The Department of Environment and Conservation (DEC) is pleased to provide this submission to assist the Standing Committee on Environment and Public Affairs in its Inquiry into the Sandalwood Industry in Western Australia.

1.0 Background

Australian sandalwood (*Santalum spicatum*) is a slow-growing, long-lived small woody tree or shrub that occurs naturally throughout the southern part of Western Australia and into South Australia. It is valuable and highly sought after for the oils contained in the heartwood, including the root butt and roots. Harvesting sandalwood normally kills the tree because it is pulled out of the ground to remove the more valuable butt and roots.

The ecology and biology of the species are reasonably well understood, researched and documented as outlined in *The Management of Sandalwood* (Kealley 1991) (Attachment 1). The research literature about the species is summarised in *Historical Review of Sandalwood (Santalum spicatum) Research in Western Australia* (Loneragan 1990) (Attachment 2).

Sandalwood oil has been used as an aromatic and medicine for centuries. Sandalwood has been exported from Australia since the 1840s with the industry being regulated since 1929. The sandalwood industry's history is well documented by Statham (1988) for Australia, and Kealley (1991) for Western Australia. The Western Australian sandalwood industry and legislation are a product of this long history.

The Western Australian sandalwood resource is now unique as the world's largest sandalwood resource, and the only remaining wild resource that has the potential to be managed for the long-term conservation of the species and sustainability of the industry.

2.0 Regulation and management of the harvesting of wild sandalwood

2.1 Legislative regime

Sandalwood harvesting is regulated under four Acts: the *Sandalwood Act 1929*, the *Conservation and Land Management Act 1984* (CALM Act), the *Wildlife Conservation Act 1950* and the *Forest Products Act 2000*. The interaction of these four Acts creates a complex legislative regime due to inconsistencies in definitions of key terms, overlapping licence requirements, inadequate provisions that are specific to sandalwood management, and the management of the industry by two agencies – the Department of Environment and Conservation (responsible for the Sandalwood, CALM and Wildlife Conservation Acts) and the Forest Products Commission (FPC) (responsible for the Forest Products Act).
The Sandalwood Act regulates the ‘pulling or removal’ of sandalwood on all lands except plantations. It provides for a statewide quota to be set for the annual sandalwood harvest, and provides that licences are required to harvest sandalwood from Crown lands and private property. The Sandalwood Act prescribes a penalty of $200 for the offence of taking sandalwood unlawfully. The Sandalwood Regulations 1993 provide for the licensing of pulling of sandalwood. They also prescribe penalties for making false statements in an application for a licence and for failing to carry a licence when pulling sandalwood. The penalty for these offences is $2,000.

The Sandalwood Act is intended to be read as one with the CALM Act.

The CALM Act sets out the various categories of land to which the Act applies, which do not always align with those in the Sandalwood Act. The CALM Act does not have licensing provisions applicable to the taking of sandalwood, however sandalwood would come within the definition of “forest produce” as defined in section 3 of the Act. If sandalwood was dealt with as “forest produce”, section 103(1) of the CALM Act would apply to the unlawful taking of sandalwood on CALM Act lands. The penalty for conviction under this section is a fine of $10,000 and imprisonment for one year.

Sandalwood is included in the scope of the definition of “flora” under the Wildlife Conservation Act, which requires licences to take (which includes harvesting) flora from Crown lands and a licence to sell flora taken from private land. The maximum penalty for unlawfully taking flora under the Wildlife Conservation Act is $4,000. However, the Wildlife Conservation Act only applies to the harvest and sale of green (live) sandalwood, as the Supreme Court has ruled in the case of Pennings v Vlak ([2005] WASC 107) that the Wildlife Conservation Act does not apply to dead flora. As a consequence, there is no regulation of the harvest or sale of dead or dry sandalwood taken from Crown land or private property under the Wildlife Conservation Act.

Sandalwood is also subject to the Forest Products Act which provides for the harvest of sandalwood under production contracts. Where a production contract is in place, for administrative purposes, Wildlife Conservation Act licences are not normally also issued to the contractor. Production contracts apply to green and dead sandalwood.

The harvest of sandalwood, whether live or dead, is also clearing under the Environmental Protection Act 1986, which provides that clearing of native vegetation is an offence unless done under the authority of a permit or an exemption applies. Clearing carried out under a licence granted under the Sandalwood Act or the Wildlife Conservation Act, or through a production contract under the Forest Products Act, is an exemption to the requirement for a clearing permit.

Sandalwood harvesting is limited to a total of 3,000 tonnes per annum under the Sandalwood Act Order in Council 1996 (Attachment 3).

Comment on the regulatory regime is provided in section 5 of this submission.

2.2 Harvesting on Crown land

The sandalwood industry has historically been based on small scale contract operations in remote areas as outlined in Forest Focus (Talbot 1883) and Landscape (Kealley 1989). In recent years in rangeland areas, larger contracts awarded by the FPC through tender processes have led to more sophisticated operations and machinery. Harvesting is concentrated into areas with better sandalwood stands to maximise profits.
Naturally occurring sandalwood on Crown land (including pastoral leases) is the property of the Crown.

Crown land sandalwood harvesting is managed by the FPC under the Forests Products Act using harvesting, carting, processing and marketing contracts awarded through normal Government tender and supply processes, or in some cases through private treaty.

Sandalwood pulling on Crown land is subject to licensing under the provisions of the Sandalwood Act and the Wildlife Conservation Act administered by DEC. FPC contractors are granted Sandalwood Act licences with the licence conditions linked to their contracts. Commercial purposes licences under section 23C of the Wildlife Conservation Act apply to contractors, but are not given where they would be duplicative with Sandalwood Act licences for industry.

2.3 Harvesting on private land

Naturally occurring sandalwood on private land is the property of the landowner.

DEC manages sandalwood harvesting on private land by issuing Sandalwood Act licences to harvest sandalwood, and commercial producer’s licences under section 23D of the Wildlife Conservation Act for the sale of green sandalwood harvested from private property.

Applications to pull sandalwood from private property are made to DEC each year between January and February for the following financial year. Inspections are conducted of application areas, and quotas are then recommended to the Minister for Environment, who approves the licensing of successful applicants.

Licences are issued under the Sandalwood Act and the Wildlife Conservation Act from early August and are valid until 30 June of the subsequent year. The DEC received revenue of approximately $500 from Wildlife Conservation Act licenses for sandalwood sale in 2011/12.

2.4 Current (legal) harvest levels

Sandalwood harvesting is subject to annual harvest limits. The Sandalwood Act Order in Council 1996 (Attachment 3) sets the total sandalwood harvest at a maximum of 3,000 tonnes per annum, with the quota divided into equal weights of dead and green timber. In accordance with an inter-agency agreement (between the former Department of Conservation and Land Management and the FPC), 300 tonnes is allocated to private property and 2,700 tonnes is allocated to Crown land (with each allocation divided 50:50 between green and dead sandalwood).

Green (live) trees are more sought after because they produce more oil than dead trees and consequently have a higher commercial value.
In 2009/10, 2010/11 and 2011/12 the FPC-managed Crown land sandalwood harvest was as follows (source: FPC annual reports).

<table>
<thead>
<tr>
<th>Product</th>
<th>2009/10 harvest (tonnes)</th>
<th>2010/11 harvest (tonnes)</th>
<th>2011/12 harvest (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green sandalwood</td>
<td>1,239</td>
<td>1,139</td>
<td>997</td>
</tr>
<tr>
<td>Roots (green)</td>
<td>242</td>
<td>207</td>
<td>182</td>
</tr>
<tr>
<td>3rd grade green</td>
<td>304</td>
<td>320</td>
<td>293</td>
</tr>
<tr>
<td>Total green</td>
<td>1,785</td>
<td>1,666</td>
<td>1,472</td>
</tr>
<tr>
<td>Dead sandalwood</td>
<td>786</td>
<td>867</td>
<td>1,061</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2,571</td>
<td>2,523</td>
<td>2,533</td>
</tr>
</tbody>
</table>

The green wood harvest of 1,785 tonnes in 2009/10, 1,666 tonnes in 2010/11 and 1,472 tonnes in 2011/12 exceeds the 1,350 tonnes allocated to the FPC. The FPC, as justification, consider products from improved utilisation (i.e. roots and third grade green sandalwood) to be in addition to the quota amount permitted for green wood harvest.

The total harvest authorised from private property by Sandalwood Act licences for 2009/10, 2010/11 and 2011/12 is tabulated below:

<table>
<thead>
<tr>
<th>Product</th>
<th>2009/10 harvest (tonnes)</th>
<th>2010/11 harvest (tonnes)</th>
<th>2011/12 harvest (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green sandalwood</td>
<td>181</td>
<td>213</td>
<td>150</td>
</tr>
<tr>
<td>Dead sandalwood</td>
<td>110</td>
<td>147</td>
<td>85</td>
</tr>
<tr>
<td>TOTAL</td>
<td>291</td>
<td>360</td>
<td>235</td>
</tr>
</tbody>
</table>

The Sandalwood Act originally limited the quantity of sandalwood that could be harvested from private land to 10% of the quota set by the Order in Council. This requirement was removed from the Sandalwood Act in 2003, but retained in the inter-agency agreement. The green wood harvest of 181 tonnes in 2009/10 and 213 tonnes in 2010/11 exceeded the 150 tonnes allocated.
to private property in the inter-agency agreement due to the absence of a coordinating arrangement between the FPC and DEC. This was corrected immediately it became apparent, with the harvest of 150 tonnes of green wood licensed under the Sandalwood Act in each of 2011/12 and 2012/13.

2.5 Illegal harvesting

The scale of illegal sandalwood harvesting appears to have expanded rapidly in recent years. In the five years to 2011, one consignment of illegally harvested sandalwood was seized and the offender successfully prosecuted. Since March 2011, 20 consignments of illegally harvested sandalwood weighing in excess of 175 tonnes and potentially valued at $2.5 million have been seized. Four consignments were detected en route to a buyer in South Australia.

The Minister for Environment made a statement in Parliament and issued a media statement on 25 September 2012 about the extent of illegal activity (Attachments 4 and 5 respectively).

The total quantity of sandalwood illegally harvested is unknown, but is thought to exceed 500 tonnes annually. This compromises the sustainability of the sandalwood resource, and the long-term future of the industry. It also represents a significant loss of revenue to the State from illegal Crown land harvests and opportunity cost to legitimate industry participants.

As with most illegal activities, the illicit sandalwood trade is predicated on the risk being worth the reward. Harvesting occurs in remote areas where detection is very difficult; people are willing to load and transport sandalwood vast distances, risking detection on the road; there are buyers prepared to accept, conceal, process and export illegal sandalwood and sandalwood oil; Commonwealth laws regulating native flora exports do not include timber or sandalwood oil; there is a large and growing international demand for sandalwood products; and the regulatory and enforcement provisions are inadequate to provide sufficient deterrent.

Improved management of the sandalwood trade requires amendments to legislation:

- to provide for the post-harvest management and regulation of pulled sandalwood, including its possession, transport, processing, dealing, import and export;
- to better regulate sandalwood plantations (to allow plantation-derived sandalwood to be distinguished in the trade from wild-collected sandalwood);
- to provide a mechanism to charge fees to cover the processing and management costs of sandalwood licences;
- to provide enforcement powers for DEC officers to be better able to detect, prevent and prosecute the illegal harvest, sale, and interstate laundering of sandalwood, which results in a substantial loss of revenue to the State; and
- to increase penalties so that they are an effective deterrent.

It is considered that these amendments to legislation would markedly improve the ability to control the illicit sandalwood trade.

In addition to legislative inadequacies, DEC has insufficient dedicated staff and resources to effectively regulate sandalwood harvesting. The increase in apprehensions and seizures in the past eighteen months has diverted resources from other tasks and is unsustainable in the long term. The issues are exacerbated by the remoteness of illegal operations, the vast areas and
distances involved, the clandestine nature of the illegal activities and the complexities of investigations, evidence gathering and prosecutions process. Amended legislation with reasonable fees could provide better for the costs of increased management to be met from the industry.

There is growing evidence that social and economic inequity is an increasingly important driver in illegal harvesting. FPC contracts are typically awarded to parties capable of preparing appropriate tender documentation and conducting relatively large-scale capital intensive harvest operations. As the price of illicit sandalwood increases (a reflection of demand significantly exceeding available supply), there is an incentive for smaller-scale harvesting to operate illegally. On-ground intelligence suggests that such operations are increasing.

3.0 Regulation and management of the sale of wild sandalwood

Sandalwood is sold as either dead or green (live trees pulled from the ground and bark removed). Most sandalwood is exported to overseas markets, particularly in Asia. Sandalwood buyers may export the raw product overseas or process the raw material into various products, including oil.

3.1 Current market prices

One tonne of green sandalwood pulled from the rangelands yields on between 24 and 30 kg of oil, with higher yields occurring in the more remote arid areas where sandalwood is slower growing.

The sale of legally harvested sandalwood from Crown land generated $7.83 million in stumpage revenue (sales revenue less charges for in-forest, administration, roading, harvest and haulage costs) for the FPC in 2011/12 (source: 2011/12 FPC annual report).
The table below provides an indication of the current market prices for different grades of sandalwood product.

<table>
<thead>
<tr>
<th></th>
<th>Legal sale Australia</th>
<th>Illegal sale Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Green sandalwood</strong></td>
<td>$9,500 - 15,000 per tonne</td>
<td>$5,000 - 7,000 per tonne</td>
</tr>
<tr>
<td>(Small green logs, green logs &amp; butts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dead sandalwood</strong></td>
<td>$9,400 - $14,800 per tonne</td>
<td>$2,000 - 5,000 per tone</td>
</tr>
<tr>
<td>(dead logs &amp; large pieces)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ground blends/low grade pieces</strong></td>
<td>$3,000 - $8,000</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Oil</strong></td>
<td>$1,100/kg</td>
<td>No market known in Australia</td>
</tr>
<tr>
<td>(Santalum spicatum)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.2 Regulation of sales

As with harvesting, the jurisdiction for regulation and management of the sale of wild sandalwood is split between the FPC and DEC. Sandalwood harvested from Crown land under contract is sold by the FPC to local and offshore purchasers through a processing and marketing contractor.

DEC regulates the sale of sandalwood (as protected flora) harvested from private land by issuing commercial producer's or nurseryman's licences to private property sandalwood pullers under section 23D of the Wildlife Conservation Act. However, these licences can only be issued for the sale of green (live) sandalwood following the Supreme Court's ruling in the case of *Pennings v Vlak* ([2005] WASC 107) that the Wildlife Conservation Act does not apply to dead flora. As a consequence, there is no regulation of the sale of dead sandalwood harvested from private property.

There are very few controls on the possession and transport of sandalwood. Neither the Sandalwood Act nor the Wildlife Conservation Act contains express provisions allowing for the regulation of the possession, transport, storage or purchase of sandalwood or flora.

In 2012 DEC introduced new licence conditions for licences under the Sandalwood Act and section 23D of the Wildlife Conservation Act to require licensees to obtain Sandalwood Transport Authority Notices (STANs) before removing harvested wood. In order to obtain a completed STAN, the licensee must take the wood from the harvesting site to the nearest weighbridge for weighing and inspection by a DEC officer. STANs provide DEC with the opportunity to verify weights in transit and monitor delivery to buyers, with a view to reconciling the quantities harvested with the amounts received by buyers.
There are currently no statutory powers to license sandalwood buyers or processors. However, section 23E(1)(b) of the Wildlife Conservation Act requires that buyers of protected flora must purchase the flora from a person lawfully entitled to sell the flora (i.e. holds a licence) and must keep or obtain a legible record of the quantity and description of all flora purchased, the date of the purchase, and the name and address of the person from whom the flora was purchased for no less than 12 months from the date of purchase. The effectiveness of this provision is limited by the Supreme Court's *Pennings v Vlak* decision, which means that the licensing and record keeping requirements of the Wildlife Conservation Act only apply to sandalwood that was live at the time it was taken.

The international export of native plants is governed by the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) administered by the Department of Sustainability, Environment, Water, Population and Communities. However, the export of bark, wood and timber from any native wood (including sandalwood) and sandalwood oil is exempt from regulation under this legislation because they are on the *List of Exempt Native Specimens* declared under that Act.

### 3.3 Sales of illegally harvested sandalwood

The majority of illegally harvested sandalwood is taken from mid-western and goldfields Crown land which includes pastoral leases. Sandalwood has also been removed from wheatbelt conservation reserves, private land and road reserves.

Unscrupulous sandalwood buyers have attempted to use the cover of allegedly plantation-grown sandalwood and sandalwood taken under private property licences to launder large quantities of unlawfully taken naturally occurring sandalwood. Claims have also been made that sandalwood has been imported from South Australia, even though South Australia prohibits the harvesting of sandalwood. Identifying the source of sandalwood based on geographic differences in sandalwood make-up (i.e. through its chemical composition and/or DNA) is challenging.

The black market for sandalwood is thought to be worth millions of dollars and most illegally harvested sandalwood is exported to Asia where it is used for medicinal and aromatic purposes or distilled for oil. Because of this lucrative market, there has been a large increase in the frequency and scale of illegal sandalwood operations. This is causing a lot of damage to the environment, and undermines legitimate operators and efforts to manage sandalwood sustainably.
4.0 The environmental sustainability of wild sandalwood

Sandalwood is naturally found throughout the semi-arid regions of southern Western Australia, including the wheatbelt, goldfields, Gascoyne and southern Pilbara, as shown in the map below. It is a slow-growing species, taking between 30 and 90 years to reach maturity.

Scientific research has shown that there is a genetic difference between the pastoral sandalwood and that occurring in the wheatbelt areas. The conservation of sandalwood needs to address these two areas as separate conservation/management units to ensure the genetic diversity of the species is maintained.

The most significant remaining stands of naturally occurring sandalwood are in the Western Australian rangelands, where sandalwood continues to be severely impacted by fire, harvesting (both legal and illegal), grazing by pastoral livestock and feral herbivores (goats, rabbits, camels) and elevated numbers of native herbivores (kangaroos) due to artificial waters, climate change, loss of seed dispersal native mammals and impacts of other land uses such as mining and infrastructure.

In the wheatbelt, historical harvesting and agricultural clearing have reduced the incidence of natural sandalwood to a fraction of its original population and range.

Prior to the 1980s, sandalwood was harvested with limited knowledge of the extent and nature of the resource. The former Forests Department undertook the first comprehensive sandalwood inventory from 1980 to 1984. The inventory estimated the total quantity of merchantable
sandalwood on areas available for harvesting at 137,100 tonnes (110,000 tonnes of green and 27,100 tonnes of dead sandalwood).

The data from this inventory and consolidated research findings informed the 1991 management plan *The Management of Sandalwood* (Kealley 1991). The management plan recommended a maximum harvest of 2,000 tonnes per annum (1,000 tonnes of green and 1,000 tonnes of dead sandalwood) with 200 tonnes taken from private property and 1,800 tonnes from Crown land. This level of harvest, especially for green wood, was based on estimates of the rate at which existing smaller trees will grow to larger (commercial) size classes. Despite the likelihood that the 1991 recommended level for green sandalwood harvesting of 1,000 tonnes per annum exceeds the environmentally sustainable harvest level, the current harvest of green sandalwood is significantly above that figure, approaching 1,700 tonnes per annum.

Further inventories for sandalwood were undertaken by the former Department of Conservation and Land Management between 1995 and 1999, building on the 1980-84 inventory and taking improved utilisation and assessment technology into account (Sawyer and Jones 2000). Unlike the previous inventory, this inventory only assessed the quantity of sandalwood available for harvest but did not consider regeneration or regrowth and therefore address sustainability. This inventory assessed total quantities of merchantable sandalwood on areas available for harvesting at approximately 233,000 tonnes (218,000 tonnes of green and 15,000 tonnes of dead sandalwood).

The FPC undertook further sandalwood inventory work from 2001, which informed a draft sandalwood resource management plan (under the Forests Products Act) in 2009. Such plans are written to manage the resource for the industry, and do not necessarily give adequate consideration to the species’ long-term conservation. DEC understands that the FPC plan is still in draft form.

4.1 Harvesting techniques and regeneration

Managed sandalwood harvesting (pulling) involves the removal of the whole tree and utilisation of all commercial material from roots to branches. The process kills the plant, however it maximises utilisation of the butt and root material that contains a high proportion (up to 25% of the tree volume) and highest quality wood (i.e with the most oils). As sandalwood rarely coppices and the coppice rarely survives (except at Shark Bay), it is better to maximise use in this way.

Both live (green) and dead sandalwood are harvested as the oils are maintained in the wood after the tree has died. The harvest of dead sandalwood utilises this product with least impact on the species and environment, and is thus preferred where possible from an environmental perspective. However, the extraction of oil from green sandalwood is better than from dead wood, and hence the industry favours green wood harvest where possible. Private landowners are encouraged to harvest dead sandalwood in preference to green sandalwood, and to manage their living sandalwood as a future resource.

Sandalwood regeneration relies on seed and a run of good seasons is required for seeds to germinate and for seedlings to survive. Unfortunately sandalwood is a very palatable shrub and slow-growing, so lengthy grazing control is required for the seedlings to survive and plants to grow to mature trees. Due to its specific regeneration requirements, slow growth rates and grazing pressure, sandalwood is declining across the rangelands. For the same reasons, planting of sandalwood seed (as part of harvesting conditions) does not guarantee long-term
survival of germinants. The information obtained from sandalwood inventories shows a lack of sandalwood regeneration across its range, and particularly on pastoral leases (Kealley 1991 (p. 9)). The decline in natural regeneration and survival coincides with the introduction of rabbits, and is exacerbated by the introduction of other herbivores, especially goats, and the associated decline of rangeland condition in many areas.

Sandalwood is expected to continue to decline in areas of the rangelands with high feral and domestic herbivore pressure for many years into the future due to the lack of natural recruitment to replace natural death of plants and harvested plants, accelerated death rates caused by the browsing of adult plants, and soil compaction around plants caused by these animals.

5.0 Other relevant matters

5.1 Problems with the regulatory regime for sandalwood

There are a number of legislative and practical issues associated with the regulation of sandalwood in its current form, including:

- Multiple Acts governing sandalwood create duplication, conflicting requirements and confusion, causing delays in granting licences;
- There is no definition of Crown land in the Sandalwood Act and no definitive answer as to how the term should be interpreted for the purposes of this legislation;
- The definition of licence in regulation 2(b) of the Sandalwood Regulations 1993 refers to a licence to take forest produce under section 88(1)(a) of the CALM Act, however trees and parts of trees appear to be excluded from the definition of forest produce in that part;
- The object of the Sandalwood Act, being about regulating the quantity of sandalwood harvested, does not reflect current understanding of the need to manage flora for conservation and sustainable use;
- Due to the overlapping legislation, there is uncertainty regarding the type of licence(s) which should be issued or granted for harvesting sandalwood on Crown land;
- The effect of the Supreme Court's Pennings v Vlak decision means that dead sandalwood cannot be licensed as protected flora under the Wildlife Conservation Act;
- There is no formal mechanism to apportion sandalwood harvests within the Order in Council limit between licensed harvesting under the Sandalwood Act and harvest contracts under the Forest Products Act;
- Provision for the collection and sale of sandalwood salvaged from sites cleared for other purposes (such as mining and infrastructure) is not addressed in the current management regime;
- The current arrangement of allowing only FPC contractors to pull sandalwood from Crown land is not supported by the legislation;
- Sandalwood harvest licences are granted for different time periods by DEC compared with production contracts entered into by the FPC;
The legislation does not sufficiently provide for the post-harvest management and regulation of pulsed sandalwood, including its transport, processing, dealing and export;

- The legislation does not provide for the regulation of sandalwood plantations;
- There is no mechanism to charge fees to cover the processing and management costs of sandalwood licences;
- There are insufficient enforcement powers for DEC officers to prevent and prosecute the illegal harvest, sale, and interstate laundering of sandalwood, which results in a substantial loss of revenue to the State and increased illegal harvest of sandalwood; and
- Penalties for the illegal taking of sandalwood are insufficient as a deterrent, being $200 under the Sandalwood Act, $4,000 in the Wildlife Conservation Act, and $10,000 in the CALM Act, for a product which is worth up to $15,000 per tonne raw.

These limitations make the task of controlling the growing illegal sandalwood trade, and consequently sustainably managing the resource, extremely difficult. Legislative reform is required to address these issues.

A DEC discussion paper that explores regulatory reform options is at Attachment 6.

5.2 Pending Commonwealth legislation

The Australian Government introduced the Illegal Logging Prohibition Bill 2012 into Federal Parliament on 23 November 2011. This Bill seeks to prohibit the possession and sale of illegally harvested timber in Australia. The scope of this Bill appears to include illegally harvested sandalwood. DEC is investigating the potential of the legislation to control the illegal sandalwood trade.

6.0 Conclusion

Based on the research, inventory and harvesting data, DEC considers that the authorised level of green sandalwood harvest is beyond an environmentally sustainable level. Combined with the other impacts (significant illegal harvesting, decreased regeneration and increased mortality), sandalwood is expected to continue to decline across its range outside of conservation reserves where harvesting is not permitted.

The regulatory regime to manage sandalwood is inadequate, lacking clarity, integration, enforcement powers and deterrents necessary to be effective.

The illegal harvest of sandalwood is rapidly increasing, reflecting increases in its price, inadequacies in the regulatory regime and unfulfilled demand.

DEC considers that legislative reforms to provide a more effective regulatory regime, and an updated species management plan and industry management plan, should be developed to ensure the continued viability of the species and of the industry.
7.0 References


8.0 Attachments

Attachment 1


Attachment 2


Attachment 3

Sandalwood (Limitation of Removal of Sandalwood) Order 1996.

Attachment 4


Attachment 5

Media Statement of 25 September 2012 by Hon Bill Marmion MLA, Minister for Environment – *Sandalwood black market on the rise*.

Attachment 6

MANAGEMENT OF SANDALWOOD

by

Ian G. Kealley

October 1991

Published by the Department of Conservation and Land Management
P.O. Box 104, Como, W.A. 6152.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acknowledgements</td>
<td>vi</td>
</tr>
<tr>
<td>1. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2. Resource Information</td>
<td>1</td>
</tr>
<tr>
<td>2.1 Distribution and Biology</td>
<td>1</td>
</tr>
<tr>
<td>2.1.1 Distribution</td>
<td>1</td>
</tr>
<tr>
<td>2.1.2 Taxonomy</td>
<td>1</td>
</tr>
<tr>
<td>2.1.3 Description</td>
<td>1</td>
</tr>
<tr>
<td>2.1.4 Phenology and Reproduction</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Silvicultural Characteristics</td>
<td>3</td>
</tr>
<tr>
<td>2.2.1 Seed Production and Viability</td>
<td>3</td>
</tr>
<tr>
<td>2.2.2 Regeneration</td>
<td>3</td>
</tr>
<tr>
<td>2.2.3 Survival and Damaging Influences</td>
<td>4</td>
</tr>
<tr>
<td>2.2.4 Growth Rates and Recruitment</td>
<td>5</td>
</tr>
<tr>
<td>2.3 Population and Resource for Harvesting</td>
<td>5</td>
</tr>
<tr>
<td>2.3.1 Introduction/Resource Assessment</td>
<td>5</td>
</tr>
<tr>
<td>2.3.2 Population Levels</td>
<td>7</td>
</tr>
<tr>
<td>2.3.3 Age/Size Class Distribution</td>
<td>7</td>
</tr>
<tr>
<td>2.3.4 The Potential Resource for Harvesting</td>
<td>7</td>
</tr>
<tr>
<td>2.3.5 Regeneration and Recruitment</td>
<td>9</td>
</tr>
<tr>
<td>2.4 Conservation</td>
<td>10</td>
</tr>
<tr>
<td>2.4.1 Conservation Through Reservation</td>
<td>10</td>
</tr>
<tr>
<td>2.4.2 Conservation Outside Reserves</td>
<td>10</td>
</tr>
<tr>
<td>2.4.3 Industry Management</td>
<td>12</td>
</tr>
<tr>
<td>2.5 Sandalwood Research</td>
<td>12</td>
</tr>
<tr>
<td>2.5.1 The Sandalwood Research Institute</td>
<td>12</td>
</tr>
<tr>
<td>2.5.2 Research Priorities</td>
<td>13</td>
</tr>
<tr>
<td>2.5.3 Ongoing Research and Development</td>
<td>14</td>
</tr>
<tr>
<td>3. Sandalwood Industry</td>
<td>16</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>16</td>
</tr>
<tr>
<td>3.2 History</td>
<td>17</td>
</tr>
<tr>
<td>3.3 The Sandalwood Export Committee</td>
<td>17</td>
</tr>
<tr>
<td>3.4 Responsible Organization and Statutory Basis</td>
<td>17</td>
</tr>
</tbody>
</table>
IV Statutory Reserves Throughout the Range of Sandalwood, Within 1980-1984 Assessment Regions, Outside of Agricultural Areas, at December 1990. 33

V Calculation of Annual Sandalwood Ingrowth from 75-125 mm Size Class to Merchantable Size Class Stems (125 mm diameter). 36

FIGURES

1 Distribution of Sandalwood in Western Australia. Conservation reserves and sandalwood assessment regions throughout the range of sandalwood outside the agriculture area. 2

2 Weight per stem of green sandalwood when harvested. 6

3 Sandalwood size class distribution for merchantable areas. 9

4 Planned 50 Years of Crown land sandalwood harvesting 1985-2035. 20

TABLES

1 Total number of living sandalwood outside agriculture areas from 1980-1984 assessment. 8

2 Estimated number of merchantable sandalwood stems and resource available outside reserves from 1980-1984 assessment. 8

3 Average stocking and number of sandalwood regeneration (0-24 mm diameter size class) outside statutory reserves from 1980-1984 assessment. 11

4 The number of living sandalwood within statutory conservation reserves (at December 1990) from 1980-1984 assessment. 11

5 Impacts on sandalwood numbers (as assessed 1980-1984) of planned 50 years of green sandalwood harvesting 1985-2035. 13

6 Sandalwood production (tonnes) 1970-1989. 18
ACKNOWLEDGEMENTS

The following documentation of sandalwood conservation in W.A. is the result of the work and contribution of staff over many years. These include staff of the former Forests Department and present staff from the Department of Conservation and Land Management involved in managing the sandalwood industry.

Without the foresight, work, advice and assistance of staff who instigated sandalwood research and resource assessment, including those in outside agencies, there would be insufficient information to compile a management program.

I would like to convey special thanks to W.G. Brennan, N.C. Caporn, P.C. Richmond, M.H. Tagliaferri, A.J. Williamson and O.W. Loneragan for management, research and assessment; B.J. Beggs, Chairman, and members of the Sandalwood Export Committee and the Australian Sandalwood Company for advice and assistance with funding of research, inventory and the Sandalwood Conservation and Regeneration Project.

Thanks also to the sandalwood harvesting contractors (pullers) for their input and adaptation to a rapidly changing industry.
1. INTRODUCTION

This wildlife management program outlines the conservation and management of Sandalwood (Santalum spicatum (R.Br.) A. DC.) in Western Australia.

The program provides a summary of biological and ecological knowledge of sandalwood, the current industry and a statement of objectives and strategies for continued management. Extensive details of the species and the history of harvesting are documented in the references.

A wildlife management program for sandalwood is required because of:

• the long history of harvesting sandalwood in Western Australia with export from 1845;
• the ongoing industry which is dependent on a resource modified by the history of harvesting, the presence of exotic herbivores, other conflicting land uses and inherited historical management and harvesting impacts;
• the necessity to ensure both viability of sandalwood populations and sustainability of the industry.

Unless superseded earlier the term of this program shall be ten years (1991-2001).

2. RESOURCE INFORMATION

2.1 Distribution and Biology

2.1.1 Distribution

The natural distribution of sandalwood in Western Australia is from latitude 24°S (approximately 80 km north of Carnarvon), eastwards along the lake system around the Nullarbor Plain into South Australia, south to a latitude of 34°S and west as far as the drier fringe of the main forest area on the Darling Ranges: an area of around 90 million ha (Fig. 1). Additional plants have been recorded in localized areas outside of the main distribution (Hewson and George 1984; Kealley 1989; Loneragan 1990).

Clearing for agriculture and the history of harvesting in the Wheatbelt region of Western Australia has reduced sandalwood occurrence in this area to only occasional remnants.

Throughout the remaining area of its natural distribution sandalwood is widespread although locally patchy.

2.1.2 Taxonomy

A description of sandalwood has recently been summarized in Flora of Australia (Hewson and George 1984):

Shrub to 4 m tall. Bark rough, grey. Branchlets stiff, spreading. Leaves lanceolate to narrowly elliptic, flat, obuse; lamina 2-7 cm long, 3-15 mm wide, concordorous, grey-green; petiole 3-5 mm long. Flowers numerous in panicles, scented; peduncle 3-5 mm long; pedicels 1 mm long. Receptacle 1-1.5 mm long. Tepals triangular-ovate, 1.5-2 mm long, scurfy inside, red-green, persistent in fruit; hair tufts small. Disc shortly lobed. Style 0.5 mm long; stigma bilobed. Drupe 1.5-2 cm diam.; epicarp green or brown; mesocarp firm, usually adhering to endocarp when ripe; endocarp smooth. Sandalwood.

It is further described and illustrated with ecological information in Forest Trees of Australia (Boland et al. 1984).

Four named species of the genus Santalum occur in Western Australia. Sandalwood (Santalum spicatum (R.Br.) A. DC.), is found only in Western Australia and South Australia. The other three species - S. lanceolatum (R.Br.), or Plumbush, S. acuminatum (R.Br.) A. DC., Quandong or Candle Nut and S. murrayanum (Mitchell) C. Gardn., Bitter Quandong - are widely distributed throughout Australia. All three lack aromatic fragrance, but Plumbush contains oil. Plumbush has an ovoid, dark plum-like fruit, and is found mainly in the north-west of Western Australia, and northern Australia. Quandong fruit has a red outer covering, a deeply pitted stone and an oily, edible kernel; Bitter Quandong has a bitter brownish-red outer covering and a finely pitted stone. Both are widespread throughout the warmer parts of temperate Australia. There are possibly other unnamed taxa on the Southern Nullarbor and near Shark Bay.

2.1.3 Description

Sandalwood (Santalum spicatum (R.Br.) A. DC.) is a small tree or shrub, maturing to 3-8 m tall and 10-30 cm stem diameter with sparse irregular spreading branches and dull grey-green fleshy leaves. Sandalwood is an obligate root hemi-parasite (Herbert 1925; Barrett 1989a) associated with a wide range of hosts that it requires for growth to maturity.

Sandalwood is well adapted to drought and is slow growing, taking 50-90 years, depending on rainfall, to achieve commercial size of 127 mm stem diameter (Loneragan 1990). Sandalwood heartwood contains highly valued, quality aromatic oils. Sandalwood is distributed from the Western Australian coast and Wheatbelt agricultural areas through the drier areas of W.A. and S.A. to north of the Flinders Ranges. It grows on a wide range of soils with best stands occurring where vegetation types mix, giving the widest range of hosts.
Various tenures including C.A.L.M. Estate
C.A.L.M. Region Boundary
Distribution of Sandalwood
Based on Western Australian State Herbarium records and Kealley, 1985
Agriculture Area Boundary
Sandalwood Assessment Regions
A Goldfields
B Murchison
C Other pastoral lands and deserts
D Yalgoo
O Northern pastoral lands, Southern eucalypt woodlands and Nullarbor
P Plumridge Lake

Figure 1
Distribution of Sandalwood in Western Australia. Conservation reserves and sandalwood assessment regions throughout the range of sandalwood outside the agriculture area
2.1.4 Phenology and Reproduction

Flowering is in response to rainfall and can occur in any season. The small primitive pungent flowers develop into fruits with a red brown leathery exocarp surrounding a smooth round hard endocarp (nut) up to 2 cm diameter.

Sandalwood nuts, produced in quantity in good seasons, are nutritious and palatable. They are similar to other nuts, high in fat (60 per cent) and rich in protein (18 per cent) yielding 2945 kJ per 100 g (Barrett 1989a). Sandalwood nuts are under investigation for human consumption, although not currently recommended until further research is conducted on the effects of santalbic acid present in the kernels.

Sandalwood nuts germinate following rain and subsequent cracking of the nut. In nature, under normal circumstances, germination rate is low with very low survival (1-5 per cent) of germinants (Loneragan 1990). Several years of above-average rainfall are required for good germination and survival.

The low germination and survival combined with susceptibility to fire, minimal coppicing, and grazing by domestic and feral herbivores has resulted in low levels of regeneration outside conservation reserves in the last 50-60 years (Section 2.3.3).

Research into phenology and reproduction has shown that:

- sandalwood flowers at 3-4 years old and sets seed at 6-7 years old (Barrett 1987a; Barrett et al. 1989; Loneragan 1990);
- sandalwood flowers regularly and consistently in natural stands with buds appearing from mid-summer to autumn. Flowering commences at differing times on different trees (Barrett 1987a);
- fruits take around 6 months to mature, ripening from October to December;
- at Curtin University of Technology, initial studies on stigma receptivity and anthesis indicate that pollen appears to be released over a short period soon after the bud begins to open. The stigma appears to be most receptive rather later with the onset of pink tepal and receptacle colouration. This study indicated that self pollination is unlikely;
- further bagging experiments were conducted in attempts to provide more definitive information on whether flowers are self or cross pollinated. Results strengthen the indication that outcrossing may occur (Fox and Barrett 1989);
- flowers are mildly, but distinctly carrion-scented and nectariferous. Flies, bees, wasps, ants, native cockroaches and moths have been observed on flowers (Barrett 1987b).

