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CROPWATCH

THE FIRST TRULY INDEPENDENT WATCHDOG FOR THOSE WORKING WITH NATURAL AROMATIC MATERIALS

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Cropwatch's Sandalwood Bibliography.

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Note: in this bibliography, articles on sandalwood are arranged by relevance to geographical origin rather than being arranged species-by-species. More information on the ecological status of individual *Santalum* species & general notes are available on Cropwatch's *Updated List of Threatened Aromatic Plants Used in the Aroma & Cosmetic Industries*. Please note also that where chemical formulae for certain sandalwood constituents are illustrated, some are added from the Cropwatch natural chemicals structure library.

***Contents*:**

Australian Sandalwoods.

***Cropwatch comments**: Australia has two commercially important Sandalwood spp.* (Santalum album & S. spicatum)*, and a number of other Sandalwood spp. of more minor economic importance* (*such as* S. acuminatum, S. lanceolatum*, and* S. murrayanum)*.*

Biocidal Properties of Australian Sandalwoods

Ritchie S.A., Williams C.R. & Montgomery B.L. (2006) "Field evaluation of New Mountain Sandalwood Mosquito Sticks and New Mountain Sandalwood Botanical Repellent against mosquitoes in North Queensland, Australia." *J Am Mosq Control Assoc*. **22**(1), 158-60. Abstract. The mosquito repellent efficacy of New Mountain Sandalwood Mosquito Sticks (containing 0.5% w/w essential oils) and New Mountain Sandalwood Botanical Repellent (containing soybean and geranium oils) was assessed. Tests were conducted in the field with 4 volunteers in a wooded area near Cairns, North Queensland, Australia. Predominant biting species were *Verrallina funerea* and *Ve. lineata*. A pair of burning Mosquito Sticks immediately upwind of the subject (acting as an area repellent) provided a 73.1% mean reduction in mosquito landing and probing over the 3-h test period. The Botanical Repellent and a DEET-based control were both 100% effective in preventing mosquito probing for 3 h. These data are consistent with other studies of area repellents in that such products provide significant protection from mosquito bites, albeit inferior to the protection provided by topically applied repellents.

Spafford H., Jardine A., Carver S., Tarala K., Van Wees M. & Weinstein P. (2007) "Laboratory determination of efficacy of a *Santalum spicatum* extract for mosquito control." *J Am Mosq Control Assoc.* **23**(3), 304-11. Abstract. The activity of QN50, a sequiterpene alcohol derived from Australian sandalwood (*Santalum spicatum*), was tested for its effectiveness against larvae of 2 mosquito species (*Culex molestus* and *Aedes camptorhynchus* [Diptera: Culicidael), nymphs of 2 species of water boatmen (*Micronecta robusta* and *Agraptocorixa* [Hemiptera: Corixidae]), immature *Daphnia* sp. (Crustacea), and mosquito eggs (*Cx. molestus*). In a series of laboratory bioassays, field-collected mosquito larvae, eggs, and immature corixids and daphnids were placed in beakers with either QN50, methoprene or source water only (control). The mosquito larvae exposed to QN50 had reduced survivorship and average longevity relative to the control and to methoprene at most concentrations used in this study. The hatching rate of mosquito eggs was unaffected by methoprene or QN50. Corixid nymphs and daphnids experienced high mortality in both methoprene and QN50 relative to the control, but there was no difference in the effect between the compounds. The results of this preliminary study suggest that further research into the mode of action and efficacy of QN50 as a potential alternative to methoprene for mosquito abatement is warranted.

Chemistry of Australian Sandalwoods

Adams D.R., Bhatnagar S.P. & Cookson R.C. (1975) "Sesquiterpenes of *Santalum spicatum*" *Phytochemistry* **14**(5-6), 1459-1460.

Birch A.J., Moslyn K.M.C. & Penfold A.R. (1953) "The sesquiterpene alcohols of *Eucarya spicata* Sprague & Summ." *Aust. J. Chem* **6**, 391-394. ***Cropwatch comments***: *Eucarya spicata* Sprague & Summ. Is the outdated botanical name for *Santalum spicata* R.Br.

Birch A.J., Chamberlain K.B., Moore B.P. & Powell V.H. (1970) "Termite attractants in *Santalum spicatum*." *Australian Journal of Chemistry* **23**(11), 2337-2341. Abstract. The oil of *Santalum spicatum* (R.Br.) A.DC. has been fractionated to yield 10-cis- (1) and 10-trans-2,6,10-trimethyldodeca-2,6,10-triene (2). These compounds have been synthesized by reduction of a

mixture of cis- and trans-farnesyl acetate. Although not identical with the trail pheromone of Nasutitermes they have similar specific trail activities, the former being the more active.

Brand J., Kimber P. & Streatfield J. (2006). "Preliminary analysis of Indian sandalwood (*Santalum album* L.) oil from a 14-year-old plantation at Kununurra, Western Australia." *Sandalwood Research Newsletter* **21.**

Braun N.A., Meier M. & Pickenhagen W. (2003) "Isolation & chiral GC analysis of beta-bisabolols - trace constituents from the essential oil of *Santalum album* L. (Santalaceae). *J. Essent. Oil Res.* **15**(1), 63-65.

Braun N.A., Mieir M., Schmaus G., Holsher B. & Pickenhagen W (2003) "Enantioselectivity in odor perception: synthesis and olfactory properties of iso-beta-bisabolol, a new natural product." *Helv Chim Acta* **86**(7), 2698-2708. Abstract. The odorous trace constituent iso--bisabolol (4) was isolated from East Indian and Western Australian sandalwood oil and synthesized by using the (E/Z)-triene 12 (iso--bisabolene) as a key intermediate. Only one of four stereoisomeric forms of 4, (6R,7R)-4a, is odor active, having a strong floral, muguet-like, very pleasant scent.

Braun N.A., Meier M., Kohlenberg B., Valder C. & Neugebauer M. (2003) "*Santalum spicatum* (R.Br.) A. DC. (Santalaceae) – nor-helifolenal and acorenol isomers: isolation & biogenic considerations." *J. Essen. Oil. Res*. **15**, 381-386.

Braun N.A. & Spitzner D. (2007) "Synthesis and natural occurrence of (Z/E)-β-and γ-curcumen-12-ol." ARKIVOC (vii) 273-279. Abstract: (Z/E)-β-Curcumen-12-ol (Z/E)-(1) was synthesized via Birch reduction of acid 6 starting from α-curcumene (5). An olefin isomerization of 1 is the key step in the synthesis of (Z/E)-γ-curcumen-12-ol (Z/E)-(2). Sesquiterpene alcohol (E)-1 was found for the first time in nature as a minor constituent of different *Santalum* species by using the synthetic sample as reference.

Bristow M., Taylor D. & Robson K. (2002) "Queensland Sandalwood (*Santalum lanceolatum*): regeneration following harvesting." *Sandalwood Research Newsletter* 2002. Abstract. In 1994, a trial, funded by Queensland Department of Primary Industries Forestry, was established near Hughenden investigating regeneration of natural stands of Queensland sandalwood from two harvestingmethods, vis, stump cutting vs. stump pulling. Merchantable size trees in five, one hectare plots wereharvested by the respective methods and vegetative regeneration was recorded over the successive fiveyear period. Overall indications are that retaining sandalwood stumps is unlikely to result in a greateramount or more successful coppice regeneration following harvesting than stump pulling, and that it may well result in less successful cpppice regeneration.. Data from the trial suggests that the propor-tion of pulled stumps that produce coppice is higher than the coppice produced through the cut stumpmethod, and these are more likely to survive. Concerns about the impact of stump pulling on soil prop-erties and erosion are unwarranted as the number of sandalwood removed from any area is relatively few and the area of soil disturbed during the operation is very small.

Bristow M. (2004) "Review of Agroforestry in Tropical Savanna Regions of Northern Australia." A Report for the RIRDC/Land & Water Australia/FWPRDC/MDBC Joint Venture Agroforestry Program Mar 2004. "# 2.4 Ord River early sandalwood plantation projects."

Brophy J.J., Fookes C.J.R. & Lassak E.V. (1991) "Constituents of *Santalum spicatum* (R. Br.) A. DC. Wood oil." *J. Essen. Record Res* **3**, 381-385.

Jones G.P., Rao K.S., Tucker D.J., Richardson B.J., Barnes A. & Rivett D.E. (1995) "Antimicrobial activity of *Santalum acuminatum* (quandong) kernels." *International Journal Pharmacognosy* **33**, 120-123.

Lawrence B.M. (2006) "Australian Sandalwood oil" in "Progress in Essential Oils" *Perf & Flavorist* **31** (Sept 2005), 62-65.

Lawrence B.M. (2009) “Australian Sandalwood oil” in “Progress in Essential Oils” *Perf & Flavorist* **34** (May 2009), 56.

Liu Y.D., Longmore R.B. & Kailis S.G. (1995) “A comparison of kernel compositions of sandalwood (*Santalum spicatum*) seeds from different Western Australian locations. *Mulga Research Centre Journal* **12**, 15-21.

Liu Y.D., Longmore R.B., Fox J.E.D. (1996) “Separation & identification of ximenynic acid isomers in the seed oil of *Santalum spicatum* R. Br. as their 4,4-dimethyloxazoline derivatives.” *Journal of the Americ. Oil Chemists Soc*. **73**(12), 1729-1731.

Liu Y.D., Longmore R.B. & Kailis S.G. (1997) "Proximate and fatty acid composition changes in developing sandalwood (*Santalum spicatum*) seeds." *Journal of the Science of Food and Agriculture* **75**(1), 27-30,

Liu Y.D., Longmore R.B., Boddy M.R. & Fox J.E.D. (1997) “Separation & identification of triximenynin from *Santalum spicatum* R. Br.” *Journal of the Americ. Oil Chemists Soc*. **74**(10), 1269-1272.

Loveys B.R., Tyerman S.D. & Loveys B.R. (2001) "Transfer of photosynthate and naturally occurring insecticidal compounds from host plants to the root hemiparasite Santalum acuminatum (Santalaceae)." *Australian J of Botany* **49**(1), 9-16. Abstract. Plant hemiparasites obtain a wide range of primary compounds from their host plants, including carbon, water and ions. In this paper, we examine the transfer of carbon from the host plant *Myoporum parvifolium* and the movement of an insecticidal compound from the host *Melia azedarach* to the root hemiparasite *Santalum acuminatum* (R.Br) (quandong). By using 14 C we determined that glucose was moving from the *M. parvifolium* host to the parasite while the carbon fixed by quandongs was found to be mostly in mannitol. Mannitol occurred in fruit, leaf, stem and root tissue and also in xylem sap. We also provide evidence from direct infusion electrospray mass spectrometry (DIEMS) that quandong fruit from trees growing near *Melia azedarach* (L.) contain an insecticidal compound. This was supported by results from a bioassay in which apple moth (*Epiphyas postvittana* Wal ker) larvae suffered higher mortality when fed only on quandong fruit that was growing nearM. azedarach than those fed on quandong fruit from trees growing away from *M. azedarach*.

Loveys B.R., Sedgley M. & Simpson R.F. (1984) “Identification and quantitative analysis of methyl benzoate in quandong (*Santalum acuminatum*) kernels. *Food Technology Australia.* **36**, 280-289

Moretta P., Ghisalbert E.L., Piggott M.J & Trengove R.D. (1998) “Extraction of oil from *Santalum spicatum* by supercritical fluid extraction.” *ACIAR Proceedings Series* **84**, 83-85. Abstract. Steam distillation, solvent extraction, supercritical fluid extraction (SCCO2) and liquid CO2 extraction were used to obtain the volatile oil from Western Australian Sandalwood (*Santalum spicatum* (R. Br.) A. DC.). Supercritical fluid extraction afforded the highest yields of extractable material and total volatiles. The percentages of five sesquiterpene alcohols, epi--bisabolol (1), (Z)--santalol (2), 2(E), 6(E)-farnesol (3), (Z)--santalol (4) and (Z)-nuciferol (5), were highest in the steam distillate. The variations in the relative amounts of these sesquiterpenes in the essential oil recovered by SCCO2 extraction of different sections of a single tree have been investigated. ***Cropwatch comments***: According to ISO 9235, the supercritical fluid extraction of aromatic material produces an extract; it cannot be termed an essential oil.

Moretta P. *et al*. (2001). "Longitudinal variation in the yield and composition of sandalwood oil from *Santalum spicatum*." *Sandalwood Research Newsletter* **14**, 5-7.

Marongiu B., Piras A., Porcedda S. & Tuveri E. (2006) "Extraction of *Santalum album* and *Boswellia carterii* Birdw. volatile oil by supercritical carbon dioxide: influence of some process parameters." *Flavour and Fragrance Journal* **21**(4), 718 - 724 Abstract. Wood of *Santalum album* and resin of *Boswellia carterii* Birdw. were used to obtain their volatile oils by means of supercritical fluid extraction with carbon dioxide. Different extraction conditions were tested: 90 bar, 45 °C; 120 bar, 60 °C; and 120 bar, 45 °C. On both matrices, a good process performance

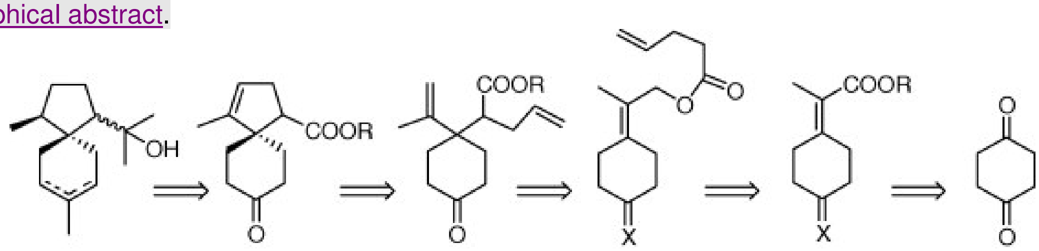
was obtained working at 120 bar and 45 ℃ (density of CO2 = 0.658 g cm-3) in the extraction vessel, at 20 bar and 15 ℃ in the separator and at CO2 flow of 1.5 kg/h. At these conditions the higher yields were obtained: 1.9% for *S. album* and 6.5% for *B. carterii.* The main compounds contained in the sandalwood volatile oil were: -santalol (46.1%), -santalol (20.4%), epi--santalol (6.8%) and trans--bergamotol (5.4%). In the corresponding HD essential oil the -santalol and -santalol contents were lower: 35.0% and 14.0%, respectively. The volatile oil of B. carterii were made up of incensole acetate (32.0%), octanol acetate (25.1%), incensole (17.8%) and phyllocladene (7.7%). The percentage of the main constituents in the oil obtained by HD was quite different. It contained larger amounts of octanol acetate (45.2%) and phyllocladene (13.2%) and lower amounts of incesole (6.1%) and incensole acetate (13.0%).

Penfold A. R. (1928) "Chemistry of West Australian Sandalwood oil." *J. Proc. Royal Soc. NSW.* **62**, 60-71.

Penfold A. R. (1932) "Chemistry of West Australian Sandalwood oil II." *J. Proc. Royal Soc. NSW.* **66**, 240-247.
Piggott M.J., Ghisalberti E.L. & Trengove R.D. (1997) "West Australian sandalwood oil: extraction by different techniques and variations of the major components in different sections of the same tree." *Fl. & Frag. J.* **12**, 43-46.

Shellie R., Marriott P. & Morrison P. (2004) " Comprehensive two-dimensional gas chromatography with flame-ionization and time-of-flight mass spectrometry detection: qualitative & quantitative analysis of West Australian sandalwood oil" *J Chromatog Sci*. **42**(8), 417-422. Abstract: The use of gas chromatography (GC)-mass spectrometry (MS), GC-time-of-flight MS (TOFMS), comprehensive two-dimensional GC (GCxGC)-flame ionization detection (FID), and GCxGC-TOFMS is discussed for the characterization of the eight important representative components, including *Z*-alpha-santalol, *epi*-alpha-bisabolol, *Z*-alpha-*trans*-bergamotol, *epi*-beta-santalol, *Z*-beta-santalol, *E,E*-farnesol, *Z*-nuciferol, and *Z*-lanceol, in the oil of West Australian sandalwood (*Santalum spicatum*). Single-column GC-MS lacks the resolving power to separate all of the listed components as pure peaks and allow precise analytical measurement of individual component abundances. With enhanced peak resolution capabilities in GCxGC, these components are sufficiently well resolved to be quantitated using flame ionization detection, following initial characterization of components by using GCxGC-TOFMS.

Srikrishna A. & Babu R.R. (2007) "Total syntheses of (±)--acorenol, β-acorenol, -epi-acorenol and β-epi-acorenol via an Ireland ester Claisen rearrangement and RCM reaction sequence." *Tetrahedron Letters* **48**(39), 6916-6919. Abstract. Total syntheses of (±)-- and β-acorenols and (±)-- and β-epi-acorenols, spiro[4.5]decane sesquiterpenes, isolated from the western Australian sandalwood oil, have been accomplished employing a combination of Ireland ester Claisen rearrangement and RCM reactions for an efficient construction of the spiro[4.5]decane present in acoranes.
Graphical abstract.



Valder C., Neugebauer M., Meier M., Kohlenberg B., Hammerschmidt F.-J., Braun NA (2003) "Western Australian sandalwood oil – new constituents of *Santalum spicatum* (R.Br) A DC. (Santalaceae)" *J. Essent. Oil Res.* **15**(3), 178-186. Abstract. Commercial Australian sandalwood oil produced from *Santalum spicatum* (R. Br.) A. DC. roots was analyzed using GC and GC/MS. Seventy constituents were identified: four monoterpenes, 64 sesquiterpenes and two others. Four compounds (Z)-beta-curcumen-12-ol, (Z)-12-hydroxysesquicineole, 6,10-epoxybisabol-2-en-12-ol andnor-helifolen12-al were found to our knowledge for the first time in nature and were

characterized using^sup 1^H-,^sup 13^C-NM MR, GC/FTIR and GC/MS analyses. ***Cropwatch comments***: The authors show lower concentration of *cis*- alpha santalol & *cis*-beta santalol, higher conc of (*Z*) *trans*-alpha bergamotol & epi-beta-santalol in the oils of *S. spicatum* compared with *S. album.* Regarding the bisabolols, the main isomer in *S. spicatum* is 6R, 7S-epi-beta-bisabolol whereas in *S album* it is 6R, 7S-beta-bisabolol. The oils should therefore be regarded as different

Valder C., Neugebauer M., Meier M., Kohlenberg B., Hammerschmidt F.-J., Braun N.A. (2003a) "*Santalum spicatum* (R.Br.) A DC. (Santalaceae) – nor-helifolenal & acorenol Isomers: Isolation and biogenic considerations" *J. Essent. Oil Res.* **15**, 381-386.

Wedding B.B., White R.D., Grauf S., Tilse B., & Gadek P.A. (2009) "Near infrared spectroscopy as a rapid, non-invasive method for sandalwood oil determination." Papers from the 11th Society for the Advancement of Breeding Research in Asia & Oceania Congress (SABRAO) In: *11th Society for the Advancement of Breeding Research in Asia & Oceania Congress (SABRAO), 10-14 August 2009, Cairns, QLD, Australia.* Abstract. Fourier Transform (FT) - near infra-red spectroscopy (NIRS) was investigated as a non-invasive technique for predicting -santalol content in sandalwood chip samples. The correlation between the NIR spectral data and the a-santalol content from the GC-MS analysis was very high (R2 = 0.93). The feasibility study indicates that it is possible to use FT-NIRS to predict -santalol content in sandalwood chip samples. The technique of utilising NIRS technology for sandalwood quality and quantity determination needs to be further developed to be utilised as a tool for commercial applications.

Australian Sandalwoods - General

Anon (1919) "Western Australian sandalwood oil. An official statement on the products." *Perff Essen Oil Record* **10**(7), 194-195.

Anon (1998) *Australian Sandalwood oil. A new century – a new alternative*. Mount Romance Australia Pty Ltd. Albany, Western Australia.

Anon (2000) "Qld: Five fined for sandalwood harvesting" *AAP General News Perth (Australia)* Dec 12th WA: sandalwood claims would be dealt with if true: Abstract Court story alleging that West Australian government officials were exporting sandalwood to dealers in Taiwan who had offered state officials bribes or prostitutes.

Anon (2002) *AAP General News (Australia) Nov 18 (2002).* Abstract: Five people fined in the Cairns Magistrate Court for illegal harvesting of the protected sandalwood plant, the Queensland EPA reportedly said.

Anon (2002) "A Crop in Crisis" – a part of "A calming influence" *Soap, Perfumery & Cosmetics* (Oct 2002) p42-3.

Anon (2006) "Big expansion for sandalwood plantation." *ABC Newsonline* Abstract 19th June 2006. An Indian sandalwood plantation in the Ord Valley is undergoing its biggest expansion in seven years. Tropical Forestry Services is planting a further 235 hectares of the exotic hardwood, increasing its total plantation to more than 800 hectares. The company plans to harvest its first crop in 2012, banking on continuing strong demand from Asia, Europe and the United States. Chief executive Tom Cullity says the company is planning processing facilities at Kununurra to produce sandalwood oil which is used for perfumes and cosmetics. "Oil is from the hardwood. Over $100,000 Australian for a tonne of hardwood. The sandalwood oil that is distilled from the hardwood is very valuable and it's used in a lot of perfumes and cosmetics," he said. The other major grower of indian sandalwood in the Ord, ITC Limited, has now planted 750 hectares, owned by investors.Its first harvest is planned for 2014.

Anon (2007) "W.A. Sandalwood set to dominate world trade." *ABC News* 11/12/2007. Abstract. The head of one of the world's leading fragrance companies believes the Ord Valley in Western Australia will overtake India, as the major producer of Indian sandalwood. The Ord has the only commerical crop of Indian sandalwood trees in the world. With a global shortage, oil from the processed timber is currently worth around $US1800 per kilogram. Georges Ferrando, from Albert Vieille, says with a processing plant due to be built in Kununurra next year, the region will become a world leader within five years. "India is number one in supplying sandalwood oil, but I think very, very quickly, Kununurra will become the supplier number one in the world," he says.

Anon (2007) "Sandalwood oil – Smells like success." *RIRDC Press release* 27.01.08 - see http://www.rirdc.gov.au/pub/media_releases/23jan07.html

Anon (2008) "Event Notes: Sustainable Indian Sandalwood in Australia." *P&F Now* June 25th 2008. ***Cropwatch comments:*** Sad to see *P & F* act as an advertising agent for TFS via their obedient reproduction of TFS promo material & sympathetic coverage of the recent Sandalwood conference at the Kimberly Grande Hotel in Kununurra Western Australia. Cropwatch has received opinions from conference attendees which give a more independent account, and that is what we should expect in *Perfumer & Flavourist* features.

Anon (2008) "Givaudan enters ethical sustainability partnership for sandalwood oil." The Givaudanian 05 Feb 2008 – see http://www.givaudan.com/vgn-ext-templating/v/index.jsp?vgnextoid=17889631fd5e7110VgnVCM1000004a53410aRCRD&cpsextcurrchannel=1 ***Cropwatch comments:*** We believe that linking to Mount Romance, with its history of involvement in animal-products, was a major mistake by the Givaudin management. We are also told Givaudin are actively sourcing "more than 190 pure & natural raw materials for fragrances. "

Applegate G.B, Davis A. & Annable P.A (1990) "Managing sandalwood for conservation in N. Queensland, Australia" in *Proc of the symposium on sandalwood in the Pacific*: April 9-11, 1990, Honolulu, Hawai/technical co-ordinators: Lawrence Hamilton, C. Eugene Conrad. pub: *Symposium on Sandalwood Conservation* (1st: 1991: Honolulu, Hawaii). Abstract.: *Santalum lanceolatum,* the commercial species of sandalwood harvested in Queensland, was worth $4.2 million in export earnings in 1988. The ecology of the species in natural forests is summarized, and information on seedling regeneration and coppice and root suckering strategies is provided. Stand characteristics and size class distribution in two different environments in northwest Queensland are provided. It is important to manage the resource for conservation. The harvesting guidelines, pricing criteria, and procedures are discussed along with information on heartwood recovery and moisture content of harvested sandalwood. Future research should be undertaken to monitor stand dynamics, growth rates, and the effects of land use practices on the distribution, growth, and dynamics of sandalwood in natural stands.

Applegate G.B. & McKinnell F.H. (1993) "The Management & Conservation Status of *Santalum* species occurring in Australia." In McKinnell F.H. ed. *Sandalwood in the Pacific Region. Symposium 2nd June 1991 at XVII Pacific Science Congress, Honolulu*, ACIAR Proceedings No. **49**, 5-12.

Barrats D.R., Wijesuriya S.R. & Fox J.E.D. (1985) "Observations on foliar nutrient content of sandalwood (*Santalum spicatum* R. Br. DC.) *Mulga Research Centre Journal* **8**, 81-91.

Barrats D.R. (1987) "Initial observations on flowering and fruiting in *Santalum spicatum* (R. Br.) A. DC the Western Australian sandalwood." *Mulga Research Centre Journal*, Australia **4**, 61-65.

Barrats D.R. (1987) "Germination & planting out techniques for the Western Australian sandalwood *Santalum spicatum*." *Mulga Research Centre Journal,* Australia **9**, 31-32.

Barrett D R (1987) Initial observations on flowering and fruiting in *Santalum spicatum* (R. Br.) A. DC. – the Western Australian sandalwood. *Mulga Research Centre Journal* **9**:33–37.

Bentley D. (1997) "Field grafting of Quandong. Acuminatum" Summer 1997 pp2-3. (*Newsletter of the Australian Quandong Industry Association*).

Bird K. (2008) "Lush secures supply of sustainable sandalwood." *CosmeticsDesign-Europe* 21.02.2008. ***Cropwatch comments.*** Further move illustrating rising tendency of natural aromatic ingredient users to by-pass essential oil traders and sign contracts directly with producers. In this case the report notes the deal is to buy Indian sandalwood from the Australian TFS Corporation, which expects sandalwood oil to be available from its'plantations by 2011. For full story - see http://www.cosmeticsdesign-europe.com/news/ng.asp?id=83433-lush-tfs-sandlewood

Bird K. (2008) "Fragrance house sources sustainable ingredients." *CosmeticsDesign-Europe* 07.02.2008. ***Cropwatch comments***. Givaudin announced a partnership with Mount Romance, according to the article, and we are also informed that Givaudin claim to be the first fragrance house using an aboriginal source of wood, since we are told that the sandalwood is harvested by aboriginal communities in SW Australia, and inspected by the independent indigenous certification body, the Songman Circle of Wisdom. Full details can be seen at http://www.cosmeticsdesign-europe.com/news/ng.asp?n=83107-givaudan-fragrance-natural-ehtical. Mount Romance's involvement with emu oil was quite well known (5,000 litres claimed to have been produced in 1997), as is Stephen Birkbeck's (MD at Mount Romance) previous track-record in crocodile & turtle farming. Given this animal-product-exploitation scenario, the "ethical sustainability relationship" between Givaudin & Mount Romance woulf have probably ring hollow with many ecology-concious consumers & vegetarians, at least. Interestingly, the farm gate value of the emu-farming industry was put at $6-8 million/y (CoAS 2003), compared with a valuation of (only) $12m for the whole of the Australian tea tree oil industry. Opposition to emu farming in Australia by the Australian Royal Society for the Prevention of Cruelty to Animals, can be viewed at http://www.rspca.org.au/pdf/B_policystatements.pdf ***Further comments.*** Aveda also have an agreement with Mount Romance for supply steam-distilled Sandalwood oil (instead, apparently, of the solvent extract initially marketed by Mount Romance as 'oil') More details, as well as their involvement with the Ingenous Communities of Mardu Peoples of Kuktabubba for harvested sandalwood can be seen at http://aveda.aveda.com/protect/we/sandalwood.asp.

Bolt C. (2001) "Tax scheme controversy fells plantation timber company" *The Financial Review* 31 July 2001 p12.

Bradfield A.E., Francis E.M., Penfold A.R. & Simonsen J.L. (1936) "Lanceol, a sesquiterpene–alcohol from the oil of *Santalum lanceolatum.* Part I." *J. Chem. Soc*., 1936, 1619 - 1625,

Brand J.E. & Jones P.J. (year?) "The influence of landforms on sandalwood (*Santalum spicatum* (R.Br) A.DC.) size structure & density in the North East Goldfields, Western Australia." *Rangeland Journal* **24**(2), 219-226.

Brand J.E. (1993) "Preliminary observations on ecotypic variations in *Santalum spicatum*. 2. Genotypic variation." *Mulga Research Centre Journal* **11**, 13-19.

Brand, J.E. (1994). "Genotypic variation in *Santalum album*." *Sandalwood Research Newsletter* **2**, 2–4.

Brand J.E. (1999) "Ecology of sandalwood (*Santalum spicatum*) near Paynes Find & Menzies, Western Australia: size structure & dry-sided stems" *Rangeland Journal* **21**(2), 220-228. Abstract. Population size structure of sandalwood (*Santalum spicatum*) was studied on four pastoral leases near Paynes Find and Menzies, in semi-arid Western Australia. Stem diameter, height, height to crown and the orientation of dry-sided stems were recorded for 1017 individual sandalwood. Populations of *S. spicatum* at Paynes Find contained only mature trees, indicating no successful recruitment for at least 30 years. In contrast, populations of *S. spicatum* at Menzies had a high proportion of seedlings and saplings. Crown measurements of mature *S. spicatum* trees indicated high grazing intensity at Paynes Find: mean height to crown at Paynes Find (147-148 cm) was significantly higher than Menzies (92-94 cm). Dry-side percentage differed significantly between directional faces, consistent with sun damage. Highest mean dry-side percentages were on stem sides facing the sun between midday and late afternoon: west, north-west, south-west and north. This directional pattern was the same between pastoral leases, and there was no interaction between pastoral lease and dry-side direction. Mean percentage of mature trees with a dry-sided stem was also significantly higher at Paynes Find (76-82%) than at Menzies (42-46%). Significantly less foliage low to the ground on mature trees at Paynes Find may have exposed the stems to more sun damage. Land systems did not significantly influence dry-side direction on Burnerbinmah or Goongarrie. No *S. spicatum* seedlings or saplings had a dry-sided stem.

