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ICFRE

Sandalwood

Vol. 2, Issue 2, July - September 2021

INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY, BENGALURU

Indian Council of Forestry Research and Education

(An Autonomous Body Under Ministry of Environment, Forest & Climate Change)


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INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION

(An Autonomous Council of Ministry of Environment Forest and Climate Change, Government of India)

VISION

To achieve long-term ecological stability, sustainable development and economic security through conservation and scientific management of forest ecosystems

MISSION

To generate, advance and disseminate scientific knowledge and technologies for ecological security, improved productivity, livelihoods enhancement and sustainable use of forest resources through forestry research and education

ZiBOC

- A new wood preservative which is comparable to CCA.
- Judicious use of preservative in a non-durable wood greatly enhances (6-8 folds) life of products.

Varieties/ Clones developed

- Developed improved germplasm of many forest tree species.
- Released 47 high performing and disease resistant clones of *Eucalyptus, Casuarina, Shisham, Melia* and *Sarpagandha* with a envisaged production gain of more than 20%. The developed germplasm are being made available to the State Forest Departments and farmers for use in plantations.

High performing and disease resistant clone of *Melia* sp.

CYCUS v. 1.0

- Casuarina Yield Calculator Utility Software (CYCUS v1.0) software has been developed to facilitate the farmer and other user agencies in yield estimation which requires only observations on girth of 100 sample trees per acre of plantation.

Wood Welding

Wood welding is new to our country. In this technique wood joints can be made without using nails and adhesives making them more natural and chemical free. A wood welding machine has been designed and fabricated at Forest Research Institute, Dehradun. Success has been achieved in spin welding of wood pieces of few species.

Wood Welding Machine

Indian Council of Forestry Research and Education

New Initiatives

- Transparent wood- a flexible and biodegradable transparent wood has been fabricated using poplar wood veneer and water soluble polymer- polyvinyl alcohol. The transparent wood exhibited high optical transmittance, high haze and light diffusing property.

Natural wood (Left most), Lignin modified wood (middle) and Transparent wood (right most) placed on a paper with letters "IWST"

Heat storage based modified Solar Kiln

- Solar heat storage system based solar kiln has been developed by Forest Research Institute, Dehradun for timber drying. The solar heat is trapped using suitable phase change material (PCM). The New solar kiln is able to trap 39 % more heat in winters as compared to traditional green-house based traditional FRI solar kiln developed during 1970.

Head based storage Solar Kiln

Xylarium

- Collection of authentic wood samples both from India and other countries, depicting wood biodiversity of the country like lightest, heaviest, sweet-smelling, foul smelling, smoothest, streaked, variegated wood and wood of different coloures, etc. The collection of wood cross sectional discs depicting variation in sapwood and heartwood colour is a unique feature of the xylarium.
- Wood identification services.

Xylarium- Collection of Authentic wood samples

Tree hollowness detection technique based on ultrasonic waves

- Forest Research Institute, Dehradun has developed ultrasonic techniques (Non-destructive testing) to detect the location and magnitude of the hollowness of the standing tree. This will help to remove the potential human hazards by way of falling down of such trees during a high wind regime in Urban Forestry.

Measurement of hollowness in a tree using ultrasonic detector

Agroforestry models

- Various agroforestry models (Poplar, Eucalyptus, Melia, Casuarina and Babool) have been developed to improve green cover, enhance farmers income and to mitigate climate change .

Poplar based agroforestry model with wheat

Innovative Bamboo Bottles

- Techniques for making bamboo bottles by using Bamboo Treatment Technologies of ICFRE. Most suitable bamboo species for making bottles are Shil Barak (*Bambusa salarkhanii*) & Barak (*Bambusa balcooa*). One full bamboo is sufficient for making 21 full size bottles and 12 small bottles.

Bamboo bottles

For further details please contact :
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Ashwini Kumar Choubey

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GOVERNMENT OF INDIA

संदेश

भारत की समृद्धिशाली संस्कृति विश्व में जिस तरह अलौकिक है, उसी तरह हर मांगलिक कार्यों, 16 संस्कारों के अवसर पर प्रयोग किया जाने वाला चंदन वृक्ष भी दिव्य एवं अलौकिक है। इसलिए इसका वर्णन भारत के लगभग सभी पौराणिक ग्रंथों में किसी न किसी रूप में हुआ है। एक सुभाषित में तो इस वृक्ष की उपमा संत से की गई है:

मूलं: भुजंगै: शिखरं विहंगै:
शाखां प्लवंगै: कुसुमानि भृंगै: ।
आश्चर्यमेतत् खलुचन्दनस्य
परोपकाराय सतां विभूतय: ।।

(जिस तरह संत पुरुष अधर्मियों के संगत में आने के बाद भी उनका कल्याण ही करते हैं। उसी तरह चंदन हर परिस्थिति में कल्याणकारी ही होता है)

इसकी बहु-उपयोगिता, औषधीय गुण संपन्नता के कारण इसका इतना कटान हुआ कि यह संयुक्त राष्ट्र संघ की **अंतर्राष्ट्रीय प्रकृति संरक्षण संघ (IUCN)** की सूची में आ गया है। हमारी संस्कृति में प्रकृति देवो भव: की हमारी संकल्पना, मांगलिक कार्य में बहु-विधि प्रयोग एवं देश के किसानों की आय दोगुनी करने का हमारे संकल्प पूरा करने के लिए, इसके संरक्षण, संवर्धन की आवश्यकता है।

काष्ठ विज्ञान एवं प्रौद्योगिकी संस्थान (आई.डब्ल्यू.एस.टी.) काष्ठ उपयोग में विभिन्न अनुसंधान कार्य-कलापों को करने के लिए और उसे लोकप्रिय बनाने के लिए जाना जाता है। यह व्यापक रूप से पारिचालित तिमाही पत्रिका, "वुड इज़ गुड : ग्रो मोर, यूज़ मोर" को प्रकाशित कर रहा है और यह शिक्षा और उद्योगों के अभिसरण द्वारा काष्ठ विज्ञान और प्रौद्योगिकी से संबंधित विभिन्न उचित पहलुओं को उजागर करने का प्रयास कर रहा है ताकि आम जन, काष्ठ विज्ञान की विभिन्न बारीकियों को समझ सके। भारतीय चंदन - भारतीय वानिकी की अमूल्य वृक्ष प्रजाति में सम्मिलित है। इस विषय पर संस्थान (आई.डब्ल्यू.एस.टी.) द्वारा विशिष्ठ अंक प्रकाशित करने के लिए मैं पूरे दल को बधाई एवं साधुवाद देता हूं। आपका यह प्रयास चंदन की महिमा को भारत और विश्व में पुनर्जीवित करने के कार्य का मार्ग प्रशस्त करेगा।

(अश्विनी कुमार चौबे)

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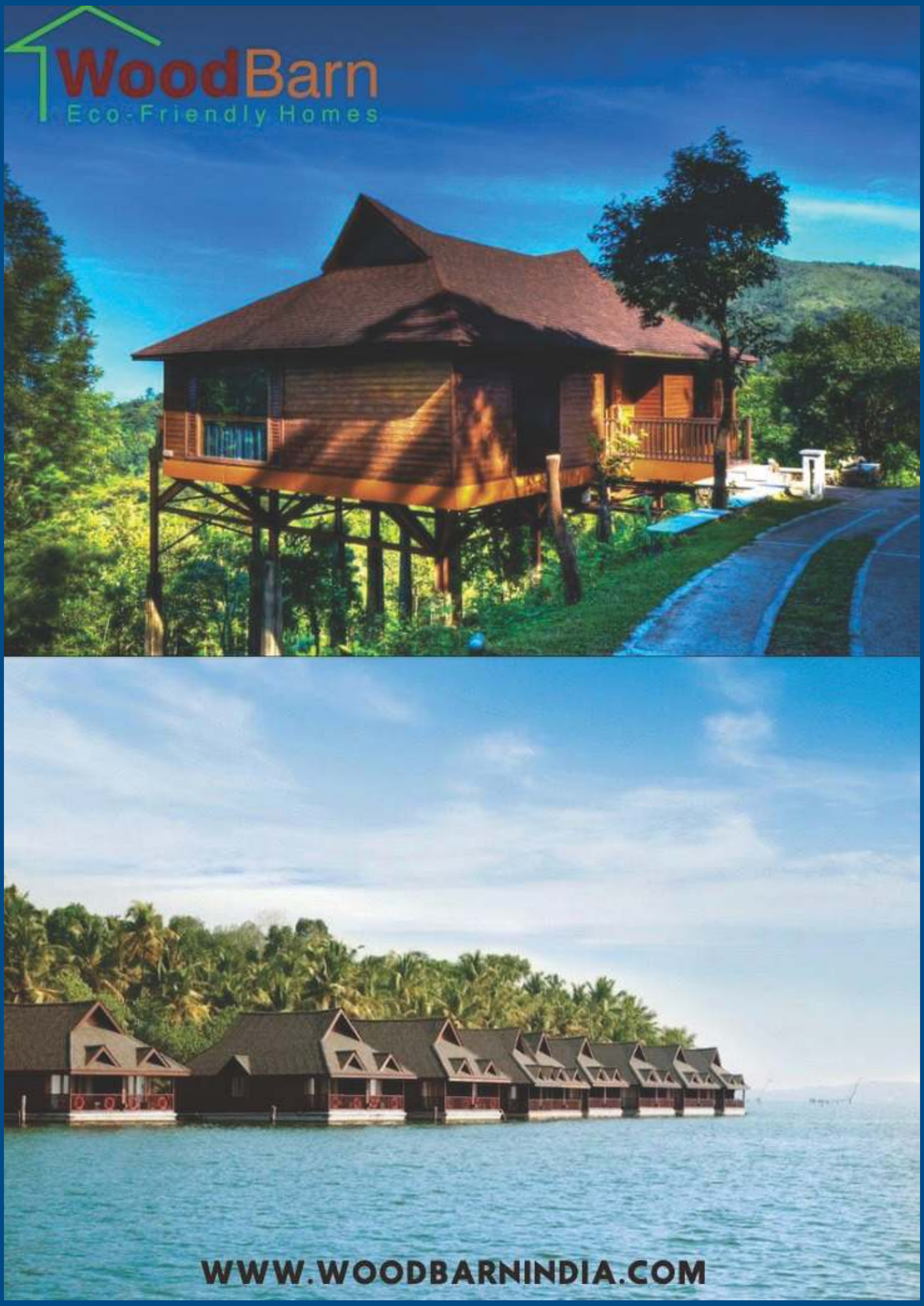
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IWST activities during July –September, 2021

Azadi Ka Amrit Mahotsav (India@75)
Poster Competition on Importance of Conservation of pollinators in different Ecosystems

As part of Azadi Ka Amrit Mahotsav celebration, Institute of Wood Science and Technology (IWST) conducted a poster competition on **"Importance of Conservation of the pollinators in different Ecosystems"** from 5-11 July 2021. About 140 students from colleges/universities of different states actively participated in the programme by sending digital posters and drawings through online mode. Best posters were selected, announced and displayed on IWST Website. The first prize was bagged by Mr. Visakh N U, Kerala Agricultural University, Kerala and second by Ms. Sayanhi Ghosh, Bangabasi Morning College, West Bengal. Ms. Francina Basil, KristuJayanti College, Karnataka and Ms. ParamitaKar, Chakdaha College, West Bengal shared the third spot. Prizes and Certificates were issued to the winners. Congratulations to the winners and all participants.

