Chapter 6

SANDALWOOD OIL

DESCRIPTION AND USES

The term sandalwood has been applied at various times to oils from several different sources. Today, almost all the sandalwood oil traded internationally is so-called East Indian sandalwood oil distilled from the heartwood and roots of *Santalum album*. Australian sandalwood oil from *S. spicatum* and West Indian and African "sandalwood" oils are no longer produced. Unless otherwise stated the following discussion relates to the East Indian type from *S. album* (referred to, here, simply as sandalwood oil).

Sandalwood oil has a characteristic sweet, woody odour which is widely employed in the fragrance industry, but more particularly in the higher-priced perfumes. It has excellent blending properties and the presence of a large proportion of high-boiling constituents in the oil (about 90 percent santalols) also makes it valuable as a fixative for other fragrances. In India, where it is produced, it is used in this manner for the manufacture of traditional attars such as rose attar; the delicate floral oils are distilled directly into sandalwood oil.

WORLD SUPPLY AND DEMAND TRENDS

Markets

India and Indonesia are the two major producers and exporters of sandalwood oil but reliable production data are not available. Domestic consumption, which is certainly high in India and probably greater than the combined total for the rest of the world, is therefore also difficult to estimate. World production/consumption is probably of the order of several hundreds of tonnes annually.

Indian exports of sandalwood oil for the period 1987/88-1992/93, together with destinations, are shown in Table 10.

The United States and France are the two largest importers of Indian sandalwood oil. Imports into the former Soviet Union have fallen in the last two years and no early recovery of this market is expected. Imports into the Middle East have increased.

The USA is also the chief destination for Indonesian exports and thus represents the biggest market for sandalwood oil outside India.

Indonesian exports for 1987-92 are shown in Table 11.

Demand for sandalwood oil fell sharply in the 1970s as a result of very high prices and competition from synthetic substitutes. However, this largely affected the lower-priced formulations and the natural oil has retained its market in the top grade products. Demand now is influenced mostly by supply factors and the way in which this affects prices.

Supply sources

Indian exports over the last six years (Table 10) have averaged about 40 tonnes pa, with no distinct trend over the period. Production is based almost entirely on exploitation of wild trees. The lack of production or domestic consumption data make it impossible to judge the state of the

supply base and whether this (and the level of exports) is likely to change in the future.

Indonesia is the only other supplier of East Indian-type sandalwood oil. Recorded annual exports over the six years 1987-92 (Table 11) averaged 15 tonnes.

Australian production of oil from *Santalum spicatum* ceased in 1971. Exports for the ten years to that date averaged less than 3 tonnes annually.

Quality and prices

There is an international (ISO) standard for sandalwood oil (ex *Santalum album*) which stipulates a minimum free alcohols (santalol) content of 90 percent (m/m). Ranges within which various physico-chemical properties must fall are also given. In the United States, an EOA standard specifies the same minimum santalol content. As a perfumery oil, the aroma characteristics are all-important and these are judged by the buyer to be acceptable or not for individual consignments.

Sandalwood oil is one of the most highly priced items in the essential oil trade, reflecting the nature of the raw material source and the tightness of supplies. In the late 1980s it was fetching almost US$200/kg. Throughout 1992 the price of oil of Indian origin offered by London dealers was about US$140-150/kg; Indonesian oil was about US$5 lower. In mid-1993 the price of Indian oil rose again to US$180/kg and this was still the price in early 1994.

PLANT SOURCES

Botanical/common name

Family Santalaceae:

Santalum album Linn.
(Sandalwood)

Other *Santalum* species occurring in Australia and islands of the Pacific have been, or are, harvested for their fragrant wood, although none (with the possible exceptions of very small quantities of *S. austrocaledonicum* and *S. yasi*) are currently used as sources of internationally traded oil. These include *S. spicatum* and *S. lanceolatum* (Australia), *S. ellipticum* (Hawaii), *S. yasi* (Fiji and Tonga), *S. macgregorii* (Papua New Guinea), *S. austrocaledonicum* (Vanuatu and New Caledonia) and *S. insulare* (French Polynesia).