2.2 Silvicultural Characteristics

Past and ongoing research has investigated the biology, regeneration and management of sandalwood with a view to:

- re-establishing the species in areas where it once occurred naturally (e.g. agricultural areas);
- managing the existing industry, and sandalwood as a species;
- providing data for commercial plantations or crops on areas where this is an acceptable land use;
- conserving the species on reserves.

Extensive research into the reproductive biology, regeneration and management of sandalwood was conducted in the Wheatbelt and Goldfields in the 1970s and '80s by the Forests Department and Department of Conservation and Land Management.

The research provided detailed information on growth rates in different climatic zones, flowering and seeding cycles and the factors which influence the success of seed germination, survival, and growth to maturity (Loneragan 1990).

2.2.1 Seed Production and Viability

Observations and experiments to determine seed production and viability found:

- seed production is variable between trees and years and related to seasonal conditions, genetic variability, hosts and nutrition. In above-average rainfall years seed production is heavy (Barrett et al. 1989; Loneragan 1990);
- observations at Bullock Holes and Calooli Sandalwood reserves phenology plots, show regular flowering and a relationship between rainfall and successful seed production in an average mature stand. In 1984 following above-average rainfall (320 mm compared with 250 mm average), 26 trees at Bullock Holes yielded 3038 seeds (variation 6 to 860 nuts per tree). At Calooli 27 trees yielded 11 858 seeds (variation 2 to 1350 nuts per tree). Average nut mass was 3.3 g;
- seed viability can be high (85 per cent) at seed fall but decreases rapidly after two years at room temperature (Loneragan 1990);
- seed can be stored for long periods in a cool store at 4-5°C, with silica gel, retaining a viability of up to 50 per cent after eight years (Loneragan 1990).

2.2.2 Regeneration

Early observations revealed that natural regeneration of sandalwood was low and growth slow. With high levels of harvesting and agricultural clearing the need for research and management was recognized and led to initial research and experimental planting of
sandalwood. Early work was carried out by the Forests Department in the 1920s and '30s at sites in the Wheatbelt and Goldfields. Results revealed low germination rates, poor survival (around 1 per cent) and problems with grazing by stock and rabbits. Best results were achieved in water-gaining sites on good loam soils, where grazing could be prevented (Loneragan 1990).

Since 1973 a series of regeneration studies were undertaken, results are as follows.

GERMINATION AND PLANTING

Initial experiments (Loneragan 1990) on germination requirements, using various treatments and planting of seeds and seedlings found:

- no beneficial effects from any pre-treatment of seed, apart from endocarp removal;
- improved germination occurred when the hard seed coat (endocarp) was removed and that seeds readily germinated under moist warm conditions;
- that planting of germinated seed adjacent to suitable hosts achieved the best survival rates (up to 30 per cent);
- that planting of 1-year-old seedlings with hosts was generally unsuccessful (survival 2-5 per cent) owing to failure of the sandalwood to achieve adequate host connections.

COPPICE TRIALS

Studies in the Goldfields (Loneragan 1990), to determine whether sandalwood could be regenerated by coppice found:

- that 4.5 per cent of stems coppiced, however, none of the coppice survived;
- that regeneration cannot be reliably obtained from coppice, either following fire or cutting. More recently, it has been found that root and stem coppicing is often successful, with survival up to 80 per cent after 2 years, in the Shark Bay area, a climatically milder zone (Barrett 1989b).

Early attempts to grow sandalwood seedlings to maturity under both controlled field conditions and in many rural localities had limited success (Fox and Wijesuriya 1985). In an attempt to better define regeneration and establishment requirements for sandalwood, Curtin University of Technology has conducted research since 1979. Publications have described the following:

- optimum conditions and methods for germinating sandalwood seed (Crossland 1981; Sawyer 1981; Chilvers 1982; Crossland 1982a; Barrett 1987b);
- regeneration techniques following harvesting including coppicing and direct sowing of seed at Shark Bay (Barrett 1989b);

From the research findings, a basic prescription and pamphlets for artificial regeneration, direct seeding and planting sandalwood in trays and pots have been developed and field tested (Underwood 1984; Barrett 1990a; Barrett 1990b). The prescription and pamphlets cover:

- seed - provenance, collection, cleaning and storage;
- nursery techniques for preparation of seed for sowing and raising seedlings for transplantation;
- selection of planting or sowing sites and sowing niches in the field;
- recommended timing of operations;
- subsequent management.

It is relatively easy to plant and regenerate sandalwood in the Wheatbelt (over 350 mm rainfall) where commercial-sized stems can be produced in 45-50 years. However, regeneration is not possible in areas grazed by sheep, cattle or goats, infested with rabbits, or subject to fire.

Planting and regeneration is far more difficult in the arid zone owing to variable seasons and difficulties of site selection. On pastoral leases planting is not considered worthwhile, unless grazing can be excluded.

2.2.3 Survival and Damaging Influences

Factors affecting survival of sandalwood regeneration and mature plants have been subject to considerable research as follows.

SANDALWOOD SURVIVAL

Studies (Loneragan 1990) on the effects of sowing seed, cultivation, fire and exclusion of grazing found:

- that fencing has a significant effect on seedling survival in grazed areas and a smaller effect on reserves, where grazing is restricted to native herbivores, rabbits and isolated introduced herbivores (stock);
- that cultivation improves germination of natural seed, however, survival is low owing to destruction of suitable host roots;
- to maintain a reasonable survival rate in the Goldfields, above-average rainfall is required for several consecutive years;
- that planting of 1-year-old seedlings with hosts was generally unsuccessful (survival 2-5 per cent) owing to failure of the sandalwood to achieve adequate host connections;
mature and regenerating sandalwood is very susceptible to fire. Studies have shown all but light scorch will kill sandalwood. Coppicing after fire does occur, however, survival is low (10 per cent).

Additional research has been conducted at Curtin University of Technology; research has been published on the following:

- optimum age and conditions for planting sandalwood seedlings (Barrett 1987b);
- soil types best suited for young plants (Wijesuriya and Fox 1985);
- water and nutrient requirements - mineral nutrition of sandalwood in relation to host plants and mineral levels in healthy plants and seedlings of different ages (Barrett et al. 1985; Wijesuriya and Fox 1985; Struthers et al. 1986);
- host suitability and parasite/host dependence (Crossland 1981; Struthers et al. 1986);
- the growth of sandalwood in relation to shade (Fox and Barrett 1989).

Grazing is the critical external factor affecting the survival of sandalwood regeneration. Environmental factors (e.g. fire and drought) are the most important factors for survival of mature sandalwood.

2.2.4 Growth Rates and Recruitment

Comprehensive studies were undertaken in the 1970s to determine the range in size of sandalwood trees and growth rates (Loneragan 1990).

Growth rates are related to factors such as site conditions, climate and soils. A wide range of growth rates were discovered with sandalwood taking 32-59 years to reach commercial size (127 mm diameter at 150 mm above the ground) in the Wheatbelt and 59-115 years near Kalgoorlie (Loneragan 1990).

More specific research has since been completed and published as follows:

- development of individual plants, haustoria, and growth rates of leaves, stems, and whole trees (Crossland 1981; Barrett et al. 1985);
- the effect of various fertilizers on growth (Crossland 1981, 1982b).

2.3 Population and Resource For Harvesting

2.3.1 Introduction/Resource Assessment

Until the late 1970s, owing to the scattered nature of sandalwood occurrence, there was uncertainty about the extent and nature of the resource. To overcome this, a five-year assessment program was undertaken from 1980 to 1984, funded jointly by the Forests Department and the Australian Sandalwood Company.

Throughout its range, sandalwood is located in a variety of habitats with greatly varying density. The resource assessment quantified and located sandalwood stands allowing mapping and planning for management of the species, production, conservation and reservation.

METHOD

Sandalwood in better stands is widely distributed with few reliable indicators to define where it will occur. The only reliable guideline is that homogeneous vegetation types, whether pure mulga (*Acacia aneura*), pure eucalypt woodland, pure hummock grassland (*spinifex*) or pure bluebush (*Maireana spp.*), generally contain little or no sandalwood.

As the assessment was the first comprehensive and systematic survey of this type, methods of assessment had to be developed.

The irregular distribution of sandalwood in the field and the inability to accurately pre-determine sandalwood occurrence were the main factors that decided the assessment method. These factors led to adoption of an assessment method of road survey using experience, aerial photography, Landsat images and vegetation maps as a guide to assessing sandalwood within all vegetation and landform types within a particular area.

Each region to be assessed was divided into discrete areas, pastoral leases and geographical features (e.g. lakes) being the most common boundaries.

Before assessment, each discrete area was investigated, and if possible pre-stratified using 1:250 000 topographic maps, vegetation maps (Beard 1974, 1975, 1976, 1981), aerial photography and Landsat imagery.

Preliminary work and pre-stratification aimed to:

- define areas that had little chance of containing sandalwood such as homogeneous vegetation types;
- identify suitable tracks and access for road survey;
- identify areas of similarity for grouping of data when extrapolating assessment results.

SAMPLING

The method used was the ‘Tally Plot Method’. It involved travelling all roads, tracks, fencelines and mineral exploration gridlines in a four-wheel drive vehicle. Cross country traverses by motorcycle and vehicle were made when needed to assess undeveloped areas.

The routes travelled were selected to sample as wide a range of vegetation and landform types as possible. The aim was to achieve a minimum 1 per cent sample of the area and to intersect all different...
vegetation types interpreted from aerial photos and Landsat images.

All sandalwood, green and dead, within 20 m each side of the track was assessed as follows.

- The diameter at 150 mm above the ground of each green sandalwood in the 40 m strip was estimated and tallied into the following size classes:
  
  0-24 mm diameter - regeneration;
  25-74 mm diameter - undersized for harvesting;
  75-124 mm diameter - undersized for harvesting;
  125-174 mm diameter - merchantable size;
  greater than 175 mm diameter - merchantable size.

All stems over 127 mm diameter at 150 mm from the ground are of merchantable size.

- Dead sandalwood was tallied as either pieces (dead sandalwood externally weathered to a grey colour) or burnt wood.
- Tallies were kept for each 1-km unit along the track using a trip meter.
- Observations were made on the occurrence of sandalwood, especially regeneration, in relation to site and vegetation.
- Routes travelled, assessment traverses and observations were recorded on 1:250 000 topographic maps of the area.
- For some areas assessed, two measured plots were established where all stem diameters (at 150 mm) within a plot 1 km x 40 m (4 ha) were measured and the plot location recorded. Results of size class distribution from these measured plots are shown in Figure 3.

The assessment method resulted in 0.8 per cent - 2.5 per cent of the areas being assessed, depending on the extent of development and access.

RESOURCE CALCULATION

The assessment data and tally plots were analysed to calculate the total sandalwood population and resource.

Where sandalwood occurred in scattered isolated pockets and boundaries could not be defined, the assessment sample was assumed to be representative and applied to the total area assessed.

If a discrete area of sandalwood could be defined from aerial photography owing to landform or host vegetation associations, it was interpreted, mapped and the assessment sample for this area was calculated and applied separately to the remainder of the area.

Tallies and assessment data were converted into resource data for the area assessed by conversion into stems per hectare, then converting this to kilograms per hectare using air-dry stem weight data from previous research (Loneragan 1990) and data obtained from shipments to the Australian Sandalwood Company. Weight per stem for harvested green sandalwood is represented in Figure 2.

![Graph](image.png)

Figure 2
Weight per stem of green sandalwood when harvested
Dead sandalwood resource was calculated for the two categories, pieces and burnt. Burnt sandalwood weighed an average 6 kg per stem. Pieces (dead sandalwood weathered to a grey colour) weighed 3 kg per stem average.

Mean green stem weights for the merchantable size classes tallied were:

- 125-175 mm diameter (mid point 150 mm) - 16.18 kg
- greater than 175 mm diameter (mid point 200 mm) - 28.76 kg

Once the resource for the sample area was calculated in tonnes per hectare, the total resource could be calculated for the area to which the sample applied.

2.3.2. Population Levels

The total population of living sandalwood, outside the agriculture areas where no assessment was done, was calculated from the 1980-1984 assessment data.

The original distribution of sandalwood in W.A. was about 90 million ha with agricultural clearing reducing the distribution by around 13 million ha.

Within the remaining 77 million ha assessment revealed considerable variation in the location and density of sandalwood. Table 1 indicates the sandalwood population within discrete regions as shown in Figure 1.

The total population of living sandalwood is around 23 million with the most dense populations in the Goldfields, Yilgarn, Lower Murchison and Plumridge Lakes regions.

2.3.3 Age/Size Class Distribution

An indication of the size class distribution for sandalwood was obtained from data compiled during the 1980-1984 assessment of sandalwood resource.

Size class data, from 15 measured 4-ha plots on 12 pastoral stations, in representative stands of sandalwood from the Goldfields and lower Murchison areas is shown in Figure 3.

A similar trend was observed throughout the entire area (8.96 million ha) assessed.

The existing size class distribution, when analysed against research results for growth rates, survival and damaging influences, is related to the introduction of grazing by domestic herbivores (sheep, goats and cattle) and feral herbivores (rabbits). The reduced number of plants below 90 mm diameter (approx 70-90 years old in pastoral areas) correlates well with the developing pastoral industry and introduction of rabbits.

In the lower Murchison where pastoral activity commenced earlier and is more developed than in the Goldfields, the impact on regeneration and smaller size classes is more severe.

2.3.4 The Potential Resource for Harvesting

Sandalwood resource available for harvesting (merchantable) consists of live sandalwood over 400 mm circumference (127 mm diameter) measured over bark at 150 mm above ground level and dead sandalwood trees of any size, in areas where harvesting is permitted.

Restrictions on harvesting areas include:
- no sandalwood harvesting whatsoever on Nature Reserves or National Parks;
- no green sandalwood harvesting on Lands Act Sandalwood Reserves;
- no green sandalwood harvesting within areas defined by CALM Act regulations (forests) 95(b) or the 20-km radius green belt around the City of Kalgoorlie-Boulder (Appendix I);
- no green sandalwood harvesting within restricted areas defined on the sandalwood licence (CLM 695) and order (CLM 265) (Appendices II and III) including:
  - within a radius of 500 m from any watering point,
  - within a radius of 2 km from any homestead or shearing shed,
  - within 100 m of the edge (table drain) of any major road,
  - within 20 m of the edge of any pastoral station service road.

The number of merchantable stems on land outside reserved and restricted areas and the sandalwood resource level calculated from the assessment is outlined in Table 2.

The 1980-1984 assessment revealed that within the distribution of sandalwood the area available for harvesting is around 52 million ha. An estimated merchantable resource of 137 100 t exists including 110 000 t of green wood and 27 100 t of dead wood.¹

The proportion of the total merchantable resource that could be harvested economically varies between regions and is influenced by:

¹ Details of the 1980-1984 sandalwood resource assessment are being prepared for publication by Caporn, N.C., Kealley, I.G., and Williamson, A.J.

Improved utilization standards introduced since 1984, mainly affecting dead wood harvesting, have increased the amount of dead wood considered merchantable.

The total merchantable resource of dead wood was calculated using 1980-1984 standards and a mean weight per utilized stem. Since completing the survey a comparison between resource assessed and actual quantities harvested was made to further refine the data. Results to date show an under-estimate (still to be quantified) of total merchantable dead wood resource in the 1980-1984 assessment, mainly owing to the changed utilization standards.
Table 1  
TOTAL NUMBER OF LIVING SANDALWOOD OUTSIDE AGRICULTURAL AREAS FROM 1980-1984 ASSESSMENT

<table>
<thead>
<tr>
<th>Region (see Fig. 1)</th>
<th>Total Area (ha x 10³)</th>
<th>Area covered by assessment (ha x 10³)</th>
<th>Number of individual sandalwood (x 10³)</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>For area assessed (%)</td>
</tr>
<tr>
<td>Goldfields 'A'</td>
<td>4 900</td>
<td>3 190</td>
<td>6 670</td>
<td>1.05</td>
</tr>
<tr>
<td>Murchison 'B'</td>
<td>2 800</td>
<td>1 140</td>
<td>2 020</td>
<td>1.07</td>
</tr>
<tr>
<td>Other pastoral lands &amp; deserts 'C'</td>
<td>50 990</td>
<td>3 125</td>
<td>11 420</td>
<td>0.80</td>
</tr>
<tr>
<td>Yilgarn 'D'</td>
<td>2 760</td>
<td>1 140</td>
<td>2 580</td>
<td>0.58</td>
</tr>
<tr>
<td>Plumridge Lake 'P'</td>
<td>367</td>
<td>367</td>
<td>500</td>
<td>0.70</td>
</tr>
<tr>
<td>Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'</td>
<td>16 000</td>
<td>-</td>
<td>160</td>
<td>-</td>
</tr>
<tr>
<td>TOTAL</td>
<td>77 817</td>
<td>8 962</td>
<td>23 350</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Table 2  
ESTIMATED NUMBER OF MERCHANTABLE SANDALWOOD STEMS AND RESOURCE AVAILABLE OUTSIDE RESERVES FROM 1980-1984 ASSESSMENT

<table>
<thead>
<tr>
<th>Region</th>
<th>Total area (ha x 10³)</th>
<th>Area available for harvesting (ha x 10³)</th>
<th>Number of merchantable stems (x 10³)</th>
<th>Weight of merchantable stems (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Green</td>
<td>Dead</td>
</tr>
<tr>
<td>Goldfields 'A'</td>
<td>4 900</td>
<td>4 160</td>
<td>1 330</td>
<td>3 000</td>
</tr>
<tr>
<td>Murchison 'B'</td>
<td>2 800</td>
<td>2 400</td>
<td>740</td>
<td>550</td>
</tr>
<tr>
<td>Other pastoral lands &amp; deserts 'C'</td>
<td>50 990</td>
<td>29 000</td>
<td>3 570</td>
<td>2 500</td>
</tr>
<tr>
<td>Yilgarn 'D'</td>
<td>2 760</td>
<td>910</td>
<td>800</td>
<td>410</td>
</tr>
<tr>
<td>Plumridge Lake 'P'</td>
<td>367</td>
<td>260</td>
<td>65</td>
<td>210</td>
</tr>
<tr>
<td>Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'</td>
<td>16 000</td>
<td>15 200</td>
<td>75</td>
<td>110</td>
</tr>
<tr>
<td>TOTAL</td>
<td>77 817</td>
<td>51 930</td>
<td>6 580</td>
<td>6 780</td>
</tr>
</tbody>
</table>

(a) Crown land resource harvested since assessment (1984-1989) includes 4 813 tonnes of green wood and 5 935 tonnes of deadwood (Table 6).
• density of stands;
• price and market conditions;
• the scale and method of field operations;
• access and management.

Current operations are located in Murchison, Goldfields, Yilgarn, other pastoral land and desert regions.

2.3.5 Regeneration and Recruitment

The sandalwood resource assessment indicated that outside conservation reserves, regeneration of sandalwood and recruitment into larger size classes, as shown in Table 3, is poor.

The lowest recorded levels of regeneration were in the developed pastoral lands of the Murchison, Gascoyne and Goldfields.

Lack of sandalwood regeneration is related to grazing by feral and domestic herbivores, mainly sheep, goats and rabbits (Mitchell and Wilcox 1988; Loneragan 1990).

Research has also shown that sandalwood has specific requirements for successful seed set, germination and survival (Barrett 1987b; Loneragan 1990). As these specific requirements are met only irregularly, successful regeneration is possibly cyclical. These cyclical regeneration events, combined with environmental changes and grazing, have led to the current poor levels of regeneration and recruitment.

Regeneration and recruitment on reserves is superior to that on vacant Crown land and pastoral leases, although still affected by feral animals (rabbits and goats).

The size class used for regeneration in Table 3 (0-24 mm diameter), represents seedlings from 1 to 20 years old assuming diameter growth rate of 1 mm per annum. Regeneration numbers as shown in Table 3 and Figure 3 indicate annual levels of recruitment around 12,500 outside reserves.

Sandalwood is declining throughout its range, outside of conservation reserves, owing to this lack of regeneration. In the short to medium term the sandalwood industry is no threat to the survival of the species. In the long term, harvesting will impact if

---

**Figure 3**

Sandalwood size class distribution for merchantable areas
failure of regeneration is not reversed, or alternative sources of supply not developed.

2.4 Conservation

Conservation of sandalwood can be achieved through adequate reservation and careful management of the sandalwood industry, efficient use of the timber resource, by minimizing conflicts between sandalwood conservation and other land uses and by promoting the regeneration and planting of sandalwood.

2.4.1 Conservation Through Reservation

Throughout the range of sandalwood there is a large area of statutory reserves that contain sandalwood to varying degrees (Table 4, Appendix IV). Reserves created under the CALM Act and Regulations and Land Act are defined in terms of vesting, tenure and purpose as follows:

National Parks - Vested in the National Parks and Nature Conservation Authority (NPNCA) as A or C Class reserves (agreement of both houses of parliament is required before the purpose of National Parks can be changed) for flora and fauna and landscape conservation, scientific study and preservation of features of archaeological, historic or scientific interest, together with recreational enjoyment by the public.

Nature Reserves - Vested in the NPNCA as A, B or C Class reserves (agreement of both houses of parliament is required before purpose can be changed on A Class reserves) for flora and fauna and landscape conservation, scientific study and preservation of features of archaeological, historic or scientific interest.

State Forest - Vested in the Lands and Forests Commission (LFC) with security of tenure identical to that of A Class reserves, but with a multiple use purpose.

Timber Reserve - Vested in the LFC, change of tenure is at the discretion of the Minister, purpose is multiple use.

Sandalwood Reserve - Not vested, no security, created under the Land Act with the purpose of timber and sandalwood conservation.

CALM Act Regulations (forests) Reserves - Reserves created under the Regulations, e.g. Reg. 95(b), cannot be changed without ministerial approval. The purpose is for sandalwood conservation.

Green Belt - The green belt around Kalgoorlie-Boulder (20 km radius) is not vested and has no security. Forest produce licences are not issued for green wood, including sandalwood harvesting, on precedent.

Pastoral Lease - CALM is purchasing pastoral leases (Lands Act) for sandalwood conservation. They remain temporarily pastoral leases in the name of the Executive Director until converted to more appropriate tenure (e.g. State Forest).

Reserves within the CALM Goldfields Region boundary are currently being reviewed during the preparation of a Regional Management Plan. Recommendations are included to improve the security of tenure of reserves, include upgrading Timber Reserves and Sandalwood Reserves to State Forests, and conversion of purchased pastoral leases to State Forest.

There are 4.6 million ha of statutory reserves distributed throughout the range of sandalwood (Table 4, Appendix IV and Fig. 1). Within reserves there is an estimated population of 3.2 million living sandalwood or around 13.7 per cent of the total sandalwood population. The area of reserves and proportion of the regional population in reserves is outlined in Table 4.

The distribution and area of conservation reserves and representative sandalwood populations in reserves is considered adequate in the Goldfields, Central deserts and Nullarbor. In the Yilgarn and Plumridge Lake areas reservation is excellent.

Additional reserves are required in the north-eastern Goldfields pastoral areas to complete reservation of representative sandalwood areas.

In the Murchison and Gascoyne districts and northern part of the range of sandalwood, reservation is inadequate. Very few areas outside of pastoral leases remain available for reservation and all areas are grazed.

2.4.2 Conservation Outside Reserves

Of the estimated sandalwood population of 23.35 million the majority (20.15 million) are outside conservation reserves.

Conservation and management of sandalwood outside reserves faces many practical problems. The most important problem is the lack of sandalwood regeneration (Table 3) in areas where grazing by domestic and feral animals, mainly sheep, goats and rabbits, occurs. Sandalwood, like a number of other long-living, palatable woody shrubs with specific regeneration requirements, is declining in the pastoral areas. Grazing impacts severely on these species.

Other issues are:

- the availability of suitable land for conversion to conservation reserves is restricted owing to existing tenure, the availability of funds for purchase and difficulties in achieving secure tenure owing to conflicting land uses;
- the impact of harvesting before the current controls were introduced;
- increases in the size and frequency of fires in the pastoral/arid zone since European settlement,
### Table 3

**AVERAGE STOCKING AND NUMBER OF SANDALWOOD REGENERATION (0-24 MM DIAMETER SIZE CLASS) OUTSIDE STATUTORY RESERVES FROM 1980-1984 ASSESSMENT**

<table>
<thead>
<tr>
<th>Region</th>
<th>Area outside reserves (ha x 10^3)</th>
<th>Average stocking of regeneration (0-24 mm size class) (s.p.h.)</th>
<th>Total number of sandalwood regeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldfields 'A'</td>
<td>4.377</td>
<td>0.009</td>
<td>39,400</td>
</tr>
<tr>
<td>Murchison 'B'</td>
<td>2.465</td>
<td>0.0008</td>
<td>200</td>
</tr>
<tr>
<td>Other pastoral lands &amp; deserts 'C'</td>
<td>49.365</td>
<td>0.0005</td>
<td>24,700</td>
</tr>
<tr>
<td>Yilgarn 'D'</td>
<td>2.085</td>
<td>0.065</td>
<td>179,400</td>
</tr>
<tr>
<td>Plumridge Lake 'P'</td>
<td>260</td>
<td>0.004</td>
<td>1,000</td>
</tr>
<tr>
<td>Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'</td>
<td>14,660</td>
<td>0.0005</td>
<td>7,300</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>73,212</td>
<td>0.0035</td>
<td>258,000</td>
</tr>
</tbody>
</table>

### Table 4

**THE NUMBER OF LIVING SANDALWOOD WITHIN STATUTORY CONSERVATION RESERVES (AT DECEMBER 1990) FROM 1980-1984 ASSESSMENT**

<table>
<thead>
<tr>
<th>Region</th>
<th>Total area (ha x 10^3)</th>
<th>Reserves (a) area (ha x 10^3)</th>
<th>Reserves as a percentage of the total area</th>
<th>Individuals in reserves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. x 10^3</td>
</tr>
<tr>
<td>Goldfields 'A'</td>
<td>4,900</td>
<td>523</td>
<td>10.7</td>
<td>1,010</td>
</tr>
<tr>
<td>Murchison 'B'</td>
<td>2,800</td>
<td>335</td>
<td>12.0</td>
<td>340</td>
</tr>
<tr>
<td>Other pastoral lands &amp; deserts 'C'</td>
<td>50,990</td>
<td>1,625</td>
<td>3.2</td>
<td>340</td>
</tr>
<tr>
<td>Yilgarn 'D'</td>
<td>2,760</td>
<td>675</td>
<td>24.4</td>
<td>1,320</td>
</tr>
<tr>
<td>Plumridge Lake 'P'</td>
<td>367</td>
<td>107</td>
<td>29.1</td>
<td>180</td>
</tr>
<tr>
<td>Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'</td>
<td>16,000</td>
<td>1,340</td>
<td>8.4</td>
<td>10</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>77,817</td>
<td>4,605</td>
<td>5.9</td>
<td>3,200</td>
</tr>
</tbody>
</table>

(a) Individual reserves and vesting are listed in Appendix IV.
which have a severe effect on the survival, distribution and regeneration of fire-sensitive sandalwood.

The current sandalwood industry is based on merchantable sandalwood that occurs outside nature conservation reserves and areas where harvesting is restricted by licence conditions (Section 2.3.4).

Within the 51.93 million ha available for harvesting (Table 2) there is an estimated (at 1985) merchantable resource of 137 000 t including 6.58 million green sandalwood trees. In addition, ingrowth of 1930 t per annum is occurring (Appendix V) which involves about 177 000 trees. The amount of this estimated resource that could be harvested economically is very subjective.

Harvesting since assessment and future harvesting, as outlined in this management program (Section 3.9), will remove around 54 000 t of green wood over 50 years (1985-2030), an estimated 3.24 million stems which is 13.7 per cent of the total existing green stems. Beyond 50 years harvest of green sandalwood will continue to reduce to a sustainable level, including salvage and normal operations in areas that can sustain harvesting. It is proposed that green wood harvest will be reduced as plantation-grown Indian Sandalwood (Santalum album) becomes available in the long term.

The impact of harvesting will vary between regions as outlined in Table 5.

2.4.3 Industry Management

Up until 1950 sandalwood harvesting was carried out with little regard for conservation of the resource or the species.

From 1950 the current industry has operated under licence conditions with strict management guidelines that assist with conservation including:

- a minimum size restriction for harvesting of live trees (127 mm diameter at 150 mm above ground level);
- excluding areas from green wood harvesting such as 500 m radius from water points, 2 km radius from homesteads and outbuildings, 100 m from any main road, 20 m from any pastoral access track;
- complete utilization of every tree harvested;
- incentives to harvest a greater amount of deadwood and salvage dead trees;
- a requirement to plant seeds when harvesting green stems;
- restricted or no harvesting in areas designated as having high conservation value (e.g. regeneration zones and fire effected areas);
- harvesting only if it causes no damage to young plants, or alteration to the distribution or conservation status of the species.

These measures have increased the proportion of Crown land dead wood harvested to the 1989 level of 60 per cent of the quota.

Quantifying of regeneration and recruitment and better resource data have resulted in a number of further recent changes. These include: removing some areas from green harvesting (e.g. Gindalbie Station owing to impacts of fires), area specific harvesting conditions (e.g. Shark Bay), and a program for acquiring further reserves.

2.5 Sandalwood Research

Research on sandalwood biology and regeneration problems commenced around 1900 and continued spasmodically to the present. Research was supported and conducted by the Forests Department, CALM, Curtin and Murdoch Universities and since 1980 with co-ordination and support from the Sandalwood Research Institute.

2.5.1 The Sandalwood Research Institute

The Sandalwood Research Institute (SRI) exists to fund and promote research on sandalwood in Australia. It was established in 1980 by the Australian Sandalwood Company as a non-profit industry research institute. It is recognised by the Australian Taxation Office as an 'approved research institute'.

The basic philosophy of the SRI is to support research and development activities which appear to have good potential to contribute to the maintenance and expansion of the sandalwood industry in W.A., in line with the State's overall plan for the future of the industry. This means that SRI will support projects concerned with either the endemic Santalum spicatum or any introduced Santalum species. Priority will generally be given to those activities which show promise of economic benefit to the industry and the State.

The basic objectives of the SRI are to promote scientific research, investigation and experimentation of:

- the incidence and habitat of sandalwood in Australia;
- reforestation of the species in Australia;
- the biotic strains of sandalwood and the union with host plants;
- the species of sandalwood in other countries and methods employed to regenerate, propagate and improve stocks of sandalwood;
- the introduction of foreign species of oil-bearing sandalwood into Australia.
### Table 5
**IMPACTS ON SANDALWOOD NUMBERS (AS ASSESSED 1980-1984) OF PLANNED 50 YEARS OF GREEN SANDALWOOD HARVESTING 1985-2035**

<table>
<thead>
<tr>
<th>Region</th>
<th>Total no. sandalwood ((x \times 10^3))</th>
<th>No. merchantable stems at 1985 ((x \times 10^3))</th>
<th>No. of stems ingrowing to merchantable size ((x))</th>
<th>Estimated no. merchantable size removed by harvesting 1985-2035 ((x \times 10^3))</th>
<th>Percentage of total stems harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldfields 'A'</td>
<td>6 670</td>
<td>1 330</td>
<td>61</td>
<td>3 040</td>
<td>990</td>
</tr>
<tr>
<td>Murchison 'B'</td>
<td>2 020</td>
<td>740</td>
<td>16</td>
<td>790</td>
<td>800</td>
</tr>
<tr>
<td>Other pastoral lands &amp; deserts 'C'</td>
<td>11 420</td>
<td>3 570</td>
<td>73</td>
<td>3 650</td>
<td>550</td>
</tr>
<tr>
<td>Yilgarn 'D'</td>
<td>2 580</td>
<td>800</td>
<td>22</td>
<td>1 090</td>
<td>800</td>
</tr>
<tr>
<td>Plumridge Lake 'P'</td>
<td>500</td>
<td>65</td>
<td>4</td>
<td>220</td>
<td>50</td>
</tr>
<tr>
<td>Northern pastoral lands, southern Eucalypt woodlands and Nullarbor 'O'</td>
<td>160</td>
<td>75</td>
<td>1</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>23 350</td>
<td>6 580</td>
<td>177</td>
<td>8 840</td>
<td>3 240</td>
</tr>
</tbody>
</table>

(a) Calculation outlined in Appendix V.

---

Its activities so far have been to disburse funds for research projects, mainly at tertiary institutions in W.A., which were deemed to provide information useful for the continuation of the sandalwood industry. These projects have covered research on both *S. spicatum* and *S. album*. The SRI has also supported an annual seminar on current sandalwood research in order to improve communication among those interested in this field.

The SRI receives administrative support from the Australian Sandalwood Company, is governed by a Board of Trustees and operates under a 5-year research and development plan (Anon. 1989b).

Support for the SRI in the past has been from funds made available by the Australian Sandalwood Company arising from Commonwealth export incentive awards. Future funds will come from the Sandalwood Conservation and Regeneration Project (SCARP), as determined in this management program and other external funds and grants. The SCARP project will contribute $100 000 annually to the SRI.

#### 2.5.2 Research Priorities

Research results and inventory data permitted the development of this management program and prescriptions for artificial regeneration, direct seeding and planting.

As a generalisation, it can be said that it is possible to regenerate sandalwood fairly reliably in the Wheatbelt, provided it is protected from fire and grazing, but regeneration in the more arid areas is much more uncertain.

Research success in establishing sandalwood has not resulted in extensive regeneration programs owing to economic constraints. In neither the Wheatbelt nor Goldfields areas does plantation culture of sandalwood for wood production alone meet normal economic criteria for return on investment.

For these reasons, attention from about 1984 was increasingly directed towards the possibility of replacing *S. spicatum* with the tropical *S. album*, which grows in India and parts of eastern Indonesia, as a plantation crop for timber production grown in tropical areas of the State.

With research on W.A. sandalwood having progressed to the stage that provides basic silvicultural knowledge, and increasing interest in Indian Sandalwood, the principal areas of research priority identified at this stage are as follows.
TISSUE CULTURE OF S. ALBUM

It is necessary to develop reliable techniques for the field establishment of sandalwood clonal material. This holds great potential for mass propagation of genotypes with superior tree characteristics and oil quality and quantity. The possibility that physiologically mature clonal material might produce oil-containing heartwood earlier than seedling plants also needs investigation.

RESEARCH ON HEARTWOOD FORMATION IN S. ALBUM

Research is required to determine how soon heartwood is formed on various soil types and what degree of genetic variation in oil content exists. An iso-enzyme technique for non-destructive assessment of oil content appears promising and needs to be further developed and refined.

ESTABLISHMENT OF S. ALBUM

There is still no reliable technique for the production of vigorous and healthy seedlings of this species. The optimum primary (nursery stage) host for W.A., or whether a host is needed, has not yet been determined. Once adequate local seed supplies are available, it is very desirable to develop a reliable method of establishing this species by direct seeding.

USE OF S. SPICATUM AS A FOOD NUT

There are promising indications that sandalwood nuts may have commercial potential but a number of aspects need further research.

SILVICULTURE OF S. ALBUM

Research into selection of optimum secondary host species, adaptability of the species to different soil types in the Kimberley area, determination of optimum stocking patterns of sandalwood and hosts, and collection of growth data are required.

2.5.3 Ongoing Research and Development

Research into aspects of Santalum spicatum and Santalum album is being conducted by CALM, Curtin and Murdoch Universities and through involvement with the Australian Centre for International Agricultural Research (ACIAR), and includes:

SANDALWOOD (SANTALUM SPICATUM)

- Sandalwood woodlots and conservation in the Wheatbelt - a project to describe and identify:
  
  variation in the morphology of sandalwood in the Wheatbelt;

  sandalwood habitats in the Wheatbelt;

  relationships between growth, morphology and habitat;

  sandalwood populations which are phenotypic variants, and of these, those which have the best characteristics for woodlots.

The project is funded by SCARP funds with results to be used in establishing trial 20-ha woodlots at Narrogin and Katanning. It is conducted by a consultant supervised by CALM (Kealley 1990).

- Identifying remnant sandalwood stands, fencing and regenerating sandalwood demonstration plots on farms in the Greenough district.

A project involving fencing plots of 3-4 ha on farms containing remnant sandalwood, to include regeneration work, vermin control and assessment of regeneration. Funded by SCARP funds, conducted by CALM (Kealley 1990).

- Coppicing and direct seeding of sandalwood at Nanga Station, Shark Bay.

A 3-year (1988-1990) project to assess the impacts of harvesting and regeneration from coppice and direct seeding. Early observations confirm that S. spicatum will produce coppice from cut stump and root suckers and direct seeding has had some success (Anon. 1989a; Barrett 1989a). Funded by the Australian Sandalwood Company conducted by Curtin University and CALM staff.