Training to IFS Officers on Practical Steps for State Forest Departments for Utilizing and Developing Forest Genetic Resources

IWST, Bangalore organized One week online training program on"Practical Steps for State Forest Departments for Utilizing and Developing Forest Genetic Resources"for serving IFS officers from Aug 02-06, 2021 sponsored by Ministry of Environment, Forest and Climate Change, Government of India. About 20 officers of 1990 to 2014 batch attended the training. Dr. M. P. Singh, IFS, Director, IWST chaired the panel discussion. The panel opined that youngsters need to be motivated to understand traditional forestry activities and proper documentation of success stories together with ecosystem services is the need of the hour. Capacity building and showcasing forestry activities whether it is ecosystem services

or raising trees outside forest through agroforestry is important. Forest Departments should simplify procedures & policies and make it user/industry friendly to maintain transparency.

Independence Day

IWST, Bengaluru celebrated 75th Independence Day of the country. Dr. M. P. Singh IFS, Director, IWST hoisted the National flag during the ceremony and addressed the scientists, staff and students of IWST.

Under Azadi Ka Amrit Mahotsav, Freedom Run Race was organized for the senior, junior and sub junior level children of IWST staff. A good number of children participated with great enthusiasm in the race which was flagged off by Sri. Surendra Kumar, IFS (Retd), Former Director, IWST. Prizes were distributed to the winners of the competition.

Training and Capacity Building for Personnel of Other Services on Sandalwood Cultivation and its Prospects

IWST organized a two day /online training on "Sandalwood Cultivation and its Prospects" for officials from various departments (other than forest department) during 26 – 27 August 2021. The training was sponsored by Ministry of Environment, Forest and Climate Change under the Umbrella Scheme: Forestry Training and Capacity Building - Training to Personnel of Other Services. About 60 officers from department of Ayush, horticulture, sericulture, agriculture, animal husbandry, judiciary, commercial tax, police, revenue, customs and watershed in addition to teaching faculty like professors and teachers from universities, colleges and schools participated in the training program.

World Bamboo Day

On the occasion of World Bamboo Day on 18 Sept 2021, Institute of Wood Science and Technology, Bangalore released the Vth issue (April-June 2021) of quarterly magazine **"Wood is Good, Grow More, Use More"** featuring exclusively bamboo related articles. A one day online training program on "Bamboo Propagation and Management" was also organized. Shri. Punati Sridhar, IFS, Executive Director, Bamboo Society of India & Former PCCF (HoFF), Karnataka Forest Department was the Chief Guest of the event.

Azadi Ka Amrit Mahotsav (India@75)
Webinar on Sandalwood Farming and Management of its Health

Under Azadi Ka Amrit Mahotsav celebration, IWST, Bangalore organized webinar on Sandalwood Farming and Management of its Health (in TAMIL) on 20 Sept 2021 for farmers to help them grow sandalwood in a healthy and sustainable way. About 426 participants from various states attended the training through Webex and Youtube.

Research Advisory Group Meeting

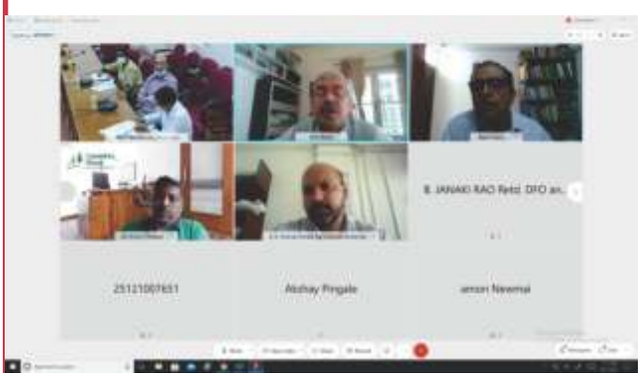
The Research Advisory Group Meeting (RAG) of the Institute of Wood Science and Technology, Bangalore was organized on 23 September 2021 to prioritize new research projects to bring in innovation in studies to be carried out in coming years and also review progress of ongoing research projects of the institute. The projects are framed to meet the requirements of Forest Departments, wood industries and other end users. The suggestions given by experts and stakeholders from different sectors are then incorporated in the project proposals. The meeting was chaired by Director, IWST and attended by Assistant Director General (Research & Planning), ICFRE, RAG members and also officers and Scientists of IWST.

Visit of Minister for Rural Development and Panchayati Raj, Government of India

Shri Giriraj Singh, Hon'ble Minister of Rural Development and Panchayati Raj, Government of India visited IWST, Bangalore on 25 Sept 2021. Principal Secretary to Government of Karnataka and Joint Secretary NRLM and Panchayati Raj were also present. Planting of sandalwood sapling was followed by presentation and discussion on various aspects of sandalwood.

Azadi Ka Amrit Mahotsav (India@75)
Webinar on Identification, Certification and Utilization of Timbers

On 27 Sept 2021, IWST, Bangalore organized webinar on Identification, Certification and Utilization of Timbers to commemorate Azadi Ka Amrit Mahotsav. It was suggested by experts that, imported timbers need to be certified before it enters India. It was expressed that forest certification or certification of timber is a prerequisite and due to the prevailing non-certification practices, India is losing its name. Implementation of timber harvest footprint methods, Due Diligence System and Green Government Procurement Policies, etc would probably help in reducing deforestation, and illegal feeling of trees and solve traceability and sustainability issues in the wood supply chain. About 90 participants from Wood Industries, Forest departments, agriculture universities and researchers discussed importance of timbers identification, utilization and chain of custody.



Hindi Pakhwada (14-28 September 2021)

IWST, Bangalore celebrated Hindi Pakhwada during 14-28 Sept 2021. During this period, various competitions were arranged for employees and students. The concluding program was held on 28 Sept 2021 with the address by Dr. M.P Singh, Director, IWST, where he encouraged increased use of Hindi as an official language in day-to-day official correspondence. He congratulated all the participants and distributed prizes to the winners

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The Indian Sandalwood: How IWST proposes to promote and popularise Sandalwood Cultivation

M. P. Singh,
Director, Institute of Wood Science and Technology, Bengaluru.

Institute of Wood Science and Technology (IWST) has been recognised as Centre of Excellence for Sandalwood Research by Indian Council of Forestry Research and Education, Dehradun. As a nodal agency for Sandalwood, IWST is in the forefront in coordinating, consolidating, supporting and trying to develop institutional mechanisms for not only reviving the past glory of sandalwood, but also striving for its conservation and sustained utilisation. IWST as a nodal agency in Sandalwood research has proposed comprehensive planto Ministry of Environment, Forests and Climate change, Government of India on a project mode for funding from Compensatory Afforestation Fund Management and Planning Authority (CAMPA) to Promote Sandalwood Cultivation for upliftment of socio economic status of Indian Farmers, details of which were published in Wood is Good (Volume 1, Issue 2, July-September 2020). The highlight of the proposed project aims at – helping in capacity building of master trainees and field trainees through-out India; Disseminating information on Sandalwood cultivation; Establishing Sandalwood based agro-forestry demonstration plots; providing Technology based support system (app based) for Sandalwood cultivation; helping in supplying Quality Planting Stock and, documenting information on various cultivation practices followed in different regions of India. The project envisages to meet the requirements of training and extension part of sandalwood cultivation and achieve the target of encouraging Sandalwood cultivation throughout India. In this project all the Indian Council of Forest Research & Education (ICFRE) institutes and centres are actively involved so that necessary technical support is provided across India. IWST will be equipping technically skilled master trainers across different ICFRE institutes These master trainers will in turn train local/field trainers at their respective institutes. These field trainees, further will train prospective Sandalwood farmers across the country. IWST will also continue conducting five days training programme on Sandalwood cultivation to all the stakeholders to enhance their scientific knowledge along with field inputs. The training provides a comprehensive exposure to the trainees from seed collection, seedling production, plantation establishment, harvesting, marketing along with legal implications. It is also intended to develop several one-acre demonstration plots with different agroforestry models that are region specific with support from Van Vigyan Kendras and Krishi Vigyan Kendras. Embodying the technical interventions, it is planned to develop and deploy mobile based application systems to help needy farmers with the correct answer at right time. As a long term objective, IWST aspires to promote sandalwood cultivation throughout India by solving the legal/policy issues associated with sandalwood cultivation and marketing.

Institute of Wood Science and Technology (IWST) is also emphasising on establishment of Special Purpose Vehicle (SPV) to facilitate cultivation, marketing and work as an advisory for national/state government in all aspects of popularising and promoting Sandalwood including Exim issues. SPV will carry out its functions under Nodal office at Bengaluru with following divisions:

1. Assessment and accreditation division:

This division shall be primarily involved in assessing the on-going activities and preparing guidelines in management of sandalwood plantations through proper Silvicultural interventions at different stages of sandalwood cultivation. Division will get involved in development of Standard Operating Procedures (SOPs) or Package of Practices (PoPs), a set of step-by-step instructions to help farmers to carryout complex routine operations for the cultivation of

Sandalwood. Therefore activities for the division include:

a Assessment of nurseries for self-sustenance in production of quality planting material

b Accreditation and quality control of nurseries for planting material and supply to the growers.

c Standardizing package of practices for cultivation of Sandalwood to achieve efficiency, quality output and uniformity of performance while reducing mis-communication and failure to comply with regulations

d Revising the classification of Sandalwood into three or four grades for selling;

e Evaluating the valuation methods of sandalwood

This wing of the SPV shall function with three expert consultants having knowledge on nursery raising & management, silvicultural practices, quality control & accreditation skills, along with one JPF and project assistant to begin with.