Brand J.E., Ryan P.C. & Williams M.R. (1999) "Establishment and growth of sandalwood (*Santalum spicatum*) in South-Western Australia: the Northampton pilot trial." *Australian Forestry* **62**(1), 33-37.

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Brand J.E., Robinson N & Archibald R.D. (2003) "Establishment & growth of sandalwood (*Santalum spicatum*) in South-Western Australia: *Acacia* host trials." *Australian Forestry* **66**(4), 294-299. Abstract. The influence of four different *Acacia* species (*Acacia acuminata*, *A. saligna*, *A. microbotrya* and *A. hemiteles*) on the establishment and growth of sandalwood (*Santalum spicatum*) was examined at two sites in the wheatbelt, Western Australia, Australia. The host seedlings were planted in June 1998, and four *S. spicatum* seeds were planted adjacent to each host at age 1 year (May 1999). Direct sowing *S. spicatum* near 1-year-old host seedlings again proved to be a successful establishment technique, with 81-91% germination per spot, at both sites. At age 3 years, the survival of *S. spicatum* near *A. saligna* (94%) and *A. acuminata* (81%) was significantly greater than near *A. hemiteles* (45%). At the same age, the mean stem diameter of *S. spicatum* growing near *A. saligna* was 53 mm, significantly greater than near *A. acuminata* (33 mm), *A. microbotrya* (20 mm) and *A. hemiteles* (11 mm). Growth was superior at the Dandaragan site, with *S. spicatum* near *A. saligna* having a mean stem diameter of 59 mm and a mean height of 2.3 m. At the host age of 4 years, the mean height of *A. microbotrya* (4.3 m) was significantly greater than *A. saligna* (3.3 m), *A. acuminata* (3.2 m) and *A. hemiteles* (1.1 m). Between host ages of 1 and 4 years, the mean survival of *A. saligna* dropped by 27%, significantly more than the other host species (2.5-10%). Mean potassium and phosphorus concentrations in the foliage of S. spicatum were significantly higher near *A. saligna* than near *A.* hemiteles. The mean potassium:calcium ratio was highest near *A. microbotrya* (2.2-3.7) at both sites. Stem water potentials in *S. spicatum* were significantly lower near A. microbotrya (-2.9 MPa) than near *A. hemiteles* (-2.2 MPa) at Dandaragan. There were no significant differences between *S. spicatum* stem water potentials at Narrogin.

Brand J., Jones P & Donovan O. (2004). "Current growth rates and predicted yields of Sandalwood (*Santalum spictum*) grown in plantations in south-western Australia." *Sandalwood Research Newsletter* **19**, 4-7 Abstract. Aromatic timber from *S. spicatum* is a valuable commodity, and this species hasthe potential to provide an income to farmers in the medium annual rainfall (400-600 mm) regions of the wheatbelt. Since 1987, *S. spicatum* plantations have beensuccessfully established in the wheatbelt, by direct seeding near 1-2 year old host seedlings, especially *Acacia acuminata*. This establishment technique has been very effective, with over 80 % survival per spot, and mean stem diameters (at 150 mm above the ground) increasing at 10-12 mm yr-1near *A. acuminata*. Allowing two years to establish both *A. acuminata* and *S. spicatum*, and then a mean stem diameter growth of only 7 mm yr-1for 18 years, the *S. spicatum* are expected to reach commercial size (127 mm) at plantation age 20 years. At this age, the expected yields are approximately 4.4 tonnes ha-1, with a net return ofover AU $14,000 ha-1. The sandalwood trees are also producing 60-170 kg ha- 1of seeds at age only 4-6 years. The value of the seeds may also provide a supple-mentary income to the sandalwood growers, while they are waiting for the trees to reach commercial size. ***Cropwatch comments***: The authors state that core samples taken from 10-year old trees produced oil containing 16.7 to 21.1% α- & β-santalols, "which are the compounds that produce the distinct sandalwood fragrance" referencing Adams *et al.* (1975), The authors take no account of the effect on the odour profile of other major components found in the oil, such as the presence of 17.8% to 20.5% farnesol, a sesquiterpene alcohol recently identified as a sensitiser by IFRA and the subject of a recent SCCP Opinion.

Braun N.A. & Meier M. (2004) "Western Australian & East Indian sandalwood oil – a comparison" *Euro Cosmetics* **12**(1), 22-29.

Bristow, M. et al. 2000. "Queensland sandalwood (*Santalum lanceolatum*): regeneration following harvesting." *Sandalwood Research Newsletter* **11**, 4-8.

Burfield T. & Wildwood C. (2004) "Cropwatch 2: Australian Sandalwood Oil: a tale of Spin & Hype" at http://www.cropwatch.org/cropwatch2.htm & www.users.globalnet.co.uk/~nodice/

Byrne M., McDonald B. & Brand J. (2003) "Phylogeography & divergence in the chloroplast genome of Western Australian sandalwood (*Santalum spicatum*) *Heredity* **91**(4), 389-395. Abstract. Western Australian sandalwood (*Santalum spicatum*) is widespread throughout Western Australia across the semiarid and arid regions. The diversity and phylogeographic patterns within the chloroplast genome of *S. spicatum* were investigated using restriction fragment length polymorphism analysis of 23 populations. The chloroplast diversity was structured into two main clades that were geographically separated, one centred in the southern (semiarid region) and the other in the northern (arid) region. Fragmentation due to climatic instability was identified as the most likely influence on the differentiation of the lineages. The lineage in the arid region showed a greater level of differentiation than that in the southern region, suggesting a higher level of gene flow or a more recent range expansion of sandalwood in the southern region. The phylogeographic pattern in the chloroplast genome is congruent with that detected in the nuclear genome, which identified different genetic influences between the regions and also suggested a more recent expansion of sandalwood in the southern region.

Byrne M., McDonald B., Broadhurst L. & Brand J. (2003) "Regional genetic differentiation in Western Australian sandalwood (*Santalum spicatum*) as revealed by nuclear RFLP analysis." *Theoretical & Applied Genetics* **107**(7), 1208-1214. Abstract. Western Australian sandalwood, *Santalum spicatum*, is widespread in the semi-arid and arid regions of Western Australia, and there is some morphological variation suggestive of two ecotypes. The level and structuring of genetic diversity within the species was investigated using anonymous nuclear RFLP loci. *Santalum spicatum* showed moderate levels of genetic diversity compared to other Australian tree species. The northern populations in the arid region showed greater levels of diversity and less population differentiation than the southern populations in the semi-arid region due to differences in the distribution of rare alleles. Equilibrium between drift and gene flow in the northern populations indicated that they have been established for a long period of time with stable conditions conducive to gene flow. In contrast, the southern populations showed a relationship between drift and gene flow indicative of a pattern of fragmentation and isolation where drift has greater effect than gene flow. The different patterns of diversity suggest that the ecotypes in the two regions have been subject to differences in the relative influences of drift and gene flow during their evolutionary history.

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Crossland T. (1982) "Response to fertiliser treatment by seedlings of sandalwood, *Santalum spicatum* (R.Br) DC." *Annual Report, Mulga Research Centre* Australia **5**, 13-16.

Crossland T. (date?) "Preliminary investigations into germination and establishment of sandalwood, *Santalum spicatum* (R. Br.) DC. *Annual Report, Mulga Research Centre* Australia **4**, 61-65.

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Donovan R.J. (undated) *A history of the sandalwood industry of Western Australia* Battye Library, Perth, Australia

Duus J. E. (1987). "Harvesting of Sandal-wood from Crown Lands in Queen-sland." (Unpublished).

Fergeus J. (undated pamphlet) "Australian sandalwood aromatic review" *Australian Botanical Products Pty Ltd.*

Flanagan F. & Barrett D.R. (1993) "Sandalwood nuts as food." *Mulga Research Centre Journal* **11**, 21-26.

Forest Products Commission WA Media Release (27 March 2006) "Preliminary oil results from a 14-year-old Indian sandalwood plantation at Kununurra, WA."

Forest Products Commission WA Media Release (16th May 2006) "First Indian sandalwood plantations established in Carnavon."

Fox J.E.D. & Brand J.E. (1993) "Preliminary observations on ecotypic variations in *Santalum spicatum.* 1. Phenotypic variation." *Mulga Research Centre Journal* **11**, 1-12.

Fox J.E.D. & Wijesunya S.R. (1985) "Sandalwood planting with property owners" *Mulga Research Centre Journal* **8**, 3340.

Fox J E D & Brand J E (1993). "Preliminary observations on ecotypic variation in *Santalum spicatum.* 1. Phenotypic variation." *Mulga Research Centre Journal* **11**:1–12.

Fox J.E.D. (1997) "Why is *Santalum spicatum* common near granite rocks?" *J. Royal Soc. of Western Australia* **80**, 209-220. Abstract. Sandford Rocks Nature Reserve is dominated by a large granite outcrop. This reserve is notably well-endowed with trees of the root parasite sandalwood (*Santalum spicatum*). These are comparatively common in and among granite exposures. Trees attain 4 m in height and 20 cm basal diameter on favourable sites but are small gnarled shrubs in rock fissures. Fruiting ability differs considerably between trees. Despite apparently high densities of rabbits, continuous regeneration appears to have occurred, but only in the vicinity of parent trees. The reserve contains a number of distinct vegetation associations that are soil determined. Although sandalwood is common near exposed granite it is rarely found in association with *Eucalyptus* stands. It is suggested that the water-shedding properties of the granite exposures are less important to sustaining sandalwood than the presence of preferentially parasitised host species.

George, A. S. (1984). "*Santalum*." in *Flora of Australia*, vol. **22**. Bureau of Flora and Fauna. Australian Government Publishing Service. Canberra, Australia.

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Gowda D. (2008) "Detergents"Decline in the Supply of Natural Sandalwood oil: deforestation, adulteration and synthetics." *Sandalwood Conference 2008 at The Kimberley Grande, Kununurra, W. Australia 13-15 May 2008*. ***Cropwatch Comments***: Gowda maintains that in spite of the official figures, the current (2008) annual production of sandalwood is 3,000 - 4,000 tons and for sandalwood oil is 120-150 tons, of which 80 tons/annum of sandalwood oil is consumed by the domestic market. Gowda is employed by Karnataka Soaps & Detergents Ltd. (KSDL) once the largest producers of sandalwood oil E.I. Gowda informs us that sandalwood oil distillation commenced in 1916 in Mysore, and 2 years later the essential oil was incorporated into sandalwood soap by KSDL. Gowda lists polyethylene glycols, African sandalwood oil, castor oil and coconut oil amongst the adulterants of E.I. Sandalwod oil.

Grant, W.J.R. & Buttrose, M.S. (1978) "Domestication of the quandong, *Santalum acuminatum.*'" *Australian Plants* **9**, 316-318

Harbaugh D. (2007) "A taxonomic revision of Australian northern sandalwood (*Santalum lanceolatum*, Santalaceae)." *Australian Systematic Botany* **20**(5) 409–416. Abstract. A previously published molecular phylogenetic analysis of the sandalwood genus, *Santalum* L. (Santalaceae), identified that the Australian endemic northern sandalwood, *S. lanceolatum* R.Br., is not monophyletic and contains a distinct, yet cryptic, lineage within it as currently circumscribed. This study examines nuclear ribosomal gene sequences of additional specimens from across its geographic range, and 30 morphological characters, in order to revise the taxonomy of *S. lanceolatum* sensu lat. (s.l.) and the segregate species that should bear the name *S. leptocladum* Gand. *Santalum lanceolatum* sensu stricto (s.s.) is distributed in the humid to subhumid regions of northern Australia north of 20°S latitude, whereas *S. leptocladum* occurs in the arid and temperate regions of central and southern Australia. Putative interspecific hybrids were discovered in two localities, and may represent either natural or human-mediated hybridisation. The results of this study have major economic and conservation implications because *S. lanceolatum* s.s., which is known to have higher levels of fragrance compounds than *S. leptocladum*, has a much more restricted range than previously thought.

Harbaugh D.T. (2008) "Polyploid and Hybrid Origins of Pacific Island Sandalwoods (*Santalum*, Santalaceae) Inferred from Low-Copy Nuclear and Flow Cytometry Data." *Int. J Plant Sci*. 169(5), 677–685. Abstract. It has been argued that polyploids are better adapted than diploids for long-distance dispersal to and establishment on oceanic islands. To address this issue in a molecular phylogenetic framework, the extensive history of auto- and allopolyploidization in *Santalum* (Santalaceae), the sandalwood genus, was studied by sequencing the low-copy nuclear gene waxy and investigating the ploidy level of all 16 species. Ploidy level was estimated by measuring the C value (total amount of DNA per nucleus) using flow cytometry and calibrating it by known chromosome numbers and new root-tip chromosome counts of several taxa. Results indicate four ploidy levels in *Santalum*: diploid (n=10), tetraploid (n=20), hexaploid (n=30), and octoploid (n=40). The waxy phylogeny suggests that at least six independent polyploid events occurred in the history of *Santalum*: two allopolyploid events between distantly related species and four putatively autopolyploid events. An additional hybrid event between two tetraploid Hawaiian clades evidently produced the tetraploid species *S. boninense*, endemic to the Bonin Islands. By finding more than twice as many long-distance island colonizations from polyploid as from diploid ancestors, this study provides novel evidence for the role of polyploidy in plant colonization throughout the Pacific Islands.

Henschke I. (2000) “Sandalwood brings sweet smell of success.” Landline. Australian Broadcasting Corp at http://www.abc.net.au/landline/stories/s206172.html

Herbert D A (1925) “The root parasitism of Western Australian Santalaceae.” *Journal and Proceedings of the Royal Society of Western Australia* **11**, 127–149.

Heuberger E., Gearon V., Birbeck S., Buchbauer G. (2002) “The essential oil of Australian sandalwood (*Santalum spicatum*) – effects of different samples on human physiology & subjective evaluation,” *33rd ISEO*, Sept 2002, Lisbon, Portugal.

Hobman, F.R. (1991) “The SA Dept of Agriculture evaluation programme for quandongs..” In *Quandongs, a viable opportunity*. Minnipa Research Centre, Oct. 18, 1991. Dept of Agriculture, South Australia

Hood J.R., Cavanagh H.M. & Wilkinson J.M. (2004) "Effect of essential oil concentration on the pH of nutrient and Iso-sensitest broth." *Phytother Res.* **18**(11), 947-9. Abstract. The role of pH on the antimicrobial activity of essential oils has not been well studied. The effect of four essential oils: *Backhousia citriodora*, *Melaleuca alternifolia, Lavandula angustifolia* and *Santalum spicatum* (0.1% to 10%) on the pH of two commonly used media, nutrient broth and Iso-sensitest broth, was therefore undertaken. Small (less than 0.5 pH units) but statistically significant differences between the pH of the two media followed the addition of *M. alternifolia*, *L. angustifolia* and *S. spicatum* essential oil. In general the effect on pH was greatest at higher concentrations and the fall in pH was greatest in the nutrient broth. The addition of *B. citriodora* essential oil to nutrient broth resulted in a fall in pH from 7.29 +/- 0.02 (no oil) to 5.2 +/- 0.03 (10% oil). This effect was not observed in the Iso-sensitest broth.

Hudson (2008) “Kununurra could become world's biggest producer of Indian Sandalwood”. http://www.abc.net.au/rural/wa/content/2006/s2244847.htm ***Cropwatch comments:*** Hopefully the 75 or so delegates (presumably manily shareholders) were impressed by reports of 3,000 + ha of sandalwood under cultivation. No party-pooper mentioned the fact that due to the high cost of sandalwood oil, the hard-pressed perfumery trade has mainly switched to cheap sandalwood synthetics on cost grounds.

Ilah A. *et al*. (2002). “Somatic embryo irregularities in in vitro cloning of sandal (*Santalum album* L.).” *Sandalwood Research Newsletter* **15**, 2-3.

Jain S.H., Angandi V.G. & Shankaranarayana, K.H. (2003) "Edaphic, environmental and genetic factors associatedwith growth and adaptability of Sandal (*Santalum album* L.) in provenances." *Sandalwood Research Newsletter* **17**, 4-5. Abstract. Sandal tree grows under different edaphic and eco climatic conditions. Consid-ering large genetic distance between provenances, it is concluded that under di-verse locality factors sandal adapts very well in terms of growth, heartwood and oil content.

Jones G.P., Tucker D.J., Rivett D.E. & Sedgley M." (1985). “The nutritional potential of the quandong (*Santalum acuminatum*) kernel.” *Journal Plant Foods* **6,** 239-246.

Jones G.P., Birkett A., Sanigorski A., Sinclair A.J., Hooper P.T., Watson T.& Rieger V. (1994) "The effect of feeding quandong (*Santalum acuminatum*) oil to rats on tissue lipids, hepatic ctochrome P450 and tissue histology." *Food and Chemical Toxicology* **32,** 521-525

Jones P. (1999) “'Growing Sandalwood (*Santalum spicatum*) on farmland in Western Australia.' *Forest Products Commission Information Sheet* Issue **1**, May 1999.

Jones P. (2002) "Estimating Returns on Plantation Grown Sandalwood (*Santalum spicatum*)" *Forest Products Commission Sandalwood Information Sheet* Issue **3,** July 2002

Jyothi P.V., Atluri J.B. & Subba R.C.(1991). "Pollination ecology of *Santalum album* (Santalaceae)." *Tropical Ecology* **32**, 98-104. Abstract. *Santalum album* L. is obligately xenogamous and blooms thrice a year at Visakhapatnam (17 degree 42'N-82 degree 18'E). The flowers anthese between 0430 and 1930 hr and soon after the anthers dehisce. The pollen grains are viable for 16 hr and the stigma is receptive for 48 hr. Nectar production begins 24 hr after anthesis and continues through flower life. Ants, bees, flies, butterflies and wasps forage at the flowers; only the last two groups serve as pollinators, wasps being the "major".

Kauber K. "Australian sandalwood oil – acute oral toxicity and acute dermal toxicity", Scantox, Denmark 2000 (unpublished). ***Cropwatch comments***: Cropwatch previously asked Scantox to release details of this study, allegedly funded by Mount Romance, which was said to include animal testing experiments. Scantox politely declined to release this confidential data. Later all references to this funded research were removed from Mount Romance's internet presence, perhaps because many perfumery companies will not accept perfumery materials manufactured by companies who have tested their products on animals. However some aromatherapy oil traders (apparently customers of Mount Romance) failed to erase the data as promptly, which is where we initially learned of the Scantox studies.

Kealley I.G. (1991) "The management of Sandalwood" Dept of Conservation & Land Management, *W. Australian Wildlife Management Program* No **8**, 3-9..

Keenan R (1996) "*Santalum lanceolatum in* Queensland." *Sandalwood Research Newsletter* - Issue **1**.Department of Conservation and LandManagement, Kununurra, Western Australia.

Kerr J. (2000) "Essential Oil Profile – Australian Sandalwood Oil" *Aromatherapy Today* **15**, 8-12.

Kerr J. (2002) "Editorial Comment" *Aromatherapy Today* **24** Dec 2002 p32-33.

Lethbridge B. (1998) "Germinating bitter quandong." *Acuminatum* Autumn 1998, p 4

Lethbridge B. (1998) "Root rot, rootstock and phosphorous acid." *Acuminatum*, Winter 1998, p 4"

Lethbridge, B. (1999) "Host plants I - Melaleucas. "*Acuminatum*, Autumn 1999, p 4.

Lethbridge, B. (2001). "Grafting compatibility of quandong, *Santalum acuminatum*.". *Sandalwood Research Newsletter* **12**, 2.

Lethbridge B. & Randell B. (2003) "Genetic and agronomic improve-ment of Quandong." RIRDC Pub-lication No. 03/110.

Lethbridge B. (2004) "Do Our Own Research (DOOR) quandong production." RIRDC publication No. W04 / 111

Lethbridge B.(2004) "Native Foods : Quandong." In The New Crop Industries Handbook. Edited by Salvin S., Bourke M. Byrne A. Rural Industries Research and Development Corporation.

Lethbridgw B. (2005) "Field grafting of Quandong (*Santalum acuminatum*)." *Sandalwood Research Newsletter* **20**. April 2005.

Luong T.M. (2002) "Competitive effects within and between *Santalum album* and pot host *Alternanthera dentata*." *Sandalwood Research Newsletter* **16**. Abstract. The growth of *Santalum album* seedlings and the preferred pot host Alternanthera dentata under nursery conditions is the first important step in establishing this species in planta-tions. A 19 week pot trial was conducted in a glasshouse at Curtin University of Technol-ogy, Perth, Western Australia. The aim was to test whether an increase in host density im-proved growth of sandalwood seedlings. *S. album* seedlings had a tendency to grow betterat lower densities of *A. dentata* (one or two hosts per pot), compared with higher densities (three or four hosts per pot). Seedlings with two hosts had greater heights, dry root andshoot weights and leaf area, while seedlings with one pot host had more leaves. There wereno clear trends between number of haustorial connections made as host density increased.As host density increased, the leaf area, root and shoot weights of *A. dentata* declined. Bothparasite and host were more affected by competition, however the host was more affected byintraspecific competition, indicated by large competitive responses to each other. *S. album* seedlings had less effect or response to density of *A. dentata* after 19 weeks, perhaps due tonot being limited by the same resources as the host at this early establishment phase

Loveys B.R. & Jusaitis M. (1994) "Stimulation of germination of quandong (*Santalum acuminatum*) and other native plant seeds. *Australian Journal of Botany*. **42**, 563-574.

Liu Y.D. & Longmore R.B. (1997) "Dietary sandalwood seed oil modifies fatty acid composition of mouse adipose tissue, brain & liver." *Lipids* **32**(9), 965-969. Abstract. Sandalwood (*Santalum spicatum*) seed oil, which occurs to about 50% of the weight of the seed kernels, contains 30-35% of total fatty acids (FA) as ximenynic acid (XMYA). This study was designed to obtain basic information on changes in tissue FA composition and on the metabolic fate of XMYA in mice fed a sandalwood seed oil (SWSO)-enriched diet. Female mice were randomly divided into three groups, each receiving different semisynthetic diets containing 5.2% (w/w) fat (standard laboratory diet), 15% canola oil, or 15% SWSO for 8 wk. The effects of SWSO as a dietary fat on the FA composition of adipose tissue, brain, and liver lipids were determined by analyses of FA methyl ester derivatives of extracted total lipid. The FA compositions of the liver and adipose tissue were markedly altered by the dietary fats, and mice fed on a SWSO-enriched diet were found to contain XMYA but only in low concentration (0.3-3%) in these tissues; XMYA was not detected in brain. Oleic acid was suggested to be a principal XMYA biotransformation product. The results were interpreted to suggest that the metabolism of XMYA may involve both biohydrogenation and oxidation reactions.

Liu Y.D., Longmore R.B. & Kailis S.G. (1997) "Proximate & fatty acid composition changes in developing sandalwood (*Santalum spicatum*) seeds." *J. Science of Food & Agriculture* **75**(1), 27-30. Abstract. Changes in the proximate composition of developing seeds of sandalwood (*Santalum spicatum* R Br) were quantified. The developing fruits were collected regularly over a period of 5 months commencing 14 days after flower opening. Rapid deposition of seed lipid began at about 91 days after flowering (DAF) at a level of 4 g kg-1 and continued to about 396 g kg-1 at 147 DAF. Protein and ash contents displayed similar trends to that of lipid with a corresponding decrease in moisture content. Fatty acid analysis of the seed oil demonstrated marked changes in composition during seed development. In particular, major increases in oleic and ximenynic acids were noted with corresponding decreases in the other fatty acids.

Lonergan O.W. (1990) "Historical review of sandalwood (*Santalum spicatum*). Research in Australia". *Perth: Research Bulletin* No 4 Dept of Conservation & Land Management Dec 1990 p28.

McKinnell F.H. (1990) "Status of management & silvicultural research on sandalwood in W. Australia & Indonesia" In Hamilton L. & Conrad C.E. ed. *Proceedings of the Symposium on Sandalwood in the Pacific*; April 9-11 1990 Tech. Rep PSW-122, Pacific Research Station, Forest Service, UJS Dept of Agric, Honolulu, 19-25. Abstract. The current status of the conservation and management of *Santalum spicatum* in Western Australia and *S. album* in East Indonesia is outlined. Natural and artificial regeneration techniques for both species in selected areas are discussed. The present Australian Centre for International Agricultural Research program on S. album in Nasa Tenggara Timur is described in relation to the management needs of the species in that province. In *S. spicatum*, research on silviculture is essentially complete, and interest is now focused on the marketability of the kernels for human consumption.

Maslin B.R., Byrne M., Coates D., Broadhurst L. *et al.* (1999) "The *Acacia acuminata* (Jam) group: an analysis of variation to aid Sandalwood (*Santalum spicatum*) " Report to the Sandalwood Business Unit, Department of Environment & Conservation, Australia (1999).

Misra U. (2009) "How India's Sandalwood Oil trade got hijacked." *Business* 6th Aug 2009. ***Cropwatch comments***: The article comments on how India went from sandalwood oil exporter to importer, with a look at Australia's 20,000 ha sandalwood plantation profect. Tim Coakley, executive chairman of the Wescorp Group of Companies is quotes as estimating that 15 to 17 tons/annum of oil of Santalum spicatum is currently produced in Australia and that exporting of oil of *Santalum album* would start in 3-7 years.

Mullholland J. (1994) "An investigation of the harvesting processing and export of Western Australia sandalwood (*Santalum spicatum*)." - Abstract of Masters Thesis University of Australia; summary available at the website of Institute of Foresters of Australia http://www.ifa.unimelb.edu.au/abstracts/master/1994/mulholland1994.htm

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Murphy M. & Mark Garkaklis M. (2003) "Hopping Into A Bright Future- The Woylie Sandalwood Story." *Sandalwood Research Newsletter* **18**.

Murthy S.G. (1985) "Sandalwood: case study of a resource in decline." *Garden* 16-19.

Oates A. (1989) *The Story of Sandalwood* The Museum of the Golfields Kalgoorlie

Owen L.N. (1949) "Lanceol, a sesquiterpene alcohol from the oil of *Santalum lanceolatum*. Part II. Some observations on the degradation product." *J. Chem. Soc*., 1949, 1582 - 1586,

Possingham J. (1986) "Selection for abetter Quandong." *Australian Horticulture* February 1986 pp55-59

Radomiljac A. (2000) see: http://users.bigpond.net.au/sellwood/kimsoc/pasttalk00.htm

Radomiljac A.M. (1998). "The influence of pot host species, seedling age and supplementary nursery nutrition on *Santalum album* (Linn.) plantation establishment within the Ord River Irrigation Area, Western Australia." *Forest Ecology and Management* **102**(2–3), 193–201. Abstract. A factorial experiment investigated the effect of six pot host species treatments (*Alternanthera nana*, *Sesbania formosa*, *Atalaya hemiglauca*, *Acacia hemignosta*, *Crotalaria retusa* and no pot host), two *Santalum album* seedling age treatments (24 and 17 weeks at field establishment) and a supplementary nursery nutrition treatment (2×100 ml 5% Ca Wuxal®) on *Sa. album* survival and growth 287 days after field establishment. Significant variation exists between pot host species in increasing *Sa. album* survival and growth. *Al. nana* and *Se. formosa* pot host species significantly increased *Sa. album* survival, height and diameter. *Sa. album* survival, height and diameter was significantly better with supplementary nursery nutrition. *Sa. album* survival and height was significantly greater and pot host species survival was significantly poorer with older *Sa. album* seedlings. Older seedlings and supplementary nursery nutrition gave higher levels of *Sa. album* field survival and growth when parasitised to poor pot host species but not when parasitised to satisfactory pot host species.

Raychaudhuri S.P. & Varma A. (1980) "Sandal spike" *Review of Plant Pathology* **59**(3), 99-107.

Razikari H. (1996) "An assessment of the commercial potential of quandong (*Santalum acuminatum*) varieties in Broken Hill. *Thesis, University of Western Sydney, Hawkesbury*.

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Robson K. (2003). “Sandalwood species x host interaction trial in North Queensland.” *Pacific Islands Forest and Trees*, 3/2003, pp. 14-16.

Robson K. (2004) “Experiences with Sandalwood in plantations in the South Pacific & N. Queensland.” In: *Prospects for high value hardwood in the “dry” tropics of N. Australia*. Proceedings of a workshop held in Mareeba, N. Queensland, Australia 19-21st Oct 2004. pub. Private Forestry North Queensland Association Inc. N. Queensland. Abstract. Sandalwood is an important commercial industry in the south western Pacific. A number of sandalwood species occur across the south western Pacific, *Santalum austrocaledonicum* in New Caledonia and Vanuatu, and *Santalum yasi* in the Fiji Islands and Tonga. Communities do the majority of sandalwood plantings, manage and harvest existing stands. There is a growing interest among villagers, other smallscale growers and Governments to expand the scale of planting in both countries. The most common type of planting is garden plantings of sandalwood by villagers. However, large investors and Governments now starting to invest in plantations across the south western Pacific.

