Commercial, Cosmetic, and Medicinal Importance of Sandal (*Santalum album*): A Valuable Forest Resource

Salman Khan, Mohsin Ikram, and Mohammad Faisal

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1 Introduction

Sandal/sandalwood (*Santalum album* Linn.) is a species belonging to the family Santalaceae from the Indian subcontinent and is considered a prominent and expensive tree that has enormous uses from perfumes to cosmetics and medicinal industries worldwide (Azad et al. 2016). Indian sandalwood is also known as "Chandan" in Hindi. It is an evergreen hemi-root parasitic tree that has larger geographical distribution ranging from 0 to 700 m (altitude variation); 0 to 38°C (varied temperature area); and 500–3000 mm (annual rainfall areas). Sandalwood normally prefers stony red soil but shows germination potential in other soil types too (Azad et al. 2016). Sandalwood can tolerate a pH up to 9.0 but unable to tolerate waterlogged conditions (Luna 1996; Rangaswamy et al. 1986; Radomijac 1998). The oil derived from sandalwood is extensively used as the medicine for the treatment of weakness, aromatherapy, skin infections, urinary infection, inflammation, etc. (Misra and Dey 2013a). It is also used in the manufacturing of

S. Khan
Forest Survey of India, Central Zone, Nagpur, Maharashtra, India

M. Ikram
School of Agriculture, Uttaranchal University, Dehradun, Uttarakhand, India

M. Faisal (✉)
Department of Agriculture, Forestry & Fisheries, Himgiri Zee University, Dehradun, Uttarakhand, India

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incense sticks (Agarbatti) (Srinivasan et al. 1992). Researchers have described sandalwood oil has anti-oxidant, antiviral, anti-bacterial, and many more properties (Benencia and Courreges 1999; Ochi et al. 2005; Misra and Dey 2012, 2013b).

Despite the large geographical distribution of sandalwood, the germination is not so high. It may be due to various factors such as seed quality, heterozygous seedlings, light intensity, unsuitable temperature and weather, insect pest, and disease-causing micro-organisms (Uniyal et al. 1985; Srimathi and Nagaveni 1995). Seeds should be from mother plant of at least 20-year-old, but due to the excessive pressure on sandalwood tree for its hardwood, they are being harvested before its silvicultural rotation age. enormous uses and religious significance have been described due to high Santalol oil content in the heartwood. The oil derived from the *S. album* contains approximately 90% a&b Santalol. Indian sandalwood (*Santalum album*) is qualitatively and economically important when compared to the other species of genus *Santalum* (Radomijac 1998). The heartwood of *S. album* is being used for many centuries in rituals and ceremonies, as a product for skincare, beauty aid, for carvings, prayer poles, valuable handicrafts, fuel for funeral pyres, coffins, and joss sticks (Jayappa et al. 1981; Rai 1990; Radomijac 1998). Sandalwood oil is largely used in perfumer and cosmetic industries and also as a coolant astringent, antipyretic, antiseptic, antiscabietic, diuretic, and aphrodisiac (Goswami and Tah 2018). Sandalwood oil has been used as a medicine since ancient times as per the Indian traditional system of medicine, Ayurveda. The oil provides relief from migraines and Herpes (Soundararajan et al. 2015). Sandalwood oil is obtained from the heartwood of stem by steam distillation process with an average yield of 4–6%; however, for an individual tree, the estimate ranges between 0.2 and 7.25% depending on the tree age, site, and position of heartwood within the tree (Rai 1990; Haffner 1993). The heartwood is close-grained, very fine, even-textured, hard (specific gravity: 0.92 and weight: 897–137 kg/m^3), durable, and renowned as a carving material (Luna 1996). The sandalwood heartwood and oil were selling at the rate of 12 Lakhs INR/tonne and 22,000 INR/kg, respectively (Jain et al. 2003). The prices of heartwood and essential oil are dependent on the quality of wood. The bark of sandalwood contains 12–14% tannin and is used as a substitute for betel nuts in few villages (Radomijac 1998). The sandalwood trees growing in dry/harsh conditions has lesser height, canopy, and diameter, but the oil content is similar to individual trees growing in fertile tracts (Kumar et al. 2011). Considering the religious and cultural importance, and uncontrolled harvesting of sandalwood, planned scientific efforts should be made to conserve it (Sandeep and Manohara 2019).