2. Extension and promotion Division

The Extension and Training division will provide necessary help and assistance to the organization for imparting the knowledge on package of practices for growing successful plantations. This division helps in setting up of sandalwood nurseries by farmers for production of quality planting material. This division will also provide necessary training to the NGOs on various aspects of agroforestry plantation such as - species, package of practices, plantation maintenance, disease and pest management, fire control, logging, transport etc. This division will be responsible for encouraging sandalwood network to bring all sandalwood growers in one network. This division promotes sandalwood cultivation and usages in the country besides, participation in national/international level exhibitions and trade fairs to create awareness about Indian sandalwood among the consumers and educate the consumers about the positive effects of sandalwood usages on human health. This division also encourage technology development and technology transfer for enhanced improvement in quality and quantity of sandalwood production. The extension wing of the SPV functions with three expert having knowledge on extension, communication, writing & editing skills as consultant along with one JPF and project assistant. The activities shall also include:

- Conducting regular training on growing successful plantations
- Training and Capacity building in nursery techniques.
- Creating awareness about Sandalwood in various social platforms
- Transfer of technology developments and package of practices to various end users,

3. Policy and market co-ordination Division

This division will help in studying the dynamics of market price for the agroforestry products and assist the growers in obtaining the optimum market price for sandalwood. It provides guidance on various activities related to market information, intelligence, research studies and economic aspects of sandalwood cultivation. This division will also participate in the market committee meetings from time to time for developing and encouraging e-marketing system by fixing the prices, minimum support prices (MSP) etc. along with other departments on issues of Trade and Commerce (T&C), Statistics, Information Technology etc. Over all this division will act as facilitator and service provider on policy inputs to the Governments to make Sandalwood cultivation farmer friendly. Collaboration with wood based industries in creating information base, organizing supply chains and wood trading platforms. This division functions with three experts as consultants having knowledge on legal & policy aspects, marketing & statistics, trade & commerce along with one JPF and project assistant. Therefore activities of the division shall include:

- Carrying out various activities related to market information and intelligence, market research studies and economic aspects of sandalwood cultivation including Exim issues
- Networking and coordinating with the Sandalwood growers and providing market price updates for Sandalwood

4. Research and Development division

The main activity of this division is to give advice on research and development needs on different aspects of sandalwood cultivation viz. pest and diseases,

protection, agroforestry model development etc. This division supports R&D projects by funding on various aspects of sandalwood cultivation and its technology development. SPV will fund basic, applied and regulatory research aspects such as plant improvement (breeding and biotechnology), plant production (agroforestry and soil science), plant protection (pathology and entomology) and sandalwood quality covering biochemistry, tree protection using electronics and engineering. This wing of the SPV functions with three additional experts having knowledge on Agroforestry, entomology, pathology as consultants along with one JPF and project assistant. The activities of this division shall include:

Conducts both basic and applied research on various aspects of Sandalwood improvement, protection and sustained utilization

Planting stock improvement and propagation of tissue culture plants

5. Administrative Division

This division deals with administration, accounts, audit, vigilance, and establishment part of the SPV for smooth functioning.

Special Purpose Vehicle (SPV) shall serve as the friend, philosopher and guide to the sandalwood development sector covering the entire value chain. The core activities are primarily directed towards research & development, transfer of technology, quality improvement, extending development support to growing sector, promotion of sandalwood in export and domestic markets. The SPV will promote cultivation of sandalwood plantations for meeting the raw material demand of the sandalwood based industry on continuous and sustainable basis. The Institutional Framework for SPV shall comprise of a Central office desk with Inspector General, Survey and Utilization, Ministry of Environment, Forests and Climate Change, Government of India. Presently, this SPV will work by hiring of experts and temporary staff as per the need basis. Other important sectors like Agriculture, Medicinal Plant, Horticulture, Biodiversity, Industry, farmers' organisation etc., shall represent in the SPV for integrated programs of sandalwood cultivation expansion. However, in the later stages this SPV may run independently as a separate institution under Ministry of Environment, Forest and Climate change (MoEF & CC). This SPV shall be a component of the MoEF & CC, Government of India.

In the meantime, Economic Advisory Council to the Prime Minister (EAC-PM) has constituted a committee namely Sandalwood Development Committee vide Official Memorandum No. EAC-PM/Sandalwood/2021 dated 3rd March 2021, details of which are annexed;

i	Dr. Bibek, Debroy, Chairman, Economic Advisory Council to the Prime Minister (EAC-PM)	-Chairman
ii	Shri. Ratan P. Watal, Member Secretary	-Co-chairman
iii	Secretary, or his nominee Ministry of Environment, Forest and Climate Change (MoEF& CC)	-Member
iv	Secretary, or his nominee Ministry of Agriculture & Farmers Welfare (MoA& FW)	-Member
v	Secretary, or his nominee Ministry of Ayurveda, Yoga, Naturopathy, Unani, Siddha, Sowa-Rigpa and Homoeopathy (AYUSH)	-Member
vi	Secretary, Ministry of commerce or his nominee	-Member
vii	Chief Executive Officer, National Medicinal Plants Board	-Member
viii	Dr. M.P. Singh, Director/Dr Arun Kumar, Scientist-G, Institute of Wood Science and Technology	-Member
ix	Dr. Shyam Vishwanath, Director, Kerala Forest Research Institute, Thrissur	-Member
x	Dr. K.T. Parthiban, Dean, Forest College & Research Institute, TNAU, Mettupalyam	-Member
xi	Shri. Pradeep Kapoor, Jagat Aroma Oils Distillery, Kannauj	-Member
	Shri. K. Rajeswara Rao, Sr. Adviser, Economic Advisory Council to the Prime Minister (EAC-PM)	- Member Convener

The SDC may induct any other expert as its member.

Terms of Reference of SDC:

i To identify issues relating to sandalwood plantations and marketing in consolation with various State Governments and agencies.

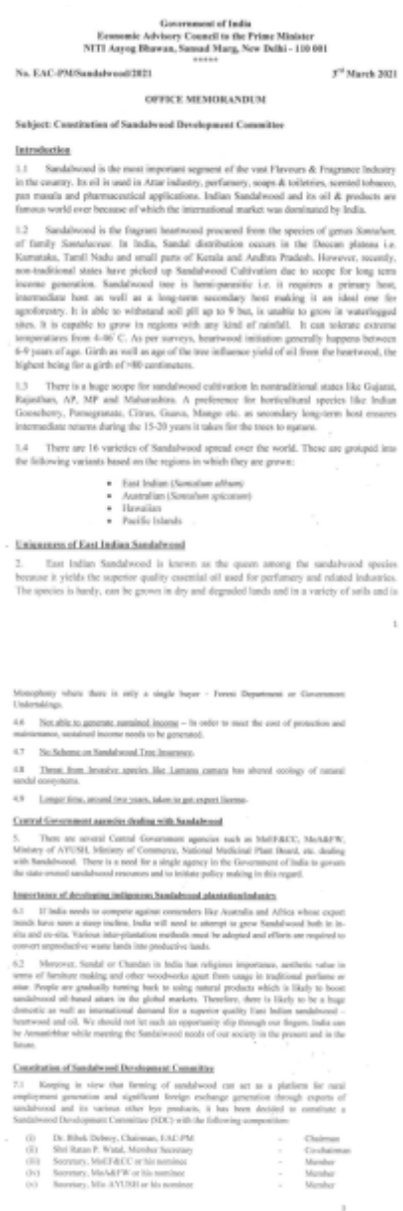
ii To examine the legal provision sand suggest amendments to increase Sandalwood Plantation and marketing in different part of the country

iii To study the Australian model of Sandalwood Plantation and its marketing, including its bye products, and suggest measures to adopt the same or any other better ways in India;

iv To study the domestic & International markets/trade for Sandalwood and its bye products and suggest measures for promoting production and marketing to increase value addition and employment domestically; and

v Any other matter relating to the development of Sandalwood in the country.

First meeting of the Sandalwood Development Committee was held in the month of April 2021 to get different viewpoints of all stakeholders. However, due to covid-19 activities of the Sandalwood Development Committee are delayed. Meanwhile it was thought to bring out a special issue on sandalwood in Wood is Good magazine to update the present scenario of sandalwood cultivation in India.



Government of India
Economic Advisory Council to the Prime Minister
NITI Aayog Bhawan, Sansad Marg, New Delhi - 110 001

No. EAC-PM/Sandalwood/2021 — 3rd March 2021

OFFICE MEMORANDUM

Subject: Constitution of Sandalwood Development Committee

Introduction

1.1 Sandalwood is the most important segment of the vast Flavours & Fragrance Industry in the country. Its oil is used in Attar industry, perfumery, soaps & toiletries, scented tobacco, pan masala and pharmaceutical applications. Indian Sandalwood and its oil & products are famous world over because of which the international market was dominated by India.

1.2 Sandalwood is the fragrant heartwood procured from the species of genus *Santalum*, of family *Santalaceae*. In India, Sandal distribution occurs in the Deccan plateau i.e. Karnataka, Tamil Nadu and small parts of Kerala and Andhra Pradesh. However, recently, non-traditional states have picked up Sandalwood Cultivation due to scope for long term income generation. Sandalwood tree is hemi-parasitic i.e. it requires a primary host, intermediate host as well as a long-term secondary host making it an ideal one for agroforestry. It is able to withstand soil pH up to 9 but, is unable to grow in waterlogged sites. It is capable to grow in regions with any kind of rainfall. It can tolerate extreme temperatures from 4-46° C. As per surveys, heartwood initiation generally happens between 6-9 years of age. Girth as well as age of the tree influence yield of oil from the heartwood, the highest being for a girth of >80 centimeters.

1.3 There is a huge scope for sandalwood cultivation in nontraditional states like Gujarat, Rajasthan, AP, MP and Maharashtra. A preference for horticultural species like Indian Gooseberry, Pomegranate, Citrus, Guava, Mango etc. as secondary long-term host ensures intermediate returns during the 15-20 years it takes for the trees to mature.

1.4 There are 16 varieties of Sandalwood spread over the world. These are grouped into the following variants based on the regions in which they are grown:

- East Indian (*Santalum album*)
- Australian (*Santalum spicatum*)
- Hawaiian
- Pacific Islands

Uniqueness of East Indian Sandalwood

2. East Indian Sandalwood is known as the queen among the sandalwood species because it yields the superior quality essential oil used for perfumery and related industries. The species is hardy, can be grown in dry and degraded lands and in a variety of soils and is

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Monopsony where there is only a single buyer - Forest Department or Government Undertakings.

4.6 Not able to generate sustained income – In order to meet the cost of protection and maintenance, sustained income needs to be generated.

