



Australian Government

**Rural Industries Research and
Development Corporation**

Australia's Sandalwood Industry

An overview and analysis of research needs

A report for the Rural Industries Research and Development Corporation

by Michael Clarke, AgEconPlus PtyLtd

December 2006

RIRDC Publication No 06/131
RIRDC Project No AGL-5A

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ISBN 1 74151 394 4
ISSN 1440-6845

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Published in December 2006

Foreword

Sandalwood includes a group of products whose research fits under the RIRDC Essential Oils and Plant Extracts sub-program of the New Industries portfolio.

Historically RIRDC has invested lightly in this sector. Long lead times between plant establishment and harvest were believed to render plantation production of the crop a non-economic proposition and wild sourced Western Australian sandalwood was a mature industry. Work by the Government of Western Australia and others has shown that the lag between plant establishment and harvest can be reduced and that there are a range of other environmental, social and economic benefits associated with growing sandalwood in Australia.

This research report provides a situation assessment for the two commercially dominant sandalwood species – Indian sandalwood (*Santalum album*) and Western Australian sandalwood (*Santalum spicatum*). Both species have expanded their area of plantation since 2000 and are forecast to dominate world supply by 2020. RIRDC considered an independent audit on their production, harvest, marketing and outlook to be both appropriate and opportune.

In addition to a sandalwood situation assessment, the report also provides a research needs analysis for both commercially dominant species. Recommendations from the research needs analysis will inform future priorities in the Essential Oils and Plant Extracts sub-program.

This project was funded from RIRDC Core Funds which are provided by the Australian Government.

This report, an addition to RIRDC's diverse range of over 1500 research publications, forms part of our Essential Oils and Plant Extracts R&D program, which aims to support the growth of a profitable and sustainable essential oils and natural plant extracts industry in Australia.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirc.gov.au/fullreports/index.html
- purchases at www.rirc.gov.au/eshop

Peter O'Brien

Managing Director

Rural Industries Research and Development Corporation

Executive Summary

What the report is about

This report is a scoping study on the sandalwood industry. It includes a research needs analysis. The report has concentrated on two species within the sandalwood genus – Indian sandalwood (*Santalum album*) and Western Australian sandalwood (*Santalum spicatum*). These two species currently dominate commercial production.

Background

Indian Sandalwood Situation Assessment

Indian sandalwood oil is a prestige product sourced from wild stocks. Indian sandalwood oil is used for a range of religious purposes and is a valuable fixative and base for luxury perfume manufacture. Indian sandalwood oil is currently limited to a supply of between 170,000 and 220,000 kg of oil pa and has undergone significant price increases in the period 1995 to 2005. Future price increases will be limited by emerging buyer resistance.

In response to high Indian sandalwood oil prices and the Western Australian Government's objective of reducing natural harvest and replacing it with plantation sandalwood, an Indian sandalwood plantation industry has emerged in Kununurra. Trial plantings have been established in other Australian locations. Australia appears to be the world leader in plantation establishment. The emerging Australian plantation industry is dominated by corporates using Managed Investment Scheme principles. This study estimates that Australian plantations will produce an additional 130,000 kg pa of Indian sandalwood oil, equivalent to 60% of current world production, by 2023.

Western Australian Sandalwood Situation Assessment

Western Australian sandalwood oil has always traded at a price discount to Indian sandalwood oil and like Indian sandalwood oil it is also currently sourced from wild stocks. Unlike Indian sandalwood oil, Western Australian sandalwood oil is sourced from a sustainably managed supply.

Demand for WA sandalwood oil will be determined, in part, by luxury perfume house commitment to the product and R&D appears to have overcome previous concerns with the product's use in perfume manufacture. In addition to sandalwood oil, the WA sandalwood tree also produces a fruiting body, which is similar to a macadamia nut. Commercialisation of the WA sandalwood nut, which is available four years after plantation establishment, may assist with the commercial viability of WA sandalwood plantations.

The price of WA sandalwood oil is sustainable at current levels and until large areas of plantation grown product are eligible for harvest from 2020. Plantations, which are dominated by a managed investment scheme in the Western Australian wheat belt, are likely to increase the supply of WA sandalwood from 12,000 kg of oil per annum in 2006 to more than 60,000 kg by 2023.

Research Needs

The research needs analysis reveals that:

1. There is an organised and active research community investigating sandalwood in Australia. The research community includes agencies of the Western Australian government, the private sector and universities.
2. Research outputs are channelled through a number of publications including the Sandalwood Research Newsletter and the Avon Sandalwooder.

3. To date, Australian research has focussed on Indian sandalwood (*S. album*) and projects have had a strong applied research focus.
4. Industry consultation revealed concern that much of the research being completed in Australia is proprietary and not available to potential investors.
5. Strong support was recorded for additional investment in sandalwood R&D and a greater role for RIRDC was requested.
6. Key research breakthroughs for both Indian and Western Australian sandalwood were identified as faster maturing and higher yielding varieties and production systems. For Western Australian sandalwood, product and market development, especially in relation to the *S. spicatum* nut, was identified as a priority.
7. Industry constraints were a corollary of research breakthroughs with the length of time between plantation establishment and harvest remaining the major barrier to profitable production. The importance of plantation design for *S. spicatum* was also highlighted.
8. Least adequately researched areas for both species were markets and plant genetics.
9. Future Indian sandalwood research should target processing, plant physiology/genetics, markets, communication and industry development and training.
10. Future Western Australian research should target market research, processing, plant physiology/genetics and sustainability.

Key Findings and Recommendations

The Australian sandalwood industry is set to dominate world supply of sandalwood oil. Substantial gaps in the industry's knowledge in relation to processing, plant physiology, markets, sustainability and industry development remain. There is a role for RIRDC in the provision of public good research that fills the breach between industry need and non-proprietary research interests. The findings from this report should inform future priorities in the Essential Oils and Plant Extracts sub-program.

Contents

Foreword.....	iii
Executive Summary	iv
Contents.....	vi
1. Introduction	1
Project Objectives.....	1
Methodology	1
2. RIRDC Essential Oils Research	2
The RIRDC Essential Oils and Plant Extracts Research Program	2
3. Indian Sandalwood (<i>S. album</i>) Situation Assessment	4
Natural Distribution, Harvest and Product Quality	4
Supply Chain and Product Uses	4
Alternatives	5
Wild Source Supply and Reserves	5
Plantation Production	7
World <i>S. album</i> Plantation Situation	7
Australian <i>S. album</i> Plantation Situation.....	8
Plantation Oil Yield Trial Results	8
Forecast Plantation Production.....	9
Industry Outlook	10
4. Western Australian Sandalwood (<i>S. spicatum</i>) Situation Assessment.....	11
Source and Product Uses	11
Supply Chain and Reserves	11
Alternatives	12
Plantation Production	12
Plantation Area	12
Trial Results and Anticipated Per hectare Oil Yield	13
Production from <i>S. spicatum</i> Plantations	13
Industry Outlook	14
5. Research Needs	15
Research History and Trends	15
RIRDC Investment.....	15
Sandalwood Research Newsletter	15
Other Sandalwood Research	17
Historical Research Compendiums	17
Consultation Findings	17
Species Most Comfortable Addressing	18
The Appropriateness of Current Sandalwood R&D Funding Levels.....	18
Major Investors in Sandalwood R&D	18
Greater Role for RIRDC Warranted.....	19
Priority Species	20
Single Greatest Research Breakthrough.....	20
Single Greatest Constraint.....	21
Least Adequately Researched Area.....	22
Research Priorities.....	23
6. Study Conclusions and Recommendations	24
7. References	25
Web Pages Visited.....	26
Key Contacts.....	27
Appendix 1: Research Completed.....	28

Abbreviations

CALM	Conservation and Land Management, WA
CPI	Consumer Price Index
DAFF	Australian Government Department of Agriculture Forestry and Fisheries
DPI	Department of Primary Industries
EOPA	Essential Oil Producers Australia
FPC	Forest Products Commission
ISO	International Standards Organisation
JCU	James Cook University
KPIs	Key Performance Indicators
MIS	Managed Investment Schemes
PNG	Papua New Guinea
SRN	Sandalwood Research News
WA	Western Australia

Acknowledgements

The Plan's authors wish to acknowledge the assistance of RIRDC and the Australian sandalwood industry. In particular we wish to thank the following individuals for their assistance with the report:

- Roslyn Prinsley and Tony Byrne, Essential Oils and Plant Extracts Program RIRDC
- Tony Page, School of Tropical Biology, James Cook University, Qld
- Peter Jones, Managing Director, Renew Environmental Services Pty Ltd, WA
- Tim Emmott and Lisa Grosskopf, Avon Sandalwood Network, WA
- Grant Pronk and Jon Brand, Forest Products Commission, WA

Naturally, all mistakes and omissions remain those of the report's author, Michael Clarke.