There is a dispute about the origin of *S. album* from India or other areas. Brand (1994) suggested that sandalwood is introduced to India from Indonesia, whereas Srinivasan et al. (1992) mentioned the use of Chandan in India from natural stands traced to 2300 years ago. Rai (1990) described that sandalwood is mentioned in the ancient epic Ramayana around 2000 B.C. Genus *Santalum* comprises 16 known species worldwide. Subasinghe (2013) mentioned *S. album* ranked one among major oil-yielding species of sandalwood followed by *S. yasi, S. asutrocaledonicum,*

S. macgregorii, S. spicatum, and *S. lanceolatum*. As of other species in genus *Santalum*, *S. album* is a xylem-tapping, obligate root hemi-parasite (Srinivasan et al. 1992) which means it has the potential to meet a considerable proportion of its net requirements for carbon through its photosynthesis (Cechin and Press 1993). Initially, sandalwood requires a primary host in the early seedling stage and a secondary host at a later stage in the field (Annapurna et al. 2006).

Naturally, sandalwood is distributed majorly in Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh, Orissa, Tamil Nadu, and other states (Arunkumar et al. 2016). Besides India, *S. album* is available from Australia, Indonesia, Malaysia, Philippines, and Sri Lanka, and, also, successfully introduced in few countries like Bali, China, Java, Kenya, Nepal, Nigeria, Papua New Guinea, Tanzania Uganda, and Zimbabwe (Li and Yu 1984). The flowering and fruiting seasons in *S. album* depend upon the locality and climate. Most of the individuals of *S. album* show flowering and fruiting twice a year (Radomijac, 1998). In India, the first flowering and fruit maturity begin in May and September, respectively (Srimathi and Nagaveni 1995). The second flowering and fruit maturation commence in November and February, respectively (Radomijac 1998). An individual tree may have flowers, mature fruits, and buds all together at a given time (Barrett 1988).

Natural regeneration is through the root suckers and seed dispersal by birds (Radomijac 1998). Natural regeneration can be profuse by using both seed germination and root-sucker techniques, provided there are suitable host plants available, low incidence of weed species, lateral shading from hosts, and protection from fire and grazing (Luna 1996; Radomijac 1998). Rai (1990) reported that under normal environmental conditions, *S. album* prefer to parasitize leguminous species. Under adequate vegetative cover and well-drained soils, seed germination is abundant. Under the optimum conditions, growth is fast with up to 30 cm height by the end of the first wet season (Luna 1996). Sandalwood requires a host which is neither too vigorous that outcompetes the tree nor too frail that the host is exhausted (Havel and McKinnell 1993). In practice, three or more types of hosts are required when establishing a seedling plantation: a short-term host (post host) in the nursery stage and two or more intermediate and long-term hosts (Radomijac 1998). The seed dormancy in *S. album* can break by nicking the testa or soaking in the Gibberellic acid (Nagaveni and Srimathi 1981; Ananthapadmanabha et al. 1988; Jayawardena et al. 2015). In India, direct sowing of seeds under potential host plants is commonly practiced, although success was also observed using seedling plantation at some places (Rai 1990; Srinivasan et al. 1992). Due to the declining status, *S. album* has been assigned with the vulnerable status by the IUCN Red list in 1998 (Awasthi 2007; Sandeep and Manohara 2019) and still assessed as vulnerable in the year 2018. Arunkumar et al. (2019) mentioned that over the last three generations due to overharvesting and illegal global trade, the population of sandalwood declined by 30% and is decreasing continuously.

2 Commercial Importance

Sandalwood is a tree species of high commercial importance due to its heartwood and essential oil. Sandalwood oil is used as fixture and base for splendor perfume manufacturing, beauty soap industries, cosmetic and pharmaceutical industries, and mostly in aromatherapy (Clarke 2006). Sandalwood oil is being used mostly in religious ceremonies, functions, and other rituals of Muslims, Hindus, Parsis, Buddhists, and others. Luxury perfume manufacturing companies, including Calvin Klein, Chanel, Yves St Laurent, and Christian Diaor, utilize sandalwood oil for their perfume-based products. Market Research Future (2020) mentioned the key players in the global sandalwood oil market as Albert Vieille SAS (France), Doterra International LLC (Utah), Eden botanicals (US), Santanol Group (Australia), Plant Therapy Essential Oils (US), Aditi Essentials (India), Haldin International (Indonesia), Jiangyin Healthway (Japan), Kanta Enterprises (India), PerfumersWorld Ltd. (Thailand), Ancient Healer (US), Khadi Natural (India), Vedic Vaani (India), Cliara Essential Oils (Sri Lanka), and Sallamander Concepts Pty Ltd (South Africa).

