An Overview of Sandalwood and the Development of Sandal in Farm Forestry in Western Australia

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Abstract

Of the four species of *Santalum* that occur naturally in Western Australia (*S. spicatum, S. lanceolatum, S. murrayanum* and *S. acuminatum*), only *S. spicatum*, and to a much less extent *S. lanceolatum*, is commercially harvested for sandalwood. Western Australia has maintained an almost entirely export-oriented sandalwood industry for more than 150 years. *S. spicatum* is mostly used for the manufacture of joss sticks in Southeast Asia, although new uses have recently been developed. *S. spicatum*, which occurs naturally in the wheatbelt and rangeland regions of Western Australia, is the focus of a research program aimed at understanding its natural regeneration requirements and its establishment in tree farms on agricultural land. *S. album* (Indian, or East Indian sandal) has a higher santalol oil content, faster growth rate, and larger tree habit than other *Santalum* species. It is the centre of a research program aimed at the development of an irrigated sandal tree-farm resource in northern Western Australia. As with most *Santalum* species, *S. album* silviculture is complex due to its parasitic requirements. A reliable nursery and silvicultural system has been developed and is routinely used. A tree-farm resource of both *S. spicatum* and *S. album* will supplement the green-wood harvest of *S. spicatum* from natural stands in the arid rangelands. The need for a coordinated approach to marketing the world's remaining supplies of sandalwood is discussed. It is important that the maximum value of this important resource is realised, and that the future global sandalwood industry is sustained.

Key words: sandalwood, Western Australia, research, management, *S. album*, *S. spicatum*, tree farm

THE WIDELY DISTRIBUTED and economically important *Santalum* genus consists of 16 species (Hamilton and Conrad 1990; Barrett and Fox 1995), which are xylem-tapping root hemi-parasites with a highly valued aromatic heartwood. Four *Santalum* species are native to Western Australia: *S. spicatum* (R.Br.) A.DC., *S. acuminatum* (R.Br.) A.DC., *S. murrayanum* (Mitchell) C. Gardn., and *S. lanceolatum* R.Br. (Hewson and George 1984). Of these, only *S. spicatum* has commercial significance. As in most regions with natural *Santalum* stands, sandalwood exploitation in Western Australia has a long and coloured history. The development of a reliable sandalwood silvicultural system is intrinsically complex due to its parasitic habit. This paper gives a succinct overview of the status of management and current research on sandal in Western Australia.

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History of the Western Australian *Santalum spicatum* Industry

Western Australian *S. spicatum* has provided the basis of a small but important export industry since the early 1840s. The boom period of the sandalwood industry (1860s–1920s), which was associated with unregulated marketing procedures and harvesting controls, lasted until 1929 (Applegate and McKinnell 1993). Between 1892 and 1901, some 50 000 t of sandalwood were exported from Western Australia; 14355 t were exported in 1920—the highest annual export quantity recorded (Statham 1990). The bulk of this wood was exported to China (Shinberg 1967; Statham 1990). However over-harvesting during this period lead to the accumulation of huge sandalwood stockpiles and to fears that the level of exploitation was not sustainable (Underwood 1954).

In 1923, in reaction to these concerns, the first serious attempts to control the Western Australian sandalwood industry occurred (Underwood 1954; Statham 1990). Western Australian Forest Department regulations were created to protect the commercial interests of sandalwood harvesters, conserve natural stands, and ensure that the Crown collected a sandalwood royalty. The 1923 regulations incorporated:

- an overall quota on production which was determined by government, but not to exceed 6000 tonnes;
- introduction of export licences;
- an increase in royalty payments; and
- the appointment of forest staff to enforce minimum size restrictions on harvesting, and check illegal sandalwood harvesting operations.

It was thought that these regulations would restrict supply, leading to an upward trend in world price and a reduction in the immense stockpiles of sandalwood.

The 1929 Sandalwood Act legalised the 1923 regulations. This Act also imposed a government set quota, of which only 10 per cent could come from private property; the Act also led to the creation of the Australian Sandalwood Company in 1930 (Statham 1990). Sandalwood exports continued until 1943 at an average of 1460 t per annum. For a two-year period (1944–45) sandalwood was not exported. It recommenced in 1946 from a very low base of 143 t, and has risen steadily since then, peaking at 2040 t in 1993 (Fig. 1).

