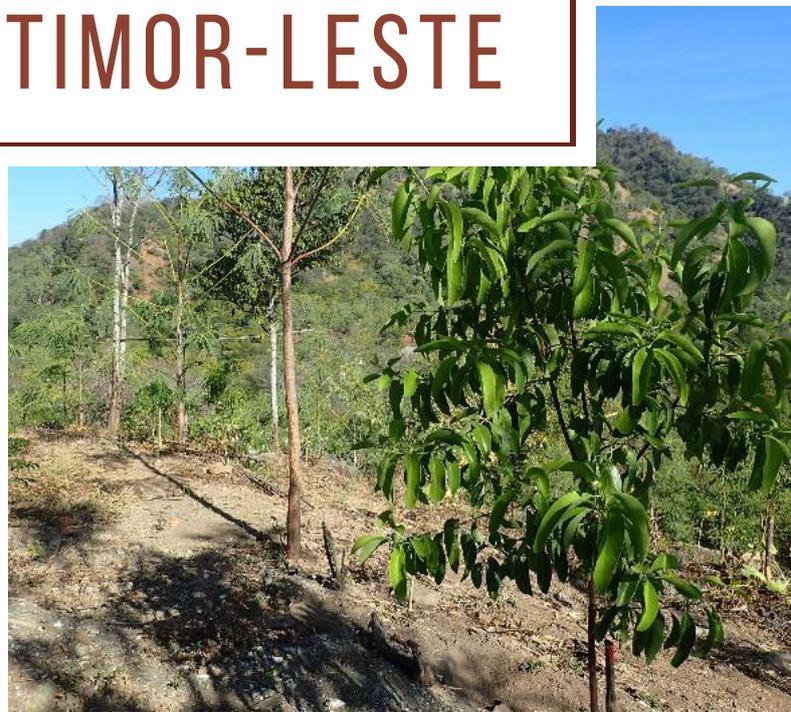




SANDALWOOD PRODUCTION AND HOSTS IN TIMOR-LESTE



THE UNIVERSITY OF
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Australian Government
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Front cover top: MAF and AI-Com staff with a young sandalwood tree at the MAF plantation, Aidabaleten, Bobonaro. Front cover bottom left, bottom right: MAF Sandalwood plantation at Aidabaleten, 12 months after planting. Rob Williams. Left: Sandalwood flowers.

FOREWORD



Sandalwood trees dotted in the landscape near the church in Soibada. Rob Williams.

The history of sandalwood and the history of Timor-Leste have been entwined for hundreds of years. The earliest visitors to our island were following the scent of the sandalwood tree which covered its hills.

Although sandalwood is a native to this island, and grows naturally in our forests it still has many secrets. One secret recently revealed was that sandalwood trees do not grow best when they are alone. Sandalwood trees rely on other trees around them to thrive and grow well.

Knowing that sandalwood is a parasitic tree, allows us to better design ways to plant and re-establish groves of sandalwood through-out Timor. This new book will act a reference on what trees are suitable to be planted with sandalwood to ensure their healthy growth and subsequent survival.

I would like to thank ACIAR, UWA and their agencies in producing this book, and encourage all who are interested in growing sandalwood in this country to learn important lessons from its pages.

Eng. Estanislau Aleixo da Silva
Minister of Agriculture and Fisheries
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1. INTRODUCTION

In Timor-Leste, sandalwood (*Santalum album*) occurs primarily in monsoon dry mixed tropical forest. This vegetation is particularly adapted to a distinct and extended dry season occurring between April and December in the northern part of the country and between August and January in the southern part of the country.

The associated vegetation is important to support the growth and development of sandalwood trees, due to the hemi-parasitic nature of the species. *S. album* belongs to a unique group of plants that form parasitic root connections with other plant species. The parasitic organs in sandalwood are found in their roots, which have specialised structures known as haustoria (Figure 1). These haustoria penetrate the roots of nearby trees and shrubs and absorb water and nutrients from them. The plants with which sandalwood forms haustorial connections are collectively known as 'hosts'. While these connections are important to the growth and survival of sandalwood, sandalwood trees also have a capacity to exploit soil resources through its own roots. This is the reason the genus is referred as 'hemi'-parasitic, as they derived part of their requirements from the parasitic connections, while the remaining is derived from the soil.

With numbers of sandalwood trees dwindling in the wild, there has been growing interest among people to plant the species as a commercial agroforestry crop. Owing to the hemi-parasitic nature of sandalwood, they must be grown in combination with other tree species to provide accessible hosts. Hosts that can perform well in the proposed agroforestry environment will have a capacity to support the sandalwood. Sandalwood trees also have a general preference to parasitise leguminous trees with a capacity to fix atmospheric nitrogen.

The aim of this document is to provide an account of the main tree species that already grow and perform well in the environment where sandalwood plantations are expected to be established in Timor-Leste. This account will include species observed in the natural, agricultural and domestic areas of Timor-Leste at an altitude of between 0 and 800m at sea level.

Left: MAF researchers Luis Patrocínio and Ida Pereira measure the diameter of a sandalwood tree in Clacuc, Manufahi.



Figure 1: Sandalwood root forming haustorial (parasitic) connection with root of another plant (host). The narrow orange coloured root is sandalwood and the larger yellow coloured root is the host species. They are joined by the small round haustorial structure, which allows sandalwood to draw nutrients and water from its host.

2. HOST TYPES AND PURPOSES

2.1 HOST TYPES

There are three main host types used for cultivating sandalwood:

- **pot host** – a herbaceous low growing plant that is easy to propagate, which is planted in the poly bag once the seedlings attain the 4 - 6-leaf stage. The size of the pot host needs to be maintained by pruning to avoid it outcompeting the sandalwood. Ideally the pot host should persist for the first few months after out planting;
- **intermediate host** – a small tree or large shrub, which is typically a short-lived (about 5 years) nitrogen-fixing legume that is planted close (1-2 m) to the sandalwood. The intermediate host supports rapid early growth of the sandalwood. The size of the intermediate host will influence the distance it is planted from the sandalwood , and it may need to be pruned to ensure it does not outcompete the sandalwood
- **long-term host** – a large tree that provides a host for the entire sandalwood rotation. It is planted at a lower density in the plantation from 4-8 m to the closest sandalwood tree. Like the intermediate host, wider spacing is required for larger trees.

2.2 PLANTING PURPOSE

Planting sandalwood is a long-term investment and requires patience over the rotation of 20-25 years. Returns can be made from harvesting:

- crop plants
- intermediate hosts
- long-term hosts
- sandalwood

Designing an appropriate layout for a sandalwood planting will benefit from prioritising the purpose of the planting. For instance if the primary purpose of the planting is to provide cattle fodder, then the density of sandalwood can be reduced to limit their influence on fodder yields (though parasitic depression on yield).



Similarly if the focus is on crop production then the density of fast growing intermediate hosts (with roots that rapidly occupy the site) may be reduced (section 3.1)

3. HOST SILVICULTURE

Host species silviculture is a critical aspect to a successful sandalwood plantation. The growth and size characteristics of the host species will influence their optimal spacing (i.e. the distance between the sandalwood tree and the host species), arrangement and management.

The ratio, spacing and arrangement of hosts and sandalwood should aim to:

- promote haustorial connections between hosts & all sandalwood trees,
- maximise the number of different host species available to the sandalwood.
- provide protection from exposure to sun/heat,
- allow room for sandalwood to extract soil resources (water & nutrient),
- permit sandalwood to intercept direct sun for part of the day.