The commercial use of Sandalwood oil is enormous. Oil is extracted by the process of steam distillation of sandal heartwood. Sandalwood oil is being used for external application as well as for consumption. It acts as an antiseptic agent and helps in fighting against ulcers, infections, and healing wounds. Studies also suggested that sandalwood oil has anticancer effects (Santha and Dwivedi 2015). Sandalwood oil can prevent skin cancer if applied on skin regularly which helps in getting the surge in commercial value of sandalwood oil. Sandalwood oil has moisturizing properties (Kapoor and Saraf 2010) and can help to nourish the skin, which can increase the demand for sandalwood oil in the global market. Moreover, sandalwood oil has a very exotic woody fragrance, so being used in aromatherapy; these factors are driving the growth of global sandalwood oil market. India accounts for approximately 90% of the world's total sandalwood production. Majority of the sandalwood production in India is by the states of Tamilnadu, Karnataka, and Kerala. Previously, sandalwood trees having a diameter less than 100 cm and below 60 years of age were not considered for harvesting but treated as a young tree due to substandard features of heartwood volume, essential oil (%), and its chemical content (Clarke 2006). According to Baldovini et al. (2011), a tree receives the utmost quality and quantity of oil once it attains the age of 60–80 years. Also, the fragrance would be of superior quality. They reported the average production of sandalwood oil lies approximately between 4.5% and 6.25%, and a larger portion of oil is recovered from its root portion (10 percent of weight) (Santha and Dwivedi 2015). Misra and Dey (2012) have mentioned that 230 different chemical compounds are present in the heartwood of *Santalum album*s, of which most are terpenoids (Baldovini et al. 2011). Phytochemical studies of sandalwood extracts show high content of saponin, tannins, and phenolics besides terpenoids (Misra and Dey 2012).

Sandalwood oil is known commercially because of its chemical constituent's α-santalol and β-santalol together known as santalol (Fig. 1). They are responsible for the high-quality fragrance emerging from sandalwood oil (Misra and Dey 2012).

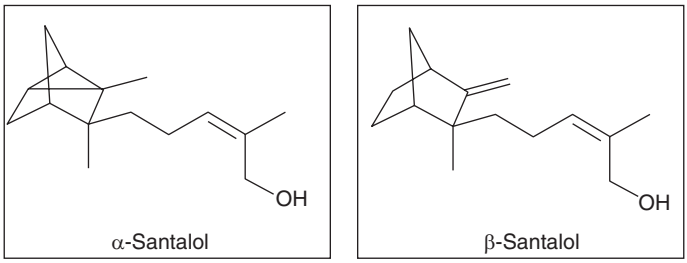

Fig. 1 Structure of α-santalol and β-santalol

Besides these, other chemical constituents of sandalwood include α-santalal, β-santalal, α-santalene, α-bergamotol, spirosantalol, and epi-β-santalal (Skaria et al. 2007) (Table 1). The chemical formula of santalol is $C_{15}H_{24}O$. Both α- and β-santalol are isomers that are used in various industries and exhibit high commercial importance. α-Santalol is mainly known for its anticancer properties (Santha and Dwivedi 2015). Sandalwood can be grown by any farmers, but they have to take prior permission from the forest department for harvesting. It is not illegal to grow sandalwood trees in India. In fact, the forest department distributes the sandalwood saplings as part of the social forestry program. In Tamilnadu, the selling of sandalwood is being regulated by the officers of the forest department. The capacity for the sale of sandalwood to individuals and temples is fixed for any officer depending upon their hierarchy. The selling price of sandalwood is being fixed and revised every year by the forest department.

States like Karnataka have legalized the commercial plantation of sandalwood. In other States, it is not illegal to grow the tree in private property, but once planted the tree shall be government property, and a pass is required to be obtained from the local forest department to harvest it. Sandalwood cultivation provides good economic return to the cultivator around the globe. The excellent quality and quantity of santalol in sandalwood oil make the Indian and Australian varieties superior to sandalwood from other countries. This is due to the high chemical content and excellent heartwood in the native species. Arunkumar et al. (2019) reported that the statue of gods and mythological figures carved from the wood has a huge demand in the Indian market and other carved objects have great cultural values throughout the world (Baldovini et al. 2011).