4.7 No Scheme on Sandalwood Tree Insurance.

4.8 Threat from Invasive species like Lantana camara has altered ecology of natural sandal ecosystems.

4.9 Longer time, around five years, taken to get export license.

Central Government agencies dealing with Sandalwood

5. There are several Central Government agencies such as MoEF&CC, MoA&FW, Ministry of AYUSH, Ministry of Commerce, National Medicinal Plant Board, etc. dealing with Sandalwood. There is a need for a single agency in the Government of India to govern the state-owned sandalwood resources and to initiate policy making in this regard.

Importance of developing indigenous Sandalwood plantation/industry

6.1 If India needs to compete against contenders like Australia and Africa whose export trends have seen a steep incline, India will need to attempt to grow Sandalwood both in in-situ and ex-situ. Various inter-plantation methods must be adopted and efforts are required to convert unproductive waste lands into productive lands.

6.2 Moreover, Sandal or Chandan in India has religious importance, aesthetic value in terms of furniture making and other woodworks apart from usage in traditional perfume or attar. People are gradually turning back to using natural products which is likely to boost sandalwood oil-based attars in the global markets. Therefore, there is likely to be a huge domestic as well as international demand for a superior quality East Indian sandalwood – heartwood and oil. We should not let such an opportunity slip through our fingers. India can be Atmanirbhar while meeting the Sandalwood needs of our society in the present and in the future.

Constitution of Sandalwood Development Committee

7.1 Keeping in view that farming of sandalwood can act as a platform for rural employment generation and significant foreign exchange generation through exports of sandalwood and its various other bye products, it has been decided to constitute a Sandalwood Development Committee (SDC) with the following composition:

(i)	Dr. Bibek Debroy, Chairman, EAC-PM	- Chairman
(ii)	Shri Ratan P. Watal, Member Secretary	- Co-chairman
(iii)	Secretary, MoEF&CC or his nominee	- Member
(iv)	Secretary, MoA&FW or his nominee	- Member
(v)	Secretary, M/o AYUSH or his nominee	- Member

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ideal to be grown in combination with horticultural species as secondary hosts. There is no uniform pattern in formation of heartwood and oil content with increasing age. Therefore, the population of East Indian Sandalwood grown anywhere in the world may have same yield.

Import/Export Trends of Indian Sandalwood

3. India is hardly able to satisfy its domestic sandalwood needs and rely mostly on Australia and African nations to meet its requirements. In the 1970s when Indonesia had banned export of Sandalwood to meet its domestic requirements, India had utilized the occasion to meet the international requirements, thereby creating an environment for over exploitation and smuggling, giving rise to notorious Sandalwood smugglers like Veerappan. This eventually led to the decline in production in India. At that time, Australia started planting East Indian Sandalwood due to its high yield and entered the international market. India faced a wide gap between demand and supply. Now, India is a huge importer of Australian Red Sandalwood powder, Sandal Wood Oil from Ethiopia and Tanzania, Wooden Frames from China. Sandalwood currently enjoys vulnerable status in India.

Reasons for Decline in Sandalwood production in India

4. The following reasons could be attributed to the decline in Sandalwood production in India:

4.1 Legal Hassles Faced by Potential Sandalwood Farmers - In most of the states, although owner of the land is legally entitled to the sandalwood tree in his land, harvesting is strictly prohibited. Owner of the land cannot fell, sell, convert or dress sandalwood obtained from such a tree or possess, store, transport or sell the sandalwood.

4.2 Security Concerns - State Acts make the owner of the land to protect the Sandalwood tree from thefts. Due to increasing global demand, theft concerns have risen to an extent that plantations have perimeter fencing and armed guards resulting in increased input cost.

4.3 Quality Planting Material of Sandalwood - Traditionally, seedlings are raised in 1500 mm poly bags while it can be grown in much smaller root trainers of 270 mm size. Sandalwood plants require primary host at the nursery stage and long-term secondary host when planted in the field. Seedlings exhibit better growth when grown in small root trainers with a leguminous host.

4.4 Lack of Scientific Studies - Information is lacking on growth, cultivation methods, disease management, heartwood formation, oil yield and host possible compatibility with horticultural crops when grown on private lands under a controlled environment. For example, closely spaced plantations/tree resulted in poor growth and yield of oil in Gujarat.

4.5 Less Incentives for Sandalwood Cultivators - In 2017, the average procurement price of Sandalwood from farmers by Karnataka Soaps and Detergents Ltd (KSDL) was Rs.6,400/kg of heartwood and a 15-year-old tree is expected to yield 15 kg heartwood under cultivated conditions. This price is much less compared to the retail price. There is a

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(vi)	Secretary, Ministry of Commerce or his nominee	- Member
(vii)	CEO, National Medicinal Plants Board	- Member
(viii)	Dr. M.P. Singh, Director / Dr Arun Kumar, Scientist - F, Institute of Wood Science & Technology, Bengaluru	- Member
(ix)	Dr Shyam Viswanath, Director, Kerala Forest Research Institute, Thrissur	- Member
(x)	Dr K.T. Parthiban, Dean, Forest College & Research Institute, TNAU, Mettupalayam	- Member
(xi)	Shri Pradeep Kapoor, Jagat Aroma (Hs Distillery, Kannauj	- Member
(xii)	Shri K. Rajeswara Rao, Sr Adviser, EAC-PM	- Member Convenor

The SDC may induct any other expert as its member.

7.2. Following would be the Terms of Reference of SDC:

(i) To identify issues relating to Sandalwood plantation and marketing in consolation with various State Governments and agencies;

(ii) To examine the legal provisions and suggest amendments to increase Sandalwood plantation and marketing in different parts of the country;

(iii) To study the Australian model of Sandalwood plantation and its marketing, including its bye products, and suggest measures to adopt the same or any other better ways in India;

(iv) To study the domestic & International markets/trade for Sandalwood and its bye products and suggest measures for promoting production and marketing to increase value addition and employment domestically; and

(v) Any other matter relating to the development of Sandalwood in the country.

The SDC shall submit its report by August 2021.

(K. Rajeswara Rao)
Senior Adviser, EAC-PM &
Member Convenor, SDC

Distribution:

Chairman, Co-chairman and Members of the Sandalwood Development Committee mentioned above

Status and Scope of Indian Sandalwood (*Santalum album* L.) in Haryana, Himachal Pradesh and Punjab

Jagdish Chander,
Principal Chief Conservotor of Forests (HoFF),
Panchkula, Haryana.

Introduction

Indian Sandalwood or simply Sandalwood (*Santalum album* L.)- a member of the family Santalaceae, has great historical, mythological, cultural, ecological, and economic significance in India and is popularly called *Chandan*, *Srigandha*, and *Chandnam* (meaning fragrant or wood for burning incense). Owing to the possession of one of the best pleasing scents of the world, fine carving characters, people's great faith in relieving stress and providing mental peace, use of wood in Puja (worship), Tilak, and many rituals in many faiths- all these make *Chandan*/ sandalwood the costliest wood of India. Therefore, it will not be exaggerating to crown it as "Green Treasure or Green Gold". A small tree attaining a height of about 10m, it is native to the tropical belt of peninsular India, eastern Indonesia (islands of Timor and Sumba) and Northern Australia (Orwa et al, 2010). The main distribution is in the drier tropical regions of India and the Indonesian islands of Timor and Sumba. Outside India, its natural distribution extends from 30 degrees N to 40 degrees S; from Indonesia to Juan Fernandez Island (Chile) in the west and from the Hawaiian archipelago in the north to New Zealand in the south.

It is truly green gold and is the second costliest wood in the world after African Blackwood (*Dalbergia melanoxylon*). However, due to illegal harvesting and overexploitation, mature trees are hard to find. So much so that in many parts of India, economically viable trees (above 30 cm dbh) are commercially extinct (Arunkumar, et al, 2019). Further, the monopoly of sandalwood trade by the Governments of Karnataka, Tamil Nadu and Kerala and its consequences have resulted in severe exploitation, pushing *S. album* into the 'vulnerable' category of the IUCN Red List.

It has deep roots in the history and culture of India since time immemorial and finds a special place in all the major religions of India. The wood is used for worshipping the God Shiva, and it is believed to be the abode of Goddess Lakshmi. It is considered a symbol of vitality and is venerated in India because people of India believe that it emanates a great spiritual radiance and it produces protective energies. Sandalwood plays an important role in various religions. *Chandan* is treated as an aid to meditation and spiritual devotion and to improve mental clarity. Hindus support the Tikka (a coloured spot on the forehead) of its paste on their forehead. Sandalwood paste is used in many religious rituals and ceremonies in many religions. In Jainism, sandalwood paste is mixed with saffron for Puja. In Buddhism, sandalwood oil is used to produce incense for worship.

Sandalwood is reported to have antiseptic and anti-inflammatory properties and is beneficial for use in minor skin irritations. It has also been reported to have anti-cancer properties and is useful in heart disease. Sandalwood is known to dissipate the effect of hot sun or fever, satiate thirst and provide a cool but refreshing feeling. The wood paste is useful in inflammation, treating boils, and applied on the forehead in fever and on skin diseases. It is one of the finest woods to carve on and is a favourite wood of carving artisans.

Chandan was introduced in North India at regular intervals but the performance of its plantations in farmlands/agriculture fields in north India was not good. However, in the jungle, it thrives very well in the company of *Lantana camara* suppressing the latter to some extent and freeing the land from the invasive problems of *L. camara*. However, ecologists have started raising fingers on it owing to its spreading nature in biodiversity rich areas. The birds aid in the dispersal of seeds. Tipu Sultan, the then ruler of Mysore, declared it a royal tree in 1792 and it

became a protected tree in his empire. In Haryana, Punjab, and Himachal Pradesh whether it is found in the forests or outside forests, it is treated within the framework of existing rules and regulations with no extra restrictions are imposed.

The acceptance or the rejection of the species and its genotypes in Karnataka, Tamilnadu, and Kerala is done based on Santalol content. However, this is not an issue in north India. If sufficient wood is available, it can be converted into furniture, and the leftover wood pieces, chips, and scrap can be used for extracting oil which can be used in making soap, cosmetics, and aromatherapy. The fine powder can be used in incense sticks. There are no restrictions on the growing of sandalwood, felling, and transporting it in Haryana and Punjab if grown in the fields. Having learned lessons from the success of agroforestry in Haryana and Punjab as there are no restrictions on farmlands, sandalwood cultivation at least in Haryana and Punjab has great scope.