1. Introduction

The purpose of this study was to produce an overview of the Australian sandalwood industry and scope industry research gaps and future research needs.

Project Objectives

The project was to provide an understanding of the current and future sandalwood industry situation including an understanding of industry research gaps, and the role, if any, for the Rural Industries Research and Development Corporation (RIRDC) in their provision.

There is currently widespread interest in the sandalwood industry including broad based interest from the public following extensive marketing of sandalwood Managed Investment Schemes (MIS). Provision of an independent scoping report on the sandalwood industry was seen by RIRDC to be both appropriate and opportune.

The report provides:

- A sandalwood industry situation assessment detailing natural distribution, harvest and product quality, supply chain, product uses, alternatives and the outlook for both Indian sandalwood (*Santalum album*) and Australian sandalwood (*Santalum spicatum*); and
- A research needs analysis including research gaps and the role if any for RIRDC's Essential Oils and Plant Extracts R&D sub-program in research provision.

Methodology

The study was completed using desk-based research techniques including:

- Finalisation of the project scope and objectives with RIRDC;
- Review of the relevant Australian and available international literature;
- Consultation with Western Australian (WA) Forest Products Commission (FPC), sandalwood researchers, Sandalwood Research News, manufacturers and marketers of essential oils, private consultants and others working in the area;
- Situation assessment documentation for both the Indian sandalwood (*S. album*) and WA sandalwood (*S. spicatum*) industries;
- Research needs analysis including preparation of a gaps analysis and assessment of the potential RIRDC role in research funding;
- Draft report documentation and circulation to RIRDC and key industry stakeholders;
- Incorporation of comments received on the draft report; and
- Submission of a final report to RIRDC.

The research was completed between June and September 2006.

2. RIRDC Essential Oils Research

The RIRDC Essential Oils and Plant Extracts Research Program

Sandalwood industry R&D is managed under RIRDC Program 1: New and Emerging Industries sub-program 1.4 Essential Oils and Plant Extracts (RIRDC 2006).

The objective of research in the Essential Oils and Plant Extracts sub-program is:

'To support the growth of a profitable and sustainable essential oils and natural plant extracts industry in Australia'.

Essential oils are largely used in the food flavouring, cosmetics and fragrance industries but their use in aromatherapy and other health care areas is growing. Changing consumer preferences in favour of natural over synthetic substances have had a strong impact on pharmaceutical and cosmetic industries, which has translated into growing demand for essential oils and plant extracts.

There is increasing interest in essential oils in Australia and there are good opportunities for producing plant extracts from both native and exotic species. The current value of production of essential oils (excluding tea tree oil) is estimated to be approximately \$10-11 million pa at the farm gate.

Essential oils include blackcurrant bud, boronia, chamomile, eucalyptus, fennel, lavender, mint, parsley, sandalwood and tea tree. The Australian essential oils industry is made up of around 150 commercial producers, with production dominated by a few larger firms. Most essential oil production takes place in Tasmania, Victoria and New South Wales. Most sandalwood oil production takes place in Western Australia.

Medicinal herbs offer potential for Australian production of plant extracts. At present, about one-third of the 250 tonnes used each year is supplied from Australia.

Australia has a comparative advantage as a reliable supplier of clean, good quality, unique oils and extracts based on the use of high technology in both production and extraction. However the Australian industry must understand the needs of processors and meet well-defined quality parameters.

Long-term strategies to deliver Essential Oils and Plant Extracts sub-program objectives are:

- Improve understanding by potential researchers and producers of markets for essential oils and plant extracts;
- Improve existing products and encourage the development of new crops and products (including uses for existing products);
- Support the development of sustainable and profitable production systems;
- Facilitate regulatory approvals for essential oils and plant extracts;
- Promote cost effective post harvest and extraction technology to improve yield and product quality; and
- Encourage the development of essential oils and plant extracts by promoting industry networks and the flow of information.

Key Performance Indicators (KPIs) for the Essential Oils and Plant Extracts sub-program are:

- Average industry oil yield per hectare;
- Availability of information for grower use;
- Availability of information on world production levels and trends;
- Extraction efficiencies;
- Levels of local production/import substitution;
- Harvest and extraction technology to improve yield and quality; and
- Encourage the development of essential oils and plant extract industries by promoting industry networks and the flow of information.

These research objectives and KPIs have been used to guide the sandalwood research needs analysis.

3. Indian Sandalwood (*S. album*) Situation Assessment

Natural Distribution, Harvest and Product Quality

Indian sandalwood oil is obtained from the heartwood of *S. album*. *S. album* occurs naturally throughout India, Sri Lanka, South East Asia (Timor, Indonesia, Malaysia, Cambodia, Vietnam, Burma and Thailand, China, the Pacific (Papua New Guinea, Fiji, Vanuatu, New Caledonia and Hawaii) and even Australia (small naturalised area in the northwest of WA which is believed to have been established through the activities of Mallacan traders).

Some 90% of the world's *S. album* output is produced in India. Indonesia currently dominates the balance of world production and export (www.plantcultures.org.uk). In India 80% of production is sourced from the states of Tamil Nadu, Kerala and Karnataka (www.agricultureinformation.com). The trade is centred on the southern city of Mysore. Most heartwood is harvested from wild stocks in natural forests.

Historically sandal trees less than 100 cm in diameter and 60 years old were considered to be too young to harvest. Heartwood volume, oil percentage and oil quality were considered to be inferior. Officially it is illegal in India to harvest sandal trees at less than 30 years of age or any sandal trees without government approval. Sandalwood poaching is commonplace and highly lucrative.

Poached sandalwood is a major contributor to overall Indian supply. Some estimate that output from poaching may be four times larger than the official harvest.

Recoverable oil percentage in heartwood varies anywhere from 2% to 7% (www.newcrops.uq.edu.au). Recoverable oil percentage is linked to the efficiency of extraction technique, the age of the tree, its growing environment and, seemingly, to the individual plants genetic composition.

There is an international (ISO) standard for sandalwood oil and with increasing illegal harvest and the product being diluted with lower value oils, the importance of the ISO standard for the measurement of minimum free alcohols (one unit of product quality) has increased.

Reports in the literature from the mid-1990s were that 'spike' disease might be a greater long term threat to Indian sandal supply than even poaching.

Supply Chain and Product Uses

Sandal heartwood is purchased by 'powder men' direct from Indian Government auctions. Powder men on-sell powdered sandalwood to producers who distil the oil. Sandalwood oil is then traded worldwide in liquid form via import-export agents. Normally quantities sold vary from 1 kg lots up to 200 kg lots. The oil is usually contained within aluminium flasks.

Only heartwood is powdered and distilled to produce oil. Sapwood is typically used in ornamental carving, altars, furniture, or incense/agarbhatti industries. The sandalwood nut or fruiting body is eaten as 'bush tucker' in some cultures and sandalwood is also used in the manufacture of chewing tobacco in Asia and India. Spent heartwood powder is manufactured into joss/incense sticks after the oil is extracted.

Sandalwood oil is widely used in religious ceremonies, medicines and perfume manufacture. Muslims, Hindus, Buddhists and Parsis sanction sandalwood oil use in religious ceremonies. In the perfume industry, sandalwood oil is used as both a fixative (for other fragrances) and a base. Prestige perfumes that make use of sandalwood oil include Yves St Laurent, Chanel, Calvin Klein and Christian Dior.

Additional interest in sandalwood oil has been linked to aromatherapy and the growth in consumption of natural products.