Brokers procure the heartwood through government auctions and reach to the producer for selling them in the powdered form. Further, through the process of distillation, the sandalwood oil is extracted from the heartwood. Eventually, oil is exported to different countries in solution form after packing in an aluminum flask. Kumar et al. (2019) reported that sandalwood seed oil in reaction with ZnCl could be used to prepare a suitable base for manufacturing insulation tapes. Also, vulcanizable oil could be obtained after reaction of sandalwood seed oil with sulfur at 220 °C. The product obtained after dissolving rosin in oil can be utilized for the manufacturing of colored enamel. Various products can be obtained after reacting

Table 1 Medicinal uses of important constituents of sandalwood

Medicinal properties	Sandalwood constituents	Biological activities	References
Antiviral	α-Santalol and β-santalol	Against HIV and RNA viruses; human papillomavirus (HPV), DNA pox virus	Benencia and Courreges (1999), Chattopadhyay et al. (2009)
Skin care	α-Santalol and β-santalol	Allergy, acne, lesions, staphylococcal/streptococcal acne; psoriasis, eczema, warts, dermatitis	
Anticancer	α-Santalol	Anticancer against skin carcinogenesis, CD-1 and SENCAR mice, breast and prostate cancer (in vitro model)	Dwivedi et al. (2006), Misra (2010)
Antigastric	Sesquiterpenoids	Against *Helicobacter pylori*: Anti-ulceration	Takaishi et al. (2005)
Insecticidal	Sandalwood oil	Mosquito repellant (*Culex*, *Anopheles*), against termites; acaricide (honeybee)	Zhu et al. (2008)
Cancer chemopreventive	α-Santalol	Against UV-B radiation-induced skin tumorigenesis, in SKH-1 hairless mice	Dwivedi et al. (2006)
Antimicrobial	α-Santalol and β-santalol	Antimicrobial activity; axillary bacteria, *Salmonella typhimurium, Staphylococcus aureus, Bacillus mycoides, Candida albicans*	Jirovetz et al. (2006)
Antitumor	Sesquiterpenoids	Antitumor promoting activity; for in vitro Epstein- Barr virus early antigen (EBV-EA) stimulation and in vivo carcinogenesis assay	Kim et al. (2006)
Antiviral	Sandalwood oil	Herpes simplex viruses (HSV) 1&2, inhibition of replication; in RC-37 cells	Misra and Dey (2013a)
Proapototic	α-Santalol	Proapototic and caspase activation, tumor suppression in human epidermal carcinoma A431 cells	Arasada et al. (2008), Bommareddy et al. (2012)
Diet	Sandalwood oil	Dietary factors/supplements, PUFA content increased	Burdock and Carabin (2008)
Nervous system stimulants	Santalols	Aphrodisiac, insomnia, alertness, olfactory stimulants of central nervous system; sedative, stimulation through calcium refluxes	Bieri et al. (2004), Ohmori et al. (2007)
Metabolism and physiology	Sandalwood oil	Attentiveness; alertness, calmness, mood relaxation, vigor, sound hearing, sedation	Kovatcheva et al. (2003), Heuberger et al. (2006)

sandalwood seed oil and with other chemical substances. Antimicrobial plasticizer, lather promoter, and solidifying and moistening substance could be formed using the sandalwood-based oil. The sapwood of sandal tree also has a variety of uses. It is mostly used in agarbatti industries and in making decorative statues/models, platforms, tables, chairs, and others. In Asia, sandalwood is consumed as a custom and culture (Clarke 2006). The powder of oil-devoid heartwood is prepared into incense sticks by the gluing process. Due to extensive use, sandalwood is in high demand in the United States and Asian countries. But there is a huge gap between demand and supply of sandalwood, and thus it leads to a sharp surge in price. Only 25% of overall trade demand is being fulfilled due to lesser production. The Asia Pacific dominates the global sandalwood oil market (Market Research Future). The consumption of sandalwood is highest in India. Tamilnadu is the largest supplier of legal sandalwood. In India, northern Tamil Nadu and southern Karnataka are considered naturally distributed areas of sandalwood. These two states together account for more than 90% of the natural population of *S. album* in India (Dhanya et al. 2010). Arunkumar et al. (2016) suggested cultivating sandalwood in places other than forest land to minimize the gap between demand and supply. Pallavi (2018) reported that Karnataka has initiated programs for sandalwood farming and inspiring the growers. During 2009, Karnataka amended its law to enable the grower to sell the sandalwood produce straight to quasi-governmental corporation/organization, for example, Karnataka Soaps and Detergents Limited (KSDL) and other, rather than selling only to the forest department. While in Kerala and Tamilnadu, the selling is being regulated by the state forest department only (Dhanya et al. 2010).