Rugkhla A. & Jones M.G.K. (1998) “Somatic embryogenesis & platelet formation in *Santalum album* & *S. spicatum*.” *J of Exptl. Botany* **49**(320), 563-571. Abstract. A reproducible system for somatic embryogenesis and plantlet formation of sandalwood has been developed. A high frequency (100%) of somatic embryos were induced directly from various explants in MS (Murashige and Skoog, 1962) medium with thidiazuron (1 or 2 M) or indirectly in medium containing 2,4-D plus thidiazuron. Within 8 weeks, white globular somatic embryos or friable embryogenic tissue developed on cultured explants. In S. album the globular somatic embryos were transferred to MS medium supplemented with IAA (6 M) and kinetin (1 and M) where they developed further, multiplied and maintained friable embryogenic tissue. After 15-30 d, mature somatic embryos (1-2 mm) with well-developed cotyledons were separated and subcultured on to medium containing GA3 (6 M) for germination. Once germinated, elongated somatic embryos (10-20 mm long) grew further in MS supplemented with lower GA3 (3 M). In S. spicatum, the addition of casein hydrolysate and coconut milk was necessary for plantlet development from somatic embryos. From histological studies, it appeared that primary somatic embryos arose from single cells or had a multicellular origin from the epidermis or cortical parenchyma. Secondary somatic embryos and friable embryogenic tissue differentiated from groups of proembryogenic cells from a superficial layer of the primary somatic

Rugkhla A., McComb J.A. & Jones M.G.K. (1997) “Intra- & inter-specific pollination of *Santalum spicatum* & *S. album*.” *Australian J of Botany* **45**(6), 1083-1095. Abstract. The flower morphology, receptivity and sexual compatibility between genotypes and species were determined in Western Australian sandalwood (*Santalum spicatum*) and Indian sandalwood (*S. album*). The results showed that the stigma of both species became receptive at anthesis and reached a peak at 3 or 4 days after anthesis. Pollen tubes took 2 days to grow to the ovary when pollinated at anthesis, and 1 day when pollinated 2 or 3 days after anthesis. The egg apparatus matured at least 2 days after pollination and varied between genotypes. Fertilisation occurred 2 or 3 days following cross pollination. Although 10–40% of ovules were fertilised following intra-specific crosses of both species, the average initial fruit set was much lower: 4% in *S. spicatum* and 19% in *S. album*. Most immature fruit (75–80%) abscised following intra-specific pollination. The number of pollen tubes that grew in styles after self-and inter-specific pollination was lower than that for intra-specific pollination. Following self and inter-specific pollination, growth of pollen tubes was arrested in the style, ovary and around the embryo sac; a few penetrated the embryo sac. Initial fruit set was low and developing fruit abscised prematurely. The results indicated that pre- and post-fertilisation mechanisms control self-incompatibility and inter-specific incompatibility between the sandalwood species.

Ryan, P.C. & Brand, J.E. 2002. Techniques to improve sandalwood (*Santalum spicatum*) regeneration at Shark Bay, Western Australia: stem coppice and direct seeding. Sandalwood *Research Newsletter* **15**, 4-7.

Samson, Basil (1980): *The camp at Wallaby Cross*. Canberra: *Australian Institute of Aboriginal Studies*; 199-202.

Sawyer (1892) through Applegate Graham B, Davis Allan G.W. & Annable. Peter A. (1990) "Managing Sandalwood for Conservation in N. Queensland, Australia" in *Proc of the Symposium on Sandalwood in the Pacific*: April 9-11, 1990, Honolulu, Hawai/technical co-ordinators: Lawrence Hamilton, C. Eugene Conrad. pub: Symposium on Sandalwood Conservation (1st: 1991: Honolulu, Hawaii).

Sedgley M. (1982). "Preliminary assessment of an orchard of quandong seedling trees." *J. Aust. Inst. Agr. Sci.* **48**(l):52-56.

Sedgley M (1982) "Floral anatomy andpollen-tube growth in the Quan-dong (*Santalum acuminatum* (R Br) a Dc)." *Australian Journal of Botany* **30**, 601-609..Abstract. Floral anatomy and pollen tube growth in the quandong were studied using light and scanning electron microscopy. The flowers had four perianth lobes and four stamens whose anthers dehisced by longitudinal slits. The pollen became caught in long unicellular hairs adjacent to the anthers. The central disc secreted nectar through raised stomata. The stigma papilla cells had a cuticle with a rough surface overlying thick PAS-positive walls. The half-inferior ovary normally contained two ovules. The embryo sac extended beyond the ovule at the micropylar end and into the placenta at the chalazal end. Half of the ovaries observed at both anthesis and 4 days following anthesis had no embryo sacs and the other half had one embryo sac. Occasional ovaries had two embryo sacs and some underdeveloped embryo sacs were observed that did not extend beyond the ovule or into the placenta. Pollen tubes had reached the ovary by 1 day following pollination and the stigma was receptive for 8 days following anthesis. Only half of the pistils had pollen tubes in the ovary. Unpollinated flowers had no pollen tube growth in the pistil.

Sen-Sarma P.K. (1982) "Insect vectors of sandal spike disease" *European J of Forest Pathology* **12**(4/5), 297-299.

Shea S.R., Radmomiljac A.M., Brand & Jones P. (1998) "An overview of sandalwood and the development of sandal in Farm Forestry in W. Australia". *ACIAR Proceedings* **84**, 9-18.

Sidheswaran P. & Ganguli S. (1997) "Sandalwood oil substitutes – a review" *Supplement to Cultivation & Utilisation of Aromatic Plants* 123-139.

Statham P. (1988). "The Australian sandalwood trade, small but significant." *Working Paper No. 100.* Canberra, Australia. Department of Economic History, The Australian National University. **36**

Statham P. (1990) "The sandalwood Industry in Australia: A history" in *Proc of the Symposium on Sandalwood in the Pacific*: April 9-11, 1990, Honolulu, Hawai/technical co-ordinators: Lawrence Hamilton, C. Eugene Conrad. Pub: Symposium on Sandalwood Conservation (1st: 1991: Honolulu, Hawaii). p26. Abstract. From its inception in 1805, when it contributed to Sydney merchant incomes from whaling ventures, until today, when it earns several million dollars in export revenue, the sandalwood industry has played a small but significant part in Australia's economic development. The history of the industry falls into three major stages: first is the off-shore exploitation of the wood from Sydney, from 1805 to the 1840's and beyond; second is the free exploitation of Australian grown sandalwood from 1844 to 1929; and finally the period of government controlled exploitation from 1929 to the present.

Struthers R., Lamont B.B., Fox J.E.D., Wijesuriya S. & Crossland T. "Mineral nutrition of sandalwood (*Santalum spicatum*)." *J. of Exptl. Botany* **37**(182), 1274-1284.

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Talbot L. (1983) "Wooden gold. Early days of the sandalwood industry." *Forest Focus* **30**, 21-31. pub W. Austr. Forest Dept, Perth.

Taylor D., Swift S. & Collins S. (2000) “Testing growth & survival of four sandalwood species in Queensland” *Sandalwood Research Letter* **10**, 6-8. Abstract. Sandalwood production in Queensland has been based on harvesting from naturally occurring *Santalum lanceolatum*, principally from relatively remote areas in northern Queensland between Hughenden and Normanton. *Santalum lanceolatum* has a relatively low oil yield in comparison to other sandalwood species and a consequent lower market value. With declining amounts of natural sandalwood available for harvest and an increasing market the potential exists for sandalwood production from plantations. To date, little work has been done in Queensland on production of Sandalwood in plantations. This report details anexperiment established in late 1999 to investigate the growth and survival of four sandalwood species, viz; *Santalum album*, S. *austrocaledonicum*, *S. yasi* and *S. macgregorii* on two sites in Queensland

Tennakoon K.U. & Cameron D.C. (2006) "The anatomy of Santalum album (Sandalwood) haustoria. *Can. J. Bot.* **84**(10), 1608-1616. Abstract. Structural attributes of *Santalum album* L. (Sandalwood) haustoria have been long overlooked in the literature. This is surprising since successful haustorial formation is key to the survival of individuals of this ecologically and economically important plant. We investigated the morphology of haustoria formed by *S. album* attached to one of its principal hosts *Tithonia diversifolia* (Hemsley) A. Gray. The bell-shaped mature haustoria were composed of a peripheral hyaline body and a centrally located penetration peg. The parasite penetration peg can penetrate the host by means of direct pressure and the secretion of cell-wall-degrading enzymes when forming a successful graft union. The latter mechanism is supported by this study as we observed no evidence of collapsed host cells as the result of parasite applied pressure. Upon reaching the xylem tissue of the host root, the penetration peg formed a thin ellipsoidal disc and the host–parasite interface was almost entirely composed of parenchymatous tissue. Luminal continuities were absent between the xylem conducting tissues of the partners, thus suggesting mass flow of solutes is unlikely to occur in this association. High densities of contact parenchyma were found at the host–parasite interface; thus it is probable that these are the principal structures formed by the parasite that facilitate the acquisition of host-derived xylem resources. This study therefore concludes that haustorial anatomy of *S. album* supports cross membrane (potentially selective) uptake of host-derived solutes as opposed to mass flow via vascular continuity.

Tennakoon K.U. & Pate J.S. (1997) “Biological and physiological aspects of the *Santalum acuminatum* (quandong) and its hosts in Western Australia.” *Sandalwood Research Newsletter* **6**: 1-2

Tennakoon K.U., Pate J.S. & Arthur D. (1997) “Ecophysiological aspects of the woody root hemiparasite *Santalum acuminatum* and its common hosts in South Western Australia.” *Annals of Botany*. **80**: 254-256

Tennakoon K.U., Pate J.S. & Stewart, G.R. (1997) “Haustorium-related uptake and metabolism of host xylem solutes by the root hemiparasitic shrub *Santalum acuminatum*. *Annals of Botany*. **80**: 257-264

Tonts M. (2001) *Sandalwood Market Study* (Draft Report) Perth: Dept of Agriculture.

Tonts M. & Selwood J. (2002) “Niche Markets, Regional Diversification and the Reinvention of Western Australia’s Sandalwood Industry” *Tijdschrift voor Economische en Sociale Geografie* **94**(5), 564-575. Abstract. Diversification and niche marketing have become very important economic strategies for many rural small businesses, farmers and communities. As part of these strategies, new opportunities often emerge for traditional products and industries. In the case of Western Australia, this has contributed to the revitalisation of the sandalwood industry. While sandalwood has been exported from Western Australia for more than 150 years, for much of the second half of the twentieth century it was of little economic significance. In recent years, however, the industry has become increasingly entrepreneurial, successfully marketing its products into niche markets in the global economy. For farmers and communities in rural areas, the revitalisation of the sandalwood industry has also provided opportunities for economic diversification and a profitable way of tackling land degradation.

Trueman S., Warburton C., James E., Fripp Y. &. Wallace H. (2001) "Clonality in remnant populations of *Santalum lanceolatum*." *Sandalwood Research Newsletter* **14**, 1–4. Abstract. *Santalum lanceolatum*, the northern sandalwood or plumbush, was very heavily harvested in Victoria and New South Wales in the late 1800s. Clearing, fire and grazing have also contributed to the species' decline. Only seven populations remain in Victoria, where we studied the five southernmost populations of the species. Since exclusion of grazing animals, the remnant populations have been reproducing asexually by root suckers. However, we observed little or no fruit production in the populations, and allozyme and RAPD analyses suggested that sexual reproduction had not been contributing to recruitment. Each population appeared to exist as a unique single clone composed of numerous ramets of a single genet. Therefore, conservation of the species in Victoria may require protection of all remnant populations, and possibly the establishment of new populations.

Vernes T. & Robson K. (2002). "Indian sandalwood industry in Australia." *Sandalwood Research Newsletter* **16**, 1-4.

Warburton C.L. James E.A., Fripp Y.J., Trueman S.J. & Wallace H.M. (2000) "Clonality and sexual reproductive failure in remnant populations of *Santalum lanceolatum* (Santalaceae)." *Biological Conservation* **96**(1), 45-54 Abstract. Habitat fragmentation can have important conservation consequences for clonal plant species that possess self-incompatibility mechanisms, as lack of genetic variability within remnant populations may result in sexual reproductive failure. Allozymes and RAPDs were used in this study to determine the extent of clonality in remnant Victorian populations of the northern sandalwood, *Santalum lanceolatum* (Santalaceae), a species that has been heavily wild-harvested. *S. lanceolatum* can reproduce asexually by root suckers, and each population was identified as a unique single clone composed of numerous ramets of a single genet. Examination of pollination and fruit set indicated that little or no sexual reproduction was occurring in the remnants, due to pollen sterility in one population and self-incompatibility or pistil dysfunction in others. Clonality, genetic isolation and sexual reproductive failure indicate that preservation of each population, and possibly the establishment of new ones, should be objectives of the conservation strategy for the *S. lanceolatum* remnants.

Warburton C.L. (2001) "Clonality in remnant populations of *Santalum lanceolatum*" *Sandalwood Research Newsletter:* **14**, 1-4. Abstract. *Santalum lanceolatum*, the northern sandalwood or plumbush, was very heavily harvested in Victoria and New South Wales in the late 1800s. Clearing, fire and grazing have also contributed to the species' decline. Only seven populations remain in Victoria, where we studied the five southernmost populations of the species. Since exclusion of grazing animals, the remnant populations have been reproducing asexually by root suckers. However, we observed little or no fruit production in the populations, and allozyme and RAPD analyses suggested that sexual reproduction had not been contributing to recruitment. Each population appeared to exist as a unique single clone composed of numerous ramets of a single genet. Therefore, conservation of the species in Victoria may require protection of all remnant populations, and possibly the establishment of new populations.

Wharton G. (1985). "Antiquarians and sandalwood-getters: the establishment of the Cape York Collection at Weipa." In: *Proceedings of the North Australian Mine Rehabilitation Workshop, No 9* Weipa, 1985.

Wijesuriya S.R. & Fox J.E.D. (1985) "Growth and nutrient concentration of sandalwood seedlings grown in different potting mixtures." *Mulga Research Centre Journal* **8**, 33-40.

Woodall G.S. & Robinson C.J. (2002) "Same day plantation establishment of the root hemiparasite sandalwood (*Santalum spicatum* (R Br) A DC: Santalaceae) and hosts." *J Royal*

Soc of Western Australia **85**, 37-42. Abstract. Interest and investment in a plantation sandalwood (*Santalum spicatum* (R Br) A DC) industry in southern Western Australia has been steadily growing over the last few years. Current plantation establishment involves planting host seedlings in year one and then direct sowing of untreated seeds of the parasitic sandalwood in year two or three. An innovative establishment technique in which host seedlings of *Acacia acuminata* Benth and partially germinated sandalwood seeds are planted on the same day was compared to the current establishment methods. The study showed that sandalwood and host establishment in one season is achievable and that it was three times more successful than the most widely used and promoted technique at present. Results also indicated that water availability influenced the germination, summer survival and growth of sandalwood. The use of small seedling hosts on well-watered, cleared land results in a higher rate of sandalwood establishment and growth.

Woodall G.S. & Robinson C.J. (2002) “Direct seeding Acacias of different form & function as hosts for Sandalwood (*Santalum spicatum*).” *Conservation Science Western Australia* **4**(3), 130-134.

Woodall G.S. & Robinson C.J. (2003) “Natural diversity of *Santalum spicatum* host species in south-coast river systems and their incorporation into profitable and biodiverse revegetation” *Australian Journal of Botany* **51**(6), 741 –753.

Woodall G.S. (2004) “Cracking the woody endocarp of *Santalum spicatum* nuts by wetting and rapid drying improves germination” *Australian J. of Botany* **52**(2), 163-169.

Chinese Sandalwood (*Santalum album*).

Chen F. (1999) "Cuttage of *Santalum album*." *Zhong Yao Cai* **22**(3), 109-111. Abstract: The effects of cuttage times, miaternal plant ages, hormones and mediums on the taking root of a cutting were studied in 1991-1996. The results showed that the sprouts of germinating and growing 20-30 days from the cut back of maternal plant as cuttings, the rate of the taking root get to about 70%; the suitable cuttage time was in June to August; the proper medium was river sands, but the effects of hormones were not obvious.

Chen Z.-X. & Lin L. (2001) “Influences of various extraction methods on content & chemical components of volatile oil of *Santalum album*.” *Guangzhou Zhongyiyao Daxue Xuebo* **18**(2), 174-177.

Gao Z., Wu Y., Dong Z. & Wu W. (2004) "Habit & control of pests in *Santalum album*." *Zhong Yao Cai* **27**(8), 549-51. Abstract: The habit of 5 species pests from South China Botanical Garden was reported in this paper, they are *Delias aglaia* Linni, *Zenzera coffeae* Nietner, *Parlatoria pergandii* Comstock, Scarab (grub), *Agrotis ypsilon* Rottemberg. Their control methods were presented.

Ma G.H.., Bunn E., Zhang J.-F., Wu G.-J. (2006) "[Evidence of dichogamy in *Santalum album* L.]" *J Integrative Plant Biology* **48**(3),300-306. Abstract. Flowering, fruit set, embryological development, and pollination trials were investigated in *Santalum album* L. Each ovary may have three to four ovules. Microsporogenesis and megasporogenesis in the same flower were synchronized at the earlier stages of flower development. However, at anthesis, when pollen was mature, the magaspore had developed only to the stage of a one- to two-nucleus embryo sac. As the eight-nucleus embryo sac developed, some mamelon cells began to undergo programmed cell death, forming holes into which the eight-nucleus embryo sacs extended, becoming "N" or "S" shaped. The development from a two-nucleus embryo sac to a matured eight-nucleus embryo sac lasted up to 10 d. Fruit-set from open pollination was less than 2%. The endosperm develops prior to division of the zygotic embryo and one to three embryos and endosperms were formed in the same fruit. A mature seed usually germinates to produce one seedling; however, two and three seedlings from one seed were also observed, albeit at a low frequency. Pollination trials showed that no seed sets when inflorescences were covered with a bag; however, artificial pollination could improve fruit set. Our pollination trials and embryological studies proved that the flower of *S. album* is dichogamous and fruit set has high heterozygosity.

Ma G.-H., YueMin H., JingFeng Z., FuLian C (2005) "Study on semi-parasitism of sandalwood seedlings." *Journal of Tropical and Subtropical Botany* **13**(3),233-238. Abstract. Semi-parasitism of sandalwood (*Santalum album*) seedlings was studied on the basis of the propagation of the different host plant species. Sandalwood plants can grow normally without host plant during its seed germination and early seedling stage. However, the subsequent growth needs roots of the host plant. Results indicated that the host plant species had a significant impact on the growth of sandalwood seedlings and their root haustoria as exhibited by the differences in haustorium's number, size and adhesiveness. Host plant species such as *Hibiscus rosa-sinensis* and *Phyllanthus reticulatus* were found as good host plants for the growth of sandalwood seedlings. Sandalwood roots lack root hairs, but its vessels were well developed, which are suitable for absorption of water and nutrients from the host's roots. The semi-parasitism of sandalwood on Hibiscus roots was also investigated.

Ma G-H. & Bunn E. (2007) "Embryology and pollination trials support dichogamy in *Santalum album* L." *Sandalwood Research Newsletter* **23** (Oct 2007) Abstract. Embryo development and pollination trials were studied in *Santalum album* L. The formation of the male (microspore) and female (megaspore) tissues in the same flower were synchronized during the early stages of flower-bud development. How-ever, at anthesis when pollen was mature, the megaspore had developed only to the stage of a 1-2 nucleate embryo sac. The development from 2-nucleate embryo sac to matured 8-nucleate embryo sac lasted up to 10 days. These results indicate thatthe flower of *S. album* is dichogamous where the pollen matures before the embryo sac. Following fertilisation of the ovule the endosperm developed prior to division of the zygotic embryo, and 1-3 embryos and endosperms were formed in the samefruit. Seed-set resulting from open pollination was less than 3%. No seed set was observed when inflorescences were coveredwith a bag; however artificial pollination increased fruit set to14%. Mature seed usually germinated to produce one seed-ling, but two- and three-seedlings from one seed were also observed at low frequency

Li Y. (1997) "Preliminary studies on grafting of *Santalum album*." *Zhong Yao Cai* **20**(11), 543-545. Abstract: With the purpose of propagating high production Clone of *Santalum album*, the best season and practical method of grafting, and the selection of shoots for scion are studied. The preliminary results show: The best season for grafting in Guangzhou District occurs from June to October, when the daily mean temperature is over 25 degrees C, the side graft is recommedable; the scion from 1-5-year old young trees is much in favor for grafting than that from adult trees. In the right condition, side grafting of *Santalum album* has had up to 80 percent success rate.

Lin L., Wei M., Xiao S., Xu X., Hu Z., Qiu J., Cai Y., Lu A., &Yuan L. (2000) "[The influence of external stimulation on content and quality of volatile oil in Lignun Santali albi]" *Zhong Yao Cai*. **23**(3), 152-4. Abstract. The authors analyzed the quality of Ligmum Santali Albi formed by the external stimulation of hormone and windburn by GC-MS-DS. The results showed that the content of volatile oil is 2.34% in the heart wood formed in 10 years tree age of *Santalum album* (SA) after 2 years stimulation continuously with a definite concentration of hormone, which is near to the 25 years tree age of SA in the same place. The GC-MS analysis showed that the content of santalol and other chemical components in volatile oil are similar to the 25 years tree age of SA. It is indicated that a definite concentration of hormone stimulated the SA may shorten the formation of the heart wood. The heart wood can be also formed by the broken branches after 2 years windburn, but its content of volatile oil is only 1/2 of the heart wood formed by hormone stimulation.

Wei M, Lin L, Qiu JY, Chai YW, Lu AN, Yuan L, Liao HF, Xiao SE. (2000) "[Wind-damage effects on quality of heartwood of Lignum Santali Albi]" *Zhongguo Zhong Yao Za Zhi* **25**(12), 710-3. Abstract. OBJECTIVE: To evaluate the wind-damage effects on quality of heartwood of Lignum Santali Albi. METHOD: GC-MS, TLC and pharmacodynamic test. RESULTS: The content of volatile oil from heartwood of Wind-damaged Lignum Santali Albi is 1.42%; the content of various components in the oil and the chromatography of different extracts are similar to those of reference drug and 25 years old trees. CONCLUSION: Wind-damage should accelerate the formation of heartwood of Lignum Santali Albi without influence on its quality.

Yu J.G., Cong P.Z., Lin J.T., Fang H.J. (1988) "Studies on the chemical constituents of Chinese sandalwood oil & preliminary structures of five novel compounds". *Yao Xue Xue Bao* **23**(11), 868-872.

Yu, J. G., Cong P.Z., *et al.* (1993). "Studies on the structure of alpha-trans-bergamotenol from Chinese sandalwood oil." *Acta Pharmaceutica Sinica* **28**(11), 840-844.

Zhu L.-J. Li Y.-H. Li B-L. Lu B.-Y & Xia N.H. (1993) *Aromatic plants & essential constituents* p60. South China Institute of Botany, Chinese Academy of Sciences, Hai Feng Publish Co, distributed by Peace Book Co. Ltd. Hong Kong, China (1993).

East African Sandalwood.

Cropwatch comments: '*East African sandalwood' includes* Osyris *spp. such as* O. lanceolata *&* O. tenuifolia).

Kamau P. & Wabuyele E. (2007) "Report on in-situ sustainable harvesting method for *Osyris lanceolata* (East African sandalwood) in Mbeere District, Kenya." pub: National Museum of Kenya, Niarobi. See http://idl-bnc.idrc.ca/dspace/handle/10625/42137
H
Koross K. (2008) "Kenya: Sandalwood Ban Proves Hard to Enforce." *The Nation (Niaobi)* 27th June 2008. ***Cropwatch comments***: Story about 7 tons of sandalwood being impounded on Wednesday at Salawa Division in the Baringo Disatrict. Villagers from Baringo & East Pokot districts sell sandalwood to dealers in spite of the trade ban in 2007. The wood finds a ready market in China. The article goes on to speculate about corrupt officials & security officers being involved in the illegal trade as well as prominent individuals and politicians.

Kreipl A. Th. & König W.A. (2004) "Sesquiterpenes from the East African sandalwood *Osyris tenuifolia*" *Phytochem* **65**(14), 2045-2049. Abstract: The essential oil of the east African sandalwood *Osyris tenuifolia* was investigated by chromatographic and spectroscopic methods. Beside several already known sesquiterpenes four new compounds could be isolated by preparative gas chromatography and their structures investigated by mass spectroscopy and NMR techniques. Two of the new compounds – tenuifolene (17) and ar-tenuifolene (15) – show a new sesquiterpene backbone. 2,(7Z,10Z)-Bisabolatrien-13-ol (23) and the cyclic ether lanceoloxide (21) belong to the bisabolanes. Graphical Abstract: The essential oil of East African sandalwood *Osyris tenuifolia* was investigated by NMR, Mass spectrometry and chemical correlations. Four new sesquiterpenes including 15 and 17 with a new skeleton were identified.

Mwang'ingo P.L. & Mwihomeke S.T. (1997) "Some highlight on a research program into cultivation of *Osyris lanceolata* (African sandalwood)." In: Mbwambo, L.R., Mwang'ingo, P.L., Masayanyika S.W and Isango, J.A (eds.). *Proceedings of the Second Workshop on Setting Forestry Research Needs and Priorities.* 18-22 August 1997 Moshi Tanzania. TAFORI, Morogoro, Tanzania. pp 82-84.

Mwang'ingo P.L. (2002) "Ecology and silviculture of *Osyris lanceolata* (African Sandalwood) An aromatic tree of Tanzania." - see http://opensigle.inist.fr/handle/10068/365227

Mwang'ingo P.L.., Teklehaimanot Z., Hall J.B. & Lulanda L.L. (2003) "African Sandalwood (*Osyris lanceolata*): resource assessment & quality variation among poulations in Tanzania: research note." *Southern Hemisphere Forestry Journal* **199**, 77-88. Abstract. African sandalwood (*Osyris lanceolata*) populations occurring in Tanzania were assessed to determine the current resource status and ascertain variation in quality existing among them. This will provide a guide in the selection of populations where conservation efforts and improvement programmes can be concentrated. The resource status was assessed through estimation of the species' density per unit area and measurements of tree dimensions. Quality variation was assessed by determining the amount of oil extracted from a given amount of wood and the proportion composition of

santalol, a prime determinant of sandalwood oil quality. The study revealed that populations supporting *O. lanceolata* in Tanzania occur mostly in arid to semiarid areas with the majority being on stony and rocky soils. However, big sized trees are supported in humid climates, being favoured by relatively low soil pH and reasonable amounts of soil nitrogen. Tree density ranged from 38 individuals to 76 per hectare. The mean tree height was 3, 8 m (2, 1 to 6, 5 m) while the mean diameter was 5, 7 cm (3, 6 cm to 8, 6 cm). The best quality and quantity of oil came from populations of relatively arid climates compared to those of humid climates. Populations differed significantly in both yield and quality. The highest yield obtained was 8, 45 ± 0, 54% from Gubali population while the highest santalol content (32, 2 ± 1, 2%) was from Bereko populations. Within trees, quantity and quality of oil was higher in wood portions close to the ground in both the root and shoot system. The amount decreased toward the root and shoot tip. The root and the shoot system were similar in quality and quantity of oil. The observed harvesting selectivity is thus primarily influenced by quality differences among populations while the large dimension and density differences among populations seem to be secondary. Inclusion of the root systems during harvesting is also a matter of maximizing the raw material to be collected rather than differences between the two portions. The exact factors controlling wood quality in the species have however remained uncertain. Probably, genetic factors alone or in combination with the environmental factors play a significant role.

Mwang'ingo P.L., Teklehaimanot Z., Hall J.B, Zilihona J.E. (2007) "Sex distribution, reproductive biology and regeneration In the dioecious species *Osyris lanceolata* (African Sandalwood) In Tanzania." *Tanzania Journal of Forestry and Nature Conservation* 76, 118-133. Abstract. Sex distribution, reproductive biology and regeneration of African Sandalwood (*Osyris lanceolata*) were assessed in six natural populations of Tanzania between January 1999 and February 2001. The aim was to acquire basic information required for efficient management, conservation and sustainable utilization of the species. The study had four objectives: to assess the spatial distribution of male and female trees in O. lanceolata supporting stands and whether this has any significance in influencing the reproductive success; to document the phenological events occurring between flower initiation and fruit ripening; to examine the reproductive success of various stages through pollination experiment; and to assess the regeneration mode and potential of the species. The study revealed that, the distribution of male and female trees in most populations was random with no evidence of sex clustering. It takes 104 days from flowering until when 25% of fruit initiated become ripe. About 75% of the initiated fruits become ripe in 163 days. This study has also demonstrated absence of agamospermy behaviour in *O. lanceolata*. A limited reproductive success was noted however, due to either low level of pollen production or limited pollinators' movement. Assisted pollination significantly increased the reproductive success of the species. The tree regenerates through seeds, rootstocks and coppice. Of the total regenerating plants assessed at sapling stage, 61% had originated from rootstock or coppice while 39% came from seed source. It is concluded that, recruitment of the species relies mainly on rootstock or coppice source although the importance of seeds cannot be ignored. Thus uprooting of the species as a mode of harvesting has to be discouraged since the practice is likely to severely limit the recruitment rate.