France, the Middle East and the USA are the world's largest sandalwood import markets. China is increasing consumption in line with its increased prosperity. India is the world's largest consumer (agrof.net).

Alternatives

Santalum spicatum, a Western Australian native, and other *Santalum spp* from as far away as the West Indies are considered to be lesser alternatives to Indian sandalwood. For example, sandalwood sourced from Sri Lanka sold for \$US160/kg in 2000 when Indian oil was selling for \$US294/kg. See Table 1 below.

Table 1 USA Import Prices and Volumes, 2000 (\$US/kg for oil)

Country	Volume (kg)	Value (\$US)	\$US/kg
India	2,296	674,064	293.58
Indonesia	3,650	885,562	242.62
Sri Lanka	25	4,018	160.72

Source: USDA data, FOB value country of origin

None of the natural alternatives to Indian sandalwood oil appear to be abundant or in a position to 'flood the market' with low cost product. The consensus in the literature is that there are few sandal trees left in the Indonesian archipelago and recently discovered supplies in PNG and the South Pacific are being harvested immature and squandered (www.american.edu.org). Hawaii, Haiti, South East Asian and East Asian supplies are all limited.

Synthetic sandalwood oil was developed in the 1970s causing a ten-year period of steep decline in Indian sandalwood prices. Synthetic sandalwood oil has similar properties to natural oil and dominates low cost uses i.e. cheaper end perfumes and cosmetics.

Indian oil prices are sustained on the basis of the products 'naturalness', history and mystique. However, the availability of alternatives, first world concerns about the sustainability/environmental impact of harvest and the need to secure consistent supplies, in volume and of a suitable quality, will cap the product's ultimate price.

Wild Source Supply and Reserves

S. album oil production and consumption estimates 1990, 2004 and 2005 assembled from a variety of sources are shown in the table below. The data should be interpreted with caution. The data does not include product sourced illegally and consumed in India. For example an estimated 75% of the sandalwood leaving the Indian state of Karnataka is estimated to be smuggled and the volume of illegal production is believed to be four times legal estimates.

Furthermore, the estimates were prepared from heartwood harvest tonnages assuming a relatively generous oil recovery rate of 6% (estimate supplied by www.American.edu.org). Some heartwood harvested will yield less than 6%.

Table 2 Estimated *S. album* Supply and Demand Balance (kg of oil)

	1990	2004	2005
Production – S. album			
India – Tamil Nadu	60,000	75,000	125,000
India – Other	60,000	75,000	75,000
Indonesia	15,000	10,000	10,000
Other	5,000	10,000	10,000
Sub-total	140,000	170,000	220,000
Consumption – S. album			
India	60,000	75,000	90,000
France	30,000	35,000	35,000
Saudi Arabia	20,000	30,000	35,000
USA	10,000	15,000	15,000
Other	20,000	15,000	45,000
Total	140,000	170,000	220,000

Source: AgEconPlus analysis and Tamil Nadu Statistical Handbook 2005

The government of Tamil Nadu, India is the world's single largest supplier of legal *S. album* heartwood from which sandalwood oil is extracted. The 2005 Government of Tamil Nadu Department of Economics and Statistics, Statistical Handbook shows an increase in supply from 2004 to 2005. It is not known whether this is a permanent increase in supply or a temporary response to increased sandalwood price and the pressure to harvest wild stocks before they are poached¹.

The Government of Tamil Nadu reported that average auction prices increased from \$US22,300/tonne in 2004 to \$US38,800/tonne in 2005. Tim Coakley of Wescorp International reports in the Avon Sandalwooder in 2006 that resistance to ongoing price increases is being recorded in India and prices have declined from recent peaks. Time series price data for *S. album* is reported in Table 3.

Table 3 Sandalwood Auction Prices Tamil Nadu (heartwood \$US/t average)

Year	Advisor Edge Investment Research (2005)	Government of Tamil Nadu
1995	10,000	
1996	10,000	
1997	11,000	
1998	12,000	
1999	15,000	
2000	16,000	
2001	17,000	
2002	18,000	14,000
2003	20,000	22,500
2004	35,000	22,300
2005	58,000	38,800

Source: Advisor Edge Investment Research and Government of Tamil Nadu Statistical Hand Book various additions

¹ One report (Croakley in the Avon Sandalwooder, 2006) indicates that the spike in volume may be associated with government disposal of material ceased from Indian poachers.

Factors working against further dramatic increases in the price of *S. album* include:

- The availability of low cost synthetic sandalwood oil;
- Limited and uncertain supply with high and rising prices relative to other perfume fixtures and bases. Limited and uncertain supply with high and rising prices will cause perfume manufacturers to seek out and commit to sandalwood alternatives when planning new prestige product lines;
- First world concerns about the environmental responsibility and sustainability of harvest of wild sandalwood supplies in India and other parts of Asia may limit the product's future appeal to some prestige perfume producers;
- The availability of *Santalum spp* worldwide. Lesser alternatives to *S. album* are available from as far away as the West Indies. Hawaii, South East Asia and East Asia also have limited supplies of *S. album* and alternative *Santalum spp* species. The consensus in the literature is that none of these countries has the capacity to flood the world sandalwood market. However, the presence of supplies of a high priced easily recovered commodity in mostly poor countries provides a strong economic incentive for harvest and supply wherever possible; and
- The development of plantations. Plantations have been planned in India since at least the mid 1980s. However, disease and chronic poaching of immature trees appears to have limited their success. Plantations in Australia of both *S. album* and *S. spicatum* are meeting with more success.

Plantation Production

World *S. album* Plantation Situation

No accurate data on the area of *S. album* plantation or its maturation date is available. The following comments gleaned from the literature provide some insight:

'In Indonesia, a 15 year programme of planting 30,000 ha of sandalwood was scheduled to start in 1990 through Perum Perhutani (HTIs), the Forestry Service, and social forestry programmes (Monk, de Fretes and Reksodiharjo-Lilley, 1997). Cultivation of sandal in India has had limited success' (United Nations Environment Programme www.unep-wcmc.org).

'Of the traditional areas in Southeast Asia where sandalwood is found, only India has made a strong effort to create plantations'
(Cindy Ramanathan, The Indian Sandalwood Trade www.american.edu/TED/sandalwd.htm).

In the south of India, in its natural zone of occurrence, sandalwood has been affected by spike disease and other insect pests. In these areas large tracts of plantations have been wiped out due to this disease. In the north no such disease has been found till date. Farmers of Himachal Pradesh, Punjab, Uttar Pradesh and Uttaranchal can earn good money from sandalwood farming (Vipan Guleria, Rakesh Mandraria and KS Verma, India Tribune 12 January 2004).

The Government of Tamil Nadu's state owned Forestry Corporation establishes and manages eucalyptus, cashew, nelli, teak and casuarina plantations along with a large-scale sandalwood distillery producing up to 20,000 kg of oil per annum from wild sourced sandal. The corporation actively seeks new plantation crops and is expanding its area under management. It is not planting sandalwood due to a combination of agronomic (spike disease) and security (poaching) concerns.

Plantation production of sandalwood is a priority for India. Agronomic constraints and theft are holding back plantation production.

Australia appears to be the world leader in *S. album* plantation establishment.

Australian *S. album* Plantation Situation

S. album was first grown experimentally in the Ord River Irrigation Area, Kununurra WA in 1983. Results were sufficiently encouraging for a fulltime research officer to be appointed by the WA government in 1992. The first private sector commercial plantations of *S. album* were established in Kununurra in 1999.

The WA FPC estimates that the area of commercial *S. album* plantation in Kununurra is increasing at an annual rate of 300 to 400 ha pa (pers comm. September 2005). Production in other parts of Australia including Carnarvon WA, South Australia and NSW, remains at the large scale trial level.

Growth in Kununurra sandalwood plantations has been driven by corporate investment and three separate MIS entities dominate Ord River planting. Table 4 summarises available information on current and forecast *S. album* plantation area. Table 4 data was sourced from relevant company web sites detailing planned *S. album* investments. Where possible this data was checked with company representatives. With this said, the data should be treated as an approximate.

