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Technical Report · January 2012

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Vanuatu sandalwood

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Page T., Tate H., Tungon J., Tabi M. and Kamasteia P. 2012. Vanuatu sandalwood: growers' guide for sandalwood production in Vanuatu. ACIAR Monograph No. 151. Australian Centre for International Agricultural Research: Canberra. 56 pp.

ACIAR Monograph No. 151

ACIAR Monographs – ISSN 1031-8194 (print), ISSN 1447-090X (online)

ISBN 978 1 921962 81 3 (print)

ISBN 978 1 921962 82 0 (online)

Technical editing and design by Biotext, Canberra

Printing by CanPrint Communications

Foreword

In Vanuatu, all forests are owned by custom landowners, and these forests play an important part in the lives of much of the population who live on the 80 islands that make up this archipelago nation. Sandalwood has been harvested and traded by landowners for centuries, but until recently only limited effort has been devoted to regenerating this important natural resource in Vanuatu.

Sandalwood is an important export product that is highly valued in the international marketplace. With other sources of plantation sandalwood being established in Australia, China and India, it is essential that Vanuatu increases the volume and improves the quality of its sandalwood to remain internationally competitive. Government and private promotion of sandalwood planting has led to a rise in smallholder plantings. Although this is encouraging, further new plantings are needed, and greater emphasis needs to be put on improving management practices (silviculture) to improve the quality of sandalwood and retain high-value, niche markets. This is particularly important because Vanuatu, due to its small land area and population, will always remain a small-volume producer.

The Australian Centre for International Agricultural Research (ACIAR) has supported research into the growing and marketing of sandalwood in Vanuatu for a number of years. Much experience in sandalwood silviculture now exists and is being applied in parts of the country. However, this knowledge needs to be more widely available in a format that local people can easily understand. Optimising management practices, such as site and host selection, spacing and weeding, can improve productivity and reduce time to harvest. Appropriate use of simple pruning can also lead to improved yields and product quality. This guide addresses these issues and will be distributed to isolated growers who are unable to visit Department of Forests offices.

A vibrant, plantation-based sandalwood industry in Vanuatu has the potential to reduce reliance on depleted wild stands, provide significant cash incomes for landowners and add considerable value to the national economy. Sandalwood's high value and small size make it unique among forestry trees in that it can be incorporated into smaller ornamental gardens and boundary plantings as well as larger commercial plantings. Its small size has also allowed women and children to be involved in its production, thereby opening up income opportunities for these groups. This growers' guide will help the people of Vanuatu and other Pacific island countries to participate in this lucrative rural industry and take advantage of its economic opportunities.

Nick Austin
Chief Executive Officer, ACIAR

Contents

Abbreviations

2CC	second cutting chips
cm	centimetre
g	gram
kg	kilogram
m	metre
mm	millimetre

Introduction

Sandalwood products

Sandalwood trees (*Santalum* spp.) are highly valued for their fragrant heartwood oils, and are recognised as one of the most precious non-timber forest products. The oils have been used for centuries for religious and customary purposes, and are now used internationally for cosmetics, aromatherapy, scenting of soaps, perfumery and medicines.

The oil-bearing heartwood is also used for ornamental or ceremonial carvings, or powdered for the manufacture of incense joss sticks, which are valued in the international agarbatti (incense) market.

Sandalwood oil

Sandalwood markets

The extraction and export of sandalwood was the first international industry in Vanuatu, and was driven primarily by Australian merchants. The export of sandalwood to China began in the late 1820s and continued for 30 years. After this period, the sandalwood trade continued sporadically, most likely as populations recovered and small commercial volumes became available. A modest commercial industry has been operating consistently since the 1970s, with a current annual quota of 80 tonnes.

Sandalwood is used mainly in India, Taiwan and Hong Kong, with smaller markets in Europe, Japan and North America. Vanuatu sandalwood production currently represents around 1% of world production; therefore, an increase in local production in Vanuatu is unlikely to have an impact on world prices.

The high demand for sandalwood products and the low level of commercial production of these trees have resulted in a sharp decline in the natural supplies of many sandalwood species. International prices for sandalwood have therefore been consistently rising over the past few decades. In Vanuatu, the price paid to villagers for 1 kg of heartwood has risen at an annual rate of 10% since 1990.

Processing sandalwood

The carving log attracts the highest price in the marketplace, followed by oil then powder. However, the profitability of each product also depends on the cost of production.

All products require the outer sapwood to be removed (desapped), which is typically done by the harvester or grower before sale. The total cost of processing is lowest for carving logs; they require further desapping, which removes the final layer of sapwood next to the heartwood and produces second cutting chips (2CC). The log ends are then sealed (usually with wax) to prevent rapid drying and cracking. Powdered wood requires additional milling and blending of different powders to achieve a final product that is acceptable for use in agarbatti. Sandalwood oil is the most expensive to produce because the heartwood needs to be powdered before the oil is extracted by an energy-intensive and complex process called distillation.

During distillation, steam is generated in a boiler, which is typically fuelled by diesel, coconut oil, wood or electricity, and passes through powdered heartwood, where it mixes with the heartwood oil. This mixture is then cooled and condensed, with the oil forming a layer on top of the water. Distillation can take several days to liberate all the oil from the heartwood.

The production of high-quality oil requires a high level of experience and knowledge of the process. The price of oil therefore contains the cost of the heartwood and other inputs, such as fuel and labour—this is why oil has a much higher price than powdered heartwood. The high input costs for oil production may mean that profitability is marginal for some processors.


Sandalwood logs


Powder and chips


Making joss sticks


An oil distillery

Biology

Vanuatu sandalwood is a small tree (5–12 m tall) that occurs naturally in west-coast Santo, western Malekula, north-western Efate, Erromango, Tanna, Aniwa, Futuna and Aneityum. Sandalwood is hemiparasitic, which means that the trees have to grow with other species to survive. When growing sandalwood seedlings, a host plant needs to be planted with the sandalwood seedling (a 'pot host'). Host plants need to be planted among the sandalwood trees in the field to promote vigorous sandalwood growth.

Habit: trees in open positions have a short, crooked and forked bole (trunk up to the first branch) with a spreading crown; in a crowded forest they can develop a single straight bole with a narrow crown.

Bark: grey to reddish brown, often with lichen on older trees.

Leaves: typically narrow in seedlings, but become broader in trees older than 3 years. The upper surface is shiny and dark green, and the lower surface is dull and light green.


Habit


Bark


Leaves

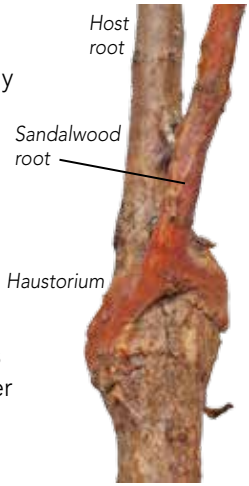
Flowers: small, with four greenish-white flower parts (tepals) that are borne in branched inflorescences twice each year. Individual flowers typically open in the morning of one day and close by the afternoon of the next.