Status in Haryana

The total geographical area of Haryana is 44,212 square kilometers. The state has four biogeographical regions namely- Shiwalik in the north, central plains, a semi-arid region in the west, and Aravalli hills in the south. The maximum altitude of Shiwalik in Haryana is 1492 m. There is no written record of the first introduction of *Chandan* in Haryana. However, it is believed that it was introduced in Haryana about half a century ago. Seedlings were planted in about half a hectare area. The seedlings did not succeed. The reasons for the failure were not recorded. The old generation of Haryana foresters believes that *Chandan* cannot grow in Haryana.

Being the most prized and sought after wood of India, the efforts to grow *Chandan* as an ornamental tree in homestead gardens continued but not with much success. Hence, nobody thought of planting *Chandan* for commercial purposes. In 1991 about 250 sandalwood saplings were planted in Chandi Mandir Western Command Headquarters near Panchkula by army officials for ornamental purposes. The plants survived for a year or so and later died probably for want of knowledge of the requirement for growing sandalwood plants.

The efforts continued to introduce it as an ornamental plant as its presence itself is considered a matter of pride in Haryana. Somehow, the forest officers are not convinced with the past performance of the species and, therefore, are not very keen to cultivate this species, but then there happened something which is now changing the attitude of foresters of Haryana. It was in the year 2005 that fifty sandalwood saplings were planted in Mallah Herbal Park near Pinjore in Panchkula district of Haryana. This herbal park was established in a jungle in Shiwalik foothills after cutting/ uprooting *L.camara*. However, the rootstocks of *L. camara* remained. The planted saplings of Sandalwood got a preferred host to attach its host to the roots of *L. camara*. Almost all *Chandan* saplings planted in this park survived.

The planted seedlings started producing seed after about seven years. The fruits were picked up by birds and dispersed in adjoining *L. camara* infested jungle. There was no human interference at all. The seeds germinated and *L. camara* favoured sandalwood in two ways – one by helping in meeting its nutritional requirement and the other by nursing and protecting the young seedlings from browsing by animals. In this way, sandalwood has now occupied about two hectares area. These observations are very important from the management of sandalwood in the jungle and on the farm. The lesson to be learned is that we cannot follow clean cultivation in areas where sandalwood is to be introduced for farming on the farmlands. In forest areas, if we give little space to sandalwood, it will slowly establish and grow even in *L. camara* infested areas. For purely technical reasons it will not be proper to introduce sandalwood in new forest habitats keeping in view the biodiversity issues. However, for managing *L. camara* infested areas, it will be acceptable to introduce it. It will be a win-win situation. On one hand, it will have some control on *L. camara*, on the other hand, sandalwood will slowly occupy the areas infested by *L. camara*. Further, the latter will not be completely removed from the area and, therefore, it will also satisfy those who say that *L. camara* has become part of the habitat in India as it has been staying in India for more than two hundred years and protects soil, provides habitat to several butterflies, birds like Red Jungle Fowl (*Gallus gallus*) and Indian white eye (*Zosterops palpebrosus*).

As regards the management of sandalwood in the area adjoining Mallah Herbal Park, the plants have not attained exploitable diameter as yet. At present, the area is small and trees are below the exploitable diameter, the protection of the plants is not an issue. Moreover, its presence in the forest area still goes unnoticed. However, once it spreads further, the protection issue is going to be there. For a win-win situation in managing *L. camara* in the forest, Haryana Forest Department is planning to allow its spread. Elsewhere in the state, the people grow it as an ornamental plant or in the botanical garden in the parks. Only about one thousand sandalwood plants are raised in Haryana Forest Department nurseries every year mainly in Shiwalik forest divisions namely-Morni Pinjore, Ambala and Yamunanagar.

The neighbouring Punjab state is promoting sandalwood cultivation on farmlands and the farmers of Punjab are showing keen interest in its cultivation and are planting it in their fields. In Haryana too, the farmers are contacting the forest department and asking for guidance. No commercial plantations have yet come up in the state but irrespective of the santalol content, the state will see some commercial sandalwood plantations at least on the absentee farmers' fields. Marketing will not be an issue as people would like to be the proud owners of sandalwood furniture or carved articles. And in this case, fragrant oil is not an issue.

Status in Himachal Pradesh

Situated in the northwestern part of India, Himachal Pradesh is a hilly state characterized by extreme landscapes and peaks. The total geographical area of the state is 55,673 km^2 and the altitude varies from 465 m to about 7000 m above mean sea level. Sandalwood is not native to Himachal Pradesh. and was introduced in Himachal Pradesh owing to its very high economic value. It is said that Shri. Sohan Lal Sood – a resident of Jwalamukhi area, then Major in Indian army got mesmerised with the species and carried with him three seedlings of sandalwood from Karnataka and returned to native place Jwalamukhi in Kangra district of H.P. Jwala Ji temple is located at an altitude of about 610 m and the Shiwalik hills in the background of Jwala Ji temple are located at about 800 m above mean sea level. It is said that he planted two sandalwood plants in his courtyard and the third one in the Jwalamukhi hills in the background of the renowned Jwala Ji temple. The plants planted in his courtyard did not survive but those planted in the forest got good host in the form of *L.camara.* The plants grew to maturity and flowering and fruiting also took place. The birds started dispersing the seeds and continue even today. At present, sandalwood is found scattered in the Jwalamukhi forest and adjoining private lands in about a 15 km radius of the Jwala Ji shrine including farmers' fields. It is spreading in the jungle at the rate of about fifty meters per annum. There is no legal ban on the cultivation of sandalwood in H.P. and the interesting point is that the species is growing on farmers' fields/land too. The forest department encourages farmers in H.P. in general and in the Jwalamukhi area, in particular, to grow sandalwood on their land owing to its very high commercial value. Himachal Pradesh Forest Department grows annually about 10,000 sandalwood seedlings in its nurseries, about 80% of this in the Dehra forest division under which the Jwalamukhi area falls.

Punjab Land Preservation Act, 1900 applies to the whole of the state. However, that is a general act applicable to all species and not to sandalwood alone. Having no specific restrictions on cultivation, harvesting, and transport of sandalwood in H.P., the farmers either let it grow or plant it on their fields, though mainly in the Jwalamukhi area. The sporadic distribution of sandalwood has also been noticed almost throughout the Dehra forest district in Kangra district. The sporadic distribution in areas other than the Jwalamukhi hill range is in addition to the presence of sandalwood in a 15 km radius in the Jwalamukhi hill range. Accordingly, sandalwood occupied area needs scientific management. However, the area finds no mention in the working plan document of the Dehra forest division. Further, possession of even one tree in Himachal Pradesh is considered to be a matter of pride. There is no doubt that the people of Himachal Pradesh like sandalwood for economic and cultural reasons. As sandalwood is growing successfully on its own in the Jwalamukhi area, there is ample scope for extending its cultivation in the entire Shiwalik region of the state especially in Hamirpur, Bilaspur, Una, lower areas of Kangra, lower areas of Solan and Sirmaur districts on farmers'

fields. There is not much information available on its impact on the biodiversity of Shiwalik. However, it can be safely said that it can play an important role in the long-term management of *L. camara* in Shiwalik. It is not an aggressive plant species and is not likely to replace other species of ecological and economic importance. It will, therefore, be a win-win situation even in the forests, let there be upliftment in the economic status of the people.

As in other parts of the country, the protection of sandalwood in the forests as well as in the farmers' fields is a big issue. The smuggling of the wood does take place. That is why the presence of trees having a commercially exploitable diameter in forests or farmers' fields is almost nil. However, there is no report of the presence of organised sandalwood smuggling mafia in Himachal Pradesh.

The maximum girth recorded in the Jwalamukhi jungle is 51cm. Analysis of the content of fragrant oil in Himachal Pradesh sandalwood has not been done. The formation of heartwood and sapwood and their ratio has not been documented. Heartwood formation is an issue, though it is not a hindrance as regards the demand for its wood in the region. Himachal Pradesh raises annually about ten thousand seedlings in the low hills, about 60% of them in the Dehra forest division. Irrespective of fragrant oil content and heartwood, the possession of *Chandan* in Himachal Pradesh in tree form or wood formation is considered as a matter of pride. If sufficient wood is available, the well-off people in the towns would like to go for its furniture and the carved decorative pieces.

Besides *L. camara,* sandalwood is also using *Cassia fistula* and *Acacia catechu* as its host as per the field observation. The average girth is just close to 30 cm at breast height. Sporadically, sandalwood is also found in Pragpur in Kangra district, Nadaun in Hamirpur and some parts of Bilaspur districts indicating that sandalwood is introduced in these areas as well.

Status in Punjab

Punjab means land of five rivers. The total area of Punjab is 50,362 square kilometers. The geography of the state comprises low Shiwalik hills in the north, fertile central plains, and semi-arid southwest. There is no written record of the first introduction of sandalwood in Punjab but it is believed that it was introduced in the state during the joint Punjab era or immediately after carving Haryana out of Punjab. However, the past introductions did not succeed. Thereafter, sandalwood was introduced in Punjab Forest Department's Research Plot in Sanur in Patiala district about 30 years ago. Thereafter, sandalwood was planted on an area of about three hectares in the Shiwalik hills of Hoshiarpur district in 2012. The plantation both in a research plot in Sanour and Shiwalik hills were successful. Sandalwood trees grown in Sanour were analysed by the Institute of Wood Science and Technology, Bangalore for heartwood and essential oil content five years ago. Sandalwood plants planted in Shiwalik hill forests reached the reproductive stage in about 7-8 years and now they are setting seeds. The seeds are being dispersed by the birds and therefore, natural regeneration is also taking place. At present, sandalwood is found in forest areas of Talwara and Dasuha in Hoshiarpur district and Shiwalik foothills of Ropar district.

Punjab forest department has established sandalwood nurseries in Talwara and Dasuya. Annually, about seventy thousand sandalwood plants are raised in these nurseries of Punjab forest department-fifty thousand seedlings in Talwara nursery, ten thousand in Dasuya nursery, and another five thousand elsewhere in the state. Punjab Government is promoting sandalwood cultivation in Punjab and distributing sandalwood saplings in holy shrines as "Prashad". Sandalwood plants are also sold @ Rs. 35 per plant within the state and @ Rs. 45 per plant for the residents of other states. A demonstration plot adjacent to Talwara nursery has also been established in Talwara. Some private nurseries have also come up in Punjab and Progressive Chandan Farmers Association (PFCA) has also come up.