Table 4 Approximate Australian *S. album* Plantation Area – Historic and Forecast (ha)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
								F	F	F
Kununurra WA	50	150	300	500	700	930	1315	1695	2045	2545
Other	0	0	50	75	100	200	220	240	260	300
Industry Total	50	150	350	575	800	1130	1535	1935	2305	2845

Source: AgEconPlus using published and unpublished data
F = forecast and is based on reported company intentions June 2006

At 30 June 2006 the industry was forecast to be approaching 2,000 ha of *S. album* plantation. This area was forecast to increase by almost 50% to 2,845 ha by 2008.

Plantation Oil Yield Trial Results

The following oil yield trial results are reported in Brand, Kimber and Streatfield (2006) and summarised in an FPC WA Media Release of 27 March 2006.

Preliminary results of oil samples taken from young FPC *S. album* trees indicate that the FPC plantation is producing good quality oil but in small amounts. The FPC indicate that the results are encouraging as the trees, which come from the first *S. album* plantation on the Ord River Irrigation Area Kununurra, WA were aged only 14 years. The FPC Media Release states that in December 2004 twenty trees were sampled for total oil yield and santalol content. 'Chips' (heartwood only) and 'cores' (heartwood plus sapwood) were taken from each sandalwood stem at 30 cm and 100 cm from the base and were analysed using solvent extraction (FPC Media Release 27 March 2006).

The trees contained approximately 34% heartwood at 30 cm, and 29% heartwood at 100 cm. The mean total extractable oil yields were 2.9-3.4% from chips and 1.8-2% from cores. These total readings are approximately half that obtained from mature trees aged over 50 years growing in India, which have an average oil yield of 5-7% (FPC Media Release 27 March 2006).

The heartwood oil contained 44.7%-46.7% α -santalol and 20.8-22.2% β -santalol. These santalol levels meet the current ISO standards for *S. album* oil, which are 41-55% α -santalol and 16-24% β -santalol. This implies that although the oil yield was low, the quality of the oil would meet sandalwood oil requirements (FPC Media Release 27 March 2006).

Oil yields were highly valuable between trees, with some as high as 7.1%, while three trees had less than 0.3%. These trees were all growing under the same conditions, which indicate that there could be some genetic control that could be exploited. Until this is better understood, future plantings at

Kununurra should aim to use seeds or progeny from known superior oil producing parent trees (FPC Media Release 27 March 2006).

These results from core samples provide evidence that the young *S. album* plantations at Kununurra are producing oil. However, whole trees need to be harvested and the amount of heartwood and oil content measured to estimate the value of the plantations (FPC Media Release 27 March 2006).

Forecast Plantation Production

From the above information and discussions with FPC anticipated per hectare oil yields were prepared. Estimates were based on assumptions given the absence of empirical data. Naturally estimates should be interpreted with considerable caution.

Preliminary results from trial FPC plantations indicate that heartwood and sapwood yields might be in the order of 20 t/ha and 30 t/ha and that these yields will be available after 15 to 20 years. A rough estimate of per hectare oil production from Kununurra might be:

- One third of total oil yield will be heartwood i.e. 8 t/ha²;
- Estimated oil yield will be 3% (higher than achieved for wild harvest *S. spicatum* but less than realised for 50-year-old Indian *S. album* trees);
- Therefore per hectare oil yield will be approximately 240 kg.

From the plantation age and area information provided in Table 4 the following national *S. album* plantation harvest estimates can be made.

Table 5 Approximate Australian *S. album* Annual Plantation Production

Year Established	Area Established (ha)	Year of Harvest	Harvest Volume (kg of oil)
1999	50	2014	12,000
2000	100	2015	24,000
2001	200	2016	48,000
2002	225	2017	54,000
2003	225	2018	54,000
2004	330	2019	79,200
2005	405	2020	97,200
2006	400	2021	96,000
2007	370	2022	88,800
2008	540	2023	129,600

Source: AgEconPlus analysis

Table 5 shows:

- The first commercial harvest of Australian plantation *S. album* is forecast to occur in 2014.
- By 2023 Australian plantation *S. album* production (129,600 kg) will account for 60% of current world *S. album* production (220,000 kg).

² Vernes and Robinson 2002 using data contained in Managed Investment Scheme commercial prospectuses estimated yield as high as 14.95 t/ha after 15 years.

Industry Outlook

On the basis of the above analysis the following conclusions on industry outlook for Indian sandalwood (*S. album*) are drawn:

- Wild source supply and reserves – constrained but no hard evidence of immediate exhaustion;
- Demand – robust demand for a prestige product whose buyers have capacity to pay. Ultimately price increases linked to robust demand will be capped by the presence of natural and synthetic alternatives, the need for assured supplies and concerns about the environmental impact of Indian wild harvest;
- Price – current price hikes reflect supply constraints but further upward pressure on price is likely to result in substitution of other products for Indian sandalwood oil; and
- Plantation production – dominated by Australian plantings in Kununurra WA. Plantation production will double Australian sandalwood output (currently confined to *S. spicatum*) by 2014 and account for 60% of current world supply by 2023.

4. Western Australian Sandalwood (*S. spicatum*) Situation Assessment

Source and Product Uses

West Australian sandalwood oil is obtained from the heartwood of *S. spicatum*, an indigenous species that covers a large proportion of the western half of the Australian continent.

S. spicatum oil has application in the perfume, incense and complementary medicines markets. It would also appear to have some potential as a bactericide (Jones 2004). Significant volumes of *S. spicatum* oil are purchased by the tobacco industry in India for flavouring chewing tobacco (Jones pers comm.). The nuts from WA sandalwood are similar to macadamia nuts and offer the potential for a saleable product earlier in the tree's life, defraying the cost of long lead times in plantation harvest (information sourced from the Avon Sandalwooder 2006).

WA sandalwood oil cannot be used as a direct substitute for Indian sandalwood oil and has its own unique characteristics. WA sandalwood oil has always traded at a price discount on international markets.

Supply Chain and Reserves

Like Indian sandalwood, WA sandalwood has historically been a wild-sourced product. The WA government maintains strict control on WA sandalwood harvest. The FPC of WA manages the harvest process and an annual quota of 2,000 tonnes pa is released. At least half this 2,000 tonne quota must be deadwood, which is unsuitable for oil extraction. Mount Romance Australia, a WA based oil extraction and marketing company, has an annual quota entitlement of 550 tonnes of heartwood 'chip'. Mount Romance Australia's supply is secured by contract with the FPC of WA through to 2016.

The WA wild harvest of *S. spicatum* is understood to be sustainable at current levels and the WA government has no plans to increase wild harvest quota. There are limited stands of *S. spicatum* on private land and there is only one other minor source of oil, originating from a private operation, in WA. There are no known overseas growers of *S. spicatum* (Jones 2004).

Total production of West Australian sandalwood oil is approximately 12 t/yr (Jones 2004).

Table 6 Estimated *S. Santalum* Supply/Demand Balance (kg of oil)

	2005
Production	
Australia – Mt Romance	11,000
Australia – Other wild	1,000
Australia – Plantations	0
Overseas	0
Total	12,000
Consumption	
Australia	9,000
Overseas	3,000
Total	12,000

Source: various published sources and project consultation

Most *S. spicatum* oil is consumed in Australia, and Mount Romance Australia is the dominant producer of *S. spicatum* oil from the WA FPC harvest.

Mount Romance Australia indicate that the demand for WA sandalwood oil is very strong with a small percentage of their output being directed into their own retail products, slightly more going directly to

India and most product going directly to luxury perfume manufacturers – the highest paying market for sandalwood oil. R&D is understood to have addressed concerns from perfume houses about the unfavourably high levels of some chemicals in *S. spicatum*.

WA sandalwood delivered to overseas markets achieves prices that range from \$10,000/t for heartwood to \$3,000/t for sapwood³. WA sandalwood prices are less than one third of prices achieved for *S. album*. On the domestic market suppliers can receive between \$A4,500/t and \$5,500/t for *S. spicatum* heartwood delivered to the buyer (Jones 2004).

WA sandalwood oil sells for \$A350/kg to \$700/kg, depending on the grade of oil. There has been some upward movement in WA sandalwood oil prices over time as domestic ‘value added’ uses for the product and overseas perfume sales have been achieved.