- The use of sandalwood as a food nut: preliminary research (Fox and Barrett 1989; Barrett 1989a; Anon 1989a) indicated research into sandalwood nut production as an alternative crop was merited.

A project funded by the SRI conducted by Curtin University has commenced.

- Ongoing studies on flower and fruit production documenting yearly crop development. Curtin University project.

- Tissue culture (vegetative propagation) of Santalum spicatum: attempts to vegetatively propagate sandalwood by both cuttings and tissue culture were unsuccessful. In tissue culture it was found to be possible to develop plantlets with shoots but after much work no way could be found to promote root formation (Chilvers 1982). Work was conducted at Murdoch University with SRI funding.

- Trial planting with farmers in the Avon Valley with 5 ha planted on seven properties. A Curtin University/National Afforestation Project.

- Assessment of genetic variation within sandalwood and its reservation status.

Apart from these ongoing projects and identified priority areas no further S. spicatum research is envisaged.

INDIAN SANDALWOOD (SANTALUM ALBUM)

- Vegetative propagation and tissue culture
Research into vegetative propagation of *S. album* was conducted at Murdoch University in an attempt to identify and reproduce high yielding strains of sandalwood. This field of research is finally, after some years, meeting with success and has reached the stage of having seedlings growing in pots for planting out in the field. These trials will give invaluable experience in handling clonal material and the vegetative propagation technique will be a very useful research tool.

Research will be ongoing funded by the SRI.

**Field Trials**

Interest in *S. album* as an alternative species to *S. spicatum* and as a commercial plantation species led to field trials commencing in the tropical Kimberley region of W.A..

CALM established several small trial plots in the Kimberley from 1986 onwards, leading towards a trial 20-ha plantation being prepared for initial planting in 1990/91, within irrigated land at Kununurra (Kealley 1990).

A summary of field research as outlined by McKean (1990) is;

'Early results (from *S. album* plantings) are very promising: mean heights of 3 m being achieved in 2 years under irrigation at Kununurra. The survival has been generally good and no real difficulties are foreseen in establishing the species routinely if a suitable nursery procedure can be developed. Early plantings used several Kimberley *Acacia* species as host. There were distinct differences in growth of the sandalwood with different Acacias, e.g. there was markedly better growth in the first two years with *A. trachycarpa* than with *A. ampliceps*. In the early trials, the sandalwood was grown under supplementary irrigation, as there is ample water available at Kununurra and the annual rainfall is only 500 mm.

All the seedlings in the initial trials were raised in the same pot as the hosts and some difficulty was encountered in finding a host which did not overcrowd the rather slow growing sandalwood seedling. Pruning the host was the answer, but that could clearly not be used in anything more than a research trial. A further problem appeared two or three years after planting out when it was found that the host was too close to the sandalwood and was pushing the sandalwood over. This prompted a move to a two stage host system: the primary host being a small, low-growing species such as *A. translucens* and the long term host being a variety of large Acacias and other species of tree.
reliable nursery technique for the establishment of the species. Although planting seedlings may not be the technique used by a large-scale regeneration program, it is an essential research tool and at the very least, a fall back operational establishment procedure, especially if seed resources are limiting.

Initial results of this and earlier research have been outlined by Fox and Barrett (1989).

It is also important to keep in touch with current research on sandalwood in Indonesia and New Caledonia, to ensure that duplication of work does not occur and that any useful developments can be followed up here. At this stage, this contact is maintained through CALM’s involvement in the ACIAR project. Should this terminate, other avenues of maintaining contact will be developed.

It is also of great interest to compare the growth of different species of sandalwood and their adaptation to a range of sites. Some additional funds were obtained from ACIAR in 1988 to support the establishment of an international species/provenance trial to follow up this aspect. It was originally intended to include Australia, Indonesia, New Caledonia, Fiji and Vanuatu, but could be extended to include other countries if desired. Progress has been slow owing to seed losses caused by cyclones and by the withdrawal of Indonesia, but the first plantings should take place in 1990 and hopefully some of the Hawaiian species may now be included. A provenance trial will be established at Kununurra as part of this project.

Research into S. album in the Kimberley including ACIAR, SRI and CALM (SCARP) will be co-ordinated and implemented by a full-time research officer funded jointly for 3 years (1991-1993) to be stationed at Kununurra.

Research in all these areas will be ongoing.

3. SANDALWOOD INDUSTRY

3.1 Introduction

Sandalwood is highly valued for the aromatic qualities of the oils contained in the heartwood. Sandalwood has been harvested and exported from Western Australia since 1845. Although varying over the years, the industry, under present market conditions, is now stable and profitable.

Sandalwood is exported by the Australian Sandalwood Company, Fremantle, as various products to Taiwan, Hong Kong, Singapore, Thailand and Malaysia where it is used, mainly in powdered form, for the manufacture of joss sticks used in religious ceremonies.

The history of the Western Australian sandalwood industry is well documented (Underwood 1954; Robertson 1958; Ware 1975; Richmond 1983; Talbot 1983; Statham 1988).

3.2 History

In the late 1920s and early '30s, four companies were exporting sandalwood and competing for markets in China. Sandalwood was being gathered (known as pulling) from the agricultural and pastoral areas of W.A. by contract pullers with no restriction on prices or quantities. Mostly these pullers were paid low rates and the industry provided only a subsistence wage to them.

By 1929 China was torn by civil war, the market collapsed and huge stocks of sandalwood accumulated at Fremantle and country rail sidings. Pullers were not being paid for wood supplied and the industry was in a state of chaos.

In order to rationalize the industry and to provide funds to pay the pullers, who were in desperate financial trouble, the Government of the day agreed to underwrite the sandalwood stocks provided the four companies merged. In 1929 the Sandalwood Act was passed and in 1930 the companies were amalgamated to form the Australian Sandalwood Company Ltd, and the Sandalwood Export Committee was established.

3.3 The Sandalwood Export Committee

The Sandalwood Export Committee was established on 22 July 1932 by agreement between the Governments of Western Australia and South Australia, the Australian Sandalwood Company Ltd, and the Co-operative Sandalwood Company (South Australia) Ltd. This agreement was renegotiated and ratified in 1952 when the parties agreed that it remain in force indefinitely until terminated by any party.

As South Australia no longer produces sandalwood for export, there has been no recent South Australia participation in the activities of the Committee and South Australia formally withdrew from the agreement from 1 January 1987.

The Sandalwood Export Committee is now composed of:

- a representative of the W.A. Minister for Conservation and Land Management who is the nominated Chairman;
- an Australian Sandalwood Company representative as a member;
- a Secretary supplied by CALM;
- also attending by invitation are advisors from CALM including The Director, Forest Resources Division, the State Sandalwood Control Officer and the Chairman of the Australian Sandalwood Company board.

16
The Committee meets approximately every two months. Subjects such as export prices and policy, payments to pullers, conservation practices in the industry and quotas to be applied to pullers are discussed and decided upon by the Committee. The Committee also sets the annual export quota based upon the availability of sandalwood, quantities required to meet market needs, conservation of the species and the long-term viability of the industry. Decisions reached are binding on the Company by virtue of the terms of the Sandalwood Export Agreement.

3.4 Responsible Organization and Statutory Basis

Sandalwood harvesting in W.A. is administered by the Department of Conservation and Land Management, according to the provisions of the Sandalwood Act (1929 as amended), CALM Act (1984 as amended) and CALM Act regulations (Forests) (Appendix 1).

3.5 Demand and Supply

Demand for selected grade sandalwood from the various markets is known to be substantially greater than the current maximum harvesting level of 2000 t.

The target harvest will be 2000 t per annum, subject to minor seasonal variations, for conservation and management reasons, to maximise returns and maintain a stable market.

Demand is tempered by the Export Committee by requiring the market to accept a substantial proportion of lower grade material which in past years was regarded as non-marketable residue.

3.6 Harvesting Level and Employment

The Sandalwood Export Committee and CALM have determined a present harvesting level (quota) of 2000 t per annum. This consists of:

- 200 t from private property, the maximum 10 per cent of the quota as allowed under the Sandalwood Act;
- 1800 t from Crown land: to satisfy conservation and management strategies this will include a minimum 45 t reserved for pastoralists under provisions of the environmental hardship policy and maximising the harvest of dead wood including salvage.

Sandalwood production from 1970-1989 is outlined in Table 6. Recent private property production is mainly from the Hampton Areas in the Goldfields, between Kambalda, Coolgardie and Kalgoorlie.

Commercial sandalwood is harvested from various regions - 1989 Crown land operation areas included:

- Plumridge Lakes area - 18.4 per cent of production;
- North Eastern Goldfields and Central Desert areas - 3.2 per cent of production;
- Goldfields - 29.8 per cent of production;
- Yilgarn - 22.8 per cent of production;
- Paynes Find Area - 20.5 per cent of production;
- Gascoyne District - 4.4 per cent of production;
- Shark Bay Area - 0.9 per cent of production.

In 1989 employment in the sandalwood industry harvesting operations included:

- 11 full-time contractors - 81.9 per cent of production;
- 7 part-time contractors - 6.6 per cent of production;
- 3 pastoralist contractors - 1.4 per cent of production;
- 5 private property licences - 10.0 per cent of production.

A further 56 sandalwood timber workers' registrations were issued to contractor's employees.

With the current stability in the industry, most of the existing contractors have been harvesting sandalwood for many years. The industry depends on small independent contractors and provides employment and income to groups, including Aboriginal communities in remote areas.

At times, sandalwood harvesting is used as supplementary income for pastoralists suffering difficulties caused by environmental hardship (e.g. fire or drought). Quotas of up to 20 t are available under these hardship provisions.

3.7 Prices and Returns

The 1990 prices received by sandalwood contractors were:

- $970 per tonne for green wood;
- $970 per tonne for dead wood (known in the industry as pieces);
- $24 per tonne as a pallet loading allowance;
- $60 per tonne isolation allowance paid to contractors operating in remote areas.

Prices are adjusted each year by the Sandalwood Export Committee after taking into consideration a number of factors, including variations in the Consumer Price Index (C.P.I.) for the year plus any special circumstances such as marked changes in operating costs owing to changed utilization standards or variation in licence conditions. Previously these prices had been set generally to operate for a financial

---

2 At the time of publication of this management program, revised Forest Management Regulations under the CALM Act are being prepared. These regulations are expected to be gazetted later in 1991.
Table 6
SANDALWOOD PRODUCTION (TONNES) 1970-1989
(Source, CALM Kalgoorlie Records)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>CROWN LAND</th>
<th>PRIVATE PROPERTY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contractors</td>
<td>Pastoralists</td>
</tr>
<tr>
<td></td>
<td>Green Wood</td>
<td>Dead Wood</td>
</tr>
<tr>
<td>Green Wood</td>
<td>Dead Wood</td>
<td>Green Wood</td>
</tr>
<tr>
<td>1970</td>
<td>660.00</td>
<td>101.00</td>
</tr>
<tr>
<td>1971</td>
<td>1243.00</td>
<td>136.00</td>
</tr>
<tr>
<td>1972</td>
<td>1027.00</td>
<td>153.00</td>
</tr>
<tr>
<td>1973</td>
<td>838.00</td>
<td>294.00</td>
</tr>
<tr>
<td>1974</td>
<td>888.00</td>
<td>424.00</td>
</tr>
<tr>
<td>1975</td>
<td>807.00</td>
<td>444.00</td>
</tr>
<tr>
<td>1976</td>
<td>741.00</td>
<td>722.00</td>
</tr>
<tr>
<td>1977</td>
<td>694.00</td>
<td>536.00</td>
</tr>
<tr>
<td>1978</td>
<td>822.00</td>
<td>610.00</td>
</tr>
<tr>
<td>1979</td>
<td>937.00</td>
<td>739.00</td>
</tr>
<tr>
<td>1980</td>
<td>1001.00</td>
<td>626.00</td>
</tr>
<tr>
<td>1981</td>
<td>964.00</td>
<td>616.00</td>
</tr>
<tr>
<td>1982</td>
<td>982.00</td>
<td>651.00</td>
</tr>
<tr>
<td>1983</td>
<td>869.19</td>
<td>841.39</td>
</tr>
<tr>
<td>1984</td>
<td>853.36</td>
<td>802.07</td>
</tr>
<tr>
<td>1985</td>
<td>785.99</td>
<td>913.39</td>
</tr>
<tr>
<td>1986</td>
<td>727.67</td>
<td>881.81</td>
</tr>
<tr>
<td>1987</td>
<td>702.46</td>
<td>926.19</td>
</tr>
<tr>
<td>1988</td>
<td>707.28</td>
<td>927.68</td>
</tr>
</tbody>
</table>

year, but from 1 January 1985 the Committee decided to set these prices for each calendar year, as this is also the negotiated period for the export prices.

The Australian Sandalwood Company arranges and pays for contract carriers to transport the sandalwood by road and rail to the processing shed at Spearwood.

Royalty charges are paid by the Australian Sandalwood Company at a rate based on 10 per cent of the monthly FOB value. This rate applied from 1 January 1987. In 1989/90 royalty yielded $985 928 to the Government.

In addition, the Australian Sandalwood Company pays the annual recoupable costs to the Department of Conservation and Land Management to cover expenses incurred on behalf of the Company and in supervising the industry. These comprise field inspections and control by Goldfields Region staff, plus secretarial and management functions at Head Office. In 1989/90 an amount of $76 830 was received.

In 1990 CALM appointed a full-time forester to supervise field operations associated with the sandalwood industry. All costs associated with the position are fully recouped from the Australian Sandalwood Company including salary, vehicle expenses, administration and overheads. The position will be ongoing, costing around $85 000 per annum.

Sandalwood is sold in various grades to Asian buyers, the 1990 FOB ($Aust) value per tonne at Fremantle was:
PRODUCTS 24/02/90

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandalwood Logs (cleaned)</td>
<td>$9 363</td>
</tr>
<tr>
<td>Sandalwood Logs (uncleaned)</td>
<td>$5 318</td>
</tr>
<tr>
<td>Pieces (dead wood)</td>
<td>$6 926</td>
</tr>
<tr>
<td>Chips</td>
<td>$4 788</td>
</tr>
<tr>
<td>Butts</td>
<td>$7 573</td>
</tr>
<tr>
<td>Powder</td>
<td>$5 000</td>
</tr>
<tr>
<td>Shavings</td>
<td>$2 952</td>
</tr>
<tr>
<td>No. 2 Chips</td>
<td>$2 500</td>
</tr>
</tbody>
</table>

The maximum amount of sandalwood received at the Company's Spearwood shed is exported, including sawdust, which is sold at reduced prices by negotiation when sufficient has accumulated to warrant marketing.

The W.A. Government shares in the profits of this commercial operation in a manner laid down in the agreement. On profits of $300 per tonne, the proportion is $221 to the Government and $79 to the Company. Any amount in excess of $300 returns 90 per cent to the Government and 10 per cent to the Company.

For the financial year 1989/90 the W.A. Government received $985 928 in royalty, $76 830 as overheads and administration and $5 086 818 as share of profits. This is a total of $6 149 576 for the year from an operation that produced a gross export income in excess of $11.15 million.

3.8 Ingrowth

Since assessment of the merchantable resource of green sandalwood, there will be an annual addition to the merchantable resource as smaller sizes grow above 127 mm diameter.

Appendix V calculates ingrowth into greater than 125 mm size class (merchantable), on the area available for harvesting, as 1 930 t per annum. Only a proportion of this would be commercial in regions where quality sandalwood and ongoing harvesting occurs.

3.9 Future Harvesting

An ongoing sandalwood industry is proposed utilizing existing merchantable green and dead resources and ingrowth. Harvesting levels will be managed to achieve conservation objectives while maintaining the industry until alternative plantation grown resources can reduce green wood harvesting of natural stands.

The assessed Crown land merchantable resource (at 1985) of 137 000 t, including 110 000 t of green and 27 000 t of dead, would permit 76 years of harvesting at the current level of 1800 t per annum. Ingrowth, calculated at 1930 t per annum, will further extend the available merchantable resource.

Many factors can have an impact on resource availability and alter future harvesting plans, such as:

- price and market conditions;
- the scale and economics of harvesting;
- changes to the tenure of areas where sandalwood grows;
- changes in land use and impacts, especially grazing;
- access and changing utilization standards;
- growth and regeneration;
- creation of new resource by plantation;
- changes in demand;
- bushfires.

These factors make long-term prediction of harvesting and resource, especially the proportion of dead and green, very difficult.

The amount of the total merchantable resource that can be considered economic for harvesting is very subjective (Section 2.3.4). A proportion occurs in scattered stands in remote regions (Table 2) and is less likely to be harvested. Initially harvesting would be concentrated in better sandalwood areas, for economic reasons, and will have differing impacts (Table 5). Management through adjustment of returns and profitability can ensure it remains economic to harvest remote and scattered resource, especially dead wood, therefore maximising dead wood resource utilization.

Future harvesting plans are outlined in Figure 4.

Harvesting since assessment (1985-1990) and planned 45 years of future harvesting (1991-2035, Fig. 4) will utilize around 30 000 t of merchantable dead wood resource and 54 000 t of merchantable green wood resource and ingrowth.

The impact on green sandalwood numbers of harvesting since assessment and planned future green wood harvesting in various regions is outlined in Table 5. Harvesting will remove 3.24 million green stems or 13.7 per cent of the total existing Crown land green stems.

Features of future Crown land harvesting are:

- Minimal changes to the current industry from 1990-2000, maintaining a harvesting level of around 800 t green and 1000 t dead wood. This permits restructuring of quotas to minimise impacts on existing contractors and gives time to refine resource data.

- A phased 20-year (2001-2020) reduction in dead wood harvest to accommodate reducing dead wood resource and allow quota reductions, industry restructuring and changes to harvesting areas. Beyond 2020, dead wood production will remain at
the level produced by concurrent green and dead wood operations, expected to be around 200 t per annum.

- The merchantable dead wood and total dead wood resource from the 1980-1984 assessment is under review. Improved utilization and changing standards may increase the resource (Section 2.3.4 Footnote). Once the resource is refined (during the life of this program) the effect on timing and quantity of the required reduction in dead wood harvest will be confirmed.

- Maintaining harvest of merchantable green wood and ingrowth at the level required to keep total production at around 1800 t per annum. In the longer term (2020 onwards), as plantation resource availability permits, there will be a phased reduction to a level of production generated from salvage operations and ongoing sustainable harvesting.

- From 2020 onwards, plantation resource, from Indian Sandalwood plantations in the Kimberley, will be phased in. It is recognized that utilizing Indian Sandalwood plantations differs significantly from harvesting W.A. Sandalwood. It is intended to utilize the opportunities created by the new plantation resource to reduce harvest of green W.A. Sandalwood, while maintaining an export industry and returns.

To meet planned future harvesting from plantations the following plantation development is required.

<table>
<thead>
<tr>
<th>Planting Years</th>
<th>Area Planted (ha per annum)</th>
<th>Volume Harvested (tonnes per annum)</th>
<th>Harvesting Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-1995</td>
<td>10</td>
<td>100</td>
<td>2021-2025</td>
</tr>
<tr>
<td>1996-2000</td>
<td>40</td>
<td>400</td>
<td>2026-2030</td>
</tr>
<tr>
<td>2001-2005</td>
<td>70</td>
<td>700</td>
<td>2031-2035</td>
</tr>
<tr>
<td>Total area of plantation 1990-2005</td>
<td>600</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This assumes a yield of 10 t/ha of heartwood with a rotation length of 30 years (Kealley 1990).

Within the life of this program (10 years) research on Indian Sandalwood silviculture will determine the optimum techniques for plantation silviculture. Based on these results, planned harvesting can be adjusted in future plans to achieve sustainable green wood harvest.

4. THE SANDALWOOD MANAGEMENT PROGRAM

4.1 Broad Objective
To conserve sandalwood as a species in W.A., and at the same time maintain the sandalwood industry by reducing harvest of the natural green wood resource.
and supplementing the natural resource by the increasing use of plantations.

4.2 Specific Objectives
Specific objectives are to:

4.2.1 Conservation Reserves
Develop and manage an effective conservation reserve system to conserve and protect representative areas of sandalwood containing viable populations of plants throughout its range.

4.2.2 Research
Carry out research and inventory to ensure the best silvicultural, protection, conservation and utilization techniques are used in management and reservation.

4.2.3 Harvesting
Adjust the level of harvest from natural stands to a level consistent with growth, with due regard to employment and economic stability. Replace harvest of natural stands with increasing use of plantations, to meet demand and achieve conservation, land use and economic aims.

4.2.4 Marketing
Ensure that sandalwood products are marketed to favour the highest value products with the maximum level of local processing.

4.2.5 Management
Maintain sandalwood harvesting operations as planned with control by the present system of licences, quotas and conditions, and continue the emphasis on efficient utilization of the resource. Update protection and regeneration prescriptions in the light of research.

4.2.6 Education
Educate and promote public awareness of sandalwood management, conservation and reservation.

4.2.7 Regeneration
Improve the establishment and survival of regeneration, throughout the range of sandalwood, by control of introduced herbivores.

4.3 Strategies
Strategies to achieve objectives are:

4.3.1 Conservation Reserves
- Investigate and review current conservation reserves with a view to establishing an effective reserve system, with secure tenure and purpose, free of encumbrances, to conserve representative stands of sandalwood throughout its range.
- Review conservation through reservation of sandalwood throughout its range using inventory and distribution data. Improve conservation status by acquiring areas for sandalwood reserves.
- Manage conservation reserves to ensure maximum protection of existing sandalwood by removing and controlling grazing by introduced herbivores and by protecting from wildfire.
- Use developed techniques for enrichment and re-establishment of sandalwood in reserves where it occurred naturally.

4.3.2 Research
- Initiate a major study of alloenzyme variation in sandalwood to document the genetic resource and integrate sandalwood conservation with reservation strategies.
- Continue research on sandalwood management in accordance with defined priorities to achieve research objectives.
- Review existing research projects, remeasure established trials and publish existing research data.
- Contribute to ongoing research co-ordination by involvement with the Sandalwood Research Institute and maintaining an overview and input to research programs.
- Conduct research into sandalwood regeneration and enrichment techniques, and silvicultural techniques for plantations of both *S. spicatum* and *S. album*.

4.3.3 Harvesting
- Restructure licences and quotas, adjust the level of green wood harvesting to achieve management objectives without disadvantaging those engaged in the industry.
- Ensure harvesting of dead wood receives priority over harvesting living trees.
- Modify licence conditions to achieve objectives.

4.3.4 Plantations
- Investigate and establish trial commercial plantations of sandalwood (*Santalum spicatum* and *Santalum album*) where this is a practical, economic and an acceptable land use.
- If it is shown that viable plantations of *Santalum album* are possible, promote the economic returns, feasibility and techniques to commence a program of plantation establishment with the long-term objective of transferring the majority of green wood harvesting to that species.
- Establish trial plots of W.A. sandalwood in the higher rainfall areas of its range and manage remnant stands throughout its former range.
4.3.5 Marketing
- Investigate and review harvesting, transport, and processing methods to achieve the most economic methods.
- Use returns from the sale of sandalwood for management, conservation and reservation.

4.3.6 Management
- Supply of sandalwood should not exceed 2000 t per annum: 1800 t maximum from Crown land, 200 t maximum from private property.
- Continue to provide advice to the Sandalwood Export Committee.
- Ensure operating areas are allocated to defined boundaries and directed to those areas where land use and conservation objectives are achieved.
- Use licence conditions to achieve management and conservation objectives and to minimise conflict with other land use objectives. Review conditions regularly.
- Provide infrastructure for management of the sandalwood industry and new initiatives associated with the management program.

4.3.7 Education
- Develop and disseminate information on sandalwood.
- Encourage landholders to regenerate and plant sandalwood and to manage remnant stands on private property.
- Use promotion, education and publicity to increase community understanding of sandalwood management.

4.3.8 Regeneration
- In conjunction with the Agricultural Protection Board and other land users, develop and implement control measures for introduced herbivores throughout the range of sandalwood.

4.4 Resources for Management
Resources for management of the sandalwood industry include finance, staff, infrastructure and the industry-funded SCARP project.

4.4.1 Finance, Staff and Infrastructure
Financial arrangements for CALM recovering industry management costs are outlined in Section 3.7. All costs incurred are recovered and these arrangements are ongoing.

Staff resources include one full-time CALM field officer funded by the industry on a recoup basis. Goldfields Region staff provide administration, infrastructure, management and support on a cost recovery basis.

Finance, staff and infrastructure are well resourced for the ongoing management of the sandalwood industry.

4.4.2 Sandalwood Conservation and Regeneration Project (SCARP)
In September 1988 the $1.5 million SCARP project co-ordinated by the Sandalwood Export Committee and supervised by CALM was commenced with funding allocated from the sandalwood industry.

The objective of this project is to improve the conservation status of sandalwood in W.A.

This will be achieved by:
- developing and managing an effective reserve system to conserve representative areas of sandalwood, containing viable populations of plants, throughout the range of the species, specifically:
  - purchasing areas for sandalwood reserves (pastoral leases),
  - purchasing grazing rights and removing grazing from reserves where sandalwood occurs,
  - fencing reserves and other management measures to control grazing by feral animals;
- co-ordinating existing research, carrying out new research and reviewing and publishing completed research to ensure the best silvicultural, protection and utilization techniques are used in management of sandalwood;
- developing plantations of sandalwood to supplement harvesting of natural stands, specifically:
  - establishing a trial 20-ha plantation of Indian Sandalwood (Santalum album) in the Ord irrigation area,
  - establishing a 20-ha trial plantation of W.A. sandalwood in the Wheatbelt (Narrogin),
  - encouraging plantings in remnant woodland on Wheatbelt farms in the Merredin, Katanning and Greenough districts;
- providing infrastructure to improve utilization and the efficiency of management of the current sandalwood industry;
- educating and promoting general awareness of sandalwood conservation and regeneration through publicity, information and interaction with landholders and the public;
- establish an extensive introduced herbivore control program to be implemented with the aim of improving the success of sandalwood regeneration.

The project is ongoing with initial objectives and timing (Kealley 1990) based on the original $1.5 million approved funds. Once projects involving the initial objectives have been implemented, ongoing funding
will be committed for maintenance and development (e.g. plantations, reserve management and research).

Achievements of the SCARP project, including projects commenced to December 1990, involving expenditure of $810 000, include the following.

RESEARCH
- A review and rewrite of unpublished past research has been completed and published (Loneragan 1990) ($37 000);
- A consultant is working on documenting remnant sandalwood in the Wheatbelt ($31 000);
- $170 000 has been directed to research projects through the Sandalwood Research Institute including research into Indian sandalwood (S. album) and W.A. sandalwood (S. spicatum).

CONSERVATION RESERVES AND MANAGEMENT
- In 1989 CALM purchased Jaurdi pastoral lease (320 000 ha) for sandalwood and nature conservation under the project ($65 000). In 1990 Mt. Elvire pastoral lease (154 000 ha) was also purchased ($85 000);
- Fencing has been completed, to control stock grazing, on Coonana and Wallaby Rocks Sandalwood Reserves in the Goldfields ($40 000);
- Conservation reserves containing sandalwood have been signposted to improve management ($10 000);
- The project has provided infrastructure for management of the existing industry including accommodation ($140 000) and equipment;
- Management work has been undertaken on purchased pastoral leases including building maintenance, fence repairs, cleanup and survey ($30 000);
- Kambalda Timber Reserve has been fenced and alternative water points provided to exclude stock grazing ($15 000);
- A 16 000-ha reserve has been created on Boolardy Station in the Murchison area in conjunction with the pastoral lessee, Land Conservation District and CALM. Fencing and survey have been completed ($25 000).

PLANTATIONS AND PLOTS
- A 20-ha plantation for Indian Sandalwood (S. album) is being established within the Ord irrigation area at Kununurra. The site has been prepared for irrigation. Planting has commenced using sandalwood and host seedlings raised at CALM's Broome nursery and by direct seeding ($45 000);
- Remnant stands of sandalwood in the Greenough area are being fenced in conjunction with landholders, regenerated and enrichment planted ($6 000);
- A field trial of Indian Sandalwood and various hosts has been established within the Ord Irrigation area, in conjunction with research being conducted by Murdoch University ($10 500);
- A 20-ha block has been purchased near Narrogin to establish a S. spicatum trial plantation and woodlot. Initial work for plantation development including site preparation for direct seeding and trials has commenced ($67 000).

EDUCATION
- A permanent display on sandalwood has been established at the Museum of the Goldfields ($25 000);
- Several publications and pamphlets on sandalwood have been produced ($6 000).

4.5 Implementation and Monitoring

Implementation of the management program will be achieved through an operational plan and the SCARP project.

A five-year operational plan reviewed annually will implement management, harvesting and marketing objectives and strategies. The SCARP project will implement objectives and strategies for reserves, research, plantations, regeneration and education.

Monitoring will be carried out by the Department of Conservation and Land Management regional staff, State sandalwood control officer, Sandalwood Field Forester with assistance from CALM's Research Division and the Sandalwood Research Institute.
REFERENCES


Beard J.S. (1974) Vegetation Survey of Western Australia: Great Victoria Desert 1:1 000 000 map and memoir. University of Western Australia Press.

Beard J.S. (1975) Vegetation Survey of Western Australia: Nullarbor 1:1 000 000 map and memoir. University of Western Australia Press.

Beard J.S. (1976) Vegetation Survey of Western Australia Murchison 1:1 000 000 map and memoir. University of Western Australian Press.

Beard J S (1981) Vegetation Survey of Western Australian Swan Region 1:1 000 000 map and memoir. University of Western Australian Press.


AN ACT to regulate the quantity of Sandalwood to be pulled or removed from Crown and other land.

[Assented to 5th December, 1929.]

BE it enacted—

1. This Act may be cited as the Sandalwood Act, 1929-1934, and shall be read as one with the Forests Act, 1918, hereinafter referred to as the principal Act.

2. The Governor may from time to time, by Order in Council, limit and restrict the quantity of sandalwood that may be pulled or removed from Crown land and alienated land during a period therein stated.

3. (1) No person shall pull or remove sandalwood—

(a) from Crown land, except under a license granted pursuant to regulations under the principal Act; or

(As amended by Acts:
No. 43 of 1930, assented to 22nd December, 1930;
No. 13 of 1934, assented to 26th November, 1934;
and reprinted pursuant to the Amendments Incorporation Act, 1938.)
(b) from alienated land, unless such person (being the grantee or lessee thereof, or a person lawfully claiming under him) is authorised to do so by a license in the prescribed form granted to him by the Conservator of Forests under this Act.

Penalty: Two hundred dollars.

(2) Licenses shall not be granted under paragraph (b) of subsection (1) of this section to authorise the pulling or removal of sandalwood in any quantity exceeding in the aggregate ten per centum of the total quantity as determined for the time being by Order in Council under section two.

(3) The granting of licenses under paragraph (b) of subsection (1) of this section shall be in the order of priority of application, and the allocation to each licensee of the quantity of sandalwood to be pulled or removed under license shall be determined by the Minister.

(4) In this section the words “alienated land” mean and include any land granted by the Crown for an estate in fee simple and any land held on conditional purchase or other lease or tenure under the provisions of the Land Act, 1898,1 or the Mining Act, 1904, but shall not include any land granted or demised subject to the reservation to the Crown of sandalwood thereon.

4. The Governor may make regulations under the principal Act for the purposes of this Act, and by such regulations may (subject to such conditions as are prescribed) exempt from this Act any land in process of clearing for agricultural purposes.

5. For the purposes of this Act the word “Sandalwood” means and includes the wood of any tree of the genera Santalum or Fusanus, and any other species of aromatic wood which is or may be used as a substitute for sandalwood.

1See now Land Act, 1933.
CONSERVATION AND LAND MANAGEMENT ACT
REGULATIONS (FORESTS) AS AMENDED

SANDALWOOD

95. No license shall be granted for the cutting, pulling, or removal of living sandalwood trees on and from the following reserves and the area of Crown land defined hereunder:

(a) Sandalwood Reserve No. 19211, Calooli.
Sandalwood Reserve No. 19212, Yellari.
Sandalwood Reserve No. 19214, Lakeside.
Sandalwood Reserve No. 19825, Bullock Holes.
State Forest No. 8, Karramindie.

(b) The Crown lands, or any portion of the Crown lands, within the area bounded by a line commencing from Kalgoorlie and extending along the Government railway line to Coolgardie, and thence along the Government railway line from Coolgardie to Widgiemooltha, thence across Lake Lefroy in a northeasterly direction to the Thirty-seven Mile peg on the Trans-Australian railway line, thence along the Trans-Australian railway line to Kalgoorlie.

96. No licensee, registered sandalwooder, or other person shall cut or pull or remove on or from Crown land any living sandalwood tree, or clean any sandalwood tree, so cut, pulled, or removed, of smaller dimension than as defined hereunder, that is to say, any sandalwood tree:

(a) of less than 330 millimetres in circumference measured over the bark at 150 millimetres from the ground level; or

(b) the log of which, when cleaned of sapwood, is less than 250 millimetres in circumference, measured at a point equivalent to 150 millimetres above ground level.

97. No person shall supply to any licensee or other person, in fulfilment of any order from such licensee or other person:

(a) any sandalwood tree of less than 330 millimetres in circumference measured over the bark at 150 millimetres from the ground level; or

(b) any sandalwood log which, when cleaned of sapwood, is less than 250 millimetres in circumference measured at a point equivalent to 150 millimetres above ground level.

being the product of any living sandalwood tree cut or pulled on Crown land.

98. The Executive Director may require any sandalwood to be inspected by an officer of the Department of Conservation and Land Management.

99. Application for a license to pull or remove sandalwood on and from land alienated from the Crown shall be made to the Executive Director in writing, and shall be accompanied by such particulars as the Executive Director may require.

100. Any person applying for a license other than the grantee or lessee of alienated land from which it is desired to pull or remove sandalwood may be required to produce to the Executive Director authority in writing from the grantee or lessee to pull sandalwood from the land therein specified.
Appendix I (continued)

101. A license to pull or remove sandalwood from alienated land may be in the Form No. 6 in the First Schedule to these regulations, and shall authorise the licensee to pull and remove the quantity of sandalwood therein specified on and from the alienated land therein defined.

102. (1) A license under regulation 101 of these regulations may be issued for any period not exceeding six months from the date thereof.

(2) No extension of any license shall be granted in the event of a licensee failing to fully exercise his rights by pulling and removing the quantity of sandalwood therein specified within the term of the license. But a licensee may make application for a further license in respect of sandalwood not pulled or removed under a previous license, and such an application shall be dealt with in order of its priority.


104. It is an offence for any person to furnish any false, incorrect, or misleading statements, particularly with reference to the ownership of alienated land, or the ownership of sandalwood on alienated land, with a view to obtaining a license under these regulations.

1At the time of publication of this management program, draft Forest Management Regulations under the CALM Act are being prepared. These regulations are expected to be gazetted later in 1991.
FOREST PRODUCE (SANDALWOOD) LICENCE NO:_____

District........................................................................................................................................................................

THIS IS TO CERTIFY that....................................................................................................................................................

of..................................................................................................................................................................................

is hereby licensed to obtain sandalwood as follows........................................................................................................

tonnes Barked......................................tonnes Pieces

From..............................................................................................................................................................................

(Description of Crown Land from where sandalwood is to be obtained)

This licence is current from ........................................................... to ......................................................................

(Date)

and is NOT VALID UNTIL THE HOLDER OBTAINS AN ORDER for this amount of sandalwood from the Australian Sandalwood Company Limited.

This licence is issued subject to the following special conditions...........................................................

..................................................................................................................................................................................

and to the General Conditions printed below.

Dated at ...........................................................this ..............................................day of ...............................................

Executive Director

Issuing Officer

GENERAL CONDITIONS APPLYING TO THIS LICENCE

1. "EXECUTIVE DIRECTOR" means the Executive Director of the Department of Conservation and Land Management.

2. This licence is not transferable to another person and must be produced upon request to any Officer of the Executive Director.

3. This licence is issued under and subject to the provisions of the Sandalwood Act, the Conservation and Land Management Act and the Regulations in force under these Acts.

4. The licensee must comply with the provisions of the Bush Fires Act.

5. The licensee is hereby authorised to obtain and remove only that forest produce for which this licence is issued from pastoral or other leases or holdings for the purpose for which this licence is issued, but this licence does not authorise the licence holder to cut through, break down or otherwise interfere with any fencing or other improvements erected upon or adjacent to the licence area.

6. This licence does not release the licensee from liability to legal action in respect of any damage caused by the licensee, his workmen, agents or any other persons acting for or on behalf of the licence holder.

7. The licensee shall keep closed all gates used by him and shall take all necessary action to prevent the movement of stock into or from any area within the licence area enclosed by fences which may have been damaged as a result of his operations.

8. The licensee shall comply with all conditions printed on the back of his Order Form (CLM 265) and with any special conditions notified in writing either on the Order Form or to him by an Officer of the Executive Director.

9. This licence shall be produced on demand to the lessees of any pastoral or other leases or holdings (or their representatives) on which the licensee may be operating.

10. This licence is not valid until the holder obtains an order for this amount of sandalwood from the Australian Sandalwood Company Limited.