Mwang'ingo P.L, Teklehaimanot Z., Maliondo S.M. & Msanga H.P. (2004). "Storage and pre-sowing treatment of recalcitrant seeds of Africa Sandalwood (*Osyris lanceolata*)." *Seed Science and Technology*, **32**, 547-560. Abstract. The best seed conditions and environment in which seeds of *Osyris lanceolata* could be stored to prolong their life span were investigated at Iringa Tree Seed Centre, Tanzania, by varying the storage moisture content of seeds and storage temperatures. The study also investigated the effectiveness of various seed pre-sowing treatments in enhancing germination and early seedling growth. Seeds stored at 3-5℃, after being dried to moisture content of 20% retained viability longer than those stored at other conditions. By the end of the 36th week, the viability was 60% with 0.5% being as an estimated rate of viability loss per week. Temperatures below 3℃ and over 13℃ decreased rapidly the life span of seeds. Moisture content below 15% and over 25% were also noted to be lethal. Thus seeds of *O. lanceolata* could be stored at least for short-term supply, although their life span generally remains short, suggesting the need for further research to find out other better storage conditions. The seed coat covering the embryo plays a significant role in limiting germination by restricting gas and water entry. It also acts as a mechanical barrier to embryo growth. Complete removal of the seed coat and soaking in hot water enhanced seed germination (66.5% and 57.5%, respectively), shortened the time of seed to commence germination and promoted early seedling growth and are thus recommended for adoption. Nevertheless, the highest germination (66.5%) attained in this study is still unsatisfactory, suggesting the existence of other types of dormancies. This calls for further investigation to identify the dormancies and the means of resolving them. The possible existence of chemical dormancies, which was not dealt with in the present study, be given a priority in future research.

Mwang'ingo P.L., Teklehaimanot Z., Lulandala L.L. & Mwihomeke S.T. (2005). "Host plants of *Osyris lanceolata* (African Sandalwood) and their influence on its early growth performance in Tanzania." *Southern African Forestry Journal* **203**(1), 55-66. Abstract. Identification of the host plants of the hemi-parasitic African sandalwood (*Osyris lanceolata*) and the influence of some on its early growth performance was investigated at Image, Nundu, Sao Hill and Iringa in the southern highlands of Tanzania. The aim was to identify host plants that support the growth of *O. lanceolata*, and to evaluate the potential of some in promoting its early growth under artificial establishment. The results revealed that *O. lanceolata* parasitises a wide range of hosts although some were preferred. The preferred hosts were *Rhus natalensis*, *Dodonaea viscosa*, *Tecomaria capensis*, *Catha edulis*, *Apodytes dimidiata*, *Brachystegia spiciformis*, *Maytenus acuminatus* and *Aphloia theiformis*. Of the preferred hosts, *Brachytegia spiciformis*, *Rhus natalensis* and *Casuarina equisetifolia* promoted most effectively the early growth of *O. lanceolata* in terms of height, diameter and overall root and shoot biomass. Possibly the light crown of these host species and the nitrogen fixing ability of *C. equisetifolia* played a significant role in conferring this advantage. The species are thus recommended as appropriate host plants when raising O. lanceolata seedlings for planting. However, a decision on whether these hosts will support the growth of *O. lanceolata* at a later stage is subject to further experimentation as they may only be serving as initial or intermediate hosts as reported in a related species *Santalum album*.

Mwang'ingo P. L. Teklehaimanot Z., Lulandala L. L. & Maliondo S. M. (2006) "Propagating *Osyris lanceolata* (African sandalwood) through air layering: Its potential and limitation in Tanzania." *Southern African Forestry Journal* **207**, 7-14. Synopsis. Propagation of African sandalwood (*Osyris lanceolata*) by air layering (marcotting) was investigated at Sao Hill, Tanzania, aiming at providing an alternative propagation technique to the use of seeds or cuttings that germinate or root poorly. Air layers were initiated on the young shoots (1 – 2 years old) of mature *O. lanceolata* trees growing at Sao Hill catchment Forest. After root initiation, which took 8 weeks, they were detached from the parents, potted in polyethylene tubes and reared at the nursery for a further three months. The factors assessed in this experiment were the effect of time at which air layers were initiated (i.e. February, June, September and December); and the influence of IBA as rooting promoter at three concentrations (50, 100 and 150 ppm). From the data collected it was observed that rooting success of up to 80% can be achieved from air layers, making this propagation technique a viable alternative to seedlings or cutting propagation. Rooting success was influenced by both the season and application of rooting hormone with optimal rooting being achieved during June and September with the addition of IBA at a rate of 50 ppm. The significance increase in rootability of air layers during June and September may be linked to the advantage of the dry season in Tanzania where reduction of plant development activities such as budding, leafing and flowering in the dormant dry season might have reduced resource competition and thus promoting the observed rooting.

Mwang'ingo P.L., Teklehaimanot Z., Hall J.B., Zilihona L.E. (2007) "Sex distribution, reproductive biology and regenerationiIn the dioecious species *Osyris lanceolata* (African Sandalwood) nn Tanzania." *Tanzania Journal of Forestry and Nature Conservation* **76**, 118-144. Abstract. Sex distribution, reproductive biology and regeneration of African Sandalwood (*Osyris lanceolata*) were assessed in six natural populations of Tanzania between January 1999 and February 2001. The aim was to acquire basic information required for efficient management, conservation and sustainable utilization of the species. The study had four objectives: to assess the spatial distribution of male and female trees in *O. lanceolata* supporting stands and whether this has any significance in influencing the reproductive success; to document the phenological events occurring between flower initiation and fruit ripening; to examine the reproductive success of various stages through pollination experiment; and to assess the regeneration mode and potential of the species. The study revealed that, the distribution of male and female trees in most populations was random with no evidence of sex clustering. It takes 104 days from flowering until when 25% of fruit initiated become ripe. About 75% of the initiated fruits become ripe in 163 days. This study has also demonstrated absence of agamospermy behaviour in *O. lanceolata*. A limited reproductive success was noted however, due to either low level of pollen production or limited pollinators\' movement. Assisted pollination significantly increased the reproductive success of the species. The tree regenerates through seeds, rootstocks and coppice. Of the total regenerating plants assessed at sapling stage, 61% had originated from rootstock or coppice while 39% came from seed source. It is concluded that, recruitment of the species relies mainly on rootstock or coppice source although the importance of seeds cannot be ignored. Thus uprooting of the species as a mode of harvesting has to be discouraged since the practice is likely to severely limit the recruitment rate.

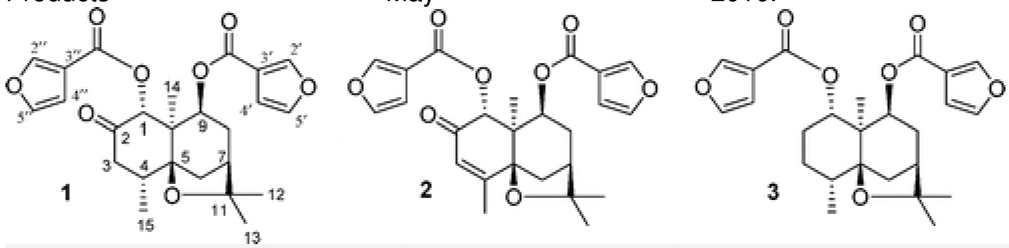
Srikrishnaa A. & Beeraiah B. (2005) "First synthesis of (′)-tenuifolene and ar-tenuifolene." *Indian J of Chemistry* Sect B. **44**(8), 1641-1643. Abstract. First total synthesis of the sesquiterpenes (′)-tenuifolene and (′)-ar-tenuifolene, isolated from the essential oil of the East African sandalwood tree *Osyris tenuifolia*, has been accomplished.

Teklehaimanot Z., Mwang ingo P. L., Mugasha A. G. & Ruffo, C. K. (2004) "Influence of the origin of stem cutting, season of collection and auxin application on the vegetative propagation of African Sandalwood (*Osyris lanceolata*) in Tanzania." *Southern African Forestry Journal* **201**, 13-24. Abstract. An investigation into the possibility of propagating *O. lanceolata* through stem cutting was carried out at Tanzania Tree Seed Agency, Iringa Zone, Tanzania. The aim was to test the potential of stem cuttings in providing an alternative/supplement to the use of seeds that are constrained with germination and storage problems. Three treatments were investigated on the rooting success and subsequent nursery performance of the cuttings: the effect of season at which cuttings are collected i.e. December, February, June and September; the effect of origin of stem cutting in a shoot, i.e. basal and terminal portions; and the effect of different levels of IBA as root promoters, i.e. 0, 50, 100 and 150 ppm. The results revealed that stem cuttings collected from the sprouting stumps have a potential to be used in propagating *O. lanceolata*. Season at which cuttings are collected; origin of the stem cuttings in a shoot and application of auxins influenced the rooting success. Stem cuttings collected in September, originating from the basal portion had the best rooting (43.8 + 3.9%). This is possibly related to the high levels of stored food in the plant after undergoing active photosynthesis during the rain season, November-May. Auxin application in interaction with the season at which cuttings were collected enhanced the number of cuttings that rooted, the number of roots formed (13 + 0.4), the length (14 + 0.3 cm) and biomass of roots (6.95 + 3.9 g) produced. The concentration to be applied for effective rooting depended on the season at which cuttings were collected. Of the origin of stem cuttings, basal portions had better rooting than the terminal portion. The high nutrition status and low nitrogen content of basal portions may play a role in enhancing their performance. Thus when raising O. lanceolata from stem cuttings, best rooting is obtained from those raised between June and September using cuttings from the basal origin of the juvenile shoots. Application of IBA between 50 and 100 ppm further enhances rooting success.

Wells R. (2006) "On the scent: Rhona Wells investigates sandalwood poaching, the ugly downside of the luxurious natural perfumery raw material trade" *Soap, Perfumery & Cosmetics* Feb 2006 **79**(2), 31. ***Cropwatch comments***: Informative one-page article on the Tanzanian situation where sandalwood logs are smuggled to India for distillation to produce sandalwood oil.

Yeboah E.M.O., Majinda R.R.T., Kadziola A. & Muller A. (2010) "Dihydro-β-agarofuran Sesquiterpenes and Pentacyclic Triterpenoids from the Root Bark of *Osyris lanceolata*." J Nat

Products May 2010. Abstract.



Three new dihydro-β-agarofuran polyesters, 1α,9β-difuranoyloxy-2-oxodihydro-β-agarofuran (1), 1α,9β-difuranoyloxy-2-oxo-3-enedihydro-β-agarofuran (2), and 1α,9β-difuranoyloxydihydro-β-agarofuran (3), have been isolated from the CHCl3 extract of the root bark of *Osyris lanceolata*, together with two known pentacylic triterpenoids, 4 and 5. Compounds 1–5 did not scavenge the DPPH radical within 30 min of reaction time. All five compounds displayed antifungal activity against *Candida albicans*. Compounds 1, 3, 4, and 5 showed antibacterial activity against the Gram-positive *Bacillus subtilis* and *Staphylococcus aureus* and Gram-negative *Escherichia coli* and *Pseudomonas aeruginosa*, with 4 and 5 being the most active. Compound 2 displayed weak antibacterial activity only against *Escherichia coli*.

East Indian Sandalwood (*Santalum album*).

Biocidal properties – E.I. Sandalwood oil.

Amer A. & Mehlhorn H. (2006) "Larvicidal effects of various essential oils against *Aedes*, *Anopheles*, and *Culex* larvae (Diptera, Culicidae)." *Parasitol Res*. **99**(4), 466-72. Abstract. Mosquitoes in the larval stage are attractive targets for pesticides because mosquitoes breed in water, and thus, it is easy to deal with them in this habitat. The use of conventional pesticides in the water sources, however, introduces many risks to people and/or the environment. Natural pesticides, especially those derived from plants, are more promising in this aspect. Aromatic plants and their essential oils are very important sources of many compounds that are used in different respects. In this study, the oils of 41 plants were evaluated for their effects against third-instar larvae of *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus*. At first, the oils were surveyed against *A. aegypti* using a 50-ppm solution. Thirteen oils from 41 plants (camphor, thyme, amyris, lemon, cedarwood, frankincense, dill, myrtle, juniper, black pepper, verbena, helichrysum and sandalwood) induced 100% mortality after 24 h, or even after shorter periods. The best oils were tested against third-instar larvae of the three mosquito species in concentrations of 1, 10, 50, 100 and 500 ppm. The lethal concentration 50 values of these oils ranged between 1 and 101.3 ppm against *A. aegypti*, between 9.7 and 101.4 ppm for *A. stephensi* and between 1 and 50.2 ppm for *C. quinquefasciatus*.

Benencia F. & Courreges M.C. (1999) "Antiviral activity of sandalwood oil against herpes simplex viruses-1 and -2." *Phytomed*. **6**(2), 119-23. Abstract: Sandalwood oil, the essential oil of *Santalum album* L., was tested for in vitro antiviral activity against Herpes simplex viruses-1 and -2. It was found that the replication of these viruses was inhibited in the presence of the oil. This effect was dose-dependent and more pronounced against HSV-1. A slight diminution of the effect was observed at higher multiplicity of infections. The oil was not virucidal and showed no cytotoxicity at the concentrations tested.

Courreges B.F. (1999). "Antiviral activity of sandalwood oil against *Herpes simplex* viruses- 1 and 2." *Phytomedicine* **6**, 119-123.

Jirovetz L., Buchbauer G., Dednkova Z., Stoyanova A., Murgov I., Gearon V., Birkbeck S., Schmidt E., Gelssler M. (2006) "Comparative study on the antimicrobial activities of different sandalwood essential oils of various origin." *Flavour and Fragrance Journal* **21**(3), 465 - 468. Abstract. In total, eight samples of different sandalwoods [*Amyris balsamifera* L., *Santalum album* L. and *Santalum spicatum* (R.Br.) A.DC.] and a mixture of - and -santalols, as well as eugenol as reference compound, were tested by an agar dilution and agar diffusion method for their antimicrobial activities against the yeast *Candida albicans*, the Gram-positive bacterium

Staphylococcus aureus and the Gram-negative bacteria *Escherichia coli*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*. The main compounds of each essential oil were investigated by gas chromatographic-spectroscopic (GC-FID and GC-MS) and -olfactory methods to obtain information about the inßuence of these volatiles on the observed antimicrobial effects. For the santalol mixture, as well as for one *S. album* and one *S. spicatum* sample with moderate concentrations of santalols, antimicrobial activity was found against all the strains used. The *A. balsamifera* sample, containing only a small quantity of -santalol and nearly no -santalol, showed high effects only against *Klebsiella pneumoniae*, while against the other strains weak or no activity was observed. Therefore, santalols in medium and/or high concentrations in sandalwood oils show a significant influence on antimicrobial potential in such natural products.

Ochi T., Shibata H., Higuti T., Kodama K.H., Kusumi T., Takaishi Y "Anti-*Heliobacter pylori* compounds from *Santalum album*."*J. Nat Products* **68**(6), 819-824. Abstract: Six new sesquiterpenes, (Z)-2-beta-hydroxy-14-hydro-beta-santalol (1), (Z)-2alpha-hydroxy-albumol (2), 2R-(Z)-campherene-2,13-diol (3), (Z)-campherene-2beta,13-diol (4), (Z)-7-hydroxynuciferol (5), and (Z)-1beta-hydroxy-2-hydrolanceol (6), together with five known compounds, (Z)-alpha-santalol (7), (Z)-beta-santalol (8), (Z)-lanceol (9), alpha-santaldiol (10), and beta-santaldiol (11), were isolated from *Santalum album*, by using bioassay-guided fractionation for *Helicobacter pylori*. The structures were determined by extensive NMR studies. The absolute configuration of compound 3 was determined by a modified Mosher method. The crude extracts as well as the isolated compounds showed antibacterial activity against *H. pylori*. Especially, compounds 7 and 8 have strong anti-*H. pylori* activities against a clarithromycin-resistant strain (TS281) as well as other strains.

Radhakrishnan A.N. & Giri K.V. (1954) "The isolation of allohydroxy-l-proline from sandal (*Santalum album* L.)." *Biochem J.* **58**(1), 57-61.

Shankaranarayana K.H., Shivaramakrishnan V.R., Ayya K.S. & Sen P.K. (1979) “Isolation of a compound from the bark of sandal and its activity against some lipidopterous & coleopterous insects.” *J. Entomol. Res* **3,** 116-118.

Shankaranarayana K.H., Ayyar K.S. & Rao G.S.K. (1980) "Insect growth inhibitor from the bark of *Santalum album*." *Phytochemistry* **19**(6), 1239-1240.

Schnitzler P., Koch C. & Reichling J. (2007) "Susceptibility of drug-resistant clinical herpes simplex virus type 1 strains to essential oils of ginger, thyme, hyssop, and sandalwood." *Antimicrob Agents Chemother*. **51**(5):1859-62. Abstract. Acyclovir-resistant clinical isolates of herpes simplex virus type 1 (HSV-1) were analyzed in vitro for their susceptibilities to essential oils of ginger, thyme, hyssop, and sandalwood. All essential oils exhibited high levels of virucidal activity against acyclovir-sensitive strain KOS and acyclovir-resistant HSV-1 clinical isolates and reduced plaque formation significantly.

Zhu J., Zeng X., O'Neal M., Schultz G., Tucker B., Coats J., Bartholomay L. & Xue RD. (2008) "Mosquito larvicidal activity of botanical-based mosquito repellents." *J Am Mosq Control Assoc*. **24**(1),161-8. Abstract. The larvicidal activity of 4 plant essential oils--innamon oil, lemon eucalyptus oil, sandalwood oil, and turmeric oil--previously reported as insect repellents was evaluated in the laboratory against 4th instars of *Aedes albopictus*, *Ae. aegypti*, and *Culex pipiens*. Sandalwood oil appeared to be the most effective of the larvicides, killing larvae of all 3 mosquito species in relatively short times. The values of LT50 and LT90 at the application dosage (0.2 mg/ml) were 1.06 +/- 0.11 and 3.24 +/- 0.14 h for *Ae. aegypti,* 1.82 +/- 0.06 and 3.33 +/- 0.48 h for *Ae. albopictus*, and 1.55 +/- 0.07 and 3.91 +/- 0.44 h for *Cx. pipiens*, respectively. Chemical compositions of these essential oils were also studied, and the lavicidal activity of their major ingredient compounds was compared with that of each of the essential oils. The acute toxicity of the 4 essential oils to fathead minnows was also evaluated. The safe use of these natural plant essential oils in future applications of mosquito control was discussed.

Contact Dermatitis – E.I. Sandalwood oil.

An S., Lee A.Y., Lee C.S., Kim D.W., Hahm J.H., Kim K.J., Moon K.C., Won Y.H., Ro Y.S., Eun H.C. (2005) "Fragrance contact dermatitis in Korea: a joint study." *Contact Dermatitis* **53**(6) , 320-323. Abstract: The purpose of this study is to determine the frequency of responses to selected fragrances in patients with suspected fragrance allergy and to evaluate the risk factors. 9 dermatology departments of university hospitals have participated in this study for the past 1 year. To determine allergic response to fragrances, 18 additional fragrances in addition to the Korean standard and a commercial fragrance series were patch-tested in patients with suspecting cosmetic contact dermatitis. Over 80% of the patients were women, and the most common site was the face. Cinnamic alcohol and sandalwood oil (*Santalum album* L.) showed high frequencies of positive responses. Of the specific fragrances, ebanol, alpha-isomethyl-ionone (methyl ionone-gamma) and Lyral (hydroxyisohexyl 3-cyclohexane carboxdaldehyde) showed high positive responses. We compared the results obtained during this study with those of other studies and concluded that including additional fragrance allergens may be useful for the detection of fragrance allergy.

Viardot-Helmer A., Merk HF, Hausen BM (2008) "[Delayed hypersensitivity to East Indian rosewood.]. *Hautarzt.* **59**(6):465-466.

Sharma R., Bajaj A.K. & Singh K.G. (1987) "Sandalwood dermatitis" *Int. J. Dermatol* **26**(9), 597. ***Cropwatch comments***: A short report about a man who had been appying *Santalum album* paste to his forehead daily for eight years. He presented with a well defined, hyperpigmented, erythematous plaque, with a mild surrounding zone of erythma. Patch tests proved positive to sandalwood, and the lesion disappeared after the application of a corticosteroid cream.

Tewary M, Ahmed I. (2006) "Bindi dermatitis to 'chandan' bindi." *Contact Dermatitis*. **55**(6), 372-4. Abstract. Bindi (meaning dot in Sanskrit) is a mark worn by most Indian women on their forehead for religious and social purposes. Traditionally it was worn by only Hindu women to signify their marital status. Nowadays, it is a huge fashion accessory, being worn in different sizes, shapes, designs and colours. The variety includes sequined designs, motifs dusted with gold and silver powder, studded with beads, or even surrounded by glittering gems. Stick-on and liquid ranges are both equally in demand. We report a case of bindi dermatitis with 'chandan' (sandalwood) bindi. To our knowledge this is the first report of contact allergic dermatitis to 'chandan' (sandalwood) bindi.

Cancer Chemoprevention – E.I. Sandalwood oil.

Arasada B.L., Bommareddy A., Zhang X., Bremmon K. & Dwivedi C. (2008) "Effects of alpha-santalol on proapoptotic caspases and p53 expression in UVB irradiated mouse skin." *Anticancer Res.* **28**(1A), 129-32. Abstract. BACKGROUND: Cancer chemoprevention by naturally occurring agents, especially phytochemicals, minerals and vitamins has shown promising results against various malignancies in a number of studies both under in vitro and in vivo conditions. One such phytochemical, alpha-santalol, a major component of sandalwood oil, is effective in preventing skin cancer in both chemically and UVB-induced skin cancer development in CD-1, SENCAR and SKH-1 mice; however, the mechanism of its efficacy is not fully understood. The objective of the present investigation was to study the effects of alpha-santalol on apoptosis proteins and p53 in UVB-induced skin tumor development in SKH-1 mice to elucidate the mechanism of action. MATERIALS AND METHODS: Female SKH-1 mice were divided into two groups: Group 1, which served as control received topical application of acetone (0.1 ml) one hour before UVB treatment; Group 2 received alpha-santalol (0.1 ml, 5% w/v in acetone, topical) one hour prior to UVB treatment. UVB-induced promotion was continued for 30 weeks. RESULTS: Pre-treatment with alpha-santalol one hour prior to UVB exposure significantly ($p < 0.05$) reduced tumor incidence and multiplicity, and resulted in a significant ($p < 0.05$) increase in apoptosis proteins, caspase-3 and -8 levels and tumor suppressor protein, p53. CONCLUSION: These results suggest that alpha-santalol prevents skin cancer development by inducing proapoptotic proteins via an extrinsic pathway and increasing p53.

Banerjee S., Ecavade A. & Rao A.R. (1993) “Modulatory influence of sandalwood oil on mouse hepatic glutathione S-transferase activity and acid soluble sulpydryl level” *Cancer Lett* **68**(2), 105-9. Abstract: The effect of the oil from the wood of *Santalum album* on glutathione S-transferase (GST) activity and acid soluble sulphydryl (SH) levels in the liver of adult male Swiss albino mice was investigated. Oral feeding by gavage to mice each day with 5 and 15 microliters sandalwood oil for 10 and 20 days exhibited an increase in GST activity in time- and dose-responsive manners. Feeding a dose of 5 microliters sandalwood oil for 10 and 20 days caused, respectively, a 1.80-fold (P < 0.001) and 1.93-fold (P < 0.001) increase in GST enzyme activity, while feeding a dose of 15 microliters of the oil per day for 10 and 20 days induced, respectively, 4.73-fold (P < 0.001) and 6.10-fold (P < 0.001) increases in the enzyme's activity. In addition, there were 1.59-fold (P < 0.001) and 1.57 (P < 0.001) increases in acid-soluble SH levels in the hepatic tissue of the mice following feeding of the oil at the dose levels of 5 and 15 microliters for 10 days. Furthermore, mice fed on a diet containing 1% 2(3)-butyl-4-hydroxyanisole (positive control) also showed an increase in hepatic GST activity and SH levels. Enhancement of GST activity and acid-soluble SH levels are suggestive of a possible chemopreventive action of sandalwood oil on carcinogenesis through a blocking mechanism.

Dwivedi C. & Abu-Ghazaleh A. (1997) "Chemopreventive effects of sandalwood oil on skin papillomas in mice." *Eur J Cancer Prev.* **6**(4), 399-401. Abstract. The essential oil, emulsion or paste of sandalwood (*Santalum album* L) has been used in India as an ayurvedic medicinal agent for the treatment of inflammatory and eruptive skin diseases. In this investigation, the chemopreventive effects of sandalwood oil (5% in acetone, w/v) on 7,12-dimethylbenz(a)anthracene-(DMBA)-initiated and 12-O-tetradecanoyl phorbol-13-acetate(TPA)-promoted skin papillomas, and TPA-induced ornithine decarboxylase (ODC) activity in CD1 mice were studied. Sandalwood oil treatment significantly decreased papilloma incidence by 67%, multiplicity by 96%, and TPA-induced ODC activity by 70%. This oil could be an effective chemopreventive agent against skin cancer.

Dwivedi C., Guan X., Harmsen W.L., Voss A.L., Goetz-Parten D.E., Koopman E.M., Johnson K.M., Valluri H.B. & Matthees D.P. (2003) " Chemopreventive effects of alpha-santalol on skin tumor development in CD-1 and SENCAR mice." *Cancer Epidemiol Biomarkers Prev.* **12**(2), 151-6. Abstract. Studies from our laboratory have indicated skin cancer chemopreventive effectsof sandalwood oil in CD-1 mice. The purpose of this investigation was to study the skin cancer chemopreventive effects of alpha-santalol, a principal component of sandalwood oil in CD-1 and SENCAR mice. alpha-Santalol was isolated from sandalwood oil by distillation under vacuum and characterized by nuclear magnetic resonance and gas chromatography-mass spectrometry. Chemopreventive effects of alpha-santalol were determined during initiation and promotion phase in female CD-1 and SENCAR mice. Carcinogenesis was initiated with 7,12-dimethylbenz(a)anthracene and promoted with 12-O-tetradecanoylphorbol-13-acetate (TPA). The effects of alpha-santalol treatment on TPA-induced epidermal ornithine decarboxylase (ODC) activity and (3)H-thymidine incorporation in epidermal DNA of CD-1 and SENCAR mice were also investigated. alpha-Santalol treatment during promotion phase delayed the papilloma development by 2 weeks in both CD-1 and SENCAR strains of mice. alpha-Santalol treatment during promotion phase significantly (P < 0.05) decreased the papilloma incidence and multiplicity when compared with control and treatment during initiation phase during 20 weeks of promotion in both CD-1 and SENCAR strains of mice. alpha-Santalol treatment resulted in a significant (P < 0.05) inhibition in TPA-induced ODC activity and incorporation of (3)H-thymidine in DNA in the epidermis of both strains of mice. alpha-Santalol significantly prevents papilloma development during promotion phase of 7,12-dimethylbenz(a)anthracene-TPA carcinogenesis protocol in both CD-1 and SENCAR mice, possibly by inhibiting TPA-induced ODC activity and DNA synthesis. alpha-Santalol could be an effective chemopreventive agent for skin cancer. Additional experimental and clinical studies are needed to investigate the chemopreventive effect of alpha-santalol in skin cancer.

Dwivedi C., Maydew E.R., Hora J.J., Ramaeker D.M. & Guan X. (2005) "Chemopreventive effects of various concentrations of alpha-santalol on skin cancer development in CD-1 mice." *Eur J*

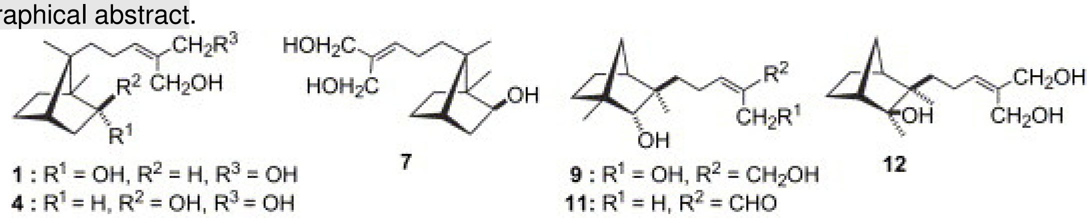
Cancer Prev. **14**(5), 473-6. Abstract. Previous studies from this laboratory have indicated that alpha-santalol (5%) provides chemopreventive effects in 7,12-dimethylbenz[a]anthracene (DMBA)-initiated and 12-O-tetradecanoylphorbol-13-acetate (TPA)-promoted skin cancer in CD-1 and SENCAR mice. Skin cancer development is associated with increased ornithine decarboxylase (ODC) activity, DNA synthesis and rapid proliferation of epidermal cells. The purpose of this investigation was to determine the effects of various concentrations (1.25% and 2.5%) of alpha-santalol on DMBA-initiated and TPA-promoted skin cancer development, TPA-induced ODC activity, and DNA synthesis in CD-1 mice. alpha-Santalol treatment at both concentrations (1.25% and 2.5%) prevented the skin cancer development. alpha-Santalol treatment (1.25% and 2.5%) resulted in a significant decrease in the TPA-induced ODC activity and incorporation of [3H]thymidine in DNA in the epidermis of CD-1 mice. There was no significant difference in the effects of 1.25% and 2.5% alpha-santalol on tumour incidence, multiplicity, epidermal TPA-induced ODC activity, or DNA synthesis in CD-1 mice.