The farmers of Punjab have tremendous interest in raising sandalwood purely for economic reasons. Annually, 25,000 to 30,000 plants are provided to the farmers in the state. There are about ten sandalwood plantations in the state on the farmers' fields. While

some are planted in household premises, office complexes for ornamental purposes, the others are planted in the fields for commercial purposes. The total area under sandalwood in the state on the farmers' fields is around twenty hectares. One good plantation of 7-8 years old has been established at Mattewara forest in Ludhiana by the forest department. However, the plantations done by the farmers are not more than 3-4 years. The plants planted in the forest perform better than the plantations in the fields. As regards the fragrant oil, the oil content in Punjab Sandalwood was 2.29% (Babita Mishra *et al*, 2018) as against a maximum of 4% in its natural home- Karnataka, Tamilnadu, and Kerala. Most of the trees yielded 1.5 to 3% oil yield (Sandeep *et al*, 2016). Oil content does not seem to be an issue as the wood with less oil content will have an immediate market for other uses like carving and furniture. The long gestation period is an issue as it is elsewhere in other parts of the country. If cultivated on scientific lines, sandalwood has great scope for enhancing the economic status of the farmers of Punjab.

Conclusion

Being the most prestigious and costliest wood of India, Sandalwood (*S. album*) was, is, and will remain a sought after wood in India and abroad. There is a big craze among the farmers of North India for cultivating sandalwood in their fields. Santalol content which imparts fragrance to the wood does not seem to be an issue in North India. It is a status symbol and the possession of sandalwood is alone considered a matter of great pride. Sandalwood tag is sufficient for making one the proud owner of sandalwood even if the wood is not high in fragrant oil. The possession of *Chandan* wood, therefore, is going to be a status symbol in north India if sufficient wood is available. Accordingly, its wood will find an evergreen market in north India. People will love to be the proud owners of sandalwood furniture and other items of interior decoration even if the fragrant oil content is low. However, protection of the trees is a big issue even in north India as elsewhere in other Indian states. There is a mixed response among the experts owing to the long gestation period of at least 25 years and the less heartwood formation in north India. Keeping in view biodiversity reasons, it will not be hundred percent correct to introduce sandalwood in new habitats but for managing *L. camara* infested forest areas, it will be a win-win situation from all angles. Moreover, not being a non-sense species, it will never attain a status of invasive species. As there are no restrictions on growing, felling, and transporting sandalwood in states like Haryana and Punjab outside forests, its cultivation will flourish at least in these states on farmlands. Therefore, sandalwood cultivation on scientific lines has a great scope in North India at least for the next one hundred years.

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Wood Technologist Association (WTA) is India's apex non-government organisation of plywood & other wood-panel based industries, providing a unique platform for all stakeholders: Government - Research Institutions – Industry – Machine Manufacturers - Technologists - Agroforestry Farmers, to interact and introduce path-breaking measures for progress of the industry.

WTA strives to make true the vision of Hon'ble Prime Minister Shri Narendra Modi of making wood-sector “ATAMNIRBHAR” and for past 12 years has been relentlessly pursuing the cause of its stakeholders, addressing their key issues and seeking suitable policy-changes with Government agencies (MoEFCC, FRI, IPRITI, FIPPI, IWST and others).

WTA, led by President: Shri S.C. Jolly & a team of professionals' technologists / field-experts, also collaborates with international wood-chambers / associations for mutual co-operation & adoption of best practises in the industry. WTA has organised host of conferences, seminars, training workshops, awareness campaigns and Industry-meets for taking forward initiatives of the industry.

WTA is a member of:

1. Bureau of Indian Standards (BIS) CED-9 CED-20 Committees.
2. President WTA (Shri S.C. Jolly) is a Member of Managing Committee of FIPPI.
3. President WTA (Shri S.C. Jolly) is a Member of Steering Committee of IPRITI.
4. President WTA (Shri S.C. Jolly) is a Life Member of IWST, Bangalore.
5. WTA, since the past decade, is in continuous dialogue with Ministry of Environment, Forests & Climate Change (MoEF&CC) and made representations to their Hon'ble Ministers: Shri Jairam Ramesh, Shri Anil Madhav Dave, Dr. Harsh Vardhan and recently to Shri Prakash Javdekar for bringing forth relevant issues of plywood industry.
6. WTA submitted Memorandums to MoEF&CC on various occasions for considering demands of the Industry /Stakeholders for driving suitable policy-changes like reduction in GST, lease of barren-land to farmers for enhancing green cover by plantation drives, research & development on Melia Dubia as substitute of face-veneer, foreign-currency savings through reduction in imports, transportation-subsidy and similar issues. Recently, on WTA's perusal, the e-Transport facility for farmers was agreed upon by Government of India.
7. WTA and FRI (Dehradun) collaborated under Green India Mission to organize Industry-Institute- Farmer- Meets at Ludhiana (Punjab), Yamunanagar (Haryana) and Pantnagar (U.P).
8. WTA's key role in agroforestry was explained to Shri C.K. Mishra (Secretary, MoEF&CC) by Shri Manoj Gwari (Secretary, WTA) at a meet organized at Forest Research Institute, Dehradun.
9. WTA hosted international delegations from Malaysia, China and Ghana for partnership - dialogue with Indian Plywood Business Groups. In a recent visit of Sarawak Timber Association from Malaysia, WTA coordinated and organized their meetings with IPIRTI and other agencies.
10. WTA, under aegis of Shri S.C. Jolly, started the National WhatsApp Group: “Agroforestry” bringing together key decision-making administrators, leading industrialists and other subject-matter experts, during the COVID times for suggesting and implementing the way-forward for overcoming challenges being faced. The patronage and active-participation of all members including Additional Secretary Dr. Alka Bhargava, Dr. Arun Rawat (DG, ICFRE & Director, FRI), Dr. M.P. Singh (Director IPIRTI & IWST), and other eminent personalities (Industry Association heads, Senior-Industrialists & Technical experts) has brought out innovative & viable solutions.
11. WTA participated and organized multiple webinars in which leading subject-experts shared views / opinion about how to tackle the problems being faced by each stakeholder
12. WTA (Shri G. Rajput, V.P) participated in R&D work with Senior Scientist Shri D.P. Khali, FRI.
13. WTA organized numerous hands-on trainings with the Industry for aspiring Technologists.
14. WTA assists in industry placement of Technologists pan-India as per their skill-set.

WTA, in coming times, endeavors to take forward the best-interest of Indian Plywood Industry!

WOOD TECHNOLOGIST ASSOCITAION

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Sandalwood – A Case for Private Enterprise with Government Support: A Scenario in Tamil Nadu

Mita Banerjee,
Additional Principal Chief Conservator of Forests,
Tamil Nadu Forest Department, Chennai.

Sandalwood is a much sought after species, getting rarer and one of the few of the costliest of these woods used in the world. India has had a virtual monopoly over sandalwood production though other countries including Australia in more recent years have started growing and trading in the species. Indian sandalwood has held sway due to its superior quality.

History

Sandalwood has been a part of the Indian heritage and culture from time immemorial and is also integral to religious ceremonies. The Ramayana, referring to the river Tambraparni (Tamara parni) says "That river with its islands covered with fair forests of sandalwood goes down the sea as a beloved maid to her lover". Recorded history on the occurrence of sandal in India is at least 2300 years old. Pali scriptures, Buddhist works and Kautilya's Artha Shastra are some of the ancient literature on which sandalwood was referred to in some detail. In his epic poem, Chilappathikaram (between 2nd and 5th centuries A.D.) Ilango-Adikal, the Tamil Poet speaks of sandalwood born in Southern Mountain (Malaya Tenmalai piranda chandanam). These references seem to indicate its being indigenous to the country.

Distribution in Tamil Nadu

In Tamil Nadu, sandalwood trees are distributed over an area of 3045 sq.kms mainly in Vellore Thiruvannamalai, Tirupattur, i.e. the erstwhile North Arcot (Javadis and Yelagiri Hills), Salem, Erode, Coimbatore, Namakkal, Villupuram and Dharmapuri districts and sparsely in Nilgiris, Madurai and Trichy districts. Dense populations are found in Chitteries, Javadis, parts of Shevaroys and Tenmalai hills. Higher girth classes were common in most of these populations earlier but the onslaught from smugglers have decimated their numbers drastically. Natural regeneration though is still good in most of the areas.

In Coimbatore region of Tamil Nadu, sandalwood is found in almost every type of soil such as on stony red soil along the higher reaches of Moyar valley, on alluvial soil along Hallurhalla, on rich loams in Hulical, Kallar, Jacanare Reserve Forests and on shallow gravelly soil on the Melur and Pillur slopes . Javadi hills in Vellore District of Tamil Nadu, where sandalwood occurs as an associate species, in its dry semi evergreen forests is made up of charnokites and leptynites.

Legal angle

As per the Tamil Nadu sandalwood possession rules, 1970 no person shall possess on stock sandalwood in excess of five kilograms without a license. A stockist storing sandalwood and its by-products should maintain a stock register showing receipt issues and balance and submit a true extract from the stock register for every financial year to the District Forest Officer by the 10th of April, of the following year. Movements of sandalwood should be as per the Madras Sandalwood Transit Rules, 1967. Tamil Nadu Forests Act, 1882, was amended in 2002 to allow cultivation of sandalwood trees on patta lands. The ownership of sandalwood trees grown on private lands which was earlier with government, now vests with the landowners but extraction and sale is still in the hands of the government i.e. after felling the sandalwood tree(s) growing in patta lands or private areas, these shall be sold only to Government. However at present market rate as determined by the auction sale price is payable to the patta sandalwood owner.

The Tamil Nadu Sandalwood Trees Patta Land

Rules, 2008 empowers the DFO to grant permission to sell sandalwood trees to the Government, to extract the same and transport the extracted trees to the nearest "Final Cleaning Depot" under proper permit. The DFO calculates and fixes the sale price of the final cleaned wood based on the average sale price of previous sale of sandalwood conducted in that "Final Cleaning Depot" and 80% of the sale price is the "net sale price" that will be paid to the owner of the Sandalwood tree after deducting 10% as charges towards extraction, transport and final cleaning and another 10% for administrative charges. The owner of the Sandalwood trees should be paid 20% of the "net sale price" within 30 days of the extraction and the balance within 90 days as per legal provisions. In reality however it takes a lot of time to complete the final cleaning process due to vacant posts and other administrative reasons making it inconvenient for the sandalwood owner sometimes.

To ensure transparency an online web portal was created under ease of doing business. Applicant needs to apply for the permission in the online web portal www.forests.tn.gov.in/tree/ which also has timelines fixed to avoid delay. Timeline for issuing NOC is 37 days. At present there are about 40 applications for felling/extraction of sandalwood received online besides those received offline indicating its acceptance.