11. The licence shall be produced on demand to the lessees of any pastoral or other leases or holdings (or their representatives) on which the licensee may be operating.
ORDER FOR SANDALWOOD FROM CROWN LANDS

(NOT TRANSFERABLE)

Order No.

To: .................................................................

To be obtained from Crown Lands (other than areas reserved for the protection of sandalwood) in the vicinity of .

144 to be consigned to the Australian Sandalwood Co. Ltd., Lot 17 Mell Road, Spearwood.

The above sandalwood must be delivered before . after which date this order will no longer be valid.

PAYMENT

Subject to the conditions relating to sandalwood production on the back of this order and any other condition or specification stipulated below the price paid will be $ ................................. per tonne.

In addition:
(a) A transport subsidy at the rate of $...................... per tonne will be paid; or
(b) the transport of sandalwood obtained under this order will be arranged by the Australian Sandalwood Co. Ltd.
(c) where the sandalwood obtained under this order is stacked in approved pallets for transport an allowance of $.................. per tonne will be paid.

Payment will be made on the quantity of sandalwood delivered, based on Spearwood or other official weighbridge weights.

PENALTIES

This order is issued under the authority and is subject to the Conservation and Land Management Act and the Department referred to is the Department of Conservation and Land Management and the Executive Director is the Permanent Head of that Department.

Should it be shown that this order has been obtained as the result of misrepresentation or incorrect statement, or that any of the conditions are not being or have not been complied with, this order may be cancelled and the whole or any portion of the sandalwood pulled or the pieces collected under this order are liable to confiscation by Departmental officers or, in the event of delivery having already been accepted by the company, the Executive Director may direct that the whole, or any portion of the proceeds of such sandalwood shall be paid to the Department.

All sandalwood supplied must have the bark completely removed and where there is brittle, shelly, charred or worm-eaten wood this must also be removed until only sound wood remains.

All pieces supplied must be free of earth.

In the event of any sandalwood being delivered to the company which is not considered to be of fair average quality or is not of the specifications as set out in this order, the Executive Director will be asked to assess its value and this decision will fix the price to be paid for such wood and will be final and binding upon the parties to this order.

The holder of this order must be fully aware of the conditions printed overhead.

The Executive Director may direct that such additional conditions be complied with as he considers necessary for the protection of the environment in the particular circumstances at the time, and such conditions are notified in writing hereunder.

ADDITIONAL CONDITIONS (IF ANY) ...........................

This order is issued on behalf of the Australian Sandalwood Co. Ltd., 9/6 Suffolk Street, Fremantle, 6160 by .................................................. on .................
Appendix III (Continued)

CONDITIONS

1. A current Certificate of Registration as a Timber Worker issued by the Department must be held by all persons engaged in the pulling or gathering of sandalwood.

2. Any quantity of sandalwood pulled or gathered in excess of the current order held is liable to confiscation by Departmental officers.

3. The holder of this order is personally responsible for any damage which results from his operations. This applies particularly to fences, mills, tanks and other improvements on pastoral leases.

4. "Before any camp is established on a pastoral lease the pastoralist or the manager must be notified by the holder of the order and its location discussed. The holder of the order must notify the pastoralist or the manager when commencing operations and when entering or leaving the lease. Reasonable liaison must be maintained with regard to sandalwood operations on the lease."

5. Camps are to be maintained in a clean and tidy condition with all refuse properly and regularly disposed of. When camps are removed the sites must be cleaned to the satisfaction of the Departmental officer.

6. No dogs will be permitted on a pastoral lease without written permission from the pastoral lessee or his manager.

7. No person shall cut down, pull out, injure or destroy any living sandalwood tree of less than 400 millimetres in circumference measured over the bark at 150 millimetres from the ground level, or any sandalwood tree growing:

   (a) Within a radius of 500 metres from any watering point.
   (b) Within a radius of 2 kilometres from any homestead or shearing shed.
   (c) Within 100 metres of the edge (table drain) of any major road.
   (d) Within 20 metres of the edge of any pastoral station service road.

8. The girth limit in condition 7 does not apply to fire killed sandalwood but where fire killed sandalwood shows any sign of coppice or root sucker growth the dead tree must be cut at ground level and such new growth left undisturbed.

9. "All other sandalwood trees removed to fulfill orders must be pulled from the ground. All green limbs containing heartwood down to 25 millimetres in diameter, all living roots down to 25 millimetres in diameter and all dead wood containing heartwood must be included in the consignment."

10. Pieces are dead sandalwood stems which have weathered externally to a grey colour.

11. Pieces must be pulled from the ground and under no circumstances are they to be cut off at the base.

12. The holder of an order must work systematically through the bush removing all green and dead sandalwood within the specifications listed above so as not to waste any sandalwood which is within the specifications as laid down and which legally can be pulled or gathered.

13. The Executive Director may direct that such special conditions be complied with as he considers necessary for the protection of the environment in the particular circumstances at the time and such conditions, if any, will be notified in writing on this order in the space provided.
### Appendix IV

**STATUTORY RESERVES THROUGHOUT THE RANGE OF SANDALWOOD WITHIN 1980-84 ASSESSMENT REGIONS, OUTSIDE THE AGRICULTURAL AREAS, AT DECEMBER 1990**

<table>
<thead>
<tr>
<th>Region/Type/Name</th>
<th>Number</th>
<th>Vesting</th>
<th>Area (ha)</th>
<th>Purpose</th>
<th>Sandalwood Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>'A' GOLDFIELDS REGION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Parks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goongarrie</td>
<td>A35637</td>
<td>NPNCA(a)</td>
<td>60 335</td>
<td>Mulga woodland near the Eucalypt-Mulga Transition</td>
<td>Good sandalwood in east, some burnt.</td>
</tr>
<tr>
<td>State Forests and Timber Reserves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Majestic</td>
<td>195/25</td>
<td>LFC(b)</td>
<td>2 226</td>
<td>Flora, Fauna and Landscape Conservation. Habitat, dimensions of Salmon Gums woodland. Virgin.</td>
<td>Good patches only.</td>
</tr>
<tr>
<td>Randell</td>
<td>194/25</td>
<td>LFC</td>
<td>16 350</td>
<td>Flora, Fauna and Landscape Conservation. A variety of inland forest and scrub types, mainly virgin in an extensive area of regrowth forest.</td>
<td>Good patches only.</td>
</tr>
<tr>
<td><strong>Sandalwood Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emu Rock</td>
<td>C19645</td>
<td>L ACT (NV)(e)</td>
<td>8 186</td>
<td>Sandalwood conservation.</td>
<td>Excellent sandalwood with reasonable regeneration.</td>
</tr>
<tr>
<td>Wallaby Rock</td>
<td>C19764</td>
<td>&quot;</td>
<td>4 356</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Coonana</td>
<td>C19640</td>
<td>&quot;</td>
<td>37 061</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Bullock Holes</td>
<td>C19825</td>
<td>&quot;</td>
<td>13 313</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Lakeside</td>
<td>C19214</td>
<td>COP(d)</td>
<td>3 787</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Calooli</td>
<td>C19211</td>
<td>&quot;</td>
<td>3 121</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Yallari</td>
<td>C19212</td>
<td>&quot;</td>
<td>6 102</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Scahill</td>
<td>C19621</td>
<td>&quot;</td>
<td>6 916</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td><strong>Other Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kalgoorlie Green Belt (20 km radius)</td>
<td>Various</td>
<td>(NV)</td>
<td>83 000</td>
<td>Green timber conservation.</td>
<td>Good sandalwood</td>
</tr>
<tr>
<td>Reserve Land</td>
<td>Various</td>
<td>(NV)</td>
<td>260 240</td>
<td>Sandalwood conservation.</td>
<td>Excellent sandalwood.</td>
</tr>
</tbody>
</table>

| | | | | | |
| **Kalgoorlie Green Belt (20 km radius)** | | | | | |
| **Reserve Land** | | | | | |
| | | | | | |
| **Kalgoorlie - Coolgardie-Widgiemooltha [Regulation 95 b]** | | | | | |
| Excluding Hampton areas and other reserves. | | | | | |
### Appendix IV (Continued)

<table>
<thead>
<tr>
<th>Region/Type/Name</th>
<th>Number (ha)</th>
<th>Vesting</th>
<th>Area (ha)</th>
<th>Purpose</th>
<th>Sandalwood Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sandalwood Occurrence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nature Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rowles Lagoon</td>
<td>A4274</td>
<td>NPNCA</td>
<td>404</td>
<td>Water &amp; Fauna</td>
<td>Isolated stems only.</td>
</tr>
<tr>
<td>Clear &amp; Muddy Lakes</td>
<td>C7634</td>
<td>NPNCA</td>
<td>1926</td>
<td>Flora &amp; Fauna</td>
<td>Isolated stems only.</td>
</tr>
<tr>
<td>Kurrawang</td>
<td>C35453</td>
<td>NPNCA</td>
<td>621</td>
<td>Flora &amp; Fauna</td>
<td>Good sandalwood.</td>
</tr>
<tr>
<td>Kambalda</td>
<td>C33300</td>
<td>NPNCA</td>
<td>3650</td>
<td>Flora &amp; Fauna</td>
<td>Good sandalwood.</td>
</tr>
<tr>
<td>Binaronca Rock</td>
<td>C32552</td>
<td>NPNCA</td>
<td>185</td>
<td>Flora &amp; Fauna</td>
<td>Isolated sandalwood stems only.</td>
</tr>
<tr>
<td>Victoria Rock</td>
<td>A9480</td>
<td>NPNCA</td>
<td>258</td>
<td>Flora &amp; Fauna</td>
<td>&quot;</td>
</tr>
<tr>
<td>Dordie Rock</td>
<td>C3211</td>
<td>MWR</td>
<td>121</td>
<td>Water, Flora &amp; Fauna</td>
<td>&quot;</td>
</tr>
<tr>
<td>Cave Hill</td>
<td>C17804</td>
<td>MWR(6)</td>
<td>202</td>
<td>Water, Flora &amp; Fauna</td>
<td>&quot;</td>
</tr>
<tr>
<td>Burras Rock</td>
<td>C7038</td>
<td>MWR(6)</td>
<td>809</td>
<td>Water, Flora &amp; Fauna</td>
<td>&quot;</td>
</tr>
<tr>
<td>Cardunia Rock</td>
<td>A39148</td>
<td>NPNCA</td>
<td>38</td>
<td>Flora &amp; Fauna</td>
<td>&quot;</td>
</tr>
<tr>
<td><strong>‘B’ MURCHISON DISTRICT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kadji Kadiji</td>
<td>1/10</td>
<td>LPC</td>
<td>6355</td>
<td>Conservation of Timber</td>
<td>Scattered sandalwood.</td>
</tr>
<tr>
<td>Timbar Reserves</td>
<td>2/10</td>
<td>LPC</td>
<td>19983</td>
<td></td>
<td>&quot;</td>
</tr>
<tr>
<td><strong>‘C’ PASTORAL LANDS &amp; DESERTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Parks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collier Range</td>
<td>A35104</td>
<td>NPNCA</td>
<td>277841</td>
<td>Representative Upper Gascoyne River Range, country ungrazed.</td>
<td>Scattered sandalwood in creeks only.</td>
</tr>
<tr>
<td>Boorabbin</td>
<td>A35004</td>
<td>NPNCA</td>
<td>26000</td>
<td>Typical heathland of the sandplains east of the Wheatbelt.</td>
<td>Isolated stems only.</td>
</tr>
<tr>
<td>Kalbarri</td>
<td>A27004</td>
<td>NPNCA</td>
<td>186071</td>
<td>Coastal cliffs, Murchison River gorges and sandplain.</td>
<td>Scattered in east only (10000 ha)</td>
</tr>
<tr>
<td><strong>Nature Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wanjarri Nature Reserve</td>
<td>A30897</td>
<td>NPNCA</td>
<td>53248</td>
<td>Flora &amp; Fauna</td>
<td>Scattered sandalwood stems only.</td>
</tr>
<tr>
<td>Queen Victoria Spring</td>
<td>A30491</td>
<td>&quot;</td>
<td>272607</td>
<td>Flora &amp; Fauna</td>
<td>Scattered sandalwood in the west.</td>
</tr>
<tr>
<td>Yeo Lake</td>
<td>A36271</td>
<td>&quot;</td>
<td>321946</td>
<td>Flora &amp; Fauna</td>
<td>Scattered sandalwood.</td>
</tr>
<tr>
<td>Mangkili Clay Pan</td>
<td>A34604</td>
<td>&quot;</td>
<td>3635</td>
<td>&quot;</td>
<td>Isolated stems.</td>
</tr>
<tr>
<td>Gibson Desert</td>
<td>A34606</td>
<td>&quot;</td>
<td>1859286</td>
<td>&quot;</td>
<td>Scattered stems in south and west (600000 ha).</td>
</tr>
<tr>
<td>Part Jilbadgi</td>
<td>A24049</td>
<td>&quot;</td>
<td>208863</td>
<td>&quot;</td>
<td>Scattered sandalwood in north (38000 ha).</td>
</tr>
<tr>
<td>Toolonga</td>
<td>40628</td>
<td>&quot;</td>
<td>405424</td>
<td>&quot;</td>
<td>Isolated sandalwood stems, scattered stems in west.</td>
</tr>
<tr>
<td><strong>Other Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part Peron Pastoral Lease</td>
<td>3114/761</td>
<td>PL</td>
<td>105200</td>
<td>Proposed pastoral lease and national park.</td>
<td>Good sandalwood in south, scattered in north and east.</td>
</tr>
<tr>
<td>Boolardy Station</td>
<td>3114/406</td>
<td>PL</td>
<td>16000</td>
<td>Sandalwood Flora and Fauna</td>
<td>Conservation area, open country paddock.</td>
</tr>
</tbody>
</table>
### Appendix IV (Continued)

<table>
<thead>
<tr>
<th>Region/Type/Name</th>
<th>Number</th>
<th>Vesting</th>
<th>Area (ha)</th>
<th>Purpose</th>
<th>Sandalwood Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D' YILGARN DISTRICT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sandalwood Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kangaroo Rocks</td>
<td>C30445</td>
<td>L Act (NV)</td>
<td>8 814</td>
<td>Sandalwood Conservation</td>
<td>Good sandalwood.</td>
</tr>
<tr>
<td><strong>Sandalwood Occurrence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nature Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duladgin Rock</td>
<td>C2179</td>
<td>NPNCA</td>
<td>1 363</td>
<td>Conservation Flora &amp; Fauna</td>
<td>Isolated sandalwood stems.</td>
</tr>
<tr>
<td></td>
<td>C2112</td>
<td>MWR</td>
<td>259</td>
<td>Water, Conservation Flora &amp; Fauna</td>
<td></td>
</tr>
<tr>
<td>Wedwarie Rock</td>
<td>C3112</td>
<td>MWR</td>
<td>259</td>
<td>Water, Conservation Flora &amp; Fauna</td>
<td></td>
</tr>
<tr>
<td>Deborah East</td>
<td>A36918</td>
<td>NPNCA</td>
<td>13 750</td>
<td>Conservation Flora &amp; Fauna</td>
<td>Good sandalwood in patches.</td>
</tr>
<tr>
<td><strong>Other Reserves</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaurdi Station</td>
<td>3114/1072</td>
<td>PL (CALM)</td>
<td>321 399</td>
<td>Sandalwood conservation.</td>
<td>Excellent sandalwood.</td>
</tr>
<tr>
<td>Mt. Elvire Station</td>
<td>3114/679</td>
<td>PL (CALM)</td>
<td>154 267</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td><strong>'P' PLUMRIDGE LAKE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part Plumridge Lake 34605</td>
<td>NPNCA</td>
<td>308 990</td>
<td>Conservation, Flora &amp; Fauna</td>
<td>Excellent sandalwood in east (107 000 ha).</td>
<td></td>
</tr>
<tr>
<td><strong>'O' NORTHERN PASTORAL. LANDS, SOUTHERN EUCALYPT WOODLANDS AND NULLARBOUR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part Plumridge Lake 34605</td>
<td>NPNCA</td>
<td>308 990</td>
<td>Conservation, Flora &amp; Fauna</td>
<td>Isolated stems only in west (202 000 ha).</td>
<td></td>
</tr>
<tr>
<td>Part Jilbadgi</td>
<td>A24049</td>
<td>&quot;</td>
<td>208 863</td>
<td>Flora and Fauna</td>
<td>Isolated stems only in south (150 000 ha).</td>
</tr>
<tr>
<td>Part Great Victoria Desert</td>
<td>A30490</td>
<td>&quot;</td>
<td>2 495 777</td>
<td>Conservation, Flora &amp; Fauna</td>
<td>Isolated stems only in the west and south (1 000 000 ha).</td>
</tr>
<tr>
<td><strong>National Parks</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frank Hann</td>
<td>A27023</td>
<td>NPNCA</td>
<td>61 420</td>
<td>Cross section of inland sand plain and heath flora, east of the Wheatbelt.</td>
<td>Isolated sandalwood only.</td>
</tr>
<tr>
<td>Mt. Augustus</td>
<td>A41051</td>
<td>NPNCA</td>
<td>9 170</td>
<td>Mt. Agustus major rock feature.</td>
<td>Isolated stems only.</td>
</tr>
<tr>
<td>Part Hammersley Range</td>
<td>A3082</td>
<td>&quot;</td>
<td>617 606</td>
<td>Gorges, watercourses, hills and mountains in the Pilbara</td>
<td>Isolated sandalwood in the south (30 000 ha).</td>
</tr>
</tbody>
</table>

**FOOTNOTES**

(a) NPNCA - National Parks and Nature Conservation Authority  
(b) LFC - Lands and Forests Commission  
(c) L Act (NV) - Lands Act (Non Vested)  
(d) COF - Executive Director of CALM  
(e) MWR - Minister for Water Resources  
(f) MW - Minister for Works  
(g) PL - Pastoral Lease
Appendix V
CALCULATION OF ANNUAL SANDALWOOD INGROWTH FROM 75-125 MM SIZE CLASS TO MERCHANTABLE SIZE STEMS (> 125 MM DIAMETER).

<table>
<thead>
<tr>
<th>Region</th>
<th>Area available for harvesting (ha x 10^3) (a)</th>
<th>Average stocking (s.p.h.) of 75-125 mm diameter size class (b)</th>
<th>Total No. of 75-125 mm size class (x 10^3) (c)</th>
<th>Number ingrowing annually (x 10^3) (c)</th>
<th>Weight of annual ingrowth (tonnes) (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldfields</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>'A'</td>
<td>4 160</td>
<td>0.73</td>
<td>3 040</td>
<td>61</td>
<td>670</td>
</tr>
<tr>
<td>Murchison</td>
<td>2 400</td>
<td>0.331</td>
<td>790</td>
<td>16</td>
<td>170</td>
</tr>
<tr>
<td>Other pastoral lands and deserts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>'C'</td>
<td>29 000</td>
<td>0.126</td>
<td>3 650</td>
<td>73</td>
<td>800</td>
</tr>
<tr>
<td>Yilgarn</td>
<td>910</td>
<td>1.202</td>
<td>1 090</td>
<td>22</td>
<td>240</td>
</tr>
<tr>
<td>Plumridge Lake</td>
<td>260</td>
<td>0.86</td>
<td>220</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Northern pastoral lands, southern Eucalypt woodlands and Nullarbor</td>
<td>15 200</td>
<td>0.004</td>
<td>50</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>TOTAL</td>
<td>51 930</td>
<td>0.17</td>
<td>8 840</td>
<td>177</td>
<td>1 930</td>
</tr>
</tbody>
</table>

(a) Available area as calculated by regions see Table 3.
(b) Average stocking (stems per hectare - s.p.h.) of 75-125 mm diameter size class from 1980-84 assessment data.
(c) Number ingrowing annually calculated using a growth rate of 1 mm per annum (Loneragan 1990). Annual ingrowth to >125 mm size class = Total No. in size class + 50.

\[
50 = \text{Size class width (125-75 = 50 mm)}
\]

Annual growth rate (1 mm)

(d) Weight of annual ingrowth is calculated as number of annual ingrowth x weight per stem (11 kg). A weight of 11 kg per stem derived from Figure 2 using 125 mm diameter.
Historical Review of Sandalwood
(Santalum spicatum)
Research in Western Australia

by O.W. LONERAGAN

Research Bulletin No. 4    December 1990

Department of Conservation and Land Management
Historical Review
of
Sandalwood (*Santalum spicatum*)
Research in Western Australia

by
O.W. LONERAGAN

Research Bulletin No 4
December 1990

Published by the
Department of Conservation and Land Management
Como Western Australia
© Department of Conservation and Land Management, Western Australia, 1990

ISSN 1032-8106

Marianne Lewis ................................................................................................................. Editor
Glenda Godfrey ........................................................................................................ Page Preparation
E.M. Mattiske & Associates ............................................................................................. Illustrations
CALM Mapping ............................................................................................................ Maps
CALM Public Affairs .................................................................................................. Production and Distribution
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>vii</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Nomenclature and Taxonomy</td>
<td>4</td>
</tr>
<tr>
<td>DISTRIBUTION AND HABITAT</td>
<td>5</td>
</tr>
<tr>
<td>Landform and Soils</td>
<td>5</td>
</tr>
<tr>
<td>Vegetation</td>
<td>5</td>
</tr>
<tr>
<td>Climate</td>
<td>5</td>
</tr>
<tr>
<td>DESCRIPTIVE FEATURES OF SANDALWOOD</td>
<td>7</td>
</tr>
<tr>
<td>Phenology</td>
<td>7</td>
</tr>
<tr>
<td>Wood</td>
<td>7</td>
</tr>
<tr>
<td>Roots</td>
<td>7</td>
</tr>
<tr>
<td>Parasitism</td>
<td>7</td>
</tr>
<tr>
<td>Adaptation to Drought</td>
<td>7</td>
</tr>
<tr>
<td>Sandalwood Oil</td>
<td>8</td>
</tr>
<tr>
<td>HISTORY OF RESEARCH ON SANDALWOOD</td>
<td>9</td>
</tr>
<tr>
<td>Early Regeneration Studies - 1895</td>
<td>9</td>
</tr>
<tr>
<td>Regeneration Studies - 1920 to mid 1950s</td>
<td>9</td>
</tr>
<tr>
<td>Regeneration Studies - 1973 to 1979</td>
<td>10</td>
</tr>
<tr>
<td>Regeneration Studies - 1981</td>
<td>10</td>
</tr>
<tr>
<td>SANDALWOOD SEED</td>
<td>11</td>
</tr>
<tr>
<td>Seed Production</td>
<td>11</td>
</tr>
<tr>
<td>Pre-sowing Seed Treatment</td>
<td>12</td>
</tr>
<tr>
<td>Seed Viability and Germination after Storage</td>
<td>12</td>
</tr>
<tr>
<td>Seed Germination at Narrogin</td>
<td>13</td>
</tr>
<tr>
<td>GERMINATION AND SEEDLING ESTABLISHMENT OF SANDALWOOD</td>
<td>14</td>
</tr>
<tr>
<td>Narrogin Trials</td>
<td>14</td>
</tr>
<tr>
<td>Kalgoorlie Trials</td>
<td>14</td>
</tr>
<tr>
<td>SANDALWOOD REGENERATION</td>
<td>16</td>
</tr>
<tr>
<td>Effects of Site Cultivation on Artificial and Natural Regeneration</td>
<td>16</td>
</tr>
<tr>
<td>Effects of Browsing on Sandalwood Regeneration</td>
<td>18</td>
</tr>
<tr>
<td>Effects of Fire and Cutting on Sandalwood Regeneration</td>
<td>19</td>
</tr>
<tr>
<td>Regeneration Studies at Narrogin</td>
<td>21</td>
</tr>
<tr>
<td>SANDALWOOD GROWTH RATES</td>
<td>22</td>
</tr>
<tr>
<td>CONCLUSIONS</td>
<td>28</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>29</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>30</td>
</tr>
</tbody>
</table>
## APPENDICES

<table>
<thead>
<tr>
<th>I</th>
<th>Statutory Reserves containing Sandalwood in Western Australia at 1990</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Seed Viability and Germination after Storage</td>
<td>34</td>
</tr>
<tr>
<td>III</td>
<td>Germination of Seed at Narrogin</td>
<td>35</td>
</tr>
<tr>
<td>IV</td>
<td>Germination and Seedling Establishment of Sandalwood - Narrogin</td>
<td>36</td>
</tr>
<tr>
<td>V</td>
<td>Germination and Seedling Establishment of Sandalwood - Kalgoorlie</td>
<td>38</td>
</tr>
<tr>
<td>VI</td>
<td>Effects of Site Cultivation on Artificial and Natural Regeneration</td>
<td>41</td>
</tr>
<tr>
<td>VII</td>
<td>Effects of Browsing on Regeneration</td>
<td>44</td>
</tr>
<tr>
<td>VIII</td>
<td>Effects of Fire and Cutting on Sandalwood Regeneration</td>
<td>46</td>
</tr>
<tr>
<td>IX</td>
<td>Regeneration Studies at Narrogin</td>
<td>48</td>
</tr>
<tr>
<td>X</td>
<td>Sandalwood Growth Studies</td>
<td>50</td>
</tr>
</tbody>
</table>
Plates

1. Sandalwood tree (3 m) at Kalgoorlie
2. A puller cutting roots
3. Tractor in use for pulling Sandalwood
4. Loading Sandalwood - Binneringie Station
5. Sandalwood stacked at Pinners camp, Gindalbie Station, ready for shipment
6. Sandalwood fruit (size range - 1.5-2 cm diameter)
7. Healthy crown growth, February 1987 in response to recent rains, West Kalgoorlie
8. Lateral root development of Sandalwood
9. 28-year-old Sandalwood plant in Frank Block, Dryandra State Forest
10. 28-year-old Sandalwood plants at Siding Road, Stokes Block, Dryandra State Forest
11. Sandalwood seedlings at Bullock Holes Sandalwood Reserve
12. 8-year-old Sandalwood plants at Bullock Holes Sandalwood Reserve
13. Gindalbie Station trial plot area; fencing trials
14. Gindalbie Station trial plot area, germination of seedling inside fence, April 1982
15. In absence of grazing, Sandalwood can grow to ground level, September 1982
16. Goat damage to Sandalwood on Yerilla Station plots, 1980
17. Coppicing of Sandalwood on Nanga Station
18. Regeneration studies at Gura Road, Dryandra State Forest. 1-year-old Sandalwood seedling
19. Regeneration and provenance studies at Gura Road, Dryandra State Forest. 3-year-old Sandalwood seedlings
20. Regeneration and provenance studies at Gura Road, Dryandra State Forest. 3-year-old Sandalwood seedlings
21. Regeneration and provenance studies at Gura Road, Dryandra State Forest. 3-year-old Sandalwood seedlings
22. Natural Sandalwood regeneration at Curries Road, Dryandra State Forest
23. Sandalwood, Kalannie, Rabbit Proof Fence Road.
Figures

1 Distribution of W.A. Sandalwood (Santalum spicatum) 2
2 Kalgoorlie yearly rainfall. 1960 - 1989 11
3 Effect of cultivation on germination and seedling survival from natural seed supply 17
4 Effect of fencing on spot sown seed 19
5 Effect of fencing on germinants of spot sown seed 20
6 Effect of rainfall, drought, rabbits and fencing on germination for spot sown seed 21
7 Sectional analysis of Sandalwood trees next to Karramindie plot 1 25
8 Summary of relationship between number of stems per tonne and the diameter class 26
9 Air dry weight of Sandalwood, showing loss in moisture content of fresh green wood and variation in relation to seasonal conditions, 1971 to 1974 26

Tables

1 Summary of climatic conditions for Kalgoorlie, Narrogin and Bunbury. 6
2 Host species recorded for Santalum spicatum. 7
3 Summary of Sandalwood sowings in 1920 to mid 1950s. 9
4 Summary of seed viability and germination tests after storage. 12
5 Percentage survival of seedlings before and after the first summer (1978-1979) and total survival after the second summer (1979-1980). 14
6 Chemical analyses of the surface soil in the Kalgoorlie Arboretum. 14
7 Germination of Sandalwood from 200 seeds per treatment at Kalgoorlie. 14
8 Germination and seedling survival from spot sowing of 100 Sandalwood seed per plot treatment. 18
9 Effects of fire and cutting on Sandalwood regeneration. 19
10 Summary of height and stem diameter growth results for Sandalwood at Karramindie and Scabhill. 22
11 Summary of Sandalwood yield in trees aged 44 years next to Karramindie (Plot 1). 23
12 Growth rate of Sandalwood at Narrogin and Kalgoorlie and the number of years needed to reach commercial diameter of 127mm (Diameter at 150 mm above ground level - d.o.b.). 24
13 Linear regressions of various components of Sandalwood trees for diameter over bark under commercial size (1,2) and all trees (3-9) in the Eastern Goldfields and Gascoyne/Greenough Regions. 24
Abstract

This paper presents a synthesis of the research information and results collected over the last century on Sandalwood in Western Australia. The information presented is based on a range of experiments and observations undertaken by a large number of individuals in the Forests Department and its successor, the Department of Conservation and Land Management.

The Western Australian Sandalwood industry is restricted by the slow growth of the *Santalum spicatum*, the low rate of natural regeneration, the low germination rate and the previously unregulated exploitation of the resource.

The Western Australian Sandalwood tree takes from 50 to 90 years to grow to a commercial size in the more arid areas of Western Australia. Flowering is sporadic as a result of irregular rainfall in the majority of areas where it still remains. The seed germinates after extremes in temperature and rainfall. Observations in the field have indicated that only 1 to 5 per cent of the seeds germinate. The rate of germination and survival is higher in reserves, protected research and plantation areas, but still below 20 per cent. This low germination and survival is further discouraged by the susceptibility of Western Australian Sandalwood to damage by fires and grazing.

Providing regeneration areas can be protected from grazing, successful regeneration of Sandalwood on an operational and plantation scale can be achieved by sowing four Sandalwood seeds per spot in appropriate well drained sites, 50-70 mm below the soil and mulched in a small depression at the drip line of the south side of a suitable host plant.
Introduction

The purpose of this Bulletin is to collate and summarize what is currently known about the life history, ecology and silviculture of Sandalwood (Santalum spicatum, (R.Br.) A.DC.) in Western Australia. Given the historical commercial importance to the State of the aromatic wood from the Western Australian (W.A.) Sandalwood and the recognized need to conserve this natural resource, very little has been published on this species.

Research on Sandalwood in Western Australia has been associated with the historical development of forestry research in the State and the awareness of the need to conserve W.A. Sandalwood (Santalum spicatum) and maintain the Sandalwood industry.

The majority of research information on W.A. Sandalwood has been accumulated from long-term observations and experimentation undertaken by officers of the former Forests Department of Western Australia. The critical aspects for the Sandalwood industry relate to the relevance of this past effort to the long-term survival of Sandalwood and therefore the Sandalwood industry in Western Australia.

In the early days of settlement, W.A. Sandalwood occurred in the Wheatbelt Region and pastoral and arid lands south of latitude 24° in Western Australia (Fig. 1).

Western Australian Sandalwood is a stoutly-branched tree or shrub, growing to a height of 8 m, with a canopy diameter of 2 m (Plate 1). Unlike other commercial tree species, W.A. Sandalwood is not sawn or chopped down: the trees are pulled out of the ground, because the root, butt, stem and branches are all valuable for commercial products and coppice is an insignificant proportion of regeneration. The following plates illustrate the cutting of roots (Plate 2), a pulling tractor which is used to extract Sandalwood (Plate 3), the loading of wood (Plate 4) and a Sandalwood pullers' camp (Plate 5). Dead W.A. Sandalwood is also salvageable. The heartwood is highly valued for its aromatic oils (Kealley 1989).

The East Indian Sandalwood (Santalum album) was once harvested from various resource areas in the Asian countries, notably Indonesia and the Spice Islands in the second century A.D., and from Timor to Calicut in about 1550. It was imported into India and China. The occurrence of disease and exploitation in the East Indian Sandalwood reduced this resource. At the time of European settlement in Western Australia (1829) India and China were obtaining the wood from the diminishing Asian resource. By 1843 the value of the Western Australian Sandalwood, through its aromatic wood for religious and artistic uses by the Chinese, was rapidly recognized by the early settlers and the Western Australian commercial industry for Santalum spicatum rapidly expanded.

The W.A. Sandalwood trade was one of the original industrial activities of the early Swan River Colony in Western Australia. The first four tons of Western Australian Sandalwood was shipped from Fremantle to Ceylon in 1845 (Talbot 1983). By 1848, Sandalwood had become Western Australia's primary industry, for example, the export trade of 3048 tons in 1868 was forty times more valuable than all the other timber exports combined from Western Australia. Historical summaries of the Sandalwood industry in Western Australia are also provided by Underwood (1954), Drake-Brockman (1960), Donovan (1975), Ware (1975), Williams (1979), and Talbot (1983).

Tambellup and other Western Australian 'Wheatbelt' towns owe their origin to Sandalwood, which proved a reliable source of income for struggling primary producers, although the Sandalwood industry was initially restricted by the need to cart the wood over long distances to the ports at Geraldton, Bunbury, Fremantle, Albany and Hopetoun. As transport facilities improved the commercial Sandalwood industry spread eastwards to Southern Cross and Kalgoorlie. Initially this spread followed the railway line in 1894 to Southern Cross and then later in 1900 to Kalgoorlie. The commercial extraction of W.A. Sandalwood in the south-west of Western Australia expanded further in the period 1904 to 1919 with the development of other railway systems.

Sandalwood also enabled many farmers to retain agricultural holdings along the Great Southern Railway (Fall 1972). Funds from Sandalwood sales assisted landowners through the difficult periods of drought, depression and market shortages for other farm produce, as well as helping many gold prospectors survive the periods between gold finds. However, the Sandalwood trade was itself subject to similar produce and market fluctuations. During
Figure 1
Distribution of W.A. Sandalwood (Santalum spicatum)
the slumps in the Sandalwood trade the local workforce had to turn to alternative employment (McMahon 1972) and many settlers were subjected to great hardships (Bolton 1972).

Slumps and gluts resulted from uncontrolled competitive marketing in the hundred years prior to the State Government's Sandalwood Act of 1929. Exploitation was destructive during the early days of settlement, when a quantity three times as large as the present residual Sandalwood resource was harvested. As a result of heavy buying, harvesting and stockpiling, China had four years' supply on hand, thereby enabling buyers from Shanghai and Hong Kong to manipulate the market; demand was subject to fluctuations. Huge stocks of Sandalwood accumulated at Fremantle and in China between 1919 and 1921. Consequently it became imperative that export be limited under Government monopoly, and a single permit was issued authorizing four firms to operate collectively from November 1923. (These amalgamated subsequently to form the Australian Sandalwood Company in 1930.) Western Australia agreed to restrict export from 1926 to 1930, because accumulated stocks continued to cause concern in the industry. Legislation in 1929 improved the management of the W.A. Sandalwood industry through an agreement between the Sandalwood Merchants' Association, formed in 1928, and the Sandalwood Export Committee which was chaired by the Conservator of Forests, Western Australia.

Unfortunately, by the time the industry was regulated for continuous employment and trade, the resource had been seriously depleted. The only significant resources remaining today are located in the eastern 'Goldfields' areas surrounding Kalgoorlie, Southern Cross, Lake Plimridge, the north-eastern Goldfields and areas surrounding Leonora, Laverton, Wiluna and the Gascoyne and Greenough Regions and areas surrounding Payne's Find, Meekatharra, Yalgoo (Fig. 1 and Appendix I). A few localized remnants still remain on previously harvested areas. These trees were left as some areas were inaccessible to the horse and dray, while others were immature at the time of earlier harvesting.

The establishment and growth of the W.A. Sandalwood (Santalum spicatum) is restricted by a low rate of natural regeneration and low germination and establishment rates of the seedlings. The Western Australian Sandalwood tree takes from 50 to 90 years to grow to a commercial size (127 mm diameter at 150 mm above the ground) in the more arid areas of Western Australia. Flowering and seed germination is spasmodic as a result of irregular rainfall and extremes in temperatures in the majority of areas where it still remains. The rate of germination and survival is higher in protected reserves, research and plantation areas, but still below 20 per cent (Kealley 1989). The low germination and survival rate is further diminished by the susceptibility of W.A. Sandalwood to damage by fires and grazing. These factors, combined with the early exploitation of the resource, made it inevitable that there would be a recognition of the need to improve research on Sandalwood and management of the industry.

These needs were recognized as early as 1895 by the first Conservator of Forests, Mr J. Ednie-Brown, who established an experimental Sandalwood farm at Pingelly and a reserve for seed production at Meckering. Unfortunately, it was not known until 1921 that Sandalwood is a root parasite, and there were extremely heavy losses, especially in the first summer months. Eventually, neither area survived agricultural clearing, grass fires and rabbit infestations. In 1921, the Conservator of Forests, Mr C.E. Lane-Poole, stated that it was urgent to commence a large-scale Sandalwood plantation in order to provide for future production before supplies became exhausted. A total of 1630 ha of land in Kalgoorlie, Southern Cross, Kondinin, Narrogin and Busselton areas were sown with Sandalwood seeds in the 1920s, but this work was discontinued during the 1930s depression. Although very little of the regeneration was successful, the few survivors have provided information on Sandalwood growth rates under different climatic conditions, which is invaluable for planning the future of Sandalwood in W.A.

