

Chapter 8

Morphology, traditional therapeutic, pharmacology, cultural and economic values of *Santalum album* L. (Santalaceae)

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Abstract: *Santalum album* L., commonly referred to as Indian sandalwood, is one of the most medicinally, economically, and culturally significant tree species, renowned for its fragrant heartwood and essential oil, the tree holds immense value in religious, medicinal, and industrial applications. This chapter provides a comprehensive review of its morphology, medicinal importance, and cultural and economic importance of sandalwood.

Keywords: Sandalwood, therapeutic practices, economic importance, cultural importance

Introduction

Santalum album L. is a small evergreen tree, belonging to the family Santalaceae, that has been a precious tree for traditional and commercial industries for centuries. Its heartwood and essential oil are particularly prized for their aromatic and therapeutic properties. The species is native to India but has been cultivated globally due to its high demand. It is commonly known as White sandalwood in English, Safed Chandan in Hindi, and Srigandha in Sanskrit (Kumar *et al.*, 2015). It is typically found in dry deciduous forests of India. It can grow up to 20 meters in height and attain a girth of 2.5 meters. This species thrives across a wide range of altitudes, from sea level to 5000 meters (Rao *et al.*, 2007). The species exhibits hemiparasitic behavior and can associate with more than 300 plant species (Sandeep and Manohara, 2019). The genus *Santalum*, distributed across South and Southeast Asia, Australia, and the Pacific, comprises 18 recognized species. Among these, *Santalum album* stands out for its widespread use and economic importance. The heartwood of *S. album* is highly valued for its aromatic oil, which is extensively used in perfumery, medicine, and incense. This oil, often referred to as the "Queen of essential oils," is a symbol of India's rich heritage and biodiversity (Fox, 2000; Sandeep and Manohara, 2019). Apart from its importance as a supremely satisfying source of fragrance, it finds use in medicine as an antiseptic, antipyretic, antiscabietic, diuretic, expectorant, stimulant, and for the treatment of bronchitis, dysuria, gonorrhea, and urinary infections (Goswami and Tah, 2018). Traditionally, sandalwood has been valued for its diverse medicinal properties. It is known to act as a diuretic, expectorant, stimulant, disinfectant, coolant, astringent, bronchial tract relaxant, and sedative. The plant has been employed in treating various ailments such as jaundice, dysentery, gastric irritability, and as a tonic for the liver and heart (Choudhary and Chaudhary, 2021). Additionally, it is used for

fever management, memory improvement, blood purification, and as an antidote to poisoning (Sandeep *et al.*, 2016; Choudhary and Chaudhary, 2021). In Ayurvedic medicine, sandalwood is used to address conditions such as bleeding piles, vomiting, poisoning, hiccoughs, diarrhoea with bleeding, intrinsic haemorrhage, urticaria, inflammation of the umbilicus, and eye infections (Goswami and Tah, 2018). The therapeutic and aromatic properties of sandalwood are attributed to its active constituents, primarily alpha- and beta-santalols (Subasinghe *et al.*, 2013; Kumar *et al.*, 2015). These compounds are responsible for its characteristic pleasant aroma and contribute significantly to its medicinal benefits. Despite its significance, the species faces challenges like habitat loss, overexploitation, and diseases, necessitating immediate conservation efforts.

Morphology

Indian sandalwood thrives in tropical and subtropical regions, preferring an annual rainfall of 500–1200 mm. It grows well in well-drained red loamy soils but can adapt to a variety of soil types. It is a small to medium-sized, evergreen, glabrous, and semi-parasitic tree. It typically reaches a height of 4 meters in Australia, while in India, it can grow up to 20 meters with a diameter of 2.4 meters (Purohit, 2018; Kardile *et al.*, 2022; Plate 1).

Bark: The bark of mature trees is hard, featuring large vertical fractures. Its color ranges from dark brown, reddish, or dark gray to almost black. Branches and Leaves: The tree has slender, drooping branchlets. The stalks are grooved and measure 5-15 cm. Leaves are thin, opposite, oblong or ovate- elliptic (3-8 x 3-5 cm), glabrous, and sparkling green above, with a glaucous and slightly paler underside.

Flower: The flowers are small (4-6 mm long), straw-colored, and purplish-brown, scarlet, green, or violet.