As the planting matures, if any of the above become limiting there may be need for management interventions. For instance, if over time the host trees may become dominant over sandalwood trees.

3.1 PLANTING CONFIGURATION

Correct tree spacing and management will help to maximise the growth of the sandalwood trees over their entire rotation. There is no definitive prescription for the spacing of sandalwood trees or their hosts in plantations in Timor-Leste. The plantation design (grid layout) will be influenced by the host species being used and their growth habits. The choice of host species (Section 4) will be influenced by local availability and adaptability to the intended planting site. Different site-specific species configurations could be used in this style of grid planting, depending on local conditions (i.e. edaphic, climatic, aspect, growing space), host species availability and grower objectives.

Left: Sesbania grandiflora (Ai-Kale/a) is a very good intermediate host for sandalwood trees. Tony Page.

In Timor-Leste a 5 m x 4 m grid layout should provide sufficient space for all the plants within a commercial sandalwood planting. Sandalwood growth can be reduced when it is planted at high densities (i.e. spacing less than 3 m x 4 m). Although good early growth can be achieved at such densities, growth can stagnate after 3 – 4 years as a result of intense competition between the sandalwood trees for soil moisture and nutrients, and light.

In a 5 x 4 m configuration, the sandalwood trees are spaced at 4 m intervals along each row, with a spacing of 5 m between each row (inter-row). A 5 m inter-row spacing will provide adequate space for vehicle access for management interventions and harvesting of both sandalwood trees and other commercial trees that are incorporated into the plantation as host species. A 5 m inter-row spacing should permit growing of crops between the rows for approximately 3–4 years. If crops need to be grown for a longer period then a wider inter-row spacing of 6–8 m could be considered.

The 4 m spacing between each sandalwood tree provides space for the planting of intermediate host species between the sandalwood. In this document we propose two distinct configurations **(a) mixed species rows** (Figure 2) and **(b) alternate species rows**. These configurations can help growers visualise the requirements for establishing a sandalwood planting. These can be established as recommended or modified according to the planting purpose (Section 2.2)

3.1.1 ‘Mixed species row’ plantings

A ‘mixed species row’ configuration can be used to maximise the number of sandalwood trees, while still maintaining good access to host trees planted on site. This configuration gives a 13% greater sandalwood stocking (375 trees) compared with an ‘alternate species row’ configuration (333 trees) for a 4 x 5m grid.

3.1.2 ‘Alternate species row’ plantings

The ‘alternate species row’ configuration is a more simplified arrangement, potentially making management of both sandalwood and hosts more efficient. In these configurations the sandalwood trees and hosts are planted in individual rows, which are alternated at a ratio of 2:1 sandalwood to hosts. Intermediate host species can potentially be planted in every row (between the sandalwood and host trees). A reduction in the stocking of intermediate hosts may be considered when crop production needs to be maximised. This reduction can be implemented by reducing the frequency of intermediate hosts within the rows or confining intermediate hosts to the sandalwood rows only.

The ‘alternate species rows’ configuration depicted in this report can be modified to include host rows of multiple host species. This host row can also potentially incorporate sandalwood trees at low density (one sandalwood every 4–5 host trees). The final spacing of host trees will be guided by their growth habits (described below) and environment the trees are growing. For instance, if large host trees with spreading canopies (eg. *Acacia mangium*) are used then spacing along the row may be increased.



3.2 PLANTING MANAGEMENT

While hosts are essential for good sandalwood growth, most can outcompete the sandalwood trees if they are planted at densities above those described above, or if their growth is left unchecked. Ongoing plantation monitoring and adaptive management (i.e. silviculture) is therefore essential to balance the benefits of the host species and their potential to induce competitive stresses on the sandalwood trees.

For some small and short-lived shrub hosts, there may be no management needs as these species will naturally die out, particularly once surrounding trees overtop them. For others, pruning and thinning may be required. Pruning may be used to prevent the overtopping of young sandalwood trees, with the pruned materials being used for fodder or mulch/green manure. For some species, the entire shrub/tree may be pruned back to ground level and allowed to regrow via coppicing, or alternatively all upper branches may be pruned to facilitate stem pollarding. Form pruning should be used to maximise the potential for high-value timber harvests from some long-term host species. As the sandalwood trees develop, some thinning of host trees and shrubs may also be required.

Left: Sandalwood seeds. Rob Williams.

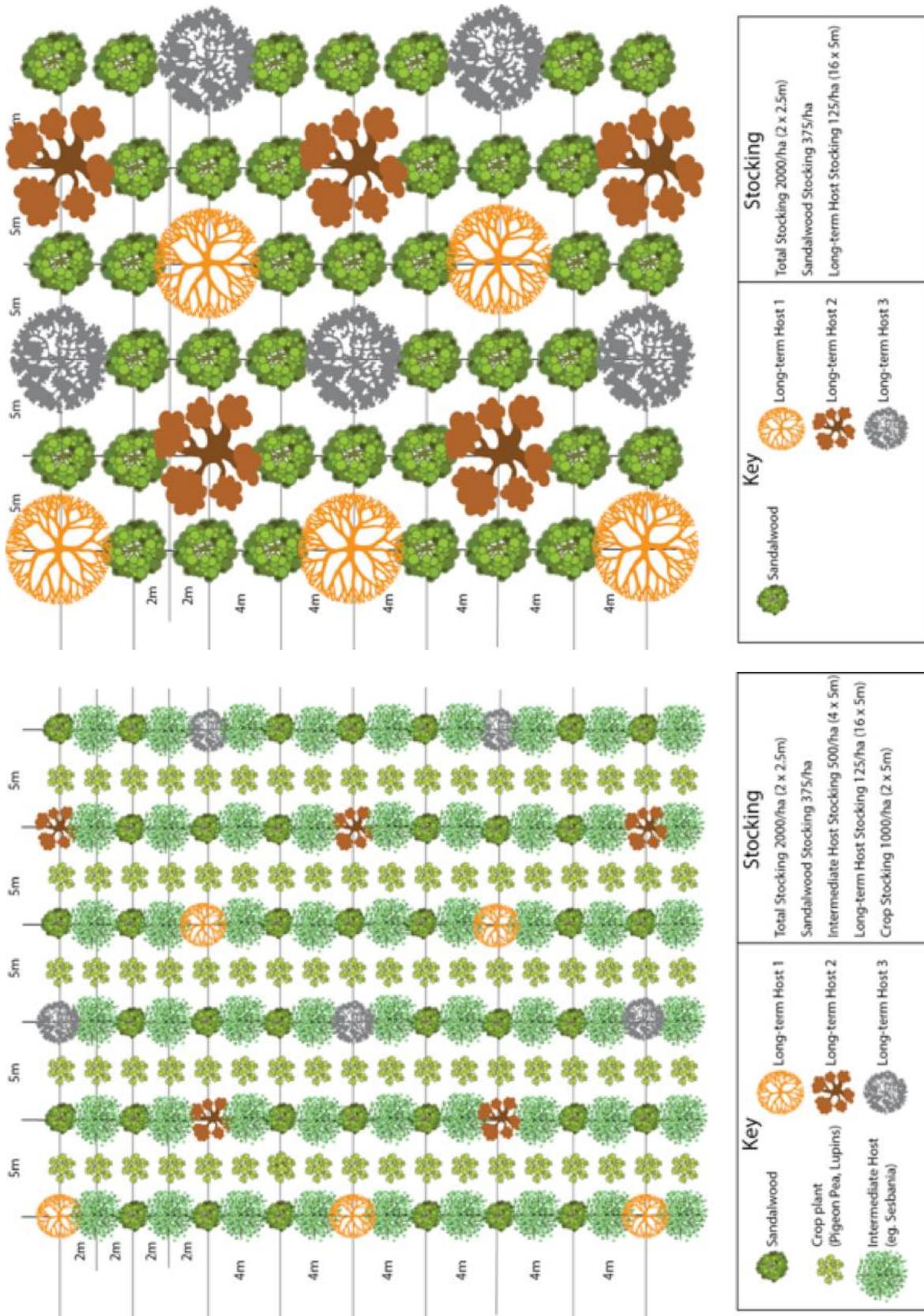


Figure 2: An example of a grid layout for a 'mixed species row' sandalwood planting. Representation of the first 5-10 years (left) and 10+ years (right). Persistence of crop plants is 3-4 years and intermediate hosts 5-10 years.