As current Sandalwood exports from Western Australia exceed $10 million, it is economically important to improve our understanding of Western Australian Sandalwood. This species also warrants a significant place in the conservation arena as it has been, and still is, an integral part of the history and ecology of the State. Specific research topics covered in this Bulletin include seed production, germination and seedling trials, regeneration, cultivation and growth rates.
NOMENCLATURE AND TAXONOMY

The taxonomy of the Western Australian Sandalwood (Santalum spicatum) has recently been summarized in Flora of Australia (George 1984).

Shrub to 4 m tall. Bark rough, grey. Branchlets stiff, spreading. Leaves lanceolate to narrowly elliptic, flat, obtuse; lamina 2-7 cm long, 3-15 mm wide, concolorous, grey-green; petiole 3-5 mm long; pedicels 1 mm long. Flowers numerous in panicles, scented; peduncle 3-5 mm long; pedicels 1-1.5 mm long. Receptacle 1-1.5 mm long. Tepals triangular-ovate, 1.5-2 mm long, scurfy inside, red-green, persistent in fruit; hair tufts small. Disc shortly lobed. Style 0.5 mm long; stigma bilobed. Drupe 1.5-2 cm diam.; epicarp green or brown; mesocarp firm, usually adhering to endocarp when ripe; endocarp smooth. Sandalwood.

Four species of the genus Santalum occur in Western Australia. Western Australian Sandalwood (Santalum spicatum, (R.Br.) A. DC.) is found only in Western Australia and South Australia, but the other three species - S. lanceolatum R.Br. (Plumbush), S. acuminatum (R.Br.) A. DC. (also called Quandong or Candle Nut) and S. murrayanum (Mitch.) C. Gardner (Bitter Quandong) are widely distributed throughout Australia. All three lack aromatic fragrance, but Plumbush contains oil. Plumbush has an ovoid, dark plum-like fruit and is widespread in tropical Australia and the Northern Territory, and extends south through the interior areas of most mainland States. Quandong fruit has a red outer covering, a deeply pitted stone and an oily, edible kernel; Bitter Quandong has a bitter brownish-red outer covering and a finely pitted stone. The Sandalwood fruit is illustrated in Plate 6. Quandong and Bitter Quandong are widespread throughout the warmer parts of temperate Australia. As Santalum spicatum has been exploited commercially in Western Australia, the research on this species has been more extensive. The research findings by the former Forests Department and the current Department of Conservation and Land Management are summarized in this Bulletin. Unless specified otherwise, Sandalwood, or W.A. Sandalwood in this Bulletin refers to the species Santalum spicatum.
Prior to the development of agriculture in Western Australia, Sandalwood was distributed mainly from latitude 24°S (approximately 80 km north of Carnarvon), eastwards along the lake system around the Nullarbor Plain into South Australia, south to a latitude of 35° and west as far as the drier fringe of the main forest area on the Darling Ranges (Fig. 1). Additional plants have been recorded in localized areas to the north of the main distribution (George 1984; Western Australian State Herbarium records) (Fig. 1).

Clearing for agricultural development in the Wheatbelt (Fig. 1) has reduced the main distribution of Sandalwood from 90 million ha by 13 million ha to about 77 million ha. The main area of Sandalwood and the area available for harvesting is around 52 million ha. This loss of Sandalwood in the Wheatbelt areas was noted in the early 1920s by Lane-Poole (1921). Most of the remaining areas of Sandalwood are under lease for sheep grazing, with exceptions on Sandalwood Reserves, State Forests, National Parks, Nature Reserves and Timber Reserves (Appendix 1).

Between 1980 and 1984 an assessment of Sandalwood was undertaken to determine the location and total Sandalwood resource. The assessment used aerial photography, Landsat imagery and ground verification via available access roads and tracks. The assessment greatly improved the knowledge on distribution, habitat and size class distribution and quantified the total Sandalwood resource throughout its range (Kealley and Caporn, personal communication).

LANDFORM AND SOILS
A framework for mapping the broad distribution of Western Australian Sandalwood is provided by the palaeo-drainage system of Beard (1973). Usually, Western Australian Sandalwood is present in the valley slopes of seasonal water-courses in the Greenough and Gascoyne Regions (Fig. 1), and around the main drainage systems of inland salt lakes. It is absent from the continental watershed and the interfluves of the Western Australian Pre-Cambrian Shield.

VEGETATION
Western Australian Sandalwood occurs predominantly in low shrublands of *Acacia* species on the alluvial lower slopes of the main drainage lines in the Greenough and Gascoyne Regions and on the fringes of the adjacent woodlands of *Eucalyptus* on the clay soils. Other occurrences are irregular and scattered through the species range. *Santalum spicatum* avoids the woodlands of almost pure species of one genus - for example, *Eucalyptus dundasii* (Maiden), *E. longicornis* (F.Muell) F.Muell. ex Maiden), *E. salmonophloia* (F.Muell.) and *E. salubris* (F.Muell.) and the Chenopod communities on the more saline areas. The previous patterns can be correlated with particular vegetation systems on Beard's vegetation maps (Beard 1972a, 1972b, 1974, 1975a, 1975b, 1976a, 1976b and 1981; Beard and Webb 1974).

CLIMATE
Western Australian Sandalwood occurs over a range of climatic conditions from Narrogin through Kalgoorlie to the semi-arid and arid areas. Early trials also included some plantings at Busselton, so the climatic conditions for Bunbury are also discussed. The climatic records for Kalgoorlie, Narrogin and Bunbury are summarized in Table 1. The climatic conditions are critical in determining its initial occurrence, its growth rates and also its ability to regenerate.

The critical differences for Sandalwood establishment and growth appear to relate to the regularity of rainfall, the length of the growing season and the regularity of frosts. The effects of recent rains on the crown foliage of Sandalwood near Kalgoorlie are illustrated in Plate 7.

The mean rainfall at Kalgoorlie is 257 mm, with the month of June averaging 31 mm. Dry spells at Kalgoorlie may occur for 5, 7 and 9 consecutive months. These dry spells appear to have a marked effect on the ability of native species to germinate and survive. On average the growing seasons vary between 4.5 months from mid-March to the end of July, and 3.5 months from mid-May to the end of August (May-July being the most reliable months for rainfall).
The mean annual maximum temperature for Kalgoorlie is 25.1°C, while the mean annual minimum temperature is 11.5°C. Based on screen temperatures in Kalgoorlie, there are 10 frosts per year under 2.2°C and the frost-free period over 2.2°C is 297 days per year.

The climatic extremes are less severe in the Wheatbelt and coastal areas where trial plantings of Sandalwood have been carried out.

Narrogin, Perth and Bunbury all have a Mediterranean climate with 75–85 per cent of the annual rainfall predominantly in the winter months (May to October for Narrogin - 78 per cent of the total rainfall, Table 1). The mean annual rainfall at Narrogin is 504 mm. Dry periods of seven consecutive months may occur in Narrogin once in 2.5 years. The length of the growing season is 5.6 months at Narrogin. The mean annual maximum temperature at Narrogin is 22.2°C, while the mean annual minimum temperature is 9.9°C. Based on screen temperatures, there are 7 frosts per year under 2.2°C.

The mean annual rainfall at Bunbury is 871 mm. Dry periods of six consecutive months may occur in Bunbury once in three years. The length of the growing season is seven months at Bunbury. The mean annual maximum temperature at Bunbury is 21.9°C, while the mean annual minimum temperature is 12.4°C. Based on screen temperatures, there are two frosts per year under 2.2°C.

### Table 1

**SUMMARY OF CLIMATIC CONDITIONS FOR KALGOORLIE, NARROGIN AND BUNBURY**

(Extracted from records of Bureau of Meteorology - Perth)

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>KALGOORLIE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature (°C) - 48 years of Records</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Maximum</td>
<td>33.6</td>
<td>31.9</td>
<td>29.7</td>
<td>25.1</td>
<td>20.4</td>
<td>17.5</td>
<td>16.5</td>
<td>18.3</td>
<td>22.1</td>
<td>25.6</td>
<td>28.9</td>
<td>32.0</td>
<td>25.1</td>
</tr>
<tr>
<td>Mean Minimum</td>
<td>18.2</td>
<td>17.6</td>
<td>15.9</td>
<td>12.4</td>
<td>8.3</td>
<td>6.2</td>
<td>4.8</td>
<td>5.4</td>
<td>7.8</td>
<td>10.8</td>
<td>13.9</td>
<td>16.5</td>
<td>11.5</td>
</tr>
<tr>
<td><strong>Rainfall (mm) - 50 Years of Records</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Rainfall</td>
<td>22</td>
<td>28</td>
<td>19</td>
<td>19</td>
<td>28</td>
<td>31</td>
<td>26</td>
<td>20</td>
<td>15</td>
<td>16</td>
<td>18</td>
<td>15</td>
<td>257</td>
</tr>
<tr>
<td>Mean Raindays</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td><strong>NARROGIN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature (°C) - 22 Years of Records</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Maximum</td>
<td>30.8</td>
<td>29.9</td>
<td>27.1</td>
<td>22.5</td>
<td>18.3</td>
<td>15.3</td>
<td>14.6</td>
<td>15.1</td>
<td>17.3</td>
<td>21.2</td>
<td>24.9</td>
<td>28.9</td>
<td>22.2</td>
</tr>
<tr>
<td>Mean Minimum</td>
<td>14.7</td>
<td>14.9</td>
<td>13.5</td>
<td>10.9</td>
<td>8.2</td>
<td>7.0</td>
<td>5.8</td>
<td>5.6</td>
<td>6.3</td>
<td>8.1</td>
<td>10.7</td>
<td>12.8</td>
<td>9.9</td>
</tr>
<tr>
<td><strong>Rainfall (mm) - 98 Years of Records</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Rainfall</td>
<td>10</td>
<td>17</td>
<td>21</td>
<td>30</td>
<td>65</td>
<td>92</td>
<td>89</td>
<td>68</td>
<td>47</td>
<td>34</td>
<td>18</td>
<td>13</td>
<td>504</td>
</tr>
<tr>
<td>Mean Raindays</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>11</td>
<td>15</td>
<td>15</td>
<td>14</td>
<td>11</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>98</td>
</tr>
<tr>
<td><strong>BUNBURY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Temperature (°C) - 21 Years of Records</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Maximum</td>
<td>27.8</td>
<td>28.2</td>
<td>26.0</td>
<td>22.5</td>
<td>19.9</td>
<td>17.8</td>
<td>16.9</td>
<td>17.0</td>
<td>18.0</td>
<td>20.2</td>
<td>22.5</td>
<td>25.5</td>
<td>21.9</td>
</tr>
<tr>
<td>Mean Minimum</td>
<td>16.4</td>
<td>17.0</td>
<td>15.4</td>
<td>13.2</td>
<td>11.1</td>
<td>9.7</td>
<td>9.0</td>
<td>8.8</td>
<td>9.7</td>
<td>11.0</td>
<td>12.9</td>
<td>14.9</td>
<td>12.4</td>
</tr>
<tr>
<td><strong>Rainfall (mm) - 108 Years of Records</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Rainfall</td>
<td>11</td>
<td>12</td>
<td>22</td>
<td>46</td>
<td>128</td>
<td>183</td>
<td>171</td>
<td>124</td>
<td>80</td>
<td>54</td>
<td>26</td>
<td>14</td>
<td>871</td>
</tr>
<tr>
<td>Mean Raindays</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>14</td>
<td>18</td>
<td>20</td>
<td>17</td>
<td>14</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>119</td>
</tr>
</tbody>
</table>
Descriptive Features of Sandalwood

PHENOLOGY

The species of *Santalum* are distinguished by their variability in height, form, leaf shape, colour and fruiting patterns (Sedgley 1982).

In the Perth metropolitan area, Western Australian Sandalwood produces flower buds at the age of three or four years, and the first seedcrop sets at six or seven years. Panicles of flower buds, terminal and axillary, appear from mid-summer (about February) to autumn, and the main blossoms are fully developed by about May. The fruits mature usually between October and January, and fall to the ground during January and February. The ripe fruit has a leathery tan-brown outer epicarp and a smooth round, inner nut or endocarp.

WOOD

The wood includes sapwood (pale yellow) and heartwood (usually dark brown). The heartwood and the roots contain the strongly aromatic Sandalwood oil. Density at 12 per cent moisture content (air dry) is 810 kg m⁻³.

ROOTS

The lateral roots of Western Australian Sandalwood may run for 25-30 m, but rarely extend more than 200 mm deep, even in deep sandy soils (Plate 8). The root butts can regenerate shoots after injury to the parent tree, but rarely do so in the field. Generally, along the whole length of the lateral roots, fine feeder roots renew the search for suitable host roots during the growing season.

PARASITISM

The root parasitism in the *Santalum* genus has been summarized by Herbert (1925). The fine roots, which develop on the extensive lateral roots of the Sandalwood, produce a lateral haustorium with roots of other species. The range of hosts which one plant may be living on may vary in number and variety (Herbert 1925; Western Australian Forests Department 1925). The haustoria are produced in large numbers, although the haustoria have only a limited functional existence.

Therefore, *Santalum spicatum*, although capable of photosynthesis, is an obligate parasite, which can survive only by parasitising through the development of haustoria on a wide range of host species (Table 2), usually of the genera *Eucalyptus* and *Acacia* (Herbert 1925; Gardner 1928; Kuijt 1969).

<table>
<thead>
<tr>
<th>Table 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOST SPECIES RECORDED FOR <em>SANTALUM SPICATUM</em></td>
</tr>
</tbody>
</table>

- *Acacia acuminata* (Benth.)
- *Acacia aneura* (F.Muell. ex Benth.)
- *Acacia colletioides* (Benth.)
- *Acacia hemiteles* (Benth.)
- *Acacia linophylica* (W.Fitzg.)
- *Acacia teregonophylla* (F.Muell.)
- *Cassia chatefaniana* (W.Fitzg.)
- *Cassia nemophila* (Cunn. ex Vogel)
- *Cassarina cristata* (Miq.)
- *Dodonaea lobulata* (F.Muell.)
- *Eremophila alternifolia* (R.Br.)
- *Eremophila dempsteri* (F.Muell.)
- *Eremophila ionantha* (Diels in Diels and E. Pritzel)
- *Eremophila oldfieldi* (F.Muell.)
- *Eremophila oppositifolia* (R.Br.)
- *Eucalyptus loxophleba* (Benth.)
- *Eucalyptus wandoo* (Blakely)

ADAPTATION TO DROUGHT

Western Australian Sandalwood is well-adapted to drought conditions. The radicle of the germinating seed is long and brittle and buries rapidly into the soil, given sufficient moisture and warmth. Development independent of a host plant is able to continue while the nutrient of the endosperm of the seed is available for the growth of the shoot above ground and the root system. Although Western Australian Sandalwood has a shallow root system, its parasitic habit allows it to draw nourishment from the extensive and deeper root systems of host plants. By means of this adaptation, Western Australian Sandalwood not only withstands drought, but may maintain growth during a dry spell. Observations have indicated that under extreme drought stress the parasite will die before the host.
SANDALWOOD OIL

The British Pharmacopoeia describes Sandalwood oil as:

- a colourless or pale yellow oily liquid with a characteristic odour and unpleasant taste, containing not less than 90 per cent W/W of free alcohols.
- Mass per millilitre is 0.964 to 0.974 grams, soluble 1 in 3 to 6 of 70 per cent alcohol.

Western Australian Sandalwood oil, has an optical rotation of -8° to -3°. East Indian Sandalwood oil has an optical rotation of -15° to -21°, has more odour and is more bitter. The optical rotation of the oil of S. lanceolatum (Plumbush) is from -30° to -40°. The oils from these two W.A. Santalum species could be blended to produce the same optical properties as the East Indian Sandalwood oil.

The oil has a specific gravity of 0.975 at 15.5°C, a refractive index of 1.507 at 20°C, and total alcohols over 90 per cent as santalol. These are principally alcohols of the sesquiterpene group. Anomalous properties of Western Australian Sandalwood oil have been explained by the content of farnesol, an acrylic primary alcohol (Birch et al. 1953).

The commercial yield of oil varies from 2.4 to 2.9 per cent for roots and butts. Trees from semi-arid areas have been recorded as producing the highest quality oil (Western Australian Forests Department 1925). Relatively fast grown plantation trees in the Dryandra Forest, near Narrogin, at 22 and 47 years have yielded 49 and 74 per cent of the yield of mature trees (i.e. 1 per cent - 2 per cent oil). Extracts from the sapwood at 22 and 47 years have yielded 13 and 19 per cent respectively of the extracts of the heartwood (i.e. percentages of oil in the sapwood of 0.2 and 0.4). Extracts from the sapwood of mature trees at Narrogin have yielded 22 per cent of the extracts of heartwood (0.6 per cent of oil in the sapwood). Mature trees at the southern limits of distribution (Ravensthorpe) yielded about 1.5 per cent oil or half of the yield of trees from the arid region. Oil yield from heartwood at 15 years of age on coastal sand near Perth was 0.5-1.0 per cent, or about quarter of that of inland mature trees.

A unique method was used to extract the Sandalwood oil. This involved subjecting the finely ground wood to extraction with a volatile solvent, then the extract was vacuum distilled (Rock 1967). The medicinal values of the oils of the Santalum spp. were recognized by the Australian aborigines and early settlers (Aboriginal Communities of the Northern Territory of Australia 1988).

Since the discovery of penicillin and the development of modern antibiotics, the medicinal importance of sandalwood oil has declined. In recent years the sandalwood oil has been substituted as a fixative in cosmetics, soaps and perfumes. Despite this decline the commercial operations have been maintained for the unique aroma of sandalwood joss-sticks. Prior to June 1950, sandalwood oil sales exceeded the value of the wood sales by $1 195 460. The export value of the oil was similar to that of the raw wood until 1971, when these supplies ceased.
History of Research on Sandalwood

EARLY REGENERATION STUDIES - 1895
Planting of Sandalwood in Western Australia commenced after the formation of the Woods and Forests Department (as a branch of the Lands Department) in 1895-1896. Initially, an area of 2 ha near Pingelly was ploughed, fenced and planted with Sandalwood nuts in August 1895. Both the native W.A. Sandalwood (*Santalum spicatum*) and the East Indian species (*Santalum album*) were sown.

The W.A. Sandalwood germinated freely. In contrast the East Indian species did not germinate freely. The seeds of the latter are smaller than the W.A. Sandalwood (George 1984) and observations have indicated that the seeds of the East Indian species lose their viability with time.

REGENERATION STUDIES - 1920 TO MID 1950s
A further 192 ha were sown with W.A. Sandalwood during the 1920s, using seeds obtained locally by contract Sandalwood pullers. The total area sown was increased to 1630 ha by 1930. In 1931, a decision was made to cease further widespread sowing until results from the areas already established could be evaluated.

During the Depression years (1929 - 1933), a series of experimental plots were established on a range of soil types, from sandy-loams at Kalgoorlie to yellow sands at Busselton (formerly growing stands of tuart (*Eucalyptus gomphocephala* (DC.))) (Table 3).

The seed was usually sown without pre-treatment. In some tests, however, the seed was cracked and soaked overnight. The soil was loosened with a hoe at 3 to 4 m intervals, and the seed sown to a depth of 20 to 50 mm (Kalgoorlie) or 50 to 100 mm (Dryandra-Narrogin).

Following the discovery, in 1921, that Sandalwood is parasitic, seeds were sown immediately beneath host plants; the density of sowing depending on the density of potential host species. In experimental areas where host plants were few or absent, seeds of *Acacia hemiteles* (Benth.) and *Cassia nemophila* (Cunn. ex Vogel) were sown either before or simultaneously with the Sandalwood sowing.

![Image](image.png)

### Table 3

<table>
<thead>
<tr>
<th>Date</th>
<th>Area (ha)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>KALGOORLIE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1927</td>
<td>160</td>
<td>Cowine, near Southern Cross</td>
</tr>
<tr>
<td>1928</td>
<td>383</td>
<td>Lakeside Sandalwood Reserve</td>
</tr>
<tr>
<td>1925-30</td>
<td>781.65</td>
<td>Karriamindie State Forest</td>
</tr>
<tr>
<td>1928-30</td>
<td>1-8</td>
<td>Calooli, Coonana and Seahill Sandalwood Reserves</td>
</tr>
<tr>
<td>NARROGIN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1921</td>
<td>15</td>
<td>Bendering Reserve 25081</td>
</tr>
<tr>
<td>1922-23</td>
<td>90</td>
<td>Bendering Reserve 25081</td>
</tr>
<tr>
<td>1925</td>
<td>93</td>
<td>Bendering Reserve 25801</td>
</tr>
<tr>
<td>1931</td>
<td>5-10</td>
<td>Dryandra Reserve 8324</td>
</tr>
<tr>
<td>1956</td>
<td>0.1-1</td>
<td>Lol Gray, Bald Rock, Corakin, Peters, Smith and Stokes Blocks Dryandra State Forest</td>
</tr>
<tr>
<td>BUSSELTON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1931-35</td>
<td>NA</td>
<td>State Forest. Young plantations of <em>Pinus pinaster</em> and <em>Pinus radiata</em></td>
</tr>
</tbody>
</table>

The seeds were often graded for size. The larger seeds (over 18 mm) were sown because it was thought they gave the young seedlings a better chance of surviving the period prior to host attachment.

Most areas were fenced to exclude kangaroos, rabbits and domestic stock. In rabbit-infested areas, sowings were often protected using galvanized iron tubes or wire netting guards.

Germination
On the basis of observations summarized in Forests Department records and the Western Australian Forests Department Annual Reports (1920-1950), the higher
germination of Sandalwood was obtained from fresh seed, treated by soaking overnight. Although some buried seed germinated four years after sowing, two years was recognized as the useful limit of viability (Western Australian Forests Department 1927).

Germination rates were invariably low, and higher germination rates occurred only after one or more years of rainfall, usually exceeding 100 mm or more, or 25 mm per month for three months from the time of sowing.

Observations indicated that sowing in January favoured seed germination. Germination of the seeds appeared to be favoured by the higher temperatures in the summer months (Table 1). Other observations indicated that the pattern of sowing in late summer or early autumn, with opening rains in autumn, followed by winter rains, produced higher seed germination results. Therefore, the combination of temperatures and prevailing soil moisture levels appeared to be the main determinants of favourable seed germination.

Establishment and Survival
On the basis of observations summarized in Forests Department records and the Western Australian Forests Department Annual Reports (1920-1950), the best overall establishment and survival results were achieved on lower slopes with loam or sandy loam soils. Light soils gave poor results in the dry seasons, while in the wet seasons clay soils gave poor results because seeds were washed away (Western Australian Forests Department 1925, 1927, 1930).

Prior to host attachment, seedlings protected from the direct rays of the sun survived three to five months longer than exposed seedlings.

Grass and shrub growth on the light to medium soils was observed to protect and sometimes to provide temporary host tissue for the Sandalwood seedlings in their establishment growth period (Western Australian Forests Department 1927).

The best establishment and survival rates were in the order of 1 per cent at Kalgoorlie and Dryandra-Narrogin. The growth potential of 28-year-old Sandalwood, that established and survived, is illustrated at Frank Block (Plate 9) and Stokes Block (Plate 10).

Pests
In these series of trials, the surviving seedlings of Sandalwood were prone to rabbit attack during the first three to four years. Although the seedlings resprouted, heavy losses were experienced following continuous grazing. In most instances, rabbits browsed the seedlings in late summer when other fodder stocks were very degraded (Western Australian Forests Department 1925).

Insect attacks on regeneration were first noted in June 1930, when new shoots and leaves were destroyed by the larvae of a native Chrysomelid beetle (Western Australian Forests Department 1930). Such attacks appear to be periodic; however, at times diseased Sandalwood was heavily affected by scale insects of *Myillaspis* and *Eriococcus* species. Damage to Sandalwood by wood borers and defoliators was usually not widespread.

Summary
These early regeneration studies indicated that germination and survival of Sandalwood was most successful on water run-on sites, and in areas where there was a range of potential host species. Seeds of 18 mm or more in diameter favoured germination and two to three spot-sown seeds at a depth of 25 to 50 mm directly below the canopy of the host species favoured the establishment of Sandalwood.

**REGENERATION STUDIES - 1973 TO 1979**
Fifty years of observations and measurements had provided useful information on Sandalwood establishment, growth rate and yields. Data on regeneration were still lacking and further research programs were developed in the 1970s. In 1973, a new series of plots were designed to examine the management of W.A. Sandalwood regeneration in the inland Mulga (*Acacia aneura*, ex Benth.) and Eucalypt woodlands. The work was carried out in the Kalgoorlie and Narrogin areas. The observations and results are summarized by topic in the following chapters.

**REGENERATION STUDIES - 1981**
On the basis of the research carried out from 1895 to 1979 a series of trials were established in the Dryandra forest near Narrogin to investigate the regeneration of Sandalwood with a diversity of seeds, seedlings and germinants on a range of site conditions. The observations and results summarized in the following chapters should assist future regeneration of Sandalwood on an operational and plantation scale.
Sandalwood Seed

SEED PRODUCTION
One of the main determinants of seed production is the prevailing climatic conditions. Observations at Kalgoorlie have revealed that in the years of moderate rainfall Western Australian Sandalwood usually flowered and set seed in one year. In contrast, after a drought spanning two years, two consecutive years of reasonably high rainfall are needed to allow full crown recovery, flowering and seed set. For example, in April 1973, the Sandalwood at Kalgoorlie flowered and set seed for the first time since the onset of a four-year drought in 1969 (annual rainfall was 55 per cent of the average during the drought) (Fig. 2). The wet year in 1973 at Kalgoorlie was also followed by a widespread and abundant seed crop in 1974. However, by 1978, seed production had fallen to less than 25 per cent (in some cases less than 10 per cent) of the higher 1974 level.

Davies (1976) recorded that fruit set at Mileura (near the mouth of the Murchison River) was correlated with April rain and cold winters. He concluded that cool conditions favoured the species, as is likely considering its southern distribution. The best years of Sandalwood seed production recorded at Mileura by Davies were 1966, 1968 and 1971. During this period the summer rainfall was average or better than average. In 1971, when there was no rain in April, both summer and winter rainfall were above average.

In 1978, the Lol Gray stand of 46 trees at Dryandra, near Narrogin, produced an average of 150-200 seeds each, with a range from nil to two thousand per tree. The seed was noticeably larger than that of the Kalgoorlie provenances. The average seed number per kilogram was 277. It was picked up in October after lying under the parent trees for ten months. Observations during this experiment indicated that emus, through their digestive processes, may have influenced local seed distributions. Similar findings were made earlier by officers of the Western Australian Forests Department (1925).

The site conditions and resultant vigour of the Western Australian Sandalwood trees can also affect the seed production levels. Observations at Calooli and Bullock

![Figure 2](image-url)

Kalgoorlie yearly rainfall (1960 - 1989)
Holes Sandalwood Reserves on different site conditions in 1978 and 1979 reflected budding and flowering of the Sandalwood trees. All the mature fruit dropped from the trees at Bullock Holes, and was collected in January 1979. No fruit matured at the less favourable ridge site at Calooli. Trees under stress did not flower, and further incipient budding and flowering in March 1979 failed to set seed in both reserves. At Bullock Holes, the average production in 1978 was 28 mature fruit per tree (and five undeveloped fruit which was not collected). The mature seed number per kilogram was 460 with the endocarp retained and the epicarp removed.

The vigour of the trees was also affected by the scale insects. The scale was particularly evident in the below-average rainfall years. It was most noticeable in August 1979. In the preceding January to March, incipient flush with some new leaves appeared in about half of the trees. Although black scale was very evident when seed production was absent during the study period in the 1970s, other observations have shown that insect infestations are reduced by adequate rain.

**PRE-SOWING SEED TREATMENT**

Several methods for the germination of Sandalwood (*S. spicatum*) and Quondong (*S. acuminatum*) seeds have been tried previously (Grant and Buttrose 1978; Crossland 1981, 1982; Sedgley 1984). All these methods involve detailed preparation of the seed and controlled conditions for germination. Observations on pre-sowing treatments have indicated that the optimum method for large quantities of Sandalwood fruit is to soak them in water for a short period. The fruits should then be tumbled together with some heavy stones in a cement mixer. The husks are then washed away and the nuts set out to dry. Soaking overnight or possibly longer, followed by drying in the sun, allows the shells to dry out. The shells then start to crack. At this stage they are ready for planting.

**SEED VIABILITY AND GERMINATION AFTER STORAGE**

A series of tests were undertaken to investigate the viability of Western Australian Sandalwood seed in the field and in storage. Previous investigations had concentrated on seed less than two-years-old.

The experiment was initiated to test the effects of moisture and temperature on stored seed (see Appendix II). The seeds were collected in October 1974. The seeds were soaked overnight and the endocarp (hard coat) of some of the seeds was cracked in a vice. Seed viability tests were carried out initially, after two years, five years, eight years and nine years on varying seed treatments. The findings are summarized in Table 4. The decline in seed viability observed in Sandalwood at five years supports similar findings by Sedgley (1984), where Quandong (*S. acuminatum*) germination rates started to decline after five years.

<table>
<thead>
<tr>
<th>Time of Seed Viability Tests (Years)</th>
<th>Seed Treatment</th>
<th>Seed Germination Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>seeds soaked overnight &amp; endocarp(^{0\circ}) cracked in vice</td>
<td>84</td>
</tr>
<tr>
<td>2</td>
<td>400 seeds with endocarp removed, four treatments(^{0\circ}), Germination terminated in 6 weeks Average for four treatments</td>
<td>76.5</td>
</tr>
<tr>
<td>5</td>
<td>400 seeds with endocarp removed, four treatments (^{0\circ}), Germination terminated in 13 weeks Average for four treatments</td>
<td>34</td>
</tr>
<tr>
<td>9</td>
<td>160 seeds with epicarp intact, four treatments (^{0\circ}) Cold Storage, with Silica Gel</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Cold Storage, without Silica Gel</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Room Temperature, with Silica Gel</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Room Temperature, without Silica Gel</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>Separate Serial of Seed stored in Cold Store, with Silica Gel</td>
<td>57</td>
</tr>
<tr>
<td>9</td>
<td>Separate Serial of Seed stored in Cold Store, with Silica Gel</td>
<td>52</td>
</tr>
</tbody>
</table>

(a) Four Treatments were:
- Temperature - Cold Store (4-5°C)
- Temperature - Room Temperature
- Moisture - With Silica Gel
- Moisture - Without Silica Gel

(b) Epicarp - outer coat
Endocarp - hard coat

The Sandalwood results indicate that the germination rate deteriorates with time and that if storage is required then the preferred option is cold storage with silica gel. In addition, a continuing regeneration program would require storing twice the annual requirements for a
period of up to eight years. The need to maintain the store of seed from the seed production years becomes critical, particularly for areas such as Kalgoorlie (see previous discussion on Seed Production).

SEED GERMINATION AT NARROGIN
A series of tests were undertaken to investigate the effects of shelling the seeds (removing the endocarp) on the germination of 25,000 Sandalwood seeds (see Appendix III).

The results indicated that the maximum germination was attained for seed without shells in 16 days, and for intact seed in 36 days. Sixty-two per cent of the unshelled seed and over 80 per cent of the shelled seed germinated. The initial germination advantages of shelling were also observed by Sedgley (1984) for Quandong (S. acuminatum). Later observations on Sandalwood indicated that although shelling the seeds appeared to favour germination, leaving the endocarp intact appeared better for seedling survival.
Germination and Seedling Establishment of Sandalwood

A series of experiments were designed to investigate the germination of Western Australian Sandalwood seedlings with different host species at Narrogin and Kalgoorlie in both nursery and field situations (see Appendix IV and Appendix V).

NARROGIN TRIALS

Host species included Mulga (Acacia aneura), Jam (Acacia acuminata, Benth.), Acacia hemiteles, Cratystylis subspinescens (F.Muell. & Tate), Maireana polypterygia ((Diels) Paul G. Wilson) and Atriplex amnicola (Paul G. Wilson).

Results are summarized in Appendix IV and Table 5. Survival was initially favourable, however, survival decreased over the first summer. The low survival of Sandalwood (2 per cent irrespective of experiment) and the better survival of the host species of Mulga (22 per cent) and Jam (17 per cent) in the field, suggested that Sandalwood failed to make satisfactory union with the roots of nurse plants while in the nursery, as well as with the roots of the natural hosts in the native vegetation near Narrogin. The latter failure of the development of haustoria was confirmed by inspection of washed roots.

Table 5


<table>
<thead>
<tr>
<th>Date</th>
<th>Seeding</th>
<th>Survival</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.11.78</td>
<td>22</td>
<td>23</td>
<td>23.5.80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period Since Planting (Months)</th>
<th>Percentage of Seedlings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia aneura (Mulga)</td>
<td>92</td>
</tr>
<tr>
<td>Atriplex amnicola</td>
<td>92</td>
</tr>
<tr>
<td>Cratystylis subspinescens</td>
<td>35</td>
</tr>
<tr>
<td>Maireana polypterygia</td>
<td>88</td>
</tr>
<tr>
<td>Santalum spicatum</td>
<td>49</td>
</tr>
</tbody>
</table>

KALGOORLIE TRIALS

A series of experiments were established in fenced plots in the Kalgoorlie Arboretum, Jeedamya Pastoral Station, and Bullock Holes Sandalwood Reserve to test the effects of a range of sites and techniques on the germination and establishment of Sandalwood seedlings. These experiments are summarized in Appendix V and the results are summarized in the following text and Table 6 and Table 7.

Table 6

CHEMICAL ANALYSES OF THE SURFACE SOIL IN THE KALGOORLIE ARBORETUM

<table>
<thead>
<tr>
<th>Treatment Type</th>
<th>Soil Depth (mm)</th>
<th>pH</th>
<th>Electrical Conductivity</th>
<th>Salts (%)</th>
<th>NaCl (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0-10</td>
<td>8.20</td>
<td>140</td>
<td>0.030</td>
<td>0.005</td>
</tr>
<tr>
<td>Irrigated</td>
<td>0-10</td>
<td>8.65</td>
<td>142</td>
<td>0.030</td>
<td>0.006</td>
</tr>
<tr>
<td>Control</td>
<td>10-20</td>
<td>8.80</td>
<td>122</td>
<td>0.026</td>
<td>0.004</td>
</tr>
<tr>
<td>Irrigated</td>
<td>10-20</td>
<td>8.55</td>
<td>122</td>
<td>0.026</td>
<td>0.003</td>
</tr>
<tr>
<td>Control</td>
<td>20-30</td>
<td>8.70</td>
<td>857</td>
<td>0.220</td>
<td>0.103</td>
</tr>
</tbody>
</table>

Table 7

GERMINATION OF SANDALWOOD FROM 200 SEEDS PER TREATMENT AT KALGOORLIE

<table>
<thead>
<tr>
<th>Locality</th>
<th>Treatment</th>
<th>Seeded</th>
<th>Soaked (in water)</th>
<th>Not soaked</th>
<th>Total</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalgoorlie</td>
<td>Irrigated</td>
<td>20</td>
<td>23</td>
<td>31</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Kalgoorlie</td>
<td>Not Irrigated</td>
<td>13</td>
<td>21</td>
<td>31</td>
<td></td>
<td>N.S.</td>
</tr>
<tr>
<td>Bullock Holes</td>
<td>Not Irrigated</td>
<td>65</td>
<td>48</td>
<td>119</td>
<td></td>
<td>N.S.</td>
</tr>
<tr>
<td>Jeedamya</td>
<td>Not Irrigated</td>
<td>30</td>
<td>48</td>
<td>78</td>
<td></td>
<td>N.S.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Locality</th>
<th>Treatment</th>
<th>With Coat</th>
<th>Coat Removed</th>
<th>Total</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalgoorlie</td>
<td>Irrigated</td>
<td>-</td>
<td>31</td>
<td>31</td>
<td>**</td>
</tr>
<tr>
<td>Kalgoorlie</td>
<td>Not Irrigated</td>
<td>-</td>
<td>21</td>
<td>21</td>
<td>**</td>
</tr>
<tr>
<td>Bullock Holes</td>
<td>Not Irrigated</td>
<td>-</td>
<td>21</td>
<td>21</td>
<td>**</td>
</tr>
<tr>
<td>Jeedamya</td>
<td>Not Irrigated</td>
<td>-</td>
<td>21</td>
<td>21</td>
<td>**</td>
</tr>
</tbody>
</table>

Significance by Binomial Proportion Test
** P<0.05
* P<0.10
N.S. P>0.10
The germination of Western Australian Sandalwood at the Kalgoorlie Arboretum improved initially with irrigation, but germination rates were low when compared with the results of the field plots (Table 7). For similar treatments and rainfall, germination from seed sown in plots in May 1975 was:

- Bullock Holes 30.5 per cent
- Kalgoorlie (control) 4.0 per cent
- Kalgoorlie (irrigated) 7.8 per cent

To review the possible effects of salinity and pH levels in the interpretation of results at the Kalgoorlie Arboretum, the surface soils were analysed for pH and salt content (Table 6).

