



# Sandalwood

## A Case Study on Use of Synthetic Biology Replacements



**Farmers Affected:** Difficult to estimate because of illegal trade

**Market Value:** 15,000 tonnes of true sandalwood are produced annually<sup>1</sup> to meet market demand, commanding between \$1,100 to 2,800 US/kg. The world market is worth up to \$27 billion US

**Uses:** Perfume, cosmetics, religious uses and rituals

**Syn Bio Companies:** Evolva (Allylix), Isobionics, Firmenich

**Hotspots:** India, Indonesia, Australia

**Still collected in the wild in:** South Africa, Tanzania, Kenya, Pacific Islands

**Also grown in:** China, Sri Lanka, Thailand, Cambodia, Costa Rica are involved in the commercial cultivation and collection of East Indian sandalwood

**Cultural Importance:** Sandalwood use dates back four millennia. "Sandal" is derived from Chandana (Sanskrit) and was known as a wood and oil in Hindu, Buddhist, Muslim, Sufi and Zoroastrian religious traditions and medicines.

**Biodiversity Considerations:** Cultivation could help preserve wild sandalwood from extinction. This crop is well-suited for intercropping, as with grafted trees.<sup>2</sup>

**Patents:** WO 2010067309, WO 2014027118, WO 2010067309, WO 2015153501

**Products:** Santalol, Santalene

**Method:** Synthetically engineered yeast organisms

**Commercialization:** Isobionics's sandalwood is still under development.<sup>3</sup> Evolva's "santalol" fragrance is to be on the market in 2017. Firmenich launched its syn bio-derived Clearwood™ fragrance in 2014 which is primarily a patchouli replacement but imparts a "soft creaminess reminiscent of natural sandalwood."

**Feedstock:** Biomass

**Brands, Identifiers:** Clearwood™

### Overview

Sandalwood refers to a fragrant oil derived from the heartwood of sandal trees. This essential oil has been used primarily in the fragrance industry; it is also used in medicine and aromatherapy. The wood is used for carving, especially religious objects; sawdust is used in incense. Documented uses date back four millennia. Legal plantations of sandalwood do exist and are increasing. However, the illegal cutting, smuggling and exploitation of sandalwood trees from wild forests is still highly problematic.

**Status: Syn bio sandalwood is under development**



R&D

Scale Up

Commercialization

Besides the pricey *Santalum album* (East Indian Sandalwood) there are also a range of cheaper faux-sandalwoods such as Amyris (West Indian sandalwood), found in Haiti and Dominican Republic.

At least two companies are focusing R&D efforts on producing a sandalwood oil fragrance using synthetic biology: Netherlands-based Isobionics, which spun off from DSM in 2008, and Swiss-based Evolva.



For more info on Synthetic Biology please visit the ETC Group website: [www.etcgroup.org/synbio](http://www.etcgroup.org/synbio)

Additionally, flavor and fragrance giant Firmenich holds patents on sandalwood biosynthesis and already markets a syn bio derived fragrance, Clearwood™, that has sandalwood notes. Syn bio sandalwood developers claim that their product will be a solution to the environmentally destructive cutting and smuggling of the tree. However, it will impact the option to scale up nascent ecologically and socially improved approaches to sandalwood growing, and will also negatively affect the production of Amyris and other cheaper alternatives.

## What is Sandalwood?

Sandalwood refers to a fragrant oil derived from the heartwood of sandal trees. Produced via steam distillation, the oil has been used primarily in the fragrance industry; it is also used in medicine and aromatherapy. The *Santalum album* tree, commonly called East Indian sandalwood, produces the most prized sandalwood oil; the tree is native to parts of China, India, Indonesia and the Philippines and is semi-parasitic, meaning that it depends on the roots of other plants for nutrients.<sup>4</sup> Several other sandalwood species are found throughout the Pacific, including on Vanuatu (*Santalum austrocaledonicum*), Fiji (*Santalum yasi*) and Hawaii (*Santalum freycinetianum* and *Santalum paniculatum*).