Description and distribution

S. album is a small to medium-sized evergreen tree, sometimes reaching up to 18 m in height and 2.5 m in girth. It is a root parasite and successful regeneration (both natural and artificial) requires, amongst other things, suitable host plants.

S. album occurs naturally in India, Sri Lanka and the Malay Archipelago (Indonesia and surrounding islands). In India it is found in the drier regions in the south of the country, especially the states of Karnataka and Tamil Nadu, up to 1400 m. Formation of heartwood, from which the oil is obtained, is said to be best between 600 m and 900 m. Moderate rainfall (850-1200 mm) spread over several months and much sunshine are conducive to good growth. Sandal has become naturalized in parts of Rajasthan, Maharashtra, Madhya Pradesh and Uttar Pradesh and has been introduced into a number of other Indian states. The wood of trees outside their natural range, however, is very variable with respect to oil content and sometimes has little or no aroma.

In Indonesia, *S. album* occurs on the neighbouring islands of Timor, Sumba, Flores, Alor and Roti, although there is now only a significant population on Timor.

Effects of oil production on the natural resource

Cultivation of sandal in India has had limited success. While it might be expected that the destructive nature of sandalwood oil production, which entails the uprooting of mature trees, would put inexorable pressure on the wild resource there is little or no quantitative information available on which to judge the extent to which this might have occurred. Sandal trees freely produce seed and natural regeneration occurs both via seedlings and through root suckers which are produced when the tree has been felled and the stump extracted from the ground. The absence

of heartwood in young trees provides little reason for felling trees less than 20-25 years old so they are allowed to grow to at least this age. The extent of heartwood formation is at its maximum at around 30-50 years.

The greatest threat to Indian sandal may be loss through spike disease rather than oil production. Trees of all ages and sizes are liable to be attacked and, if infected, succumb to the disease within about three years.

In Indonesia, continuous harvesting combined with very little regeneration (due to fires, shifting cultivation and uncontrolled cattle grazing) has led to a serious decline in the *S. album* population.

Elsewhere, too, the consequences of destructive harvesting (either for oil production or for sale of the log for incense production [see PRODUCTS OTHER THAN OIL]) are being increasingly recognized and some attempts have been made to quantify loss of the resource. In 1985 it was estimated that live *S. spicatum* stands in Western Australia were sufficient for a further 23 years harvesting before depletion, although favourable technical and economic changes could extend this period. Collection of dead wood (which forms an increasing proportion of the harvested logs) will contribute to a further extension.

HARVESTING/PRIMARY PROCESSING

In India, trees above 60 cm girth are harvested during the post-monsoon period. In areas affected by spike disease only dead and dying trees are harvested. After uprooting, the wood is cut into billets which are then transported to a central depot. The sapwood and heartwood parts of the trunk are clearly demarcated and sapwood is removed accordingly. Roots are primarily heartwood and require no initial division. The value of the wood and the high price that it fetches make smuggling something that the authorities have to contend with.

In preparation for distillation the billets of wood are chipped and then reduced to a powder. Most sandalwood oil is now produced by steam distillation of the powder. In former times direct water distillation, in which the raw material is immersed in water and distilled, was used. The high-boiling nature of the oil makes distillation rather slow and it takes many hours to complete.

Yields and quality variation

The yield of heartwood varies from locality to locality and the age of the tree. In India, trees of 100 cm girth have been reported to yield between 85 kg and 240 kg of heartwood according to the area from which they come.

The yield of oil is highest in the roots, about 10 percent (as received basis), and lowest in chips which are a mixture of heartwood and sapwood (1.5-2 percent). The oil content of the heartwood varies from tree to tree and is higher for older trees. In India, yields of about 0.9 percent have been reported from the heartwood of 10-year old trees, while mature trees of 30-50 years age have yielded 4 percent oil. The oil content also varies according to the colour of the heartwood. Light-coloured wood yields 3-6 percent oil, while dark brown wood yields about 2.5 percent oil.

Oil from the younger trees also has a slightly lower proportion of santalols than the mature trees (ca 80 percent cf 90 percent), another reason for not harvesting at too young an age.