The production of sandalwood throughout the world is largely affected by unscientific harvesting and insect pest attacks. Sandalwood Spike Disease (SSD) is a major threat to the plantation and affects the production (Mondal et al. 2020). In North India, no such disease with this extent has been reported till date, but the disease is prevalent in South India. Thus, agrarian of Himachal Pradesh, Punjab, Uttarkhand, and Uttar Pradesh may have a worthy opportunity by which they can earn good money from sandalwood farming.

Pallavi (2018) reported the declining production of sandalwood in India. It was mentioned earlier that 80% of the global sandalwood requirement was fulfilled by India, but now the production has fallen to 400 tonnes/year. A similar condition was also reported in Australian sandalwood production, although, during 2018, the overall sandalwood demand was largely supplied by Australia only. The commercial significance of a sandalwood tree solely depends on the following factors: quality and quantity of essential oil distilled out from heartwood and quantity of heartwood. The price of sandalwood in India is increasing continuously. Despite the availability of sandalwood from various countries, the Indian variety is considered as best over others due to its superior class heartwood (Soundararajan et al. 2015). Soundararajan et al. (2015) mentioned that India utilizes most of its sandalwood production and small pieces in the form of statues/idols/handcrafts (maximum fifty grams) can only be exported. In the year 1984, Food and Agriculture Organization, United States, stated the importance of sandalwood and categorized it as a significant tree for the

conservation effort. After this, the demand for sandalwood essential oil and handicraft increased. There is global sandalwood demand of at least 10,000 metric tonne/year mostly by the United States and Western Europe.

India produced around 4000 tons of heartwood annually during the 1930s–1950s, but now declined to 500 tons annually. Meanwhile, the cost was 20,000 INR/Ton in the year 1980 which goes to 2,00,000 INR/Ton in the year 1990, and 40,00,000 INR/Ton during the year 2004 which rose to 75,00,000 INR/Ton in 2014 (Sadhu 2017). Soundararajan et al. (2015) reported that sandalwood oil import was about 61 ton during 2008–2009. Sandalwood is a potential species showing a business of one billion dollars worldwide. The global sandalwood oil market is anticipated to reach a compound annual growth rate (CAGR) of 6.99% from 2019 to 2024 and reach USD 156 million by the end of 2024 (Market Research Future 2020).

3 Cosmetic Importance

Most of the fatty acids obtained through the process of hydrolysis are being utilized in the preparation of beautification products (Kumar et al. 2019). The seed oil of sandalwood exhibits exceptional stability and enormous pharmaceutical importance (Li et al. 2013). Oil derived from the sandalwood seeds may be useful in the cure of dermatological problems and has cosmetic effects (Kumar et al. 2019). The oil contains Santalbic (Ximenynic) acid, which helps to keep the skin naturally glowing and young due to its antiaging characteristics (Kumar et al. 2019). Seed oil has diuretic, antiviral properties, and is being used in the treatment of atopic dermatitis, rashes, chronic psoriasis, etc. Ravikumar et al. (2018) reported through an experiment on rodents that consumption of sandal seed oil may keep fit and healthy from unnecessary fat. Also, cutaneous circulation systems can be maintained and regulated by using sandalwood seed oil (Kumar et al. 2019).

Sandalwood oil is a major ingredient of face cleanser, facials, skin toner, beauty enhancer, etc. Powder products of *S. album* are being sold in the market under various brand names that can be used with a suitable mixture such as clay (Multani Mitti) for an easy face pack. The concentrated form of sandal oil should not be used directly on the skin as it may cause harm (Nautiyal 2019). Sandalwood oil is being used as a homemade therapy for skin problems due to ultraviolet sun rays (Fig. 2). It is mostly used to cure sunburn, skin irritation, and itching. Sandalwood essential oil is used against skin injuries and helps to heal them fast. Agglomeration of collagen, skin rupture, scratches, and sensitivities can be prevented and treated by applying sandalwood-based products (Karuppusamy and Pullaiah 2016). Sandalwood oil has antiseptic properties that prevent the development of microbes on the skin including bacteria that causes inflammation/acne and other dermatological problems. It was advised to use sandalwood paste (sandal talc+milk) over the infected area (Jirovetz et al. 2006; Nautiyal 2019). Big brands manufacture facewash and skin creams that provide comfort from tiredness and purify the skin from dirt (Singh et al. 2013). Sandal oil is also used to provide relief to the protein which