Fruit: firm and green when young, red when ripening, and purplish black when mature. Each fruit contains a single seed covered with a juicy flesh and has a scar on the top from the tepals.

Seeds: small and about 10–15 mm in diameter. The outer surface is smooth or slightly textured, and light brown. Seeds from the southern islands are generally spherical; seeds from the northern islands are slightly elongated.

Wood: the inner heartwood is yellow to red, and the outer sapwood is pale yellow to white. Heartwood is rich in oils that are highly aromatic and commercially valuable.

Roots have specialised outgrowths (haustoria) that penetrate the roots of nearby trees and shrubs and absorb water and nutrients from them.




Flowers


Fruit


Seeds

Wood

Nursery

A common method for establishing new sandalwood plants is to sow seeds in a substance that promotes germination (a germination medium), and raise seedlings in soil-filled poly bags in a nursery before planting them in the field.

Seed collection and storage

It is important to use good-quality seeds because they produce strong, healthy seedlings. Use the basic methods of preparation outlined on the next page.

A sandalwood plantation in Hokua

Collecting and preparing seeds

1. Pick

Pick ripe fruit from the tree, and collect fruit that has recently fallen to the ground. Ripe fruit are soft, shiny and purple to black.

Immature fruit are hard, dull and green. Do not collect seeds from green fruit because they will not be viable.

ripe

immature

2. Soak

Soak the ripe fruit in a bucket of water overnight (about 12 hours) to loosen the flesh.

3. Clean

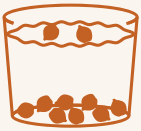
Rub the soaked fruit between your palms to remove the flesh from the seed.

Rinse the seed in clean water to remove any impurities.

flesh

seed

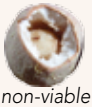
4. Float



Place the seeds in a bucket of water.

Discard seeds that float, since most of these will not be viable. Non-viable seeds break easily when pressed between the thumb and forefinger and have a small kernel that is shrunken away from the shell. Viable seeds have a kernel that fills the shell and sink in water.

Collect the seeds that sink, because these are viable.



non-viable

viable

5. Dry

Dry the cleaned seeds on a flat surface in a warm, dry area, but not in full sun because this can overheat and kill the seeds.

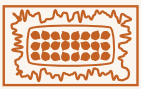
6. Store

Store dried seeds in a clean calico or paper bag, in a cool, dry place away from rats. Seeds stored like this can remain viable for up to 6 months, but should be sold or used as soon as possible.

Dried seeds stored in a sealed container in a refrigerator (2–4 °C) remain viable for more than 1 year.

Seeds stored in plastic bags can sweat and rot.

7. Transport



Keep seeds cool and dry during transport.

If sending seeds as a parcel, place the calico bag in a box and pack it with scrunched paper so that the seeds do not become too hot during transit. Seeds can be transported in a plastic bag, but only if they are completely dry.

Germination

Seeds germinate best when they are sown in a free-draining medium such as 2:1 mix of river sand and soil. Composted sawdust is also a very good germination medium.


Growing medium


Germinated seed

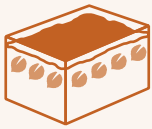

Seedlings ready for transplanting to poly bags

Germinating seeds

1. Nick

'Nick' the seed shell to expose the kernel. Nicked seed begins to germinate after 2 weeks, whereas seeds that are not nicked may take 6 weeks to germinate.

2. Sow



Sow seeds in a seedling tray or pot, just (5–10 mm) below the surface of the medium so that the seeds do not touch each other.

3. Water

Keep the medium moist but not wet. During the wet season, trays may need to be brought out of the rain.

4. Protect

Protect germinating seedlings from full sun and predation by rats and birds.

Growing seedlings

Seedlings are ready to be transplanted to poly bags once they develop two true leaves.

Pricking out seedlings

1. Prepare poly bag Use a sterilised growing medium in the poly bags that has 50% sand to assist drainage and 50% soil to improve water-holding capacity.

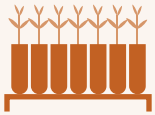
2. Prick out

Prick out the seedlings (when they are at the 2-leaf stage) by lifting the root system with a cleaned stick and pulling gently on the base of the stem.

3. Transplant

Plant the seedling firmly in the medium and cover the roots.

4. Raise bags



Place the poly bags on raised benches, particularly during the rainy season, to help drainage.

5. Protect

Cover the seedlings during periods of heavy rain to reduce the chance of the growing medium becoming saturated. Grow the seedlings under shade (e.g. shady tree or shade cloth).

Planting the pot host

The pot host *Alternanthera* (see page 30) should be planted as stem cuttings after the sandalwood is at the 4–6-leaf stage. If the pot host is planted too early, it will grow quickly to overtop the young seedling, leading to stunted growth and death of the sandalwood. If the pot host is planted too late, the sandalwood may grow slowly.

Hardening seedlings

Once the seedlings reach the 10–12-leaf stage, they need to be progressively moved to areas of higher light levels to 'harden' or acclimatise them to conditions in the field. They should have 50% shade in the first month, then 25% shade for another month, and then one to several months in full sun, before they are planted in the field. Seedlings transplanted directly from the shade to a full-sun position in the field typically have poor survival.

A seedling is ready to plant in the field when it shows at least two of the following signs:

- The seedling is actively growing, with new shoots, and has deep green leaves.
- The bottom of the stem is slightly woody (i.e. changes from green to brown).

- Height is about 20–30 cm.
- The seedling has small branches developing at the junction of the leaf and main stem.
- Some small roots are visible through the holes in the bottom of the plastic.

Seedling ready for transplanting in the field

Raising wildlings

Seedlings germinated naturally under an existing sandalwood tree can be collected and transplanted to the nursery or another location (such seedlings are called wildlings). This is a simple method of establishing new stands of sandalwood:

- Select sandalwood trees that are fruiting or are otherwise known to fruit heavily.
- Clean all undergrowth from beneath the canopy of the selected sandalwood trees.
- Loosen the soil in the cleared area by shallow digging or cultivating only the top 5 cm of soil. Wildlings begin to germinate in the cultivated area about 1–2 months after the soil is disturbed.

Digging up a wildling

- Water the cultivated area during dry periods, if possible, or after the first seedlings break through the soil.
- Keep the cultivated area free from weed regrowth.
- Remove seedlings when they are approximately 10 cm high by gently digging the seedling from underneath, trying not to disturb or break too many roots.
- Transplant seedlings immediately to poly bags or another location, such as the sandalwood plantation.
- Water seedlings well after transplanting.

Wildling ready for transplanting

Nursery construction

A plant nursery is any place that grows seedlings for planting at another site. Plant nurseries take on many different forms, but good-quality sandalwood seedlings can be produced in even very basic nurseries, provided that the nursery is in a sheltered position with ample natural light and accessible fresh water.

