley), and from the Western, Gulf, Central and Northern districts. Locally, okari nut occurs in lowland forests associated with flat or gently sloping terrain in rainforest or in ravines. It is commonly planted close to villages for the purpose of producing the edible nut which is highly prized. The species appears to tolerate poor drainage and grows at locations with annual rainfall of 2000–7000 mm.

Uses The main value of the tree is the highly palatable kernels. Wood is used for furniture. The trees are generally not harvested for timber because of their value as nut trees.

Botanical description *T. kaernbachii* is a buttressed tree, 35 (–45) m tall, with a large, spreading crown. The outer bark is grey or grey-brown, with the inner bark purple or mauve, then brown against the cambium. Twigs are hairy when young. Leaves are obovate-elliptical to narrowly obovate-elliptical, 12–35 cm x 5–13 cm. Flowers are in erect spikes, typically with buds globular, usually densely hairy, 8–10 mm long overall, with calyx lobes triangular, 2 mm, densely hairy, 10 mm across calyx cup and with a style 20 mm long. The flowers are pollinated by insects. The fruit is a samara, ellipsoid in shape, slightly flattened 9–11 x 6–8 x 5–6 cm, coated with short reddish-brown hairs when young, becoming fleshy, ±glabrous, not winged, and red when ripe. Fruit contains a massive woody stone, splitting on germination into 2 ±equal halves with the edible seed (okari nut).

Flowering, fruiting and seed set Okari nut trees appear to flower fairly regularly every year between December and March. In Madang, however, it is recorded as flowering in September. Fruit matures April–November. Seed is reported to be collected June–August in Lae, Oomsis and Bulolo areas. It would be useful to compare these times with availability of okari nuts in markets.

Seed collection and processing The fruit is collected from beneath the tree, or picked from the trees when ripe. The fruit turns red in colour when mature, at which time it is shed. The fruit is the stored unit and therefore does not require processing.

Storage and viability Storage behaviour is unknown, but is likely to be recalcitrant. Moisture content is 55% (based on seed bought from food markets). *T. kaernbachii* is stored as fruit.

Nursery techniques The nut is either directly sown into polybags or in prepared nursery beds. Seed germinates 15–60 days after sowing. Germination is 5–25% after 4 months, with sporadic germination expected beyond that period. After the seedling has completed shedding the outer nut, the seedlings from beds are potted into polybags. They are of plantable size when they have 3 or 4 pairs of leaves.

Vegetative propagation In trials conducted at PNG Forest Research Institute (FRI), material 10 cm in length dipped in a rooting hormone gel (Clonex© purple 0.3 % a.i IBA) gave about 10% strike (the fraction of cuttings to produce roots). This result should be bettered using a more species-specific technique.

Research on *Terminalia richii* by the South

Pacific Regional Initiative on Forest Genetic Resources (SPRIG) gave good results, with 78% of soft tip and woody material producing roots using 0.8% IBA (Alatimu 1998; Collins *et al.* 2000), indicating that this species has potential for vegetative propagation.

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6.26. *Toona ciliata* M. Roem. and *Toona sureni* (Blume) Merr

Family Meliaceae
Comon name New Guinea red cedar

Distribution and habitat *Toona* occurs naturally in Australia, Papua New Guinea (PNG), South East Asia, southern China, the Philippines, the Indian subcontinent and Indonesia. In PNG, *T. ciliata* occurs in Morobe province, New Britain and Manus. *T. sureni* has been recorded from Bulolo, Wau and the Markham Valley in Morobe Province, Koitabu and south of Manumu Village in the Central Province and Mt Suckling, sharing the border of Northern, Central and Milne Bay Provinces (National Herbarium specimens). It has also been found in Manus Province. Red cedar occurs in both primary and secondary rainforests where annual rainfall is 1200–2500 mm, with high humidity and a dry season of 3–4 months. The species thrives at the bottom of slopes, on well-drained fertile slightly alkaline soils. It grows poorly in compact clays and infertile sands. Both species show their best development in moist, tropical rainforest on fertile alluvial or volcanic soils.

Uses Red cedar has potential for inclusion in agroforestry systems. The timber is highly sought after for use in house and boat construction, for high grade furniture and carvings, and to make railway carriages, tea chests, oil casks, pencils and musical instruments. The flowers yield a red or yellow dye which is used to colour silk. Various parts of the plant, but especially the bark, are used medicinally, e.g. as an astringent and in the treatment of chronic infantile dysentery and ulcers. Other non-wood products include green animal fodder and food for honey bees (it is a major source of nectar and possibly pollen). The leaves and the bark are used as medicine. Some extracts from the bark and the leaves have insect-repellent properties.

Botanical description *T. ciliata* and *T. sureni* are tall trees (40 m high) with stem diameters (above buttresses) up to 2–3 m. Tree boles are often irregular in cross section, and older trees are often buttressed at the base with buttresses extending well up the trunk. The inner bark is mottled green and pink, darkening on exposure. The outer bark is smooth, dark brown, with square scales shedding in irregular patches. In *T. ciliata,* the flowers are white to creamy-white, calyx 5–lobed, each lobe about 0.1–0.2 cm long. Edges are fringed 0.2 cm long. *T. ciliata* is monoecious with male and female flowers in the same inflorescence. In *T. sureni*, the inflorescences are large, terminal, occasionally axillary, pendulous panicles up to 40 cm long; pyramidal, many flowered and fragrant. Rachis and young bracts are sparsely covered with short white hairs. Flowers are pollinated by insects. Fruit is a dry, thin walled oblong capsule; dehiscent, opening from the top. Fruit is 2–3 x 0.8–1.2 cm, 5-valved. The seed is 1–2 x 0.3–0.5 cm, about 5 per loculus, light brown, winged at both ends.

Flowering, fruiting and seed set Red cedar flowers from July through to late August with fruit set early September–November. Occasionally fruit set has occurred in January. There are about 280 000–425 000 seeds of *T. ciliata* per kg (Phongoudome, unpublished) and 200 000–300 000 seeds of *T. sureni* per kg.

Seed collection and processing Red cedar fruit (a capsule) is normally ready for collection when it turns from green to a golden colour, but it must be gathered prior to seed shed. Mature green fruit can be collected without any detriment to seed viability. The cedar tip month (*Hypsipyla robusta*), which can cause serious damage to seed crops, appears to be less active while the fruit is still green than at full maturity. Timing of seed collection is often critical, as the fruit may open and shed its seed shortly after maturing, especially under hot windy conditions. In PNG the optimum time for seed collection is late November–early December, but early seed collections, from June to July, are recorded in the PNG National Tree Seed Centre seed collection register. Fruit must be collected off the tree by climbing with the aid of iron spurs, or a bamboo hook. Fruit that has been removed from the branches is placed on calico sheets or loosely packed in cotton bags. Avoid letting the fruit sweat or go mouldy by minimising the amount of time it is kept in a closed container, and store it in a cool place out of direct sunlight. Once collected, the fruit should be spread out, preferably under shade, to dry. Once the fruit has opened the seed can be cleaned through a combination of sieving,

winnowing and hand picking.