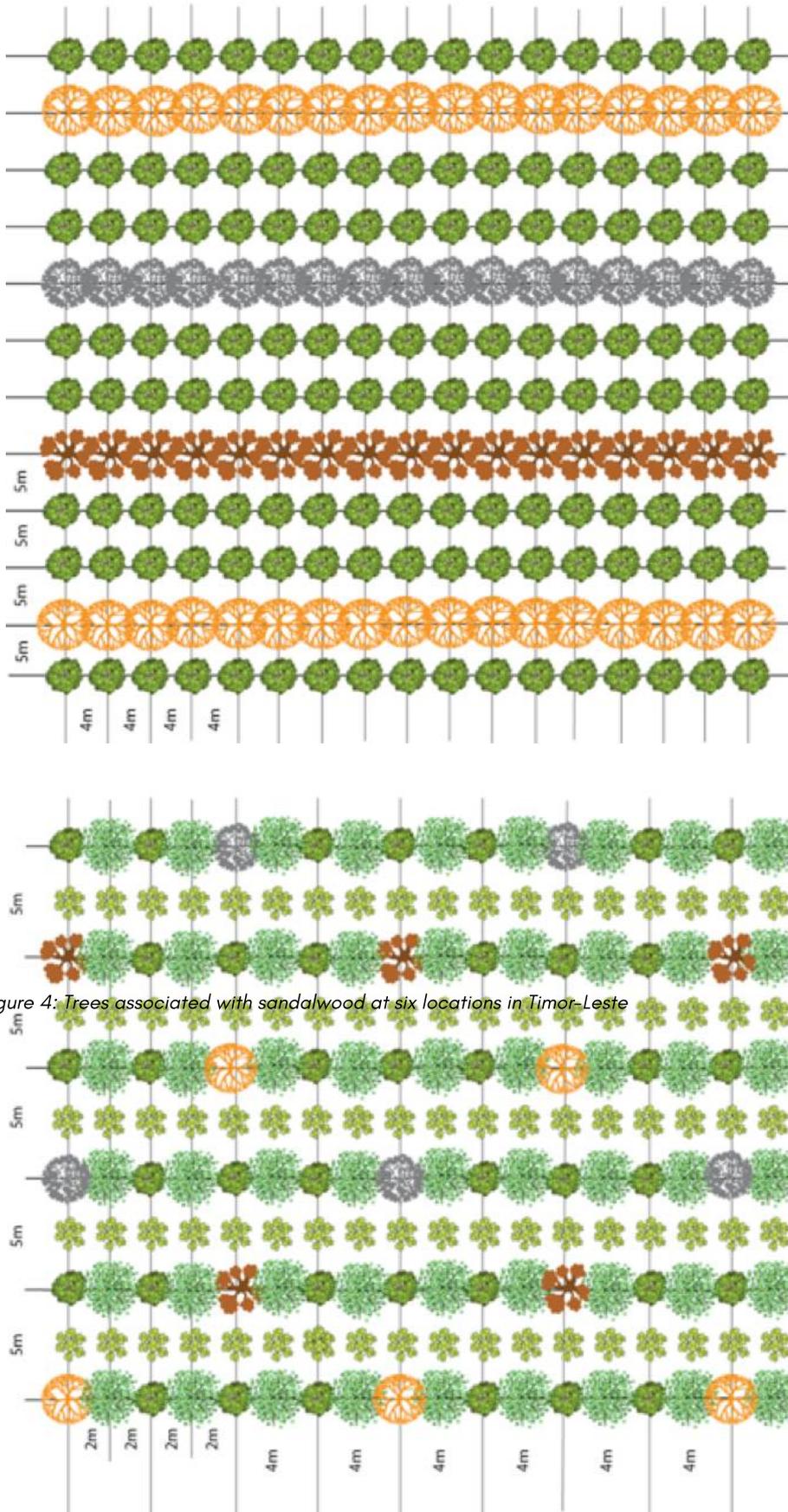


Figure 4: Trees associated with sandalwood at six locations in Timor-Leste

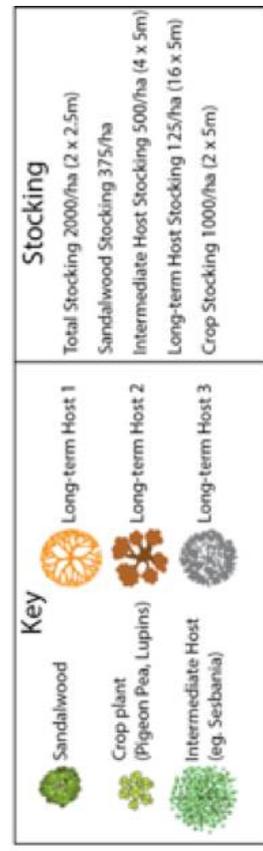
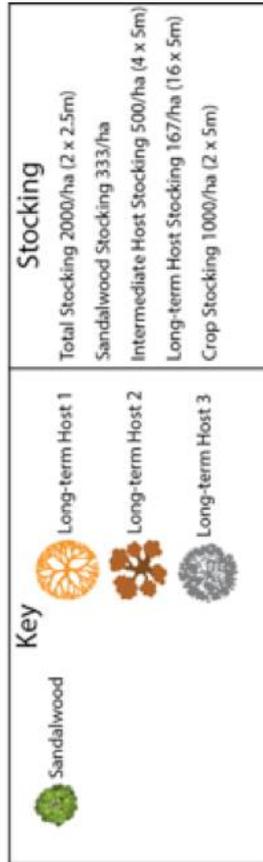


Figure 5: An example of a grid layout for a 'alternate species row' sandalwood planting. Representation of the first 5-10 years (left) and 10+ years (right). Persistence of crop plants is 3-4 years and intermediate hosts 5-10 years. * note the change in scale between the two images to demonstrate the incorporation of three hosts in the system.

4. HOST PLANTS

Sandalwood trees can prefer some hosts over others (i.e. nitrogen fixing legumes), but it is important that the host tree is suited to the target environment of the planting. Ideally the host species are selected based on their suitability as a host as well as to potentially provide another commercial product and/or environmental service(s). In short - the host trees should be very easy to propagate and grow, which will allow the grower to focus on looking after the sandalwood. The different functions of different types of hosts are reviewed in this section, and specific host profiles are provided in Section 5. It is important to note that with all host species, maintenance of a plant free zone immediately around the base of the sandalwood will promote early growth. For the pot host *Alternanthera*, allow a 5 cm radius (Section 5.1.1), and for all other plants a minimum of 10 cm radius.