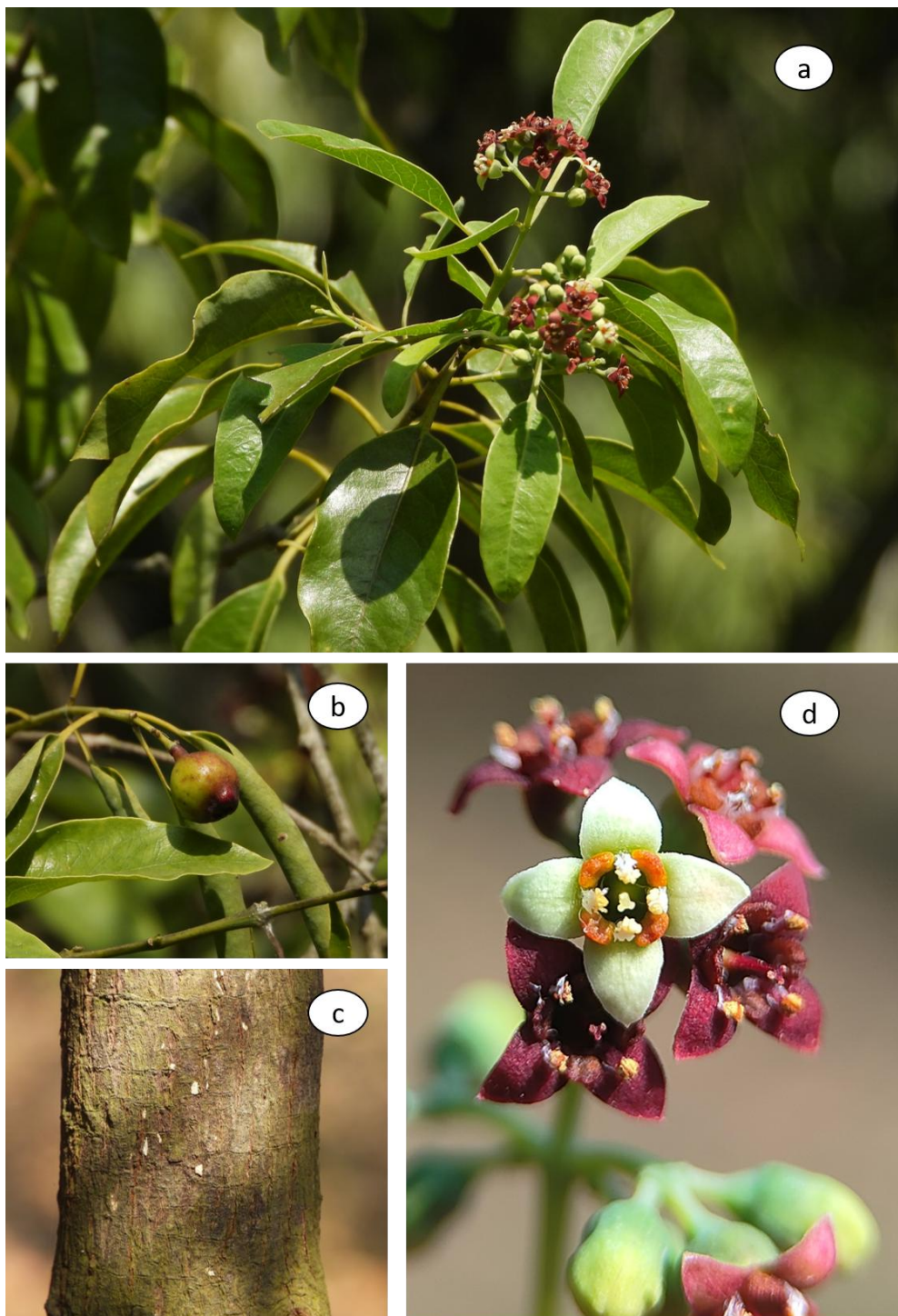


Plate 1: Vegetative parts of *S. album* a) leaves and flowers, b) fruits, c) bark, d) flowers

They are odourless and grow in terminal or axillary panicle cymes, appearing in small clusters of up to six flowers.

Heartwood: Yellowish-brown, aromatic, and dense, forming after 10-15 years of growth. Highly valued for its aromatic oil.

Fruit: The fruits are small, globose berries.

The tree begins to bloom at a young age of 2-3 years. It flowers twice a year, typically during March-May and September-December. The inflorescence is axillary or terminal, trichotomous, and panicle cymose.

Traditional medicinal uses

The medicinal use of sandalwood dates back over 3000 years, as recorded in ancient Ayurvedic texts like Sushruta and Charaka Samhita. Ayurveda is based on the theory of Tridosha- the three biological forces (Vata, Pitta, and Kapha).