Storage and viability Storage behaviour is orthodox. *T. sureni* seed has a moisture content of 5–10%. The correct storage regime can have a big effect on the longevity of seed of red cedar. Floyd (1989) found that viability of seed stored at –4°C for 5 years was 97%, and even after 12.5 years viability was 38%. After 12 months, 93% seed viability was recorded when seed was placed in a polythene bag and stored at 0°C (Gurdev-Chand *et al.* 1996). In Australia, seed stored at 3–5°C for 5 years maintained 97% viability, and after 12.5 years viability was up to 38% (Boland 1998).

Nursery techniques Seed can be sown directly into nursery beds or pots. Germination takes 7–28 days. Pricking out may be done once the seedlings have reached their 2–3 leaf stage. After 3–4 months in the nursery the seedlings are ready for transplanting into the field.

Vegetative propagation Cuttings can be used for *T. ciliata* propagation. Cuttings from 2-year-old seedlings have given better results (53% rooting) than cuttings from mature trees. A success rate of 60% was obtained using stem cuttings, from 2–4-year-old plants of *T. sureni*, treated with indole-3-butyric acid (IBA) and placed in a sawdust medium (Gintings *et al.* 1995). The South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) has studied the vegetative propagation of *T. ciliata* seedlings and found these easy to propagate, with around 90% rooting in all experiments (Collins and Walker 1999; Collins *et al.* 2000). Best results were achieved using a sand or sand:peat medium; if peat is unavailable alternatives are composted coconut husks or sawdust (Walker 1998).

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6.27. *Vitex coffasus* Reinw

Family Verbenaceae
Comon name Vitex, bitum, garamut (pidgin)

Distribution and habitat *Vitex* is a genus of about 250 species with a pantropic distribution. *Vitex cofassus* is found in Sulawesi, Borneo (K. Aken, *pers. comm.* 2003) the Moluccas, Solomon Islands and Papua New Guinea (PNG). In PNG, vitex is found in most if not all provinces. The species is common, locally co-dominant in most well-drained lowland rainforests and valleys from sea level up to 1000 m asl. *V. cofassus* is frequently associated with *Pometia pinnata, Araucaria, Elmerrillia* and *Spondias* species.

Uses Vitex timber is used for general heavy construction, boat building, bridge and wharf decking, wood turning, joinery, flooring, cabinet making, window sills and stair treads. Traditional uses of vitex include house posts, carvings including paddles (Solomon Islands), and garamut and kundu drums. A very valuable timber, vitex is exported in moderately large quantities from PNG and the Solomon Islands. Trees have a poor bole form when planted in the open: for timber production they need to be established in gaps or through enrichment plantings in existing forest.

Botanical description *V. cofassus* is a medium-sized to large tree up to 36 m tall and reaching 1.3 m in diameter, often with a short, crooked and deeply fluted bole and a large irregular crown with sparse foliage. Outer bark light grey-brown, fissured, peeling off in long strips. Leaves, opposite simple, elliptical to lanceolate, 22 x 6 cm, tip acuminate, base rounded, margin entire; venation unicostate reticulate, prominent on the underside; coriaceous, medium to dark green, glabrous on both sides (Havel 1975). Flowers are in axillary and terminal panicles made up of cymes, small, 1 cm diameter with purple corolla. Fruit is a small, globular (less than 1.0 cm) drupe with a 4-cell stone: each stone contains 1--4 seed.

Flowering, fruiting and seed set Vitex flowering occurs sporadically from location to location and from province to province, and continues throughout the year. Observations in Lae recorded flowering in January–February, fruit development March–April and seed maturity in April. A period of 3–4 months elapses from flowering to seed set. One cycle may start in January and finish in June, followed by a non-reproductive period before the commencement of another cycle. Trees at low altitudes appear to flower earlier in the year than those at higher altitudes. Fruit turns blue-black when ripe. There are about 10 500 seeds/kg. There are no known predators, but the ripe drupes may be attractive to small soft-beaked birds.

Seed collection and processing Seed is usually cleaned on the day of collection or the following day. If the fruit is stored prior to de-pulping, it must be held in a cool, moist location. The fleshy pulp is best removed by placing the fruit in a container of water and removing the pulp by hand. The de-pulped seed is then cleaned by washing in running water, allowed to surface dry in a shady spot prior to storage or sowing.

Storage and viability Vitex seed appears to be orthodox in behaviour (Hong *et al.* 1998). Stored seed of vitex tends to have strong dormancy, although fresh seed germinates more easily. Moist storage under refrigeration (3–5°C) is considered best (1 year).

Nursery techniques Seed is sown 1 cm apart in rows 15 cm apart, or broadcast and covered with 1 cm of soil. Mulching of the seed bed is recommended to reduce evaporation during the dry season. Alternatively, seed can be sown directly into containers. Seed germinates 10–40 days after sowing; if fresh seed is used up to 100% germination can be achieved, but stored seed may give only 20% less.

Vegetative propagation The Solomon Islands have successfully propagated *V. cofassus* using both adult and juvenile tip cuttings (Basil Gua, *pers. comm.* 2003).

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Appendix I. Phenological Data for PNG Forest Species