Dwivedi C., Valluri H.B., Guan X. & Agarwal R. (2006) "Chemopreventive effects of alpha-santalol on ultraviolet B radiation-induced skin tumor development in SKH-1 hairless mice." *Carcinogenesis*. **27**(9),1917-22. Abstract. Recent studies from our laboratory have shown the chemopreventive effects of alpha-santalol against 7,12-dimethylbenzanthracene (DMBA) initiated and 12-O-tetradecanoylphorbol-13-acetate (TPA) promoted skin tumor development in mice. The objective of the present investigation was to study the effects of alpha-santalol on ultraviolet B (UVB) radiation-induced skin tumor development and UVB-caused increase in epidermal ornithine decarboxylase (ODC) activity in female hairless SKH-1 mice. For the tumor studies, 180 mice were divided into three groups of 60 mice each, and each group was divided into two subgroups of 30 mice. The first subgroup served as control and was treated topically on the dorsal skin with acetone. The second subgroup served as experimental and was treated topically on the dorsal skin with alpha-santalol (5%, w/v in acetone). The tumorigenesis in the first group was initiated with UVB radiation and promoted with TPA; in the second group it was initiated with DMBA and promoted with UVB radiation; and in the third group it was both initiated and promoted with UVB radiation. In each case, the study was terminated at 30 weeks. Topical application of alpha-santalol significantly ($P<0.05$) decreased tumor incidence and multiplicity in all the three protocols, suggesting its chemopreventive efficacy against UVB radiation-caused tumor initiation, tumor promotion and complete carcinogenesis. In a short-term biochemical study, topical application of alpha-santalol also significantly ($P<0.05$) inhibited UVB-induced epidermal ODC activity. Together, for the first time, our findings suggest that alpha-santalol could be a potential chemopreventive agent against UVB-induced skin tumor development and, therefore, warrants further investigations.

Kaur M., Agarwal C., Singh R.P., Guan X., Dwivedi C. & Agarwal R. (2005) "Skin cancer chemopreventive agent, {alpha}-santalol, induces apoptotic death of human epidermoid carcinoma A431 cells via caspase activation together with dissipation of mitochondrial membrane potential and cytochrome c release." *Carcinogenesis* **26**(2), 369-80. Abstract. alpha-Santalol, an active component of sandalwood oil, has been studied in detail in recent years for its skin cancer preventive efficacy in murine models of skin carcinogenesis; however, the mechanism of its efficacy is not defined. Two major biological events responsible for the clonal expansion of transformed/initiated cells into tumors are uncontrolled growth and loss of apoptotic death. Accordingly, in the present study, employing human epidermoid carcinoma A431 cells, we assessed whether alpha-santalol causes cell growth inhibition and/or cell death by apoptosis. Treatment of cells with alpha-santalol at concentrations of 25-75 microM resulted in a concentration- and a time-dependent decrease in cell number, which was largely due to cell death. Fluorescence-activated cell sorting analysis of Annexin V/propidium iodide (PI) stained cells revealed that alpha-santalol induces a strong apoptosis as early as 3 h post-treatment, which increases further in a concentration- and a time-dependent manner up to 12 h. Mechanistic studies showed an involvement of caspase-3 activation and poly(ADP-ribose) polymerase cleavage through activation of upstream caspase-8 and -9. Further, the treatment of cells with alpha-santalol also led to disruption of the mitochondrial membrane potential and cytochrome c release into the cytosol, thereby implicating the involvement of the mitochondrial pathway. Pre-

treatment of cells with caspase-8 or -9 inhibitor, pan caspase inhibitor or cycloheximide totally blocked alpha-santalol-caused caspase-3 activity and cleavage, but only partially reversed apoptotic cell death. This suggests involvement of both caspase-dependent and -independent pathways, at least under caspase inhibiting conditions, in alpha-santalol-caused apoptosis. Together, this study for the first time identifies the apoptotic effect of alpha-santalol, and defines the mechanism of apoptotic cascade activated by this agent in A431 cells, which might be contributing to its overall cancer preventive efficacy in mouse skin cancer models.

Kim T.H., Ho H., Takayasu T., Tokuda H., Machiguchi M. & T. (2006) "New antitumor sesquiterpenoids from *Santalum album* of Indian origin." *Tetrahedron* **62** (29), 6981-6989. Abstract. Three new campherenane-type (1, 4, 7) and three new santalane-type (9, 11, 12) sesquiterpenoids, and two aromatic glycosides (21, 22) together with 12 known metabolites including β-santalols (14, 18), (E)-,β-santalals (15, 19), β-santaldiols (16, 20), -santalenoic acid (17), and vanillic acid 4-O-neohesperidoside were isolated from *Santalum album* chips of Indian origin. The structures of the new compounds, including absolute configurations, were elucidated by 1D- and 2D-NMR spectroscopic and chemical methods. The antitumor promoting activity of these isolates along with several neolignans previously isolated from the same source was evaluated for both in vitro Epstein–Barr virus early antigen (EBV-EA) activation and in vivo two-stage carcinogenesis assays. Among them, compound 1 exhibited a potent inhibitory effect on EBV-EA activation, and also strongly suppressed two-stage carcinogenesis on mouse skin.
Graphical abstract.



Kim T.K., Ito H., Hayashi K., Hasegawa T., Machiguchi T. & Yoshida T. (2005) "Aromatic Constituents from the Heartwood of *Santalum album* L." *Chem. Phar. Bull.* 53(6), 641-644. Abstract. A phytochemical investigation of the polar constituents in the heartwood of Indian *Santalum album* L. resulted in the isolation of three new neolignans (1—3) and a new aromatic ester (4), along with 14 known components. The structures of the new compounds (1—4) were established using spectroscopic methods.

Matsuo Y. & Mimaki Y. (2010) "Lignans from *Santalum album* and their cytotoxic activities." *Chem Pharm Bull* **58**(4):587-90. Abstract. A new neolignan, (7R,8R)-5-O-demethylbilagrewin (1), together with four known lignans (2-5), were isolated from the heartwood of *Santalum album* (Santalaceae). The structure of 1 was determined by analysis of extensive spectroscopic data. The isolated compounds and derivatives were evaluated for their cytotoxic activities against HL-60 human promyelocytic leukemia cells and A549 human lung adenocarcinoma cells. Compounds 1 and 2 exhibited cytotoxicity against HL-60 cells with IC(50) values of 1.5+/-0.02 and 4.3+/-0.13 microM, and against A549 cells with IC(50) values of 13.6+/-0.32 and 19.9+/-1.27 microM, respectively. The aldehyde group of 1 and 2 was revealed to be a structural requirement for the appearance of cytotoxicity in this type of lignans. These tumor cell deaths were shown to be mediated through induction of apoptosis.

Palep S. & Lebwohl M. (2007) "Inhibitory effects of alpha- and beta-santalol on UVB-induced mouse skin carcinogenesis." *Journal of the American Academy of Dermatology* **56**(2) Suppl. 2, pAB36.

Chemistry of E.I. Sandalwood.

Anonis D.P. (1998) “Sandalwood & sandalwood compounds” *Perf. & Flav.* **23**(5), 19-24.

Bajgrowicz J.A. & Frater G. (2000) "Chiral recognition of sandalwood odourants." *Enantiomer* 5(3-4), 225-234. Abstract: Looking for more efficient sandalwood oil smelling compounds, new

campholenic aldehyde derivatives with rigidifying cyclopropane rings were prepared. For some of them, having the lowest odor threshold ever measured for this type of odorants and a very appreciated scent, close to that of the scarce natural sandalwood oils, pure stereoisomers were obtained and their olfactory properties were evaluated. Thus acquired structure-odor relationship data, together with consolidated and completed previous knowledge on structurally different sandalwood-smelling compounds, allowed to propose new models of the sandalwood olfactophore.

Beyer A., Wolschann P., Becker A., Pranka E. & Buchbauer G. (1988) "Conformational calculations in odiferous molecules of sandalwood." *Montash. Chem*. **119**, 711.

Beyer A., Wolschann P., Becker A., Pranka E. & Buchbauer G. (1988) "Conformational calculations in sandalwood odour molecules" *Flav. Frag. J.* **3**, 173.

Bhati A. (1962) "Studies in the Sandalwood oil Series. 111. Chain Effect on Terpene Transformations." *J of Organic Chemistry* Dec 1962 p4485. Abstract. Thc carboxyl chain of some moleciiles has been found to be responsible for causing rearrangements and controlling their course, This chain effect, which opcrates during reactions involving carbonium ions, is illustrated with examples from Sandalwood oil chemistry.

Bohlmann F. & Zedro C. (1968) "Isolierung von (-)-a-santalal aus Piqueria Trinerva" *Tetrahedr. Lett.* 1533.

Braun N.A., Meier M., Schmaus G., Hölscher B. & Pickenhagen (date?) "Enantioselectivity in odour perception: synthesis & olfactory properties of iso-b-bisabolol, a new natural product" *Helv. Chim. Acta* **86**, 2698-2708.

Briggs C.H. (1915). "Some notes on Sandalwood, its assay, yield of oil, and changes in the oil during distillation." *J of Industrial. & Engineering. Chemistry* **8**(5), 428.

Brocke C., Eh M. & Finke A.(2008) "Recent developments in the chemistry of sandalwood odorants." *Chem Biodivers* **5**(6), 1000-10. Abstract. Natural sandalwood oil, a unique and valuable ingredient in fine perfumery, has been the focus of scientific interest for many years. Due to its scarcity and its high price, the search for novel synthetic raw materials imitating the characteristic odor profile of sandalwood oil is as challenging as ever. In this context, the preparation of the novel sandalwood odorants 26, 33, and 39 will be discussed, including their sensory properties and structure-odor relationship.

Brunke E.-J. & Hammerschmidt F.-J. (1980) "New Constituents of East Indian Sandalwood oil". *Proceedings of VIII Congress Intl. Des Huiles Essentielles* Oct 1980 Pub. 1982 Fedarom.

Brunke E-J. & Rojahn W. (1980) "Sandalwood Oil" *Dragoco Report* **5**/1980, 127-135.

Brunke E-J (1983) "Woody Aroma Chemicals" *Dragoco Report* **6**/1983 p146

Brunke E-J. & Hammerschmidt F.-J. (1988) "Constituents of East Indian sandalwood oil – an eighty year old stabilty test" *Dragoco Report* **4**/1988 pp107-113.

Brunke E.J. & Schmaus (1995) "New active odour constituents in Sandalwood Oil: part 2: Isolation, structural elucidation and synthesis of nor-a-trans-bergamotenone" *Dragoco Report* **6**/1995 p245-257.

Brunke, E. J., Vollhardt J., et al. (1995). "Cyclosantalal and epicyclosantalal-new sesquiterpene aldehydes from East Indian sandalwood oil." *Flavour and Fragrance Journal* **10**(3), 211-219

Brunke E-J, Fahlbusch K-G, Schmaus G & Volhart (1997) "The chemistry of sandalwood odour – a review of the last 10 years". In *Rivista Ital. EPOS* (Actes des 15emes Journeés Internationales Huilles Essentielles; Digne-les-Baines, France 5-7th Sept 1996 special issue 01/97) pp49-83.

Brunke E.J. & Tumbrink L. (1986) "First total synthesis of spirosantalol." *Progress in Essential Oil Research* pp321-327.

Brunke E.-J. Hammerschmidt F.-J. & Struwe H. (1980) "(+)-epi-Santalol isolierung aus sandelholzol und partialsynthese aus (+) -alpha-santalol. *Tetrahedron Lett.* (1980) 2405.

Brunke E.-J. & Klein E. (1982) "Chemistry of sandalwood fragrance" In *Fragrance Chemistry. The Science of Smell*, Academic Press NY p397.

Buchbauer G., Stappen I., Pretterklieber C & Wolschann P. (2004) “Structure–activity relationships of sandalwood odorants: synthesis and odor of tricyclo β-santalol” *Eur J Med Chem* **39**(12), 1039-1046. Abstract: In a series of structure–odor relationship investigations the synthesis of a new tricyclic β-santalol derivative is described. The product of a multi-step synthesis appears in an olfactive evaluation more or less odorless may be slightly creamy but definitely with no sandalwood odor. This modification with a bulky aliphatic bridge in the neighbourhood of the quaternary C3-atom demonstrated the sensitivity of sandalwood odor on the structure of β-santalol analogues.

Buchbauer G., Winiwarter S. & Wolschann P. (1992) "Surface comparisons of some odour molecules: conformational calculations on sandalwood odour V.” *J. Comput. Aided Mol. Des*. 6(6), 583-592. Abstract: Molecular surface comparison seems to be a very suitable tool for the investigation of small differences between biologically active and inactive compounds of the same structural type. A fast method for such comparisons, based on volume matching followed by the estimation of comparable surface dots, is presented and applied on a few selected sandalwood odour molecules.

Demole E., Demole C. & Enggist P. (1976) “A chemical investigation of volatile constituents of volatile constituents of East Indian sandalwood oil (*Santalum album* L.)” *Helv. Chim. Acta* **59**, 737. Abstract. Distillation foreruns from East Indian sandalwood oil (*Santalum album* L.), representing 5-8% of the oil, have been investigated using fractional distillation, preparative column chromatography, gas liquid chromatography (GLC.), and chemical treatments. This allowed the isolation and characterization by their spectral data of 46 compounds. 32 of them were newly identified sandalwood oil constituents including 4 novel substances: santalone (2), 4-methylcyclohexa-1,3-dien-1-yl methyl ketone (4), 5,6-dimethyl-5-norbornen-exo-2-ol (7), and (E)-5-(2,3-dimethyl-3-nortricyclyl)-pent-3-en-2-one (20). The other constituents identified were 1-furfuryl-pyrrole (10) and 10 phenols accompanied by 17 terpene and sesquiterpene derivatives. Endo-2,endo-3-dimethyl-norbornan-exo-2-ol (6), an -santenol (z), precursor, was present in the last group of constituents. The compounds 2, 4, 6, 7, 20 have been synthesized as well as another novel constituent, endo-2-mythyl-3-methylidene-norbornan-exo-2-ol (5).

Dimoglo A.S., Beda A.A., Shvets N.M., Gorbachov M.Yu., Kheifits L.A. & Aulchenko S. (1995) "Investigation of the relationship between sandalwood odour & chemical structure: electron topological approach.” *New J of Chemistry* **19**(2), 149-154.

Hatt H.H. & Schoenfeld R. (1956) “Some seed fats of the Santalaceae family.” *J. Sci Food Agric* **7**(2), 130-133. ***Cropwatch comments***. The drying oil from the hard-shelled seeds (50-60% fixed oil) contains 30-35% santalbic acid and 1% stearolic acid. Tthese acetylenic compounds inhibit lipoenzymes in experimental animals.

$$CH_3(CH_2)_5CH{=}\underset{H}{C}-C{\equiv}C-(CH_2)_7COOH$$

santalbic acid

Hayashi K., Haseegawa T., Machiguchi T. & Yoshida T. (2005) “"Isolation and structure of a new aroma constituent from Indian Sandalwood, *Santalum album* L." *Nippon Kagakkai Koen Yokoshu* **85**(2), 863. Abstract. This work presents the isolation and structural elucidation of a new aroma compound in the major component from Indian sandalwood tree, *Santalum album* L., not from sandalwood oil obtained through steam distillation. We have found that the compound has a novel hemiacetal structure and has sandalwood odor stronger than those of.alpha.- and.beta.-santalols (the major components of sandalwood oil). (author abst.)

Heissler D. & Riehl J.-J. (1980) "Synthesis with benzenesulfenyl chloride. On the structure of a $C_{12}H_{18}$ hydrocarbon from East Indian sandalwood oil" *Tetrahedron Letters* **21**(49), 4711-4714. Abstract: The tetracyclic hydrocarbon was synthesized by means of the electrophilic addition of benzenesulfenyl chloride to an appropriately substituted methylenenorbornene. The synthetic methodology used to prepare this letter compound includes a mild enol ether hydrolysis with acidic silica gel.

Hopkins C.Y. & Chisholm M.J. (1969) "Fatty acid composition of some Santalaceae seed oils." *Phytochem*. **8**, 161-165.

Howes M.-J. R., Simmonds M.S.J. & Kite G.C. (2003) "Evaluation of the quality of sandalwood essential oils by gas chromatography–mass spectrometry" *Journal of Chromatography A*, **1028**(2), 307-312. Abstract: Trade and historic oils from 'sandalwoods', labelled as *Amyris balsamifera*, *Eremophila mitchelli*, *Fusanus acuminatus* (= *Santalum acuminatum*), *Santalum album*, *S. austrocaledonicum*, *S. latifolium*, *S. spicatum* and *S. yasi*, were assessed using gas chromatography–mass spectrometry (GC–MS). Using GC–MS, none of the oils assessed complied with the internationally recognised standard of a 90% santalol content, and only about half of the trade sandalwood oils met with recent International Organisation for Standardisation standards. The majority of trade oils, reportedly from *S. album*, contained approximately 50–70% santalols (*Z*-α and *Z*-β). Thus, the internationally recognised specification (90% santalols) for S. album requires re-evaluation by more efficient analysis methods. In view of the issues associated with the quality of sandalwood oils being traded, specifications of ≥43% *Z*-α-santalol and ≥18% *Z*-β-santalol for *S. album* oil estimated by GC–MS are suggested. GC–MS are recommended as it assists with authentication and quality control issues associated with sandalwood oils. ***Cropwatch comments***: The authors seem confused. The '90% santalols figure' is largely a relict of the past from when santalols in sandalwood oil were estimated by wet chemical methods – either by the acetylation method e.g. by EOA Determination 1B as set out in EOA Spec. No 103, or by wide-bore GC. This result is inaccurate and non-comparable to the superior information revealed by modern high performance capillary GC/MS determinations. The latter can break down the identity of a number of santalol isomers within sandalwood oil, and can help identify other sesquiterpene alcohols which might have previously have been included with the total santatols figure by the wet chemical procedure. Thus, by high performance capillary gas chromatography, a different story unfolds, and some 16 years previously, Verghese *et al*. (1990a) established that in Sandalwood oil E.I. the normal range is as follows: α-santalol 40-45% and β-santalol 17-27% [Lawrence (1991) q.v.]. The ISO standard ISO 3518 (2002) for sandalwood oil is surely taken by most workers as the current standard for the commodity and sets the limits on the *Z*-α-santalol content to 41-55% and the *Z*-β-santalol content to 16-24%. Although smaller amounts of other santalols are present in Sandalwood oil e.g. epi-β-santalol, Cropwatch does not accept that the situation for steam distilled sandalwood oils is quite as Howes *et al*. present it to be. Sandalwood extracts – via the benzene (etc.) extraction of sandalwood powder to produce sandalwood concrete, followed by methanolic extraction to produce a so-called 'oil' – can however produce high santalol containing sandalwood commodities in higher yield than steam distillation, which are sometimes traded as 'oils' or mixed in with the normal oil. Co-distillation technology with high boiling solvents (which are subsequently removed) can also produce high santalol containing sandalwood 'oils'. East African sandalwood oil and certain fractions of Australian sandalwood oil have also frequently been added as adulterants to traded East Indian sandalwood oils. The analyst should be aware therefore that not everything offered as sandalwood oil is as necessarily '100% derived from the named botanical source' – but this is hardly news to any experienced essential oil analyst!

Jie M. S. F. L. K., Pasha M.K. *et al*. (1996). "Ultrasound-assisted synthesis of santalbic acid and a study of triacylglycerol species in *Santalum album* (Linn.) seed oil." *Lipids* **31**(10), 1083-1089.

Jirovetz L. *et al*. (1988). “Differentiation of double bond isomers of sesquiterpene alcohols in East Indian sandalwood oil by means of GC-MS and GC-FTIR: Dihydrosantalols.” *Spectroscopy* **6**(5-6), 283-294.

John M.D., Paul T.M. & Jaiswal P.K. (1991) “Detection of adulteration of polyethylene glycol in oil of sandalwood” *Indian Perfumer* **35**(4), 186-187..

Kim T.H., Ito H., Hayashi K., Hasegawa T., Machguchi T., & Yoshida T. (2005) "Aromatic constituents from the heartwood of *Santalum album*." *Chem Bull Pharm* (Tokyo) **53**(6), 641-646. Abstract: A phytochemical investigation of the polar constituents in the heartwood of Indian *Santalum album* L. resulted in the isolation of three new neolignans (1-3) and a new aromatic ester (4), along with 14 known components. The structures of the new compounds (1-4) were established using spectroscopic methods.

Kim T.H., Ito H., Hatano T., Haswegawa T., Akiba A., Machiguchi T., Yoshida T. (2005) "Bisabolane & santalane-type sequiterpemoids from *Santalum album* of East Indian origin" *J. Nat Products* **68**(12), 1805-1808. Abstract: Six new bisabolane-type (1-3) and santalane-type (4-6) sesquiterpenoids, together with (+)-alpha-nuciferol, (+)-citronellol, and geraniol, were isolated from the heartwood of *Santalum album* of Indian origin. Their structures, including two bisabolol diastereomers (1, 2), were established on the basis of spectroscopic data interpretation.

Kovatcheva A., Buchbauer G., Golbraikh A. & Wolschann P. (2003) “QSAR modeling of alpha-campholenic derivatives with sandalwood odor.” *J Chem Inf Comput Sci.* **43**(1), 259-66. Abstract. Three-dimensional quantitative structure-activity relationship (3D-QSAR) models were developed for a series of 44 synthetic alpha-campholenic derivatives with sandalwood odor. These compounds have complex stereochemistry as they contain up to five chiral atoms. To address stereospecificity of odor intensity, a 3D-QSAR method was developed, which does not require spatial alignment of molecules. In this method, compounds are represented as derivatives of several common structural templates with several substituents, which are numbered according to their relative spatial positions in the molecule. Both wholistic and substituent descriptors calculated with the TSAR software were used as independent variables. Based on published experimental data of sandalwood odor intensities, two discrete scales of the odor intensity with equal or unequal intervals between the threshold values were developed. The data set was divided into a training set of 38 compounds and a test set of six compounds. To build QSAR models, a stepwise multiple linear regression method was used. The best model was obtained using the unequal scale of odor intensity: for the training set, the leave one out cross-validated R(2) (q(2)) was 0.80, the correlation coefficient R between actual and predicted odor intensities was 0.93, and the correlation coefficient for the test set was 0.95. The QSAR models developed in this study contribute to the better understanding of structural, electronic, and lipophilic properties responsible for sandalwood odor. Furthermore, the QSAR approach reported herein can be applied to other data sets that include compounds with complex stereochemistry.

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Kuttan R. & Radhakrishnan A.N. (1972) "Studies on the biosynthesis of sym-homospermidine in sandal (*Santalum album* L.)." *Biochem J.* **127**(1), 61-67. Abstract. The biosynthesis of the newly isolated polyamine, sym-homospermidine (NH2–[CH2]4–NH–[CH2]4 –NH2), was studied by using radioactive amino acids. Arginine was the most effective precursor, being about 10 times as active as ornithine. Unlabelled agmatine and putrescine markedly inhibited the incorporation of [14C]arginine into homospermidine. Similarly the incorporation of ornithine was inhibited by unlabelled arginine and putrescine. γ-Aminobutyraldehyde, the oxidation product of putrescine, was considered to be one of the intermediates in the biosynthesis of homospermidine. The biosynthesis may involve a Schiff-base formation of putrescine with γ-aminobutyraldehyde and subsequent reduction. A limited synthesis of spermidine also takes place under these conditions.

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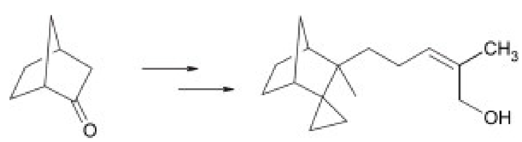
Graphical abstract:


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Ananthapadmanabha H.S., Rangaswamy C.R.; Sarma C.R.., Nagaveni H.C., Jain S.H.. Venkatesan K.R. & Krishanappa H.P. (1984). "Host requirements of sandal (*Santalum album* L.).". *Indian Forester* **110** (3).

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Angadi V.G., Ramalakshmi S., Jain S.H., Rangaswamy C.R. & Theagarajan K.S. (1999). "Allozymicvariation in the seed tissue of Sandal (*Santalum album* L.) population of different provenances." (unpublished).

Angadi V.G., Jain S.H., Rajeevalochan A.N., Ravikumar G. & Shankaran-yana K.H. (2002) "A note on peroxidase reagents to distinguish between highand low yielders of Sandal (*Santalum album*) in the field." *Sandalwood Research Newsletter* 2002.

Anil V.S., Harmon A.C.& Rao K.S. (2000) "Spatio-temporal accumulation and activity of calcium-dependent protein kinases during embryogenesis, seed development, and germination in sandalwood." *Plant Physiol*. **122**(4), 1035-43. Abstract. Western-blot analysis and protein kinase assays identified two Ca(2+)-dependent protein kinases (CDPKs) of 55 to 60 kD in soluble protein extracts of embryogenic cultures of sandalwood (*Santalum album* L.). However, these sandalwood CDPKs (swCDPKs) were absent in plantlets regenerated from somatic embryos. swCDPKs exhibited differential expression (monitored at the level of the protein) and activity in different developmental stages. Zygotic embryos, seedlings, and endosperm showed high accumulation of swCDPK, but the enzyme was not detected in the soluble proteins of shoots and flowers. swCDPK exhibited a temporal pattern of expression in endosperm, showing high accumulation and activity in mature fruit and germinating stages; the enzyme was localized strongly in the storage bodies of the endosperm cells. The study also reports for the first time to our knowledge a post-translational inhibition/inactivation of swCDPK in zygotic embryos during seed dormancy and early stages of germination. The temporal expression of swCDPK during somatic/zygotic embryogenesis, seed maturation, and germination suggests involvement of the enzyme in these developmental processes.

Anil, V. S. &. Rao K..S. (2000). "Calcium-mediated signaling during sandalwood somatic embryogenesis. Role for exogenous calcium as second messenger." *Plant Physiology* August 2000 **123**(4), 1301-1311. Abstract. Calcium-dependent protein kinase (CDPK) is expressed in sandalwood (*Santalum album* L.) seeds under developmental regulation, and it is localized with spherical storage organelles in the endosperm [Anil *et al*. (2000) *Plant Physiol.* **122**: 1035]. This study identifies these storage organelles as oil bodies. A 55 kDa protein associated with isolated oil bodies, showed Ca(2+)-dependent autophosphorylation and also cross-reacted with anti-soybean CDPK. The CDPK activity detected in the oil body-protein fraction was calmodulin-independent and sensitive to W7 (N-(6-aminohexyl)-5-chloro-1-naphthalene sulfonamide) inhibition. Differences in Michaelis Menton kinetics, rate of histone phosphorylation and sensitivity to W7 inhibition between a soluble CDPK from embryos and the oil body-associated CDPK of endosperm suggest that these are tissue-specific isozymes. The association of CDPK with oil bodies of endosperm was found to show a temporal pattern during seed development. CDPK protein and activity, and the in vivo phosphorylation of Ser and Thr residues were detected strongly in the oil bodies of endosperm from maturing seed. Since oil body formation occurs during seed maturation, the observations indicate that CDPK and Ca(2+) may have a regulatory role during oil accumulation/oil body biogenesis. The detection of CDPK-protein and activity in oil bodies of groundnut, sesame, cotton, sunflower, soybean and safflower suggests the ubiquity of the association of CDPKs with oil bodies.

Anil V.S. & Rao K.S. (2001) "Purification and characterization of a Ca(2+)-dependent protein kinase from sandalwood (*Santalum album* L.): evidence for Ca(2+)-induced conformational changes." *Phytochemistry* **58**(2), 203-12. Abstract. An early development-specific soluble 55 kDa Ca(2+)-dependent protein kinase has been purified to homogeneity from sandalwood somatic embryos and biochemically characterized. The purified enzyme, swCDPK, resolved into a single band on 10% polyacrylamide gels, both under denaturing and non-denaturing conditions. swCDPK activity was strictly dependent on Ca(2+), K(0.5) (apparent binding constant) for Ca(2+)-activation of substrate phosphorylation activity being 0.7 microM and for autophosphorylation activity approximately 50 nM. Ca(2+)-dependence for activation, CaM-independence, inhibition by CaM-antagonist (IC(50) for W7=6 microM, for W5=46 microM) and cross-reaction with polyclonal antibodies directed against the CaM-like domain of soybean CDPK, confirmed the presence of an endogenous CaM-like domain in the purified enzyme. Kinetic studies revealed a K(m) value of 1.3 mg/ml for histone III-S and a V(max) value of 0.1 nmol min(-1) mg(-1). The enzyme exhibited high specificity for ATP with a K(m) value of 10 nM. Titration with calcium resulted in the enhancement of intrinsic emission fluorescence of swCDPK and a shift in the lambda(max) emission from tryptophan residues. A reduction in the efficiency of non-radiative energy transfer from tyrosine to tryptophan residues was also observed. These are taken as evidence for the occurrence of Ca(2+)-induced conformational change in swCDPK. The emission spectral properties of swCDPK in conjunction with Ca(2+) levels required for autophosphorylation and substrate phosphorylation help understand mode of Ca(2+) activation of this enzyme.

Anil V.S., Harmon A.C. & Rao K.S. (2003) "Temporal association of Ca(2+)-dependent protein kinase with oil bodies during seed development in *Santalum album* L.: its biochemical characterization and significance." *Plant Cell Physiol.* **44**(4),367-76. Abstract. Calcium-dependent protein kinase (CDPK) is expressed in sandalwood (*Santalum album* L.) seeds under developmental regulation, and it is localized with spherical storage organelles in the endosperm [Anil *et al.* (2000) *Plant Physiol.* 122: 1035]. This study identifies these storage organelles as oil bodies. A 55 kDa protein associated with isolated oil bodies, showed Ca(2+)-dependent autophosphorylation and also cross-reacted with anti-soybean CDPK. The CDPK activity detected in the oil body-protein fraction was calmodulin-independent and sensitive to W7 (N-(6-aminohexyl)-5-chloro-1-naphthalene sulfonamide) inhibition. Differences in Michaelis Menton kinetics, rate of histone phosphorylation and sensitivity to W7 inhibition between a soluble CDPK from embryos and the oil body-associated CDPK of endosperm suggest that these are tissue-specific isozymes. The association of CDPK with oil bodies of endosperm was found to show a temporal pattern during seed development. CDPK protein and activity, and the in vivo phosphorylation of Ser and Thr residues were detected strongly in the oil bodies of endosperm from maturing seed. Since oil body formation occurs during seed maturation, the observations indicate that CDPK and Ca(2+) may have a regulatory role during oil accumulation/oil body biogenesis. The detection of CDPK-protein and activity in oil bodies of groundnut, sesame, cotton, sunflower, soybean and safflower suggests the ubiquity of the association of CDPKs with oil bodies.

