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A Mini-Review of *Santalum album* L. (*Santalaceae*)

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Abstract

The *Santalum album* L., belonging to the family Santalaceae, is one of the valuable sources of natural fragrance with high medicinal and commercial values. It has fragrant heartwood and is widely cultivated in India and other countries such as Australia and Indonesia. The availability and production of the *Santalum album* have declined significantly due to overharvesting and spike disease. The *Santalum album* flourishes on well-drained and loamy soil with a pH range of 6–9. It also grows on laterite soil, but not waterlogged ground, and preferably on slopes of hills exposed to the sun. It requires a minimum of 20 to 25 inches of rainfall per year; more than 80 inches is detrimental. The species is hemiparasitic, having photosynthetic capacity, but water, mineral nutrients, and organic substances are acquired via the haustorium of the host plant. Host plants are divided into three categories, including pot, intermediate, and long-term hosts. The selection of suitable host species is critical to ensuring high levels of the *Santalum album* field survival and growth. Indian Sandalwood is extensively used as a fragrance ingredient in perfumes, creams, soaps, detergents, lotions, etc. Furthermore, it is used as a flavoring substance in food products. Indian Sandalwood possesses various medicinally significant activities such as antiviral, antimicrobial, antibacterial, antioxidant, anti-inflammatory, anti-aging, anti-hypercholesterolemia, and anti-hair loss.

Keywords: Indian Sandalwood, Host plants, Habitat, Spike disease, Traditional medicine.

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INTRODUCTION

Santalum L., belonging to the family Santalaceae, is a hemiparasitic genus with 20 species, mainly distributed throughout India, Australia, and the Pacific Islands (Jiao et al., 2018; Sanjappa and Sringeswara, 2022). The *Santalum* species are recognized as xylem tapping root hemiparasites, and they are well known for their fragrant heartwood-derived oil used to scent incense and perfumery and are generally known as “Sandalwood” (Jiao et al., 2018; Fatima et al., 2019a). Wild *Santalum* populations are endangered in many regions due to their high value and the increasing demand for Sandalwood products, habitat loss, uncontrolled fire, grazing, and illegal and excessive logging of the *Santalum* species (Radomiljac, 1998; Bunney et al., 2023).

The *Santalum album* L. is an evergreen hemiparasitic tree commonly known as white Sandalwood (English), safed Chandan (Hindi), sandal safaid (Urdu), etc. (Sultana and Rahman, 2018). This species is indigenous to peninsular India and is also found in Australia, Belgium, China, Cambodia, Fiji, Indonesia, Japan, and Madagascar (Purohit, 2018; Nurochman et al., 2018; Fatima et al., 2019b). The *Santalum album* wood is highly fragrant and is the second most expensive kind of wood in the world after African Blackwood, *Dalbergia melanoxylon* Guill. & Perr. (Santha and Dwivedi, 2015). Unfortunately, the availability and production of the *S. album* have declined significantly due to overharvesting and poaching of natural resources, so severe that it has been categorized as 'Vulnerable' by the International Union for Conservation of Nature (IUCN) in 2020 (Bisht and Kumar, 2021).

The *Santalum album* is mainly a cross-pollinating species, and the pollination is facilitated by insects such as *Apis cerana indica*, *Monomorium destructor*, and *Camponotus* spp. (Krishnakumar et al., 2018). The tendency for outbreeding in the *S. album* is reinforced by asynchronous flowering, heterostyly, insect pollination, and self--incompatibility (Veerendar et al. 1996; Kulkarni and Muniyamma, 1998). The flowers are produced twice a year, and the fruits are drupe, purple-brown when fully ripe, and single-seeded (Dutt et al., 2021). Seeds are obtained by removing the fleshy portion of the fruits, and their viability is retained for up to six months under normal conditions and then gradually diminishes (Ramya, 2010). Fresh seeds exhibit dormancy for 2–3 months (Jayawardena et al., 2015). Natural regeneration occurs using seeds, and seeds are usually dispersed by birds and normally take three months to germinate (Bhaskar, 1992; Balasubramanian et al., 2011).