4.1 Annual crops

It has been demonstrated that the value of a sandalwood planting is greatly improved through the incorporation of annual crops during the establishment phase. Incorporation of annual crops provide the following advantages:

- **Efficiency of labour** - the act of tending crops benefits the sandalwood through reduced weed competition. The process of manual weeding practiced in smallholder agriculture improves the environment for the root growth of the sandalwood trees.
- **Improved income generation** - crops capitalise on the site preparation and provide early returns from this investment. This early income is very important to offset the long-term costs of maintaining the sandalwood.
- **Early host availability** - annual crops can support the health and vigour of the young sandalwood seedlings by providing hosts. Leguminous crops are the most suitable for this purpose.
- **Protection from exposure** - annual crops that have an erect habit can provide the sandalwood protection from the elements, particularly the sun and heat. Those crops that persist during the first dry season offer the best protection.

The leguminous food crop *Cajanus cajan* (pigeon pea) would be considered to be the most compatible species for planting with sandalwood since it (1) is an exceptional host, (2) provides good shade protection for young seedlings and (3) is a recognised food crop in Timor-Leste. Common food crops such as maize (*Zea mays*), peanut (*Arachis hypogaea*), cassava (*Manihot esculenta*) and papaya (*Carica papaya*) can all be grown in combination with sandalwood.

The use of large leaf herbaceous crops such as *Colocasia esculenta* (taro) and *Musa* spp. (banana) can be used, provided they are planted in the middle of the inter-row. Maintenance of adequate distance is important to avoid both root competition and disturbance of the sandalwood crown. Banana should only be used towards the end of the 'agricultural period' once the sandalwood trees are well established.



Groundcover crops can also be considered as they are potentially very good sandalwood hosts. The prostrate and smothering habit of groundcover crops can offer efficiencies in weed control and potentially provide a host. Some species can have high vegetative vigour and have a tendency to grow all the way to and, for climbing shrubs, ascend the stem of the sandalwood seedlings. Maintenance of a 10–20 cm plant free radius around the sandalwood will help to limit problems associated with excessive competition. Leguminous ground cover crops such as *Glycine max* (Soybean) and *Vigna radiata* (Mungbean) have a very short growing season and are harvested before they could provide any host support for the establishing sandalwood seedlings.

Sweet potato (*Ipomoea batatas*), pineapple (*Ananas comosus*) and *Citrullus lanatus* (water melon) have been used effectively as a companion crop for sandalwood. While they are not necessarily a superior host plant, they provide an efficient means to maintain a weed free site. For this crop it is essential to maintain a weed free area of 20cm radius around the sandalwood seedling.

4.2 Forage species

Sandalwood agroforestry systems that use fodder tree legumes (FTL) are very much suitable for application in Timor-Leste. The two most commonly used FTLs are *Sesbania grandiflora* (ai-turi) and *Leucaena leucocephala* (ai-kafe). Both these trees have proven to perform well as sandalwood hosts. The short-lived *Sesbania* can be incorporated as an intermediate host while *Leucaena* is more suitable as a long-term host. Systems that use both these species can be recommended, although restricted to cut-and-carry approach only. The primary purpose (Section 2.2) of the planting needs to be determined before deciding on spacing and arrangement. Native forage legumes/trees can also be considered, particularly as a back-up source of forage during times of drought. The most suitable native forage legume is *Acacia leucophloea* (ai-maró), which can also potentially provide durable timber for local construction. *Garuga floribunda* is another local species suited to dry environments that is used as a living fence with the leaves used as cattle fodder. *G. floribunda* could potentially be used as a long term host within a sandalwood system. *Erythrina* (*Erythrina poeppigiana*) is used as a living fence, coffee shade tree, and fodder species. It can also be used as a host for sandalwood provided the canopy is not allowed to

Left: Sandalwood seedlings. Rob Williams.

dominate. Therefore consideration for adequate spacing or canopy pruning would be required to use this species as a host. Herbaceous forage legumes can be considered where cattle movement can be controlled within the planting. Control of cattle is required to limit the physical damage and trampling of sandalwood and host trees in the system. Cattle may be controlled by tethering or establishment of barriers and fences. Portable electric fencing may be an efficient method of control, but would require an initial capital outlay. 'Species row' layouts (Section 2.4.1) with wide spacing between rows, would be an appropriate configuration for systems that utilise forage legumes and controlled grazing. Species that may be considered include *Arachis pintoi* (pinto peanut), *Stylosanthes* spp. (Stylo), *Clitoria ternatea* (butterfly pea) and *Lablab purpureus* (lablab). It is best to avoid climbing vigorous perennial legumes such as *Centrosema*, *Mucuna puriens*, *Calopogonium* and some *Desmodium*, unless there will be well managed grazing of the site.

4.3 Horticultural (fruit) trees

Fruit trees can potentially be used as long term hosts although there is little information related to the suitability and performance of different fruit trees. Citrus species are demonstrated to perform well as sandalwood hosts. Citrus is a diverse genus with many suited to tropical production including. Citrus is not widely planted in Timor-Leste, but pomelo (*Citrus maxima*) may be a locally available citrus that could be used as a host in sandalwood systems. The Global Climate Change Alliance in Timor-Leste (GCCA-TL) has established sandalwood systems in combination with various fruit and nut trees including cashew (*Anacardium occidentale*), mango (*Mangifera indica*) and avocado (*Persea americana*).

4.4 Timber trees

Timber trees are well placed to be incorporated into sandalwood systems owing to their potentially low maintenance, deep root systems and longevity. It is possible that some timber trees could be used for two sandalwood rotations. Suitable timber species found within the environmental range of sandalwood in Timor-Leste include *Pterocarpus indicus*, *Acacia mangium*, Philippine teak (*Gmelina arborea*). *Acacia mangium* is an excellent host provided when established at low density in combination with sandalwood. If *A. mangium* is planted at close spacing its canopy will dominate the sandalwood. While teak (*Tectona grandis*) is a widespread plantation species in Timor-Leste, it is not considered to be a suitable host species owing to its aggressive root system and dominant canopy. Local fruit/nut species that may be considered include *Canarium indicum*, *Pometia pinnata* (ai-maras), which are also timber species.

4.5 Ornamental trees

In certain circumstances it may not be possible to source planting material for suitable host trees. Under these circumstances growers can assess the suitability of trees that grow in the domestic landscape (i.e. garden and agricultural areas). Ornamental trees often have a number of traits making them potential candidates for sandalwood hosts, including:

- Ease of propagation and not necessary to produce in a plant nursery. Some examples include self sown, direct seeding, wilding transplant, truncheon cutting.



- Adaptability to a wide range of soil types and climates.
- Do not require supplemental irrigation.
- Rapid growth.
- Pest and disease tolerant or resistant.
- Tolerant of drought and poor soil nutrition.

Some ornamental trees do however have features that are not conducive to being a good sandalwood host including:

- Aggressive root systems that outcompete the sandalwood: e.g. *Albizia falcataria*, *Artocarpus altilis*, *Mangifera indica*
- Spreading crowns that dominate the site and shade the sandalwood (*Samanea saman*, *Delonix regia*, some *Albizia*).
- Can be carriers of disease (even though they are tolerant themselves) (*Delonix regia* can carry *Phellinus* root rot).
- Can be weedy and increase labour inputs for weed control.