Examples of different sandalwood nurseries are:

1. a greenhouse constructed from timber and plastic film, which is useful in cooler regions to keep the seedlings warm
2. a seedling bed with coconut leaves on a timber frame for shade
3. a seedling bed with managed *Glyricidia* trees for shade
4. a raised, sawn timber seedling bench with 50% shade cloth
5. a seedling bed with no shade, used for hardening seedlings before planting
6. a seedling bed with 20% shade cloth on a timber frame
7. seedlings in 1-kg rice bags on a raised timber bench with natural shade.


1


2


3


4


5


6


7

Nursery management

In addition to appropriately managing the pot host and progressively hardening the seedlings, attention to hygiene, preparation of growing medium, drainage, and appropriate watering and fertilisation regimes will provide good results.

Hygiene

Good hygiene in the nursery can ensure the development of healthy seedlings. The key is to keep the nursery free from plant debris (e.g. prunings, fallen leaves, dead seedlings), which will limit the potential for disease to develop. Many unexplained problems in the nursery can be attributed to diseases caused by unseen fungi and bacteria. Sterilising the growing medium can help to prevent diseases being brought in by the soil. The medium can be sterilised by sandwiching it in black plastic and leaving it in the sun for a day, or heating it over a fire in a steel drum.


Sterilising medium in the sun

Sterilising medium in a steel drum

Watering seedlings with a hose

Seedlings in full sun during the dry season may need to be watered every day, but during the wet season shelter from the rain may be necessary.

Fertiliser

Improved growth can be achieved by using fertile soil. A friable, rich volcanic soil will have more nutrients than a heavy clay soil. Additional nutrients can be added to the soil by applying dilute solutions of worm castings, composted organic matter, or commercial liquid and/or slow-release fertiliser.

Drainage

A poorly draining medium can lead to waterlogging, particularly during the wet season. Waterlogging is one of the main causes of seedling death in the nursery. It is therefore important to include sand in the medium to improve drainage.

Watering

The watering regime for seedlings raised in a nursery will vary according to the amount of rainfall and the position of the seedling in the nursery (e.g. 50% shade versus full sun).

Establishing a plantation

Garden planting showing sandalwood and host plants (circled)

Site selection

Suitable sites for establishing new sandalwood plantations, appropriate for rapid heartwood development:

- have a slight slope facing north to west
- have volcanic soil overlying coral limestone
- receive good sunlight (not rainforest)
- have free-draining soil (i.e. that does not hold water for extended periods)
- are free from the fungus *Phellinus noxius* (see page 40)
- have a distinct annual dry season, particularly in the cooler months.

Site preparation

The best sandalwood growth rates occur when sandalwood is established at the same time as a new garden area. A site can be selectively cleared, leaving trees that serve as good hosts (see page 30). It is important to kill stumps completely by burning to ensure that they are not a source of infection with *Phellinus* (see page 40).

Sandalwood seedlings generally establish well when they are planted during the gardening season. The timing of the gardening season in Vanuatu varies between islands, but typically occurs at the start of the dry season during June, July or August.

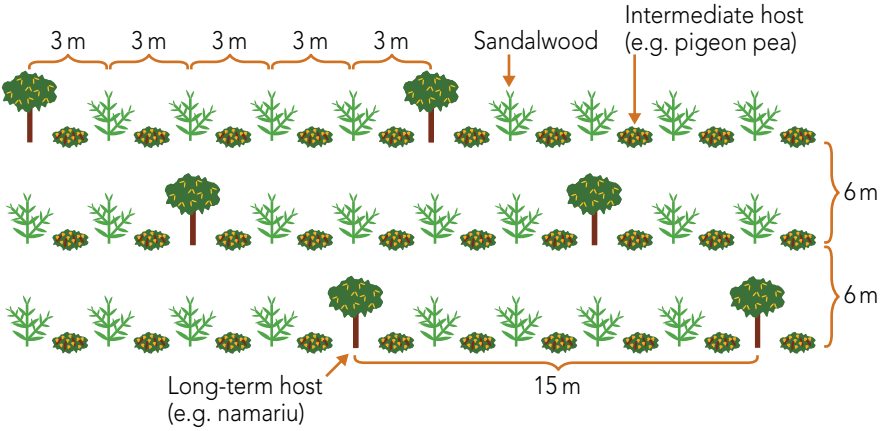
Poor weed control in the first few years of the plantation is the main cause of tree death and plantation failure. Selecting a site with fewer weeds can help to reduce the labour inputs for controlling weeds. Sites that have many vigorous weeds need to be manually weeded every week.

Establishing sandalwood in a new garden area makes the task of controlling the weeds less onerous because the weeds in the garden and sandalwood planting can be controlled at the same time. Better early growth of sandalwood occurs in newly established gardens than in older gardens where soil nutrients have been depleted. Sandalwood also benefits from fertiliser that is applied during the establishment years. As a guide, Nitrophoska Blue (or equivalent organic fertiliser) may be applied at 25–50 g at 6 months, 50–100 g at 12 months, and 200 g at 24, 36 and 48 months. This fertiliser needs to be evenly distributed around the base of the tree, but not touching the stem.

Sandalwood spacing

The distance between sandalwood and host trees (see page 30) is critical to ensure good growth over the entire rotation of the plantation. The minimum spacing of sandalwood trees is 3 m × 6 m or 5 m × 5 m, with large, long-term host trees planted at least every fifth tree within each row. At a spacing of 3 m for sandalwood, the host trees would be spaced every 15 m. It is recommended that each row is 'offset' so that every sandalwood is within 5–6 m of a long-term host (see below).

The number of intermediate host trees will depend on the size of the host tree. In the example below, pigeon pea has been included



Wide spacing in a large-scale commercial planting

in every interspace between the sandalwood trees. Larger intermediate hosts such as coral tree, *Sesbania* and cassis may be spaced more widely—say, every second or third sandalwood tree. In contrast, pinto peanut can be planted across the whole site and, when managed correctly, can fill the entire ground level and support all the sandalwood trees, as well as suppressing weeds.

In commercial plantings, it is important that the spacing between the rows is large enough (at least 4 m) for a tractor to slash between the rows.

A sandalwood planting can be established by direct seeding, or the planting of wildlings or nursery-raised seedlings.

Direct seeding

Good results can be achieved by sowing sandalwood seed directly in the soil at the planting site. Although a direct-seeded site requires high maintenance, seedlings managed appropriately can have greater early vigour than those transplanted from the nursery.

To achieve good survival, the area needs to be managed as intensively as a nursery:

- Keep the cultivated area free from weeds.
- Water seedlings frequently during hot, dry conditions (daily watering may be required).
- Provide the seedlings with shade, if necessary (e.g. an adjacent tree or a frame with coconut leaves).

Planting seedlings

The planting technique that is used can mean the difference between vigorous early growth and seedling loss. It is much better to take the time to plant properly than to rush this important step. Young seedlings enter a period of stress immediately after transplanting, and this stress should be minimised by good planting practices so that seedlings quickly restart leaf and root growth.