Germination is hastened by osmopriming, acid scarification (e.g., sulfuric acid), coconut water treatment, and soaking seeds in 500 ppm gibberellic acid (Jayawardena et al., 2015; Priyadharshini and Lekha, 2021; Debta et al., 2023). Artificial regeneration is achieved by vegetative propagation (through stem cuttings, grafting, and root suckers) and micropropagation (axillary shoot proliferation, somatic embryogenesis, and adventitious shoot induction) (Rao and Ram, 1983; Bapat and Rao, 1999; Radhakrishnan et al., 2001; Sanjaya et al., 2006; Bele et al., 2012; Crovadore et al., 2012; Herawan et al., 2014; Peeris and Senarath, 2015; Krishnakumar and Parthiban, 2018; Patil et al., 2018; Tate and Page, 2018; Teja et al., 2023).

Most of the existing *S. album* populations are not dense. The resources of *S. album* have been declined, due to natural or unnatural reasons. Natural reasons include change calamities, fire, drought, flood, spike disease, animal grazing, invasive weeds, including *Lantana camara* L., and the spread of monoculture plantations of *Eucalyptus* L'Hér. etc., and unnatural reasons include overexploitation, unorganized cutting of the trees, illicit felling and smuggling, etc. (Rocha et al., 2014; Purohit, 2018; Sahu et al., 2021; Bunney et al., 2023; Yadav et al., 2023). The market for the *S. album* perfume has increased, but the supply of heartwood resources has decreased for the reasons mentioned above.

MATERIAL and METHOD

An electronic search of published articles was conducted from 1966 to 2024 through PubMed, Google Scholar, Scopus, Web of Science, and local databases. Furthermore, cross-references were used to find more sources. Search terms included combinations of *Santalum album*, *S. album*, Sandalwood, Indian Sandalwood, morphology, host plants, habitat, chemical compound, traditional medicine, and spike disease.

MORPHOLOGICAL CHARACTERISTICS

The *Santalum album* is a hemiparasitic medium-sized evergreen tree, glabrous with thin drooping branches, and reaching up to 20 m in height. The bark is tight, reddish, dark brown, dark gray or brownish black, smooth in young trees, rough with deep vertical cracks in older trees, and red inside. The heartwood is yellowish-brown and is strongly scented. Leaves are simple, thin, usually opposite, elliptic-lanceolate and ovate or ovate elliptical, 3–8 x 3–5 cm, glabrous and entire; tip rounded or pointed; petioles 1–1.3 cm long; venations noticeably reticulate. The *Santalum album* flowers at the beginning of two to three years. Generally, it flowers twice a year, from March to May and September to December. Flowers are small, straw-colored, violet, green, or reddish, about 4–6 mm long, and up to 6 in small axillary or terminal clusters. Perianth includes 4 campanulate limbs, valvate triangular, 4 stamens, exerted, alternating with 4 rounded scales. The ovary is semi-inferior and unilocular. Fruit is a globose, fleshy drupe, red, purple to black when ripe, about 1.3 cm in diameter, with a hard ribbed endocarp and crowned with a scar, almost stalkless, smooth, and single-seeded. Seeds are naked, lack testa, and viable seed production occurs when the tree is five years old (Sindhu et al., 2010; Kumar et al., 2015; Kumar et al., 2019).