- a) **Cardiovascular Health:** It acts as a blood purifier and heart tonic. Calms anxiety, reduces nervous tension, and enhances memory (Goswami and Tah, 2018).
- b) **Digestive Support:** It helps to treat gastric irritability, jaundice, diarrhoea, vomiting, and bleeding piles. Promotes liver health and supports digestion, often used with herbs like Triphala (Sindhu *et al.*, 2010).
- c) **Respiratory and Genitourinary Disorders:** It eases chronic bronchitis, mucous inflammation, and bladder infections. Works as a diuretic and expectorant (Goswami and Tah, 2018).
- d) **Skin and Wound Care:** It is applied as a paste to treat wounds, acne, sunburn, itching, and inflammation. Its cooling properties soothe irritated skin and assist in fever management (Moy and Levenson, 2017).

- e) **Nervous System:** It reduces depression, anxiety, and confusion, acting as a sedative (Choudhary and Chaudhary, 2021).
- f) **Immunity Boost:** It plays a significant role in Ayurvedic purification rituals and seasonal immunity-boosting practices.
- g) **Joint Health:** It helps to treat joint pain and arthritis through topical applications of sandalwood paste combined with yoga and exercise (Goswami and Tah, 2018).
- h) **Kidney health:** The wood, root, bark, and leaves of the plant are utilized for the treatment of liver infections like jaundice (Aftab *et al.*, 2023).
- i) **Hair health:** Sandalwood oil is highly effective in addressing hair issues like dandruff, reducing hair fall, and controlling excess sebum on the scalp due to its astringent properties. It treats split ends, enhances hair shine, and promotes growth. A blend of sandalwood oil with lavender or sesame oils, when massaged into the scalp, further eliminates dandruff and nourishes hair (Aftab *et al.*, 2023).

The aroma of sandalwood helps in reducing anxiety, depression, and nervous tension. It balances Vyanavayu (circulatory system) and calms Sadhkapitta (caretaker of the heart) (Choudhary and Chaudhary, 2021). Sandalwood oil, extracted from the heartwood, is widely used in perfumery, aromatherapy, and cosmetics.

It is a pale yellow, viscous liquid with a sweet, woody aroma. It acts as a base in Indian attars and enhances the stability of delicate scents. Sandalwood is recognized for its role in treating genitourinary and bronchial infections, gastric disorders, chronic bronchitis, and mucous inflammation, liver diseases like jaundice, anxiety, confusion, and memory loss etc (Goswami and Tah, 2018).

Pharmacological potential

Many researchers have documented the pharmacological properties of this plant parts. The followings properties are discussed below.

Hepatoprotective activity: Sandalwood leaves' hydro-alcoholic extract demonstrates hepatoprotective effects by reducing liver damage markers and increasing antioxidant enzyme levels, protecting against CCl₄ and paracetamol-induced toxicity (Kumar *et al.*, 2015).

CNS effects: Sandalwood oil and its active component, α -santalol, show memory enhancement, sedative, and neuroprotective effects. These properties include dopamine receptor modulation and applications in treating sleep disorders and psychosis (Rani *et al.*, 2024).

Anti-ulcer activity: Hydroalcoholic extracts from sandalwood stem effectively inhibit stress- and chemically-induced gastric ulcers (Ahmed *et al.*, 2013).

Antibacterial and antiviral activity: Sandalwood oil exhibits strong antibacterial activity against resistant strains such as MRSA, *Candida* species, and *Helicobacter pylori*. Its antiviral properties include effectiveness against HSV-1, HSV-2, influenza, HPV, and skin viruses (Rani *et al.*, 2024).

Antifungal activity: Effective against fungal strains like *Microsporum canis*, *Trichophyton mentagrophytes*, and *T. rubrum*, sandalwood oil is valuable in treating dermatophytic infections (Kumar *et al.*, 2015).

Antioxidant efficacy: Sandalwood demonstrates robust antioxidant activity by scavenging free radicals, reducing lipid peroxidation, and protecting cardiac tissue from oxidative stress. α -Santalol enhances glutathione levels, indicating chemopreventive potential (Jagetia and Baliga, 2004).

Diabetes and anti-hyperglycemic effects: In diabetic mice models, sandalwood oil and α -santalol reduce oxidative stress and blood glucose levels, showing potential for managing diabetes (Kulkarni *et al.*, 2012).

Hemolytic activity: The hemolytic activity of sandalwood leaf extract indicates its cytotoxicity to healthy cells, with studies showing red blood cell lysis due to the presence of saponins. This effect is observed only with parenteral administration (Gorde, 2024).

Nutritional and phytosynthetic benefits: Sandalwood berries are rich in vitamins (C, E, and niacin) and bioactive compounds, contributing to their antioxidant and nutraceutical properties. Leaves are also used in environmentally friendly nanoparticle synthesis with antibacterial applications (Kumar *et al.*, 2015).

Dermatological applications: Sandalwood oil is used for treating skin ailments like acne, rashes, and psoriasis due to its antimicrobial and anti-inflammatory properties (Solanki *et al.*, 2014).