The depleting population of mature sandalwood

Sandalwood is one of the few most expensive woods of the world, probably second only to the African blackwood, mostly used for musical instruments, others in competition with it being pink/red ivory, Bocote, Ironwood/Lignum vitae (an endangered species and the national tree of the Bahamas which has been exploited to the brink of extinction), agarwood used for essential oil, purple heart, etc. International demand for sandalwood is estimated to be 10,000 MT per year. USA and France have been the two largest importers of Indian sandalwood oil.

Given the demand both in the domestic and international market, there has been rampant smuggling of sandalwood in all the States bearing the species. In Tamil Nadu the Goondas Act was unleashed for habitual offenders with reference to sandalwood smugglers but to no avail. Sandalwood production in the country has fallen from about 4,000 tonnes per annum in the 1960s to less than 1,000 tonnes during the 1990s. Earlier policy involved extraction of dead and dry sandalwood trees including roots up to 2.5 cm diameter from the forests (the root contains high oil content). While there have been years in the late 1980s when over 2000MT of sandalwood has been extracted in Trichy and Sathyamangalam alone, at present barely a few hundred metric tonnes are available collectively in all sandalwood depots put together.

There is quite a catch 22 situation prevailing. Price of sandalwood escalated as the species became more and more difficult to obtain and laws governing its trade kept tight, with its handling and trade mostly left in the hands of the government. Expensiveness drives the illegal trade through smuggling. The scarcer it became, the higher was the price offered and younger trees, even saplings with little or no heartwood began to be felled and smuggled. The price of Sandalwood in India has been increasing in leaps and bounds with price of about Rs. 20,000 per tonne in 1980, Rs. 2,00,000 per tonne in 1990; Rs. 40,00,000 per tonne in 2004 and 75,00,000 per tonne in 2014. The only solution can be flooding the market with sandalwood which is possible if it is grown by as many people and in as widespread an area as possible.

India dominated the international sandalwood market at one point of time. Almost all the S. album in India is now consumed in the domestic market. Export of timber from India is totally banned except for handicraft pieces of sandalwood upto 50g weight. FAO, 1984 noted that it is a priority species for in situ conservation. Since then, sandalwood oil and handicrafts have become more important. The Tamil Nadu Handicrafts Development Corporation which has been assisting artisans using sandalwood, markets the products through the State owned Poompuhar. However most artisans have shifted to using other wood in the absence of enough sandalwood and due to its prohibitive costs. This makes a further case for growing the species in more areas.

Challenges

As for most tree crops, the long gestation period for sandalwood is a factor discouraging its planting. Protection though is the biggest challenge facing conservation of sandalwood. Regeneration in the species is copious in Tamil Nadu when conditions are favourable. The tree starts flowering at an early age of 2 to 3 years. Trees mostly flower twice a year from March to May and September to December. But the young growth falls prey to wild animals and cattle grazing and browsing. Even if it escapes grazing and browsing mere suspicion of heartwood having developed gets the young trees felled by smugglers scouting for the wood. There are very few trees of girth over 30cm left in the natural forests. Evenso, farmers have been growing the species on their lands and good plantations over 15 years old are seen in different districts in the State such as Salem, Namakkal, Tiruchirapalli, Vellore, Coimbatore, etc. Most of these are plantations raised without giving publicity in the news or other media since that attracts the attention of smugglers more easily leading to the loss of atleast a few trees due to theft. This is a welcome change from times when uprooted of sandalwood saplings from their private land was preferred by the people since protection of sandalwood was a responsibility of the people by law and failure or inability to do so was punishable under law.

A related issue for safeguard of the valuable trees is the contrast in laws. Sandalwood bearing States have had very strong laws to prevent felling, transport, possession etc. but on crossing the borders the laws were not applicable. Thus godowns, essential oil extraction units, etc. for sandalwood sprang up in other States facilitating smugglers. Government policy needs to be such that laws are uniform across the country and protect the trees from smugglers without hampering farmers from growing and sale of the same.

Government has been interested in promoting sandalwood plantations, reason why the stringent laws in sandal bearing States like Karnataka, Tamil Nadu, Kerala etc. was changed around early 2000s. A lot of research has also been done by the research wing of the Tamil Nadu forest department all through over 100 years of its existence even under British rule. Genepools have been created with genetic stock of sandal from different States. Sandalwood has over 150 host plants, some of the good hosts being Casuarina equisetifolia, Acacia nilotica, Pongamia pinnata, Melia dubia, Wrightia tinctoria and Cassia siamea. Even grass is observed to be good as a host for the species. In Tamil Nadu, sandalwood has been grown with several species on trial basis such as greens, lantana, pulses like Cajanus cajan, etc. and even tissue culture tried.

National Bank for Agriculture and Rural Development (NABARD) and other banks finance projects for its commercial planting by farmers while 75% subsidy is provided by the National Medicinal Plant Board which lists sandalwood as one of the prioritized species for cultivation. Interest in growing sandalwood in private areas is very high but the legal implications that lock up profits from harvest but more importantly fear of loss from theft prevents many from attempting plantations of sandalwood. The magnitude of risk can be assessed from the fact that instances have been recorded of illegal fellings even in offices or residences of senior government officers of different departments. Private growers of sandalwood are often faced with instances of such theft leading to personal loss. Lack of quality insurance against loss or damage for the highly valuable wood is a big deterrent for cultivators. Even so, various ingenuous methods are being tried by enterprising farmers and others. Some have formed groups so they can take turns in watching out against thefts during the night. Many opt for camouflage. For example planting is done amidst bushes of weeds or thorny species. Once the tree starts growing then it is covered with climbers like pepper, etc. Barbed wire coiled around trees to make use of saws difficult is also seen. The more well-to-do farmers have invested in costly systems of protection both physical barriers and electronic surveillance or other similar systems. For security, modern techniques may be encouraged such as infra-red intrusion alert systems, solar fence, RFID for tracking and so on.

Providing subsidy for protective measures to at least small and marginal farmers may encourage them to opt for sandalwood. Insurance schemes tailor-made for *S. album* can be encouraged. Sale to government can also be made more attractive or optional instead of compulsory as at present. Tamil

Nadu has proposed for planting 60,000ha outside forest areas mostly in farmers' fields that are left fallow. If the project viz Tamil Nadu Biodiversity and Greening project comes through, it can give a big impetus to native species especially sandalwood. Since sandalwood comes up well in different soil types as often found in fallow lands and requires little attention, growing well in sunlight with frugal watering, sandalwood can be a good option for interested farmers.

Further reading:

Ananthapadmanabha H S (2000) Sandalwood and its marketing trend. My Forest 36: 147-151.

List of training programs offered by Institute of Wood Science and Technology

Sandalwood : Farming and Management of its Health

Course content : Basics of raising healthy nurseries and plantations of sandalwood with special focus on good silvicultural practices for the best health of sandalwood, management of pest and disease of sandalwood with practical demonstrations in field; economies, oil extraction and protection details
Course Director : Dr. R. Sundaraj
Contact : 080-22190154, 9740433959, rsundararaj@icfre.org
Course Fee : Rs. 9000/- (With boarding and lodging) + 18% GST; Rs. 6000/- (Without loding facility) + 18% GST

Extraction and Quality Assessment of Sandalwood and other Essential Oils

Course content : Basics of essential oil, extraction techniques of essential oil, quality assessment of essential oil, Value addition of essential oil, practical demonstration of essential oil extraction an dtesting of essential oil for quality control
Course Director : Dr. Rakesh Kumar
Contact : 080-2210191, 9412973726, rakesh@icfre.org; 080 2290193, 9482594201
Course Fee : Rs. 9000/- (With boarding and lodging) + 18% GST; Rs. 6000/- (Without loding facility) + 18% GST

Sandalwood: Seed handling, Nursery and Plantation Technology

Course content : Components of nursery; propagation techniques; composting; concept of root trainers based seedling production; seed technology; supplementary nutrition; bio-fertilizers; pest management in nursery and quality assessment of seedlings (includes one day field tour an dhalf day field visit to KSDL)
Course Director : Dr. B.N. Diwakar and Dr. N. Ravi
Contact : 080-2210191, 9483252839, bndiwakar@icfre.org; 080 2290155, 9435524070,nravi@icfre.org
Course Fee : Rs. 15,000/- (With boarding and lodging) + 18% GST; Rs. 10,000/- (Without loding facility) + 18% GST

Sandalwood: Tissue Culture Techniques

Course content : Modes of propagation through tissue culture; Media preparation; Explant collection; Surface sterilization and inoculation; Shoot multiplication and rooting; Potting mixture preparation and hardening in mist chamber
Course Director : Ms. Tresa Hamalton
Contact : 080-22190137, 93604731665, tresa@icfre.org; 080 2290155, 9435524070,nravi@icfre.org
Course Fee : Rs. 9,000/- (With boarding and lodging) + 18% GST; Rs. 6,000/- (Without loding facility) + 18% GST

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Status and occurrence of Sandalwood in Andhra Pradesh

Chiranjiv Chaudhary,
Principle Chief Conservator of Forests,
Forest Department, Govt. of Andhra Pradesh.

The distribution of natural sandalwood in forest areas of Andhra Pradesh forests is very scanty and dispersed. Natural sandalwood population is found mostly in Forest Divisions which are contiguous to sandalwood areas neighboring State of Karnataka namely Chittoor West Division and Ananthapuramu Division. Further, due to scattered nature of sandalwood trees in natural forests, state has not followed/ recommended any specific management practice in the Working Plans. In addition, due to its scattered nature and immature status the calculation of growing stock is difficult. Most of the crop falls in the category of saplings except for few poles. Regeneration is seen to be moderate to low. There were attempts to raise Sandalwood plantations in the RFs however the results were not encouraging due to poor success rate of such plantations.

Presence of natural sandalwood regeneration is reported from Kadiri, Penukonda, Bukkapatnam and Ananthapuramu ranges of Ananthapuramu Forest Division and district . The sandalwood found is in sapling and pole stages. The average age of the Sandalwood population is 10 to15 years.

Blocks and Compartments:-

The Range wise Natural Regeneration of Sandalwood found in Ananthapuramu Division as per random sample enumeration (As per working plans) and to enhance value of growing stock based on the past experience is given in Table 1.

Table 1. Statement showing the extent of area under Sandalwood based on enumeration in Anantapuram forest division

S. No.	Name of the Range	Area (in ha.)
1	Anantapuramu	1520
2	Bukkapatnam	1800
3	Kadiri	655
4	Penukonda	1768
		5743

In addition to the Ananthapuramu Forest Division, natural population of Sandalwood is also reported from Chittoor West Forest Divisionin Pedduru, Naniyala and Narayanapuram beats. There were attempts to raise Sandalwood plantations in the RFs (Reserve Forests) however it was not successful.