WHITE SANDALWOOD HABITAT

The *Santalum album* grows naturally in a variety from weathers of the warm desert in Australia, through seasonally dry monsoon climate in India, Eastern Indonesia, and Vanuatu, to subtropical climate in Hawaii and New Caledonia (Applegate et al., 1990). The *Santalum album* flourishes on well-drained, and loamy soil with a pH range of 6-9 (Applegate et al., 1990). It also grows on laterite soil, but not waterlogged ground, and preferably on slopes of hills exposed to the sun (Kumar et al., 2015). It needs a minimum of 20 to 25 in. of precipitation per year; more than 80 in. is detrimental (Solanki et al., 2014). Soil moisture is a critical environmental factor for the growth of the *S. album* because it determines the soil nitrogen and carbon content (Thinley et al., 2020). The best wood grows in the driest regions, especially on red and stony ground or on rocky ground, although the trees often remain small, giving the highest yield of oil (Sindhu et al., 2010). The suitable range of annual temperature between 19–29ºC, altitude between 451–1951 m, annual rainfall between 982–1984 mm, soil moisture between 3.7–115 kg/m^2, soil pH between 3.1–7.3 and slope between 0^O to 70^O with an average slope 40.7^O (for avoiding waterlog condition) are reported for the growth of the *S. album* in India (Rajan and Jayalakshmi, 2017; Thinley et al., 2020).

The *Santalum album* recruitment and growth are strongly affected by drought, extreme fluctuations in rainfall, and increasing evapotranspiration rates (McLellan et al., 2021). Seedling-related traits like photochemical reflectance index, relative water content, shoot and root weight, and root–shoot ratio correlated with different climatic parameters (Madhuvanthi et al., 2024). Seedlings are very susceptible to drought and are readily killed by exposure to the sun because of disorders of the plant's physiological metabolism system (Barrett and Fox, 1994; Zhang et al., 2022). Side shade is considered most desirable at the sapling stage, and diffuse light is beneficial until plants are about five years old or 4 m tall. The *Santalum album* thrives best when young in the shade of bushes and clumps of vegetation. Overhead shade is desirable only in very hot localities. As the *S. album* becomes established, it requires abundant sunshine. Indeed, the *S. album* is a sciophil as a seedling, becoming more heliophilic once established (Barrett and Fox, 1994).

HOST KINDS OF *SANTALUM ALBUM* AND THEIR SIGNIFICANCE

The *Santalum album* is a known parasite of more than 300 species from grasses to trees, and even other sandal trees (self-parasitism) (Dutt et al., 2021). It can reach a height of 20 m by attaining a girth of 2.5 m (Sandeep and Manohara, 2019). The selection of suitable pot host species is critical to ensure high levels of the *S. album* field survival and growth (Rai, 1990). The *Santalum album* initially needs shade and later plentiful light for its growth and development. However, being a hemi-root parasite, it needs a host for survival, especially to get mineral nutrients and water, despite being able to photosynthesize. Likewise, it is specific in selecting consistent associates in nature (Doddabasawa et al., 2020). Therefore, the choice of an appropriate host assumes significance. Several studies (Radomiljac, 1998; Nge et al., 2019; Doddabasawa et al., 2020) showed that the performance of the *S. album* relies on the host features such as good root growth, an even distribution of root growth within the pot, nodule formation (Fabaceae), thin and watery lateral root system, capability to resist top pruning, low level of competition, low allopathic influences, low growth structure, hemiparasitic compatibility and persistence in the field after out planting, sparse crown, slow-growing nature, translocation of nutrients, sap flow of xylem tissue and higher water use efficiency. Also, the distance between the parasite and its host is impressive in the growth of the *S. album*. Indeed, the appropriate distance of the relationship between parasite and host eliminates competition for above-ground resources, especially for light (Doddabasawa et al., 2020). The successful growth of the *S. album* relies on the supply of nutrients from the host plant through "haustoria" and shade at the young stage (Lion, 2017). Indeed, the dependence of the *S. album* on hosts is to obtain calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), nitrogen (N), phosphorus (P), proline, sugars, amino acids, and malic acid for the synthesis of carbohydrates (Doddabasawa and Chittapur, 2021). The formation of haustorium is more or less bounded to younger roots, and originates from outer layers of rootlets, unlike lateral rootlets, which are formed deep in the hosts' tissues (Das and Tah, 2017).