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Bagchi S.K. & Kulkarni H.D. (1987). "A note on seedling abnormality frequency in the half-sib progenies of *Santalum album*." *Indian Forest* **113**, 650-651.

Balachandran N. & Kichenamourthy S. (2007) "Profile of natural stands of *Santalum album* L. in the Pondicherry region, India." *Sandalwood Research Newsletter* **22**. Abstract. The enumeration of sandal and its habitats, soil type, girth, height, status of re-production and associated plants were studied within the Pondicherry region in India. A total of 463 mature sandal trees (girth at breast height (gbh) ≥ 10 cm) and 360 sapling trees (<10 cm gbh) were recorded from 10 different locations, 5habitats and 4 soil types. The analyses of growth (girth and height), reproduction and associates were compared with different soil types. Generally clay with lime-stone and sandy soils had substantially greater numbers of sandal trees than clayand red earth soils. *Azadirachta*, *Glycosmis*, *Morinda* and *Phoenix* were the most predominant associated species across all soil types.

Bapat V.A. & Rao P.S (1985) “Regeneration of somatic embryos and plantlets from stem callus protoplasts of the sandalwood tree (*Santalum album* L.).” *Current Sci* **54**, 978-982. Abstract. Somatic embryos obtained from embryogenic tissue of sandalwood (*Santalum album*) were grown on White’s medium containing abscisic acid (ABA, 1.89, 3.78 or 18.92 IM) and various concentration of sucrose (87.6 to 350.4 mM) to unduce maturation. The embryos were isolated and dessicated for 10,20 or 30 days. One lot of the dessicated somatic embryos was encapsulated in sodium alginate gel and the other lot was not encapsulated. Both encapsulated and non-encapsulated dessicated somatic embryos showed revival of growth on rehydration on White’s medium and developed into plants. The dessication tolerance and regeneration of viable plantlets depended on the pretreatment given to somatic embryos. Embryogenic tissue subjected to dry state for 30 days showed revival of somatic embryogenesis upon transfer to a fresh nutrient medium. Implications of maturation & dessication of somatic embryos on its ger-minability are discussed,

Bapat V.A. & Rao P.S. (1984) “Regulatory factors for *in vitro* multiplication of sandalwood tree (*Santalum album*). 1. Shoot bud regeneration and somatic embryogenesis in hypocotyls cultures ” *Proceedings of The Indian Academy of Science. Plant Sciences*. **93**(1), 19-22. Abstract. Large number of plantlets were obtained in hypocotyls cultures of *Santalum album* either through direct differentiation of shhot buds and their subsequent induction into rooted plants, or through callus induction and somatic embryogenesis. Factors which triggered both these morphogenetic processes were investigated.

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Bapat V. A., Iyer R.K., *et al.* (1996). “Effect of cyanobacterial extract on somatic embryogenesis in tissue cultures of sandalwood (*Santalum album*).” *Journal of Medicinal & Aromatic Plant Sciences* **18**(1), 10-14.

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Bhatnagar S.P. (1959). “Some observa-tions on the post-fertilization devel-opment of the embryo sac of Santalum.” *Phytomorphology* **9**, 87-91.

Bhattacharya A. & Lakshmi S.G. (1999). “Isolation and characterization of PR1 homolog from the genomic DNA of sandalwood (*Santalum album* L.).” *Current Science* **77**(7), 958-961. Abstract. Genomic library was constructed using nuclear DNA prepared from tender leaves of sandalwood. Subsequently, screening with heterologous probes we could isolate the PR1 genomic hemolog, Restriction mapping and hybridization experiments were carried out to obtain the coding region for PR1 gene. A 750 bp EcoRI fragment thus obtained was subcloned to yield pSaPR1, which was compared with the related sequences. Southern hybridization with genomic DNA digests was carried out to check its genomic organization. The induction of this gene was observed in the somatic embryos treated with salicylic acid, thereby implying its possible involvement during systemic acquired resistance.

Bhattacharya, A. & Sita G.L. (1998). “cDNA cloning and characterization of a proline (or hydroxyproline)-rich protein from *Santalum album* L.” *Current Science* **75**(7), 697-701.

Bieri S., Monastyrskaia K. & Schilling B. (2004) "Olfactory receptor neuron profiling using sandalwood odourants" *Chem Senses* 29(6), 483-487. Abstract: The mammalian olfactory system can discriminate between volatile molecules with subtle differences in their molecular structures. Efforts in synthetic chemistry have delivered a myriad of smelling compounds of different qualities as well as many molecules with very similar olfactive properties. One important class of molecules in the fragrance industry are sandalwood odorants. Sandalwood oil and four synthetic sandalwood molecules were selected to study the activation profile of endogenous olfactory receptors when exposed to compounds from the same odorant family. Dissociated rat olfactory receptor neurons were exposed to the sandalwood molecules and the receptor activation studied by monitoring fluxes in the internal calcium concentration. Olfactory receptor neurons were identified that were specifically stimulated by sandalwood compounds. These neurons expressed olfactory receptors that can discriminate between sandalwood odorants with slight differences in their molecular structures. This is the first study in which an important class of perfume compounds was analyzed for its ability to activate endogenous olfactory receptors in olfactory receptor neurons.

Bock J. (2003) "Sandalwood oil's effect on the autonomic nervous system" *Original Internist* 3/1/2003. Abstract: The hypothesis is sandalwood oil causes a decrease in sympathetic tone as accessed by patients with Heart Rate Variation (HRV), blood pressure (systolic, diastolic, and pulse pressure) and pulse rate.

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Burdock GA & Carabin IG (2008) "Safety assessment of sandalwood oil (*Santalum album* L.)." *Food Chem Toxicol*. **46(**2), 421-32. Abstract. Sandalwood (*Santalum album* L.) is a fragrant wood from which oil is derived for use in food and cosmetics. Sandalwood oil is used in the food industry as a flavor ingredient with a daily consumption of 0.0074 mg/kg. Over 100 constituents have been identified in sandalwood oil with the major constituent being alpha-santalol. Sandalwood oil and its major constituent have low acute oral and dermal toxicity in laboratory animals. Sandalwood oil was not mutagenic in spore Rec assay and was found to have anticarcinogenic, antiviral and bactericidal activity. Occasional cases of irritation or sensitization reactions to sandalwood oil in humans are reported in the literature. Although the available information on toxicity of sandalwood oil is limited, it has a long history of oral use without any reported adverse effects and is considered safe at present use levels.

Castro J.M., Linares-Palomino P.J., Salido S., Altarejos J., Nogueras & Sanchez A. (2005) "Enantiospecific synthesis, separation & olfactory evaluation of all diastereomers of a homologuee of the sandalwood odournt Polysantol." *Tetrahedron* **61**(47), 11192-11203. Abstract. The four stereoisomers of (5E)-4,4-dimethyl-6-(2′,2′,3′-trimethylcyclopent-3′-en-1′-yl)-hex-5-en-3-ol, a homologue of the valuable sandalwood-type odorant Polysantol®, were enantiospecifically synthesized from (+)- and (–)-α-pinene, through (–)- and (+)-campholenic aldehyde, by aldol condensation with 3-pentanone, deconjugative α-methylation and reduction. The mixtures of epimeric alcohols obtained after reduction were separated by means of derivatization with (–)-(1S)-camphanic chloride. The enantiomerically pure final products were evaluated organoleptically.

Chabra S. K. & Rao A.R. (1993). "Postnatal modulation of xenobiotic metabolizing enzymes in liver of mouse pups following translactational exposure to sandalwood oil." *Nutrition Research* **13**(10), 1191-1202.

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Chapuis C. (2004) "In the quest for a virtual pseudo receptor for sandalwood-like odorants. Part I: The empirical approach." *Chem Biodivers*.**1**(7):980-1021. Abstract. Based on similarities between naturally occurring (-)-(*Z*)-β-- or (+)-(*Z*)-α-santalol ((-)- 1 or (+)-2, resp.) and the reversed (E)-configured synthetic derivatives from campholenal (7a), a simple model A was developed. Besides reconciliation of this stereochemical aspect, this initial model also tentatively explained the enantiodiscriminations as well as the large spectra of distances separating the OH function from the lipophilic quaternary center(s) reported for different classes of substrates. Evolution, modifications, and refinement of this imperfect model allied with the research for alternative possibilities are illustrated, along with a historical guideline, in the light of olfactively challenging synthetic seco-substructures as well as literature reports. Despite evolution of the inadequate model A and a plausible interpretation of the lipophilic part, the topological positions of the OH function and its vicinal alkyl substituent could nevertheless not be fully ascertained by this approach. This apparently inconclusive empirical concept prompted us to turn our attention towards a computerized methodology, which will constitute the second and third part of this study.

Chawla G. (2008) ""The demise of India's supply: resorting to substitutes to meet demand." *Sandalwood Conference 2008 at The Kimberley Grande, Kununurra, W. Australia 13-15 May 2008*. ***Cropwatch Comments***: Chawla illustrates the demise of EI sandalwood's decline via the annual production figure for sandalwwod sales in Tamilnadu, which peaked at 2330.5 tons in 1999-2000, against just 14 tons in 2007-8. Also of interest were facts about the selection of 79 or more sandalwwod trees maintained at the IWST germplasm bank in Gottipura and about the clonal seed orchards from these trees maintained at Nalla Nallal and Jarakabande and at the Andhra Pradesh Forest Department Research Center, BIOTRIM, at Tirupathi. .

Christenson P.A., Secord N. & Willis B.J. (1981) *Phytochemistry* **20**(5), 1139-1141. Abstract: An analysis of East Indian sandalwood oil (*Santalum album*) has resulted in the isolation and identification of trans-β-santalol and epi-cis-β- santalol.

Choudhuri J.C.B. (1963) "Sandalwood tree & its diseases." *Indian Forester* **89**(7), 456-462.

Choueiri A. (2008) "Sustainable ingredients in the fragrance industry and the use of Indian Sandalwood in L'Oreal products". *Sandalwood Conference 2008 at The Kimberley Grande, Kununurra, W. Australia 13-15 May 2008* ***Cropwatch Comments***: Drawing on data from Edwards M. *Fragrances of the World*, Choueiri (Head of Lancome UK) includes the point that of 106 current fragrances listing sandalwood, only 36 detail Indian sandalwood, and of those, only 16 detail Mysore sandalwood (the rest we assume use sandalwood from other sources). Of these sixteen current fragrances allegedly employing Mysore sandalwood, four are supplied by IFF, two by Givaudin (Quest), one by Firmenich and one by Symrise. The present situation of shortage seems a far cry from the original launching of three fragrances containing authentic sandalwood by the antique pharmacy of Santa Maria Novella, Florence in 1828.

Das S., Das S., Pal S., Mujib A., Sahoo S. S., Dey S., Ponde N. R. & Dasgupta S.(1999). "A novel process for rapidmass propagation of *Santalum album* L. in liquid media and bioreactors." In: Giberti, G. (Ed) Proc. WOCMAP-2. *Acta Hort*. 502(ISHS), 281-288.

Das S., Ray S., Dey S. & Dasgupta S. (2001). "Optimisation of sucrose, inorganic nitrogen and abscisic acid levels for *Santalum album* L. somatic embryoproduc tion in suspension culture." *Process Biochemistry* (details?)

Desai V. B., Hiremath R.D., *et al.* (1991). “On the pharmacological screening of HESP and sandalwood oils.” *Indian Perfumer* **35**(2), 69-70.

Desai V.B. & Shankaranarayana K.H. (1990) “On utilization aspects of sandal seed oil.” *Res Industry* **35**, 232-233.

Dey S. (2002) “Mass cloning of *Santalum album* L. through somatic embryogenesis: scale up in bioreactor.” *Sandalwood Research Newsletter* (Australia), **13**, 1-3. Abstract. *Santalum album* L., the East Indian Sandalwood, enjoys acceptance worldwide because of the uniquefragrance in it’s oil and wood. The natural propagation of this important plant faces twin threats –spike disease and poaching. Regeneration by silvicultural methods being insufficient to meet the demand, several biotechnological routes of propagation has been tried. Somatic embryogenesis offers highest clonal propagation efficiency. Scale up in air-lift bioreactor improves embryo quality, saves laboratory space and minimizes incubation time as well as production cost.

Dijkstra J. & Hiruki C. (1974) “A histochemical study on sandal (*Santalum album*) affected with spike disease and its diagnostic value.” *Netherlands J. of Plant Pathology* **80**(2), 37-47.

Dijkstra J. & Lee P.E. (1972) “Transmission by dodder of sandal spike disease and the accompanying mycoplasma-like organisms via *Vinca rosea*.” *Netherlands J. of Plant Pathology* **78**(5), 218-224.

Doran J.C., Thomson L.A.C. &. Brophy J.J.(2002). “Sandalwood.” *Paper to Regional Workshop on Sandalwood Research, Development and Extension in the Pacific Islands and Asia.* Noumea, New Caledonia, 7–11 October 2002.

Erligmann A. (2001) “Sandalwood oils” *Int. J. of Aromatherapy* **11**(4), 186-192.

European Patent EP1059086 “Use of sandal wood oil or constituents of sandal wood oil for the prevention and treatment of warts, skin blemishes and other viral-induced tumors.” Abstract The present invention provides a method for the prevention and treatment of viral-induced tumors, more specifically, human warts. The method uses sandalwood oil and/or derivatives from the sandalwood oil to prepare medicaments for the prevention and treatment of viral-induced tumors (i.e., warts caused by the human papillomavirus (HPV)) in humans. The method of the invention comprises the topical administration of the sandalwood oil or a composition derived therefrom to the human epidermis and/or to the genital tract as needed. The present invention is also concerned with a unique antiviral composition useful for topical application. The antiviral composition according to this invention is also effective against other DNA viruses such as the DNA pox virus that causes *Molluscum contagiosum* and may be effective against other DNA viruses such as AIDS virus and RNA viruses. The sandalwood oil compositions are also effective against genital warts and HPV of the genital tract and will prevent cancer of the skin and cervix. Sandalwood oil or a constituent of sandalwood oil, is also effective in preventing dryness of the skin, rashes and flakiness associated with seborrheic dermatitis, psoriasis and allergic or eczematous rashes of the skin. This oil or constituent is also effective in the treatment of acne lesions of the face and the body and in the eradication of pustular acne lesions caused by Staphylococcal *acne* and Streptococcal bacterial infections.

Fernandes P. C., Bapat V.A. *et al*. (1992). “*In vivo* germination of encapsulated somatic embryos of *Santalum album* L. (Sandalwood).” *Indian Journal of Experimental Biology* **30**(9), 839-841.

Fernandes, P., Bapat V.A., *et al*. (1994). “Effect of crushed seed homogenate on germination of synthetic seeds of *Santalum album* L.” *Indian Journal of Experimental Biology* **32**(11), 840-841.

Fernandes P. C., Bapat V.A., *et al.* (1994). “Investigations on the development of somatic seeds of *Santalum album* L. (Sandalwood).” *Proceedings of the National Academy of Sciences India Section B Biological Sciences* 64(1), 1-8.

Florento A. (1997) “Sandalwood oil faces trouble as crop is destroyed by fire” *Chemical Marketing Reporter* March 31, 1997.

Fox J.E.D.. (2000) “Sandalwood: the royal tree” *Biologist* London **47**(1), 31-34. Abstract. Sandalwood is the most valuable tree in the world. As with gold, platinum and diamonds, it owes its value to a demand based on ritual, fashion and scarcity. It is the stuff of mystery and intrigue, and fortunes can still be made from it.

Fragrance raw materials monographs (1974): “Sandalwood oil, East Indian.” *Food & Cosmetics Toxicology* **12**(7-8), 989-990.

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Gleason J. (2009) “Comparing notes: Formulating with coumarin, sandalwood & ethyl linalool: an extended conversation with fine fragrance perfumers Kevin Verspoor & Pierre Gueros.”” *Perf & Flav* **34**, April 2008, pp26-29. ***Cropwatch comments***: In spite of the promising title, one short section on sandalwood tells you littlethat you probably didn’t know already, namely that sandalwood oil E.I. can be used in almost every type of perfume, making it full and long-lasting, and it is difficult to overdose.”.

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Haffner D. (1993). “Determining heartwood formation within *Santalum album* and *Santalum spicatum*.” *Sandalwood Research Newsletter* **1**, 4–5.

Hart H.H. & Schoemfelt F. (1956) “Some seed fats of Santalaceae & Oleaceae.” *Aust J Chem* **12**, 190.

Haque M.H. & Haque A.U. (date?) United States Patent 6406706; EP Patent 1,059,086, 2000 "Use of α- and β-santalols major constituents of sandal wood oil, in the treatment of warts, skin blemishes and other viral-induced tumors." Abstract. The present invention provides a method for the treatment of viral-induced tumors in mammals, more specifically, human warts. The method uses α- and β-santalols, or mixtures or derivatives thereof, to prepare medicaments for the treatment of viral-induced tumors i.e., warts caused by the human papillomavirus (HPV) in humans. The method of the invention comprises the topical administration of α- and β-santalols, or mixtures or derivatives thereof, in a composition derived therefrom, to the human epidermis, as needed. The present invention is also concerned with a unique antiviral composition useful for topical application. The antiviral composition according to this invention is also effective against other DNA viruses such as the DNA pox virus that causes Molluscum contagiosum and may be effective against other DNA viruses such as AIDS virus and RNA viruses. The α- and β-santalols composition, or mixtures or derivatives thereof, may also be effective in the treatment of genital warts and HPV of the genital tract and in the treatment of cancer of the skin and cervix. The α- and β-santalols, or mixtures or derivatives thereof, may also be effective in the prevention of dryness of the skin, rashes and flakiness associated with seborrheic dermatitis, psoriasis and allergic or eczematous rashes of the skin. The α- and β-santalols, or mixtures or derivatives thereof, may also be effective in the treatment of acne lesions of the face and the body and in the eradication of pustular acne lesions caused by staphylococcal acne and streptococcal bacterial infections.

Henfrey A (1856). "On the develop-ment of *Santalum album*." *Transac-tions of the Linnean Society of Lon-don (Botany)* **22**, 69-79.

Heuberger E., Hongratanaworakit T. & Buchbauer G. (2001) “Biological properties of the essential oil of East Indian sandalwood (*Santalum album* L.) and its main compounds alpha- and beta-santalol.” Oral presentation *4éme Symposium Internat. D’Aromatherapie Scientifique*, March 2001, Grasse, France.

Heuberger E., Hongratanaworakit T., Buchbauer G. (2001) “Die Wirkung von Sandelholzöl auf das autonome Nervensystem und die subjective Befindlichkeit.” *Vortrag 3, Internat. Primavera Life-Kongress* Oct 2001.

Heuberger E, Hongratanaworakit T, Buchbauer G. (2006) "East Indian Sandalwood and alpha-santalol odor increase physiological and self-rated arousal in humans. *Planta Med.* **72**(9), 792-800. Abstract. In Ayurvedic medicine, East Indian Sandalwood is an important remedy for the treatment of both somatic and mental disorders. In this investigation, the effects of inhalation of East Indian Sandalwood essential oil and its main compound, alpha-santalol, on human physiological parameters (blood oxygen saturation, respiration rate, eye-blink rate, pulse rate, skin conductance, skin temperature, surface electromyogram, and blood pressure) and self-ratings of arousal (alertness, attentiveness, calmness, mood, relaxation and vigor) were studied in healthy volunteers. Compared to either an odorless placebo or alpha-santalol, Sandalwood oil elevated pulse rate, skin conductance level, and systolic blood pressure. alpha-Santalol, however, elicited higher ratings of attentiveness and mood than did Sandalwood oil or the placebo. Correlation analyses revealed that these effects are mainly due to perceived odor quality. The results suggest a relation between differences in perceived odor quality and differences in arousal level.

Hill R., Harne R.W. & Nayar R.M. (1969) “Mycoplasma-like bodies associated with sandal spike” *Nature* **224**, 1121-1122.

Hongratanaworakit T. Dissertation, *Effects of fractions of sandalwood oil on human physiological parameters by inhalation and massage*. Vienna, Austria. June 2001. (through Bock J. (2003).

Hongratanaworakit T., Heuberger E., Buchbauer G. (2000). “Effects of sandalwood oil & alpha-santalol on humans I: Inhalation.” Poster presentation, *31st ISEO*, Sept 2000, Hamburg, Germany.

Hongratanaworakit T, Heuberger E. & Buchbauer G. (2004) “Evaluation of the effects of East Indian sandalwood oil and alpha-santalol on humans after transdermal absorption.” *Planta Med.* **70**(1),3-7. Abstract. The aim of the study was to investigate the effects of East Indian sandalwood oil (*Santalum album*, Santalaceae) and alpha-santalol on physiological parameters as well as on mental and emotional conditions in healthy human subjects after transdermal absorption. In order to exclude any olfactory stimulation, the inhalation of the fragrances was prevented by breathing masks. Eight physiological parameters, i. e., blood oxygen saturation, blood pressure, breathing rate, eye-blink rate, pulse rate, skin conductance, skin temperature, and surface electromyogram were recorded. Subjective mental and emotional condition was assessed by means of rating scales. While alpha-santalol caused significant physiological changes which are interpreted in terms of a relaxing/sedative effect, sandalwood oil provoked physiological deactivation but behavioral activation. These findings are likely to represent an uncoupling of physiological and behavioral arousal processes by sandalwood oil.

Husain M., Ponnuswamy A.M. & Ponnuswamy P.K. (1982) “An innovation in the vegetative propagation of sandal (*Santalum album* L.).” *Indian J. Forest.* **5**, 1-7.

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Iyengar G.S. (1937). "Life-history of *Santalum album* L." *Journal of Indian Botanical Society* **16**, 175-195

Iyengar A.V.V. (1968). "The East Indian sandalwood oil." *Indian Forester* 57, 57-68

Iyengar A.V.V. (1972) “Control of sandal spike” *Current Science* **41**(9), 318-319.

Iyenger A.V.V. (1972) "Some aspects of sandal spike disease" *J. Scient. Ind. Res.* **31**, 331-342.

Jain S.H. Angadi V.G., Shankaranarayana K.H. & Ravikumar G. (2003) "Relationship between girth and percentage of oil in trees of sandal (*Santalum album* L.) provenances." *Sandalwood Research Newsletter* **18**. Abstract. In three provenance areas of sandal viz. Bangalore, Thangli (Karnataka) and Maryoor (Kerala), studies have been made in respect of GBH and oil. It was observed that percentage of oil remains nearly constant at 4 % after 80 cm girth and that rise in oil percentage beyond 80 cm girth was found to be just marginal.

Jain S.H., Angadi V.G., Ravikumar G., Thegrajan K.S. & Shankaranarayana (1999) "Studies on cultivation & chemical utilisation of sandal (*Santalum album* L.)." *PAFAI Journal* **1**, 49-53.

Jain S.H., Angadi V.G., Rajeevalochan A.N., Shankaranarayana K.H., Theagarajan K.S. & Rangaswamy C.R. (1998) "Identification of provenances of Sandal in India for genetic conservation" *ACIAR Proceedings*, No.**84**, 1998, 117-120.

Jain S.H. Augundi V.G. Rajeevalochan K.H., Shankaranarayana K.H., Theagarajan K.S. & Rangaswamy C.R (1992) "Identification of provenances of sandal in India for genetic conservation." In: *Sandal & Its Products ACIAR Proceedings* **84,** 117-120**.** .

Jain S.H. & Rangaswamy C.R. (1998). "Soil properties and their relationship to the growth of Sandal (*Santalum album* L) in three study areas in Karnataka." *My Forest* **24**, 141-146.

Jirovetz L, Buchbauer G, & Jager W. (1992) "Analysis of fragrance compounds in blood samples of mice by gas chromatography, mass spectrometry, GC/FTIR and GC/AES after inhalation of sandalwood oil." *Biomed. Chromatography* **6**, 133-134. Abstract. After inhalation experiments with sandalwood oil and the pure fragrance compounds coumarin and alpha-terpineol, substances were detected and measured in the blood samples of test animals (mice) using gas chromatography/mass spectrometry (GC/MS) (MID) in connection with GC/FTIR (SWC), GC/AES (carbon and oxygen trace) and flame ionization detection/gas chromatography. Using tiglinic acid benzyl ester as the internal standard the following concentrations in serum could be found: alpha-santalol 6.1 ng/mL, beta-santalol 5.3 ng/mL and alpha-santalene 0.5 ng/mL. In separate inhalation experiments with coumarin and with alpha-terpineol the corresponding concentrations were 7.7 ng/mL and 6.9 ng/mL, respectively.

Jones C.G., Ghisalberti E.L., Plummer J.A. & Barbour E.L. (2006) "Quantitative co-occurrence of sesquiterpenes; a tool for elucidating their biosynthesis in Indian sandalwood, *Santalum album*." *Phytochemistry*. **67(**22), 2463-8. Abstract. A chemotaxonomic approach was used to investigate biosynthetic relationships between heartwood sesquiterpenes in Indian sandalwood, *Santalum album* L. Strong, linear relationships exist between four structural classes of sesquiterpenes; alpha- and beta-santalenes and bergamotene; gamma- and beta-curcumene; beta-bisabolene and alpha-bisabolol and four unidentified sesquiterpenes. All samples within the heartwood yielded the same co-occurrence patterns, however wood from young trees tended to be more variable. It is proposed that the biosynthesis of each structural class of sesquiterpene in sandalwood oil is linked through common carbocation intermediates. Lack of co-occurrence between each structural class suggests that four separate cyclase enzymes may be operative. The biosynthesis of sandalwood oil sesquiterpenes is discussed with respect to these co-occurrence patterns. Extractable oil yield was correlated to heartwood content of each wood core and the oil composition did not vary significantly throughout the tree.

Jones C.G., Keeling C.I., Ghisalberti E.L., Barbour E.L., Plummer J.A., Bohlmann J.(2008) "Isolation of cDNAs and functional characterisation of two multi-product terpene synthase enzymes from sandalwood, *Santalum album* L." *Arch Biochem Biophys.* 2008 May 27. Abstract. Sandalwood, *Santalum album* (Santalaceae) is a small hemi-parasitic tropical tree of great economic value. Sandalwood timber contains resins and essential oils, particularly the santalols, santalenes and dozens of other minor sesquiterpenoids. These sesquiterpenoids provide the unique sandalwood fragrance. The research described in this paper set out to identify genes involved in essential oil biosynthesis, particularly terpene synthases (TPS) in *S. album*, with the long-term aim of better understanding heartwood oil production. Degenerate TPS primers

amplified two genomic TPS fragments from *S. album*, one of which enabled the isolation of two TPS cDNAs, SamonoTPS1 (1731bp) and SasesquiTPS1 (1680bp). Both translated protein sequences shared highest similarity with known TPS from grapevine (*Vitis vinifera*). Heterologous expression in Escherichia coli produced catalytically active proteins. SamonoTPS1 was identified as a monoterpene synthase which produced a mixture of (+)-alpha-terpineol and (-)-limonene, along with small quantities of linalool, myrcene, (-)-alpha-pinene, (+)-sabinene and geraniol when assayed with geranyl diphosphate. Sesquiterpene synthase SasesquiTPS1 produced the monocyclic sesquiterpene alcohol germacrene D-4-ol and helminthogermacrene, when incubated with farnesyl diphosphate. Also present were alpha-bulnesene, gamma-muurolene, alpha- and beta-selinenes, as well as several other minor bicyclic compounds. Although these sesquiterpenes are present in only minute quantities in the distilled sandalwood oil, the genes and their encoded enzymes described here represent the first TPS isolated and characterised from a member of the Santalaceae plant family and they may enable the future discovery of additional TPS genes in sandalwood.

Jones C.G (2008) *The best of* Santalum album*: Essential oil composition, biosynthesis and genetic diversity in the Australian tropical sandalwood collection.* PhD thesis for Univ W Australia June 2008. Abstract. An investigation into the heartwood and essential oil content of Australian plantation sandalwood, *Santalum album* was undertaken. Genetic diversity of 233 *S. album* five *S. austrocaledonicum* and fifteen *S. macgregorii* trees growing in the Forest Products Arboretum, Kununurra WA, was assessed using nuclear and chloroplast RFLPs. Nuclear genetic diversity of the *S. album* collection was very low with expected and observed heterozygosity levels of 0.047. This was lower than the results previously reported in the bliterature for trees in India, however a different technique was used. Based on allelic patterns, the collection was able to be catagorised into 19 genotypes: each representing some shared genetic origin. Some groups were highly redundant, with 56 trees being represented, whilst others were populated by just one tree. The essential oil yield and heartwood contents of trees from these genetic groups were compared. Yields were highly variable both within and between groups of trees which share a common genetic history, suggesting a significant environmental component was contributing to the observed phenotype despite identical soil and climatic oconditions.

Ancestral lineages were tested using chloroplast RFLP's, although a lack of shared mutations between species made this difficult. Only one *S. album* tree from S. Timor was resolved using nuclear RFLPs, with the other trees being grouped with material sourced from India. There was no resolution of Indian *S. album* from Timorese using chloroplast RFLPs, however one *S. album* tree grown from Indian seed possessed a single unique mutation. The low genetic diversity of the Ausatralian *S. album* collection is likely to be a combination of incomplete seed sourcing and highly restricted gene flow during the evolution of the species. Combined with information gathered on the phylogeny of the genus by other researchers, *S album* is postulated to have arisen from an over-sea dispersal out of northern Australia or Papua New Guinea 3 to 5 million years ago.