Species	Location[1]	Altitude (m)	Flowering[2]	Fruiting[2]	Seed fall[2]
Adenanthera pavonina	Gogol		Jan, Sep, Oct (Jan)	Nov–Mar* (Nov, Mar)	
Agathis alba			Aug	Sep–Oct	Nov–Dec
Alangium javanicum	Gogol	200	Mar–Jul	Jun–Sep (Mar–May)	May
Alangium javanicum	Oomsis	100	Jun	Jul	Aug
Alangium javanicum	Talasia, WNB	100	Jul	Aug	Sep
Aleurites moluccana	Bulolo (N)	700–1000	(Jan–Apr), (Aug–Nov)	(May–Jul), Nov–Dec	(Jul–Aug), Feb–Apr
Aleurites moluccana	Highlands		Sep–Jan	Jun (Oct–Dec)	
Aleurites moluccana	Keto/Aseki (N)	1850	Jan–Mar, Aug–Nov	Mar–May	Jun–Aug
Aleurites moluccana	Oomsis (N)	134	(Dec–Feb) Jul–Sep	Mar–May	Jun–Jul
Alseodaphne archboldiana	Gogol		Jul–Sep	Oct–Nov	
Alstonia scholaris			Jan–Feb	Feb–Mar (Oct–Dec)	Mar–Apr
Alstonia scholaris	Gogol		Sep* (Sep)	Oct* (Oct)	
Amoora cuculata	Gogol		Nov–Jan	Jan–Mar	
Anisoptera polyandra			Oct	Nov	Dec–Feb
Anisoptera thurifera			(Nov–Feb)	(Mar–May)	May–Jun
Anthocephalus chinensis	Bulolo (N)	700–1000	(Nov–Dec) Feb–Mar	(Jan–Apr)	May–Aug
Anthocephalus chinensis	Oomsis (N)	134	Sep–Nov	Oct–Dec	Feb–Apr
Anthocephalus chinensis	Gogol		Sep–Dec (Nov)	Jan–Dec* (Jan–Mar)	
Antiaris toxicaria			Sep–Oct	Nov–Jan	Jan–Feb
Aphanamixis macrocalyx	Gogol		Nov–Jan	Feb–Apr	
Aphananthe philipinensis	Gogol		Nov	Dec–Mar	
Araucaria cunninghamii	Bulolo (N)	700–1000	(Mar–Apr)	(May–Aug)	(Oct–Dec)
Araucaria cunninghamii	Wau (N)	1075	(Jan–Feb)	(Mar–Jul)	(Oct–Dec)
Araucaria hunsteinii	Bulolo (N)	700–1000	(Jan–Feb)	(Mar–Jul)	(Aug–Oct)
Araucaria hunsteinii	Wau (N)	1075	(Feb–Mar)	(Mar–Jul)	(Aug–Oct)
Artocarpus altilis	Gogol		Jan–Nov* (Apr–Jun)	Mar–Dec* (Aug, Oct–Dec)	
Artocarpus altilis	Bulolo (P)	700–1000	Oct–Nov Mar–Apr	Dec–Jan Jun–Sep	Feb–Mar Oct–Nov
Artocarpus altilis	Kaiapit (P)		Jan–Mar, Nov	Feb–Apr	May–Jul
Artocarpus altilis	Nadzab(P)	83		Apr–Jun	Jun–Aug
Artocarpus altilis	Oomsis (P)	134	Mar–Jun	Apr–Jul	(Jul–Sep)
Artocarpus sepicana	Gogol		Aug*	Nov–Oct* (Nov)	
Artocarpus vrieseanus	Gogol		Mar–Apr, Oct	Jun–Nov* (Sep)	
Bombax ceiba	Gogol		Jun–Jul	Jan–Sep*	
Bridelia macrocarpa	Gogol		Feb–Nov* (Sep)	Mar–Jan* (Nov, Dec)	
Burckella obovata	Gogol		Dec–Jan	Feb	
Buchanania arborescens	PNG (H 22)	10–1000	(Feb)–(Aug–Sep)–Nov	(Mar)–(Oct)–Dec	(Apr)–(Nov)
Buchanania heterophylla	Gogol		Apr–Oct (Aug)	Jul* (Jul, Sep)	
Buchanania macrocarpa	PNG (H 10)	10–800	Jan–Nov (Jul–Aug)	Mar–Dec (Sep–Oct)	Nov–Aug (Nov)
Calophyllum euryphyllum	Ma, N, NB		(Aug–Sep)	(Jan–Mar)	(Jan–Mar)
Calophyllum inophyllum			Nov–Dec	Jan	Jan–Mar
Cananga odorata	Gogol		Jul* (Oct)	Sep–Jul* (Dec–Jan)	
Cananga odorata	PNG (H 18)	0–500)	Dec–Aug	Jan–Sep (Jan–Feb)	Mar–Nov (Mar, Jul–Aug)
Canarium indicum			Dec–Jan (Jun–Aug)	(Jan–Mar) Aug–Sep	Apr, Oct–Nov
Canarium indicum	Gogol		Jul–Dec* (Nov)	Jan–Dec* (Jan, Feb)	Feb–May

Species	Location[1]	Altitude (m)	Flowering[2]	Fruiting[2]	Seed fall[2]
Canarium vitiensis	Gogol		May–Dec* (Oct)	May* (May, Sep, Oct)	
Carallia brachiata	Gogol		Nov, Dec, Apr, Aug	Jun* (Sep)	
Castanopsis acuminatissima	M, H		Apr, Aug		
Castanospermum australe			Nov–Dec	Jan	Feb–Mar
Castanospermum australe	M		Sep	(Dec), Mar	
Casuarina grandis			Aug, Dec	Jan, May, Sep	Feb–Mar, Oct–Nov
Casuarina oligodon	M, H			Apr, Aug, (Oct–Nov)	Feb–Mar (Oct–Nov)
Celtis latifolia	Gogol		Apr, May, Nov, Dec* (May)	May* (Jun)	
Celtis luzonica	M		Oct		
Celtis nymanii	Gogol		Oct	Nov–Dec (Nov)	
Celtis philipinensis	Gogol		Apr–Aug* (May)	May–Oct* (Jun)	
Cerbera floribunda			Jan	Feb–Mar	Apr–May
Cerbera floribunda	Gogol		Jan–Dec* (Jan)	Mar* (Mar–Apr)	
Chesocheton cumingianus	Lae	50	Nov–Dec	Jan–May	May
Cryptocarya aff. *massoy*	Lae	50	Feb–Mar	Apr–Jun	
Delonix regia			Jul–Sep		
Dillenia indicum					Apr–May
Diospyros lolin	Gogol		Jan–Dec* (Oct)	Mar/# (Feb)	
Diospyros papuana	Gogol		Aug* (Sep)	Oct*	
Diospyros pilosanthera	Gogol		Jun, Aug	Jul–Nov	
Dracontomelom dao	Bulolo (N)	700–1000	Sep–Oct	Jan–Feb	Apr–Jun
Dracontomelom dao	Nadzab(N)	76	Oct–Dec	Feb–Mar	May–Jul
Dracontomelom dao	Lae	50	Feb–Mar	Apr–Jun	
Dracontomelom dao	Oomsis (N)	134	Mar–Apr Aug–Oct	Nov–Jan	(Feb–Apr)
Dracontomelom dao	Gogol		Sep* (Nov, Dec)	Jul* (Jul)	
Drypetes lasiogynoides	Gogol		Nov* (Nov, May)	Jun–Jul (Jun)	
Dysoxylum arnoldianum	Gogol		Sep–Oct	Oct–Jan (Nov)	
Elaeocarpus amplifolius	Gogol		Feb* (Feb)	Apr* (Mar, Apr)	
Elaeocarpus multisectus	Gogol		Mar–Dec* (Mar)	May* (Jun)	
Elaeocarpus sphericus	Aseki (N)	1850	Jan–Mar	Apr–May	(Jun–Aug)
Elaeocarpus sphericus	Bulolo (N)	700–1000	(Feb–Mar)	Mar–Apr, (Jul–Sep)	(Jul–Sep)
Eleuthurostylus reinstipulata	Gogol		Sep, Nov	Dec and Sep	
Elmerrillia papuana	Aseki (N)	1850	Jun–Aug	Aug–Oct	Apr–May, Oct–Nov
Elmerrillia papuana	Bulolo (N)	700–1000	Sep (Nov–Jan)	(Feb–Apr)	(Apr–Jun)
Elmerrillia papuana	Oomsis (N)	134	Jul–Aug	Sep–Nov	Apr–Jun
Endiandra latifolia	Gogol		Jan–Mar	Apr–Jun	
Endospermum medullosum	Lae (N)	76	Dec–Feb &Mar–Apr	Feb–May	Jan, May–Jun, Oct
Endospermum medullosum	Bulolo (N)	700–1000			
Endospermum medullosum	Oomsis (N)	134	Feb–Mar, Jul–Sep	Mar(Sep–Oct)	Jan, May(Jun)
Endospermum medullosum	Gogol		May–Oct*	Jul*	
Endospermum microphyllum	M		Sep		
Eriandra fragrans	Gogol		Feb, May	Jun, Jul and Feb	
Erythrospermum candidum	Gogol		May		
Eucalyptus deglupta				Jan–Dec	All year
Euodia elleryana	Gogol		Mar* (Mar)	May* (Jul)	
Euodia elleryana	M, O		Jan, Mar		
Ficus melinocarpa	Gogol		Sep–Nov (Sep)	Oct–May*	