For plantations, host plants are divided into three categories: pot, intermediate, and long-term hosts (Fox et al., 1996; Radomiljac et al., 1998; Radomiljac et al., 1999). In addition, host plants were considered good, medium, and poor hosts, relying on growth, biomass, and the number of haustoria produced by the *S. album* when associated with various hosts (Ananthapadmanabha et al., 1988). The studies showed that Fabaceae is one of the most preferred host families of plants for the *S. album* growth because as the *S. album* tree ages, there is an increasing demand for nitrogenous compounds, which the Fabaceae family can provide (Radomiljac, 1998; Barbour, 2008). For example, Barbour (2008) reported that *Sesbania formosa* (F.Muell.) N.T.Burb. (Fabaceae) is a suitable pot host for the *S. album* in Australia, and Srikantaprasad et al. (2022) showed that *Prosopis* L. (Fabaceae) is an appropriate host for the commercial cultivation of the *S. album* in hot semi-arid conditions. Also, Thinley et al. (2020) mention that parasitizing *Desmodium* spp. (Fabaceae) by a mature Sandalwood tree reveals a potential supply of nitrogen by the host, as the *S. album* with age needs more nitrogen. When the *S. album* seedlings are transplanted into plastic pots, seeds or seedlings of a pot host plant should also be transplanted into the pots. Host plants (pot host) could include these species: *Aerva sanguinolenta* (L.) Blume, *Albizia lebbeck* (L.) Benth., *Alternanthera ficoidea* (L.) Sm., *Alternanthera nana* R. Br., *Calotropis procera* (Aiton) W.T.Aiton, *Calliandra calothyrus* Meissn., *Casuarina equisetifolia* L., *Chromolaena odorata* (L.) R.M. King & H. Rob., *Crotalaria juncea* L., *Dalbergia latifolia* Roxb., *Desmanthus virgatus* (L.) Willd., *Mentha arvensis* L., *Pongamia glabra* (L.) Panigrahi, *Sesbania formosa, Terminalia catappa* L., and *Trithonia diversifolia* (Hemsl.) A. Gray (Radomiljac, 1998; Applegate et al., 1990; Taide et al., 1994; Fox et al., 1996;

Tennakoon and Cameron, 2006; Barbour, 2008; Chakraborty et al. 2020; Thinley et al., 2020). In northern Western Australia, the herbaceous *Alternanthera nana* is a great host, as it facilitates high *S. album* durability and growth following field establishment (Radomiljac et al., 1998; Radomiljac et al., 1999).

The intermediate and long-term hosts are propagated simultaneously in different nursery containers, and both host kinds are strategically placed within the plantation (Radomiljac et al., 1999).

The intermediate host functions as a `bridging agent' between the pot host and long-term host and should facilitate early the *S. album* plantation growth. Intermediate hosts finally die or become less significant following the *S. album* attachment to the long-term host, which should survive as the final host for the whole cycle length (Radomiljac et al., 1999). Intermediate hosts should be established on the plantation site before planting the *S. album* to allow a good connection to its roots and host species, and the *S. album* seedlings should be planted close to their hosts (Applegate et al., 1990). Favorable characteristics of an intermediate host are mild strength or endurance to lopping (e.g., *Paraserianthes falcataria* (L.) I.C.Nielsen), a thin canopy, long-lived, a nitrogen-fixing legume, vast enough crowns, thorny or leathery leaves to protect of grazing animals, indigenous and some other benefit for locals (e.g., fuel wood, fodder, or fruit) (Applegate et al., 1990). Combinations of the *S. album* and intermediate hosts have proven successful in the past, including *Acacia nilotica* (L.) Willd. ex Delile, *Arachis pintoi* Krapov. & W.C.Gregory, *Cajanus cajan* (L.) Millsp., *Casuarina equisetifolia*, *Desmanthus virgatus*, *Erythrina poeppigiana* (Walp.) O.F.Cook, *Murraya koenigii* (L.) Sprengel, *Pongamia pinnata* (L.) Pierre, *Sesbania grandiflora* (L.) Poiret, *Wrightia tinctoria* (Roxb.) R.Br, and *Terminalia* spp. (Applegate et al., 1990; Fox et al., 1996; Page et al., 2012; Page et al., 2018; Doddabasawa et al., 2020; Thinley et al., 2020).