Anticancer activity: Sandalwood oil, particularly its active component α -santalol, has demonstrated chemopreventive properties against various cancers. Studies report its efficacy in delaying chemically induced skin cancer in CD-1 and SENCAR mice, as well as UVB-induced skin carcinogenesis in SKH-1 mice. Additionally, it shows activity against melanoma, non-melanoma, and breast cancers by inducing cell cycle arrest and apoptosis. α -Santalol triggers apoptotic cell death in human epidermal carcinoma A431 cells through caspase activation, mitochondrial depolarization, and cytochrome release. In SKH-1 mice, topical application of α -santalol reduced ornithine decarboxylase levels, supporting its chemopreventive potential (Gorde, 2024).



Figure 1: Significance of *S. album*

Bioactive compounds

The heartwood of mature *Santalum album* trees is the primary source of its expensive oil. Oil yield varies with tree age, heartwood location, and growth environment. Mature heartwood contains more essential oil than sapwood. The bark of *S. album* contains tannins (~14%), fatty acids, and betulinic acid (0.05%), along with flavonoids like vitexin and isovitexin. Betasitosterol and urs-12-en-3-beta-yl-palmitate contribute to its chemosterilant and insect growth-inhibitory activities (Sharifi-Rad *et al.*, 2022). Sandalwood seeds are rich in polyunsaturated fatty acids, particularly ximenynic acid (79–82%), which is characteristic of the Santalaceae family (Bisht and Kumar, 2021). Other constituents include oleic acid (12.3–18.0%) and palmitic acid (~0.8%). The pericarps yield ~5% oil, comprising fatty acids (79.5%), primarily palmitic acid (~38.8%) and oleic acid (~40.3%). Other notable constituents include esters (5.0%), aldehydes (1.2%), squalene (1.7%), and vitamin E

(2.5%). Minor components like phytosterols, sesquiterpenoids, and fragrant aldehydes contribute to the oil's properties. Deoiled seed meal is rich in protein (52.5%), minerals (e.g., potassium, zinc, calcium), and amino acids such as phenylalanine, leucine, glycine, and glutamic acid (Shivatara and Dheeraj, 2018; Bisht and Kumar, 2021). The leaves contain various flavonoids, including vitexin, orientin, and isorhamnetin. These contribute to their pharmacological activities, such as antioxidant and antimicrobial properties.

Cultural and economic importance

Sandalwood has occupied an important place in Hindu religious ceremonies, traditional medicine, and cultural practices, solidifying its status as a tree of immense historical and cultural importance (Figure 1). It has a history spanning thousands of years, valued for its fragrance, medicinal, cultural, and economic importance (Sandeep and Manohara, 2019). This exploration combines insights from ancient texts, historical accounts, and contemporary literature. *S. album* is first recorded in ancient Indian texts like the Vedas and Ayurvedic teachings. The Atharva Veda mentions sandalwood paste in ceremonies and medicinal applications. Religiously, Sandalwood is integral to Hindu rituals, offered to deities, and used in idol dedication (Sandeep and Manohara, 2019; Khan *et al.*, 2021). Buddhism and Jainism also document the use of sandalwood for incense and religious artifacts. Historically, sandalwood was a prized item in prehistoric trading networks. It was traded along the Silk Road, reaching China, the Middle East, and Europe, establishing its economic importance (Choudhary and Choudhary, 2021). The fragrant heartwood found in the stem and root is the most economically important part of the tree. It is converted into chips and steam-distilled to produce sandalwood oil, which is highly valued in industries like perfumery, cosmetics, and pharmaceuticals (Khan *et al.*, 2021). The fragrance of sandalwood is attributed to Santanol,

polyphenol. The sapwood, also known as "white wood," is used for producing incense sticks ("agarbattis"). Sandalwood has significant export value for countries like India, Australia, and Indonesia, contributing greatly to their economies (Purohit, 2018; Kumar *et al.*, 2019). The wood is used in Hindu religious rituals and for making items such as idols, rosaries, and ceremonial paste. Parsis use sandalwood for temple fire rituals. Pieces of sandalwood are also placed in funeral pyres by Hindus. Sandalwood is used for crafting cabinets, jewel boxes, caskets, and deed cases. It is popular for making carvings of deities. Darker shaded wood, being more fragrant, is used for aromatic products, while lighter honey-coloured wood is preferred for ornamental works. The wood is resistant to white ants, enhancing its durability. The leaves also yield pale yellow wax, which has economic value (Purohit, 2018).

Conclusion

Santalum album stands as a significant plant to the harmonious relationship between nature and human utility. Balancing its medicinal and economic exploitation with conservation is essential to preserving this valuable species for future generations. With advancements in science and technology, sustainable practices can secure their place in both natural ecosystems.

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