Species	Location[1]	Altitude (m)	Flowering[2]	Fruiting[2]	Seed fall[2]
Ficus polyantha	Gogol			Oct–Nov	
Ficus variegata	Gogol			Sep/# (Nov)	
Flindersia pimentaliana			(Jan–Mar)	Apr–Jun, Oct	Jul–Sep
Ganophyllum falcatum	Gogol		Oct		
Garcinia dulcis	Gogol		Mar, Aug, Sep	Jul–Oct	
Garcinia hunsteinii	Gogol		Oct, Nov	Dec–Feb	
Garuga floribunda	Gogol		Jan, Jul, Aug	Jan, Jul–Aug (Jul)	
Garuga floribunda	M		Aug	Oct	
Gastonia spectabilis	Gogol		May–Oct (Aug)	Jul–Jan (Nov)	
Geigera salicifolia	M		Mar, Sep	Mar	
Gigasiphon schlecteri	Gogol			Jun–Aug	
Gmelina moluccana	Gogol		Aug* (Nov)	Oct* (Dec)	
Gnetum gnemon	M			Dec–Jan	(Jan–Mar)
Gymnacranthera paniculata	Gogol		May–Nov* (May)	Jun–Dec (Jul)	
Gymnostoma papuana	H			Dec	
Gyrinops ledermannii	S		Feb–Mar, Sep	Dec, Feb–Apr	
Haplolobus floribundus	Gogol		May* (Sep)	Jun*	
Haplolobus floribundus	Lae	50	Nov–Dec	Jan–Jun	May–Jun
Hernandia ovigera	Gogol		Feb* (May)	Mar* (Jun, Aug, Sep)	
Hibiscus ellipticifolius	Gogol		May* (Jul)	Jun–Sep (Aug)	
Homalium foetidum	Gogol		Jan–Dec* (Oct)	Jun–Mar* (Dec)	
Homalium foetidum	M		Sep		
Hopea iriana	Gogol		Jun, Nov	Jun, Nov	
Horsfieldia helwegii	Gogol		Jun*	Aug*	
Horsfieldia spicata	Gogol		Dec, Jul, Aug	Jul–Feb*	
Intsia bijuga	Gogol		Jan–Nov (Aug)	Jan–Dec (Feb)	
Intsia bijuga	M		Dec	Oct–Jan, Jul	
Intsia palembanica	Gogol		Jul* (Feb)	Jan–Dec* (Apr)	
Kingiodendron novoguineense	Gogol		May–Sep* (May)	Jun–Aug (Jun)	
Lagerstroemia piriformis	Gogol		Aug, Nov	Sep–Oct	
Lithocarpus celebiscus	Aseki (N)	1850	(Jan–Mar)	(Apr–May)	(May–Jun)
Lithocarpus celebiscus	Bulolo (N)	700–1000	(Jan–Mar) (Jul–Sep)	(Apr–May) (Oct–Nov)	(May–Jun)
Lithocarpus celebiscus	Wau (N)	1,075	Jan–Mar, Jul–Sep	Apr–May	May–Jun
Lithocarpus schlecteri	Aseki		Apr–Sep		
Lithocarpus schlecteri	Bulolo		Nov–Jan	Nov	
Lithocarpus schlecteri	Highlands		Apr		
Lithocarpus vinkii	M			Dec	
Litsea timoriana	Gogol		May* (Sep, Oct)	Jul–Jan* (Jul, Nov)	
Mangifera minor	Gogol		Jun, Jul	May–Nov* (Aug, Oct, Nov)	
Mangifera minor	PNG (H–13)	10–1100	Jul–Sep (Sep)	(Jul–Oct)	(Oct–Nov)
Maranthes corymbosa	Gogol		May–Aug	Jun–Oct (Jul, Aug)	
Mastixiodendron pachyclados	Gogol		Jan–Mar (Feb)	Feb–Jun (Apr)	
Microcos ramiflora	Gogol		May–Nov (Oct)	May* (Jan, Feb)	
Myristica fatua	Gogol		Feb–Dec*	Jun–Apr* (Jul, Oct, Mar)	
Myristica fatua var. *papuana*	Lae	50	Dec–Jan	Feb–May	May
Myristica hooglandii	Gogol		Apr* (Mar, Apr)	Apr–Aug (May)	
Myristica sp.	Gogol		May–Nov* (Jun)	Jun–Feb* (Jul)	
Nauclea sp.	Gogol			Jun–Aug	
Neiosperma citrodorum	Gogol		May, Nov	Apr*	
Neonauclea obversifolia	Gogol		Mar, Apr	May–Jul	