Essential oil yield & composition was assessed for 100 *S. album* trees growing in the collection, ranging in years from 8 to 17 years. Oil content of the heartwood ranged from $30 mg.g^{-1}$ to $60 mg.g^{-1}$ and the transition zone $36 mg.g^{-1}$ to $90 mg.g^{-1}$. Sapwood contained almost no sesquiterpene oils. Despite the highly variable total yields, the chemical profile of the oil did not vary, suggesting there was limited genetic diversity within this region of the genome. Strong positive correlations existed between sesquiterpenoids in the essential oil of *S. album*. This was particularly evident in the santalenes and α-bergamotene, although trends were also seen in the curcumenes, bisabolene and bisabolol, and an unidentified group of sesquiterpenes. Co-occurrence patternes indicate shared chemical intermediates from which compounds are partitioned, resulting in multiple product formation. To further test the multiple product hypothesis two terpene synthase (TPS) genes werte isolated from *S. album* leaf and wood cDNA. These were cloned and the enzymes were heterologously expressed in *Escherichia coli*. One enzyme *sa*sesquiTPS1 converted the universal sesquiterpene precursor farnesyl diphosphate into germacrene D-4-ol, helminthogermacrene, α-bulnescene, γ-muurolene and α- andβ-selinene. The other enzyme *sa*monoTPS1 converted geranyl diphosphate into (+)-α-terpineol, and (-)-limonene, with small amounts of sabinene, linalool, α-terpinolene, myrcene and geraniol. These

represent the first TPS genes to be isolated from sandalwood and will enable further elucidation of the oil biosynthesis genes.
This thesis `completes a three-pronged approach to understanding the underlying causes of oil yield variance in *S. album*. As a species for which so little is known, the research presented here provides a major leap forward for tree improvement, breeding and silviculture. Hence the best of sandalwood research is presented.

Jones C. (date?) "Indian Sandalwood: Genetic and oil diversity and bio-chemistry of the Australian germplasm collection." *Sandalwood Research Letter* ?

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Preen C. (2005) "Update on Sandalwood Essential Oil" *Aromatherapy Regulation News* Summer 2005 Newsletter **2**(2), 4. Aug 2005. ***Cropwatch comments***: Further proof, if it were needed, that some Aromatherapy (AT) organisation officials have been 'in denial' about the role of aromatherapy as a consumer market affecting the serious demise of sandalwood species - here Preen attempted to shift the blame to the perfumery trade. Further, Preen argued that *Santalum album* is not actually endangered (the IUCN Red List http://www.iucnredlist.org/search/details.php/31852/all classifies it as vulnerable), wrings her hands a little about sandalwood smuggling, and pledges faith in the much-criticised sandalwood replanting schemes to eventually solve the problem 30-40 years hence. Cropwatch currently observes that little, if any, Sandalwood oil East Indian is currently available on the spot market, and what there is, is practically always adulterated - it is of note that the AT professional organisations have no formal analytical standards for sandalwood oil used in aromatherapy to determine whether or not this is the case. Further, the carbon footprint of sandalwood oil is particularly unacceptable wrt climate change concerns, with excessive energy consumption occurring as a result of long distillation times. Therefore by continuing to defend the use of E.I. sandalwood oil in AT, one can only conclude that any ecological interests have been inappropriately sold out to the commercial interests of AT essential oil traders, who anyway have an unhealthy & unseen influence on the policy of many AT professional organisations. Further, aromatherapists are likely to be indirectly supporting gangland by consuming sandalwood oil, most of which is either smuggled with or without the help of corrupt officials or otherwise illegally produced. This was a completely wrong-headed & misleadfing article (in Cropwatch's humble opinion, of course)..

Radomiljac, A. M., J. A. McComb, *et al.* (1998). “Xylem transfer of organic solutes in *Santalum album* L. (Indian sandalwood) in association with legume and non-legume hosts.” *Annals of Botany* **82**(5), 675-682.

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Santalum album L. under large-scale plantation conditions, until recently, has been largely unsuccessful. In this experiment, the growth of *S. album* seedlings grown with the herbaceous pot host *Alternanthera nana* R. Br. for 134, 109, 84, 60 and 35 days in a nursery container prior to field establishment was examined after 11, 16 and 23 weeks in the field. *S. album* survival and growth was greater, and root:shoot ratio was lower for the 23 weeks for *S. album* seedlings grown with *A. nana* compared with seedlings grown without a host. Seedlings grown with *A. nana* for 134 days in the nursery prior to field establishment had greater stem diameter, height and root, shoot and total plant dry weight (DW) over the 23 weeks in the field than all other treatments. Seedlings grown with A. nana for 109 days in the nursery prior to field establishment had greater field survival than all other treatments. *A. nana* survival in the field remained high when grown with *S. album* for 134 and 109 days in the nursery prior to field establishment whereas survival within remaining treatments declined significantly and *A. nana* growth was significantly less. *S. album* grown with *A. nana* for 134 days in the nursery prior to field establishment had a lower root:shoot ratio than all other treatments at all assessments. A strong negative linear relationship exists between *S. album* root:shoot ratio and *A. nana* DW, whereas a positive linear relationship exists between *S. album* DW and *A. nana* DW. Foliar phosphorus and sodium concentrations for *S. album* were lower and foliar potassium concentration higher when seedlings were grown with *A. nana* for 134 days in the nursery prior to field establishment compared with the remaining treatments at the 16-week assessment. The period of the *S. album*:-*A. nana* association in the nursery significantly influenced S. album survival and growth following field planting.

Radomiljac A. M. & McComb J.A. *et al.* (1999). "Intermediate host influences on the root hemi-parasite *Santalum album* L. biomass partitioning." *Forest Ecology and Management* **113**(2-3), 143-153. Abstract. *Santalum album* L. seedlings parasitised on the N2-fixing woody hosts *Sesbania formosa* (F. Muell.) N. Burb., *Acacia trachycarpa* E. Pritzel and A. ampliceps Maslin and the non-N2-fixing woody host *Eucalyptus camaldulensis* Dehnh. were grown for 38 weeks in 25 l nursery containers. S. album growth was greater and root : shoot ratio lower for *S. album* seedlings grown with N2-fixing hosts compared with seedlings grown with *E. camaldulensis* or with no host. Seedlings grown with *S. formosa* had a greater stem diameter, height, leaf area, root and shoot dry weight (DW) than all other treatments. S. album grown with S. formosa and A. ampliceps had a lower root : shoot ratio than all other treatments at all assessments. The root : shoot ratio of unattached *S. album* increased exponentially over the 38 week period. Seedling growth declined for all treatments between the 33 and 38 week harvests, except for those seedlings attached to *A. trachycarpa*. A strong positive linear relationship was shown between *S. album* leaf area and shoot DW irrespective of host species. No relationship was found between *S. album* shoot DW and root : shoot ratio with host shoot DW. The combined E. camaldulensis and *S. album* root system supported a smaller S. album shoot biomass compared with the *S. album* shoot biomass supported by the combined root systems of the N2-fixing hosts and *S. album*. Compared with all other host species the A. trachycarpa root system was more efficient in supporting its own shoot biomass and the total biomass of *S. album.* Host use efficiency (S. album shoot DW/host shoot DW) values of *S. formosa* and *A. trachycarpa* were greater than the host use efficiency values of *A. ampliceps* and *E. camaldulensis*. Values for unparasitised S. formosa leaf area, shoot and root DW and root : shoot ratio were greater than those for parasitised plants.

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Ral S N (1990) "Status and cultivation of sandalwood in India." In: *Proceedings of the Symposium on Sandalwood in the Pacific* (eds L Hamilton. & C E Conrad). General Technical Report PSW – 122. USDA Forest Service, Berkeley, 66–71. Abstract: Sandalwood (*Santalum album*) has been part of Indian culture and heritage for thousands of years, and was one of the first items traded with other countries. The heartwood yields fragrant oil, which is used mainly in the perfume industry but also has medicinal properties. The wood is used for carving and manufacturing incense. Generally *S. album* is found in the dry deciduous forests of Deccan Plateau, mostly in the states of Karnataka and Tamil Nadu, The evergreen tree regenerates naturally when conditions are favorable and has been spreading in its distribution. Lack of understanding of the dynamics of hemiparasitism by sandalwood has caused failure of pure plantations in the past; haustorial connections with its hosts supply sandalwood with nitrogen, phos-phorus, and potassium. Plantable seedlings can now be raised in the nursery in 6-8 months with the protection of a nematicide and fungicide. Several tech-niques for planting seeds directly in the field have also been developed. A tree that is growing well can put on an annual increment of 1 kg per year. The sandalwood resource in India is currently threatened by four factors: fire, browsing by livestock, spike (little leaf) disease, and smuggling.

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Sanjaya B.M., Thrilok S.R. & Vittal R.R. (2006) "Micropropagation of an endangered Indian sandalwood (*Santalum album* L*.). J. of Forest Research* **11**(3), 203-209. Abstract *Santalum album* is known as East Indian sandalwood. It is the most economically important tree harvested for heartwood oil, and India is among the chief exporters of sandalwood and its products. Multiple shoots were induced from nodal shoot segments derived from a 50- to 60-year-old candidate plus tree (CPT) on Murashige and Skoog (MS) medium supplemented with 0.53 μM α-naphthaleneacetic acid (NAA) and 11.09 μM 6-benzylaminopurine (BA). In vitro differentiated shoots were multiplied on MS medium with 0.53 μM NAA, 4.44 μM BA, and additives: 283.93 μM ascorbic acid, 118.10 μM citric acid, 104.04 μM cystine, 342.24 μM glutamine, and 10% (v/v) coconut milk. New shoots were harvested repeatedly for up to three subculture passages on fresh medium at 4-week intervals. Microshoots treated with 98.4 μM indole-3-butyric acid (IBA) for 48 h produced roots on growth-regulator-free, quarter-strength MS basal salts medium with vitamin B5 and 2% sucrose. In vitro root induction was achieved from microshoots pulsed with 1230 μM IBA for 30 min in soilrite rooting medium. The percentage of rooting in soilrite was higher than that for agar medium, and in vitro raised plants were established in the field and showed normal growth.

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Setzer W.N. (2009) "Essential oils & anxiolytic aromatherapy." *Nat Prod Commun*. **4**(9), 1305-16. Abstract. A number of essential oils are currently in use as aromatherapy agents to relieve anxiety, stress, and depression. Popular anxiolytic oils include lavender (*Lavandula angustifolia*), rose (*Rosa damascena*), orange (*Citrus sinensis*), bergamot (*Citrus aurantium*), lemon (*Citrus limon*), sandalwood (*Santalum album*), clary sage (*Salvia sclarea*), Roman chamomile (*Anthemis nobilis*), and rose-scented geranium (*Pelargonium* spp.). This review discusses the chemical constituents and CNS effects of these aromatherapeutic essential oils, as well as recent studies on additional essential oils with anxiolytic activities.

Shankaranarayana K.H., Ravikumar G. Rajeevalochan A.N. , Theagarajan K.S. & Ramaswamy C.R. (1998) "Content & composition of oil from central and transition zones." In: *Sandal & Its Products. ACAIR Proceedings (84)* eds A.M. Radomiljac H.S. Aanathapadmanabba, Wellburn R & Satyanarayana Rao. Publication Australian Centre for International Agricultural Research, Canberra 86-88 (1998).

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Sheen J. & Stevens J. (2001) "Self-perceived effects of Sandalwood" *Intl J. of Aromatherapy* **11**(4), 213-219. Abstract: Eight female participants used the essential oil of *Santalum album*, East Indian Sandalwood, as a perfume daily for a week. Their self-perceived effects were analyzed for common experiences, using the grounded theory method. Four categories of the experience were developed into an initial theory of the effects of sandalwood. It was found that sandalwood did have self-perceived effects, which varied with initial psychological state and emporal factors. The observed self-perceived effects of calming, ability to manage and well being have limited co-relation with claimed therapeutic effects. A further self-perceived effect, uplifting, was observed such that further investigation is required. This study is a demonstration of the initial steps of a holistic research model that would allow for aromatherapy, essential oils, their therapeutic effects and the experience of their use to be researched. Thus a sound scientific knowledge base for the profession of aromatherapy, relevant to its practice can be developed.***Cropwatch comments***: Recommended reading on self-perceived therapeutic effects of sandalwood!

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host plants. Differences in K, Ca, N and Cu levels between parasitized and uninfected Acacias imply that the host plant contributes to the nutrition of sandalwood. The high K/Ca ratio in sandalwood confirms that K uptake in preference to Ca is a general feature of all categories of angiosperm parasites.
Patterns of distribution of nutrients between various parts of sandalwood and *A. acuminata* depend on the type of nutrient, but levels are usually highest in leaves of both species and the haustoria. Although K, Ca and Na are much lower in the kernels than in vegetative parts of the parasite, only seedlings without supplementary Ca in a nutrient omission experiment failed to grow at all in the absence of hosts. Growth is not dependent on the level of K in the unattached plants but other evidence indicates it may have a role in water uptake in the attached plant. Calcium supply has a marked effect on internal Ca levels and growth of unattached plants. Compared with field plants, levels of Ca, and to a lesser extent Zn, were much higher in plants of the Ca/K treatment that produced greatest growth over 34 weeks.
Haustorial formation is enhanced by the presence of *A. acuminata* roots. However, competition for nutrients, especially Ca, from co-planted *A. acuminata* seedlings results in suppression of growth of young sandalwood compared with their growth in the absence of the host species.

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Jiko L.R. (2000) "Status & current interest in Sandalwood in Fiji" *Sandalwood Research Newsletter* **10**, 1-3. Abstract. *Santalum yasi*, the only sandalwood species in Fiji, earned 4.74 million Fijian dollars in foreign exchange over the period 1987-90. This recent resurgence in the utilisation of sandalwood has created an interest among landowners in planting and restocking new areas with the species. Information is presented on early history, traditional uses, growing conditions, silviculture and marketing of *yasi*, together with some notes on current research directions.

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Hawaii (*Santalum haleakalae* - Maui only*, Santalum freycinetianum, Santalum. paniculatum & Santalum ellipticum*).
Le Barron, Russell K. (1970)."Hawaii's sandalwood. Aloha Aina." *Department of Land and Natural Resources*, State of Hawaii; 6-7.

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Merlin M. & VanRavenswaay D. (1990) "The History of Human Impact on the Genus *Santalum* in Hawaii." *Proceedings of the Symposium on Sandalwood in the Pacific* April 9-11, 1990, Honolulu, Hawaii. Abstract: Adaptive radiation of *Santalum* in the Hawaiian archipelago has provided these remote islands with a number of endemic species and varieties. The prehistoric Polynesian inhabitants of Hawai'i utilized the sandalwood trees for many of the same traditional purposes as their South Pacific ancestors who had developed ethnobotanical relationships with *Santalum*. The ancient Ha-waiians probably reduced the number and geographical distribution of sandal-wood trees significantly through their extensive cutting and burning, especially in the dry forest regions. Nevertheless, vast numbers of the fragrant trees still existed in Hawai'i at the time of Western contact in 1778. Within a century after this contact, the extensive trade in sandalwood produced a massive decline in the Hawaiian species of *Santalum*. Although cultivation attempts during this cen-tury with both introduced and native sandalwood species have had limited success in Hawai'i, there is renewed interest in developing a sustainable forest industry based on the production of sandalwood for export trade. Biologists in general, however, have cautioned against large-scale harvesting of the remain-ing *Santalum* trees, suggesting that more research be undertaken first to determine the distribution & vigor of the remaining species.

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Stemmermann L. (1980). "Vegetative anatomy of the Hawaiian species of *Santalum* (Santalaceae)." *Pacific Science* **34**(l):55-75

Stemmermann R.L. (1980). "Observations of the Genus *Santalum* (Santalaceae)" in *Hawaii Pacific Science* **34**(1), 41-54. Abstract. Some of the taxonomic problems of species of Santalum in Hawai'i are resolved by proposing one new taxon and two combinations. These are based on observations of the genus in the field, herbarium studies, and anatomical differences found.

Stemmermann L. (1990) "Distribution and Status of Sandalwood in Hawaii." *Proceedings of the Symposium on Sandalwood in the Pacific* April 9-11, 1990, Honolulu, Hawaii. Abstract. This paper attempts to summarize what is known of the distribution and status of sandalwoods in Hawai'i. Four species of sandalwood are recog-nized as being endemic to the Hawaiian Islands, and one has been introduced. Ecological factors affecting the present and former distribution of Hawaiian sandalwoods are considered.

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Wilkinson K.M. (2007) "Propagation Protocol for 'iliahi (*Santalum freycinetianum*)." *Native Plants Journal* **8**(3),248-251. Abstract. 'Iliahi or Hawaiian sandalwood (*Santalum freycinetianum* Gaudich. [Santalaceae]) is a hemiparasitic plant that can be readily grown in the nursery, provided some general guidelines are followed. Seeds germinate best if scarified and sown fresh. Plants can be grown to outplanting size (20 cm [8.0 in] tall with stems 8 mm [0.3 in] in diameter) in just 8 to 12 mo using controlled release fertilizer. The best survival and growth occurs when sandalwood is grown with a companion plant. Keywords sandalwood, nursery host plant, Santalaceae, Hawai'i Nomenclature USDA NRCS (2007) Click for larger view Jack Jeffrey inspects *Santalum paniculatum* tree on Mauna Kea. Photo by Craig Elevitch [Begin Page 250] Iiahi or Hawaiian sandalwood (*Santalum freycinetianum* Gaudich. [Santalaceae]) is endemic to the Hawaiian islands of O'ahu, Kaua'i, Lana'i, Maui, and Moloka'i. It is found in dry, mesic, and wet forest, with rainfall of 50 to 380 cm (20 to 150 in) and at elevations of 250 to 950 m (820 to 3120 ft). It is a hemiparasitic plant, meaning its roots attach to the root systems of other plants to.

Marquesas Islands (*Santalum insulare*, *Santalum marchionense*).

Butaud J-F, Raharivelomanana P, Bianchini J-P & Baron V. (2003) "A new chemotype of Sandalwood (*Santalum insulare* Bertero ex A DC.) from Marquesas Islands" *J. Essen. Oil Res*. **15**, 323-6. Abstract. Volatile constituents of sandalwood (S. insulare) concrete from the island of Nuku-Hiva in Marquesas Islands were studied using GC, GC-MS, HPLC and NMR. The investigation of nine main compounds showed important variations among sandalwood samples (from 3.5 to 53.2% for α-santalol and from trace to 29.3% for (Z)-nuciferol). Statistical analysis put in relief a geographical segregation between sandalwoods growing in dry area in Terre-Déserte (14.6% of α- and β-santalol, 17.1% of (Z)-nuciferol and 11.7% of 6,13-dihydroxybisabola-2,10-diene) and sandalwoods growing in wetter area of the other parts of the island (60.9% of α- and β-santalol, 1.2% of (Z)-nuciferol and 0.7% of 6,13-dihydroxybisabola-2,10-diene). The chemotype rich in (Z)-nuciferol of Terre-Déserte constitutes a rare and new chemotype, which is described for the first time.

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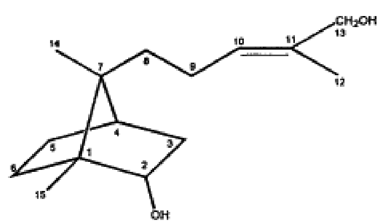
New Caledonia (*Santalum austrocaledonicum*).

Alpha T., Raharivelomanana P., Blanchini J.-P., Faure R. & Cambon A. & Joncheray L. (1996) "Santalenes from *Santalum austrocaledonicum.*" *Phytochemistry* **41**, 829-832.

Alpha T., Raharivelomanana P., Blanchini J.-P., Faure R. & Cambon A. (1997) "A sequiterpenoid from *Santalum austrocaledonicum* var. *austrocaledonicum*." *Phytochemistry* **46**, 1237-1239. Abstract. A new sesquiterpenoid, campherene-2,13-diol, has been isolated and characterized from the heartwood of *Santalum austrocaledonicum* var *austrocaledonicum*. Its structure has been established by the use of 1D and 2D NMR spectral techniques and shown to contain the campherenane skeleton.



Alpha T., Raharivelomanana P., Blanchini J.-P., Faure R. & Cambon A. (1997) "Bisabolane sesquiterpenoids from *Santalum austrocaledonicum*". *Phytochemistry* **44**, 1519-1552. Abstract. Two new sesquiterpenoids, 6,13-dihydroxybisabola-2,10-diene and 7,13-dihydroxybisabola-2,10-diene, were isolated, together with (E)-anceol, from the heartwood of *Santalum austrocaledonicum* var. *austrocaledonicum*. The compounds were characterized by one- and two-dimensional NMR.

Alpha T., Raharivelomanana P., Blanchini J.-P., Faure R. & Cambon A. (1997) "Identification de deux nouveaux dihydroxyles du bisabolene a partir de santal oceanien." In *Rivista Ital. EPPOS* (*Actes des 15emes Journeés Internationales Huiles Essentielles:* Digne-les-Bains, France., 5,6& 7 Sept 1996 Special Issue 01/97 pp 84-91.

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Bottin L, Vaillant A, Sire P, Cardi C, Bouvet J M (2005) "Isolation and characterization of microsatellite loci in *Santalum austrocaledonicum*, Santalaceae", *Molecular Ecology Notes*, **5**(4), 800-802.

Bottin L., Isnard C., Godefroy C., Lagrange A., Butaud. & Raharivelomanana, Bianchini & Bouvet J.M. (2005). "Chemical variability of sandalwood in New-Caledonia." Technical note CIRAD 20p + annexes.

Bottin L., Verhaegen D., Tassin J., Olivieri I., Vallant A. & Bouvet J.M. (2005) "Genetic Diversity & Population Structure of an Insular tree, *Santalum austrocaledonicum* in New Caledonian archipelago." *Molecular Ecology* **14**(7), 1979-89. Abstract: We present a study of the genetic diversity and structure of a tropical tree in an insular system. *Santalum austrocaledonicum* is endemic to the archipelago of New Caledonia and is exploited for oil extraction from heartwood. A total of 431 individuals over 17 populations were analysed for eight polymorphic microsatellite loci. The number of alleles per locus ranged from 3 to 33 and the observed heterozygosity per population ranged from 0.01 in Mare to 0.74 in Ile des Pins. The genetic diversity was lowest in the most recent islands, the Loyautes, and highest in the oldest island, Grande Terre, as well as the nearby small Ile des Pins. Significant departures from panmixia were observed for some loci-population combinations (per population FIS = 0-0.03 on Grande-Terre and Ile des Pins, and 0-0.67 on Loyautes). A strong genetic differentiation among all islands was observed (FST = 0.22), and the amount of differentiation increased with geographic distance in Iles Loyaute and in Grande Terre. At both population and island levels, island age and isolation seem to be the main factors influencing the amount of genetic diversity. In particular, populations from recent islands had large average FIS that could not be entirely explained by null alleles or a Wahlund effect. This result suggests that, at least in some populations, selfing occurred extensively. Conclusively, our results indicate a strong influence of insularity on the genetic diversity and structure of *Santalum austrocaledonicum*.

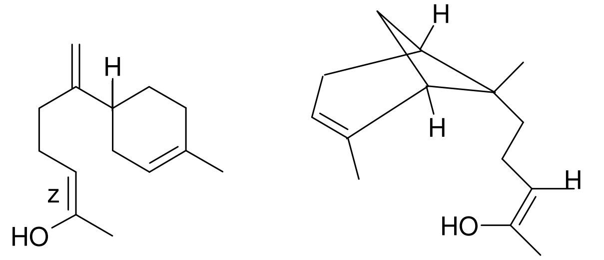
Bottin L. (2006) *Thesis: Ecole Nationale Superieure d'Agrnomie de Montpellier. Agro Montpellier*: *Déterminants de la variation moléculaire et phénotypique d'une espèce forestière en milieu insulaire: cas de Santalum austrocaledonicum en Nouvelle Calédonie*. – see http://tel.archives-ouvertes.fr/tel-00097974/en/ Abstract. Les îles océaniques constituent de véritables « laboratoires naturels » pour comprendre l'impact des forces évolutives sur la biodiversité. Les effets de dérive génétique et l'impact de la sélection naturelle apparaissent d'autant plus exacerbés que les îles sont isolées et soumises à de forts gradients environnementaux. Notre étude associe des marqueurs moléculaires neutres et des caractères liés à l'adaptation afin d'évaluer l'influence de ces différentes forces dans le contexte insulaire de Nouvelle-Calédonie sur l'espèce forestière *Santalum austrocaledonicum*. L'étude des microsatellites nucléaires et chloroplastiques montre une différenciation nette des populations des petites îles Loyauté et un isolement par la distance au sein de l'île la plus vaste, Grande Terre. En outre elle met en évidence un déficit en hérérozygotes au sein de certaines populations pouvant être attribué à une sous-structuration spatiale ou un régime de reproduction autogame. La variation de la taille des feuilles et des graines, caractères liés à l'adaptation, résulte des effets de dérive mais aussi de la sélection naturelle provoquée par des contrastes environnementaux notamment par des différences de pluviométrie. De même la composition chimique du bois de coeur, analysée par chromatographie, subirait, en plus de la dérive, une pression sélective exercée par le cortège

d'insectes et de champignons phytophages. Cette étude exploratoire permet de dégager de nombreuses perspectives de recherche relevant des questions évolutives en milieu insulaire. Sur un plan opérationnel, elle permet de définir des unités de gestion de l'espèce associant caractères adaptatifs et variables moléculaires.

Bottin L., Isnard C., Lagrange A. & Bouvet J.M. (2007) "Comparative molecular and phytochemical study of the tree species *Santalum austrocaledonicum* (Santalaceae) distributed in the New-Caledonian archipelago." *Chem Biodivers*. **4**(7):1541-56. Abstract. We have tried to elucidate the origin of phytochemical variation in trees by studying concomitantly the chemical and microsatellite variations in *Santalum austrocaledonicum*. Eight natural populations were sampled in the New-Caledonian archipelago, a total of 157 individuals being analyzed. The main components, as revealed by gas chromatography (GC), were alpha- and beta-santalol (as in other sandalwood species), although the level of (Z)-lanceol was particularly high. Most of the chemical variation was observed within populations (83.7%). With microsatellites, the variation between populations was more pronounced (32% of the total variation). Although the chemical variation between populations was small, we investigated the effects of genetic drift and migration by comparing the chemical- and molecular-differentiation patterns. The poor congruence between neighbor-joining trees, confirmed by the non-significant Mantel test between the molecular and chemical distance matrices (R=0.26, P=0.12), showed that genetic drift and migration are not the main evolutionary forces acting on chemical differentiation between populations. We could not find any effect of soil and rainfall conditions neither. Although the impact of drift and migration cannot be discounted in rationalizing between-population differentiation, the low variation among populations could result from a stabilizing selection caused by the same phytopathogen charge across the natural range.

Bottin L., Tassin J., Nasi R. & Bouvet J.-M. (2007) "Molecular, quantitative and abiotic variables for the delineation of evolutionary significant units: case of sandalwood (*Santalum austrocaledonicum* Vieillard) in New Caledonia." *Conservation Genetics* **8**(1), 99-109. Abstract. Various approaches have been developed to define conservation units for plant and animal species. In this study we combined nuclear microsatellites (from a previous published study) and chloroplast microsatellites (assessed in the present study), leaf and seed morphology traits and abiotic variables (climate and soil) to define evolutionary significant units (ESU) of Santalum austrocaledonicum, a tree species growing in New Caledonia. Results for chloroplast microsatellites showed that the total population heterozygosity was high, (H cp = 0.84) but varied between islands. Differentiation was strong in the total population (F stcp = 0.66) but also within the main island Grande Terre (F stcp = 0.73) and within Iles Loyauté (F stcp = 0.52), highlighting a limited gene flow between populations. These results confirmed those obtained with nuclear microsatellites. The cluster analysis on molecular markers discriminated two main groups constituted by the populations of Grande Terre and the populations of Iles Loyauté. A principal component analysis of leaf and seed morphology traits singled out the populations of Iles Loyauté and the western populations of Grande Terre. Quantitative genetic analyses showed that the variation between populations was under genetic control (broad sense heritability close to 80%). A high correlation between rainfall and morphological traits suggested an impact of climate on this variation. The integration of these results allows to define two ESUs, one corresponding to Grande Terre and Ile des Pins and the other the Iles Loyauté archipelago. This study stresses the need to restore some populations of Grande Terre that are currently threatened by their small size.

Braun N.A., Meier M. & Hammweschmidt F.-J. (2005) "New Caledonian sandalwood – a substitute for East Indian sandalwood oil?" *J. Essen Oil Res* **17**, 477-480. Abstract: Three qualities of New Caledonian sandalwood oil were analysed using GC and GC/MS. Eighty-four constituents were identified: 10 monoterpenes, 72 sesquiterpenes and two others. In addition b-bisabolol/epi-b-bisabolol isomers were isolated and characterised via chiral GC chromatography. Our results indicate that New Caledonian sandalwood oil is much closer related to East Indian sandalwood oil than its West Australian counterpart. ***Cropwatch comments***: Arguably in 2005, the world production of sandalwood oil was approx. 50 tons/annum, set against a demand of 200 tons/annum. How then can the authors maintain, bearing in mind New Caledonia's very limited production capability (1-2 tons at most), that this oil can be a substitute for the ever-scarcer East Indian Sandalwood oil? Furthermore, the authors assume that the GC analytical trace similarity (i.e. between E.I. sandalwood oil against New Caledon sandalwood oil) will make it an automatic pertfumery substitution choice, without performing detailed odour profiling trials, or by comparing perforemance in product In fact the authors own figures show considerable differences in compositiomn exist between New Caledonoium & E.I. sandalwood oils, especially in respect to the high (Z)-lanceol (9.1%) and high (Z)-trans-α-bergamotol (9.9%) figures.