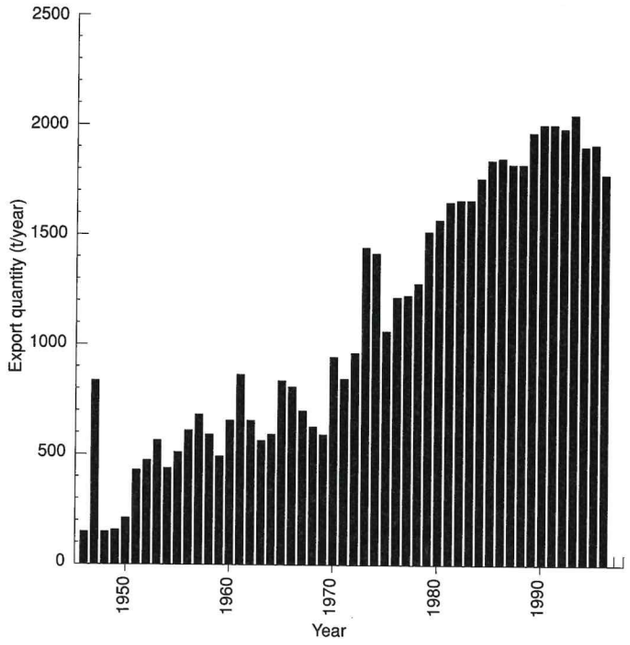

Figure 1. Western Australia sandalwood (*Santalum spicatum*) exports, 1946–96. (Sources: Statham 1990; CALM annual reports.)

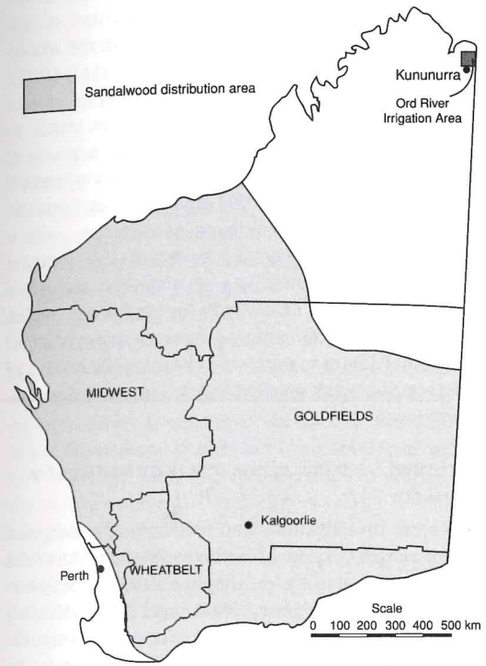

Figure 2. Distribution of *Santalum spicatum* in Western Australia. (Adapted from Hewson and George 1984; Loneragan 1990; Kealley 1991; Mitchell and Wilcox 1994; CALM data 1997).

Management and utilisation of *Santalum spicatum* in W.A.

The management of *S. spicatum* is controlled by the Department of Conservation and Land Management (CALM) in accordance with State legislation and departmental management plans (Kealley 1991). *S. spicatum* is distributed over 42 million hectares and there is an estimated sandalwood resource of 117000 t (CALM data 1996). *S. spicatum* is a shrub or small tree about eight metres high with a bushy growth habit (Hewson and George 1984; McKinnell 1990; Barrett and Fox 1995). It occurs naturally over a large area of Western Australia, from the edge of the high forest zone out to the desert interior (Fig. 2). It has virtually disappeared from the 300–600 mm rainfall zone due to widespread agricultural clearing (McKinnell 1990). A large proportion of the current *S. spicatum* population occurs on pastoral lease land where the predominant natural host species are *Acacia acuminata* Benth. and *A. aneura* F. Muell. ex Benth. (Loneragan 1990).

Revenue gained from sandalwood sales directly assists the conservation of *S. spicatum* and is used to fund the management and conservation of the population, which includes the purchase of pastoral leases for conservation reserves, silvicultural and ecological research, plantation establishment and resource inventories.