Species	Location[1]	Altitude (m)	Flowering[2]	Fruiting[2]	Seed fall[2]
Neubergia corynocarpa	Gogol		Oct–Dec	Jan–Mar	
Octomeles sumatrana	M, Mad		Year round	(Oct–Dec), May	Apr–May, Jul–Sep
Palaquium lobianum	Gogol		Sep, Jan–Mar	Oct–Jul*	
Palaquium amboinensis	Gogol		Apr, Sep, Dec	May–Jul	
Pangium edule	Bulolo (N)	1000	Sep–Oct	(Oct–Dec), Mar	(Jan–Mar)
Pangium edule	Gogol		Sep	–	
Paraserianthes falcataria			Oct		
Paratocarpus veninosus	Gogol		Jan–Mar	Mar–May	
Parkia versteeghii	Gogol		Oct, Apr	–	
Pimeleodendron amboinicum	Gogol		Jul–Sep (Sep)	Jul–Dec* (Oct)	
Planchonella obovata	Gogol		Jan–Mar, Aug (Feb)	Nov–Apr* (Mar)	
Planchonella thyrsoidea	Gogol		Jul–Sep	Oct–Dec	
Planchonia papuana	Gogol		Sep–Nov	Dec–Mar	
Polyalthia discolor	Gogol		Oct–Aug*	Dec, Jan, Feb, Sep	
Polyalthia oblongifolia	PNG (H–8)		Jan–Oct	Feb–Sep	Mar–Oct
Polyalthia oblongifolia	Lae	50	Mar–Apr	Dec–Feb, Apr	Feb
Polyalthia rumphii	Gogol		Dec–Mar (Feb–Mar)	Apr	
Pometia pinnata	Gogol		Jul* (Sep)	Sep* (Oct)	
Pometia pinnata	M, NB, Ma		Mar, Aug–Dec	Mar–Apr, Oct–Jan	
Pometia pinnata	Lae	50	Apr, Aug–Sep	May, Oct–Dec	Dec
Pongamia pinnata	Gogol		Sep–Nov (Oct)	Nov–Jan (Dec)	
Pouteria anteridifera	Lae	50	Nov–Dec	Jan–May	May
Pterocarpus indicus	Gogol		May/# (May)	Dec–Mar)	
Pterocarpus indicus	M, O		Jul–Sep	Apr, Dec–Jan	
Pterocarpus indicus	Lae	50	Oct–Nov	Dec–Feb	Feb
Pterocymbium beccarii	Gogol		May–Sep (Aug)	Aug–Sep	
Pterygota horsfieldii	Gogol		Sep* (Apr)	Jan–Dec* (Jul)	
Sarcocephalus coadunata	Gogol			Aug–Sep	
Semecarpus mangificus	PNG (H–13)	30–1,200	Jan–Oct (Jan, Apr, Jul–Aug)	Feb–Nov (May, Jul–Aug)	Mar–Dec (Jul–Aug)
Serianthes hooglandii	Ma			Aug–Sep	
Sloanea forbesii	Gogol		Sep–Jun* (Sep)	Oct–Jul* (Feb)	
Sloanea sogerensis	M		Oct, Jan		
Sloanea sogerensis	Gogol		Jul–Apr*	Sep, Oct, May, Jun	
Spondias cytherea	PNG (H–6)		Apr–Oct	Jay–Nov	Jun–Dec (Dec)
Spondias dulcis	Gogol		Aug* (Oct)	Jan–Dec* (Feb)	
Sterculia schumanniana	Gogol		Oct–Aug* (Jun)	Dec, Aug, Sep	
Sterculia ampla	Gogol		Jul–Apr* (Dec)	Jul–May* (Feb)	
Sterculia schumanniana	M			Oct	
Sterculia shillinghawii	Gogol		Sep* (Oct)	Jun–Apr* (Dec)	
Syzygium branderhostii	Gogol		–	Jul–Nov*	
Syzygium malaccense	Gogol		Sep–Oct	Oct–Nov	
Syzygium pteropodum	Gogol		Jan–Dec* (Nov, Dec)	Feb* (Feb, Oct)	
Syzygium versteeghii	Gogol		Jul–Mar* (Aug)	Sep–Nov (Sep–Oct)	
Tectona grandis			Mar–Apr		May–Sep
Teijsmanniodendron bogoriense	Gogol		Jan–Dec* (Aug)	Oct* (Sep)	
Terminalia brassii	M, NB		Apr	Jan–Mar	
Terminalia brassii			Jan–Feb, May–Jun		Apr–May, Jul–Sep
Terminalia catappa			Nov–Mar	Dec–Apr	
Terminalia complanata	Gogol		Sep–Oct	Oct–Nov	
Terminalia complanata	M, Ma, NB		(Nov–Feb)	Jan–Mar	

Species	Location[1]	Altitude (m)	Flowering[2]	Fruiting[2]	Seed fall[2]
Terminalia impediens	Gogol		Sep–Jul* (Sep)	Aug–Jan	
Terminalia kaernbachii	Bulolo (P)	700–1000	(Jan–Mar)	(Apr–May)	(Jun–Aug)
Terminalia kaernbachii	Gogol		Feb* (Sep)	Mar* (Oct, Nov)	
Terminalia kaernbachii	Oomsis (P)	135–655	(Dec–Feb)	Feb–Apr	May–Jun
Terminalia katikii	Gogol		Sep	Oct–Nov	
Terminalia microcarpa	Gogol		Sep–Oct (Sep)	Oct–Nov (Oct)	
Terminalia sepicana	Gogol		Aug–Oct (Sep)	Jan–Nov* (Oct)	
Terminalia solomonensis	M		Sep	Sep	
Terminalia solomonensis	Gogol		Aug, Sep	Sep–Oct	
Tetrameles nudiflora	Gogol		Aug–Oct (Aug)	Oct, Nov, Sep, Dec	
Thespesia fissicalyx	Gogol		Aug* (Sep, Oct, Jul)	Sep* (Nov, Dec, Aug)	
Timonius kaniensis	Gogol		Jul–May* (Oct)	Jun* (Nov)	
Toona ciliata	Lae	50	Mar, May	Mar–Apr	Apr
Toona sureni/ ciliata	M, Ma		Jun–Aug	Sep–Nov (Feb)	Nov
Trichadenia philipinensis	Gogol		Sep–Dec	Oct–Mar	
Tristiropsis acutangula	Gogol		Jul–May* (Jan)	Jun* (Apr, May)	
Vatica papuana	Gogol		Jul–Apr* (Apr)	Aug–May* (Sep)	
Vitex cofassus	Gogol		Jan–Dec* (Dec)	Jan–Dec* (Jan)	
Vitex cofassus	Lae	50	Jan–Feb	Mar–Apr	Apr
Vitex quinata	Gogol		Feb* (Oct)	Nov* (Nov, Jan, Feb)	
Wrightia laevis	Gogol		Nov, Oct	Nov–Feb	
Xanthophyllum papuanum	Gogol		Aug* (Sep)	Oct* (Oct)	
Xylopia papuana	Gogol		Jan–Oct*	Mar, Apr, Nov, Dec	
Ziziphus angustifolius	Gogol		Oct, Sep	Nov*	

Legend

[1] M = Morobe, Ma = Manus, Mad = Madang, H = Highlands, NB = New Britain, O = Oro Bay, P = planted tree, N = natural tree; H followed by number = number of herbarium records

[2] **Flowering and fruiting symbols**

= continuous throughout the year

* = sporadic

( ) = peak periods

The data in this appendix are based on four sources:

1. Phenological records from Gogol Forest between 1986–88 made by Emerick Devage and others of PNGNFS
2. Phenological record cards
3. NTSC seed collection guide chart
4. Phenological observation (2002) under Project

Appendix II. Phenological Data Form

NTSC Phenological data form for individual trees

Species: ..... **Location of observations:** .....