Table 1. Ornamental trees identified in Dili and small towns in Timor-Leste

Species	Host Suitability	Common name	Tetun
<i>Artocarpus altilis</i>	No	breadfruit	kulu kisa
<i>Bougainvillea</i> sp.	No	bougainvillea	ai-trapadeira
<i>Calliandra calothyrsus</i>	Yes	calliandra	kaliandra
<i>Calophyllum inophyllum</i>	No	calophyllum	ai-sampulo
<i>Cassia fistula</i>	Yes	golden shower	ai-kadus, ai-arus
<i>Cassia javanica</i>	Yes	java shower	Kadus
<i>Casuarina equisetifolia</i>	Yes	casuarina	ai-kakeu
<i>Cocos nucifera</i>	No	coconut	nu'u
<i>Delonix regia</i>	Can be	Poinciana	ai-akasi
<i>Duranta erecta</i>	Can be	duranta	ai-andar
<i>Ficus</i> sp.	No	fig	hali
<i>Garuga floribunda</i>	Yes	garuga	ai-feu
<i>Grevillea robusta</i>	Can be	Australian silver oak	grevilha
<i>Leucaena leucocephala</i>	Yes	Leucaena	ai-kafe
<i>Mangifera indica</i>	No	Mango	ai-has
<i>Morinda citrifolia</i>	Can be	noni	mengudu (Indo)
<i>Muntingia calabura</i>	Can be	Panama Berry	cereza
<i>Peltophorum pterocarpum</i>	Can be	yellow flame tree	soga (Indo)
<i>Plumeria</i> spp.	No	frangipani	ai St. Antonio
<i>Polyalthia longifolia</i>	Can be	Indian mast tree	globakan
<i>Prosopis</i>	Yes		-
<i>Samanea saman</i>	No (too big)	Raintree	ai-matan dukur
<i>Senna simea</i>	Yes	Siamese cassia	ai-kaixote
<i>Sesbania grandiflora</i>	Yes	Hummingbird tree	ai-kale/a
<i>Tabebuia rosea</i>	Can be	Pink trumpet	hali Porugal
<i>Terminalia catappa</i>	No (too big)	Beach almond	ai-katapa
<i>Wodyetia bifurcata</i>	No	foxtail palm	ekor tupai (Indo)
<i>Ziziphus mauritiana</i>	Can be	Chinese apple	ai lok

Left: Sr Mario Sacaio with a sandalwood tree in Soibada.

4.6 Native trees



Sr. Oscar with native host trees in a plantation at Clacuc, Manufahi. Tony Page.

Native trees that occur within the range of sandalwood offer insight into the species in which sandalwood can naturally host. These species are locally available and can potentially be utilised for sandalwood systems. In October 2017 six sandalwood locations (Aidabaleten, Clacuc, Hatudu, Lahomea, Soibada and 'South Road') were surveyed and the associated species were identified (Figure 4). Those considered to have the most potential for use as hosts in planted sandalwood systems include *Sesbania grandiflora* (fodder), *Leucaena leucocephala* (fodder and fuelwood), *Acacia oraria* (fuelwood), *Cassia fistula* (ornamental), *Pterocarpus indicus* (timber), *Casuarina equisetifolia* (wind-break, fuelwood, poles for local construction), *Acacia leucophloea* (fodder and timber), *Albizia* spp. and *Tamarindus indica* (food). The botanical details for each of these species are outlined in Section 5. *Acacia auriculiformis* (fuelwood) is an introduced species in Timor-Leste that is a well recognised host species for sandalwood. Other Timor native or naturalised species identified in other countries as sandalwood hosts include *Acacia mangium*, *Azadirachta indica* (neem), *Melia azaderach* (chinaberry), *Ziziphus mauritiana* and *Senna simea* (ai-caixote) (da Silva et al. 2016).

Native vegetation can potentially be used for 'enrichment' plantings where sandalwood is inter-planted within existing wild trees. Enrichment plantings can potentially offer a low-cost option for establishing sandalwood without encroaching on productive agricultural land. Timor's *Eucalyptus alba* woodlands may be suitable for enrichment plantings. Without adequate site preparation (some competition removal) and follow-up maintenance (weed and fire control) however, enrichment plantings can experience high sandalwood mortality. Two woody weeds in Timor-Leste that are potentially suitable hosts include *Prosopis* sp. (mesquite) and *Vachellia nilotica* (prickly acacia). While it is not recommended to propagate and plant these two weed species, there may be scope for enrichment planting in or adjacent to areas where the species occur. It must be noted that any future control of the weed trees is likely to have a negative affect on the sandalwood. This is particularly relevant if the weed trees are controlled using systemic herbicides, because the herbicide will be transferred to the sandalwood through its haustoria and kill it also.

Table 2: Trees associated with sandalwood at six locations in Timor-Leste

Species	Common	Tetun	Aida- baleten	Clacuc	Hatudu	Laho- mea	Soi- bada	Sth Rd.
<i>Acacia leucophloea</i>	-	ai-maró (kemak)	x		x			x
<i>Acacia oraria</i>	-	-	x					
<i>Aegle marmelos</i>	bael	ai-dila fatuk/tukun	x					
<i>Albizia procera</i>	-	ai-samtuku fuik	x	x				
<i>Albizia species</i>	-	ai-samtuku fuik	-					
<i>Aleurites moluccana</i>	candlenut	ai-kamii	x		x		x	x
<i>Alstonia scolaris</i>	milky pine	ai-hanek	x		x	x		x
<i>Annona muricata</i>	soursop	ai-ata boot			x			
<i>Areca catechu</i>	betelnut	bua					x	
<i>Barringtonia asiatica</i>	-	butun (Indo)		x				
<i>Bombax ceiba</i>	bombax	ai-lele	x		x			
<i>Carica papaya</i>	papaya	ai-dila			x			
<i>Cassia fistula</i>	golden shower	ai-kadus, ai-arus	-		x			
<i>Casuarina equisetifolia</i>	casuarina	ai-kakeu	x				x	
<i>Celtis philippensis</i>	-	Suati-kemak		x				
<i>Cerbera manghas</i>	sea mango	bintaro		x	x		x	
<i>Chromolaena odorata</i>	siam weed	du'ut funan mutin			x	x		
<i>Corpa</i> (sago palm)	-	ai tali/kadiru		x				
<i>Delonix regia</i>	Poinciana	ai-akasi	x			x		
<i>Dysoxylum species</i>	-	-		x				
<i>Eucalyptus alba</i>	white gum	ai-bubur	x		x			
<i>Exocarpos latifolia</i>	broad-leaf ballart	-	x					
<i>Ficus sida</i>	-	ai-kun		x			x	
<i>Garuga floribunda</i>	garuga	ai-feu	x					
<i>Glyricidia sepium</i>	glyricidia	gamal				x		
<i>Gmelina arborea</i>	gmelina	teka Filipina		x			x	
<i>Grewia breviflora</i>		grevilha					x	
<i>Jatropha gossypifolia</i>	bellyache bush	ai meta oan				x		
<i>Leucaena leucocephala</i>	Leucaena	ai-kafe	x	x	x	x		x
<i>Mangifera indica</i>	mango	has Timor			x			
<i>Nauclea orientalis</i>	-	-		x				
<i>Polyalthia longifolia</i>	Indian mast tree	globakan						x
<i>Psidium guajava</i>	guava	guyaba			x			
<i>Pterocarpus indicus</i>	rosewood	ai-na	x					
<i>Schleichera oleosa</i>	Macassar oil tree	ai-dak	x		x		x	
<i>Senna simea</i>	siamese cassia	ai-kaixote						x
<i>Sesbania grandiflora</i>	sesbania	ai-kale/a	x			x		
<i>Sterculia feotida</i>	-	ai nitas		x	x			
<i>Swietenia macrophylla</i>	mahogany	mahoni			x	x		
<i>Syzigium species</i>	-	jambulao			x			
<i>Tamarindus indica</i>	tamarind	ai-sukaer	x	x				x
<i>Tectona grandis</i>	teak	ai-teka		x	x	x		x
<i>Timonis timon</i>	-	katimun			x			
<i>Vachellia nilotica</i>	prickly acacia	pete						x
<i>Ziziphus mauritiana</i>	desert apple	ai-lok	x	x	x			

5. HOST SPECIES

5.1 POT HOST

5.1.1 *Alternanthera nana*



Common Name: *Alternanthera*, Hairy Joyweed, Downy Joyweed

Family: Amaranthaceae

Subfamily: Gomphrenoideae

Origins: Native to northern Australia.