VALUE-ADDED PROCESSING

No further processing of the oil is carried out until it is prepared for fragrance use by the end-user.

PRODUCTS OTHER THAN OIL

Sandalwood is much prized as a wood for carving and is used for making souvenirs and other items requiring fine workmanship. In India sapwood of sandal is used for wood turning, particularly toy making; the wood comes mainly from trimmings and immature trees killed by spike disease.

Sawdust from heartwood prepared for distillation is valuable enough to be collected and sold for

use as an incense for religious purposes as well as for scenting clothes and cupboards.

Outside India, where exports of logs are prohibited, there is a thriving market for sandalwood as an incense in joss-stick manufacture. Australia supplies most of this market at present, mainly from *S. spicatum* which has a low oil content and which is, therefore, less attractive as a direct source of oil. Exports of logs from Western Australia were almost 2,000 tonnes in 1989, valued at A$11.5 million. Log exports from other sources have amounted to a few hundred tonnes or less from individual species.

The cotyledons and kernel of sandal seeds contain a fixed oil which has drying properties. Oil-free sandal seed meal is rich in protein and could be utilized as an animal feed if available in sufficient quantities.

DEVELOPMENTAL POTENTIAL

The nature of sandalwood oil and its origin in the heartwood of mature trees makes it an oil that although high in value is not attractive as a short or medium-term source of income for those who might consider cultivating the tree. In India, under natural conditions in the forest, sandal is slow-growing. Growth rate may be increased by improvement of soil fertility and other measures but vigorous growth leads to much reduced heartwood formation. Assuming that existing propagation and cultivation problems can be overcome, opportunities for utilizing sandal as anything other than a long-term cash crop are likely to depend on the identification of elite trees as a source of material for planting. This in turn requires the establishment of a wide-ranging screening programme to search for such trees, not only within *S. album* but amongst other species of *Santalum*. Production of oil from superior trees might then offer possibilities for commercial exploitation in the smaller island communities of the Pacific.

Research needs

Although sandal is highly valued, most research in India has focused on spike disease and little work has been done on the silvicultural and genetic aspects of sandal cultivation. Despite much effort, however, complete characterization of the mycoplasma-like organism believed to be responsible for the disease has still not been achieved. Research is still required to elucidate the precise cause of the disease and the best form of treatment if the risk of infection is not to make sandal cultivation for oil production an unacceptable investment risk.

Research needs include the following:

- Investigation of the intrinsic variability in oil yield and quality within natural populations of *S. album* at the provenance and individual tree level. Indonesia and other sources outside India (where most research to date has been undertaken) should be particularly targeted for sampling. It is known for other genera which occur naturally in Asia (*Pinus*, for example) that marked differences can occur between continental and insular populations of the same species.

- Correlation of heartwood and oil content of trees from natural populations of *S. album* outside India. Very little information is available on the growth characteristics of Indonesian trees and the rate at which they produce heartwood.

- Provenance trials to determine the relative performance of different *S. album* populations.

- Consolidation of tree improvement work already begun in India involving selection of plus trees for high oil content and resistance to spike disease.

- Investigation of oil yields and quality for species of *Santalum* other than *S. album*. The latter species appears to be richer in oil than most others but a systematic study of inter- and intra-species variability is needed to fill the gaps in the present state of knowledge. Where oil yields appear promising, quality assessment should be extended to end-user evaluation; chemical analysis alone is not sufficient to judge the commercial acceptability of oils intended for perfumery use.

- Development of improved propagation techniques and cultivation practices.

- Investigation of the suitability of other tree crops as hosts for cultivated sandal which might themselves serve as sources of income until the sandal is ready for harvesting.

SELECTED BIBLIOGRAPHY

ADKOLI, N.S. and KUSHALAPPA, K.A. (eds.)(1977) Proceedings of All India Sandal Seminar, Bangalore, 7-8 February, 1977. *Myforest*, Special Issue. 88 pp. Bangalore: Karnataka Forest Department.

EOA (1975) Oil of sandalwood East Indian. EOA No. 103. 1 p. Essential Oil Association of USA.