Observations to be made as close as possible to the same date each month. When observing trees use the following symbols to record developments relating to flower bud, flowering and fruiting development.

Flower buds: I – initiated; E – early; F – fully developed; R – rare; C – common; A – abundant

Flowers: I – initiated; E – early; F – fully developed; R – rare; C – common; A – abundant

Fruit: I – initiated; E – early; F – fully developed; R – rare; C – common; A – abundant; G – green; GP – green purple; P – purple-black; S – shedding

Tree No.	Phenology of —	Jan/Date	Feb/Date	March/Date	Apr/Date	May/Date	Jun/Date	Jul/Date	Aug/Date	Sep/Date	Oct/Date	Nov/Date	Dec/Date
1	Buds												
1	Flowers												
1	Fruit												
2	Buds												
2	Flowers												
2	Fruit												
3	Buds												
3	Flowers												
3	Fruit												
4	Buds												
4	Flowers												
4	Fruit												
5	Buds												
5	Flowers												
5	Fruit												
6	Buds												
6	Flowers												
6	Fruit												
7	Buds												
7	Flowers												
7	Fruit												

Appendix III. Information on Seed Collection and Storage of Species Described in Section 6

Species	Month of collection[1]	Fruit size (cm)	Fruit/ kg	Seed/kg	Storage behaviour / unit stored[2]	Seed mc (%) (fresh)	Storage temperat e (°C)[3]	Storage life (y)	Days to germinate	Germination of fresh seed (%)	Vegetative propagation
Aleurites moluccana	Jun-Aug Feb–Apr	5 x 6 wide	90	345	O?/S	36	18–20	1	10–80	25–55	Unknown
Anisoptera thurifera	May–Jul	1	500–1 00	1200	R/F	51	3–5	3 wk*	18–35	45–90	25% air layering
Anthocephalus chinensis	May–Jun	6–7 diam	8	8 million	O/S	10	3–5	0.5–1	8–21	60–90	From stumps
Araucaria cunninghamii	Oct–Dec	7	5	4000–5000	O/S	23	–15	<6	12–20	75–80	Easily propagated
Araucaria hunsteinii	Sep–Oct	12 x 20	1	5000–6000	R/S	53	3–5	0.5–1.5	7–21		90% cuttings root
Artocarpus altilis	Yr round	12 x 25	<1	200	R/S	60	15	3*	14–28	90–95	Root and shoot cuttings
Calophyllum euryphyllum	Jan–Apr	5	30	60	R?/F or S	68	3–6	? mo	5–28	40–60	Difficult <15% root
Canarium indicum	Feb–May, Oct–Nov	5 x 2		35–100	?/S		3–5	0.5			<10% cuttings root
Casuarina oligodon	Aug–Dec	0.5–1		675 000	O/S	10–12	3–5	>1	5–21	20	60% cuttings root
Dracontomelon dao	Feb–Jul	2	100	400–700	R/nut		3–5	<0.5	28–60	30–85	93%cuttings root
Elmerrillia papuana	Apr–Jun	3–6 long		30 000	R/S	37	3–5	Few mo	18–38	89 (fresh)	unknown
Endospermum medullosum	Jan, Jul–Aug	0.6–0.9	9000	35 000	R/S	51	3–5	0.5?		35–50	36% cuttings root
Gnetum gnemon	Jan–March	2			O?/S		3–5		15–20		Cuttings, budding and layering
Intsia bijuga	Apr–Jul	15– x 5		160	O/S	10	3–5	>1	9–11		35–65%, 90% cuttings root
Octomeles sumatrana	Apr–May, Jul–Sep	1 long		15 000	O/S	7	3–5, –18		8–16	40	cuttings
Pangium edule	Jan–Mar	18 x 12 wide		30–40	R/S	72	3–5		26–60	60–85	Unknown
Pometia pinnata	sporadic	4	150	300–500	R/S	35–55	3–5	0.5?	7–10	90	95% cuttings root
Pterocarpus indicus	Jan–Apr°	5 x 1	3000	17 000	O/F	16–17(4)	3–5	>1	3–30	10–20	high% of cuttings strike
Santalum macgregorii	Sporadic	1	2000	4000	O?/S		3–5	<1y	20–>100	low	27% cuttings root
Schleinitzia novo-guineensis	March				O	10–12	3–5	>1	Pre-treat 5–28		cuttings
Serianthes hooglandii	May–Aug	16 long x 7 wide		4200	O/S		25	>5	5–?		unknown

Species	Month of collection[1]	Fruit size (cm)	Fruit/ kg	Seed/kg	Storage behaviour / unit stored[2]	Seed mc (%) (fresh)	Storage temperature (°C)[3]	Storage life (y)	Days to germinate	Germination of fresh seed (%)	Vegetative propagation
Terminalia brassii	Sporadic	10		70 000	O/S	5	18–20	>2	3–21	7–21	Not determined
Terminalia catappa	Feb–March?	5		500–2000	O?/S		3–5		3–8		Unknown
Terminalia complanata	Mar–Apr & Jun–Aug	1.5		1100	O?/F		3–5		10–50		Not determined
Terminalia kaernbachii	Jun–Aug	10 x 6		??	R?'F	55	3–5	R?/F	15–60	5–25	10% cuttings root
Toona ciliata (c)and *Toona sureni* (s)	Sep–Nov	2–3 x 0.8–1.2		360 000 c 250 000 s	O/S	5–10	3–5°C	5	7–28	25	60% & 90%
Vitex cofassus	Apr (sporadic)	1		10 500	O?/S		3–5°C	<1 y	10–40	0–20 (100%)	Unknown