To ensure that *S. spicatum* is managed on a sustainable basis, harvesting is strictly controlled through a limited number of harvesting contracts issued to private sector sandalwood pullers. Harvesting contracts are issued for specific supply areas, and the quota for each contract is related to the sustained yield of that area. Minimum stem diameter limits for living trees are imposed at harvesting. These limits are calculated on the basis of the population distribution within defined landforms. Dead trees of any size are harvested, since fire or drought readily kills *S. spicatum* trees (Kealley 1987; McKinnell 1990). Harvesting live trees is strictly controlled to ensure that two-thirds of living trees on particular landforms are retained. Current harvesting procedures produce a 1:1 ratio of dead and green heartwood. Virtually the whole tree is utilised down to about 2 cm diameter pieces, including root and branch heartwood and bark material. The identification of alternative uses of *S. spicatum*, such as oil distillation for aromatherapy and medicinal purposes, to supplement the traditional Southeast Asia market use for joss stick manufacturing is ongoing. CALM retains full possession of the sandalwood resource from harvesting to sale, with harvesting, transport, processing and marketing conducted by the private sector on a contract basis.

Recent technological advances have allowed CALM to conduct a number of specific projects aimed to further improve CALM's management of *S. spicatum*. These include the utilisation of remote-sensing techniques to gather inventory data of the widely distributed population. Coupled with this inventory program is the phenotypic selection of candidate *S. spicatum* 'plus' trees. This initiates the first stage of a tree breeding program which will ultimately supply seed for direct-sowing regeneration in the rangelands, and tree-farm establishment in the higher rainfall agricultural zones. A *S. spicatum* tree-

farm resource may supplement the harvest from natural stands.

Santalum spicatum ecology in the W.A. rangelands

The majority of *S. spicatum* harvesting in Western Australia occurs in the arid pastoral regions of the Goldfields and Midwest: the rangelands (Fig. 2). Inventories have shown that regeneration is generally poor on developed and grazed pastoral leases (Kealley 1991). Also, it is heavily grazed by domestic and feral herbivores, such as sheep, goats and rabbits (Loneragan 1990). To conserve sandal and promote regeneration in the rangelands, CALM has purchased Jaurdi, Mt Elvire and Goongarrie and Burnerbinmah pastoral leases over the past ten years. These stations have been de-stocked of sheep, and goats are controlled through mustering and eradication programs. CALM is currently developing cooperative management schemes that provide incentive for other leaseholders to better manage the *S. spicatum* population on their leases.

Long-term trials have been established on these stations to monitor *S. spicatum* recovery after de-stocking. Besides grazing, the trials are also examining other factors affecting regeneration such as host species and soil type (Brand 1996). *S. spicatum* seeds have been sown beneath many potential host plants in the rangelands, mainly from the genera *Acacia*, *Senna* and *Eremophila*. The potential hosts grow on a variety of land types including granite outcrops, greenstone ridges, sandplains, washplains and saline soils. A better understanding of suitable host species and of soil types in which to grow *S. spicatum* will help future regeneration programs in the rangelands.

S. spicatum root biomass and oil content are being investigated to determine whether a higher proportion of root should be harvested. The commercial value of *S. spicatum* roots that remain after conventional harvesting is not known. If a significant proportion of the *S. spicatum* root is not extracted using conventional harvesting techniques, then a new technique could be used to increase tree utilisation. This harvesting procedure would have to be practical in terms of time efficiency and cost.

Santalum spicatum tree-farm systems for the W.A. wheatbelt region

Research into the establishment of commercial *S. spicatum* tree farms in the wheatbelt has also been conducted by CALM for more than ten years. The objective is to establish *S. spicatum* on farms with a medium to high annual rainfall (400–600 mm). Planting *S. spicatum* would also form part of the revegetation program to reduce salinity in the wheatbelt (Havel and McKinnell 1993; Bailey et al. 1997).

S. spicatum is commonly established by direct seeding beneath 1–2 year-old host trees, such as *A. acuminata*. This simple technique is a practical method of incorporating *S. spicatum* into wheatbelt farm forestry programs. Establishment success and initial growth rates have been encouraging, with a mean annual diameter increment of 7.5 mm (at 150 mm). This growth-rate is very fast compared with trees growing naturally in the rangelands, which normally have an annual diameter increment of 1–2 mm. Current research is examining the effects of host species, stocking rates and soil types on *S. spicatum* growth.

Irrigated *Santalum album* tree-farm systems for northern W.A.

Recent investigations into techniques for irrigated *S. album* plantations in northern Western Australia also have the objective of supplementing the *S. spicatum* green-wood harvest from natural stands (Kealley 1991). Indian sandalwood, due to its religious significance and high heartwood santalol oil content, is the most economically important of all *Santalum* species (Srinivasan et al. 1992; Radomiljac et al. 1998b). With very few exceptions, *S. album* has endured a level of exploitation unrivalled by other timber species.