The *Santalum album* tree requires a long-term host for mineral nutrient replenishment, water supplementation to support plant water potential, and tiniest competition in above-ground parts apart from adequate sunlight (Doddabasawa et al., 2020). A mature *S. album* tree parasitizes on long-term suitable such as *Acacia auriculiformis* A. Cunn. ex Benth., *Acacia oraria* F. Muell., *Acacia spirorbis* Labill., *Adenanthera pavonina* L., *Cassia fistula* L., *Cassia javanica* L., *Cassia siamea* Lamk, *Casuarina equisetifolia, Casuarina junghuhniana* Miq., *Hibiscus tiliaceus* L., *Leucaena leucocephala* (Lam.) de Wit, *Paraserianrhes falcataria* (L.) Nielsen, *Pinus roxburghii* Sarg., *Prosopis juliflora* (Sw.) DC., *Pterocarpus indicus* Willd., *Senna formosa* H.S. Irwin & Barneby and *Citrus* L. species (orange, pamplemousse, lime or lemon) (Radomiljac, 1998; Fox et al., 1996; Page et al., 2012; Page et al., 2018; Doddabasawa et al., 2020; Thinley et al., 2020).

INDIAN SANDALWOOD AND USES

The *Santalum album*, naturally known as Indian Sandalwood, is one of the valuable sources of natural aroma with high therapeutic and commercial values (Bisht and Kumar, 2021). All parts of Indian Sandalwood, such as wood, root, bark, leaves, and fruits have been used in medicine and industry. For example, its fruits are edible, the seed contains fatty oil, which is suitable for the manufacture of paint, and the bark contains approximately 12-14% tannin and has profitable potential in the tanning industry (Kumar et al., 2015). A wide variety of articles, such as cabinet panels, hand fans, boxes, letter openers, combs, jewel cases, card cases, picture frames, bookmarks, and pen holders are made from Indian Sandalwood (Arun Kumar et al., 2012). Also, Indian Sandalwood has religious and ritual significance in a few countries, especially in India and Nepal (Bahadur, 2019).

For example, rich Hindus place pieces of Indian Sandalwood in the funeral pile, or the heartwood and sapwood are powdered together to produce incense or joss sticks used in religious ceremonies (Kumar et al., 2019). However, Indian Sandalwood is mainly grown for its heartwood to obtain fragrant oil. The essential oil of Indian Sandalwood develops in the heartwood and root of the trees, and this process needs about 15 to 20 years, but fully matured trees of 60 to 80 years produce the grandest oil content with high quality and a high level of fragrance (Santha and Dwivedi, 2015). Indian Sandalwood oil is acquired by steam distillation of the fragrant heartwood of Indian Sandalwood (Francois-Newton et al., 2021). Sandalwood oil is highly ranked for its sweetly fragrant, persistent, spicy, warm, woody note, tenacious aroma, and fixative properties. (Divakara et al., 2017). The chemical components reported in Indian Sandalwood oil are sesquiterpenes, terpenes, phenols, and lactones (Burdock and Carabin, 2008). More than 100 constituents that belong to different chemical classes have been identified in the heartwood, and the main constituents are α-santalol (up to 50% of the natural Indian Sandalwood oil) and β-santalol (up to 30% of the essential oil) (Brocke et al., 2008). Indian Sandalwood oil is vastly utilized as a fragrance ingredient in perfumes, creams, soaps, detergents, lotions, etc. (Sultana and Rahman, 2018). Furthermore, it is used as a flavoring substance in food products such as baked food, frozen dairy desserts, gelatin, candy, pan masala, puddings, and alcoholic and non-alcoholic beverages (Sanyal and Sikidar, 2016). Indian Sandalwood oil is authorized for food use by the United States Food and Drug Administration (FDA), Flavor and Extract Manufacturers Association (FEMA), and Council of Europe (CoE) (Burdock and Carabin, 2008).