Alternatives

Trials are underway in Queensland, Northern Territory and WA to investigate the potential of other *Santalum* species. In addition a number of small research trials and feasibility studies are underway in the eastern states of Australia testing other native species. Some show fragrance/fixative potential. At this stage none threatens the commercial dominance of WA sandalwood (*S. spicatum*).

Plantation Production

Since 1987, the FPC and its predecessor, the Department of Conservation and Land Management have established *S. spicatum* plantations on farmland in the wheat belt of WA with an aim of supplementing the harvest of natural stands with plantation timber. The FPC has successfully established *S. spicatum* plantations mainly in the medium annual rainfall (400-600 mm) regions (south-western WA), but some trial sites have also been successfully established in lower rainfall areas.

A low rainfall requirement makes *S. spicatum* an ideal plantation timber for large areas of cleared land in the wheat belt, which are too dry to support other plantation timbers (Brand, Jones and Donovan 2004).

Plantation Area

FPC establishes WA sandalwood plantations in share farming agreements with private landholders. Between 1999 and 2003, the FPC planted 50-150 ha of *S. spicatum* each year (Brand, Jones and Donovan 2004). In 2005 and 2006 the FPC’s target was for 150 ha of new *S. spicatum* plantation increasing to 300 ha in 2007. The FPC aims to maintain plantation establishment at around 300 ha pa.

In addition to FPC’s shareholder agreements there are a number of private individuals establishing *S. spicatum* plantations in WA on a small scale and corporates with both private investment funds and managed investment schemes planting Western Australian sandalwood.

A single managed investment scheme is the largest investor in *S. spicatum* plantations. Its most recent sandalwood project offering was for 4,000 woodlots of 0.5 ha each and this offering builds on the company’s current management of 2,700 ha of Australian sandalwood plantation.

S. spicatum is also suitable for plantation production in other parts of Australia, including southern South Australia and the tablelands of NSW and Queensland. The total area outside WA was estimated by this study at less than 200 ha in 2006.

Total current and forecast *S. spicatum* plantation area is shown in Table 7.

³ Jones (pers comm.) notes that these 2004 prices are now low against 2006 estimates.

Table 7 Approximate. *S. spicatum* Plantation Area – Historical and Forecast (ha)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
								F	F	F
FPC Share Farming Agreements	200	300	400	500	600	700	750	850	1150	1450
Private Landholder Plantations	50	60	65	70	75	80	85	90	95	100
Corporates incl. MIS companies	400	1000	1500	2000	2400	2800	3200	4200	5200	5500
Industry Total	650	1360	1965	2570	3075	3580	4035	5140	6445	7050

Source: AgEconPlus analysis

F = forecast and is based on reported intentions

There was an estimated 5,000 ha of *S. spicatum* in plantation at 30 June 2006.

Trial Results and Anticipated Per hectare Oil Yield

Trials to date indicate that 4-5 t of sandalwood can be produced per hectare over a 20-year period (Brand *et al* 2004)⁴ and while it is possible to harvest as early as 15 years the commercial returns are significantly reduced. The market places early harvest product into lower price grades (Jones 2001).

The yield of oil from Western Australian sandalwood grown in plantation is forecast to be similar to wild sourced product i.e. one tonne of Western Australian sandalwood averages 2% by weight. A rough estimate of per hectare oil production from plantation grown *S. spicatum* might be:

- Saleable heartwood of 4.5 t/ha;
- Estimated oil yield of 2%;
- Therefore per hectare oil yield will be approximately 90 kg.

Production from *S. spicatum* Plantations

From the plantation age and area information provided in Table 7 and the above yield information, the following *S. spicatum* plantation harvest estimates can be made. The estimates are at best approximations.

Table 8 Approximate *S. spicatum* Annual Plantation Production

Year Established	Area Established (ha)	Year of Harvest	Harvest Volume (kg)
1999	650	2019	58,500
2000	710	2020	63,900
2001	605	2021	54,450
2002	605	2022	54,450
2003	505	2023	45,450
2004	505	2024	45,450
2005	455	2025	40,950
2006	1105	2026	99,450
2007	1305	2027	117,450
2008	605	2028	54,450

Source: AgEconPlus analysis

⁴ Geoff Woodall in the Avon Sandalwooder 2005 suggests yields of 3t of merchantable sandalwood per hectare after 20 years may be optimistic in lower rainfall areas.

Table 8 shows:

- Plantation production will be in full swing by 2019 when Australian *S. spicatum* plantations will yield almost 60,000 kg of oil. This is equivalent to around one quarter of current world sandalwood production.
- Production will peak in the years 2026 and 2027 when the largest MIS company plantation is eligible for harvest.

The simplistic analysis presented in Table 8 makes no allowance for holdover of stock to manage the supply of *S. spicatum* entering the market place.

Industry Outlook

On the basis of the above analysis the following conclusions on industry outlook for WA sandalwood (*S. spicatum*) are drawn:

- Wild source supply and reserves – sustainable at current levels;
- Demand – dependent on Australian marketing capacity. The strength of commitment by luxury perfume houses to the product is the major determinant of its outlook;
- Price – sustainable at current levels at least until large areas of plantation grown product are eligible for harvest from 2019;
- Plantation production – dominated by Australian managed investment scheme plantings in the wheat belt of WA. Plantation production will potentially increase supply from 12,000 kg of oil in 2006 to 60,000 kg of oil by 2019.

5. Research Needs

The sandalwood research needs analysis was completed for both *S. album* and *S. spicatum*. Research needs were informed by a review of the research literature and industry consultation.

Research History and Trends

Key sources used to identify sandalwood research literature were the:

1. RIRDC's Plant Extracts and Essential Oils Program project database;
2. Sandalwood Research Newsletter; and
3. Project consultation.

RIRDC Investment

To date RIRDC has funded only one sandalwood industry project, the project was:

'Efficient sourcing and fractionation of sesquiterpenoid alcohols from Australian sandalwood'

The project was completed in 2003. The project was to address the impact of provenance on both oil yield and fractionation. The report delivered most strongly on fractionation. Key findings were:

RIRDC and the Essential Oils and Plant Extracts R&D Committee have been reluctant to fund sandalwood oil R&D in the past given concerns that long maturation times for both *S. album* and *S. spicatum* plantations would mean that industry development could not be accomplished as an economic proposition. The wild sourced *S. Spicatum* industry was supply limited and effectively fully mature. This current project was commissioned by RIRDC, in part, to review this paradigm.

Sandalwood Research Newsletter

The absence of RIRDC investment in sandalwood research in no way applies that the field has been vacant.

The Sandalwood Research Newsletter (SRN), a web based periodical for the communication of research, development and extension related to the genus *Santalum*, has been active since 1993. The SRN publishes findings from both Australian and international research and is serviced from the School of Tropical Biology at the James Cook University. The aim of the SRN is to increase public awareness of the natural source of sandalwood products and the need for genus conservation and plantation establishment. The SRN notes that increasing scientific awareness through the international *Santalum* species literature can:

1. Promote *Santalum* species conservation;
2. Stimulate *Santalum* species plantation establishment;
3. Increase research and development linkages between interested organisations; and
4. Increase *Santalum* species literature exposure.

A catalogue of research publications listed in the twenty-one issues of the SRN prepared since its commencement in 1993 is provided in Appendix 1. The catalogue excludes research publications targeting *Santalum acuminatum*, the quandong. The quandong is primarily grown as a fruit and was considered to be outside the essential oils focus of this project.

From Appendix 1 it can be seen that from the 56 projects identified in the SRN:

- 30 have been concerned with Australian research priorities while the balance have been publications originating from overseas research projects, principally in India, East Timor and the Pacific;
- 18 projects have focussed on *S. album*, 4 have focussed on *S. spicatum* and the balance are either directed at other *Santalum* species (found in Queensland, the Pacific or Asia) or have been of a general nature (eg the convening of a workshop on *Santalum* species);
- Research can be broadly classified into Stage 1, Stage 2 or Stage 3 investigations, with Stage 1 being concerned with pure research for the generation of knowledge, Stage 2 being concerned with outcomes that can be implemented and Stage 3 being associated with communication of those outcomes to potential adopters. Review of SRN projects indicates half the projects reported in the SRN have been applied/Stage 2 research, 16 have been pure/Stage 1 research and the balance have been concerned with extension.