Planting seedlings to ensure the best chance of survival

Plant only in soil that has good soil moisture and when the weather is not too hot.

1. Dig hole

Dig a hole that is wider but only slightly deeper than the poly bag.

2. Cut poly bag

Cut the poly bag carefully to minimise disturbance and breakage of the roots.[a]

3. Remove bag

Pick up the seedling and carefully remove the cut poly bag.

4. Plant

Place the seedling in the hole without disturbing the roots.

5. Fill hole

Fill the hole and press the soil in only very slightly with hands. Never stamp the seedling in with feet, as this will break the roots of the seedling.

6. Watering

If the soil from the bag breaks apart and/or the roots are disturbed, it is important to water the seedling immediately to reduce the stress of transplanting.

[a] To reuse the poly bag, follow the steps on the next page.

Planting seedlings and saving the poly bag for reuse

1. Wet

Wet the soil in the poly bag.

2. Hold

Invert the seedling and hold the top of the soil in the palm of the hand.

3. Remove bag

Gradually remove the bag without disturbing the soil or roots.

Continue steps 4 to 6 on the previous page.

Pruning saplings

The carving log, which is the most valuable sandalwood product, is formed in the heartwood of the lower trunk with no branches. Through formative pruning in the first 3–4 years of a tree's life, a farmer can promote a single-stemmed trunk and improve the chances of a tree forming a carving log.

Heartwood development begins in the roots and butt of the tree and progresses up the main trunk. A fork in the trunk will typically slow the rate of vertical heartwood development up the main stems. Therefore, the volume of heartwood in two large branches is typically less than that in an equivalent-sized main stem.

Formative pruning

Formative pruning of young saplings is the most effective pruning method because it removes only a very small amount of productive photosynthetic leaf material. This is achieved by 'pinching' off all growing tips that compete with the central leader.

Regular formative pruning means that there is little (or no) need for heavier pruning with secateurs, loppers or a bush knife.

Form pruning

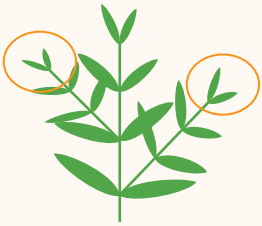
Often a tree is not pruned for a year or more and needs to be pruned to bring it back to being a tree with a single trunk. Form pruning is distinct from formative pruning in that it requires a knife or secateurs. This method is effective for young saplings up to 4 years old, but less effective for older trees. Older trees should be left unpruned, because pruning can introduce heartwood rot or disease.

Formative pruning

1. Identify central leader

The central leader is the main, central growing point of the tree.

2. Identify competing leaders



A side shoot that may compete with the central leader grows from below the central leader.

3. Remove side shoots

Break off the tips of side shoots by pinching them between fingers and thumb.

4. The pruned sapling

The growing tip of only the central leader remains.

Form pruning

1. Identify forked sapling Select saplings with a forked trunk.

2. Remove fork Remove the fork by cutting the unwanted branch with a sharp knife or secateurs.

Form pruning (continued)

3. Identify competing leader A competing leader is a branch growing vertically towards the top of the tree.

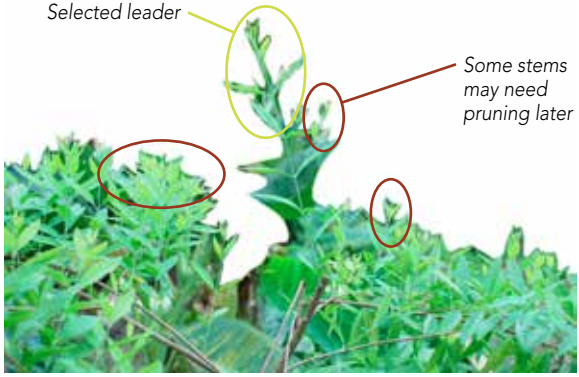
4. Remove competing leader Remove the competing leader with secateurs.

5. The pruned tree

Remedial pruning

Pruning back to a single leader is often necessary when the central growing tip is damaged, possibly by wind, a bird or a falling branch. This can be done immediately after growth recommences.

The images to the right demonstrate multiple competing leaders (brown circles) growing mainly from a single branch after the original leader was damaged by a falling branch (orange circle). Competing leaders are removed with secateurs, leaving a clear leader (green circle). Some stems may need additional pruning later if they begin to compete with the selected central leader.



Correctly pruned

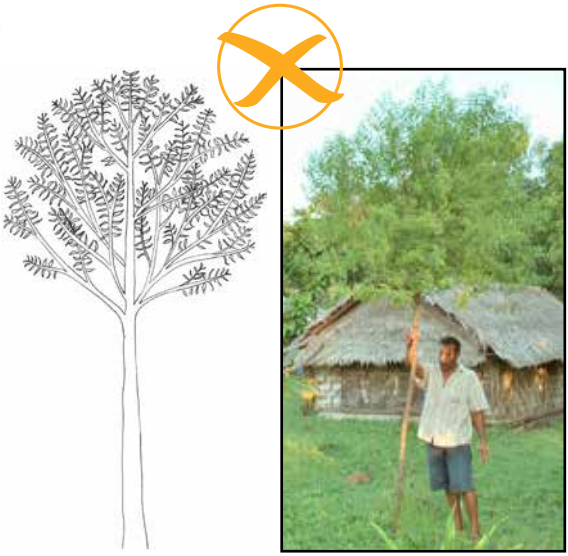
A sandalwood tree that has been correctly pruned has:

- one trunk and a single leader at the top
- a canopy of leaves that extends approximately two-thirds of the height of the tree, providing a good area for photosynthesis, which will ensure a vigorous tree
- a canopy that tapers towards the top, providing good balance (a low centre of gravity).

Incorrectly pruned

An example of a sandalwood tree that has been incorrectly pruned has:

- an inappropriate shape—in this case, a 'lollipop', because too many lower branches have been removed
- a reduced canopy—this reduces photosynthetic capacity and hence the vigour of the tree
- many branches at the top, which make the tree top heavy and unstable, particularly in the wind.



Hosts

The plants with which sandalwood forms haustoria (see page 10) are called hosts. Sandalwood forms haustoria with many different species, but some species (particularly legumes) support greater growth and vigour in the sandalwood. There are three main host types used for cultivating sandalwood:

- pot host—planted in the poly bag after the seedling reaches the 4–6-leaf stage and typically persists in the field for a time after planting
- intermediate host—small tree or large shrub, typically a short-lived (about 5 years) nitrogen-fixing legume that is planted close to the sandalwood
- long-term host—large tree that provides a host for the entire sandalwood rotation; it is planted at a lower density in the plantation and at least 3 m from the closest sandalwood tree.

Sandalwood without a host has yellow leaves and only a few new shoots

Pot host

Alternanthera

Alternanthera nana

Alternanthera nana with sandalwood seedlings in poly bags

Alternanthera is routinely used as the first host for sandalwood in the nursery. Sandalwood growth is more vigorous when *Alternanthera* is planted in the poly bag than when seedlings are planted without it. However, the pot host has to be regularly pruned; otherwise, the *Alternanthera* can smother the sandalwood, eventually killing it. Particularly in wet conditions, the stem of *Alternanthera* can fasten onto the stem of the sandalwood, causing it to rot and die.