The odor profile of oil derived from *Santalum album* is complex, described by olfactory scientists as “lactonic, floral-woody, milky-urinous, animalic, somewhat musky.”<sup>5</sup> An estimated 70 constituents contribute to the oil’s scent, though  $\beta$ -santalol, which accounts for about one quarter of the oil’s weight, is considered to be “the main sandalwood odor constituent;”<sup>6</sup> *a*-santalol is another major constituent, though its odor is weak. *a*-santalol and  $\beta$ -santalol are sesquiterpene alcohols.<sup>7</sup> So-called West Indian or “poor man’s” sandalwood, derived from the wood of *Amyris balsamifera*, is not botanically related to East Indian Sandalwood and does not contain santalols, but is used as a lower-cost substitute in cosmetics, fragrances and soaps.

## Sandalwood as a Natural Product

India used to be the largest producer of sandalwood oil, meeting over 80 percent of world demand. Over-exploitation and illegal traffic have caused production to decline drastically in recent years. It now attempts to grow more sandalwood both *in situ* and *ex-situ* by inter-plantation methods.<sup>8</sup>

The case of East Indian Sandalwood is particularly complex due to its vulnerability and history of exploitation. IUCN’s Red List categorized *Santalum album* as vulnerable in 1998, noting that its status needed updating.<sup>9</sup> In India, where the government is considered the owner of all standing sandal trees, forest supplies are virtually non-existent due to poaching, fire and spike disease.<sup>10</sup> With increasing frequency, therefore, poachers are going after trees growing in urban areas.<sup>11</sup> As recently as April 2015, smugglers were caught with 77 kg of sandalwood logs illegally cut from trees growing within the city limits of Coimbatore, Tamil Nadu.<sup>12</sup>

By 2009, when *Forbes India* reported on the country’s collapsing sandalwood oil trade, most of the family-owned distilleries in the oil-producing center of Kannauj (Uttar Pradesh) were already shuttered.<sup>13</sup> When Indonesia – formerly the world’s largest supplier of raw sandalwood – banned the export of its sandalwood in the late 1970s, the result was inflated prices on the world market; exporting India’s raw wood quickly became more lucrative than making oil, leading to the “widespread smuggling and mindless exploitation of sandalwood forests.”<sup>14</sup> Australia then took over as the world’s dominant sandalwood supplier – through its indigenous sandalwood species, *Santalum spicatum* – and began establishing its first plantations of *Santalum album*.

Now most of the world’s East Indian sandalwood comes from plantations in Australia’s tropical northwest region of the Ord River Valley.



Making sandalwood paste by hand  
Photo (cc) Harsha KR

Two companies control sandal tree plantations – a newly-formed private investment group called Santanol and Tropical Forestry Service (TFS).

Santanol's *Santalum album* plantations span 2,000 hectares; TFS has more than 9,000 hectares.<sup>15</sup> While profitable for the companies, the plantations have been declared a “disaster” for the region – sandal trees have supplanted food crops (melons, pumpkins, chick peas, bananas) and have taken land from indigenous communities.<sup>16</sup> In 2014, TFS completed its first commercial harvest of about 15,000 sandal trees<sup>17</sup> and almost the entire crop was purchased by Galderma, a Swiss pharmaceutical company wholly owned by Nestlé. They bought 470 kg of oil (worth \$2.1 million US)<sup>18</sup> for use in an over-the-counter acne treatment in the USA.<sup>19</sup>

Besides true sandalwood, there are also a number of faux sandalwood species that are used by perfumers and product manufacturers to impart a cheaper sandalwood scent. An example is Amyris or ‘West indian Sandalwood’ – traditionally sourced from Haiti and the Dominican Republic. See box overleaf. There are already more than a dozen commercial sandalwood fragrance substitutes produced via conventional chemical synthesis – Givaudan Corporation sells three: Sandalore®, Sandela® and Brahmanol®.

### Cultural and Biodiversity Considerations

Oil derived from *Santalum album* is problematic environmentally and socially. Cropwatch, a watchdog organization monitoring the natural aromatic products industry, notes that “the carbon footprint of sandalwood oil is particularly unacceptable with respect to climate change concerns, with excessive energy consumption occurring as a result of long distillation times.”<sup>20</sup>

Cropwatch further notes that buyers of sandalwood are “likely to be indirectly supporting gangland,” since most oil is “either smuggled with or without the help of corrupt officials or otherwise illegally produced.”<sup>21</sup>

The poaching of sandal trees standing in forests and cities is unacceptable, but plantations are not the solution if they take land, water and food away from local communities. Is there any other choice, then?