The results illustrate only slight differences in the pH and salt content of the surface soils for the control and irrigated treatment sites at the Kalgoorlie Arboretum. Therefore the surface soil differences are insufficient to influence the germination rates in the various treatments.

Percentage germination results for the Kalgoorlie Arboretum suggest that germination improves with overnight soaking of seed and with irrigation (Table 7).

In field trials, results for treatments to encourage germination were somewhat inconsistent and no better than the controls, pooling all sites (Table 7 and Appendix V - Experiment V-2). Removing the endocarps of the seeds decreased survival in the Jeedamya plot. This coincided with a reported mice plague at the Jeedamya homestead. Some of the Sandalwood seeds lying exposed on the ground under mature Sandalwood trees were eaten by rodents at Jeedamya. What appeared to be a better germination in retaining the endocarps of the seeds was probably caused by the plague of mice eating more of the seeds that already had the endocarp removed. At the Bullock Holes Sandalwood Reserve, there was no difference between these treatments, and no evidence of field mice.

The increase in the population of rodents (mice) and rabbits in the pastoral areas coincided with above-average rainfall during 1973-1975.

Concurrently, seed treatments to improve moisture relationships for seed (soaking, peat, seed coat removal) in the non-irrigated and irrigated plots were tested in the Kalgoorlie Arboretum. These results were inconclusive.

In general, an adequate supply of water seems to favour Sandalwood germination, but survival is determined mainly by the availability of host roots. In the field trials, survivals were significantly closer to the nearest host, within 2.5 m in open woodland and within 1.25 m in open low woodland.

In other tests, cultivation was found to assist germination but not survival. The latter was probably a result of the destruction of the host roots during cultivation. Mortality of seedlings and deficiency of host plants were most pronounced in the Kalgoorlie Arboretum. Germination was also most deficient in this area. It was decided that follow-up work on these techniques should be re-located to the more favourable nursery conditions at Narrogin.
Sandalwood Regeneration

EFFECTS OF SITE CULTIVATION ON ARTIFICIAL AND NATURAL REGENERATION

A series of trials were established, in May 1974, to test the effects on Sandalwood germination and survival of site, natural seed supply and artificial sowing, and cultivating the seedbed. Four sites were selected for the studies, in relation to their representation of plant communities and their location from Kalgoorlie and Coolgardie, on two Pastoral Stations (Gindalbie and Jeedamya, located 60 km north-east and 160 km north of Kalgoorlie) and two Reserves (Bullock Holes and Calooli, located 40 km north-east of Kalgoorlie and 15 km south-west of Coolgardie respectively (Appendix VI). The sites differed in their location, soil types and dominant plant communities (Appendix VI).

A good year of seed production in 1973 at Kalgoorlie was followed by two wet years, both favourable for germination and establishment of Sandalwood seedlings. Although seedlings of six and seven months old were observed to establish haustoria on host roots at Kalgoorlie in 1975, observers have also noted that seedlings when dug up at twelve months (Western Australian Forests Department Annual Report 1924) had not always parasitised a host plant. Therefore the older seedlings cannot be assumed to have established haustoria at 12 months. Results are summarized in Figure 3 and Table 8.

A series of illustrations in Plates 11, 12, 13 and 14 reflect the range of regeneration and germination of seedlings at Bullock Holes and Gindalbie.

Results illustrate that far more seedlings established in the cultivated than the uncultivated soil. Nevertheless the plants on the cultivated soils were far less stable than those on the uncultivated soils, as the higher germination was followed by a greater mortality in the following summer months. Improved germination was probably a result of the burying of seeds by the rotary hoe (Fig. 3).

The severe drought that occurred at Kalgoorlie in 1976 and 1977 resulted in significant Sandalwood seedling mortality in the field trials (Table 8, Fig. 3).

Drought of this severity is rare, as only one other drought of a similar severity has been recorded since 1895. This suggests that the germination and survival rates recorded in these experiments are a benchmark in that they represent likely patterns under the worst germination and establishment conditions. The 1976-77 drought continued to cause high mortality in both the experimental seedling population of Sandalwood and in the mature Sandalwoods and host shrubs well into 1978 and 1979.

The seedlings, given equal initial germination from spot sowing, were favoured by uncultivated soils during 1975 and 1976 (Fig. 3). These differences appeared to be affected by the occurrence of two years of severe drought. As droughts occur at relatively frequent intervals in the semi-arid areas of Western Australia, the results in October 1977 (Fig. 3) reflect the earlier comments about the low establishment rate of Sandalwood. The effectiveness of cultivation must then be questioned in areas which are subject to periods of drought.

The seedlings in cultivated soil suffered greater mortality, both relative and absolute, than did the seedlings in uncultivated soil (Fig. 3). This mortality may be related to the parasitic nature of Sandalwood. The new seedling has little chance of surviving its first summer unless it develops a haustorial link with the root systems of the host species for a supply of water and nutrients. Cultivation appears to have destroyed the fine surface roots of potential hosts, leaving the Sandalwood seedlings to perish.

Other factors may have contributed to seedling mortality. One possibility is that the cultivated soil dries out more rapidly. Another is the potential competition between seedlings.

A sequence of three wet years appears to be necessary for the succession of flowering, seed set, germination and establishment of Sandalwood seedlings in the field. Such a sequence occurs infrequently in the inland areas. The results from the field trials in the more favourable years of 1973 to 1975 assisted in evaluating germination and establishment needs of Sandalwood, however, little is known on a regional scale of the impacts of the changes in climatic conditions on natural regeneration of this species.
Figure 3
Effect of cultivation on germination and seedling survival from natural seed supply
Table 8
GERMINATION AND SEEDLING SURVIVAL FROM SPOT SOWING OF 100 SANDALWOOD SEED PER PLOT TREATMENT

<table>
<thead>
<tr>
<th>Season and Date of observation</th>
<th>On Reserves, Calooli + Bullock Holes</th>
<th>On Pastoral Stations, Gindalbie + Jeedamya</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not Cultivated</td>
<td>Cultivated</td>
</tr>
<tr>
<td></td>
<td>Fenced</td>
<td>Fenced</td>
</tr>
<tr>
<td>No. sown in May 1974</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>1974 Germination and Survival</td>
<td>Wi July 1974</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Sp October 1974</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Su January 1975</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Sp October 1975</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Su January 1976</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Au April 1976</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sp October 1976</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Au April 1977</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sp October 1977</td>
<td>0</td>
</tr>
<tr>
<td>1975 Germination and Survival</td>
<td>Sp October 1975</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Su January 1976</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Au April 1976</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Sp October 1976</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Au April 1977</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sp October 1977</td>
<td>1</td>
</tr>
</tbody>
</table>

Wi = Winter, Sp = Spring, Su = Summer, Au = Autumn

The findings on longer-term survival were restricted by the drought conditions in the latter part of the 1970s.

EFFECTS OF BROWSING ON SANDALWOOD REGENERATION
Previous workers and observers have noted the lack of Sandalwood regeneration in Western Australia. The fate of seedlings is often thought to be affected by the grazing of herbivores (sheep, rabbits, goats, camels, donkeys, horses, cattle and kangaroos) as shown in Plate 15 and Plate 16.

A series of fencing trials were established to investigate the impact of grazing on Sandalwood regeneration on a range of sites in the Kalgoorlie area.

Results are summarized in Appendix VII, Table 8 and Figures. 4, 5 and 6. The results confirmed that fencing was not significant on reserves, but was significant on the stations. Whether Sandalwood regeneration occurs naturally, or is artificial, it is evident that the chance of survival on grazing areas of pastoral stations (covering most of the residual Sandalwood country) is very low. Hot dry seasons reduce the amount of succulent foliage and domestic and feral animals (sheep and goats) range over the land and graze the Sandalwood seedlings.

The impact of rabbits and native herbivores was evident on the reserves, however, the impact was markedly less than on the stations with the larger numbers of introduced herbivores (sheep and goats).
EFFECTS OF FIRE AND CUTTING ON SANDALWOOD REGENERATION

Observers have reported Sandalwood coppice in the Wheatbelt, with coppicing after fire, and after cutting at Bendering reported by G.H. Drake-Brockman in 1921:

(1) Large trees sprouted after a grass fire had passed and the trees appeared to have been killed;

(2) Other severely scorched trees frequently suckered from the base;

(3) Young trees were generally killed outright by fire;

(4) Trees cut at ground level have frequently suckered and produced marketable timber.

As coppicing might be a more positive method for replacing the harvested crop of Sandalwood a series of experiments were established in 1974-75 to investigate recovery after cutting and from wildfires on reserves. Results are summarized in Appendix VIII and Table 9.

Figure 4
Effect of Fencing on spot sown seed (800 seeds in each treatment)

Table 9
EFFECTS OF FIRE AND CUTTING ON SANDALWOOD REGENERATION

LAKESIDE SANDALWOOD RESERVE - EFFECTS OF WILDFIRE IN JANUARY 1975 (see Appendix VIII)

<table>
<thead>
<tr>
<th>Fire Impact</th>
<th>No. Burnt</th>
<th>No. Surviving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightly scorched trees</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>(only 2 produced fresh growth in the crown and stem)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate to severely burnt</td>
<td>33</td>
<td>20</td>
</tr>
<tr>
<td>Burnt trees (Total)</td>
<td>44</td>
<td>28</td>
</tr>
<tr>
<td>Unburnt trees (Total)</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

CALOOLI SANDALWOOD RESERVE - EFFECTS OF CUTTING IN 1975 AND 1976

<table>
<thead>
<tr>
<th>Cutting Treatment</th>
<th>Numbers Coppicing</th>
</tr>
</thead>
<tbody>
<tr>
<td>After 4 Months</td>
<td>At the end of 1976</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>16 cut in summer 1975 (moist)</td>
<td>4</td>
</tr>
<tr>
<td>16 cut in winter 1975 (moist)</td>
<td>0</td>
</tr>
<tr>
<td>32 cut in winter 1976 (dry)</td>
<td>0</td>
</tr>
</tbody>
</table>

The practice of pulling the whole tree from the ground and harvesting the runner roots down to 40 mm diameter was historically accepted in the Sandalwood industry (current licence conditions include harvesting roots down to 25 mm heartwood). Yields are increased by between one-and-a-half and two times by harvesting the butt and roots of the tree. The early observers recognized the potential for coppicing, if the effects of grazing could be minimized. Although the initial observations looked promising the results from the detailed investigations suggested that the coppice survival was low. The studies in the Kalgoorlie area confirmed that 10 to 15 per cent of stumps coppiced when the soil was moist, but then completely failed within two years, probably when the soil dried out.
Figure 5
Effect of fencing on geminants of spot sown seed (400 seeds in each treatment)
Twenty-eight of the study population coppiced from roots and butts after fire, but only 9 of those burnt survived (Table 9, Appendix VIII).

A preliminary study in another Sandalwood area (Hampton Hill Station, 75 km north-east of Kalgoorlie) burnt in November 1974 and harvested in January 1975, started with promising regeneration from coppice growth, but showed similar failure with time. In this area, most of the burnt Sandalwood trees were snapped off by the operators. The residual stumps and roots coppiced during a very wet period in early 1975. In one stand of 82 stems, 60 (73 per cent) coppiced. Mortality in 1976 reduced survivors to 40 trees: 47.5 per cent of the original population. By 1978, the survival rate was less than 10 per cent.

The cutting trials at Calooli showed a low number of plants coppicing (4 plants or 6 per cent) and all coppice growth did not persist (Table 9, Appendix VIII).

All the studies confirmed that coppicing could not be relied upon as a source of Sandalwood regeneration in the Kalgoorlie area. These findings appear to differ from recent observations at Shark Bay where coppicing of roots appears to be a possible option for regeneration of *Santalum spicatum* (Plate 17). The latter differences in coppicing capability may relate to genetic variations in the populations at Shark Bay or the different climatic and site conditions.

**REGENERATION STUDIES AT NARROGIN**

In 1981, a series of trials were carried out at Dryandra State Forest to research operational requirements for planting Sandalwood. Research into provenance, planting methods, planting stock and site factors was undertaken. Trials were established in an area of *Jam (Acacia acuminata)*. Results are summarized below and in Appendix IX. The regeneration trials at Gura Road in Dryandra State Forest are illustrated in Plates 18, 19, 20 and 21. Examples of 1-year and 3-year-old seedlings are illustrated.

The results indicated that sowing germinated seeds at four per spot produced one surviving germinant per spot (Appendix IX). In the niches where W.A. Sandalwood established and grew most successfully it was observed that a clump of three or four Sandalwood trees can be grown to maturity. In an operational regeneration program the potential number of failed spots can be offset by increasing the number of plants at each spot.

Planting of germinated seed under full shade on a well drained, brown sandy loam slope will produce twice as many survivals as any other method (Appendix IX).

Successful artificial regeneration of Sandalwood can therefore be achieved by sowing four germinated Sandalwood seeds per spot in appropriate well drained sites, 50 mm below the soil and mulched in a small depression at the drip line of the south side of a host plant, protected from grazing.
Sandalwood Growth Rates

During 1974 and 1978 studies were undertaken to determine the range in size of Sandalwood trees and the rate of growth. The natural variation in plant size and rates of growth are predictably related to factors such as site conditions, climate and soils. Results were extrapolated to determine the length of time Sandalwood needs in different regions to attain commercial size. Results are presented in Tables 10, 11, 12 and 13; Figures 7, 8 and 9; and Appendix X.

A wide range in rates of growth were observed between the largest and smallest trees within different sites (Tables 10 and 11). Observations indicated that local site conditions influenced both host and Sandalwood growth rates. The length of time required to attain commercial size (127 mm diameter at 150 mm above ground) varied from 32 to 59 years at Dryandra to 59 to 115 years at Kalgoorlie (Table 12). These differences in growth rates appeared to be related primarily to the varying site and climatic conditions in the two regions.

| Table 10 |
| Height (m) & Stem Diameter Growth Results for Sandalwood at Karramindie and Schaill |

| Year Sown | 1940 | 1974 | 34 years | Stem at 75 mm above ground | Stem at 150 mm above ground | Bark (twice thickness) at 300 mm |
|———|———|———|———|———|———|———|
| **Karramindie** | 1930 | | | | | |
| Plot | 1.50 | 3.80 | 2.30 | 0.62 | 1.12 | 16 | 107 | 91 | 100 | 78 | 72 | 22 |
| (6 trees) | 1.25 | 3.60 | 2.35 | 13 | 107 | 94 | 6 | 80 | 74 | 10 | 105 | 95 | 21 |
| Mean tree | 1.07 | 3.78 | 2.71 | 0.66 | 1.31 | 10 | 105 | 95 | 102 | 81 | 21 |
| Annual increment | 0.074 | | | | | |
| Sample tree | 1.15 | 3.68 | 2.53 | 13 | 96 | 83 | 2.44 |
| **Karramindie** | 1925 | | | | | |
| Plot E (12 trees) | 1.50 | 2.95 | 0.55 | 24 | 70 | 46 | 65 | 47 | 18 |
| Mean tree | 1.50 | 2.50 | 1.00 | 24 | 70 | 46 | 70 | 54 | 14 |
| Annual increment | 0.030 | | | | | |
| **Schaill** | 1930 | | | | | |
| Mean (14 trees) | 1.08 | 1.93 | 0.85 | 18 | 57 | 39 | 56 | 38 | 16 |
| Annual increment | 0.025 | | | | | |
| Mean (12 trees) | 0.91 | 1.23 | 0.32 | 15 | 38 | 23 | 37 | 22 | 11 |
| Annual increment | 0.010 | | | | | |

22
### SUMMARY OF SANDALWOOD YIELD IN TREES AGED 44 YEARS NEXT TO KARRAMINDIE (PLOT 1)

<table>
<thead>
<tr>
<th>Sample Trees and Parameters of Sections</th>
<th>Wood &amp; Bark</th>
<th>Total Wood &amp; Bark</th>
<th>Heartwood</th>
<th>Sapwood</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Largest Tree</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total height 3.86 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter at 75 mm above ground (mm)</td>
<td>104</td>
<td>25</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>Diameter at 150 mm (and at 300 mm)</td>
<td>78</td>
<td>(20)</td>
<td>56</td>
<td>22</td>
</tr>
<tr>
<td>Diameter at 650 mm for heartwood to 40 mm</td>
<td>78</td>
<td>18</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Volume for above (m$^3$ x 10$^3$)</td>
<td>4.2</td>
<td></td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Per cent by volume (%)</td>
<td>100</td>
<td>40</td>
<td>60</td>
<td>30</td>
</tr>
<tr>
<td>Diameter at 1250 mm for stem to 55 mm</td>
<td>55</td>
<td>16</td>
<td>39</td>
<td>18</td>
</tr>
<tr>
<td>Volume for above (m$^3$ x 10$^3$)</td>
<td>6.2</td>
<td></td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Per cent by volume (%)</td>
<td>100</td>
<td>55</td>
<td>45</td>
<td>25</td>
</tr>
<tr>
<td>Weight by stem (kg)</td>
<td>2.5</td>
<td></td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Number of stems per tonne</td>
<td>400</td>
<td></td>
<td>770</td>
<td></td>
</tr>
</tbody>
</table>

| **Large Class**                        |             |                   |           |         |
| Mean height 3.54 m                     |             |                   |           |         |
| Diameter at 75 mm above ground (mm)    | 91          | 21                | 70        |         |
| Diameter at 150 mm (and at 300 mm)     | 90          | (21)              | 69        | 46      |
| Diameter at 450 mm fork for heartwood to 40 mm | 83    | 18                | 65        | 43      |
| Volume for above (m$^3$ x 10$^3$)      | 2.7         |                   | 1.6       | 0.7     |
| Per cent by volume (%)                 | 100         | 40                | 60        | 25      |
| Diameter at 920 mm for stem to 55 mm   | 55          | 16                | 39        | 16      |
| Volume for above (m$^3$ x 10$^3$)      | 4.5         |                   | 2.2       | 0.8     |
| Per cent by volume (%)                 | 100         | 55                | 50        | 20      |
| Weight by stem (kg)                    | 1.9         |                   | 0.7       |         |
| Number of stems per tonne              | 525         |                   |           |         |

| **Small Class**                        |             |                   |           |         |
| Mean height 2.76 m                     |             |                   |           |         |
| Diameter at 75 mm above ground (mm)    | 71          | 18                | 53        |         |
| Diameter at 150 mm (and at 300 mm)     | 70          | (16)              | 54        | 33      |
| Diameter at 650 mm for heartwood to 55 mm | 55    | 15                | 40        | 18      |
| Volume for above (m$^3$ x 10$^3$)      | 2.2         |                   | 1.3       | 0.4     |
| Per cent by volume (%)                 | 100         | 40                | 60        | 20      |
| Weight by stem (kg)                    | 1.1         |                   | 0.35      |         |
| Number of stems per tonne              | 910         |                   |           |         |

---

*Volume (m$^3$ x 10$^3$) - 0.0785 x d$^2$ (cm) x L (m) (Avery 1975)*

*Weight converted from 880 kg/m$^3$ (Tables 8, 9, Figs 2, 3).*

A range of measurements were also undertaken in 1974 and 1978 on Sandalwood trees in the Narrogin and Swan Coastal Plain areas. The length of time required to attain a commercial size (stem diameter of 127 mm) varied with climatic and soil conditions, in different plant community types within the three regional areas (Appendix X):

**Narrogin (335-385 mm annual rainfall)**

**PLANT COMMUNITY TYPES**

- Ploughed Broombush - *Acacia acuminata*:
  - 45 - 50 years
- Unploughed Broombush - *Acacia acuminata*:
  - 80 - 130 years

**Swan Coastal Plain (875-890 mm annual rainfall)**

**PLANT COMMUNITY TYPES**

- *Banksia* spp. on Bassendean Sand Dune System:
  - 35 years
- *Eucalyptus gomphocephala* (DC.):
  - 35-70 years
### Table 12
GROWTH RATE OF SANDALWOOD AT NARROGIN AND KALGOORLIE AND NUMBER OF YEARS NEEDED TO REACH COMMERCIAL DIAMETER OF 127 MM (DIAMETER OVER BARK AT 150 MM ABOVE GROUND LEVEL - D.O.B.)

<table>
<thead>
<tr>
<th>Locality</th>
<th>State Forests and Reserves</th>
<th>Age (yrs)</th>
<th>Number of Trees (n)</th>
<th>Mean d.o.b. (mm)</th>
<th>Annual d.o.b. increment (mm)</th>
<th>Age to reach d.o.b. 27 mm (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrogin</td>
<td>Dryandra S.F. Reserve 8324</td>
<td>22</td>
<td>337</td>
<td>88.0</td>
<td>4.0</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>47</td>
<td>106</td>
<td>101.5</td>
<td>2.16</td>
<td>59</td>
</tr>
<tr>
<td>Kalgoorlie</td>
<td>Karramindie S.F. Plot 1 as above</td>
<td>52</td>
<td>288</td>
<td>91.4</td>
<td>1.76</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>44</td>
<td>10</td>
<td>95.0</td>
<td>2.16</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>49</td>
<td>12</td>
<td>70.0</td>
<td>1.43</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>Seahill Reserve</td>
<td>44</td>
<td>26</td>
<td>48.2</td>
<td>1.10</td>
<td>115</td>
</tr>
</tbody>
</table>

### Table 13
LINEAR REGRESSIONS OF VARIOUS COMPONENTS OF SANDALWOOD TREES FOR DIAMETER OVER BARK UNDER COMMERCIAL SIZE (1,2) AND ALL TREES (3-9) IN THE EASTERN GOLDFIELDS AND GREENOUGH/GASCOYNE REGIONS.

<table>
<thead>
<tr>
<th>Y (kg)</th>
<th>N</th>
<th>y</th>
<th>S.D.</th>
<th>a</th>
<th>b</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Total weight</td>
<td>15</td>
<td>15.8</td>
<td>7.2</td>
<td>-7.728</td>
<td>0.2750</td>
<td>0.70</td>
</tr>
<tr>
<td>2 Twigs (&lt;10 mm d.o.b. + leaves)</td>
<td>15</td>
<td>4.93</td>
<td>2.15</td>
<td>-2.922</td>
<td>0.0917</td>
<td>0.78</td>
</tr>
</tbody>
</table>

Based on 15 trees with d.o.b. under 127 mm

<table>
<thead>
<tr>
<th>Y (kg)</th>
<th>N</th>
<th>y</th>
<th>S.D.</th>
<th>a</th>
<th>b</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Total weight</td>
<td>22</td>
<td>28.5</td>
<td>20.8</td>
<td>-29.32</td>
<td>0.5441</td>
<td>0.94</td>
</tr>
<tr>
<td>4 Sound roots</td>
<td>13</td>
<td>3.0</td>
<td>1.7</td>
<td>-1.35</td>
<td>0.0370</td>
<td>0.82</td>
</tr>
<tr>
<td>5 Commercial logs</td>
<td>22</td>
<td>10.2</td>
<td>7.4</td>
<td>-10.53</td>
<td>0.1952</td>
<td>0.95</td>
</tr>
<tr>
<td>6 Butt log section - 9 broken butts</td>
<td>22</td>
<td>3.6</td>
<td>2.1</td>
<td>-0.91</td>
<td>0.0428</td>
<td>0.74</td>
</tr>
<tr>
<td>7 Stem log sections</td>
<td>22</td>
<td>7.0</td>
<td>7.2</td>
<td>-12.01</td>
<td>0.1790</td>
<td>0.90</td>
</tr>
<tr>
<td>8 Total branchwood</td>
<td>22</td>
<td>8.4</td>
<td>5.7</td>
<td>-6.11</td>
<td>0.1366</td>
<td>0.87</td>
</tr>
<tr>
<td>9 Twigs (&lt;10 mm d.o.b. + leaves)</td>
<td>22</td>
<td>8.3</td>
<td>5.7</td>
<td>-6.10</td>
<td>0.1360</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Based on 22 trees including 7 with d.o.b. <127 mm (ranging 55 - 180 mm)
Plate 1: Sandalwood tree (3 m) at Kalgoorlie

Plate 2: A puller cutting roots

Plate 3: Tractor in use for pulling Sandalwood

Plate 4: Loading Sandalwood Binneringie Station

Plate 5: Sandalwood stacked at Pinner's camp, Gindalbie Station, ready for shipment.

Plate 6: Sandalwood fruit (size range - 1.5-2 cm diameter).
Plate 7: Healthy crown growth, February 1987 in response to recent rains, West Kalgoorlie.

Plate 8: Lateral root development of Sandalwood.

Plate 9: 28-year-old Sandalwood plant in Frank Block, Dryandra State Forest.

Plate 10: 28-year-old Sandalwood plants at Siding Road, Stokes Block, Dryandra State Forest.

Plate 11: Sandalwood seedlings at Bullock Holes Sandalwood Reserve.

Plate 12: 8-year-old Sandalwood plants at Bullock Holes Sandalwood reserve.
Plate 13: Gindalbie Station trial plot area; fencing trials.

Plate 14: Gindalbie Station trial plot area, germination of seedling inside fence, April 1982.

Plate 15: In absence of grazing, Sandalwood can grow to ground level, September 1982.

Plate 16: Goat damage to Sandalwood on Yerilla Station Plots 1980.

Plate 17: Coppicing of Sandalwood on Nanga Station.

Plate 18: Regeneration studies at Gura Road, Dryandra State Forest. 1-year-old Sandalwood seedling.
Plate 19: Regeneration and provenance studies at Gura Road, Dryandra State Forest.
3-year-old Sandalwood seedling.

Plate 20: Regeneration and Provenance studies at Gura Road, Dryandra State Forest.
3-year-old Sandalwood seedlings.

Plate 21: Regeneration and provenance studies at Gura Road, Dryandra State Forest.
3-year-old Sandalwood seedlings.

Plate 22: Natural Sandalwood regeneration at Curries Road, Dryandra State Forest.

Plate 23: Sandalwood, Kalannie, Rabbit Proof Fence Road.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Tree Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A large sample tree</td>
<td>3.80</td>
</tr>
</tbody>
</table>

**Diameter (mm):**
- At Ground Level
- At Height of 1m

---

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Average Tree Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Mean of six large trees</td>
<td>3.70</td>
</tr>
</tbody>
</table>

**Diameter (mm):**
- At Ground Level
- At Height of 0.92 m

---

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Average Tree Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Mean of twelve medium trees</td>
<td>2.50</td>
</tr>
</tbody>
</table>

**Diameter (mm):**
- At Ground Level
- At Height of 0.66m

---

**SCALE:**
- 40 mm
- **Tw = TRUE HEARTWOOD**
- **Sw = SAPWOOD**
- **B = BARK**

**Figure 7**

Sectional analysis of Sandalwood trees next to Karramindie plot 1
Additional measurements were undertaken on constituent parts of 22 Sandalwood trees ranging from 87 to >138 mm stem diameter from three localities where Sandalwood pulling operations were in progress, north and north-east of Kalgoorlie (Morapoi Station - 8 trees; and Edjudina Station - 7 trees) and between Payne's Find and Morawa (Karara Station - 7 trees) see Table 13 and Appendix X.

The plantation trees sampled at Karramindie State Forest (Plot 1) were cut and measured by the sectional method to derive volume and increment of the truewood, sapwood and bark (Fig. 7).

Results indicated that bark and sapwood had a constant thickness of 21-22 mm and that predictably the larger and taller trees had a higher component of heartwood.

Figure 8
Summary of relationship between number of stems per tonne and the diameter class (mm)

- Total Wood (without bark), from 12.01.73
- Heartwood (without bark and sapwood), from 14.09.71
- Total Wood (without bark), from 14.09.71

Figure 9
Air dry weight of Sandalwood, showing loss of moisture content of fresh green wood and variation in relation to seasonal conditions, 1971 to 1974
In addition, on the basis of these figures it was possible to calculate that the proportion of heartwood exceeds sapwood in trees with a stem diameter greater than 102 mm (over bark).

Relationships between stem diameters and numbers of stems per tonne are summarized in Figure 10 and Appendix X. In general the number of harvested (pulled) stems needed to produce a tonne is about 60 per cent of the number required if stems were cut at ground level, almost 90 and 150 respectively at the commercial size stem diameter of 127 mm.

The proportions of sapwood and heartwood vary inversely with overall tree size, as do most tree species. Wood density was 880 kg.m\(^{-3}\) (± 50 kg) after drying for one month (Fig. 8). There were no real differences between total wood and heartwood in these samples. Further drying over summer reduced the density to 810 kg.m\(^{-3}\), which over 3 years had showed a seasonal variation of ± 13 kg.
Conclusions

Conclusions from the W.A. Sandalwood research program from 1895 to 1981 are:

1. The viability of the nuts decreases rapidly after two years and best germination is obtained from fresh mature seed.

2. A series of consecutive wet years are required for the trees to flower and set seed. A following wet year is needed for germination and establishment of the seedlings. This sequence of favourable years must be extended following drought. Such a sequence is less predictable in the drier inland areas near Kalgoorlie than in the Wheatbelt.

3. Cultivation improves germination, probably owing to the burying of the seeds.

4. The significance of cultivation is reduced during periods of drought.

5. Spot-sowing seeds, about 50-70 mm deep, without cultivation improves survival of seedlings over spot-sowing in cultivated soil.

6. Seedling survival improves if grazing animals are excluded by fences, especially on the pastoral stations.

7. Sandalwood regeneration cannot be reliably obtained from coppice, following either fire or cutting.

8. From the experiments with seedlings of Western Australian Sandalwood and host species, a high mortality of Sandalwood and the better survival of the Mulga and Jam seedlings indicated that the Sandalwood may have failed to make satisfactory union with the roots of the host plants, either in the field or in the nursery.

9. The direct seeding trials confirmed that establishment by this method was very uncertain under the harsh conditions prevailing in the field.

10. Germination and survival of Sandalwood seedlings in the field is favoured by proximity to the host and semi-shade.

11. Successful artificial regeneration of Sandalwood on a plantation scale can be achieved by sowing four germinated Sandalwood seeds per spot in appropriate well-drained sites, 50 - 70 mm below the soil surface and mulched in a small depression at the drip line of the south side of a host plant, and protected from grazing.

In conclusion the potential for widespread regeneration and establishment of Sandalwood in Western Australia is feasible if the natural limitations on this species are recognized. The possibility of re-establishing Sandalwood in the Goldfields and the Wheatbelt similar to those illustrated (Plates 22 and 23) should be encouraged for the future of Sandalwood in Western Australia.
Special thanks are due to the Conservator of Forests and the Australian Sandalwood Company for encouragement and funding.

The author would like to thank the many individuals and organizations involved in Sandalwood research within the State of Western Australia over the last century. In particular:

Officers and staff of the former Forests Department and the Department of Conservation and Land Management; P.C. Richmond, N.C. Caporn, M.J. Tagliaferri, B. Brennan for field work on research plots; J. Humphries, R. McAlinden for nursery and field trials at Narrogin; I. Kealley, R. Underwood, J.J. Havel, F.H. McKinnell, P.N. Hewett for critical reviews of the research;

Officers of the Department of Agriculture for assistance in field studies at Kalgoorlie;

E.M. Mattiske, M. Lewis, I. Kealley for their critical editing and advice in the preparation of this document. In addition the helpful comments by the referees M. Sedgley, J. Noble, I. Abbott and J. McGrath;

The Sandalwood Conservation and Regeneration Project (SCARP) for funding the rewriting and publishing costs.
References


beard, j.s. (1972a). the vegetation of the jackson area, western australia. vegetation survey of western australia, map and explanatory memoir 1:250 000 series. vegmap publication, sydney.

beard, j.s. (1972b). the vegetation of the southern cross area, western australia. vegetation survey of western australia, map and explanatory memoir 1:250 000 series. vegmap publication, sydney.

beard, j.s. (1972c). the vegetation of the kalgoorlie area, western australia. vegetation survey of western australia, map and explanatory memoir 1:250 000 series. vegmap publication, sydney.

beard, j.s. (1973). the elucidation of palaeodrainage patterns in western australia through vegetation mapping. occasional paper 1, vegetation survey of western australia. vegmap publications, applecross, western australia.


beard, j.s. (1975a). the vegetation of the nullarbor area. vegetation survey of western australia. 1:1 000 000 series, explanatory notes to sheet 4. university of western australia press, nedlands.

beard, j.s. (1975b). the vegetation of the pilbara area. vegetation survey of western australia. 1:1 000 000 series, explanatory notes to sheet 5. university of western australia press, nedlands.

beard, j.s. (1976a). the vegetation of the shark bay and edel area, western australia. vegetation survey of western australia, map and explanatory memoir 1:250 000 series. vegmap publication, sydney.


birch, a.h., mostyn, k.m.c. and penfold, a.r. (1953). the sesquiterpene alcohols of eucarya spicata. australian journal of chemistry 6: 391-394.

bolton, g.c. (1972). a fine country to starve in. university of western australia press, nedlands.


APPENDIX I

Statutory Reserves containing Sandalwood in Western Australia at 1990.

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality Index</th>
<th>Number</th>
<th>Vesting</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GOLDFIELDS**

**National Parks**

1. Goongarrie A35637 NPNCA 60335

**State Forests and Timber Reserves**

2. Majestic 195/25 LFC 2226
3. Randalls 194/25 LFC 16350
4. Kambalda 199/25 LFC 3342
5. Kangaroo Hills 198/25 LFC 6600
6. Karramindie SF No. 8 LFC 781

**Sandalwood Reserves**

7. Emu Rock C19645 L ACT (NV) 8186
8. Wallaby Rock C19764 L ACT (NV) 4556
9. Coonana C19640 L ACT (NV) 37061
10. Bullock Holes C19825 L ACT (NV) 13313
11. Lakeside C19214 L ACT (NV) 3787
12. Coonana C19211 L ACT (NV) 3121
13. Yellari C19212 L ACT (NV) 6102
14. Scabhill C19621 L ACT (NV) 6916

**Other Reserves**

15. Kalgoorlie Green Belt (20 km radius) VCL (NV) 83000
16. Reserve land between Kalgoorlie and Widgiemooltha (excluding other reserves and Hampton areas) Reg. 95(b) Various (NV) 260240

**Nature Reserves**

17. Rowles Lagoon C4274 NPNCA 404
18. Clear & Muddy Lakes C7634 NPNCA 1926
19. Kurrawang C35453 NPNCA 621
20. Kambalda C33300 NPNCA 3650
21. Binaronca Rock C32552 NPNCA 185
22. Victoria Rock C8480 NPNCA 258
23. Dordie Rock C3211 WSSD 121
24. Cave Hill C17804 WSSD 202
25. Burra Rock C7038 WSSD 809
26. Cardunia Rock A39148 NPNCA 38

**N.E. GOLDFIELDS**

27. Wanjarri Nature Reserve A30897 NPNCA 53248
### APPENDIX I (continued)

<table>
<thead>
<tr>
<th>No.</th>
<th>Locality Index</th>
<th>Number</th>
<th>Vesting</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GASCOYNE RIVER AREA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Collier Range National Park</td>
<td>A35104</td>
<td>NPNCA</td>
<td>277841</td>
</tr>
<tr>
<td>29</td>
<td>Karroun Hill Nature Reserve</td>
<td>A36936</td>
<td>NPNCA</td>
<td>309000</td>
</tr>
<tr>
<td>30</td>
<td>Kadji Kadji Timber Reserves</td>
<td>1/10 LFC</td>
<td>6355</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2/10 LFC</td>
<td>19983</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MURCHISON DISTRICT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Boorabin Nature Reserve</td>
<td>A35004</td>
<td>NPNCA</td>
<td>26000</td>
</tr>
<tr>
<td>32</td>
<td>Sandalwood Reserves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Kangaroo Rocks</td>
<td>C30445</td>
<td>Lands (NV)</td>
<td>8814</td>
</tr>
<tr>
<td>34</td>
<td>Wedwarie Rock</td>
<td>C2179</td>
<td>NPNCA</td>
<td>1363</td>
</tr>
<tr>
<td>35</td>
<td>Deborah East</td>
<td>C2112</td>
<td>MWS</td>
<td>259</td>
</tr>
<tr>
<td>36</td>
<td>Mt Manning</td>
<td>C3112</td>
<td>MWS</td>
<td>259</td>
</tr>
<tr>
<td>37</td>
<td>Jilbadgi Sandalwood Reserves</td>
<td>A24049</td>
<td>NPNCA</td>
<td>208863</td>
</tr>
<tr>
<td>38</td>
<td>Biljahnie Rock</td>
<td>C29920</td>
<td>NPNCA</td>
<td>1036</td>
</tr>
<tr>
<td>39</td>
<td>Condamin Rock</td>
<td>C29823</td>
<td>NPNCA</td>
<td>323</td>
</tr>
<tr>
<td>40</td>
<td>Walyahmoning Rock</td>
<td>A35752</td>
<td>NPNCA</td>
<td>20925</td>
</tr>
<tr>
<td></td>
<td>Other Reserves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Jaurdi Station</td>
<td>3114/1072</td>
<td>PL (CALM)</td>
<td>321399</td>
</tr>
<tr>
<td></td>
<td>YILGARN DISTRICT &amp; N.E. WHEATBELT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Boorabin National Parks</td>
<td>A35004</td>
<td>NPNCA</td>
<td>26000</td>
</tr>
<tr>
<td>32</td>
<td>Sandalwood Reserves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Kangaroo Rocks</td>
<td>C30445</td>
<td>Lands (NV)</td>
<td>8814</td>
</tr>
<tr>
<td>34</td>
<td>Wedwarie Rock</td>
<td>C2179</td>
<td>NPNCA</td>
<td>1363</td>
</tr>
<tr>
<td>35</td>
<td>Deborah East</td>
<td>C2112</td>
<td>MWS</td>
<td>259</td>
</tr>
<tr>
<td>36</td>
<td>Mt Manning</td>
<td>C3112</td>
<td>MWS</td>
<td>259</td>
</tr>
<tr>
<td>37</td>
<td>Jilbadgi Sandalwood Reserves</td>
<td>A24049</td>
<td>NPNCA</td>
<td>208863</td>
</tr>
<tr>
<td>38</td>
<td>Biljahnie Rock</td>
<td>C29920</td>
<td>NPNCA</td>
<td>1036</td>
</tr>
<tr>
<td>39</td>
<td>Condamin Rock</td>
<td>C29823</td>
<td>NPNCA</td>
<td>323</td>
</tr>
<tr>
<td>40</td>
<td>Walyahmoning Rock</td>
<td>A35752</td>
<td>NPNCA</td>
<td>20925</td>
</tr>
<tr>
<td></td>
<td>Other Reserves</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Jaurdi Station</td>
<td>3114/1072</td>
<td>PL (CALM)</td>
<td>321399</td>
</tr>
<tr>
<td></td>
<td>CENTRAL DESERT AREAS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Queen Victoria Spring</td>
<td>A30491</td>
<td>NPNCA</td>
<td>272607</td>
</tr>
<tr>
<td>43</td>
<td>Great Victoria Desert</td>
<td>A30490</td>
<td>NPNCA</td>
<td>2495777</td>
</tr>
<tr>
<td>44</td>
<td>Plumridge Lake</td>
<td>A34605</td>
<td>NPNCA</td>
<td>308990</td>
</tr>
<tr>
<td>45</td>
<td>Yeo Lake</td>
<td>A36271</td>
<td>NPNCA</td>
<td>321946</td>
</tr>
<tr>
<td>46</td>
<td>Mangkili Clay Pan</td>
<td>A34604</td>
<td>NPNCA</td>
<td>3635</td>
</tr>
<tr>
<td>47</td>
<td>Gibson Desert</td>
<td>A34606</td>
<td>NPNCA</td>
<td>1859286</td>
</tr>
<tr>
<td></td>
<td>SOUTH COAST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Coconarup</td>
<td>C30795</td>
<td>(NV)</td>
<td>8553</td>
</tr>
<tr>
<td></td>
<td>WHEATBELT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Dryandra</td>
<td>51/52 LFC</td>
<td>26680</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other Reserves</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Vesting Codes**
- L Act - Land Act
- NV - Not Vested
- LFC - Lands and Forests Commission
- VCL - Vacant Crown Land
- NPNCA - National Parks and Nature Conservation Authority
- MWS - Metropolitan Water Supply
- WSSD - Water Supply, Sewerage and Drainage

*There are numerous small and large wheatbelt conservation reserves that contain remnant Sandalwood stands. There are too many to list here.*
APPENDIX II

Seed Viability and Germination after Storage

HYPOTHESES
H1: The age of seed affects the long term viability of Sandalwood seed.
H2: The storage of seed affects the long term viability of Sandalwood seed.