S. album tree farm development in northern Western Australia has been made possible by an immense man-made dam near Kununurra which supplies water to flood-irrigate 13000 hectares of agricultural land known as the Ord River Irrigation Area (ORIA) (Fig. 2) (Radomiljac and Borough 1995). The establishment of *S. album* and other tropical timbers within the ORIA also has the objective of ameliorating the imminent problem of a rising ground-watertable Rising ground-watertables and ground-water salinisation have reduced the productivity and sustainability of irrigated agricultural schemes worldwide.

A series of recent silvicultural studies has identified a protocol for *S. album* silviculture; as for other *Santalum* species, this silvicultural system is more complex than traditional monocultural systems as it involves the establishment of a debilitating root hemi-parasite (Radomiljac 1998; Radomiljac et al. 1998a).

Global sandalwood production has declined markedly over the past 20–30 years (Srinivasan et al. 1992; Havel and McKinnell 1993; Radomiljac et al. 1998b), due to:

- unsustainable exploitation and spike disease (Rai 1990);
- uncontrolled fire and grazing (Havel and McKinnell 1993);
- illegal harvesting (Murthy 1985);
- inappropriate plantation silvicultural systems (Harisetijono and Suriamihardja 1993); and
- regulations that are a disincentive to *Santalum* conservation (Husain 1983).

The comparative advantage of *S. album* tree farms at ORIA is that there are no evident impediments to successful plantation development. There has been no report of major *S. album* pest and disease problems, a sound silvicultural system has been developed and is now routinely used, uncontrolled fire and grazing do not occur, and the ORIA is close to major Southeast Asian markets.

Nursery propagation commences in October and it usually takes about nine months to raise robust *S. album* seedlings. Seed propagated *S. album* is raised in large nursery containers. Three months after germination, cuttings of a herbaceous pot-host (*Alternanthera* spp.) are placed into each seedling container (Radomiljac 1998). This parasite-host combination continues throughout the nursery phase and into the early stages of field establishment. Intermediate and long-term host seedlings are raised simultaneously in the nursery, and are strategically placed in the field at establishment. Field establishment occurs in June and July. The long-term host, which must persist as the final host for the entire rotation-length, is planted up to four metres from the *S. album* seedling. The rotation-length for ORIA tree farms is still unclear, but is estimated to be 25–30 years. An intermediate host is planted between the *S. album* and long-term host seedlings. The intermediate host is parasitised for 4–5 years, until it dies (Radomiljac and McComb 1998). Superior intermediate hosts are usually fast-growing, short-lived leguminous trees (Fig. 3) (Radomiljac and McComb 1998).

Rather than considering *S. album*'s parasitic requirements an impediment to tree-farm development, the current research program is investigating the incorporation of one or more high-value timber species in the silvicultural system to act as long-term hosts. A biodiverse farm forestry system, producing two or more high-value timber products, appears possible.

International Sandalwood Management and Marketing Cooperation

A period of sandalwood scarcity is looming in both India and Indonesia, the main producers of *S. album*. In these countries, the decline in the sandalwood resource is due to heavy pressure for clearing forested land for food production, the destruction of sandal host trees for wood products such as fuelwood, and illegal harvesting (Srinivasan et al. 1992; Havel and McKinnell 1993). For example, in India the volume in the official sales of sandalwood from the two main producing States, Karnataka and Tamil Nadu, has declined. Also, whereas 25 years ago only 10 trees were harvested to produce a tonne of sandalwood, about 100 trees are required now (Karnataka and Tamil Nadu State Forest Department data), indicating that the average size of *S. album* trees being harvested has fallen significantly. This is strong evidence of serious resource decline.

There is interest in *Santalum* species plantation establishment in response to the pressures on sandalwood supplies. In many developing countries, a major incentive to plantation establishment is the increasing pressure for conversion of natural forest land to agriculture. This means that increasing demands for timber supplies must be met, at least in part, by producing more timber from intensively managed plantations. For *Santalum*, plantations are the only way to redress increasing problems of resource availability of this important genus (Hamilton and Conrad 1990).