Size & Habit: A prostrate, erect or ascending herb or shrub, 0.2 – 0.6 m high. Leafy stems are clothed in erect white hairs. Leaves are simple, opposite, 17 – 30 mm long by 8 – 12 mm wide. The upper surface is glabrous, the underside has hairs along the mid-rib when young. In its natural environment it grows in vine thickets. It can grow well on a range of sites and soil types, and has been reported as a noxious weed in some locations. Flowers are borne in sessile inflorescences forming a rounded head occurring in the leaf axils or on the ends of branches. The flowers are white, with 5 sepals and 3 – 5 stamens, occurring between April to September. The fruit is a utricle, forming a tightly-packed head-like structure, 2 mm x 2 mm.

Propagation Methods: It is most commonly grown from cuttings.

Host Silviculture: *A. nana* is routinely used as the first host for sandalwood in the nursery. Sandalwood growth has been found to be far more vigorous when *A. nana* is planted in the poly bag than when seedlings are planted without it. Stem cuttings of *Alternanthera* should be planted into the pot after the sandalwood is at the 4 – 6-leaf stage. This timing is important, for if the cuttings are planted too early, they will grow quickly and overtop the young seedling, leading to stunted growth and death of the sandalwood. Alternatively, if they are planted too late, the sandalwood is likely to grow slowly, well below its potential.

Regular pruning of the *Alternanthera* is required, both in the nursery and in the field following out-

planting. This is critical to prevent this host species from smothering the sandalwood, which will eventually kill it. While very little maintenance of the *Alternanthera* is required after out planting, it is important to keep the sandalwood stem free of the *Alternanthera*, particularly during wet conditions. This is important because the stem of *Alternanthera* can fasten onto the stem of the sandalwood, causing the stem to rot and the young sandalwood sapling to die.

Other Uses: Herbaceous ornamental garden plant.

5.2 INTERMEDIATE HOST

5.2.1 *Sesbania grandiflora*



Common Name: Ai-Kale/a

Family: Fabaceae

Subfamily: Fabioideae

Origins: Native to Australia, India, Indonesia, Malaysia, Myanmar and the Philippines.

Size & Habit: A small, very fast-growing and short-lived open branching tree that grows up to 8 – 15 m tall with a stem of up to 25 – 30 cm in diameter. The tree's roots are normally heavily nodulated with large nodules. Leaves are alternate, compound and pinnate, 15 – 30 cm long with 12 – 20 pairs of oblong, rounded leaflets, 3 – 4 cm long and about 1 cm wide. They turn bright yellow before shedding.

In its natural environment, it is a lowland species of hot, humid environments. It does not tolerate cool temperatures (below about 10 °C). It is highly tolerant of waterlogging and is ideally suited to seasonally flooded environments where it will develop floating, adventitious roots. It tolerates a range of soils (including alkaline, poorly-drained, heavy clays, saline, or low-fertility soils), but performs best on well-drained, deep loamy soils. It prefers a bimodal rainfall distribution (and annual rainfalls of between 2,000 – 4,000 mm), growing rapidly during the wet season, but is capable of withstanding prolonged dry seasons of up to 9 months. It is not wind resistant and has poor shade tolerance.

The flowers are clustered, with 2 – 5 large (5 – 10 cm in length, about 3 cm wide before opening) curved and oblong-shaped pink, red or white pea-like flowers hanging at the leaf base. The fruits are pods, long (30 – 50 cm) and narrow (8 mm), hanging vertically in the tree.

Propagation Methods: It is easily propagated by seed. It is not hard seeded and usually germinates well without scarification. Pre-treatment could involve either scratching or nicking the round end of each seed, avoiding the cotyledon, or soaking in cold or tepid water for 24 hours. Germination rates of 85 – 90% are commonly achieved. Seed can be propagated in the nursery or sown directly into well-worked soil at the planting site at the beginning of the rainy season.

It can also be propagated vegetatively by stem and branch cuttings.

Seed & Seedling Availability: The pods contain 15 – 40 small pale-coloured bean-like seeds up to 8 mm in size. There are between 17,000 – 30,000 seeds/kg.

Seeds can be planted directly into the land, or grown in poly bags in a nursery to allow accurate planting out. Seeds are readily available from the fruit pods of mature trees.

Host Silviculture: It is recommended that this moderate-sized intermediate host tree be spaced a minimum of 2 m from each sandalwood tree.

Form pruning may be required to produce a clear bole for timber production.

Other Uses: Timber, firewood, fibre, food (leaves, seeds, pods, flowers), fodder, shade and shelter, live fence posts, gums, N-fixation, soil improver (green manure) and traditional medicines.

5.2.2 *Cajanus cajan*





Common Name: Pigeon Pea

Family: Fabaceae

Subfamily: Fabioideae

Origins: Native to Afghanistan, Bangladesh, Bhutan, India, Sri Lanka, Ethiopia, Kenya, Malawi, Tanzania and Uganda.

Size & Habit: A fast-growing annual or short-term perennial (1 – 5 years) woody shrub of between 0.5 – 4 m in height (commonly 1 – 2 m), with stems up to 15 cm diameter. Young stems are angled and pubescent. Leaves are trifoliate, alternate and set in a spiral around the stem.

In its natural environment, it is a plant of the semi-dry lowlands but it has wide adaptability. It tolerates a wide range of soils (from sands to heavy black clays) but needs free-drainage. It grows well in a range of climatic conditions, including tropical humid zones with annual rainfall up to 2500 mm and semi-arid zones with an annual rainfall of only 400 mm. It develops a deep and quick-growing taproot.

Flowers are usually yellow but may also be striated with purple streaks or plain red, generally occurring over a two month period as days become shorter. Fruit is a flat pubescent pod, 4-9 cm long, 1 cm wide.

Propagation Methods: Readily propagated by seed. It is commonly grown via direct seeding into well-prepared soils at the planting site. No pre-germination treatment is needed and inoculation is usually not necessary. Emergence is complete 2 – 3 weeks after sowing.

Stem cuttings rarely succeed.

Seed & Seedling Availability: The pods are best picked when the seed has reached physiological maturity and is just beginning to lose its bright green colour. Pods contain up to 9 seeds of various colours (brown, red, black), about 3 mm long.

Pigeon pea is a minor crop in many parts of Timor, and seed would be available in markets prior to planting time. Seedlings grow very slowly, but if planted at the start of the wet season, shrubs will

persist till August the next year.

Host Silviculture: It is recommended that this small-sized, short-lived intermediate host shrub be spaced a minimum of 1.5 m from each sandalwood tree, but higher density plantings (i.e. 1 m spacing) could be considered as it will have minimal effect on sandalwood growth through competition.

Direct seeding may be the simplest and cheapest means of incorporating this species into the sandalwood plantation and is therefore recommended. It may be regularly pruned for fodder production.