BACKGROUND
Previous investigations on the viability of Sandalwood seed had concentrated on seed less than two years old. In view of the irregularity of seed production in the field in response to the infrequent occurrence of conditions suitable for seed production, the concepts of long term viability of seed in the field and in storage required testing. To this end a series of tests were undertaken to investigate the viability of Sandalwood seed in the field and in storage.

METHODS
1. In October 1974 seeds were collected from the Kalgoorlie area.
2. In December 1974 the seeds were subsampled.
3. 800 seeds were soaked overnight. The endocarp of the seeds were then removed using a vice on the following day. These seeds were then subdivided into 2 sets of 100 seeds for each of the following 4 treatments:
   - Cold Store (4-5°C)
   - Room Temperature
   - With Silica Gel
   - Without Silica Gel

   The 2 sets were then stored for 2 and 5 years prior to the testing of the viability of the seeds.
4. The remaining seed was then stored in 20-L hard plastic containers with screw-top lids.
5. After eight years a separate serial batch of seed which had been stored in the cold with silica gel was tested. This was repeated at nine years. The first viability test was done at 25°C, the second at 20°C.
6. After nine years the viability of 160 medium-sized seeds with their epicarp intact was tested (40 seeds for each of the four treatments defined above).

RESULTS
The results indicate that the germination rate deteriorates with time (Table 4, p. 12). Irrespective of treatment the seed germination percentages fall from 84 (0 Years) to 76.5 (2 years) to 34 (5 years). After five years the type of storage affects the germination rate, with the combination of cold storage with silica gel being the favoured combination.

Therefore the results support the Hypotheses that the age and storage of the seed affects the long term viability of the Sandalwood seed.

In addition the germination trials eventually became standardized as follows:

15 cm diameter petri-dishes are partly filled with vermiculite;
Sandalwood seed is placed in the vermiculite;
Fungicide is then dusted over seed;
Water is added to the vermiculite;
A piece of hessian (large enough to cover seeds) is moistened in a solution containing fungicide;
This is placed over the seed and the lid is replaced;
Seed is placed in germination cabinet (operating at 22°C-25°C);
Hessian is periodically re-moistened and replaced.
APPENDIX III

Germination of Seed at Narrogin

HYPOTHESES

H1: The endocarp of the Sandalwood seed restricts the rate of seed germination.

H2: The endocarp of the Sandalwood seed restricts the survival of seedlings.

BACKGROUND

In view of the limited natural germination of Sandalwood seeds in the environment, tests were undertaken to investigate the likelihood of the endocarp affecting the germination of seed and survival of seedlings.

METHODS

1. 25 000 Sandalwood seeds were collected in October 1977.

2. All seed trials were undertaken at the Narrogin nursery.

3. The seeds were divided into two equal sets; one set with endocarps intact and one with endocarp removed. All seeds were sown on 11 October 1977. All seeds were half-buried in the surface of a 50:50 mixture of peat moss and coarse sand. This was placed out in trays 50 mm deep on an electrically heated, thermostatically controlled hot bed at 22°C, under a polythene plastic tent.

4. Inspections were made every morning and germinations recorded. When fine white hyphae of mycelium appeared on the fourth day, a fungicide (Captan) mist was applied by hand spray, and then repeated 8 days later.

5. When the radicle of a seed appeared it was transferred to a standard pot (100 mm) or veneer tube (Plate 12) with or without host plants. The seedlings were raised in the nursery for subsequent planting in a field trial. Some seed was allowed to continue to grow in the sand-peat moss medium. These germination studies were terminated on 22 December 1977, when a final count was made of germinants and remaining seed.

RESULTS

Maximum germination was attained for seed without shells in 16 days (27 October 77) and for intact seed in 36 days (16 November 77). The last of the germinants from the shelled seed was set out in containers five days before the first of the unshelled seed (16 November 77). Therefore the results support the hypothesis that the endocarp of the Sandalwood seed restricts the rate of seed germination.

Sixty-two per cent of the unshelled seed and over 80 per cent of the shelled seed germinated. However, later observations showed seedlings from the intact seeds survived better. Therefore the results do not support the second hypothesis that the endocarp of the Sandalwood seed restricts the survival of seedlings.

The radicles of the germinating seed left in the sand-peat or vermiculite medium were white and brittle, and rapidly grew 40-80 mm long before incipient branching.

In summary, although shelling the seeds appeared to favour germination, leaving the endocarp intact appeared better for seedling survival.
Germination and Seedling Establishment of Sandalwood - Narrogin

HYPOTHESIS

H1: The presence of host species increases the germination rate of Western Australian Sandalwood.

BACKGROUND

A series of tests were undertaken to investigate the germination of Sandalwood with host seedlings at Narrogin.

Experiment IV-1

METHODS

1. Both seed-germinants and seedlings of Sandalwood were tested with *Acacia aneura* seedlings, with and without three other possible nurse seedlings (namely - *Maireana polysterigia*, *Atriplex rhagodioides* and *Cratystylis subspinescens*).

2. This experiment was repeated three times on ten units within a fenced area of State Forest near Narrogin.

3. Initial seed viability was 82 per cent in April 1978.

4. To protect the brittle roots, seed-germinants were transferred to veneer tubes immediately following emergence of the white tip or swelling of the radicle.

5. Germination was timed to enable planting out of 4- to 5-month-old seedlings in mid-winter on 27 June 1978.

6. Inspections were recorded before and after summer, at 4 months after planting (1 November 1978), 9 months after planting (23 March 1979) and 23 months after planting (23 May 1980).

RESULTS

The results for seed-germinants and seedlings of Sandalwood were 51 per cent and 48 per cent survival respectively before summer. As these percentages were similar for seed-germinants and seedlings of Sandalwood after planting, the results were pooled and are presented in Table 5. Survival percentages dropped over the first summer to 5 per cent for both and then to 2 per cent two years after planting (Table 5, p. 14).

For the 1-year-old host seedlings, mortality was also high after planting. *Acacia aneura* survived the best, from 92 per cent before summer to 71 per cent after summer and then to 22 per cent, two years after planting among the natural vegetation of the Wandoo woodland at Narrogin.

Experiment IV-2

METHODS

A second experiment was designed to test the establishment and survival of 1200 Sandalwood (*Santalum spicatum*) with the host species of Jam (*Acacia acuminata*).

1. 1200 Sandalwood seeds were sown together with 1200 *Acacia acuminata* seeds in sets of 30 cells (5 x 6) in polystyrene trays. The cells in the trays were 5 cm square and 8 cm deep.

2. The resulting germinants were planted out, at four and a half months, in the first week of August 1979 into five sites (240 at each site). Individual cells were cut or broken out of the trays on two sides, leaving two sides intact. Each was planted without further disturbance to the roots, into holes dug with a mattock.

RESULTS

Three and a half months after planting in the 1979 trials, there was a significant difference (P=0.05) between species. Sandalwood survived better (P=0.53 ± 0.02) than Jam (P=0.25 ± 0.02). However, after summer Jam (*Acacia acuminata*) (17 per cent) was surviving significantly better than Sandalwood (2 per cent). General observations indicated that survival was better in the fenced than on the unfenced areas. No other differences were found.
SUMMARY
The high mortality of Sandalwood and the better survival of Mulga (Acacia aneura) and of Jam (Acacia acuminata) in the field indicated that Sandalwood failed to make satisfactory union with the roots of nurse plants while in the nursery, as well as with roots of the natural hosts in the native vegetation. This was confirmed in the nursery by inspection of washed root systems of surplus plants.

In summary, insufficient seedlings established for conclusive results. The failure of Sandalwood to make haustorial connections may have affected the testing of this hypothesis. Therefore the results did not conclusively support the Hypothesis.
APPENDIX V

Germination and Seedling Establishment of Sandalwood - Kalgoorlie

INTRODUCTION
A series of experiments were undertaken between 1974 and 1977 to investigate the effects of a range of sites and techniques on the germination and establishment of Sandalwood seedlings at Kalgoorlie. The experiments were undertaken in fenced plots in the Kalgoorlie Arboretum, Jeedamya Pastoral Station and Bullock Holes Sandalwood Reserve.

HYPOTHESES
H1: Watering seed beds increases the germination and establishment rates of Sandalwood seedlings.

H2: Cultivation of seed beds increases the germination and establishment rates of Sandalwood seedlings.

H3: The strategic placement of buried seed affects the germination and establishment rates of Sandalwood seedlings.

H4: The germination and establishment rates of Sandalwood seedlings is increased if seed is placed close to potential host plant.

Experiment V-1
METHODS
The first experiment was established in May 1974 at the Kalgoorlie Arboretum in a typical open woodland of Salmon Gum - Redwood (Eucalyptus salmonophloia - Eucalyptus transcontinentalis), dominated by Acacia hemiteles in the understorey on red loam soils, to test the following factors:
1. Watering, to simulate better than average rainfall, and unwatered.
2. Seedbed cultivation.
3. Seed placement, on soil surface and buried; all seed dusted with protectant before sowing - Ceresan (1.5 per cent w/w Hg as mercuric acetate; not to exceed 1.5 g/L of dust to seed).
4. Distance of the seed from the base of the Acacia host plant, systematically distributed in four radial lines of 25 Sandalwood seeds for optimum seedling establishment between 0 to 5 m from the host stem.

RESULTS
From 1600 seeds sown in 10 treatments in May 1974, only one germinant emerged in 1974. A further 13 emerged in 1975, in the uncultivated block which had not been watered.

Insufficient germinations occurred to test the four hypotheses.

HYPOTHESES
H1: The watering of seed beds increases the germination and establishment rates of Sandalwood seedlings.

H2: The removal of the endocarp increases germination of Sandalwood.

H3: The soaking of seed overnight increases the germination of Sandalwood.

H4: The use of peat increases seed germination and seedling survival of Sandalwood.

Experiment V-2
METHODS
The second experiment included trials at the Kalgoorlie Arboretum and field trials at Bullock Holes Sandalwood Reserve and Jeedamya Pastoral Station.

An experiment at the Kalgoorlie Arboretum was established in May 1975 to test the following four factors. Two replicates of 25 seeds at 1-m spacing between spots in block treatments were used in the experiment.

<table>
<thead>
<tr>
<th>Month</th>
<th>Watering Rates (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall</td>
<td>May</td>
</tr>
<tr>
<td>Average-mm</td>
<td>26</td>
</tr>
<tr>
<td>1974 Unwatered</td>
<td>29</td>
</tr>
<tr>
<td>1974 Watered *</td>
<td>25</td>
</tr>
</tbody>
</table>

(* 25 L m² = 25 mm)
1. Endocarp, retained and removed.

2. Seed soaked overnight and not soaked.

3. Seed spot sown, with peat in peat pots and without peat; all seed dusted with Ceresan (as in first experiment) - half of these placed in bottom of peat pots, three-quarters filled with peat.

4. Irrigated and not irrigated.

Trickle irrigation, to supplement the natural rainfall was adjusted to 4.5 L m$^{-2}$ per week (20 mm per month) - this was exceeded by 93 mm rainfall in the three months of May (45 mm), July (38 mm) and October (70 mm).

Two replicates of the unwatered treatments were established concurrently in two fenced field plots, at Bullock Holes Sandalwood Reserve and Jeedamya Pastoral Station. The fenced plots were 18 m x 20 m. Treatments at random were marked with numbered metal tags along the fence, 1 m apart between lines and 25 seeds within lines were sown in spots 0.8 m apart for each treatment and replicated (x2). Individual spots were marked with coloured wire markers.

The soil was moist below 75 mm in all plots at the time of sowing. Seeds without peat pots were sown 100 mm deep and covered with 50 mm of soil. Seeds with peat pots were sown 125 mm deep and covered with 30 mm of moist soil.

A survey was made of mortality and survival of Sandalwood seedlings, in relation to distance to the nearest host.

RESULTS

Kalgoorlie Arboretum
From 2400 seeds sown in 96 units of 25 seeds for 8 treatments replicated (x 2), in 3 irrigated plus 3 non-irrigated plots, 335 germinants (14 per cent) and 55 (2 per cent) seedlings survived. Results were significant, at the 95 per cent level of confidence.

The results support the first hypothesis, that the irrigation and watering increases germination of Sandalwood.

For all sites pooled, out of 200 seeds given no treatment, 14 survived (7 per cent). No other treatment exceeded this result (peat, soaking or seed coat removed).

In the Kalgoorlie Arboretum, the nearest hosts were further away (outside the plot) and no seedlings survived.

Field Trials - Bullock Holes Sandalwood Reserve and Jeedamya Pastoral Station
In field trials, results for treatments to encourage germination were somewhat inconsistent and no better than no treatment, pooling all sites (Table 7 - p. 14). Removing the endocarp decreased survival in the Jeedamya plot. This coincided with a reported mice plague at the Jeedamya homestead. The apparent higher germination rates in the seeds which retained the hard coats was probably caused by the plague of mice eating more of the seeds which already had the endocarps removed. At the Bullock Holes Reserve, there was no difference between these treatments, and no evidence of field mice. Therefore the results are not consistent and the second hypothesis was not validated.

In other tests, cultivation was found to assist germination but not survival. The latter was probably a consequence of the destruction of the host roots during cultivation. Mortality of seedlings and deficiency of host plants were most pronounced in the Kalgoorlie Arboretum. Germination was also most deficient in this area.

The results supported the third hypothesis as soaking the seed increased the germination in most instances.

The results for the peat applications were not consistent, so the fourth hypothesis was not validated.

Survivors in the field trials, compared with germinants which died, were significantly closer to the nearest host: within 1.3 ± 0.6 m at Jeedamya Station and within 2.6 ± 0.3 m at Bullock Holes.
Experiment V-3 and V-4
METHODS
The third experiment, established in August 1976, repeated the previous treatments in two irrigated blocks in the Kalgoorlie Arboretum, one at 5 L/spot (0.25 m²) per week (or 1000 mm/year) and another, twice weekly (i.e. at 10 L/wet spot diameter of 56 mm per week, or eight times the average annual rainfall). Quantities were measured from a surplus trickle point in each system and timing of 5 L according to the time required to fill 0.5 L container at each watering.

The fourth experiment was established in May 1977 to test four factors:
1. Endocarp, retained and removed.
2. Peat in the pot mixture (with peat and without peat).
3. With seedling host of Mulga (Acacia aneura) and without; irrigated plot replicated with Cratystylis subsinuata, non-irrigated plot replicated with Atriplex rhagodioides.
4. Irrigated and not irrigated.

Twelve treatments by random numbers in each block were located 2.5 m apart between lines; and 30 spots, at two seeds per spot were sown 1.5 m apart between spots. All seeds were dusted with Ceresan before sowing. The seedling host plants were raised in 120-mm pots at Narrogin nursery.

Trickle irrigation was established at 8 L/spot, twice weekly in June, July and August (that is four to six times the monthly average) and thereafter three times weekly. Owing to the drought, sprinkler irrigation during summer was prohibited by law. Irrigation of the plot was terminated in December 1977 and the Kalgoorlie trials were suspended.

RESULTS
From 720 seeds sown in the irrigated plot, germination commenced in August. There were 20 randomly distributed germinants in September, four months after sowing. Owing to lack of response Experiment 4 was suspended in December 1972.

Experiment V-5
METHODS
The fifth experiment was established to review the effects of early uniform pre-treatment of seed with endocarp retained and sown in irrigated and non-irrigated blocks (as for Experiment 4). Pre- treatments were applied to two sets of three factors with 16 treatments in the first set and 8 in the second:

The first set of factors were:
1. Soaked in water, starting hot and cold.
2. Four periods of soaking - 1, 3, 9 and 27 days.
3. Sowing in moist peat, in peat pot and without peat.

The second set of factors were:
1. Soaked in sulphuric acid, full and half strength (acid slowly added to water). The seeds were then washed in lime water.
2. Four periods of soaking of 2, 15, 20 and 40 minutes.
3. Sowing in moist peat in peat pot, with and without permanganate of potash (KMnO₄, 1:400).

The 1440 seeds were dusted with Ceresan before sowing. The seeds were sown in units of 30 seeds with six host Mulga (Acacia aneura) seedlings per treatment, five seeds sown in spots regularly distributed around each seedling host, planted at 1.5 m apart. This required 288 hosts for a total of 48 treatments, 144 for each block of 24 treatments.

RESULTS
From 720 seeds sown in 24 treatments in the irrigated plot, there were three germinants in October, three months after sowing. Owing to lack of response this Experiment was suspended in December 1977. Viability of the seed was 82 per cent (tested at the Forests Department Headquarters, Como).
APPENDIX VI

Effects of Site Cultivation on Artificial and Natural Regeneration

HYPOTHESES
H1: The cultivation of the site and seed bed increases the germination of Sandalwood seed.

H2: The cultivation of the site and seed bed increases the survival of Sandalwood seedlings.

INTRODUCTION
A series of trials were established, in May 1974, to test the effects of site, of natural seed supply (or seed in situ) and artificial sowing, and of cultivating the seedbed on Sandalwood germination and survival. Four sites were selected for the studies in relation to their representation of plant communities and their distance and direction from Kalgoorlie (in parentheses), namely:

Pastoral Stations
Gindalbie Station in open woodland (70 km north north-east),
Jeedamya Station in low open woodland (145 km north);

Reserves
Bullock Holes Sandalwood Reserve in open woodland (42 km north-east),
Calooli Sandalwood Reserve in low open woodland (48 km south-west).

The open woodland is mainly Salmon Gum (Eucalyptus salmonophloia, F. Muell.) and Mulga (Acacia aneura, F. Muell. Ex Benth.), with Acacia hemiileles (Benth.), Acacia tetragonophylla (F. Muell.), Casuarina cristata (Miq.) and Cassia nemophila (Cunn. Ex Vogel) dominating the understorey. Gindalbie trial area occurs on a wide drainage course of alluvial red clay loams, and Bullock Holes trial area occurs on a shallow course of alluvial gravelly silty-loam over red clay.

The low open woodland is mainly Jam (Acacia acuminata, Benth.) at Calooli Sandalwood Reserve and Mulga (Acacia aneura) at Jeedamya Station. The understorey species at both sites include Eremophila species. Jeedamya trial area occurs on a hard red sandy clay loam over calcrite at 150-300 mm and Calooli trial area occurs on a ridge of iron-oxidised, stony fragments over heavy red (crab-hole) clay.

The rainfall for Kalgoorlie in 1973 was 388 mm. This was evenly distributed with 270 mm falling in the months from April to August and 118 mm in the remaining seven drier months. In 1974, an autumn rainfall of 198 mm preceded sowing in May. After sowing, the average rainfall for the field areas was 84 mm in August, 30 mm in September and 49 mm in October - December. Ephemeral flooding, with 210 mm in April was followed by winter rainfalls of 113 mm to July, and a further 82 mm to October. Drought conditions followed at Kalgoorlie, with annual rainfalls of 127 mm in 1976, 153 mm in 1977 and 212 mm in 1978.

METHODS
Eight treatments were established at the four sites in May 1974. The three factors tested were:

1. Natural seeding on soil surface compared with artificial spot sowing (75 mm deep).
2. Seedbed cultivated with rotary hoe and not cultivated.
3. Rabbit-proof netting was used in an enclosure (20 m x 80 m) and an unfenced block (20 m x 80 m) (See Appendix VII).

Natural Seed Supply
The trial areas were selected near a minimum of two Sandalwood seed trees, which were fruiting in October 1973. The natural seed supply was abundant at Gindalbie with about 15 000 seeds per plot, frequent at Bullock Holes with about 5000 seeds per plot and moderate at Calooli and Jeedamya with about 1500 seeds per plot. All seed dropped to the ground early in the summer of 1974.

Cultivation was carried out with a rotary hoe to a depth of 150 mm. The cultivation was carried out beyond the tree crown canopies to avoid damage to the established trees. Most of the fallen seed was buried. There was no cultivation under the crowns, and seed in these areas...
remained on the surface. In addition to natural seed fall for each of the four treatments (cultivated and not cultivated on reserves and pastoral leases) 100 seeds were placed on the soil surface and marked to test surface germination and survival.

**Artificial sowing**

At each of the four sites 100 seeds were used for the two artificial spot sowing treatments (with and without cultivation). These were sown 75 mm below the soil surface and covered with 25 mm of soil. Spots were prepared by mattock to the width and the depth of the blade. After sowing, the soil was pressed firmly over the seed. All spot-sown and surface seed treatments were marked with painted wire markers.

Two units of 200 hard-coated seeds were tested for viability in the laboratory. Germination in one month was 35 per cent and the capacity increased subsequently to 82 per cent.

**RESULTS**

**Natural Seed Supply**

Seeds of the germinants were found by careful, random inspection to be located at a depth of 70-100 mm below the soil surface.

Germination from natural seed was highest in the cultivated Gindalbie plots; there were 388 germinants in 1974 and 271 in 1975. The results presented in Figure 3 (p. 17) for the two reserves (Calooli and Bullock Holes) and the two stations (Gindalbie and Jeedamya) reflected a marked decrease in numbers on all areas by October 1977. The survival of natural seedfall germinants for all plots in October 1977 was less than 1 per cent (27 seedlings) (Fig. 3).

The results show germination of natural seed fall increased in the cultivated plots supporting Hypothesis 1. In cultivated areas, the survival of seedlings was higher (at October 1977) thereby supporting Hypothesis 2.

For the marked seed on the surface, germination occurred only at Gindalbie, two germinated in 1974 and two in 1975, all on cultivated ground (i.e. germination of 2 per cent on cultivated ground and 0 per cent on uncultivated ground at Gindalbie). Surface sowing was unsuccessful.

**Artificial Sowing**

In 1974, the best germination from the spot sown seeds occurred on the reserves where 20 per cent of seeds germinated, however, there was no difference between germination on the cultivated plots (22 per cent) and uncultivated plots (18 per cent).

In 1975, the best germination of seed occurred on the stations (27 per cent) where there was a significant difference (P<0.05 level) in germination on cultivated plots (15 per cent) and uncultivated plots (38 per cent) (Table 8, p 18). During continued observations until October 1977, of the 1975 station germination results indicated that seedlings in the uncultivated soil were surviving better than those in the cultivated soils (significant at P>0.05 level) (Table 8, p 18). This was not the case with 1974 germination on reserves or stations and 1975 germination on reserves.

The results from the spot sown seeds were too inconsistent to prove either Hypotheses 1 or 2 for artificial sowing.
SUMMARY OF SANDALWOOD GERMINATION
(Natural Seed Supply)

<table>
<thead>
<tr>
<th>Month and Year of Observation</th>
<th>2 Stations</th>
<th>2 Reserves</th>
<th>Total Surviving</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not Cultivated</td>
<td>Cultivated</td>
<td>Not Cultivated</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>July 1974</td>
<td>0</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>October 1974</td>
<td>3</td>
<td>401</td>
<td>13</td>
</tr>
<tr>
<td>January 1975</td>
<td>0</td>
<td>126</td>
<td>12</td>
</tr>
<tr>
<td>October 1975</td>
<td>1</td>
<td>16</td>
<td>75</td>
</tr>
<tr>
<td>January 1976</td>
<td>0</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>April 1976</td>
<td>0</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>October 1976</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>April 1977</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>October 1977</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

1 - Number of seedlings present from the 1974 germination event.
APPENDIX VII

Effects of Browsing on Regeneration

HYPOTHESIS
H1: The fencing of areas increases the germination and survival of Sandalwood seedlings.

INTRODUCTION
Many observations in the past have noted the lack of Sandalwood regeneration. The fate of seedlings is often thought to be affected by the grazing pressures of herbivores (sheep, rabbits, goats, camels, donkeys, horses, cattle and kangaroos).

To test the impact of grazing on Sandalwood regeneration a series of fencing trials were established on a range of sites in the Kalgoorlie area.

METHODS
A series of trials were established, in May 1974, to test the effects of grazing on Sandalwood germination and survival. A series of fenced and unfenced areas were designated on the four sites, (see further methods for these treatments in Appendix VI), namely:

Pastoral Stations
Gindalbie Station
Jeedamya Station

Reserves
Bullock Holes Sandalwood Reserve
Calooli Sandalwood Reserve

At each of the four sites, half of each block (40 m x 80 m) was enclosed (20 m x 80 m) with stock-proof and rabbit-netting fences and half was left unfenced (20 m x 80 m) (Plate 9).

Movements of animals were noted from time to time.

RESULTS
Rabbits were present throughout the Goldfields in the period 1974 to 1976. Colonies were located near one of the four plots (Calooli Sandalwood Reserve) for a relatively short period in 1976. Rabbit droppings were seen, but no other activity was recorded at the Jeedamya plot in 1976 and Gindalbie plot in 1977. Kangaroo droppings were recorded at the Gindalbie Station and Bullock Holes Sandalwood Reserve plots in 1975 and 1976. Kangaroos were sighted at Jeedamya in 1977. Rodents, field mice in particular, were active at Jeedamya early during observations. Sheep grazing was heavy on the station plots at Gindalbie and Jeedamya. Twenty sheep were counted at the plot on one occasion.

From the 1600 seeded spots, 553 germinants were recorded with germination occurring in winter/spring 1974 and 1975 (Table 8, p. 18). By January 1976, 164 seedlings still survived inside the fenced plots and 94 seedlings outside.

Notwithstanding the continuous drought from mid 1975 until 1978, overall survival to October 1977 of 38 seedlings (4.7 per cent of seeds planted) in fenced areas was significantly greater (P<0.05 level) than survival of 9 seedlings (1.1 per cent of seeds planted) in unfenced areas for all plots pooled (Table 8, p. 18).

Results for pooled survival of germinants for unfenced (grazed) plots on stations and reserves in October 1977, revealed that survival of 9 seedlings (6.8 per cent of germinants) on reserves was significantly better (P<0.05 level) than on stations where no germinants survived. In the fenced plots there was no significant difference between survival on the station plots where 22 seedlings (16.5 per cent of germinants) survived and on the reserves where 16 seedlings (10.1 per cent of germinants) survived.

By October 1977 of the total of 292 germinants on reserves, 16 (10.1 per cent) in fenced areas and 9 (6.8 per cent) in unfenced were surviving. On the stations from 261 germinants in fenced areas the survival was 22 (15 per cent) and in the unfenced was nil. Fencing was a significant factor on stations but not on reserves (P<0.05).
APPENDIX VII (continued)

Germination and seedling survival from spot sowing at 200 Sandalwood seed per plot treatment - summary

<table>
<thead>
<tr>
<th></th>
<th>2 Stations (Gindalbie + Jeedamya)</th>
<th>2 Reserves (Calooli + Bullock Holes)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sown germinants</td>
<td>No.</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Fenced</td>
<td>400</td>
<td>133</td>
<td>22 16.5</td>
</tr>
<tr>
<td>Unfenced</td>
<td>400</td>
<td>128</td>
<td>0 0</td>
</tr>
<tr>
<td>Total</td>
<td>800</td>
<td>261</td>
<td>22 8.4</td>
</tr>
</tbody>
</table>

Grazing by sheep at the Gindalbie plot commenced with the dry season in October 1975 and coincided with seedling mortality owing to drought.

Sheep ranged more actively for green feed and grazing pressure increased with drought. Mortality during the first year was 61 per cent inside the fence and 94 per cent outside the fence. During the second year of the study the drought developed, and by the third year many mature plants had died.

At the Jeedamya plot, rabbits were observed in October 1974 and sheep in February 1975. Feed was abundant early in 1976 and only the tops of the plants were grazed at this stage. Heavy grazing commenced in May 1976. The effects of fencing at Jeedamya were similar to those at Gindalbie. An initial advantage by chance of germinants in the unfenced plot was subsequently lost owing to grazing.

In the unfenced plot in the Calooli Reserve, rabbits nipped off some seedlings in October 1974. On the basis of observations the activity of rabbits appeared to decrease temporarily for a short period in early 1975, allowing some recovery of seedlings. However, the rabbits increased their grazing activities again in the months of April to October 1975, when 88 per cent of deaths occurred in the cultivated, unfenced area owing to rabbit browsing. Little damage occurred among seedlings in the uncultivated plots. The rabbit population was evidently limited and the rabbits preferred to graze on the soft, cultivated ground, where initially there were more seedlings. Rabbit activity ceased during the 1976-77 summer. With continuation of the drought, by October 1977, fencing in the reserve had little effect on survival of seedlings from spot sowing.

At the Bullock Holes Reserve, fencing had little effect on survival of Sandalwood seedlings. Slight rabbit damage occurred in October 1975. Kangaroos and emus frequented the areas throughout the observations, without evidence of grazing.

In summary, fencing increases the germination and survival of Sandalwood seedlings, therefore the results support the Hypothesis. The differences between fenced and unfenced are clearer on the pastoral stations.
APPENDIX VIII

Effects of Fire and Cutting on Sandalwood Regeneration

Experiment VIII-1: Coppice after the 1975 Wildfire, Lakeside Reserve

HYPOTHESIS

H1: The occurrence of fire increases regeneration in Sandalwood.

INTRODUCTION

Many observations in the past have noted the lack of Sandalwood regeneration. Early observations on coppice growth of Sandalwood in the Wheatbelt suggested that coppice regeneration may be an option for the harvesting of Sandalwood.

To evaluate the productivity of recovery from burning and cutting a series of experiments were established in 1974-75 on fenced areas protected from grazing on a reserve and on a pastoral station.

METHODS

An area of approximately 40 ha of typical Salmon Gum - Gimlet (Eucalyptus salmonophloia F.Muell. - Eucalyptus salubris F.Muell.) and Mirret (Eucalyptus celastroides Turcz.) woodland, 10 km east of Kalgoorlie, was burnt in wildfire on the 9-10 January 1975. Within this burnt area 56 Sandalwood trees were selected and graded into scorch categories, 12 trees were selected in the same size-class range in adjacent unburnt areas. All trees were numbered and their positions mapped to assist in future relocation.

Periodic assessments of recovery or deterioration in crowns, stems and roots, and of flowering and fruiting, were carried out at intervals of three months for the first 15 months and half-yearly for the next two years.

RESULTS

The results of the 56 burnt and 12 control trees are summarized below:

<table>
<thead>
<tr>
<th>Description of Fire Effects</th>
<th>No.</th>
<th>% of Burnt Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (Unburnt Trees)</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Light scorch of crown, little or no butt scorch</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>Light-medium scorch only, butt scorch to 0.5 m, and heavy-medium scorch up to 50% defoliation, bole and branches blackened to 1.5m</td>
<td>22</td>
<td>39</td>
</tr>
<tr>
<td>Severe scorch, more than 50% defoliation, total bole blackened and branches scorched</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>Destroyed, stems burnt to ground</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Pieces, dead before fire</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Of the total of 44 burnt trees, 9 (16 per cent) survived and appeared to have healthy crowns by October 1977, and all others in the burnt areas were killed by the fire. None of the unburnt control trees died during the study (Table 9, p. 19).

The results do not support the Hypothesis that Sandalwood regeneration is increased by the occurrence of fire.
APPENDIX VIII (continued)

Experiment VIII-2: Coppice after Cutting at Ground Level

HYPOTHESIS
H1: The cutting of Sandalwood at ground level increases the regeneration of Sandalwood through coppicing.

INTRODUCTION
The potential for coppice regeneration had been noted by Drake-Brockman in 1921, and the possibility of utilizing coppicing as an operational technique for Sandalwood regeneration was explored by a series of trials.

METHODS
Four blocks were established, each of about 4000 m$^2$, at Calooli Sandalwood Reserve and Gindalbie Station. These blocks were adjacent to existing regeneration plots. The size of the trees were ranked and matched for grazing treatments within the blocks. The following factors were investigated to review the coppice production:

1. Grazing - fenced (open wire ringlock excluding large animals) and not fenced;
2. Season - summer and winter;
3. Soil - moist and dry;
4. Vermin - guard (1 cm bird netting to exclude small animals) and no guard;
5. Location - Gindalbie and Calooli.

All stems were cut with a chainsaw as prevailing field practices utilized this technique of cutting.

Trees were identified and numbered (1-128) and their position mapped in the four blocks (32 stems in each block). Of these 128 trees:

- 64 were felled with a chainsaw, 16 after summer moist soil treatments (trees were felled in March 1975) and 16 in the winter moist soil treatment (July 1975). Another 32 were cut down in the dry winter treatment (July 1976).

- The other 64 trees were retained for subsequent treatments, which owing to the results obtained were later shown to be unnecessary.

- Of the 64 trees felled, 32 trees were fenced in blocks and 32 were left unfenced. Within the blocks, half of the trees were guarded with netting and half of the trees were left unguarded.

- Stem diameters at 150 mm above ground, ranged from 76 mm to 222 mm. Periodic assessments were carried out quarterly for the first year and then at longer intervals.

RESULTS
Of the 16 trees cut down in March 1975, four coppiced after 4 months. No coppice subsequently survived.

There was no coppice from 48 stems cut during the winter treatments and the experiment was terminated.

Therefore the results do not support the Hypothesis that cutting at ground level increases coppicing in Sandalwood.
APPENDIX IX

Regeneration Studies at Narrogin

INTRODUCTION
A series of techniques for sowing and germinating Sandalwood seed were investigated at Narrogin. An attempt was made to study the problems of different seed viability and diversity of sites.

METHODS
Planting was carried out in 1981 in a partially stocked stand (87 m x 207 m) of Jam (Acacia acuminata) trees in the Dryandra State Forest. The area was fenced and three treatments were allocated at random in 30-m strips (3 m apart) in three replicates x 10 units per treatment x 3 m between spots, pegged and labelled on site. The following seven factors and a combination of treatments on a suitable site for Sandalwood were investigated with plants raised in the Narrogin nursery:

1. Two seed sources:
   - Narrogin,
   - Kalgoorlie.

2. Three sorts of planting stock:
   - seed sown at 3 and 4 per niche,
   - germinated seed sown at 2 per niche,
   - nursery seedlings planted at 1 per niche.