The dominance of Australian, *S. album* projects that are stage 2/Development oriented implies an increasingly commercial industry.

Analysis of Appendix 1 data using DAFF research classification criteria and RIRDC Essential Oils and Plant Extracts Program KPIs is summarised in Table 9.

Table 9 Projects Reported in the Sandalwood Research Newsletter 1993 to 2006

Classification	No of Projects	Share of Total Projects
Plant physiology and genetics	13	23%
Production - industry competitiveness	24	43%
Production – sustainability	5	9%
Processing - extraction efficiency	0	0%
Distribution, storage and transport	0	0%
Markets, supply forecasting	2	4%
Communication, technology transfer	11	20%
Industry Training and Development	1	2%
Total	56	100%

Source: SRN website and AgEconPlus analysis

From the table it can be seen that 66% of projects have been concerned with understanding *Santalum* physiology and genetics and ‘what makes sandalwood grow’. For an industry with a short history of plantation production this would seem to be an entirely appropriate research priority.

Analysis of projects reported in the SRN was provided to industry stakeholders as part of a research priority setting survey. Survey results are reported in the Consultation Findings section below.

Other Sandalwood Research

In addition to RIRDC research and literature documented through the SRN, the Centre of Excellence in Resource Management, University of Western Australia has produced the following research reports:

- Pate JS, Woodall GS, Jeschke WD and Stewart GR. (1994) Root xylem transport of amino acids in the root hemi parasitic shrub *Olex phyllanthi* and its multiple hosts. *Plant Cell and Environment* 17 1263-1273.
- Woodall GS and Robinson CJ 2002 Same day plantation establishment of the root hemi parasite sandalwood (*Santalum spicatum* (R. Br.) A.DC: *Santalaceae*) and hosts. *Journal of the Royal Society of Western Australia* 85:37-42
- Woodall GS and Robinson CJ 2002 Direct seeding Acacias of different form and function as hosts for Sandalwood (*Santalum spicatum* (R. Br.) A. DC). *Conservation Science Western Australia* 4 (3)
- Woodall GS and Robinson CJ 2003 The natural diversity of *Santalum spicatum* host species in south coast river systems and their incorporation into profitable biodiverse revegetation. *Australian Journal of Botany* 51, 1-13
- Woodall GS 2004 Cracking the endocarp of *Santalum spicatum* nuts by wetting and rapid drying improves germination. *Australian Journal of Botany* 52:163-169.

These research reports have not been incorporated into Table 9 or the stakeholder survey. Their presence was revealed by the survey.

Historical Research Compendiums

Also revealed by the survey were two historical research compendiums. Conservation and Land Management (CALM), WA and the Australian Sandalwood Company commissioned Joe Havel to prepare a comprehensive review of sandalwood research, which was completed in 1993. In addition O.W. Loneragan completed a Historical Review of Sandalwood Research in WA in 1990, published by CALM (Research Bulletin N0.4).

Consultation Findings

A sandalwood research priority-setting questionnaire was prepared and distributed to known industry stakeholders who were asked to complete the survey and nominate any additional relevant stakeholders. Stakeholders identified included:

- The RIRDC Essential Oils and Plant Extract R&D Steering Committee;
- Commercial plantation growers, small scale growers and sandalwood oil processing and marketing businesses; and
- Researchers, industry consultants and Government agencies.

In total eighteen complete data sets were collected and these data sets covered most known Australian *S. album* and *S. spicatum* production.

Stakeholders were asked about:

- The species they were most comfortable addressing;
- The appropriateness of current sandalwood industry R&D funding levels;
- Who were the major investors in R&D in this sector;
- The role for RIRDC in sandalwood R&D;
- Which species was deserving of the greater share of R&D investment;
- Their perspective on the single greatest research breakthrough for the industry;
- The single greatest constraint to the industry;
- The least adequately covered research area; and
- Their priorities for future research.

Results are summarised in the text below.

Species Most Comfortable Addressing

Responses were relatively evenly split with:

- 10 stakeholders indicating they were most comfortable addressing *S. spicatum*; and
- 8 Stakeholders indicating they were comfortable addressing either *S. album* or both species.

The Appropriateness of Current Sandalwood R&D Funding Levels

All but one respondent indicated the need for additional sandalwood R&D.

Major Investors in Sandalwood R&D

The WA Government was identified as the single greatest investor in both the *S. spicatum* and *S. album* R&D. The private sector, especially the large managed investment firms and universities were also noted for their contributions.

Comments included:

- Large scale managed investment scheme operators are preparing to invest heavily in industry R&D. Evidence of this preparedness is already being seen in WA.
- The significant changes in Indian sandalwood silviculture have been driven by the managed investment scheme industry. The WA Government is currently decreasing their expenditure on R&D in this area.
- Private enterprise investment is OK but information is needed which can be shared amongst the general community. Currently, in WA, State Government investment is through a government trading enterprise and not all research originating from this body is made available to landholders wishing to invest in sandalwood production.
- The WA Government has recently become a major plantation investor but has a clear conflict of interest. A large proportion of the *S. spicatum* R&D has been funded through the state government but the results are not freely available to the public.
- Private enterprise, WA Government and the universities have all contributed and are needed to contribute in the future.
- In WA the state government is investing in R&D. However much of the R&D is covered by intellectual property agreements and not freely available to investors.

Greater Role for RIRDC Warranted

Positive comments on a greater role for RIRDC included:

- Australia will be the major international supplier of sandalwood – both *S. spicatum* and *S. album* by 2012, making this a significant Australian rural industry. It is time for RIRDC to take a more active role in this industry.
- Producers of *S. album* face the difficult task of entering a fragmented industry previously dominated by India. Indian sandalwood (*S. album*) has never been harvested or processed in Australia and support to develop industry specific technology is essential.
- Australian Indian Sandalwood may need assistance with market development similar to that offered by RIRDC to other essential oils to stimulate the limited domestic demand and constrained western market for Indian Sandalwood oil.
- Identification of markets and product development is critical eg uses for deadwood and sandalwood nuts.
- Sandalwood is a diversification option for farmers but there is a strictly limited supply of information available to farmers outside the work undertaken by the Avon Sandalwood Network and the Centre for Excellence in NRM at the University of WA.
- Yes, better late than never. RIRDC can play an important role through the provision of funds but needs to fund research that potentially benefits all players, not just a government agency or a single private company.
- A valuable role for RIRDC would be funding workshops and communication processes in addition to research projects.
- Currently there is no government research initiative. The industry lacks direction in oil yields and growth rates. There is a good resource of old trees at Kununurra. The old CALM data could be expunged from the archives and reassessed for papers, etc. Despite the level of research investment over a decade or more, the amount of public information is poor.
- More specific R&D is required on the chemical aspects of sandalwood production.
- Yes, market development work is needed.
- Coordinate and assist research into nut oil and uses/properties, growth rates, oil quality under irrigation.
- To date there has been no breeding focus in respect to the oily nut and little if any consideration for the nuts as a viable crop.
- Yes, the current level of R&D is inadequate given the growth of this industry and its potential.

A single negative comment was received on the question of a greater role for RIRDC:

- Due to the slow growth (maturation in 35-40 years) any R&D is a very long and low returning process.

Recent changes in the nature of the sandalwood enterprise i.e. the establishment of large scale plantations, use of the crop as a diversification option in the wheat belt and the potential of more rapid income generation from earlier maturing irrigated production and nut harvest suggest a role for RIRDC's Essential Oils and Plant Extracts program in the future.

Priority Species

Nine stakeholders indicated that *S. spicatum* was the priority species for research, two stakeholders indicated *S. album* while seven stakeholders believed both species warranted priority attention. One stakeholder indicated that an additional species, *S. lanceolatum* should also receive research priority.