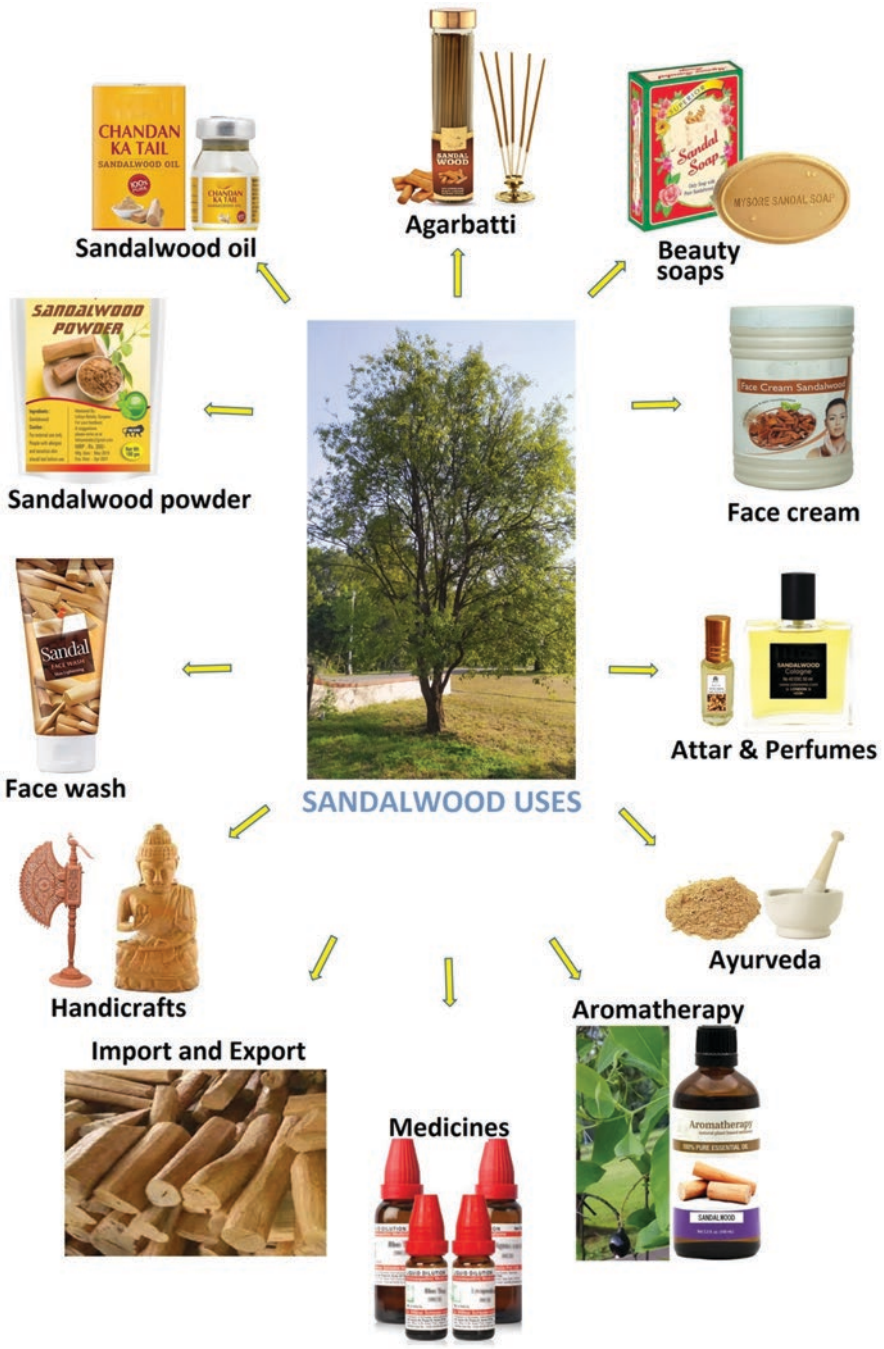

Fig. 2 Uses of sandalwood in commercial, cosmetic, and medicinal industries

helps in signaling without any side effect. Sandalwood oil possesses antioxidant property, which comforts the skin from the effect free radicals (Scartezzini and Speroni 2000).