GUENTHER, E. (1952) Oil of sandalwood East Indian. pp. 173-187. In *The Essential Oils*, Vol. 5. New York: Van Nostrand Co.

HAMILTON, L. and CONRAD, C.E. (Tech. Coords.) (1990) *Proceedings of Symposium on Sandalwood in the Pacific, Honolulu, Hawaii, 9-11 April, 1990. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-122*. 84 pp. Berkeley, USA: USDA, PSRS.

ISO (1979) Oil of sandalwood (*Santalum album* Linnaeus). *International Standard ISO 3518-1979 (E)*. 2 pp. International Organization for Standardization.

MCKINNELL, F.H. (ed.) (1993) *Proceedings of Symposium on Sandalwood in the Pacific Region held at XVII Pacific Science Congress, Honolulu, Hawaii, 2 June, 1991. ACIAR Proceedings No. 49*. 43 pp. Canberra: ACIAR.

NAYAR, R. (1988) Cultivation, improvement, exploitation and protection of *Santalum album* Linn. *Advances in Forestry Research in India*, 2, 117-151.

RAO, P.S. (1987) Clonal multiplication of plants of economic value: sandalwood, mulberry and oil palm. pp. 225-229. In *Proceedings of Workshop on Increasing Crop Productivity, Bombay, 20-21 June, 1986*. New Delhi: Oxford and IBH.

SEN-SARMA, P.K. (1982) Sandalwood - its cultivation and utilization. pp. 395-405. In *Cultivation and Utilization of Aromatic Plants*. Atal, C.K. and Kapur, B.M. (eds). 815 pp. Jammu, India: Regional Research Laboratory, CSIR.

SHANKARANARAYANA, K.H. and PARTHASARATHI, K. (1984) Compositional differences in sandal oils from young and mature trees and in the sandal oils undergoing colour change on standing. *Indian Perfumer*, 28(3/4), 138-141.

STATHAM, P. (1990) The sandalwood industry in Australia: a history. pp. 26-38. In *Proceedings of Symposium on Sandalwood in the Pacific, Honolulu, Hawaii, 9-11 April, 1990. USDA Forest Service, Pacific Southwest Research Station, General Technical Report PSW-122*. Berkeley, USA: USDA, PSRS.

SURIAMIHARDJA, S. (1978) [Problems on sandalwood (*Santalum album* Linn.) silviculture and improving its production]. pp. 115-125. In *Proceedings of Third Seminar on Volatile Oils, Bogor, Indonesia, July, 1978*. Bogor: Balai Penelitian Kimia.

VERGHESE, J., SUNNY, T.P. and BALAKRISHNAN, K.V. (1990) (+)-a-santalol and (-)-b-santalol (Z) concentration, a new quality determinant of East Indian sandalwood oil. *Flavour and Fragrance Journal*, 5, 223-226.

YADAV, V.G. (1993) Sandalwood: its origin, synthetic substitutes and structure-odour relationship. *PAFAI Journal*, 15(4), 21-54.

Table 10
Exports of sandalwood oil from India, and destinations, 1987/88-1992/93
(tonnes)

	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93
Total	39	26	34	37	65	42
Of which to:						
France	11	8	14	10	8	9
USA	10	5	5	6	14	8
Soviet Union	7	2	4	7	2	-
Japan	3	2	2	2	4	2
UK	2	1	2	3	3	3
Switzerland	3	2	2	2	1	2
W. Germany	1	2	1	1	3	1
United Arab Emirates	1	~	2	4	5	3
Singapore	~	~	~	~	21	~
Oman	-	-	~	~	~	9

Source: Indian national statistics
Note: Year runs April to March

Table 11
Exports of sandalwood oil from Indonesia, and destinations, 1987-92
(tonnes)

	1987	1988	1989	1990	1991	1992
Total	22	19	12	13	10	13
Of which to:						
USA	16	12	7	10	1	6
Netherlands	2	3	3	-	6	-
Singapore	~	2	-	-	3	3
Switzerland	1	-	-	-	-	3

Source: Indonesian national statistics