Intermediate hosts

Pinto peanut

Arachis pintoi

Pinto peanut is a prostrate perennial shrub. It is a very suitable intermediate host because it is a nitrogen-fixing legume, does not compete with sandalwood for light and effectively suppresses weed growth. The plant propagates naturally by creeping stems (stolons), which can be easily removed to establish new plants.

Pigeon pea

Cajanus cajan

Pigeon pea is a short-lived (3–5 years) leguminous shrub that can be planted by direct seeding. Because of its relatively small size, it can be planted close (1–2 m) to a young sandalwood seedling, while not being so big that it reduces sandalwood growth through competition (see page 39). It is possible to plant one pigeon pea for every sandalwood tree (even at close sandalwood spacing).

Sesbania

Sesbania grandiflora

Sesbania is another short-lived perennial legume that is highly suitable as an intermediate host. It grows slightly bigger than pigeon pea. Although it can be planted close to a sandalwood seedling, it should not be planted at the same density; one *Sesbania* plant should be planted for every 2–3 sandalwood trees.

Intermediate to long-term host

Coral tree

Erythrina poeppigiana

The coral tree may be used as an intermediate host and planted 1–2 m from sandalwood, provided that it is regularly pruned. Alternatively, it may be used as a long-term host planted at least 3–4 m from the sandalwood. The coral tree is a fast-growing legume that can add significant amounts of nitrogen to the soil. It does, however, require regular pruning to maintain a manageable size and ensure that it does not outcompete sandalwood during the establishment years. The prunings are very useful as green manure. The spacing of these hosts should be one for every 2–3 sandalwood trees.

Cassis

Leucaenea leucocephala

Cassis is a good sandalwood host. Although the species is exotic to Vanuatu, it often occurs in wild sandalwood populations. Cassis is, however, very competitive and invasive, and sandalwood growth will be severely reduced if cassis growth is not controlled by heavy pruning and weeding of naturally occurring seedlings. Cassis is a good indicator of suitable growing sites for sandalwood.

Long-term hosts

Brau

Hibiscus tiliaceus

Early observations indicate that brau can be a good host for sandalwood. Some forms of the tree can be unruly, and growth needs to be controlled by pruning. The planting of straighter, more upright forms (man-brau) would be more easily managed in a sandalwood plantation. Brau is an adaptable tree that is used widely as a living fence or hedge in Vanuatu, and may be used to limit entry to the sandalwood plantation by people and cattle.

Oak tree or coastal she-oak

Casuarina equisetifolia

Oak tree has been used widely as a sandalwood host. It provides good side protection without overtopping the sandalwood. Trees grow rapidly, but can be easily controlled with minimal pruning. Spacing needs to be at least 15 m × 6 m to allow sufficient space for the growth and development of the sandalwood. Trimmings and thinnings may be used for firewood.

Bluwota or rosewood

Pterocarpus indicus

Sandalwood occurs naturally with bluwota, and early research indicates that bluwota is a good host for sandalwood. Bluwota is a very large tree, and therefore spacing would need to be at least 15 m × 6 m to ensure that these trees do not dominate the sandalwood later in the rotation. This tree produces valuable hardwood timber and, if managed by pruning, may produce a commercial product after two sandalwood rotations.

Namariu

Acacia spirorbis

Namariu is an excellent host species for sandalwood in Vanuatu, and occurs in the wild on all islands with natural populations of sandalwood. Naturally occurring areas of namariu are an indicator of good sites for growing sandalwood. Namariu is a large, long-lived tree and may be used as a host for more than one sandalwood rotation. If pruned and maintained to produce a clean, straight bole, its timber can be used for local construction and fencing.

Red seed or biza

Adenanthera pavonina

Red seed, a legume, is often found growing in wild populations of sandalwood. Although it has not been used widely as a host, red seed may be a good host for sandalwood in smallholder agroforestry plantings. This tree is large and, like bluwota, can produce high-quality hardwood timber of commercial value.

Citrus (orange, pamplemousse, lime or lemon)

Citrus species

Citrus species are the main non-nitrogen–fixing species recommended as sandalwood hosts. However, if there are not enough citrus trees relative to the number of sandalwood trees, the citrus can be killed by the sandalwood. The use of citrus as a long-term host has the advantage of providing supplementary income during the maturation of the sandalwood trees.

Weeds

Every newly planted seedling requires a weed-free area of at least 1 m^2 for at least 3 years. The most common cause of plantation failure is inadequate weed control during the years of establishment. This means that labour inputs for weed control need to be considered in any new sandalwood planting.

There are three forms of effective weed control:

- Manual pulling is used during the wet season, when conservation of soil moisture is not an issue.

- Mechanical cutting ('brushing') with a bush knife is used during the dry season, when conservation of soil moisture is important.

- Chemical control with grass-selective or contact/knockdown herbicides can be used, but these herbicides are generally too expensive and inaccessible for smallholders. Systemic broad-spectrum herbicides (such as glyphosate) should be used with extreme caution. A systemic herbicide can move through the vascular system of the weeds and into the sandalwood through its haustoria, which can retard growth and potentially kill the sandalwood. Contact/knockdown herbicides may be used if spray drift is adequately controlled.

Mechanical cutting of weeds

Sandalwood thrive with good, weekly weed control

Poorly controlled weeds have swamped any sign of sandalwood saplings

Several vines, locally known as rope weeds, are the most problematic

for establishing sandalwood in Vanuatu. These vines include *Glycine max* (soybean), *Merremia peltata* (merremia or big leaf) and *Mikania micrantha* (mile-a-minute or American rope).


Soybean

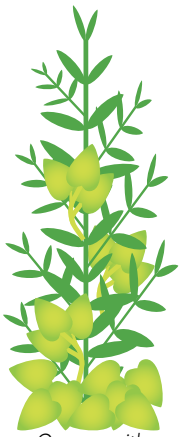

Merremia

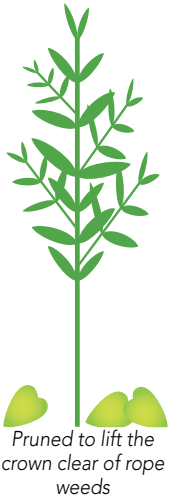

Mile-a-minute overrunning sandalwood

Weed control—pulling and cutting

If manual weed control is used, in weedy sites it is best to clean around the base of each tree every 1–2 weeks.

Rope weeds often need to be cut or pulled (depending on the season) on a weekly basis after seedlings have been planted. This weeding regime needs to be maintained for a number of years, until the trees begin to shade out the weeds. If the rope weeds are too big, they can only be cut. Only small rope plants in the wet season can be pulled out easily.