Other Uses: Food (fresh and dried peas), fodder, timber, fuelwood, fibre for basket making, N-fixation, soil improver (structure, infiltration and organic matter improvements), erosion control, shade and shelter, traditional medicines and apiculture.

5.3 LONG-TERM HOSTS

5.3.1 *Leucaena leucocephala*



General Common Name: Ai-kafe

Family: Fabaceae

Subfamily: Mimosoideae

Habitat: An abundant tree found in agricultural, urban and disturbed forests. It is a small fast-growing tree native to southern Mexico and northern Central America (Belize and Guatemala) and is now naturalized throughout the tropics.

Size & Habit: A long-lived evergreen and fast-growing species that can grow as a highly branched large shrub up to 3 m in height or a small to medium-sized tree reaching up to 15 m in height (commonly 5 – 7 m). As a tree, it can achieve a clear bole up to 5 m with upright angular branching and a narrow open crown. The leaves are bipinnate with 6 – 8 pairs of pinnae bearing 11 – 23 pairs of leaflets 8 – 16 mm long.

Adaptability: In its natural environment, it occurs in tropical warm climates and commonly colonises disturbed and degraded sites. It will thrive on a wide range of sites and rainfall environments (from 650 – 3,000 mm per annum) that are more or less frost-free, including marginal areas with an extended dry season. It tolerates a wide variety of soil types including mildly acid soils (pH >5.2). It is well adapted to clay soils but is not tolerant of poorly-drained soils, especially during seedling growth. It is deep rooted. It is an invasive species.

Uses: Timber, firewood and charcoal, food (young pods, seeds, leaf tips), fodder, shade and shelter, dyes, gums, apiculture, N-fixation, soil improver (green manure), erosion control.

Propagation Methods: Can be readily propagated from seed. Fresh seed often has an impermeable waxy coat which must be broken before the seed will imbibe water and germinate. Scarification to break this dormancy usually involves soaking in hot water for 2 minutes or nicking the seed coat at the distal (cotyledon) end using a sharp tool. Seed must be inoculated before planting with a suitable Rhizobium strain.

Seed & Seedling Availability: Mature seed pods are typically available on trees all year round. Each pod contains up to 20 small, hard, dark-brown seeds. There are 15,000 – 20,000 seeds/kg.

Host Silviculture: It is recommended that this moderate-sized intermediate host large shrub/small tree be spaced a minimum of 3m from each sandalwood tree.

It will require form pruning for potential timber production, and branches can be regularly pruned, or the tree may be coppiced to facilitate fodder and firewood production.

It can be very competitive, being a prolific seeder and readily establishing on moist bare soils. Sandalwood growth can therefore be severely reduced if this species is not controlled by heavy pruning and active regeneration control to maintain the desired density.

5.3.2 Acacia oraria



Common Name: Ai-suli

Family: Mimosaceae

Subfamily: Mimosoideae

Habitat: Infrequent tree found within the monsoon dry mixed forests, particularly in proximity to the coast.

Size & Habit: A small tree 3-10 m tall with the stem not exceeding 30 cm in diameter. The bark is layered with the inner blaze described as fibrous and stringy. Phyllodes 4.5-11 cm long, 10-45 mm wide with 3 main longitudinal nerves. Phyllodes have a whitish-green or glaucous appearance.

Adaptations: Adapted to long dry seasons, and poor thin soils.

Reproduction: Cream coloured round flowers 5mm in diameter and borne in a 3-5 headed raceme. Seed pots usually in a single open col 8-12 cm long 10-15 mm wide. Seeds encircled by a conspicuous, red or orange aril. Flowering in Nov-Dec with seed set early the following year.

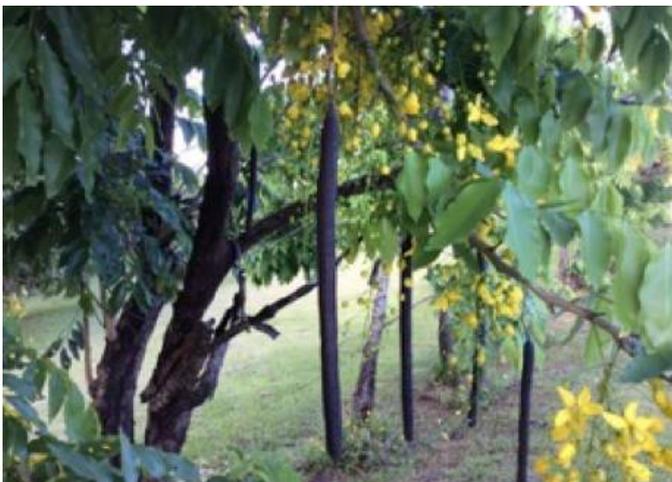
Propagation: Propagation is by seed. Germination rates can be improved by seed scarification or hot water treatment where hot water (70-80 °C) is poured over the seeds and left to soak for 24

hours. The floating infertile seeds can be discarded, swollen seeds sown, and the remaining can be retreated.

Uses: The heavy and hard wood can be used for house or fence posts and fuel wood. It is also used for soil protection, control of *Imperata cylindrica* and as a fire-break in savannah areas.

Host Silviculture: As a small tree it can be easily incorporated into a sandalwood mixed species woodlot, to increase the number of potential hosts available to the sandalwood. Form pruning can be implemented to limit the lateral spread of the crown, with prunings potentially used for firewood.

5.3.3 *Cassia fistula*



General Common Name: Golden Shower Tree, Golden Rain Tree

Common Name: Ai-kadus

Family: Fabaceae

Subfamily: Cesalpinoideae Habitat: Introduced species located in urban and domestic environments

Size & Habit: A medium sized fast-growing deciduous tree commonly to 10 m tall (may reach up to 20 m) with a straight trunk to 5 m and spreading branches. Trunks may reach up to 1 m in diameter. Leaves are alternate, pinnate, 30 – 40 cm long, with 4–8 pairs of ovate leaflets that are 7.5 – 15 cm long and 2 – 5 cm wide.

Adaptations: Grows best in well drained soils, is drought resistant and can potential. It can withstand a moderate amount of shade, is drought resistant, but not frost hardy.

Reproduction: The profuse flowers are bright yellow and are produced in terminal, drooping racemes, 30 – 60 cm long. The fruit is an indehiscent dark brown pod between 40 – 60 cm long and 1.5 – 1.5 cm in diameter, pendulous and cylindrical in shape. It develops rapidly and has a pungent odour when opened. The fruit pods develop numerous transverse septa between the 25 – 100 hard, lustrous-brown seeds.

Propagation: The species is commonly propagated by seed. The seed pods are filled with a sticky black pulp when fresh, which adheres to the septa upon drying. Pods are easily collected from the ground and opened with a knife. Rapid (next day) and high germination rates (84 – 90%) have been achieved following soaking seeds in concentrated sulphuric acid for up to 30 minutes and then thoroughly washing and soaking in water for 24 hours before sowing. Manual scarification of the seed coat can also improve the rate of germination.

Uses: Food (flowers), timber, fuelwood, apiculture, tannins, traditional medicines.

Host Silviculture: It is recommended that this moderate to large-sized long-term host tree be spaced a minimum of 3 m from each sandalwood tree and only incorporated into the plantation at the mid-point between each second or third sandalwood tree (i.e. 12 – 18 m apart). This will ensure that these trees do not dominate the sandalwood trees later in the rotation.

Form pruning may be required to produce a clear bole for timber production. It will coppice vigorously and produce many root suckers which may need to be controlled.

5.3.4 Cassia javanica



General Common Name: Pink Shower, Java Cassia

Family: Fabaceae

Subfamily: Caesalpinaceae.