It is important that the Indian supply of sandalwood be maintained: if it disappears, there are potentially serious downstream effects for Australia and South Pacific producers such as PNG, Vanuatu and Fiji. If the natural sandalwood market collapses due to supplies declining below a certain level, there could be three serious outcomes for those countries. First, there would be overwhelming pressure to overharvest to compensate for the loss of the Indian resource, thus destroying current management programs, and possibly leading to the loss of some species. Second, the opportunity to develop viable and sustainable industries based on *S. yasi*, *S. macgregori* and *S. austrocaledonicum* in the smaller South Pacific countries would be lost. Third, alternatives to sandalwood or sandalwood oil may be found, making it difficult to recapture the market when plantation sandalwood becomes available.

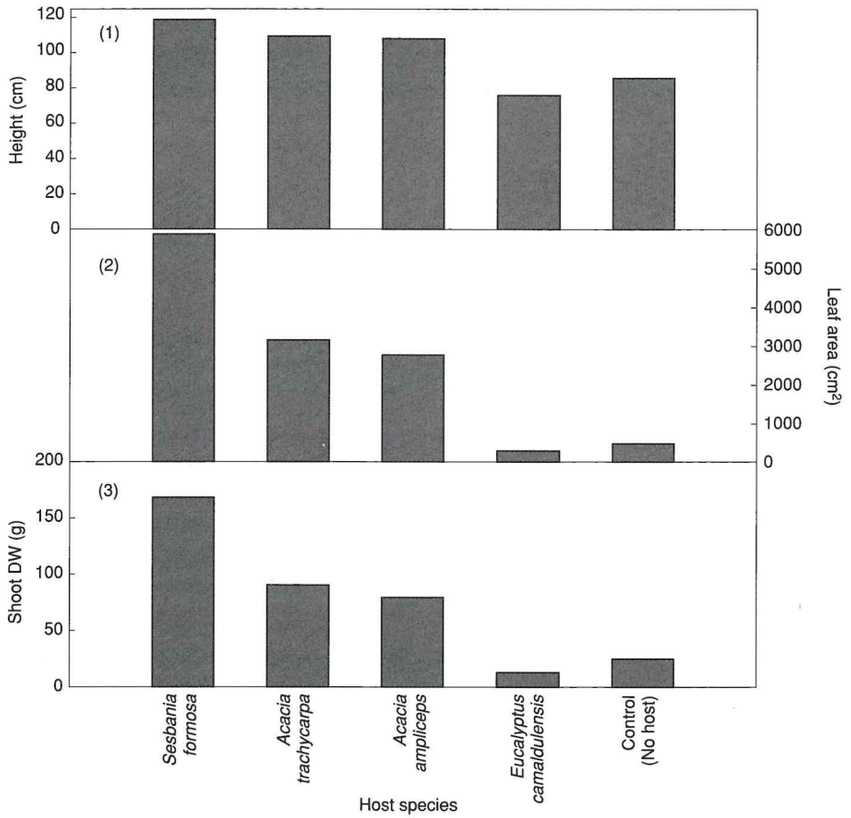

Figure 3. *Santalum album* (i) mean height, (ii) mean leaf area and (iii) mean shoot dry-weight (DW) whilst grown with *Sesbania formosa* (Papilionaceae), *Acacia trachycarpa* (Mimosaceae), *A. ampliceps*, *Eucalyptus camaldulensis* (Myrtaceae), and as a no-host control for 38 weeks as single-plant pairings in 25-litre pots under nursery conditions, near Kununurra.

The benefits of a coordinated sandalwood marketing strategy are clear in light of the looming global sandalwood supply crisis. A fragmented sales approach, such as in Indonesia, PNG, Vanuatu and Fiji, allows many buyers to purchase sandalwood from a position of strength, often offering low prices for premium sandalwood logs (Gjerum et al. 1995). This cheaply purchased wood is either on-sold at greatly inflated prices or stockpiled to wait for supply levels to fall further. The production and marketing of sandalwood is shrouded with mystique and secrecy which makes the task of gaining reliable information on global supply trends and prices very difficult. This creates large discrepancies in trade between large and small producers. For example, both India and Indonesia supply sandalwood from the same species, *S. album*, and therefore one would assume that the product quality is similar. However India receives about US$13 000 per tonne, whereas Indonesia prices are as low as US$4000–5000 (Radomiljac et al. 1998b). A further complication to sandalwood marketing is the large volume of traded illegal wood. This trade not only threatens the future supply of sandalwood from natural stands, but also severely undercuts the value of legally produced wood.

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