Overrun with rope weeds


Pruned to lift the crown clear of rope weeds

When rope weeds are a particular problem, the lower branches of the sandalwood may be pruned to 'lift' the crown of the tree away from the ground. This leaves only the trunk for the rope weeds to attach to. Although this might not reduce the frequency of brushing, it can help reduce the time spent brushing during a visit.

Host competition

Sandalwood does not grow well under high competition for soil nutrients, water and light from other plants, including hosts. Although hosts are necessary for good sandalwood growth, most can outcompete sandalwood if they are too dense or their growth is left unchecked. Planting among cassis thickets often leads to stunted sandalwood growth, with pronounced leaf yellowing (see top right image).

Yellowing sandalwood in cassis thicket

Sandalwood competition

Sandalwood growth is severely reduced when it is planted at a high density (spacings less than 3 m × 4 m). Although good early growth can be achieved at such densities, after 3–4 years growth will stagnate as a result of competition between sandalwood trees for soil nutrients, water and light. The two images to the right are severe examples of the effects of high-density plantings. The trees in the centre image are limited by both the high planting density (1.5 m × 1.5 m) and the high number of host trees (oak trees) planted around the sandalwood. The trees in the bottom image are 10 years of age; they are spindly because of a high planting density and lack of available long-term hosts.

Crowded sandalwood surrounded by oak trees

Crowded sandalwood with too few hosts

Diseases

Phellinus noxius

Navwun at the base of a sandalwood trunk

Navwun-infected sandalwood losing its leaves

Phellinus noxius is a fungal root infection (locally known as navwun), which has the potential to kill sandalwood seedlings and trees. The leaves of affected trees will rapidly turn from green to brown before dropping within a few weeks of showing the first symptoms. If the disease is present, a brown skin, which is the fruiting body of the fungus, can be seen at the base of the tree.

The disease is spread through the root systems of affected trees, and infection can therefore rapidly spread to other trees in a plantation.

Phellinus *prevention*

The best way to control *Phellinus* is to prevent infection by:

- avoiding planting in areas where the disease is already established
- selecting a site that is free-draining and on a slight slope; waterlogged soil promotes the growth of the fungus
- removing all living stumps when clearing a new site, because living stumps and roots are the most likely sites for *Phellinus* spores to establish a new colony; stumps should be burned to ensure that they are completely dead
- allowing a short period of fallow after clearing, or ensuring that the refuse and roots of old trees that may harbour *Phellinus* have decomposed
- planting herbaceous plants adjacent to each sandalwood tree (e.g. *Euphorbia tithymaloides* [vinil], *Alpinia purpurata* [red ginger] and *Cordyline fruticosa* [cordyline or nangaria] are said to help prevent the spread of infection, although it is not known how)

- avoiding unnecessarily cutting into the sandalwood tree with a bush knife
- pruning during dry conditions to limit the chance of infection of cut stems and to help the rapid healing of the wound (because sandalwood grows rapidly during the dry season)
- avoiding movement of infected plants into the sandalwood plantation.

Phellinus *control*

Controlling *Phellinus noxius* can be difficult. When a tree becomes infected by the fungus, it is important to reduce its spread to other trees in the plantation by:

- reducing the number of people walking around and touching the affected areas of the tree and then touching other (healthy) trees without washing their hands and feet with soap and water
- removing and burning any fallen branches from the plantation
- cutting a wide circle (5–10 m diameter) around the affected tree with a spade to cut the roots
- disinfecting any tools used on an infected tree by washing them with soap and water, and then placing them in a fire or boiling water before using them on a healthy tree.

At the first sign of symptoms, such as drying leaves, some growers believe that the following control methods help reduce the spread of infection:

- Plant herbaceous plants adjacent to each sandalwood tree (e.g. vinil, red ginger, nangaria).
- Excavate a hole around the trunk of the affected sandalwood tree and place plenty of cut bush lemons in the immediate root zone, as is done in coffee production in Tanna.

If a tree is killed by *Phellinus*, it remains a source of infection for other trees. The dead tree needs to be burned on site to kill any disease remaining in the wood and soil. It is also important to dig and break the roots to reduce movement of the fungus along the roots to other trees in the plantation.

Leaf blackspot

Blackspot

Blackspot is a fungal disease that affects the leaves of sandalwood, particularly in saplings. Although blackspot will not usually kill a tree, it is an indication that conditions are too humid for sandalwood. Blackspot can appear intermittently, and its presence will depend on seasonal environmental variation. If blackspot is persistent for most of the year, this is a good indication that the climate is not ideal for growing sandalwood. The effect of blackspot on growth rates and heartwood formation is not known.

Pests

Sap-sucking insects

Various sap-sucking insects occur on sandalwood trees, including mealy bugs and aphids (order Hemiptera), and also beetle borers (order Coleoptera). These insects are abundant in some localised areas and at particular times of the year, but none is considered to be a serious pest of sandalwood. These insects are more common on weaker or stressed saplings, and rarely occur on vigorously growing trees.

The best method of controlling these pests is to ensure that the sandalwood trees are planted in an appropriate site, with good weed control. Such practices will help to promote tree vigour to ensure that these pests do not become a problem.

Mealy bugs and aphids have been controlled using white oil pesticide; however, the spray should be applied only to the pest (broadcast spraying should not be used), to avoid killing non-target beneficial insects.

Some insects, such as ladybirds (order Coleoptera, family Coccinellidae), can be effective predators of mealy bugs and aphids, and their presence in the plantation should be promoted.


Mealy bugs


Borer beetle

Trees infested with mealy bugs or aphids are often covered in sticky honeydew, which is a sweet by-product of feeding. This honeydew can promote the growth of blackspot, and infestations of ants seeking the available sugars.

Other problems

Grazing cattle

The leaves of all sandalwood species are highly palatable to cattle. Both feral and village cattle can graze young saplings and severely reduce the chance of plant survival. Sandalwood trees may need to be at least 5 years old before they can tolerate cattle grazing.

The only effective method of controlling cattle grazing is to remove or tether the cattle, or fence the plantation. Without such control, cattle grazing can completely destroy a young sandalwood plantation.

Cattle grazing of sandalwood is a particular problem in Erromango, where feral cattle preferentially graze sandalwood. In isolated locations, the fences need to be particularly strong because, without people around, cattle have been known to deliberately break a fence to get to the sandalwood.

Sandalwood damaged by grazing

An adequate fence requires three strands of barbed wire with reinforced end stays and fence posts at 1.5 m intervals.

Seed predation by birds

The sweet flesh of sandalwood fruit is a prized food for many types of birds. Fruit consumption by birds is the main reason that not enough seeds are collected for planting or sale. The problem is more pronounced in isolated locations, because birds are left undisturbed for long periods and it is difficult for a farmer to collect seeds regularly.

Positioning new plantings close to village or garden areas will help the farmer maintain the trees and limit seed loss from consumption by birds.