Z-lanceol (Z)-trans-alpha-bergamotol

Brennan P. & Merlin M (1993). "Biogeography and traditional use of *Santalum* in the Pacific Region". pp. 30–38. In: McKinnell, F.H. (ed.). 1993. *Sandalwood in the Pacific Region*. Proceedings of a symposium held on 2 June 1991 at the XVII Pacific Science Congress, Honolulu, Hawaii. ACIAR Proceedings 49. ACIAR, Canberra, Australia. Abstract. *Santalum* has a disjunct? known distribution among the islands of the Pacific Ocean. During the prehistoric period, Melanesian and Polynesian Islanders, who had access to native sandalwood trees and shrubs, utilised the aromatic heartwood for a variety of medicinal and other purposes. Some uses had significant social import, motivating trade of Santalum from Fiji to Tonga for status and aesthetic reasons. Pre-contact trade of sandalwood may also have occurred between other South Pacific Islands in Eastern Polynesia. The biogeography of *Santalum* spp. is described, and some aspects of the ancient and more recent history of the use of, and human environmental impact on, sandalwood species in the Pacific are reviewed.

Bulai P. & Nataniela V. (2002).. "Research, development and extension of Sandalwood in Fiji - A new beginning." Paper to *Regional Workshop on Sandalwood Research, Development and Extension in the Pacific Islands and Asia*. Noumea, New Caledonia, 7–11 October 2002.

Chauvin J.P. & Ehrhart Y. (1998). "Germination of two provenances of *Santalum austrocaledonicum* var. *austrocaledonicum*." *ACIAR Proceedings* **84**: 113–116.

Chauvin, J.P. (1990). "La production de plants de santal en Nouvelle Caledonie." *Bois et Forests des Tropiques* N°**218**, 1-10.

Cherrier, J-F (1993). "Sandalwood in New Caledonia". In F.H. McKinnell (ed) *Sandalwood in the Pacific Region*. Proceedings of a symposium held on 2 June 1991 at the *XVII Pacific Science Congress*, Honolulu, Hawaii. Canberra: *ACIAR Proceedings* No.49. pp19-23. Abstract. Results of research on wood formation in *Santalum austrocaledonicum* in New Caledonia are discussed. There is high variability of heartwood content at any tree size. Trees also reach maturity at different heights and diameters, making predictive models of limited value. The best correlation of yield of heartwood is with sapwood width. The latter is positively correlated with recent growth rate. Sapwood is at a minimum and the proportion of heartwood is highest when the tree matures and growth rate is reduced. It is concluded that the management of sandalwood to maximise heartwood production is complex.

Douheret J. (1981). "Le santal en Nouvelle Calédonie." *Nature calédonienne* 11/1981.

Ehrhart Y. (1996). "The status of the genus *Santalum* and *Agathis* in New Caledonia." Paper at *SPRIG (South Pacific Regional Initiative on Forest Genetic Resources) Meeting,* Nadi, Fiji 2–4 December 1996. Unpublished.

Lawrence B.M. (2008) "Progress in Essential oils. New Caledonian Sandalwood oil." *Perf. & Flav.* **33** (Juy 2008) p 44.

Veillon J.M. & Jaffré T. (1995) "Sandalwood (*Santautm azrstrocaledonicum* Vieillard) in New Caledonia: taxonomy, distribution, ecology." In L Gerum, JED Fox and Y Ehrhart (eds.) Sandalwood seed, nursery and plantation technology. Proceedings of a regional workshop for Pacific Island Countries; August 1-11, 1994; Noumea, New Caledonia. RAS/92/361. Field Document No. 8. UNDP/FAO South Pacific Forestry Development Programme, Suva, Fiji. Pp. 25-36.Abstract. Sandalwood is represented in New Caledonia by a single species, *S.austrocaledonicum*, which is divided into three varieties showing different geographic distributions: the Nouméa area for the pifosulicm variety, the foot of ultramafic rock formations for the minutzim variety and the Loyalty Islands, the Isle of Pines and a few locations in New Caledonia for the *austrocaledonicum* variety. It is mainly limited to secondary vegetation stands with diverse flora, but can also be found in sclerophyll forest and in low altitude scrub, which could well be its original environment. It grows in extremely varied soils, with a pH of 4 to 8 or more, containing a variety of exchangeable bases (Ca, K, Na); these soils may be rich in magnesium, nickel and chrome. Its foliar mineral composition features relatively high concentrations of nitrogen and potassium, low to medium-level concentrations of phosphorus and highly variable levels of calcium. As in other Pacific islands, sandalwood, which is highly sought after for its wood and essential oils, has undergone intensive harvesting in New Caledonia. This overexploitation, along with the destruction of its original biotopes (sclerophyll forest and low-altítude scrub) by both agricultural and grazing activities and fire, has contributed to the growing scarcity of this species through the disappearance of numerous stands.At the present time, the minufum variety, which may well be an edaphic scrubland variety, can only be found in a single location and must be considered as an endangered species. Urgent action is therefore necessary for its survival.

Tonga (*Santalum yasi*).

Erhart Y. (1997) "Technical Report on Sandalwood Workshop, Tonga 17–21 November 1997. CIRAD–Forêt/New-Caledonia

Kaufusi S. (1995) "Status of the Sandalwood tree in Tonga." In:: Gerum, L., J.E.D. Fox, and Y. Ehrhart (eds.). 1995. *Sandalwood Seed, Nursery and Plantation Technology. Proceedings of a regional workshop for Pacific Island Countries, August 1–11, 1994*, Noumea, New Caledonia. RAS/92/361. Field Document 8. UNDP/FAO South Pacific Forestry Development Programme, Suva, Fiji.Gerum, Fox, and Ehrhart (eds) ,

Kaufusi S, Harmani S, and Thomson L. (1999). "Sandalwood work on 'Eua, Kingdom of Tonga.". *Sandalwood Research Newsletter*. CALM, Kununnura, Western Australia.

Siwatibau S., Bani C, & Kaloptap J. (1998). "SPRIG Rapid Rural Appraisal Survey of selected tree species in Vanuatu." *Report by Island Consulting to CSIRO Division of Forestry/SPRIG Project.*

Yuncker T, 1959. Plants of Tonga. B.P. Bishop Museum Bulletin, 220pp.

Vanuatu (*Santalum austrocaledonicum*).

Barrance A.J. (1989). "Controlled development of sandalwood in Vanuatu - a mid-term review of the five year moratorium on sandalwood cutting." *Vanuata Forest Service*, June 1989.

Barrance, A. 1989 (November). Research Trials: Results of trials up to 1989. Research report on file, Forestry Department, Port Vila, Vanuatu.

Berry A. (2002). Vanuatu country report. In proceedings of SPC Regional Workshop On Sandalwood Research, Development And Extension In The Pacific Islands And Asia. 7-11 October 2002, Noumea, New Caledonia. (2002).

Bule L. & Daruhi G. (1990) “Status of sandalwood resources in Vanuatu.” *Proceedings of the Symposium on Sandalwood in the Pacific April 9-11, 1990, Honolulu, Hawaii* Abstract. On eight islands of Vanuatu archipelago, sandalwood stands have been heavily exploited since the late 1800's. Because of the over-exploitation, which worried the Vanuatu Government, a moratorium was imposed in early 1987. The status of the valuable wood and the beginnings of research into one of the country's potential commodities are reviewed.

Channel S. & Thompson L. (1999) “Development of a Sandalwood conservation strategy for Vanuatu. In *Forest Genetic Resources* No **27**, 68-72.

Daruhi, G. (1991). “Sandelwud blong Vanuatu. A bright future?” Sandalwood paper for the XVII^{e} P.S.A. Congress. Honolulu, Hawaii. Forestry Department, Vila.

Ehrhart Y. 1998. “Oil composition of the sandalwood (*Santalum austrocaledonicum*) from Erromango and Aniwa Islands, Vanuatu.” Report for CIRAD–Foret, Nouvelle–Calédonie, 10 June 1998. Unpublished.

Neil P.E. (1986) “Sandalwood of Vanuatu” *Forest Research Report 5/86, Vanuatu Forest Service* (**5**/86): ii + 7.

Page T., Tate H., Tungon J., Sam C., Dickinson C., Robson K., Southwell I., Russell M., Waycott M., Leakey R. (2004). "Evaluation of heartwood and oil characteristics in nine populations of *Santalum austrocaledonicum* from Vanuatu." *Sandalwood Research Newsletter* ? Abstract. Heartwood cores were collected from 222 trees across nine populations on six different islands from Vanuatu. Oil was ethanol extracted and oil concentration and the main constituents were determined for each of the cores sampled andanalysed on a tree-to-tree and site-by-site basis. Heartwood oil concentration and all major oil constituents exhibited significanttree-to-tree variation, within and between all populations. Each population had a range of trees with high and low concentrations of α- and β-santalol. The popula-tions from the two northern islands had a greater proportion of trees with high santalol content than the populations sampled from the southern islands

Tacconi L. & Mele. L. (1995). *Economic Aspects of Sandalwood Cultivation in Relation to the Erromango Kauri Protected Area. Vanuatu Forest Conservation Research Report 7*. Department of Economics and Management, University College, University of New South Wales, Campbell, Canberra, Australia.

Tacconi L. & Mele I. (1997). “Sandalwood Cultivation and the Establishment of the Erromango Kauri Protected Area, 71-85.” In: Tacconi, L. and Bennett, J. (Eds) *Protected Area Assessment and Establishment in Vanuatu: a Socioeconomic Approach* ACIAR Monograph 38, ACIAR, Canberra, 180p.

Tate H., Sethy M. & Tungon J. (2004) "Grafting Sandalwood in Vanuatu." *Sandalwood Research Newsletter* ?. Abstract. Historically sandalwood plantings in Vanuatu have been established mainly by seed propagation and transplanted wildings. This method continues to be very important for village communities to grow sandalwood collected from their natu-ral sources. With increasing interest across the country in planting sandalwoodthe Department of Forests (DoF) is actively encouraging improved clonal seed orchards to keep up with demand. Clonal propagation of mature trees by cuttings has been difficult to achieve byconventional methods, but grafting has proven a viable alternative method. Thesuperior individuals identified within the current ACIAR sandalwood project are now being grafted using the methods developed in conjunction with SPRIG

General Pacific Region

Allen J.A. (2002).” *Santalum freycinetianum* Gaudich.” In Vozzo, J.A. (ed.). *Tropical Tree Seed Manual. Agriculture Handbook* 721. U.S. Forest Service, Washington, DC.

Alpha T., Raharivelomanana P., Bianchini J.-P., Faure R., Cambon A., & Joncheray L. (1995) "alpha-Santaldiol & beta-santaldiol, two santalane sesquiterpenes from *Santalum insulare*." *Phytochem.* **41**(3), 829-831. Abstract. Two new sesquiterpene alcohols, beta-santaldiol and alpha-santaldiol, have been isolated from the heartwood of *Santalum insulare* var. *marchionese* and, by means of two-dimensional NMR experiments, shown to have the beta- and alpha-santalane skeleton respectively.

Alpha, T. (1997). *Etude des concrètes et des essences de santal d'origine océanienne. Elucidation de nouveaux sesquiterpenoïdes par la RMN multi-impulsionnelle et bidimensionnelle*. Ph.D. Thesis. Université Française du Pacifique, Papeete, French Polynesia.

Alpha, T., P. Raharivelomanana, J.-P. Bianchini, Y. Ehrhart & A. Cambon. (1997). "Etude de la composition chimique d'essences de santal d'origine du Pacific Sud." pp 499–465 In: *Revista Italiana EPPOS (Actes des 15èmes Journées Internationales Huiles Essentielles*; Digne-les-Bains, France, 5, 6 & 7 Septembre 1996, Special issue 01/97.

Applegate G.B. (1990). "Sandalwood in the Pacific: A state of knowledge. Synthesis and summary from the April 1990 symposium." pp 1–11. In: Hamilton, L., and C.E. Conrad (eds.). 1990. *Proceedings of the Symposium on Sandalwood in the Pacific, April 9–11, 1990, Honolulu, Hawai'i.* General Technical Report PSW–122. Pacific Southwest Research

Barrau, J. (1960). "Plantes utiles des îles du Pacifique–Le Santal." *Bulletin des études Pacifiques,* July 1960.

Brennan, P., and M. Merlin. (1993). "Biogeography and traditional use of *Santalum* in the Pacific Region". In: F. McKinnell (ed.). Proceedings of a symposium held on June 2, 1991 at the XVII Pacific Science Congress, Honolulu, Hawai'i. *ACIAR Proceedings* **49**. ACIAR, Canberra, Australia.

Butaud J.F. & Tetuanui W. (2002). "Le Santal en Polynésie Française." *Proceedings of the Regional Workshop on Sandalwood Re-search, Development and Extension in the Pacific Islands andAsia, 7-11 October, 2002,Noumea, New Caledonia*

Butaud J.-F. (2004) "*Santalum insulare* (Bertero ex A. DC.): Distribution and ecology." *Sandalwood Research Newsletter* **19**. July 2004. Abstract. The Eastern Polynesian sandalwood is one of the sixteen *Santalum* species of Asia and the Pacific. It is known under the name puahi in Marquesas Islands, ai in Cook Islands and ahi elsewhere in its geographical area. Overexploited during the beginning of the 19th century, Polynesian sandalwood is still used for carvingor in powder mixed with coconut oil (monoi ahi or pani puahi) for cosmetic or medicinal purposes.

Butaud J.F. (2003). "Autécologie et phytosociologie des Santals de Polynésie française." *Proceedingsof the Regional Workshop on San-dalwood Research, Developmentand Extension in the Pacific Is-lands and Asia*, 7-11 October, 2002, Noumea, New Caledonia.

Butaud J.-F., Rives F., Verhaegen D. * Bouvet J.-M. (2005) "Phylogeography of Eastern Polynesian sandalwood (*Santalum insulare*), an endangered tree species from the Pacific: a study based on chloroplast microsatellites." *Journal of Biogeograohy* **32** (10) , 1763–1774. Abstract. Aim: Patterns of genetic variation within forest species are poorly documented in island ecosystems. The distribution of molecular variation for *Santalum insulare*, an endangered tree species endemic to the islands of eastern Polynesia, was analysed using chloroplast microsatellite markers. The aims were to quantify the genetic diversity; to assess the genetic structure; and to analyse the geographical distribution of the diversity within and between archipelagoes. The ultimate goal was to pre-define evolutionary significant units (ESUs) for conservation and restoration programmes of this species, which constitutes a natural resource on small, isolated islands.

Location Eleven populations, each representative of one island, covering most of the natural occurrence of *S. insulare* were sampled: five populations from the Marquesas Archipelago; three from the Society Archipelago; and three from the Cook–Austral Archipelago. These South Pacific islands are known for their high degree of plant endemism, and for their human occupation by Polynesian migrations. The extensive exploitation of sandalwood by Europeans nearly 200 years ago for its fragrant heartwood, used overseas in incense, carving and essential oil production for perfume, has dramatically reduced the population size of this species.
Methods We used chloroplast microsatellites, which provide useful information in phylogeographical forest tree analyses. They are maternally inherited in most angiosperms and present high polymorphism. Among the 499 individuals sampled, 345 were genotyped successfully. Classical models of population genetics were used to assess diversity parameters and phylogenetic relationships between populations.
Results Four microsatellite primers showed 16 alleles and their combinations provided 17 chlorotypes, of which four exhibited a frequency > 10% in the total population. The gene diversity index was high for the total population (He = 0.82) and varied among archipelagoes from He = 0.40 to 0.67. Genetic structure is characterized by high levels of differentiation between archipelagoes (36% of total variation) and between islands, but differentiation between islands varied according to archipelago. The relationship between genetic and geographical distance confirms the low gene flow between archipelagoes. The minimum spanning tree of chlorotypes exhibits three clusters corresponding to the geographical distribution in the three main archipelagoes.
Main conclusions The high level of diversity within the species was explained by an ancient presence on and around the hotspot traces currently occupied by young islands. Diversity in the species has enabled survival in a range of habitats. Relationships between islands show that the Cook–Austral chlorotype cluster constitutes a link between the Marquesas and the Society Islands. This can be explained by the evolution of the island systems over millions of years, and extinction of intermediary populations on the Tuamotu Islands following subsidence there. Based on the unrooted neighbour-joining tree and on the genetic structure, we propose four ESUs to guide the conservation and population restoration of Polynesian Sandalwood: the Society Archipelago; the Marquesas Archipelago; Raivavae Island; and Rapa Island.

Butaud J.-F., Raharivelomanana P., Bianchini J.-P. Faurec R. & Gaydou E.M. (2006) "Leaf C-glycosylflavones from *Santalum insulare* (Santalaceae)" *Biochemical Systematics and Ecology* **34**(5), 433-435

Butaud J.-F., Raharivelomanana P., Bianchini J.-P. & Gaydou E.M. (2008) "*Santalum insulare* Acetylenic Fatty Acid Seed Oils: Comparison within the *Santalum* Genus." *J of American Oil Chemists Society* **85**(4), 353-356.. Abstract. The sandalwood kernels of *Santalum insulare* (Santalaceae) collected in French Polynesia give seed oils containing significant amounts of ximenynic acid, E-11-octadecen-9-oic acid (64–86%). Fatty acid (FA) identifications were performed by gas chromatography/mass spectrometry (GC/MS) of FA methyl esters. Among the other main eight identified fatty acids, oleic acid was found at a 7–28% level. The content in stearolic acid, octadec-9-ynoic acid, was low (0.7–3.0%). An inverse relationship was demonstrated between ximenynic acid and oleic acid using 20 seed oils. Results obtained have been compared to other previously published data on species belonging to the *Santalum* genus, using multivariate statistical analysis. The relative FA *S. insulare* composition, rich in ximenynic acid is in the same order of those given for *S. album* or *S. obtusifolium*. The other compared species (*S. acuminatum*, *S. lanceolatum*, *S. spicatum* and *S. murrayanum*) are richer in oleic acid (40–59%) with some little differences in linolenic content.

Chauvin J.-P. & Erhart J. “Germination of two provenances of *Santalum austrocaledonicum* var. *austrocaledonicum.” ACIAR-Proceedings Series* **84**, 113-116.

Doran J., Thomson L., Brophy J., Goldsack B., Bulai P., Faka'osi & Mokosa T. (date?) "Variation in heartwood oil composition of young sandalwood trees in the South Pacific (*Santalum yasi*, *S. album* and F1 hybrids in Fiji, and *S. yasi* in Tonga and Niue)." Abstract. This study was undertaken during 2003 as part of AusAID’s SPRIG (South Pacific Regional Initiative in Forest

Genetic Re-sources) project. It had the primary aim of extending the knowledge base on the production of heartwood and heartwood oils in young Pacific Island sandalwoods, *Santalum yasi*, the introduced *S. album*, and the spontaneous F1 hybrid, *S. album* ×*yasi*. A solvent (pentane) extraction technique was used to determine heartwood oil chemistry, following verification againststeam distillation. The heartwood was obtained from trees by non-destructive coring. Ages of the trees sampled ranged between 5 years and more than 25 years. Many of them had not yet started to lay downheartwood at their base. For those that had, heartwood was restricted to the lower most cores i.e. 0.1m or 0.2m above groundor very occasionally extending to 0.3m in older trees. Tree-to-tree variation in oil quality in *S. yasi*, as determined by allow-able α-santalol and β-santalol levels in the International Standard (2002) for *S. album*, was substantial indicating a potentialof improvement through selection and breeding if genetic parameters are favourable. Trees in Fiji of the spontaneous F1 hy-brid, *S. album* × *yas*i, were very vigorous and the heartwood oil of two (out of three) of the 7-year-old trees with heartwoodwas of excellent quality. The results suggest that rotation lengths of 25 to 30 years for the Pacific sandalwoods may be more realistic than the 15 to 20 year rotation lengths suggested by some workers.

Ehrhart Y. (1997). *Technical Report on Sandalwood Workshop, Tonga* 17–21 November 1997. CIRAD–Forêt/ New Caledonia, Pouembout. Unpublished.

Ehrhart Y. (1998) "Descriptions of some sandal tree populations in the South West Pacific : consequences for the silviculture of these species and provenances." In : Radomiljac A.M. (ed.), Ananthapadmanabho H.S. (ed.), Welbourn R.M. (ed.), Satyanarayana Rao K. (ed.). *Sandal and its products : proceedings of an international seminar. Canberra* : ACIAR, p.105-112. Sandal and its Products, 1997-12-18/1997-12-19, (Bangalore, Inde). Abstract. Many of the islands of the South West Pacific that bear sandal have been visited and the stands described. Mostly the population is depleted, but some stands still exist. Depending on the status of the existing population, several possible management strategies are feasible. The aim is to rebuild stands which are as diverse as possible which will be able to be managed sustainably in a few decades. Some are presently managed with the objective of regular annual heartwood production with an increase of the stock. The observations reported here, especially those regarding shade intensity, can be used to improve the silviculture of the various provenances which differ markedly. Even aspects of seed storage differ, and this demande further investigation. New techniques, which differ significantly from those previously identified for the Ile des Pins provenance, are proposed. (Résumé d'auteur)

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Harbaugh D.T. & Bruce G. Baldwin B.G. (2007) *American Journal of Botany* **94**, 1028-1040. "Phylogeny and biogeography of the sandalwoods (*Santalum*, Santalaceae): repeated dispersals throughout the Pacific." Abstract. Results of the first genus-wide phylogenetic analysis for *Santalum* (Santalaceae), using a combination of 18S–26S nuclear ribosomal (ITS, ETS) and chloroplast (3' trnK intron) DNA sequences, provide new perspectives on relationships and biogeographic patterns among the widespread and economically important sandalwoods. Congruent trees based on maximum parsimony, maximum likelihood, and Bayesian methods support an origin of *Santalum* in Australia and at least five putatively bird-mediated, long-distance dispersal events out of Australia, with two colonizations of Melanesia, two of the Hawaiian Islands, and one of the Juan Fernandez Islands. The phylogenetic data also provide the best available evidence for plant dispersal out of the Hawaiian Islands to the Bonin Islands and eastern Polynesia. Inability to reject rate constancy of *Santalum* ITS evolution and use of fossil-based calibrations yielded estimates for timing of speciation and colonization events in the Pacific, with dates of 1.0–1.5 million yr ago (Ma) and 0.4–0.6 Ma for onset of diversification of the two Hawaiian lineages. The results indicate that the previously recognized sections *Polynesica*, *Santalum*, and *Solenantha*, the widespread Australian species *S. lanceolatum*, and the Hawaiian species *S. freycinetianum* are not monophyletic and need taxonomic revision, which is currently being pursued

Hirano R.T. (1990) "Propagation of Santalum, Sandalwood tree." *Proceedings of the Symposium on Sandalwood in the Pacific April 9-11, 1990, Honolulu, Hawaii* Abstract. The history of the genus *Santalum* (sandalwood) in Hawaii is re-viewed, along with all the early reference regarding its botany and horticulture. This paper gives some seed germination and viability information on *Santalum haleakalae* Hbd. and *S. paniculatum* H. & A. both native to Hawaii and *Santalum album* L. native to Indonesia. Germination was shown to be highly variable: as early as 26 days after sowing for *S. album*, 75 days for *S. paniculatum*, and 155 days for *S. haleakalae*. Seed viability varied from 324 days in S. album, 387 days in S. *haleakalae* and 824 days in *S. paniculatum*. Germination percentages ranged from 38 percent to 77 percent. This study also showed that supplemental chelated iron is essential in the propagation of all the species tested.

Lhuillier E., Butaud J.F. & Bouvet J.M. (2006) "Extensive clonality and strong differentiation in the insular pacific tree *Santalum insulare*: implications for its conservation." *Ann Bot (Lond).* **98**(5), 1061-72. Abstract. BACKGROUND AND AIMS: The impact of evolutionary forces on insular systems is particularly exacerbated by the remoteness of islands, strong founder effects, small population size and the influence of biotic and abiotic factors. Patterns of molecular diversity were analysed in an island system with *Santalum insulare*, a sandalwood species endemic to eastern Polynesia. The aims were to evaluate clonality and to study the genetic diversity and structure of this species, in order to understand the evolutionary process and to define a conservation strategy. METHODS: Eight nuclear microsatellites were used to investigate clonality, genetic variation and structure of the French Polynesian sandalwood populations found on ten islands distributed over three archipelagos. KEY RESULTS: It was found that 58 % of the 384 trees analysed were clones. The real size of the populations is thus dramatically reduced, with sometimes only one genet producing ramets by root suckering. The diversity parameters were low for islands (n(A) = 1.5-5.0; H(E) = 0.28-0.49). No departure from Hardy-Weinberg proportion was observed except within Tahiti island, where a significant excess of homozygotes was noted in the highland population. Genetic structure was characterized by high levels of differentiation between archipelagos (27 % of the total variation) and islands (F(ST) = 0.50). The neighbour-joining tree did not discriminate the three archipelagos but separated the Society archipelago from the other two. CONCLUSIONS: This study shows that clonality is a frequent phenomenon in *S. insulare*. The genetic diversity within populations is lower than the values assessed in species distributed on the mainland, as a consequence of insularity. But this can also be explained by the overexploitation of sandalwood. The differentiation between archipelagos and islands within archipelagos is very high because of the limited gene flow due to oceanic barriers. Delineation of evolutionary significant units and principles for population management are proposed based on this molecular analysis.

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Tennakoon K.U., Ekanayake S.P. & Etampawala L. (2000). "An overview of *Santalum album* research in Sri Lanka." *International Sandalwood Research News Letter* **11,** (1-4). Abstract. This paper outlines the background and present status of *Santalum album* research in Sri Lanka. The cur-rent project is a detailed study undertaken to investigate the biology, ecology, siviculture and physiology of sandalwood in Sri Lanka. Assessments made during the pilot study and the experimental data collectedfrom the two established model nurseries of sandalwood will be used to provide training and know how tothe farmers and interested governmental and non-governmental organisations to establish their own San-dal nurseries and subsequent sandalwood plantations. This project is funded by the Community Environ-ment Initiative Facility implemented by the Environment Action 1 project of the Ministry of Forestry and Environment. Sri Lanka under a World Bank fund.

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Alongi D.M. & de Carvalho N.A. (date?) "The effect of small-scale logging on stand charfacteristics & soil biogeochemistry in mangrove forests of Timor Leste." *Forest Ecology and Management*, **255** (3),1359-1366. Abstract. The impact of small-scale cutting of mangroves by family groups was examined in three high-salinity forests on the dry tropical, north coast of Timor Leste. Before logging, these forests were characterized by moderately dense stands (3633–9610 stems ha−1) of Ceriops tagal, Rhizophora apiculata, Bruguiera gymnorrhiza, and Avicennia marina, with average basal areas of 13–34 m2 ha−1, total above-ground biomass of 51–221.5 t ha−1, canopy cover of 61–73%, and leaf area index (LAI) of 4.9–5.4 m2 leaf area m−2 ground area. Approximately 1 year after the start of harvesting, these forests experienced a 30–50% decline in live stems and a 46–86% loss of above-ground biomass with more canopy gaps between less dense, smaller trees. There was some evidence of selectivity of trees 5–15 cm dbh in size, interpreted as a trade-off between cutting trees small enough for women and children to carry but large enough to warrant cost/benefit of selling for firewood. Concentrations of most particulate nutrients increased in surface soils in the harvested stands, reflecting bark, leaves, twigs, and small branches discarded on the forest floor. Interstitial concentrations of dissolved sulfide, metals, and ammonium also increased due to enhanced soil desiccation (evidenced by increased salinity) and decline in solute uptake and O2 translocation to live roots. Rates of anaerobic soil metabolism (sulfate reduction) declined after the onset of cutting, attributed to the decline in live roots and their metabolic activities. These cutting operations, although small-scale, are unsustainable as these forests are likely to be slow-growing in such highly saline soils. A community-based approach to conservation and sustainable management of the remaining mangrove forests of Timor Leste is recommended.***Cropwatch comments:*** Article mentions decline of sandalwood forests, once plentiful with white sandalwood up to 1915, through export of wood to China, Indonesia & Europe

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Zhang Q., Tang Y., Wang R., Wang S., Fang M., Zhang Y. & Zheng X. (2009) "[Effect of *Santalum album* on tissue distribution of danshensu in rabbits by HPLC]" *Zhongguo Zhong* Yao *Za Zhi 34*(15), 1968-70. Abstract. OBJECTIVE: To investigate the influence of Shi herb (*Santalum album*, SA) to the tissue distribution of danshensu (DSS) which is the main hydrosoluble component of Jun herb (*Salvia miltiorrhiza*, SM) in rabbits by HPLC. METHOD: Rabbits were oral administrated decoction of SM and SM-SA, respectively. Perchloric acid (10%) was used to precipitate the tissue samples of rabbits heart, brain, liver, kidney, acetic ether was used to extracte supernatant, and the internal standard was p-hydroxybenzoic acid. The content of DSS of SM in tissues was detected. RESULT: The content of DSS reached the highest point close to 50 min in the mentioned tissues. Before and after co-administration, the sequences of average concentration of DSS in tissues were C(kidney) > C(heart) > C(brain) > C(liver) and C(kidney) > C(liver) > C(brain) > C(heart) respectively. Compared with SM administrated singly, the content of DSS in every tissues of co-administration was higher. CONCLUSION: In Danshenyin Formulae, SA can increase concentration of DSS in target tissues significantly, and therefore therapeutic effect of SM for cardiovascular disease is raised.