[1] The suggested months for collection are based on observations and are only a guide. Phenological studies have shown considerable variation between seasons and between locations, making it impossible to accurately predict collection time for most listed species.
[2] O = orthodox; R = recalcitrant; S = seed; F = fruit
[3] Storage temperatures: 18–20°C = air-conditioned room; 3–5°C = refrigerator; –15 to –18 = freezer
* Refer to species description for more detailed information

Appendix IVa. Seed Collection Data Sheet

Species:											Latitude:	Longitude:	Seedlot:
Location:											Province:		Alt (m)
Habitat:					Provenance name for database:						Rainfall:		
Vegn structure:			Soil texture:		Associated species:				Freq.	Ht (m)	Comments		
Species frequency:			Soil pH:										
Aspect:			Soil colour:										
Slope:			Geology:										
Seed crop:			Predation status:										
Bud:			Root suckers:										
Flower:			Coppice:		Map:								
Coll. No.	Bot. spec.	Film No.	Ht (m)	Age	Bole		Crown				Description & notes	Seed weight (g)	Viability / 10 g
					dbh (cm)	Form	Den.	Brn	Wdt	Ht (%)			
Team:							Date:				Collected as bulk Collected as individuals	Total wt		

Appendix IVb. Template for a Botanical Field Note Book
FLORA OF PAPUA NEW GUINEA

Species: .....

Coll. No.: ..... Date: .....

Locality: .....

.....

Alt.:..... m Lat.: ..... S Long: ..... E

Habitat: .....

.....

Habit: .....

.....

Appendix V. Plant Collection Procedures and Specimen Preservation

The following is a guide to the equipment and techniques required to make and preserve plant collections.

1. Equipment

Field press

A press typically consists of two hardwood frames with each frame made from—

4 wooden strips about 20 x 12 x 450 mm, and

6 wooden strips about 20 x 12 x 300 mm.

Make the press by spacing the strips evenly to form two similar rectangular lattices, and nailing or riveting securely at intersections. Alternatively you may use two pieces of 12 mm plywood cut to 300 x 450 mm; holes drilled in each piece will assist circulation of air. Webbing handle straps on each frame aid in carrying the press. If using a press of the hardwood frame type, it is useful to fit a piece of corrugated cardboard, 300 x 450 mm, immediately inside each frame. Corrugated cardboard may also be used elsewhere in the press to separate specimens and assist circulation of air.

- **Newspaper, cardboard and foam**
  A newspaper, folded in half, is excellent for interleaving with specimens. Corrugated cardboard can be used to separate woody or bulky specimens from delicate ones. The use of foam (c. 10 mm thick) in the press results in evenly pressed specimens, especially bulky specimens.
- **Press straps**
  A pair of strong webbing straps with claw buckles is excellent. Sash cord may also be used. In either case, the minimum length is 1.5 m.
- **Field notebook**
  A pocket-sized notebook which will stand up to wet conditions is essential. Use a pencil which is water-proof — both at the time of collection, and later.
- **Tie-on tags**
  Large enough to take your name (or initials) and field number. They may also be used to label collecting bags.
- **Clippers**
  A pair of secateurs.
- **Diggers**
  A trowel, preferably with a steel shank.
- **Scrapers**
  A large spatula is excellent for scraping up mosses and lichens.
- **Collecting bags**
  Plastic bags, in a couple of sizes, and rubber bands to close them. Small brown-paper bags for collecting fruit, seed and bryophytes.
- Felt-tipped pens
  For numbering bryophyte collections.
- **Hand lens**
  At least 10x.
- Topographic maps and GPS
  Topographic maps are necessary for locating your position and determining altitude. A GPS (Global Positioning System) unit makes fixing an accurate latitude and longitude easy.
- **Safety gear**
  A hat, long-sleeved shirt and long trousers to afford protection from the sun, a jumper and water-proof raincoat to protect you from cold and rain, a first-aid kit, water and food, and a trip plan outlining your intended destination/s and expected time of return left with someone who will raise help if necessary.
- **Rucksack or backpack**
  To carry all of the above and collected specimens. A big one!

2. Collecting

- Select vigorous, typical specimens. Avoid insect-damaged plants.
- Specimens should be representative of the population, and thus should include the range of variation of the plants. Roots, bulbs, and other underground parts should be carefully dug up, and the soil removed with care.
- Make sure the specimen includes flowers and/or fruit. It may be a good idea to collect extra flowers and fruit for identification purposes.
- In collecting large herbs, shrubs and trees, different types of foliage, flowers and fruit should be col lected from the same plant. Collect sufficient material to fill an herbarium sheet (c. 450 x 300 mm) and still leave enough room for the label. Plants too large for a single sheet may be divided and pressed as a series of sheets.
- Bark and wood samples are often desirable additions when collecting woody plants. There are special requirements for the identification of some plants — see separate list. *A Eucalyptus* specimen, where possible, should include mature leaves, juvenile leaves, buds, fruit and bark.

Other general hints for collecting are:

- Bulky plants or parts can often be halved or sliced before pressing. Odd fragments — bark , fruit or seed — should be kept in numbered or labelled envelopes or packets with the main specimen.
- Very bushy twigs should be pruned to make a flatter specimen, in such a way that it is obvious where pieces have been removed.
- Spiny plants may first be placed under a board and stood on, before pressing, to prevent tearing of the paper in the press.
- Succulent plants should be killed before pressing by soaking them in methylated spirits for 15–20 min utes. Bulbs also should be killed, or they may sprout on the herbarium sheet!
- Water plants must be floated out in a dish of water and lifted out on a sheet of stiff white paper slipped under them in the water; excess water is dried off before pressing the plant in the usual way, leaving it on the white paper to which it can remain permanently stuck. A piece of waxed paper placed over the top of the plant will prevent it adhering to the drying paper.
- Tall rosette plants and grasses may be pressed complete by bending them once or more into the shape of a 'V', 'N' or 'M'.
- Dioecious plants should be represented by both sexes.
- Palms — several herbarium sheets are necessary to show the various portions of the leaf, inflorescence and fruit of these species. Photographs of the tree and of each part are essential.
- Cones of some gymnosperms and Pandanaceae may have to be enclosed by wire mesh to prevent them falling apart.

3. Pressing and Care of Specimens

- Specimens should be pressed as quickly as possible after collection. If prompt pressing is impractica ble, specimens may be stored in plastic bags, preferably wrapped in damp (but not wet) paper. Bags should not be packed tightly, and should be kept cool and moist. Make sure that each bag is correctly labelled for locality.
- Place each specimen, with numbered tie-on tag attached, in a fold of several sheets of newspaper, and place in the press. As you fill the press, if necessary, occasionally add a sheet of corrugated cardboard to act as a ventilator, and try to keep the contents level to ensure even distribution of pressure. This may require the use of alternate corners of the fold for bulky roots and other parts, or packing foam around a bulky specimen. Close the press and exert pressure with the straps.
- The plants in the press should be dried fairly quickly, in a warm place if possible. The specimens must not be left in damp paper or they will become mouldy. It is therefore necessary during the first few days to go through the press daily, changing the plants into dry newspaper. Thereafter continue to inspect the press daily and change the paper as necessary until the plants are dry.