Sandalwood oil is being used in hair care as one of the essential ingredient in shampoos and conditioners (Fig. 2). Also, sandalwood oil has antifungal properties against zoophilic dermatophyte fungus (Chaumont and Bardey 1989). Santalbic acid present in seed oil can be beneficial in problems such as erysipelas, varicosities, cellulitis, and alopecia (Hettiarachchi et al. 2013). It also helps in removing harmful toxic substances from the skin, prevents the oxidation process, enhances skin robustness, and prevents elastosis (Ravikumar et al. 2018). Deepak et al. (2014) described that the sandalwood leaf constituent saponin causes hemolysis of RBCs. Sandalwood tree has great ethno-botanical importance such as the paste of sandalwood and Shikakai (*Acacia concinna*) is used for marking on the forehead, and this will keep the mind cool and concentrated (Sharma and Kumar 2013). Also, brides use sandalwood to perfume their bodies. Sandalwood finds a special place on various auspicious occasions, such as the birth of babies, thread ceremonies, marriages, and other religious functions. Sandalwood attar is manufactured by the process of distillation which is an important constituent in a variety of products, such as agarbattis, soaps, perfumer, beauty creams, and hair care merchandises (Skaria et al. 2007) (Table 1).

4 Medicinal Importance

Sandalwood essential oil has remarkable uses in our daily life, including cosmetic, commercial, and aromatherapy. Besides this, a major portion of sandalwood is known for its importance as a medicinal tree. Changing consumer preferences toward organic products over synthetic substances showed strong demand for essential oils and plant extract in pharmaceutical and cosmetic industries. There is increasing interest in essential oils throughout the world. The essential oil can be collected from *Eucalyptus*, Lavender, Mint, and Tea (Clarke 2006), but the sandalwood oil is above all. Sandalwood essential oil is being used in aromatherapy (Skaria et al. 2007) since ancient times. In women, during pregnancy, sandalwood oil is one of the safe essential oil which is allowed to be used (Skaria et al. 2007).

Sandal is very important as a medicinal plant. Therefore, it is being promoted by the National Medicinal Plant Board (NMPB) as a priority medicinal plant. Sandalwood oil can be used against fever, germs, disease-causing microbes, scabies, and can help in promoting diuresis. Sandal oil is also beneficial in the treatment of colds, congestion, inflammation in the chest, UTI (urinary tract infection) issues, inflammation of the bladder, and painful urination (Goswami and Tah 2018). Similarly, the use of santalbic acid against swelling and sensitivity is reported by Kumar et al. (2019). Indian sandalwood contains significantly higher quality and quantity of α-santalol and β-santalol. Santalols (C15 isoprenoids) also called sesquiterpenoids are major bioactive principles of sandalwood oil (Misra and Dey

2013c). Heartwood oil exhibits anti-inflammatory actions and is suitable to treat skin infections including pimples. Santha and Dwivedi (2015) mentioned α-santalol as an anticancerous agent and can be utilized as a chemopreventive substance that is nontoxic and proven against tumorigenesis.

Sandalwood has antioxidant activity and is being utilized as homemade medicines (Scartezzini and Speroni 2000). Misra and Dey (2013b) reported through the experiment conducted on Albino mouse that sandalwood oil has the capability to lower blood glucose level and oxidation process. Also, antitumor and anti-angiogenic potential actions of α-santalol have been identified in *Homo sapiens* malignant hepatoma cells brought by liver carcinogen, DEN (diethylnitrosamine) in rodents (Hegde et al. 2014). Sandalwood is beneficial in cardiovascular inflammation like myocarditis (Khan et al. 2014). Zhang et al. (2012) conducted the phytochemical analysis of VOCs (Volatile Organic Compounds) from fruits oils of Indian sandalwood through hydro-distillation and solvent extraction. It was reported that there are almost 66 volatile compounds of which hexadecanoic acid and omega-9 fatty acids account for almost up to 70%. Other compounds included were α- and β-santalol, sesquiterpene, derivatives of carboxylic acids, Squalene, and plant sterols. Squalene is a triterpene hydrocarbon that shows anticancerous properties and prevents cell damage by free radicals (Owen et al. 2000). It helps prevent the growth of cancerous cells formed due to chemicals and protects from (Deoxyribonucleic acid) DNA oxidation.