The Sandalwood tree and its products have been utilized to cure various diseases since ancient times. Pedanius Dioscorides, a Greek botanist, authored De Materia Medica an encyclopedia in Greek on medicinal plants, which was the source for all modern pharmacopeias. It consists of five volumes and studies 600 plants. The *Santalum album* was recorded by Dioscorides in De Materia Medica, since then, it has been continually cited and used in various traditional systems of medicine, such as the Ayurvedic system of medicine, the traditional Chinese medicine (TCM) and the Unani system of medicine (Sultana and Rahman, 2018).

In the Indian traditional medicine system Ayurveda, Indian Sandalwood has mainly been used as a demulcent, expectorant, diuretic, antiseptic, antispasmodic, cooling, antipyretic, diaphoretic, antidiabetic, aphrodisiac, carminative, cicatrisant, antiseptic, antiphlogistic, astringent and in the treatment of urinary infection, herpes zoster, psoriasis, urethritis, palpitations, heart weakness, eye infections, biliousness, sunstroke, hyperacidity, acute dermatitis, intrinsic hemorrhage, bleeding piles, urticaria, vaginitis, fever, poisoning, vomiting, bronchitis, dysuria, bleeding piles, hiccoughs, inflammation of umbilicus poisoning, the initial phase of pox, and gonorrheal recovery (Banerjee et al., 1993; Paulpandi et al., 2012; Arun Kumar et al., 2012; Misra and Dey, 2013; Kumar et al., 2015; Sharma et al., 2017; Sneha and Mujumdar, 2020; Francois-Newton et al., 2021). In traditional Chinese medicine (TCM), Indian Sandalwood (=Tan Xiang) is utilized by herbalists to treat anxiety, nervous tension, immune booster, skin diseases, eczema, acne, frigidity, fatigue, dysentery, gonorrhea, impotence, cystitis, vomiting and stomachache (Misra and Dey, 2013; Santha and Dwivedi, 2015; Kumar et al., 2015; Kumar et al., 2019). Also, according to Chinese medicine, Indian Sandalwood functions in any kind of chest aches originating either from the lungs or heart (Misra and Dey, 2013; Kumar et al., 2015). In the Unani system of medicine, it has anti-inflammatory, antiseptic, analgesic, blood purifier, cardio tonic, exhilarant, nerving tonic, and expectorant properties, and it is helpful to treat cardiac, liver, skin, gastric ulcers, gastrointestinal, respiratory disorders, and locomotor diseases (Ahmed et al., 2013; Sultana and Rahman, 2018).

In addition, Pharmacological studies showed that Indian Sandalwood and its oil possessed various biological effects ranging from antiviral (Benencia and Courreges, 1999), aromatherapy (Heubeger et al., 2006), antimicrobial (Kumar et al., 2006), anticancer (Bommareddy et al., 2007), antibacterial (Misra and Dey, 2012), anti-hyperglycemic (Misra et al., 2013), anti-ulcer (Ahmed et al., 2013), antioxidant (Shamsi et al., 2014), anti-proliferative (Sharma et al., 2017), anti-inflammatory (Sharma et al., 2018), anti-aging (Francois-Newton, 2021), anti-hypercholesterolemia (Rasheed et al., 2023), and anti-hair loss (Montoli et al., 2023).