### Amyris - West Indian Sandalwood from Haiti and Dominican republic

Amyris (Botanical name: *Amyris balsamifera*) is a small tree native to the Caribbean and Gulf of Mexico. Its fragrance is similar to sandalwood but it does not belong to the genus *Santalum*. Indigenous peoples of Haiti traditionally called amyris wood “candlewood” because of a high essential-oil content that caused it to burn quickly. The essential oil of amyris wood has a characteristic woody, sweet, smoky character.

Production areas for this wood are very hard to reach. The gathering and cutting in Haiti is done by indigenous farmers and takes a great deal of physical effort. According to Bernard P. Champon Sr., owner of the Haiti Essential Oil Company, in 2001, “Only the wood from trees that have died naturally is used. Collection of wood is carried out by ‘speculators’, who transport the material to the distilleries for sale.”<sup>22</sup> Exports of Haitian amyris oil first began in 1943-44 according to an agricultural assessment of Haiti produced by USAID in 1987.<sup>23</sup> According to *Perfumer & Flavorist* magazine, throughout the first decade of the 21st century, Haiti’s annual production of amyris oil was 60 metric tonnes (Note: This estimate was published in 2009, one year before the earthquake<sup>24</sup>). Though Haiti may still be distilling some amyris oil, the supply of native amyris wood is often described as depleted. Current reports suggest that all the *Amyris balsamifera* distilled in Haiti is coming from the Dominican Republic and is smuggled across the border.<sup>25</sup> Gilbert Assad of Arome et Essence d’Haïti, reported to ETC Group in April 2015 that, currently, amyris production is virtually non-existent in Haiti, due to the depleted supply of native wood but is still collected and distilled in Dominican Republic.<sup>26</sup> The introduction of a syn bio substitute for East Indian Sandalwood may conceivably also hit the market for faux sandalwoods such as Amyris with implications for these struggling pickers and distillers.



*Red sandalwood seedpods Photo (cc) Gail Hampshire*

Do we have to choose between environmentally/socially destructive natural sandalwood oil, a chemical synthesis, and a syn bio oil produced by specially engineered microbes?

While the case of sandalwood oil dramatically illustrates the vulnerability and tragedy that can occur in natural product supply chains, it also illustrates the potential to support small producers as discussed in the case of Vanuatu, in *Implications and the Future*, ahead.

### Synthetic Biology Production

At least two companies are focusing R&D efforts on producing a sandalwood oil fragrance using synthetic biology: Netherlands-based Isobionics, which spun off from DSM in 2008, has a syn bio derived sandalwood under development.<sup>27</sup> Swiss-based Evolva inherited a commercial development programme for syn bio sandalwood oil when it acquired Allylix Inc. in 2014.

Evolva expects to put its santalol fragrance on the market in 2017.<sup>28</sup> Swiss perfumer Firmenich SA launched its syn bio-derived Clearwood™ fragrance in 2014. While Firmenich primarily describes the trademarked Clearwood™ as a “soft, clean version of patchouli,”<sup>29</sup> the company notes that when used as a fragrance building block, Clearwood™ imparts a “soft creaminess reminiscent of natural sandalwood.”<sup>30</sup> Several patents have been granted or applied for related to the production of  $\alpha$ -santalol and/or  $\beta$ -santalol via engineered microorganisms.

In a patent on a syn bio method to produce  $\beta$ -santalene as a precursor of  $\beta$ -santalol (the major contributor to sandalwood scent), Firmenich makes the case for the value of creating an alternative to botanically-derived sandalwood oil:

“Due to over-exploitation of the natural resources, difficulties of cultivation, slow growth of the *Santalum* plants, the availability of sandalwood raw material has dramatically decreased during the past decades. Therefore, it would be an advantage to provide a source of  $\beta$ -santalol, which is less subjected to fluctuations in availability and

quality. A chemical synthesis of the sandalwood sesquiterpene constituents is so far not available... the present invention has the objective to produce  $\beta$ -santalene while having little waste, a more energy and resource efficient process and while reducing dependency on fossil fuels.”