A sandalwood tree that is a particularly valuable source of seeds may be protected by using a net over its canopy or branches. Another method, which has a limited effect, is hanging shiny objects in the branches of the tree to distract and frighten the birds. Scarecrows can also be effective. However, many birds are quick to see through these tricks, so it is important to place these objects in the plantation only as the seeds mature and quickly remove them after the farmer has finished harvesting the seeds.

Fire

Sandalwood does not tolerate fire and will die even when exposed to a low-intensity fire. Fuel loads in sandalwood smallholdings should be kept to a minimum by removing wood debris from the site. During dry periods, care should be taken to limit people lighting fires close to and upwind of the sandalwood plantation.

Sandalwood should not be planted in areas prone to wildfire (e.g. near dry bamboo). Fire-resistant tree species (such as mango) can be planted as a buffer to limit the spread of fire to the plantation.

Cyclones

Ideally, sandalwood plantings should be established in areas with good wind protection, to limit the damage caused by cyclones. The use of windbreak trees known to be tolerant to high winds, such as whitewood (*Endospermum medullosum*) and oak, can reduce the wind speed in a sandalwood planting. Sandalwood trees tend to break under cyclonic winds, but can recover through new growth from the damaged stem.

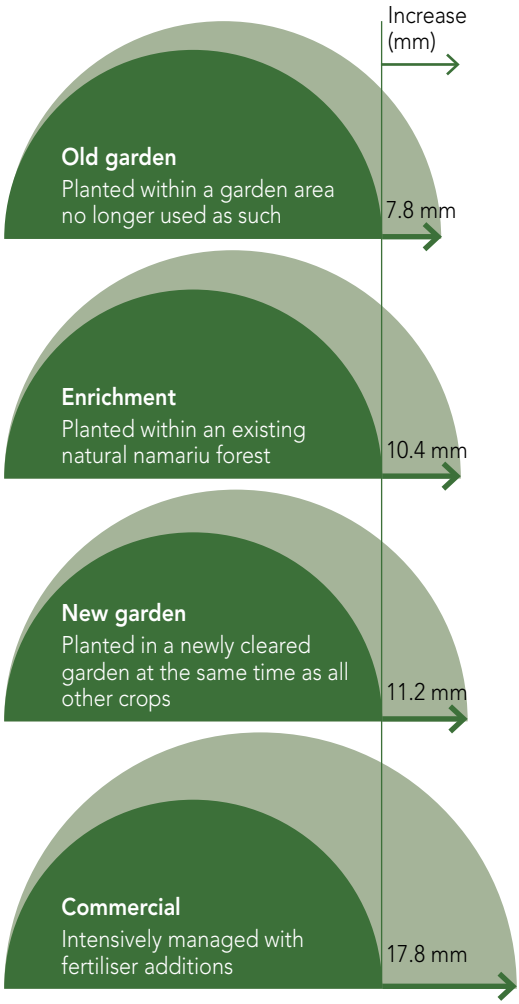
Heartwood and harvesting

Tree growth rates

The value of a sandalwood tree is largely determined by the weight of its heartwood and the concentration and composition of its oil. Determining the rate of heartwood development in a sandalwood tree is important because it will affect the length of its commercial rotation. The weight of the heartwood is invariably limited by, or dependent on, the diameter of the trunk.

Basal trunk diameter (10 cm above ground level) was measured for 1,685 sandalwood trees planted under four management regimes (see diagram for definitions) across five islands (Santo, Malekula, Efate, Erromango and Tanna).

Sandalwood grown under commercial conditions had significantly higher growth rates than sandalwood under all other management regimes, largely due to the attention to host tree planting and addition of fertiliser. However, there were no statistical differences between new garden and enrichment regimes in the mean growth rate in basal diameter for these two planting types combined, which was 10.8 mm per year. Trees planted in old garden areas had significantly lower growth rates than trees grown under other management regimes. Although 93% of the data were collected from trees aged 10 years and under, these differences in early growth rates are likely to persist in later years.



Average annual increase in basal trunk diameter (at 10 cm above ground level) under various management regimes

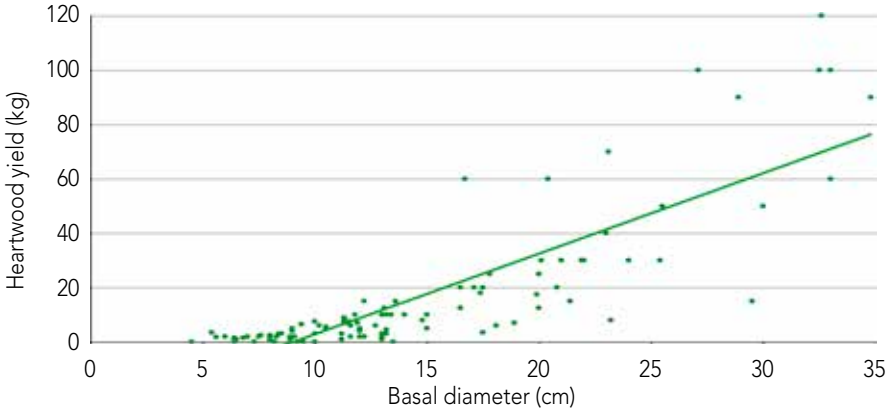
Heartwood development

Many experienced sandalwood farmers in Vanuatu believe that the rate of heartwood development is strongly associated with soil type, rainfall and the level of sun exposure on the canopy of the sandalwood tree. The most experienced farmers say that sandalwood develops heartwood rapidly when it is grown in a shallow soil or soil with a high level of stone inclusions, together with a distinct annual dry period and exposure to full sun. The expected period for harvest under these conditions was 15–20 years, but may be as much as 30–40 years for trees growing in areas of deep fertile soil, high and evenly distributed rainfall throughout the year, and a shaded canopy.

Sandalwood harvesting

The time needed to develop enough heartwood for harvest will vary between trees and growing environments. Tree size is a good indication of when the tree is ready for harvest. In Vanuatu, the minimum size at which a tree can be harvested is a trunk diameter of 15 cm at breast height, which corresponds to a tree with a basal diameter of about 20 cm. Under good growing conditions, a tree of this size is approximately 15–20 years old.

Oil is particularly concentrated in the roots and butt of the sandalwood tree; therefore, the stump and roots need to be dug out to gain maximum saleable value from the tree. Heartwood is present in the branches of older trees, but is unlikely to be in the branches of planted sandalwood with a rotation of 15–20 years.



Relative level of heartwood development among differently sized trees sampled in Tanna and Erromango


1


3


2


4


5

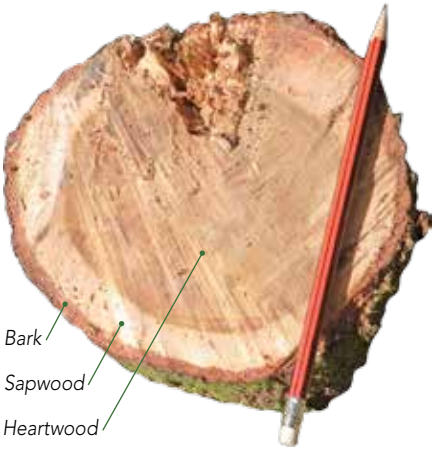

8


6


7

The images show how sandalwood is harvested:

1. **Measure tree trunk** at breast height to identify suitable trees.
2. **Reduce canopy** with a bush knife to collect branches and make felling less damaging to nearby trees.
3. **Collect and weigh** cut branches with a portable scale.
4. The stripped tree is ready for felling and digging out.
5. **Fell trunk** and cut into logs using a chainsaw before **or** after digging out the roots.
6. **Dig out roots** using shovels.
7. The exposed roots ready for cutting and collecting.
8. Cut roots ready for weighing.