SPIKE DISEASE

The Spike disease of Indian Sandalwood has attracted worldwide attention due to its destructive nature (Gowda and Narayana, 1998a). For a long time, spike disease was assumed to be viral because of the disease syndrome and its graft-transmissibility, but electron microscopic studies showed that spike disease of the *S. album* is due to a mycoplasma-like organism (MLO) (Gowda and Narayana, 1998b; Hull et al., 1969; Disjktra and le, 1969). Phytoplasmas (formerly known as mycoplasma-like organisms) are bacterial plant pathogens that can cause devastating yield losses in cultivated crops and other plants (Wang et al., 2022). They are obligate symbionts of plants and insects and in most cases require both hosts for diffusion in nature (Hogenhout et al., 2008). In plants, these pathogens are seen exclusively in the sieve tubes of phloem tissues of leaves, petioles, stem, and root (Balasundaran and Muralidharan, 2004) and spread throughout the plant by moving through the pores of the sieve plates that divide the phloem sieve tubes (Hogenhout et al., 2008). Insect vectors of phytoplasmas are phloem feeders of the Order Hemiptera, mostly psyllids, leafhoppers, and planthoppers (Weintraub and Beanland, 2006). The symptoms of spike disease are similar to those of so-called 'yellow diseases' (Gowda and Narayana, 1998b). It is distinguished by an extreme reduction in the size of leaves, stiffening and reduction of internodes, the occurrence of short dead branches, yellowing and stiffening of leaves, and the occasional occurrence of tufts of axillary shoots arising from the main branches in the advanced stage, the whole shoot looks like a chimney brush (Ananthapadmanabha, 1998; Gowda and Narayana, 1998a, b; Sunil and Balasundaran, 1998).

Spiked trees usually die within 12–36 months (Sunil and Balasundaran, 1998). Several attempts have been made to detect the diseased plants by determining the length/breadth ratio of leaves (Ananthapadmanabha, 1998), staining techniques by light and fluorescent microscopes such as aniline blue (Ghosh et al., 1985), Dienes' stain (Ananthapadmanabha et al., 1973), Mann's stain (Parthasarathi et al., 1966), Hoechst 33258 (Ghosh et al., 1985), and A DNA-specific fluorochrome, 4,6-diamidino-2- phenyl indole (DAPI stain) (Sunil and Balasundaran, 1998), electrophysiological studies using Shigometer (Ghosh et al., 1985), Immunological techniques using Enzyme Linked Immunosorbent Assay (ELISA) (Balasundaran and Muralidharan, 2004), and molecular techniques such as restriction fragment length polymorphism analysis (RFLP) (Sunil and Balasundaran, 1999). Spike disease caused by MLO-like organisms is sensitive to tetracycline (Ananthapadmanabha, 1998). Infusion of an aqueous solution of 500 mg of tetracycline antibiotics, dissolved in 500 ml of water, in spiked trees, gave remission of disease symptoms lasting for three to five months (Ghosh et al., 1985).

CONCLUSION

The research on the *S. album* has been a subject of interest for many scientists. Many of them confirmed its traditional use and found even new possibilities for its potential use. Scientists have documented that it is a strong antiviral, antimicrobial, anti-inflammatory, and antioxidant, which are the reasons for its use in the cosmetic, pharmaceutical, perfume, and alimentary industries. Indian Sandalwood studies confirm that environmental factors influence the growth, development, and quality of the heartwood of Indian Sandalwood. Indian Sandalwood plants require host plants to meet their nutritional needs to grow and flourish. By knowing the types of host plants, both at the nursery level (pot host) and planting in the field (intermediate and long-term hosts), communities can make a selection for cultivating Indian Sandalwood in the future. The *Santalum album* is a vulnerable species, according to the IUCN being detrimentally affected by unnatural (e.g., overharvesting) and unnatural (e.g., spike disease) reasons. Conservation of the *S. album* should be done since planting in the field includes shade, flood, drought, fire avoidance, avoiding grazing animals, inhibiting overexploitation, and preventing pest and disease attacks.

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