### Implications and the Future

Evolva and Firmenich are correct to argue that existing natural sandalwood oil production is problematic but that doesn't necessarily mean that synthetic biology should be the remedy. While the case of sandalwood oil dramatically illustrates the vulnerability and difficulties of always retaining natural products supply chains, it also illustrates the potential to support small producers: 2014 marked the first time that essential oil distilled from the heartwood of Vanuatu sandal trees was produced on Erromango in Republic of Vanuatu (formerly known as the New Hebrides in the South Pacific).<sup>31</sup>

Since the 19th century, Erromango's sandalwood had been bought, traded and stolen for processing in other countries. But in 2014, Pacific Provender Ltd, a family-owned business, established the first-ever sandalwood distillery on Erromango.<sup>32</sup> The “Erromangan Sandalwood and Essential Oil Association” represents 42 farmers; while the “Department of Forests of the Republic of Vanuatu” has trained and employed Ni-Vanatuans (indigenous) sandalwood growers to process the oil and produce value-added sandalwood products.<sup>33</sup>

Pacific Provender director Jeff Allen declared the project a success, reporting, “Everyone overseas who smelled our oil from Erromango loved it and wanted to buy more.”<sup>34</sup> Even though Vanuatu’s sandalwood oil is not from the traditionally most-prized species of sandal tree, that may be a price that has to be paid until (and if) India’s sandal trees can recover and are protected. While every “livelihood project” – including the one on Vanuatu – must be scrutinized to assess its environmental credibility and social worth, small producers acting as stewards of native sandal trees should be supported in their efforts.

## Endnotes

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- 3 <http://isobionics.com/index-Sandalwood%20Oil.html>
- 4 *The IUCN Red List of Threatened Species*, Version 2014.3; [www.iucnredlist.org](http://www.iucnredlist.org); downloaded on 23 April 2015.
- 5 Gutnther Ohloff, Wilhelm Pickenhagen, Philip Kraft, *Scent and Chemistry: The Molecular World of Odors*, Zutrich:Wiley-VCH, 2012, p. 302.
- 6 *Ibid.*
- 7 *Ibid.*, p. 301.
- 8 “In India, the National Medicinal Plant Board & National Horticultural Mission are assisting sandalwood cultivation and interplanting with other medicinal plants through their State Agencies. There has been a healthy response from the private land owners for commercial cultivation and the harvesting of commercially planted sandalwood in India is expected by the year 2015 onwards, particularly in arnataka. Furthermore, many farmers and entrepreneurs are setting up plantations of Indian Sandalwood in the states of Gujarat, A.P., M.P, Maharastra, Rajasthan & Assam on a large commercial scale of some 5000 hectares.” *Proceedings of the Art and Joy of Wood Conference*, 19-22 October 2011, Bangalore, India - available at [www.fao.org/3/aap001e/ap001e15.pdf](http://www.fao.org/3/aap001e/ap001e15.pdf)
- 9 *The IUCN Red List of Threatened Species*, Version 2014.3; [www.iucnredlist.org](http://www.iucnredlist.org); downloaded on 23 April 2015. The status of *Santalum Album* has not been updated since 1998.
- 10 Spike disease is caused by a microscopic pathogen (phytoplasma) that kills sandal trees within two years after visible symptoms: small leaves that turn pale-green or yellow and stand out stiffly. See abstract of J. A. Khan, P. Srivastava and S. K. Singh, “Identification of a ‘Candidatus Phytoplasma asteris’-related strain associated with spike disease of sandal (*Santalum album*) in India,” *Plant Pathology* (2006) 55, 572.
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- 28 Edison Investment Research Ltd., report on Evolva, 11 February 2015, p. 4. According to Edison, Evolva's sandalwood has a 60% "likelihood of success." Evolva commissioned the report from Edison.
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- 36 Australian Sandalwood (*Santalum spicatum*, syn. *Eucarya spicata*). (Also referred to as West Australian Sandalwood). Native to the desert-like areas of SW Australia, close to Perth. Substantial plantations have also now been established – around 15,000 ha with annual additions of 1-2,000 ha. A second sandalwood species, *Santalum lanceolatum*, is also found in Australia, principally in Queensland, NSW, and northwestern part of Western Australia, but is little used commercially. *Santalum paniculatum* is only found in Hawaii. Around 7000 ha is reported to be under sustainable management. Commercial oil is now coming onto the market. *Santalum yasi* is found in the Fiji, Samoa and Tonga. It is traditionally included in mixed cropping agroforestry cultivation systems. The species hybridizes readily with *S. album* resulting in variable quality of oil depending on the source trees. From: [www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Market\\_Data\\_and\\_Information/Market\\_information/Market\\_Insider/Essential\\_Oils/Sandalwood%20oils.pdf](http://www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Market_Data_and_Information/Market_information/Market_Insider/Essential_Oils/Sandalwood%20oils.pdf)