Essential oils and aroma chemicals stimulate olfaction and amygdala. The brain starts being calm by inhaling the aroma or fragrance of sandalwood oil (Skaria et al. 2007). Sandalwood is important medicine benefitting against coughs due to its soothing characteristics. It is excellent in regulating high blood pressure and starts acting soon after its application on the epidermis (Nautiyal 2019). The essential oil derived from sandal is useful in reducing pain and inflammation (Misra and Dey 2013c). It is used in suppressing muscle and neurological spasms. As per the classical medicinal system, heartwood-derived oil helps in relieving mental health disorders, UTI issues, gastrointestinal problems, and other ailments (Ravikumar et al. 2018; Nautiyal 2019). The bark, root, and stem of sandalwood are effectively utilized for relief against gonorrhea, hypoglycemia, and skin ailments (Jeevan Ram and Raju 2001). In Western Australia, Seed kernels were made into a paste with water and boiled for a considerable time; further, the paste was applied over sores, bruises, lesions, and aching joints and muscles as a medicine (Hettiarachchi 2014). Cribb and Cribb (1981) mentioned that the European settlers used to consume locally available *Santalum spicatum* and *S. accuminatum* seeds for arthritic pain.

Novel technologies are making it easier to identify the constituents of any biological substance and where it can be used. Technologies could help us to utilize these chemical constituents derived from any compound in the treatment of any disease/disorder through drug designing (Misra and Dey 2013a). New possibilities of application could be identified, such as α-santalol derived from sandal heartwood can be useful in curing the disease like “Senile dementia” and tumor (Kim et al. 2006; Bommareddy et al. 2012). A similar report was suggested by Misra and Dey (2013d) about the use of sandalwood and its oil as a classical medicine. These days,

people rely more on herbal medicine and avoid chemical-based medicines. So, sandalwood and other similar important medicinal plants have great potential to take over the allopathic system of medicine. Misra and Dey (2013d) mentioned that sandalwood finds extensive applications in traditional medicinal systems and is gaining importance in modern pharmacological investigations as a source of anticancer (Bommareddy et al. 2012), anti-*Helicobacter pylori* (Ochi et al. 2005), and antiviral (Benencia and Courreges 1999) biomolecules.

5 Conclusion

Indian sandalwood (*Santalum album*) is an important tree species due to its aromatic heartwood, containing α-santalol and β-santalol, which is used in medicines, cosmetics, perfumes, and aromatherapy. The major component of the sandalwood essential oil is α-santalol and β-santalol. Indian sandalwood is of high grade when compared to other regional varieties and thus high in demand. Tamilnadu and Karnataka are the largest producers of Indian Sandalwood, although it is available throughout India as a plantation and in natural habitat. Commercially, sandalwood is an expensive tree species due to its extensive uses in various industries. In religious functions, sandalwood is an essential ingredient in various rituals. In India, the sandalwood market is being regulated in collaboration with the forest department. It is expected that the global sandalwood oil market will reach CAGR of 6.99% from 2019 to 2024 and touch USD 156 million by the end of 2024. Sandalwood has high cosmetic importance due to its application in various product manufacturing. Sandalwood oil is being used in the preparation of beauty products, face packs, moisturizers, treatment of skin infections, and wounds. The oil exhibits antiseptic, anti-tremorogenic, and antiaging properties. Sandalwood is known to be used in our ancient medicinal system, Ayurveda. Sandalwood has shown its uses in hepatoprotective activity, central nervous system effects, antiulcer activity, antibacterial activity, antifungal activity, antiviral activity, antioxidant efficacy, anticancer activity, hemolytic activity, antipyretic activity, anti-inflammatory activity, antihyperglycemic, cardioprotective activity, physiological effects, metabolic effects, genitourinary system effects, insecticidal activity, and aromatherapy. Future research should be conducted on this important tree as it has enormous capabilities of treating various diseases/ailments. Farmers should be motivated in the cultivation of sandalwood with the necessary support and mechanism for its harvesting in collaboration with the forest department. Such policies and guidelines should be formed which helps the farmers to get support from seeding to final harvesting including the plantation management.

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