• Delicate plants and petals at risk of being lost in the paper-changing process should be kept in tissue-paper (e.g. 'Kleenex' or toilet-paper) folders throughout changes. A properly dried plant specimen is brittle.

4. Field Notes

At the time of collection, a numbered tag should be tied to the specimen. The best system of collection numbers to use is consecutive — i.e. begin at 1 and go up. Avoid anything elaborate. Each number should refer to a single collection, and should never be repeated. All duplicates of a collection should bear the same number.

Recorded the collection in the field notebook, together with information about that collection. As much as possible of the following data should be included:

- Exact locality — a good plain-language description, and latitude and longitude
- Altitude
- Nature of the habitat — type of soil, topography, slope, aspect
- Associated species, vegetation type
- The plant proper — record features which will not be evident from the pressed specimen, e.g. whether it is a tree or shrub, height, branching, notes on root system, odour, etc., as well as those features which may be lost on drying, e.g. flower colour and odour
- Date of collection.

For more information refer to the following
http://www.anbg.gov.au/projects/collecting/collection-procedures.html

Appendix VI. Building a Porta-propagator

1. Materials

Timber (naturally durable or treated)

Front legs	3 x 50 mm x 50 mm x 1700 mm
Back legs	3 x 50 mm x 50 mm x 1600 mm
Cross members	25 x 50 mm x 50 mm x 1200 mm
Roof lengths	2 x 50 mm x 50 mm x 2800 mm
Roof members	5 x 50 mm x 50 mm x 1400 mm
	2 x 50 mm x 50 mm x 1500 mm

Plastic

Top	1 x 1300 mm x 2600 mm
Back	2 x 600 mm x 2600 mm
Front	1 x 600 mm x 2600 mm
Shade cloth	1 x 2500 mm x 3000 mm (70%)

Metal

Frame brace	4 x 3800 mm (gal punch strapping)
Frame brackets	54 x 50 mm x 3 mm 'L' galvanised brackets
Wire mesh	2 x sheets 1300 mm x 2600 mm (20 mm2 holes)
Bolts	110 x 100 mm tank bolts and nuts
Nails	16 x 200 mm nails

Irrigation

Soft polypipe	13 mm x 2700 mm x 1
	13 mm x 600 mm x 2
	13 mm x 1000 mm x 1
	13 mm x 100 mm x 1
Total length	13 mm x 5000 mm (soft polypipe)
Clamps	5 x 13 mm clamps
Elbow	1 x 13 mm elbow
Filter	1 x 13 mm inline filter
End stops	1 x 13 mm end stop
T piece	1 x 13 mm 'T' piece
Sprinklers	5 mist sprinklers

In addition, other items will be needed to provide and control the water flow: the details will depend on the nature of the services available at the site. Likely environments are:

No electricity, no water supply

12 volt pump (Flojet 2100 – 7 amp, 2.2 GPM)
12 volt car battery and trickle feed solar panel
Balance arm unit (Sage Horticulture)
100 litre plastic drum

Electricity but no water supply

12 volt pump (Flojet 2100 – 7 amp, 2.2 GPM)
Solenoid and transformer
Balance arm unit (Sage Horticulture)
100 litre plastic drum

No electricity but with pressure water supply

Galcon EZ timer (model 2040)
Electricity and with pressure water supply
Solenoid and transformer
Balance arm unit (Sage Horticulture).

2. Equipment needed

Tape measure
Wood saw
Hammer
Drill and 5 mm and 10mm drill bits
Wire cutter
Screwdriver
Shifting spanner
Staple gun and staples (or tacks)

3. Building a porta-propagator

Step 1: Building the frame

The frame is constructed from the durable or treated timber listed in the materials list.

- Cut the timber into the required lengths: 3 front legs, 3 back legs and 25 cross members
- Position the 'L' brackets on each of the legs. Each side leg has 6 brackets, and each middle legs has 9. See the accompanying plan for measurements of the locations of the brackets.
- Bolt the 11 bottom cross members into place.

Before the rest of the frame can be put together, the wire mesh for the base has to be fitted.

- Cut the mesh to size, and also cut the 6 spaces in the wire for the legs to pass through. Put it in place by resting it on the cross members at the first level.

With the base wire in place, the rest of the frame can be put together.

- Bolt the cross members at the second and third levels into place — 7 at each level.
- Cut the galvanised metal strapping into 4 lengths of 2000 mm and 2x 3000mm
- Tack this bracing across the diagonals on each end and at the back of the frame
- Again cut a piece of wire mesh to size, and make the 6 spaces in the wire for the legs to pass through. Rest this mesh on the cross members at the third level.
- Construct the roof of the frame, using 5 cross members with 2 longer pieces length-ways.

Step 2: Porta-propagator covering

Now that the frame is completed, it is time to apply the plastic covering.

- Cut the plastic to fit the ends and back.
- Tack or staple this plastic into position. Tack or staple the sheeting on all four edges — the top, sides and bottom.
- Cut and position plastic sheeting to fit the top. This plastic sits on top of the top wire mesh, not on the roof frame.
- Cut and position plastic sheeting to fit the front of the propagator. This sheet should be fixed only at the top, so it can be lifted as a flap.
- The final covering is the shade cloth — over the top, and down the sides and back of the frame. This can also be tacked or stapled in position.

Step 3: Irrigation (see attached diagram)

Now the frame is completed with coverings, it is time to install the irrigation system.

- Cut a piece of polypipe to a length of 2.7 m. This is to be positioned under the top sheet of wire mesh, and the mist sprinklers will be installed in it. First, push a end block into one end of the pipe and a elbow into the other. Then place it in position. Fix it in place by either clamps or wire.
- With top pipe in place, screw the 5 mist sprinklers in position, spacing them equally.
- Join the rest of the irrigation pipe together as in the accompanying diagram.

4. Suppliers

Sage Horticulture Australia Ph +61 (3) 9553 3777 http://www.sagehort.com.au	Solenoid and transformer Balance arm unit
Any irrigation supplier	12 volt pump Pel solar panel Galcon timer

Robson, K. 2001. Report on 'Vegetative Propagation of Tropical Tree Species'. South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) training course. Queensland, Australia, 8–26 October 2001.