3. Two planting methods:
   - mattocked spots,
   - ploughed furrows.

4. Two seed treatments:
   - strips sprayed with herbicide,
   - not sprayed.

5. Three degrees of shade:
   - open,
   - half shade,
   - full shade.

6. Two drainage conditions:
   - freely drained slope,
   - a water gaining site on clayey flat.

7. Sandalwood established alone and with a variety of host seedlings, including Jam (Acacia acuminata), Mulga (Acacia aneura), Sheoak (Casuarina cristata) and fragrant grey bush (Cratystylis subspinescens).

RESULTS
Seed Source and Planting Stock
Results from the direct seeding indicated that all the Kalgoorlie seed failed. Eighteen per cent of the Narrogin seed germinated, however, only 9 per cent of the germinated seed survived the summer.

Results from the planted seedlings indicated a variation in success between the Narrogin and Kalgoorlie provenance, as follows:

33 per cent of seedlings of Narrogin provenance surviving at the end of summer, and
8 per cent of seedlings of Kalgoorlie provenance surviving at the end of summer.

The sowing of germinated seeds indicated similar results initially, as follows:

31 per cent of 360 Narrogin germinated seeds survived as seedlings in spring, and
29 per cent of 520 Kalgoorlie germinated seeds survived as seedlings in spring.

Results had altered after summer, as follows:

34 per cent of 360 Narrogin germinated seeds survived as seedlings, and
23 per cent of 520 Kalgoorlie germinated seeds survived as seedlings.

These results are similar to those for the planted seedlings.

Sowing germinated seeds at four per spot produced one surviving germinant per spot, as follows:

23 per cent of spots for Kalgoorlie seed, and
27 per cent of spots when pooled with Narrogin provenance seed.
Site Preparation
Chemical spraying of weeds before sowing or planting had no effect on Sandalwood germination or survival. Sandalwood germination and survival was higher on spot sown areas compared with seed sown in furrows. In contrast there appeared to be no differences in planting seedlings in furrows or spots.

Site Conditions
Germination and survival on the well-drained slope was consistently better than on the water gaining clayey flat (winter flooded).

The influence of shade was evident from a comparison of the survival of germinated seedlings, where:
- 55 per cent survived under full shade, compared with
- 43 per cent survival in the open.

Seedling Host Species
Survival of host species were:
- 72 per cent Jam (*Acacia acuminata*),
- 69 per cent Mulga (*Acacia aneura*),
- 32 per cent Sheoak (*Allocasuarina huegeliana*),
- 8 per cent *Cratystylis subspinescens*.
HYPOTHESES

H1: The natural variation in plant size and rates of growth are affected by site conditions.

H2: The site conditions, climate and soils affect the plant sizes of Sandalwood.

H3: The site conditions, climate and soils affect the growth rates of Sandalwood.

INTRODUCTION

During 1974 a number of studies were undertaken to determine the range in size of Sandalwood trees and the rate of growth.

The natural variation in plant size and rates of growth are predictably related to factors such as site conditions, climate and soils.

Experiment X-1: Growth Rates - Kalgoorlie

METHODS

In 1974, numbered trees were sampled from two locations sown between 1925 and 1930 at Karramindie State Forest and Scahill Sandalwood Reserve, both near Kalgoorlie:

- Karramindie - 530 ha of gently sloping sites with heavy loam soils
- Scahill - 91 ha of sandy flats

A total of 22 trees were measured at Karramindie and 26 at Scahill. All 48 trees had previously had measurements taken at 1-3 month intervals for the first two years following sowing, then at 3-6 months for five years, and next in 1939 and 1940 (Table 10, p. 22).

In 1974, individual trees were grouped into 1.5 m height classes and data were summarized for measurements at 44 and 49 years of age, representing the period over which establishment occurred. Measurements were pooled and adjusted to one age of 44 years. A sample tree of mean height was chosen to represent each height class.

At Karramindie five sample trees were each matched with a tree in the surrounding plantation. These plantation trees were cut and measured by the sectional method to derive volume and increment of the truewood, sapwood and bark.

Volume was calculated from the formula (Avery 1975):

\[ V = 0.0785 \times D^2 \times L \]

where:
- \( V \) = volume in cubic metres \( \times 10^3 \)
- \( D \) = mid-diameter in centimetres
- \( L \) = length in metres

Height and diameter relationships for all plot trees were used to derive information on growth rate, production of timber and age at which Sandalwood reaches commercial size. Sandalwood weight was determined using a density figure of 880 kg.m\(^3\), established in concurrent studies of wood density (surface-air-dry for one month, so that this figure is essentially wood density of green Sandalwood).

RESULTS

For the largest sample tree, commercial heartwood of 1.15 kg grew in 44 years. Eight hundred and seventy trees of this size would be required to produce 1 tonne of heartwood. The relative volumes of the material in the commercial section of the Sandalwood consisted of 30 per cent heartwood, 30 per cent sapwood and 40 per cent bark. Bark and sapwood had a combined consistent thickness of 21-22 mm.

Comparable trees in the largest group (98 mm diameter) have 2.5 kg of total wood and 1.3 kg of heartwood equivalent to 400 trees per tonne and 770 trees per tonne of heartwood respectively (Table 11, p. 23).

Experiment X-2: Growth Rates - Kalgoorlie, Narrogin

METHODS

In 1978, 731 trees were measured (height and stem diameter): 228 trees in 16 ha of 8 km x 20 m transects through Karramindie State Forest (Kalgoorlie) and all
443 trees in the plots at Dryandra State Forest (Narrogan). The age required to attain the commercial size limit of 127 mm stem diameter was extrapolated from the mean diameter for the age at 1978.

RESULTS
A wide range in rates of growth were observed between the largest and smallest trees within different sites. At Dryandra, observations of adjacent groups of 47-year-old Sandalwood trees in woodlands dominated by *Eucalyptus wandoo* and *Acacia acuminata* demonstrated the effect of site conditions on Sandalwood and host survival and growth rates. At one site, hosts had died and Sandalwood growth was slow compared with a water-gaining site adjacent to farmland regularly dressed with fertilizers where vigorous Sandalwood trees were observed up to 3 to 4 m from hosts.

The time required to attain commercial size varied from 32 to 59 years at Dryandra to 59 to 115 years at Kalgoorlie (Table 12, p. 24). The latter differences appeared to relate primarily to differences in site and climatic conditions in the two regions.

**Experiment X-3: Growth Rates - Narrogin and Swan Coastal Plain**

METHODS
A range of measurements were also undertaken in 1974 and 1978 on Sandalwood trees in the Narrogin and Swan Coastal Plain areas. The growth rates for known aged trees were extrapolated to determine the time required to attain the commercial size of 127 mm (Table 12, p. 24).

RESULTS

Narrogin District
1. Twenty three to fifty years was required for growth to commercial size in winter rainfall (500 mm annual rainfall):

   In Jam - Wandoo (*Acacia acuminata* - *Eucalyptus wandoo*) communities:
   • 23 to 30 years from the 1956 trials at Bald Rock, Corakin, Stokes and Lol Gray Blocks at Dryandra State Forest.

   • 50 years in the adjacent open flat Wandoo-Jam reserve for the 1931 trials and lowland of the Bendering Reserve for the 1928 trials.

   In Wandoony - Jam (*Eucalyptus wandoo* - *Acacia acuminata*) communities:
   • 30 - 38 years from the 1956 trials in Peters block within the Dryandra State Forest.

   In Wandoony - Rock Sheoak (*Eucalyptus wandoo* - *Allocasuarina huegeliana*) communities:
   • 50 years in Smith Block within the Dryandra State Forest for the 1931 trials (plus a few replantings in 1962).

2. 50 to 100 years was required for growth to commercial size in winter rainfall (335-385 mm annual rainfall):

   In ploughed broombush flat and lowland Jam communities:
   • 45 - 50 years from 1918-21 trials.

   In unploughed broombush flat (Pikaring Reserve) and granitic ridge Jam (Bendering Reserve) communities:
   • 80 - 130 years from 1918-21 trials.
   (Recent deaths were observed in 1969 at 50 years (Plate 3)).

Swan Coastal Plain
3. 35 to 70 years was required for growth to commercial size in winter rainfall (875-890 mm annual rainfall):

   In coastal Bassendean sand near Perth:
   • 35 years from 1964 records (Plates 6 and 7).

   In *Eucalyptus gomphocephala* forests,
   Ludlow - between Busselton and Bunbury.
APPENDIX X (continued)

443 trees in the plots at Dryandra State Forest (Narrogin).

The age required to attain the commercial size limit of 127 mm stem diameter was extrapolated from the mean diameter for the age at 1978.

RESULTS
A wide range in rates of growth were observed between the largest and smallest trees within different sites. At Dryandra, observations of adjacent groups of 47-year-old Sandalwood trees in woodlands dominated by Eucalyptus wando and Acacia acuminata demonstrated the effect of site conditions on Sandalwood and host survival and growth rates. At one site, hosts had died and Sandalwood growth was slow compared with a water-gaining site adjacent to farmland regularly dressed with fertilizers where vigorous Sandalwood trees were observed up to 3 to 4 m from hosts.

The time required to attain commercial size varied from 32 to 59 years at Dryandra to 59 to 115 years at Kalgoorlie (Table 12, p. 24). The latter differences appeared to relate primarily to differences in site and climatic conditions in the two regions.

Experiment X-3: Growth Rates - Narrogin and Swan Coastal Plain

METHODS
A range of measurements were also undertaken in 1974 and 1978 on Sandalwood trees in the Narrogin and Swan Coastal Plain areas. The growth rates for known aged trees were extrapolated to determine the time required to attain the commercial size of 127 mm (Table 12, p. 24).

RESULTS
Narrogin District
1. Twenty three to fifty years was required for growth to commercial size in winter rainfall (500 mm annual rainfall):

   In Jam - Wandoo (Acacia acuminata - Eucalyptus wando) communities:
   • 23 to 30 years from the 1956 trials at Bald Rock, Corakin, Stokes and Lol Gray Blocks at Dryandra State Forest.

   • 50 years in the adjacent open flat Wandoo-Jam reserve for the 1931 trials and lowland of the Bendering Reserve for the 1928 trials.

   In Wandoo - Jam (Eucalyptus wando - Acacia acuminata) communities:
   • 30 - 38 years from the 1956 trials in Peters block within the Dryandra State Forest.

   In Wandoo - Rock Sheoak (Eucalyptus wando - Allocasuarina huegeliana) communities:
   • 50 years in Smith Block within the Dryandra State Forest for the 1931 trials (plus a few replantings in 1962).

2. 50 to 100 years was required for growth to commercial size in winter rainfall (335-385 mm annual rainfall):

   In ploughed broombush flat and lowland Jam communities:
   • 45 - 50 years from 1918-21 trials.

   In unploughed broombush flat (Pikaring Reserve) and granitic ridge Jam (Bendering Reserve) communities:
   • 80 - 130 years from 1918-21 trials.
   (Recent deaths were observed in 1969 at 50 years (Plate 3)).

Swan Coastal Plain
3. 35 to 70 years was required for growth to commercial size in winter rainfall (875-890 mm annual rainfall):

   In coastal Bassendean sand near Perth:
   • 35 years from 1964 records (Plates 6 and 7).

   In Tuart (Eucalyptus gomphocephala) forests, Ludlow - between Busselton and Bunbury.
• 35 years from plantings in 1931 near Wattles and Pinus radiata (2-years-old) near the new alignment of the South Western Highway (picnic site).

• 70 years from 1935 plantings near Wattle (Acacia pycnantha, Acacia saligna and Pinus pinaster – 8-years-old).

Experiment X-4: Fibre Mass Assessment of Parts and Whole Trees Eastern Goldfields and Gascoyne and Greenough Regions.

METHODS

Twenty-two trees were pulled from three localities where operations were in progress, north and north-east of Kalgoorlie (Morapoi Station - 8 trees; and Edjudina Station - 7 trees) and between Payne’s Find and Morawa (Karara Station - 7 trees). The whole tree and constituent parts were fresh weighed and measured to investigate the relative mass of each component: roots, stems, branches, twigs and leaves. Measurements also included stem diameters over bark at 150 mm above the ground, total height of the tree and crown width. Each tree was pulled out of the ground and the solid roots down to 40 mm wood diameter were harvested.

Trees ranged in size:
9 trees were under 87 mm stem diameter,
4 trees ranged from 88 mm to 112 mm stem diameter,
5 trees ranged from 113 mm to 137 mm stem diameter,
4 trees exceeded 138 mm in stem diameter.

Components of each tree were then segregated and measured, as follows:

1. Root and butt measurements taken were:
   Removed roots and butt at 150 mm;
   Diameters at both ends of bark, sapwood and true hardwood, mid-diameter over bark and length;
   Weighed pieces with and without bark.

2. Logwood and branchwood measurements taken were:
   Delimbed and recorded log and branch dimensions of each piece, i.e. mid and end diameters and length;
   Trimmed logwood and branchwood to 40 mm diameter of heartwood;
   Recorded dimensions, both ends of bark, sapwood, heartwood and mid girth over bark;
   Weighed with and without bark.

3. Branch measurements taken were:
   Weighed individual branches;
   Each branch, total length;
   Estimated point of non-edibility (10 mm considered too large to be browsed);
   Recorded end diameters under bark and length, from 40 mm diameter of heartwood to 40 mm diameter of total wood.

4. Leaf and twig measurements taken were:
   From each branch of each tree, removed approximately ten to twelve leaves with twigs;
   Subsampled 12 to 14 leaves per tree and combined 100 leaves within each locality - separated leaves and twigs, measured area of leaves, fresh and oven dry weights.

The relationships between the various components in various size classes were analysed using linear regressions (Table 13, p. 24).

RESULTS

An average tree reaching commercial size will have a total fresh weight of 40 kg of which 45 per cent will be marketable, as follows:
On the basis of these figures it was possible to calculate that the proportion of heartwood exceeds sapwood in a stem diameter (over bark) of 102 mm, as follows:

<table>
<thead>
<tr>
<th>Diameter over Bark (mm)</th>
<th>% Heartwood in Total Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>7</td>
</tr>
<tr>
<td>76</td>
<td>28</td>
</tr>
<tr>
<td>102</td>
<td>49</td>
</tr>
<tr>
<td>127</td>
<td>69</td>
</tr>
</tbody>
</table>

The relationship between stem diameter - d (mm) and stem weight - w (kg) was calculated for air-dried weight at one month from a fresh sample of 22 Sandalwood trees as follows:

Cut Stems: \[ W = 0.000437 d^2 \] \( r = 0.97 \ *** \)
Pulled Stems: \[ W = 0.000719 d^2 \] \( r = 0.97 \ *** \)

From these equations, relationships between stem diameter and number of stems per tonne were derived (diameter in millimetres):

No. Cut Stems per Tonne = 2288329 \( d^2 \)
No. Pulled Stems per Tonne = 1390820 \( d^2 \)

In general, the number of pulled stems needed to make a tonne is about 60 per cent of the number required if stems were cut at ground level, almost 90 and 150 respectively at the commercial size of 127 mm stem diameter.
CONSERVATION AND LAND MANAGEMENT

Citation

This order may be cited as the Sandalwood (Limitation of Removal of Sandalwood) Order 1996.

Limitation

(1) The quantity of sandalwood that may be pulled or removed from Crown land and alienated land during each period to which this subclause applies is limited to a total of 3,000 tonnes, comprising—
   (a) a total of 1,500 tonnes of green sandalwood; and
   (b) a total of 1,500 tonnes of dead sandalwood.

(2) Subclause (1) applies to—
   (a) the period commencing on 1 July 1996 and ending on 30 June 1997; and
   (b) each succeeding period commencing on 1 July and ending on the next 30 June.

1995 order repealed

3. The Sandalwood (Limitation of Removal of Sandalwood) Order 1995* is repealed.

[* Published in Gazette 22 August 1995, pp. 3789-90.]

By Command of the Lieutenant-Governor and deputy of the Governor,

J. PRITCHARD, Clerk of the Council.

CENSORSHIP

NOTICE OF EXEMPTION

I, Cheryl Lynn Edwardes, being the Minister administering the Censorship Act 1996 acting in the exercise of the powers conferred by subsection 2 of section 70 of that Act, do hereby exempt drive-in theatres from the requirements of subsection 1 of section 70 of that Act.

CHERYL LYNN EDWARDES, Minister for Fair Trading.
MR W.R. MARMION (Nedlands — Minister for Environment) [2.01 pm]: Today I bring to the attention of the house a concerning rise in the illegal harvesting, processing, transporting and sale of sandalwood. Sandalwood is protected flora in Western Australia, and a limited number of harvesting licences are issued each year to ensure the sustainability of the industry. The sandalwood black market is thought to be worth millions of dollars and most illegally harvested sandalwood is exported out of Australia to Asia where it is used for medicinal and aromatic purposes. Sandalwood can command up to $15,000 a tonne on the black market. This lucrative market has resulted in a big increase in the frequency and scale of illegal sandalwood operations, which is causing a lot of damage to the environment and undermining legitimate operators.

I am pleased to report that the Department of Environment and Conservation, with the assistance of Western Australia Police, have been working very hard to curb this activity and have made several seizures of illegally harvested sandalwood and harvesting equipment. Since March last year, about 166 tonnes of illegally harvested sandalwood valued at up to $2.5 million has been seized, including 75 tonnes from a wheatbelt property and more than 40 tonnes in the goldfields in the past two months. This month six tonnes was seized at Eucla and a consignment of 15 tonnes originating from Western Australia was intercepted in Port Augusta, South Australia. This was a direct result of continued liaison between DEC and its interstate counterparts on this issue. Investigations into illegal operations are continuing, and charges are expected to be laid.

In response to the increase in the illegal trade, DEC launched a compliance operation across Perth and the south west this month, which is targeted at sandalwood dealers and exporters. As part of Operation Lighthouse, DEC visited several sandalwood dealers and exporters and checked their sandalwood stocks and records. Dealers were also advised of the introduction of sandalwood transport authority notices, which are required to transport sandalwood that has been taken for sale from private property under a licence issued by DEC. Sandalwood buyers have a legal obligation to ensure they purchase the product only from licensed sandalwood pullers, and make a record of their purchases.

The message is clear: anyone involved in the sale, transporting or processing of illegally harvested sandalwood faces prosecution and the loss of their operating equipment. I assure the house that while there is much more work to be done, this government is very serious about putting a stop to this environmentally damaging trade. It is a challenging task for investigators, and I thank DEC and WA Police for their diligence and tireless efforts.
Sandalwood black market on the rise

- Illegally harvested sandalwood seizures increasing
- DEC launches operation to crack down on illegal operators

A compliance operation targeted at sandalwood dealers and exporters has been launched in response to a spike in seizures of illegally harvested product.

Environment Minister Bill Marmion said the Department of Environment and Conservation (DEC) launched Operation Lighthouse across Perth and the South-West this month in a bid to curb the illegal trade of native sandalwood, which can command up to $15,000 per tonne.

"The black market for sandalwood is thought to be worth millions of dollars and most illegally harvested sandalwood is exported out of Australia to Asia where it is used for medicinal and aromatic purposes," Mr Marmion said.

"Since March last year, DEC, with assistance from WA Police, has seized about 166 tonnes of illegally harvested sandalwood valued at up to $2.5million, including 75 tonnes from a Wheatbelt property and more than 40 tonnes in the Goldfields in the past two months.

"Just last week, six tonnes was seized at Eucla and a consignment of 15 tonnes originating from Western Australia was intercepted in Port Augusta, South Australia. Because the black market is so lucrative, we have seen a significant increase in illegal activity, and unfortunately it is causing a lot of damage to the environment and undermining legitimate operators."

As part of Operation Lighthouse, DEC has visited several sandalwood dealers and exporters and checked their sandalwood stocks and records.

Dealers were also advised of the introduction of Sandalwood Transport Authority Notices, which are required to transport sandalwood taken for sale from private property under a licence issued by DEC.

"Sandalwood buyers have a legal obligation to ensure they only purchase the product from licensed sandalwood pullers and make a record of their purchases," the Minister said.

"Anyone involved in the sale, transport or processing of illegally harvested sandalwood faces prosecution and the loss of their operating equipment."

Investigations into illegal operations are continuing and charges are expected to be laid.

**Fact File**

- Sandalwood harvesting on Crown land, pastoral leases and private land is regulated
- DEC issues annual harvesting licences under a quota system
- Any information on illegal sandalwood activities, particularly vehicle movements and registrations, can be reported to DEC's Wildlife Watch hotline on 1800 449 453

Minister’s office - 6552 6800
25/09/2012
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DISCUSSION PAPER
REFORMING REGULATION OF THE HARVESTING AND SALE OF SANDALWOOD

Issue
In recent years, an increase in illegal sandalwood harvesting driven by higher commodity prices for sandalwood has highlighted uncertainties and limitations in the existing legislative regime for the regulation of sandalwood. As a result, practical difficulties are being experienced in regulating the harvesting of sandalwood for the sustainable management of the species and its habitat.

Background
Sandalwood has been exported from Australia in its raw state since the 1840s. In 1929 the Sandalwood Act 1929 was introduced to regulate the quantity of sandalwood that could be pulled or removed from Crown and other lands. The second reading speech on introduction of the Bill indicates that the Sandalwood Act was intended to be primarily about controlling quantities of sandalwood harvested for purposes of price control. By limiting the amount of sandalwood harvested each year, the State could ensure a certain amount of royalties were received for sandalwood obtained from Crown land.

The Sandalwood Act was to be read as one with its principal Act, the Forests Act 1918, which established measures for long-term sustainable timber production. According to the Sandalwood Act, licences to pull or remove sandalwood from Crown land were to be granted pursuant to regulations under the Forests Act, meaning sandalwood was managed as forest produce. The amount of sandalwood that could be harvested each year was set by an Order in Council.

The introduction of the Conservation and Land Management Act 1984 (CALM Act) resulted in the repeal of the Forests Act, and its replacement by the CALM Act as the principal Act to be read as one with the Sandalwood Act. The main object of the CALM Act is "to make better provision for the use, protection and management of certain public lands and waters and the flora and fauna thereof". The CALM Act regulates the management of forest produce on most
Crown land, including State forests and unallocated Crown land. However, the CALM Act's licence provisions for taking forest produce from Crown lands do not apply to trees or parts of trees, thereby appearing to exclude sandalwood. The harvesting of sandalwood on Crown land is currently managed by the Forest Products Commission (FPC) under the contract provisions of the *Forest Products Act 2000* (FP Act).

Since the Sandalwood Act commenced, the management of commercially significant native flora species has shifted from treating them purely as a resource to developing measures for their conservation for both natural and economic values. This is reflected in the *Wildlife Conservation Act 1950* (WC Act), which was amended in 1976 to incorporate flora management provisions.

The high demand for sandalwood in recent years has highlighted the shortcomings of the current legislation to appropriately manage this species in terms of both production and conservation, and necessitates urgent change.

**Current Status**

The management of sandalwood is complex due to the interaction between four pieces of applicable legislation (the Sandalwood Act, CALM Act, FP Act and WC Act) and two agencies, the Department of Environment and Conservation (DEC), which administers the Sandalwood, CALM and WC Acts, and the FPC, which administers the FP Act. The legislation contains inconsistencies in its definitions of key terms, overlapping licence requirements, and inadequate provisions that are specific to sandalwood management.

The current loss of revenue to the State due to illegally harvested sandalwood is substantial, as sandalwood on Crown land is the property of the Crown. Investigations have revealed that an estimated 500 tonnes of sandalwood have been illegally harvested annually in recent years, valued at approximately $2.5 million per annum on the illegal market. The existing regulatory regime does not adequately address the illegal harvest of sandalwood.

In respect of harvesting from natural stands of sandalwood on private land, current practice is for DEC to grant a licence pursuant to section 3(1)(b) of the Sandalwood Act, and a commercial producer’s or nurseryman’s licence pursuant to section 23D of the WC Act for the sale of sandalwood. However, sandalwood plantations on private land are excluded from licence
requirements under the Sandalwood Act, but a WC Act under section 23D licence is still required to enable the sale of plantation sandalwood that has been lawfully taken.

On Crown land, a production contract may be entered into for the harvesting and sale of sandalwood pursuant to part 8 of the FP Act. These contracts are separate from Sandalwood Act licences, but operate in conjunction with a licence issued under the WC Act. A WC Act section 23C(1)(a) commercial purposes licence is required to take sandalwood (which is protected flora) from Crown land.

There are currently no sandalwood plantations on Crown land.

The WC Act only applies to the harvest and sale of green (live) sandalwood, as the Supreme Court has ruled in the case of *Pennings v Vlak* ([2005] WASC 107) that the Act does not apply to dead flora. As a consequence, there is no regulation of the harvest or sale of dead or dry sandalwood taken from Crown land or private property under the WC Act.

The harvest of sandalwood, whether live or dead plants, is clearing under the EP Act. Clearing that is authorised by section 23D (commercial producer's or nurseryman's licence), section 23C (a commercial purposes or scientific/any prescribed purposes licence), or section 23F (consent of the Minister in relation to a "licensee" taking rare flora) of the WC Act, under a licence granted under section 3(1) of the Sandalwood Act, or through a production contract under the FP Act, does not require a clearing permit.

Further complicating the administrative arrangements, there are a number of significant ambiguities, omissions and inconsistencies within the various pieces of legislation regulating sandalwood which make enforcement very difficult. Resolution of these issues will require substantial legislative change.
Main issues
In summary, there are a number of legislative and practical issues associated with the regulation of sandalwood in its current form, including:

- Multiple Acts governing sandalwood create duplication, conflicting requirements and confusion, causing delays in granting licences;
- There is no definition of 'Crown land' in the Sandalwood Act and no definitive answer as to how the term should be interpreted for the purposes of this legislation;
- The definition of licence in regulation 2(b) of the Sandalwood Regulations 1993 refers to a licence to take forest produce under section 88(1)(a) of the CALM Act, however trees and parts of trees appear to be excluded from the definition of forest produce in that part;
- The object of the Sandalwood Act, being about regulating the quantity of sandalwood harvested, does not reflect current understanding of the need to manage flora for conservation and sustainable use;
- Due to the overlapping legislation, there is uncertainty regarding the type of licence(s) which should be issued or granted for harvesting sandalwood on Crown land;
- The effect of the Supreme Court's Pennings v Vlak decision means that dead sandalwood cannot be licensed as protected flora under the WC Act;
- There is no formal mechanism to apportion sandalwood harvests within the Order in Council limit between licensed harvesting under the Sandalwood Act and harvest contracts under the FP Act;
- Provision for the collection and sale of sandalwood salvaged from sites cleared for other purposes (such as mining and infrastructure) is not addressed in the current management regime;
- The current arrangement of allowing only FPC contractors to pull sandalwood from Crown land is not supported by the legislation;
- Sandalwood harvest licences are granted for different time periods by DEC compared with production contracts entered into by the FPC;
- The legislation does not sufficiently provide for the post-harvest management and regulation of pulled sandalwood, including its transport, processing, dealing and export;
- The legislation does not provide for the regulation of sandalwood plantations;
- There is no mechanism to charge fees to cover the processing and management costs of sandalwood licences;
- There are insufficient enforcement powers for DEC officers to prevent and prosecute the illegal harvest, sale, and interstate laundering of sandalwood, which results in a substantial loss of revenue to the State and increased illegal harvest of sandalwood; and
- Penalties for the illegal taking of sandalwood are insufficient to be a deterrent, ranging from $200 in the Sandalwood Act to $10,000 in the CALM Act for product which is worth up to $15,000 per tonne raw.

Options for consideration

1. Repeal the Sandalwood Act, and incorporate sandalwood licensing into the *Wildlife Conservation Act 1950*.

The WC Act provides for the conservation and protection of wildlife, including both fauna and flora. The property in protected flora on Crown land is vested in the Crown and it cannot be taken without a licence issued by the Minister. A licence is also required to sell protected flora that has been lawfully taken from private land. As live sandalwood is classed as protected flora then these provisions of the WC Act currently apply to its taking and sale.

The aim of the WC Act is in line with aims for the sustainable management of sandalwood, particularly if sandalwood is to be managed in terms of its conservation value as well as for its value as a product. The WC Act is structured to provide for the sustainable use of flora. There are already other flora with quotas, royalties and specific management regimes under the WC Act such as *Boronia megastigma* and *Banksia hookeriana*. As the licence provisions in the WC Act are already used for sandalwood in certain situations, amendments to fully incorporate sandalwood would be entirely compatible. Benefits of this option include that fees are payable for WC Act licences, and the State can collect royalties from flora harvested on Crown land.

Penalties under the WC Act are a maximum of $4,000 for taking protected flora, and $10,000 for taking specially protected flora. While significantly greater than penalties in the Sandalwood Act, these are considered likely to still be insufficient to deter illegal sandalwood taking, considering the high prices that it can now command. The WC Act provides a range of enforcement powers to authorised officers, including the ability to stop and search vehicles, and to seize flora that is believed to have been illegally taken. Some post-harvest management is also required, as flora taken from Crown land must be tagged or otherwise identified, and records must be kept of the
sale and purchase of protected flora. These provisions are useful to manage the post-harvest sandalwood trade, but some additional powers to those provided for in the WC Act may be required to adequately manage sandalwood. These might include a delivery note system, certification to distinguish plantation from wild-source sandalwood, interstate import and export controls and the ability to license and manage dealers and processors.

Although the WC Act enables quotas to be set for individual licences, it does not currently allow a quota to be imposed on the total State sandalwood harvest. Consideration would need to be given to whether an amendment to achieve this is required, and to enable the apportionment of the quota between harvests from Crown land and private land, or whether the apportionment should be managed administratively. Furthermore, mining tenements under the WC Act fall within the meaning of private land and no licence to take flora from them is required (although licences for sale may still be necessary). Consideration would need to be given whether to amend the definition of “private land” under the WC Act.

Due to the decision of the Supreme Court in *Pennings v Vlak*, it would also be necessary to amend the definition of flora to include dead flora to enable regulation of the collection and sale of dead sandalwood.

The management of sandalwood would be greatly simplified by application of the WC Act alone, in place of the Sandalwood Act and CALM Act.

2. Incorporation into the CALM Act

As the Sandalwood Act is currently to be read as one with the CALM Act, the option of amalgamating them seems practical on the surface. The CALM Act contains licence provisions for forest produce and requires royalties to be paid on what is taken. The current definition of forest produce in section 87(1), which deals with licensing, on its face excludes sandalwood, so if this option were pursued the definition would require amendment to clarify the ambiguity. Penalties for contravening licence conditions under the CALM Act, or unlawfully taking forest produce, range from $4,000 to $10,000. Enforcement powers available to authorised officers under the CALM Act are not as extensive as those under the WC Act.

The primary difficulty with pursuing this option is that the CALM Act is principally concerned with the management of Crown land and is not well suited to species management. The CALM Act
applies to most categories of Crown land but does not apply to private land. The amendments that would be required to enable regulation of sandalwood harvesting on private land would represent a significant departure from the current scope of the CALM Act. Such a major change to the purpose and scope of the CALM Act does not seem viable. The CALM Act also lacks certain provisions that are required for the regulation of sandalwood, including regulation of plantations and the imposition of licence fees.

3. Incorporation into the Environmental Protection Act
One of the objects of the EP Act is “for the conservation, preservation, protection, enhancement and management of the environment”. Unauthorised clearing of native vegetation is an offence under section 51A. Subject to a fee the CEO may grant permits to allow specified clearing activity. The EP Act also contains strong enforcement and penalty provisions, which would be effective in the prevention and prosecution of illegal sandalwood harvesting.

While these aspects of the EP Act would be beneficial for the regulation of sandalwood, the Act is not designed with species management in mind and substantial amendments would be required. The EP Act does not deal with the imposition of quotas or collection of royalties for harvesting vegetation. It does not distinguish between private and Crown land, which is an important distinction for the regulation of sandalwood. Extensive amendments would also be required to the EP Regulations to provide for the regulation of sandalwood post-harvest and in plantations.

This option would require substantial amendments to the EP Act that are not closely aligned with its current aim and scope.

4. Incorporation into the Forest Products Act
The FP Act is concerned with the commercial harvesting of forest products from Crown land, and the establishment of commercial plantations on Crown and private land. Sandalwood falls within the current definition of forest products for the purposes of the Act. Under this option, the FPC would become the body responsible for the administration and regulation of sandalwood harvesting statewide.
However, the FP Act is concerned only with commercial arrangements for harvesting and plantations. It contains no regulatory provisions, no offences, no enforcement powers and no provisions to regulate the harvest of sandalwood from private land.

This option would require very significant amendments to the FP Act, including entirely new suites of provisions dealing with enforcement powers, and the regulation of private land by the FPC.

5. Retain an amended Sandalwood Act as stand-alone legislation

This option would involve severing the current linkage between the Sandalwood Act and the CALM Act. This would remove some of the current problems around the application of the sandalwood regulatory regime to Crown land, but would also require very significant amendments in order to make the Sandalwood Act an effective regulatory tool.

Clear definitions of Crown land and alienated land would need to be inserted into the Sandalwood Act. New provisions would be required to provide for licence fees, to regulate plantations, and to regulate the sale of sandalwood.

The Sandalwood Act contains no provisions to provide enforcement powers for authorised officers. Substantial additions would need to be made to the Act to provide a new suite of search and seizure powers. Given the general political sensitivity over new search and seizure powers, this could be controversial. In addition, penalties for the illegal taking of sandalwood are inadequate in the current Sandalwood Act and would need to be significantly increased to act as a deterrent.

A dedicated Sandalwood Act would provide certainty to the regulation of sandalwood. However, it would be a significant undertaking considering that sandalwood management can more easily be incorporated into existing legislation and regulated by the same means as other protected flora species.
6. Retain an amended Sandalwood Act linked to the Wildlife Conservation Act
Under this option, the licensing provisions in the Sandalwood Act would be repealed, and the licensing and regulation of sandalwood harvesting, as well as sale and the collection of royalties, would be undertaken pursuant to the WC Act.

The confusing definitions of Crown land and alienated land in the Sandalwood Act would be deleted in favour of those in the WC Act. The provisions for setting quotas would remain in the Sandalwood Act, and would be amended to allow for apportionment of the quota between Crown land and private land. Essentially, under this option the amended Sandalwood Act would have no function other than to allow for statewide quotas to be set, and the bulk of the sandalwood regulatory regime would be under the WC Act.

However, significant amendments to the WC Act would still be required to address the issues identified in the discussion of option 1 above concerning the definition of flora, the difficulties surrounding the issuing of licences on mining leases, and the relatively low penalties. It is doubtful that this option would resolve the issues with sandalwood regulation that arise from the interaction of multiple Acts.

7. Retain an amended Sandalwood Act linked to the Environmental Protection Act
There is little to recommend this option, as the EP Act does not contain many provisions on which the Sandalwood Act could usefully rely to fill the current gaps in its regulatory scheme. As noted for option 3, while the enforcement and penalty provisions in the EP Act provide powers which are unavailable under the Sandalwood Act, many aspects of the EP Act are not applicable to the regulation of sandalwood harvesting and sale. Furthermore, section 5 of the EP Act states that the EP Act overrides inconsistent provisions in any other statute, which could complicate the interpretation of the relationship between the two statutes.

8. Retain an amended Sandalwood Act linked to the Forest Products Act
This option would require substantial amendments to both the Sandalwood Act and the FP Act, as the FP Act is currently not equipped to be used for the regulation of sandalwood harvesting. The difficulties with the FP Act in this respect are highlighted in the discussion of option 4 above. This approach would entail the FPC becoming responsible for the regulation of all sandalwood harvesting, creating a potential conflict of interest, as the FPC would grant licences both to contractors on Crown land for which it receives royalties, and to private landholders.
Preferred Option

Repealing the Sandalwood Act and incorporating its substantive provisions into the WC Act (option 1) is considered the preferred approach for ensuring a sustainable environmental and economic future for the sandalwood industry.

The WC Act is the statute most suited to encompass the regulation of sandalwood harvesting and sale in a manner similar to the existing arrangements, while resolving the difficulties inherent in the existing statutes and their interaction. This approach requires much simpler amendments than incorporating the Sandalwood Act into the other statutes considered. Furthermore it also enables the regulation of all sandalwood activities to be brought under one statute, administered by one agency (DEC). It is also capable of encompassing an arrangement where the FPC continues to hold a monopoly over sandalwood licences on Crown land, if that is considered desirable. Adoption of this approach would not change the current situation for land owners/occupiers in terms of the commercial harvesting of sandalwood on private property. In addition, consideration of sandalwood from a resource utilisation perspective is still adequately addressed as the WC Act facilitates and promotes sustainable harvesting.

Importantly, it emphasises the importance of the conservation and sustainable future of sandalwood in regard to the regulation of its harvesting and sale.

The only other approach of comparable ease of implementation is option 6, retaining an amended Sandalwood Act linked to the WC Act. However, option 6 continues the complexity inherent in having two statutes governing the one activity. Option 5 would result in a dedicated Sandalwood Act and provide certainty to the regulation of sandalwood, however enhancing it would be a significant undertaking of doubtful merit, particularly considering that it would be for the management of a single species.