Desapped heartwood

Removing bark and sapwood with a bush knife

Sapwood chips

Preliminary processing

Sandalwood is sold by weight. Before selling it, the only requirement is to remove the sapwood from around the heartwood. This is usually done by gradually cutting the sapwood away with a bush knife. This process results in two waste products: pure sapwood chips and second cutting chips (2CC), which are both used in the manufacture of incense. The 2CC are chips that retain some heartwood.

Sale

The minimum price paid for sandalwood heartwood is set each year by the Vanuatu Department of Forests. Since 1990, the minimum price has been increasing at an annual rate of 10%—consistently above the consumer price index of 2.6% over the same period. Recently, increased competition in Vanuatu has meant that the actual prices paid are often above the minimum price. Sandalwood buyers will generally collect and pay for sandalwood on the farm.

Prices for sandalwood sapwood vary from year to year—for example, in 2010, the price of sapwood in Vanuatu ranged from 20 to 50 vatu (US$0.20–0.50) per kilogram. The price of 2CC will depend on the proportion of heartwood attached to the sapwood chips.

At the sapwood prices in 2010, it is difficult to make a profit from harvesting immature trees purely for sapwood. However, there is some value in saving the sapwood (i.e. chips from the initial desapping and debarked branches) and 2CC by storing them separately in large copra-type bags, keeping them dry and waiting until there is enough for sale.

For a hectare of planted sandalwood (at 3 m × 6 m spacing), approximately 550 trees may be available at harvest.

Heartwood logs ready for sale

Producing oil in a still

If we assume an equal volume of sapwood and heartwood (18 kg each) and 1.5 kg of 2CC, then the volume of sapwood and 2CC would be approximately 10 and 0.8 tonnes per hectare, respectively.

The price of sapwood and 2CC is relatively low and much more sensitive to oversupply than sandalwood heartwood. As the decision to sell the two lower grade products is up to the grower, any planting venture should not include these products in its calculations.

Sourcing capital

Joint-venture plantings

Joint-venture plantings typically involve a partnership between a smallholder and an investor. The investors entering into these joint ventures in Vanuatu range from wage earners in the urban centres to foreign investors. The success of these ventures depends largely on an equitable agreement and regular communication between the partners. With improved mobile telecommunications in Vanuatu, it is now possible for partners to communicate more regularly than before.

Joint ventures involving foreigners have had mixed success; the most successful have been those where a solid relationship was formed before entering any contractual arrangements. Joint ventures that involve close family members are generally successful.

Joint ventures may involve the investor providing tools (chainsaw, fencing, spades, knives, etc.), seedlings and/or poly planter bags, as well as money to employ local labour to assist with clearing, planting and maintenance. The landowner provides the land and agrees to manage and maintain the trees for the entire

rotation. At maturity, each partner gets half the trees and has the right to market their own sandalwood.

Less ambitious arrangements include those where the investor provides the smallholder with poly planter bags and small tools. After five years, an inventory of the planting is completed and the planting is registered as a plantation with the Department of Forests. The investor provides a small retainer each year from year five to harvest, and the smallholder agrees to sell their sandalwood to the investor at market price.

Sandalwood as collateral

With a rotation of at least 15 years before making any return, the economic benefits of plantation sandalwood may only be realised well into the future. However, sandalwood can be used as security for accessing credit services. Using sandalwood in this way can help to bring forward the benefits of planted sandalwood to support business opportunities and stimulate local economic activity.

Smallholders have expressed interest in using their immature sandalwood plantings as collateral for securing a personal loan. Vanuatu's Personal Property Securities Act (No. 17 of 2008) allows crop assets to be used as security for loans, and the National Bank of Vanuatu can use an immature sandalwood planting as security for microfinance. However, the bank often deems a smallholder as unemployed and therefore the likelihood of that smallholder securing such a loan is limited.

Other financial institutions in Vanuatu will not currently consider sandalwood at any stage of maturity as security for loans. The reasons given by these institutions are the high risks of these assets to natural disaster, the logistical constraints of liquidating these assets upon default, and many smallholders not having a reliable source of income to service such loans.

Frequently asked questions

Will the prices of sandalwood decline with more plantations?

The demand for sandalwood has been increasing over the past decade, but supplies from natural forest have dwindled. There is currently much greater demand than supply for all sandalwood products. Sandalwood planting in Vanuatu has been increasing over recent years and is likely to continue. The current global plantation resource will only partially replace wild-harvested trees and, even with new plantations being established, it is likely that demand will outstrip supply. Consistent prices for sandalwood products are expected in the short to medium term (15–30 years). The long-term price (30 years plus) is dependent on the planting activity of other countries, such as Australia, India and China.

How long do I need to grow the trees before they can be sold?

Heartwood development varies between trees and sites. A tree planted on an appropriate site (see page 19) may be harvested after 15 years. In Vanuatu, variation between trees in a plantation means that sequential harvesting may take place from 15 to 25 years. Trees that are planted on inappropriate sites may develop heartwood very slowly and take 30 years or more before they can be harvested.

I only have a few sandalwood seeds—what should I do?

Many people without sandalwood trees have found it difficult to source seeds. When starting to plant sandalwood, it is best to plant the first seedlings in an area that is visited often. Planting a few trees in the village area adjacent to the house is a good way to learn about growing the tree, because you will be able to observe it daily and tend to it when required. Once the trees planted in the village mature, the seeds may be easily collected before the birds consume them.

Are coconut plantations suitable for sandalwood production?

There are not many examples of combined sandalwood–coconut agroforestry systems in Vanuatu. However, given the prevalence of coconut plantations, interplanting with sandalwood could provide additional income to such a production system. It is recommended that sandalwood is planted, along with host species, at least 3 m from the nearest coconut palm (see page 20) and that only small numbers of trees are planted initially, to determine the suitability of the site. If sandalwood grows well under these conditions, more sandalwood could be planted.

Further reading

For other relevant information regarding the production of Vanuatu sandalwood, please refer to:

Thomson L.A.J. 2006. *Santalum austrocaledonicum* and *S. yasi* (sandalwood) ver. 2.1. In 'Species profiles for Pacific island agroforestry', ed. by C.R. Elevitch. Permanent Agriculture Resources: Holualoa, Hawai'i. Accessible at <www.agroforestry.net/tti/Santalum-a-y-sandalwood.pdf>.

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