Comments received included:

- Australian sandalwood requires greater investment as it is one of the few viable tree cropping options for low rainfall farmers in the wheat belt.
- A well-developed WA sandalwood (*S. spicatum*) industry can deliver many more environmental and social benefits than the *S. album* industry offers. There are more gaps in our knowledge of *S. spicatum*. I estimate that there has been about ten times more investment in *S. album* R&D than in *S. spicatum*, yet over 5,000ha of *S. spicatum* have been established.
- *Spicatum* is a dryland crop yielding nuts after 4 years. *S. album* is a much longer risky crop to grow. *Spicatum* is suited to a much larger acreage of land.
- *Spicatum* plantation development will deliver triple bottom line outcomes for rural Australia, and address a range of NRM issues, mainly salinity/water quality and biodiversity. Also it will provide a risk management and drought proofing for current dryland agricultural systems.
- Both species warrant additional research. There is a worldwide shortage in sandalwood oil and the projects need to be long term because of the decades of delay needed between planting and harvest.
- Both species require investment. The two species are likely to end up in different markets so should be viewed differently.
- Both, plantations are developing rapidly for both species in WA. End use of products requires investigation.
- The Northern Sandalwood (*S. lanceolatum*) has the potential to be planted across the dry tropics of Australia (Qld, NT and WA) and with recent discoveries of forms with exceptional oil quality and yield there needs to be some investment into developing a plantation industry on this species and hybrids.

Comments tend to favour the further development of the plantation *S. spicatum* industry.

Single Greatest Research Breakthrough

Consultation findings on the single greatest research breakthrough are presented separately for *S. album* and *S. spicatum*.

Single greatest *S. album* research breakthrough comments included:

- Work on the rate of heartwood synthesis.
- Understanding factors and mechanisms that limit growth – it's not all genetics!
- Reducing the time required between planting out and harvest for plantations.
- Successful nursery propagation techniques for *S. album*.
- Cracking nursery protocols for seedling production.
- Genetics that give good tree form and good oil yield and quality.

S. album breakthroughs concentrate on faster production and higher oil yields.

Single greatest *S. spicatum* research breakthrough comments included:

- New product development.
- Knowing with confidence that a high quality product can be produced without irrigation in less than 20 years.
- Understanding factors and mechanisms that limit growth – it's not all genetics!
- It is likely that multiple products can be developed from the large nut of *S. spicatum* – this area requires urgent attention.
- Reducing the time required between planting out and harvest for plantations.
- Identifying the link between mid-weight range mammal grazing and *S. spicatum* natural regeneration
- Genetics that give good tree form and good oil yield and quality.
- Sustainable native harvest practices.
- Development of suitable genetic material through breeding programs to enable productive broad-scale plantation development.
- Nut oil and its uses
- Single greatest research breakthrough will occur when research places more importance on the nut industry over timber production.
- Solid markets and product development for the nut.

S. spicatum breakthroughs also highlight faster production and higher oil yields. In addition they target the importance of product and market development, especially in relation to the *S. spicatum* nut.

Single Greatest Constraint

Single greatest *S. album* constraint:

- Synthetic sandalwood oil is the greatest threat.
- Unreal expectations – total production, heartwood yield, quality and unreal price expectations.
- The time required between planting out and harvest for plantations.
- Federal and state agencies attempting to increase revenues through exploitation of intellectual property.
- Market opacity.
- The long rotation period due to delayed heartwood production.
- Poor yielding trees
- Inadequate scientific training of staff involved in sandalwood oil production

To some extent constraints are a corollary of research breakthroughs and highlight the length of time between plantation establishment and harvest.

Single greatest *S. spicatum* constraint:

- Supply of good quality wood in the medium term.
- Untapped markets and product opportunities yet to be realised. Underdeveloped nut industry, as the wood has such a long rotation (10 to 20 years) if the nut industry was viable adoption would speed ahead.
- Inappropriate plantation design leading to plantation failure at year 10-15. Poor understanding about constraints on growth and appropriate hosts in different regions of Australia.
- The time required between planting out and harvest for plantations.
- Federal and state agencies attempting to increase revenues through exploitation of intellectual property.
- Market opacity.
- The long rotation period due to delayed heartwood production.
- Poor yielding trees.
- Lack of investment, poor understanding by government and agricultural industry of how rising oil prices will drive production of low input food crops.
- Inadequate scientific training of staff involved in sandalwood oil production.
- Land purchases by WA government that result in further restrictions on harvesting.
- Escalating land prices inhibiting profitable plantation development.
- Lack of history of commercial production.
- Current production of timber is a 20-year rotation – too long need the nut market in short-medium term to increase private investment.
- Failure by government to invest in the development of *S. spicatum* – risk management in agricultural development and research.

Once again constraints are similar for *S. album* and *S. spicatum* in relation to length of time between plantation establishment and harvest. The importance of appropriate plantation design is also highlighted.

Least Adequately Researched Area

Least adequately researched area for *S. album*:

- Markets.
- Value adding opportunities and products.
- Chemical analysis of oil.
- The physiological process of oil creation in heartwood.
- The physiological process of heartwood development and methods of heartwood oil induction in young trees.
- Genetics and the chemistry of sandalwood oils with respect to their extraction and marketability.
- The true value of album plantation wood upon reaching harvest – will there still be a market

Markets and genetics dominate *S. album* research gaps.

Least adequately researched area for *S. spicatum*:

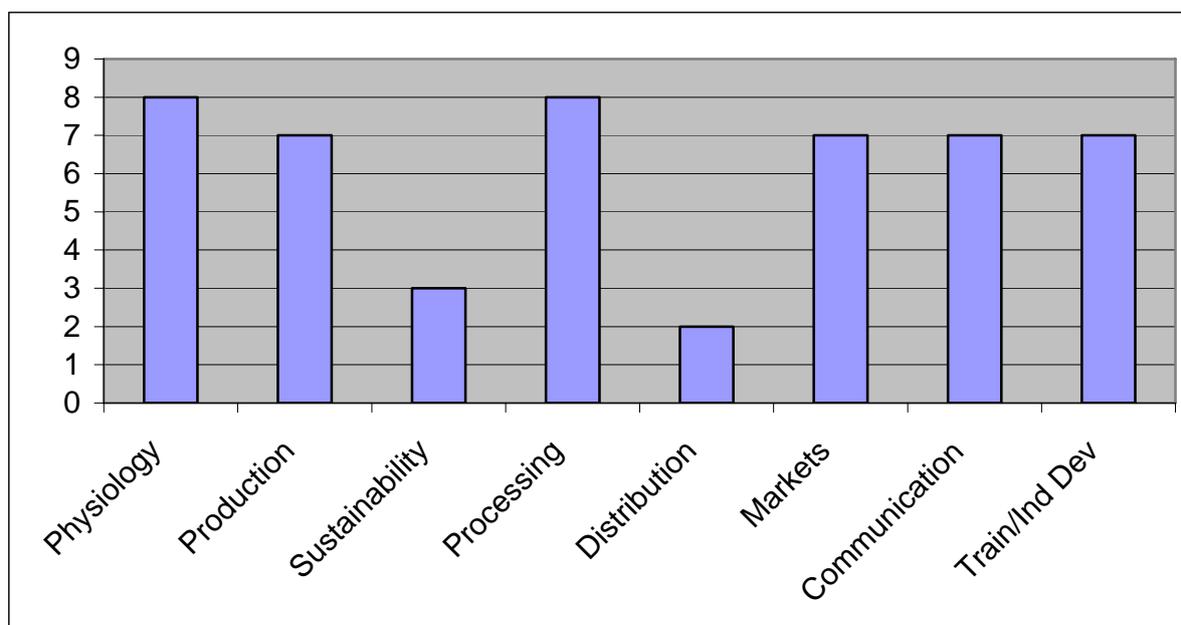
- Value adding opportunities.
- Value added products.
- Markets.
- Extraction of oil from nuts.
- Chemical analysis of oil.
- Processing with respect to chemical quality.
- The physiological process of oil creation in heartwood.
- The physiological process of heartwood development and methods of heartwood oil induction in young trees.
- Genetics and the chemistry of sandalwood oils with respect to their extraction and marketability.
- Lack of knowledge in processing, extraction, distribution, storage and transport.
- Markets for nuts, seeds.
- Nut oil and its uses/application.
- Nut genetics – size, yields, nutritional analyses and opportunities/constraints arising from these analyses.
- Nut production and market development.
- Value of nuts – oil, food source, medical, etc

The market potential of nuts dominates *S. spicatum* research gaps.