Habitat: Introduced species, located in urban and domestic environments

Origins: Native to China, Indonesia, Malaysia, Mauritius, Myanmar, Thailand, United States, and many Pacific Islands

Size & Habit: A fast-growing medium-sized deciduous/semi-deciduous tree commonly reaching a height of 25 m (occasionally up to 40 m). The trunk commonly has many shoots, often resulting in a wide-open, arched and spreading crown. Leaves are paripinnate with 5 – 15 pairs of elliptical-ovate to oblong leaflets 2.5 – 5 cm x 1.5 – 2.5 cm that are rounded at the apex and base.

Adaptations: Can occur across a wide range of ecological conditions generally at lower elevations. It usually grows in more open forests including deciduous monsoon forests and savanna-like habitats, but also in closed evergreen primary forests. It will grow well at altitudes up to 400 m.

Reproduction: The masses of showy open-clustered flowers occur in Spring on racemes up to 16 cm long and range in colour from pale pink to crimson with yellow coloured stamens. The seed pods ripen during the early dry season and are long (20 – 60 cm x 1.5 cm diameter) cylindrical dark brown pods that hang from the crown. Seed pods can be collected from the ground and opened with a knife. One obovate seed (6 mm – 9 mm long x 5 mm – 7 mm wide x 2.5 mm – 5.5 mm thick) is found within each septum of the fruit.

Propagation: Is commonly propagated by seed. Seeds start to germinate after 7 days with most germination occurring between 14 and 30 days. The germination rate is typically 70%, with around 50% of sown seeds yielding good plants.

Uses: Timber (general construction, furniture), N-fixation, tannins and dyes (bark), traditional medicine.

Host Silviculture: It is recommended that this moderate to large-sized long-term host tree be spaced a minimum of 3 m from each sandalwood tree and only incorporated into the plantation at the mid-point between each second or third sandalwood tree (i.e. 12 – 18 m apart). This will ensure that these trees do not dominate the sandalwood trees later in the rotation.

Form pruning may be required to produce a clear bole for timber production.

It will coppice vigorously.

5.3.5 Pterocarpus indicus



Common Name: Ai-na

Family: Fabaceae

Subfamily: Faboideae

Habitat: In Timor-Leste people distinguish between the local and the imported form of the species. The local form is a common tree found within the monsoon dry mixed forests.

Size & Habit: A large tree reaching heights of 30 – 40 m with a stem diameter of up to 2 m. The trunk is commonly fluted and buttressed. It has a wide-spreading crown with compound-pinnate leaves bearing about 12 large (7 cm x 3.5 cm – 11 cm x 5.5 cm) alternate leaflets. In Timor-Leste the tree is largely deciduous during the extended dry season.

Adaptations: Wide adaptation to a range of ecological conditions and may be considered a pioneer species. It grows best in the open environments and tolerates a wide range of soils from coastal sands to inland clays.

Reproduction: The flowers are yellow to orange-yellow, fragrant, 1.5 cm long and borne in large axillary panicles up to 13cm long. The fruit is a disc-shaped pod 2 cm – 3 cm in diameter, surrounded by a flat 4 cm – 6 cm diameter membranaceous wing which aids seed dispersal by the

wind. The fruits take four months to mature and each fruit contains between 1 – 3 seeds. Mature fruits can be found on the tree during the deciduous phase during the dry season.

Propagation: Readily propagated by seed which germinate in 8 – 100 days, but the initial growth of seedlings and saplings can be relatively slow. Around the world the species is widely propagated by truncheon cuttings. Stem cuttings can be taken from trees of any age and size. Cuttings of 6 cm diameter or larger will root better than cuttings of smaller diameter. Young leaf-bearing stems will not root at all. Cuttings are also grown in the form of stakes 1.5 m – 3 m long and as much as 10 cm diameter. Such truncheons root in about 3 months and produce up to 10 radiating shoots at the top, making a symmetrical crown very quickly. **In Timor-Leste people are either not aware of, or the local form of the species is not adapted to propagation by truncheon cuttings.**

Uses: This tree produces valuable hardwood timber and, if managed by good form pruning, may produce a commercial product after two sandalwood rotations. It is observed that local form produces more durable timber than the introduced form, with the former capable of being used in ground applications.

Other Uses: Timber (general construction, furniture, cabinet making, decorative veneers, ornamental woodturning), firewood, dye (wood), shade and shelter, N-fixation, apiculture, traditional medicine.

Host Silviculture: It is recommended that this large-sized long-term host tree be spaced a minimum of 5 m from each sandalwood tree and only incorporated into the plantation at the mid-point between each second or third sandalwood tree (i.e. 12 – 18 m apart). This will ensure that these trees do not dominate the sandalwood trees later in the rotation.

5.3.6 *Casuarina equisetifolia*



Common Name: Ai-kakeu

Family: Casuarinaceae

Habitat: Located primarily in domestic and agricultural landscapes as single trees and small woodlots.

Origins: Native to Australia, Bangladesh, Brunei, Cambodia, Fiji, Indonesia, Malaysia, New Zealand, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Tonga, Vanuatu, Vietnam.

Size & Habit: A tall evergreen tree with a finely-branched and typically conical-shaped crown. It grows to between 6 – 35 m in height with a typically straight trunk that is branchless up to 5 – 8 m. Stem diameters commonly range between 20 – 50 cm can, occasionally with buttresses. Foliage consists of slender, much-branched green to grey-green twigs and needle-like branchlets bearing minute scale-leaves in whorls of 6 – 8.

In its natural environment it is commonly confined to a narrow strip adjacent to sandy coasts, on sand dunes, in sands alongside estuaries and behind fore-dunes and gentle slopes near the sea. The climate in its natural range is semi-arid to sub-humid. It grows on a range of soils and performs well in sandy soils and can be grown at altitudes from sea level to 1500 m. It is highly tolerant to drought and aerosol salt, has good tolerance to soil salinity and is capable of withstanding high temperatures and high winds. It can also withstand waterlogging for short periods.

Reproduction: Flowers are unisexual. The female inflorescence occurs on a short lateral branchlet and is cylindrical or cone-shaped. The infructescence (multiple fruits) is a woody, cone-like structure (resembling a small conifer cone) 10 – 24 mm long and 9 – 13 mm in diameter. The cones are usually available year-round on trees. Each separate fruit within the cone contains a single small winged seed. Abundant seeds are produced but viability averages about 50% even for fresh seed.

Propagation: Mainly propagated by seeds, which are sown without any pre-treatment Germination takes up to 2 weeks, but should be protected during germination from consumption ants. Seedlings raised in nursery beds can be transplanted into containers after attaining 5 – 10 cm height. Container seedlings which are 25 – 30 cm height are suitable for out planting.

Uses: Timber (in Timor-Leste they can be used as narrow poles for local construction), firewood and charcoal, soil stabilisation and erosion protection, shade and shelter, windbreaks, N-fixation.

Host Silviculture: It is recommended that this large-sized long-term host tree be spaced a minimum of 4 m from each sandalwood tree and only incorporated into the plantation at the mid-point between each second or third sandalwood tree (i.e. 12 – 18 m apart). This will ensure that these trees do not dominate the sandalwood trees later in the rotation. Planting at higher densities than this recommendation may exhaust soil moisture and lower groundwater tables, while excess leaf litter can have allelopathic effects.

It is a poor self-pruner and so form pruning will be required to produce a clear bole for timber production.

Inoculation of the seedlings with pure strains of *Frankia* is recommended when the species is introduced to a new area.