Research Priorities

S. album research priorities identified through consultation are summarised in Figure 1.

Figure 1 Indian Sandalwood (*S. album*) Research Priorities

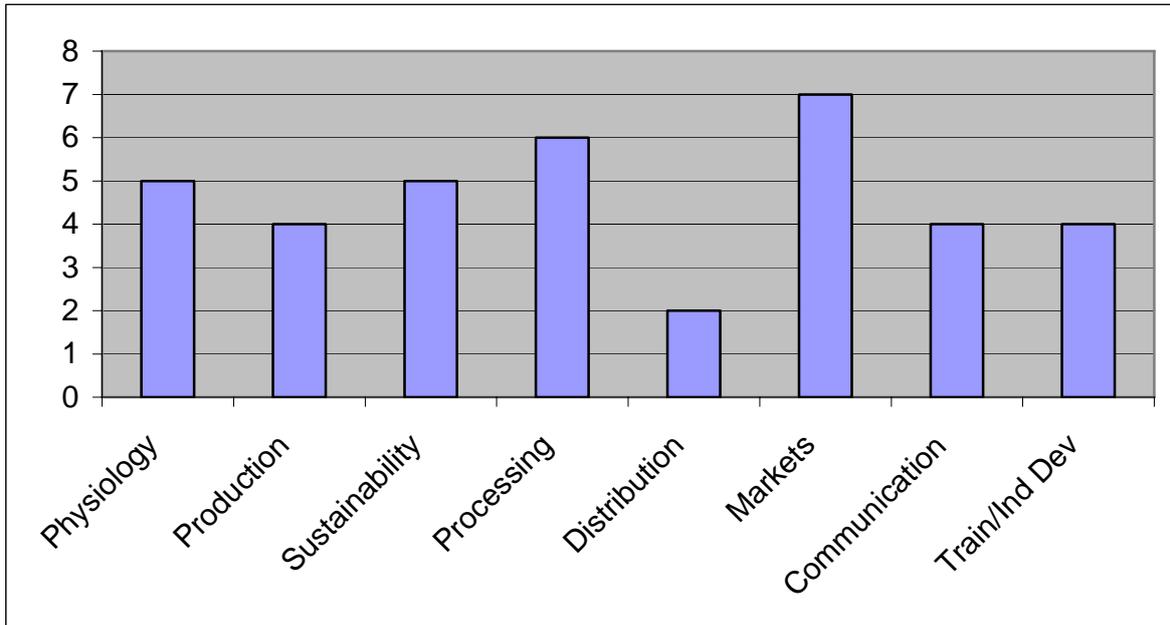


Source: AgEconPlus industry consultation

Highest priorities for *S. album* research relate to the processing of Indian sandalwood oil, understanding plant physiology and genetics to maximise oil production and minimise maturation times, markets, communication and industry development and training.

S. Spicatum research priorities are shown in Figure 2.

Figure 2 Western Australian Sandalwood (*S. spicatum*) Research Priorities



Source: AgEconPlus industry consultation

Highest priorities for *S. spicatum* research relate to market research, processing, plant physiology and genetics and sustainability.

6. Study Conclusions and Recommendations

The Australian sandalwood industry is set to dominate world supply of sandalwood oil. Substantial gaps in the industry’s knowledge in relation to processing, plant physiology, markets, sustainability and industry development remain. There is a role for RIRDC in the provision of public good research that fills the gap between industry need and non-proprietary research interests. The findings from this report should inform future priorities in the Essential Oils and Plant Extracts sub-program.

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Appendix 1: Research Completed

Sandalwood Research News Publications 1993 to 2006

Year	Sandalwood Research Newsletter Publication
2006	Preliminary analysis of Indian sandalwood oil from a 14-year-old plantation at Kununurra, WA Evaluation of heartwood and oil characters in 9 populations of <i>S. austrocaledonicum</i> from Vanuatu Grafting of sandalwood in Vanuatu Molecular and morphological phylogeny of sandalwoods: Insights for biogeography and taxonomy
2005	Variation in heartwood oil composition of young sandalwood trees in the south Pacific Indian sandalwood: Genetic and oil diversity, biochemistry of the Australian germplasm collection
2004	<i>Santalum insulare</i> (Bertero ex A. DC.): Distribution and ecology Current growth rates and predicted yields of <i>S. spicatum</i> grown in plantation in south-western Aust Sandalwood growers network gains momentum
2003	Growth performance of sandal (<i>Santalum album</i> L.) with different host species Relationship between girth and percentage of oil in trees of <i>S. album</i> provenances Hopping into a bright future - The woylie sandalwood story Genetic diversity between sandal populations of different provenances in India Edaphic, environmental and genetic factors associated with growth and adaptability of <i>S. album</i> in provenances
2002	Indian sandalwood industry in Australia Competitive effects within and between <i>Santalum album</i> and pot host <i>Alternanthera dentata</i> A note on peroxidase reagents to distinguish between high and low yielders of sandal (<i>Santalum album</i>) in the field Somatic embryo irregularities in in vitro cloning of sandal Techniques to improve sandalwood (<i>Santalum spicatum</i>) regeneration at Shark Bay, Western Australia Sandalwood work in SPRIG
2001	Clonality in remnant populations of <i>Santalum lanceolatum</i> Longitudinal variation in the yield and composition of sandalwood oil from <i>Santalum spicatum</i> Mass cloning of <i>Santalum album</i> L. through somatic embryogenesis: scale up in bioreactor Current sandalwood seed source in Timor island Preliminary results from <i>Santalum macgregorii</i> ex situ conservation planting Sandalwood re-visited in Western Australia East Timor (Timor Timur) sandalwood plantation development: a feasibility study An overview of <i>Santalum album</i> research in Sri Lanka Queensland sandalwood (<i>Santalum lanceolatum</i>): Regeneration following harvesting
2000	Status and current interest in sandalwood in Fiji Can sandalwood in East Nusa Tenggara survive? Lessons from the policy impact on resource sustainability Testing growth and survival of four sandalwood species in Queensland Sandalwood work on 'Eua, Kingdom of Tonga <i>Santalum album</i> in the Top End, Northern Territory, Australia The influence of pot host species seedling age and supplementary nursery nutrition on <i>S. album</i> plantation est, WA

Year	Sandalwood Research Newsletter Publication
1999	Sandalwood (<i>Santalum spicatum</i> (R.Br.) A. Dc.) excavation study Somatic embryogenesis in <i>Santalum album</i> L <i>Santalum macgregorii</i> F. v. Muller in Papua New Guinea
1998	Nutrition studies on young sandalwood seedlings in the absence of hosts Sandalwood work in the South Pacific Regional Initiative on Forest Genetic Resources Project
1997	Direct somatic embryogenesis from mature embryos of sandalwood Workshop on sandalwood in Papua New Guinea
1996	<i>Santalum lanceolatum</i> in Queensland <i>Santalum austrocaledonicum</i> seed germination study Forthcoming roving sandalwood workshop
1995	Sandalwood - Scope for commercial propagation on community lands in India Sandalwood Workshop, 1-11 August 1994, Noumea, New Caledonia
1994	The effect of host plants on the growth of sandalwood seedlings (<i>Santalum album</i> Linn.) Selection of sandalwood (<i>Santalum album</i>) candidate plus trees in Timor Tengah Selatan district The need for increased <i>Santalum</i> species research collaboration for germplasm conservation Genotypic variation in <i>Santalum album</i> Germplasm conservation of sandalwood Determining heartwood oil content within <i>Santalum album</i> and <i>S. spicatum</i>
1993	Self and cross pollination in <i>Santalum spicatum</i> and <i>S. album</i> Determining heartwood formation within <i>Santalum album</i> and <i>S. spicatum</i> Introduction and overview of <i>Santalum</i> research in Kununurra

Source: www.jcu.edu.au/school/tropbiol/srn/index.html