Recently, many farmers have raised sandalwood plantation in their farm lands, as raising sandalwood plantations generate additional income to the farmers. Progressive farmers/ agri entrepreneurs and enthusiasts have raised Sandalwood plantations mostly as inter crop and sometimes as bund/ boundary plantation as well. The details of Sandalwood plantations in Andhra Pradesh are as follows:-

Table 2: Details of Sandalwood Plantations in Andhra Pradesh (in ha.)

S. No	Circle	Division	Area under Sandalwood Plantations within RF	Area under Sandalwood Plantations outside RF	Remarks
1	Ananthapur	Ananthapur	0	20.63	Rishi Valley School
2		Chittoor (West)	70	141.4	raised Sandalwood wood plantations in 350 acres
		Circle Total	**70**	**162.03**	
3	WLM Circle Tirupati	Chittoor (East)	0	0	
4		Rajampet	0	0	
5		Tirupati	0	60	TTD area
	Circle Total		**0**	**60**	
	Grand Total		**70**	**222.03**	

Sandalwood Depot:

The Government Sandalwood Central Depot, Chittoor is the only depot for stocking and sale of sandalwood in the state of Andhra Pradesh. The quantity of seized and confiscated sandalwood received from all the Divisions in the State is stocked in the central depot for centralized sale through auction. The available sandalwood stock in the central depot as on date is about 1105 kg.

Ministry of Skill Development and Entrepreneurship, Government of India has recognized Institute of Wood Science and Technology, Bengaluru (IWST) as a **Centre of Excellence (CoE)** in the field of Skilling Ecosystem in the country

भारत का राजपत्र
The Gazette of India

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CG-DL-E-29122021-232237

असाधारण
EXTRAORDINARY

भाग I—खण्ड 2
PART I—Section 2

प्राधिकार से प्रकाशित
PUBLISHED BY AUTHORITY

सं. 27] नई दिल्ली, मंगलवार, दिसम्बर 28, 2021/पौष 7, 1943
No. 27] NEW DELHI, TUESDAY, DECEMBER 28, 2021/PAUSA 7, 1943

MINISTRY OF SKILL DEVELOPMENT AND ENTREPRENEURSHIP

NOTIFICATION

New Delhi, the 24th December, 2021

No. EP/54/2021-MSDE.— In pursuance of the directives under para 4.1.3 and 4.9.6 of the National Policy on Skill Development and Entrepreneurship 2015 and the Guidelines for recognition of "Centre of Excellence" framed thereunder vide Notification w.e.f. 09.08.2019 and as revised on 31.05.2021 and 12.11.2021 regarding setting up centre of excellence for skill development, **Institute of Wood Science and Technology, Bengaluru (IWST)** has been recognized as a **Centre of Excellence** (CoE) in the field of Skilling Ecosystem in the country, as per the meaning and interpretation of the expression "Centre of Excellence", as contained in the Guidelines as mentioned above. This recognition shall initially be for a period of five years from the date of issue of this Notification, subject to the following conditions:

(i) Institute of Wood Science and Technology, Bengaluru (IWST) should try to achieve all the parameters as enlisted in respect of Desirable Outcomes in the CoE guidelines;

(ii) Institute of Wood Science and Technology, Bengaluru (IWST) will submit its Annual Report to MSDE detailing out its activities;

(iii) Institute of Wood Science and Technology, Bengaluru (IWST) would facilitate periodic site visit by MSDE for monitoring.

SANTANU MITRA, Senior Economic Adviser

Logjams in conservation *vis-a-vis* protection of Sandalwood- scenario in Kerala

D. Jayaprasad, Principal Chief Conservator of Forests,
and **J.R.Ani,** Assistant Conservator of Forests,
Kerala Forest Department, Thiruvananthapuram.

Sandalwood is one of the most economically important tree species occupying a pre-eminent position in Indian forestry. The tree has been synonymous with ancientIndian culture and there are many a references on its importance and medicinal value in the age-old writings and Indian epics.

Cynosure of commercial wood industry

Sandalwood is often cited as one of the most expensive woods in the world because of its oil content. Both the wood and oil produce a distinctive fragrance that has been highly valued for centuries. Consequently, all sandalwood bearing forests in the country have suffered large scale illicit felling and over harvesting in the past. India has already imposed an export ban on Sandalwood and initiated conservation measures to protect the species.

In sandalwood tree the oil content is highest in the root, next highest in the stem at ground level, and gradually tapers off towards the tip of the stem. While there are several species in genus Santalum, Indian sandalwood is prized for being the most potent, with 90% content of the active ingredient santalol. Nearly 85% of the supply of Indian sandalwood comes from the southern states of Karnataka, Tamil Nadu and Kerala. Annual production has fallen from a high of 4,000 tonnes in the early 1970s to less than 300 tonnes today.

Distribution of Sandalwood in Kerala:

Sandalwood is naturally occurring in 11 forest divisions of Kerala (Table 1). About 40% of total sandalwood area found in Kerala is located in Marayoor forest division. Sandalwood stand located in Marayoor forest division serve as one of the major source of seed for the propagation of sandalwood in India.

Table 1: Distribution of sandalwood in various forest divisions of Kerala

Sl. No.	Forest Divisions	Area (Ha.)	No. of Sandalwood trees
1	Marayoor	1460.77	57751
2	Mannarkkad	878.16	51197
3	Munnar WL	353.27	6638
4	Wayanad South	185.00	4122
5	Thenmala	224.00	3293
6	Chalakudy	125.00	2430
7	Nenmara	149.50	1483
8	Parambikulam	114.00	1397
9	Kasargod	162.00	918
10	Periyar East	9.00	858
11	Wayanad North	10.00	152
	Total	**3670.70**	**130239**

Major threats for sandalwood

The production of sandalwood in India is decreasing annually at the rate of 20 percent since 1995. This decline in sandalwood production is mainly due to the depletion of sandalwood trees in the forest as well as private holdings. Natural and anthropogenic factors can be attributed to the depletion of sandal wood resources. Limiting factors to natural regeneration of sandalwood in forests include recurrent annual fires, lopping of trees,

spread of stem borers, proliferation of weeds and introduction of mono culture plantations like eucalyptus that have altered the ecology of natural sandalwood ecosystems. There isan urgent need to grow and conserve this important species not only in forest habitat but also in areas outside forests. Realizing the sharp decline in the sandalwood population in the state of Kerala, and the State Government has formulated speciallegal provisions and policies to protect and conserve it.

Though the effective intensive protection measures in the last decade helped tobring down illicit felling of sandalwood to a considerable extent, the sandalwoodareas are always under threat of exploitation. Therefore, the protection strategies evolved over time needs to be continuously improvised and strengthened. The tree naturally comes up in the forests coming under 11 Forest Divisions in Kerala. However, due to the intense illegal felling in the past, naturally occurring Sandalwood trees in Kerala are now mostly confined to Marayoor Forest Division. During the beginning of the century, illicit felling of Sandalwood in Marayoor had reached a whopping number of 2660 per year. Hence a separate division i.e., Marayoor Sandalwood Division was carved out of Munnar Division in the year 2005. The sandalwood bearing areas were fenced with chain link and patrolling was intensified by engaging staff and forest watchers engaged round the clock with improvement of logistics and communication techniques. These interventions have successfully brought down the illicit felling of Sandalwood in Marayoor to a level of about one tree per month subsequently. Under the JICA funded Eco-restoration project through Attappadi Hills Area Development Society (AHADS), sandalwood trees were significantly regenerated in Mannarkkad Division which now has more than 51000 trees, almost matching the number of trees in the Marayoor Sandalwood Divisionper se. Experience in Attappadi is a standing testimony to the fact that with proper protection measures, Sandalwood can be augmented in many places in Kerala where it is naturally present.

Effective protection measures for the sandalwood trees are done in Marayoor by providing chain link fencing, construction of permanent camp sheds, engaging sufficient protection mazdoors, engaging dog squad etc. With all the efforts put in, illicit felling of sandalwood trees could be considerably reduced and similar sandalwood protection measures are contemplated in other forest divisions of Kerala.

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Status of Sandalwood in the State of Maharashtra

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In antiquity the Indian sub-continent was known to be the source and exporter of mainly luxury goods such as gold, gems, spices, fine textiles, perfumes, sandalwood and ivory. Sandalwood oil from *Santalum album* is widely used in the cosmetic industry and is expensive. This has led to many species of plants of genus Santalum being traded under the term 'sandalwood'. Within the genus Santalum alone there are many species that are labelled as sandalwood. Trading of oil from closely related species such as *Santalum spicatum* or *Santalum austrocaledonicum* as sandalwood oil is also noticed. On many occasions traders do not truly know where the oil has come from as species from different plant families are also called 'sandalwood'. Other species that may be traded include oil from *Amyris balsamifera, Osyris lanceolata,* etc. However, it is the oil of *Santalum album* that takes the pride of being traded at premium.

Presently, economically viable trees (>30 cm girth at breast height) are very few. The species is also threatened by 'spike disease' which leads to mortality of trees due to changes in the physiology of the species. Minor threats in form of decline in habitat quality from over grazing and fire has also put the species at risk.

The extent of risk was so high that the Maharashtra State Government had to put a complete ban on felling of *Santalum album* trees in the whole State from 31.03.2008 onwards. This ban enabled the field officers to exercise strict control on exploitation of this species and movement of any produce of this species. This ban was however, relaxed in the State on 12.05.2017 upon its recovery in private areas and as also to convey the message of 'Grow more' to the general public.

Reduced availability has increased the value – for wood and oil in the national and international market and this could act as a fillip for bringing larger area under sandalwood tree plantations. Natural occurrence of 'Chandan' in Maharashtra is limited to the dry regions of Western Maharashtra and its occurrence in forest areas is negligible and only about 600 hectares of area is known to have Chandan trees in forests in Yavatmal and Amravati Circles. However, plantation by agriculturists have been carried out in the districts of Ahmednagar, Nashik, Pune, Jalna, Latur, Solapur, Dhule and Jalgaon. The success of these plantations is yet to be ascertained as plants are yet to attain maturity. Areas in Vidarbha region of the State has also seen successful plantations of Chandan and results therefrom are also awaited since exploitation is yet to be carried out. Exploitation of such plantations are presently subject to the rules laid down by the State Government which are being liberalised to encourage participation of private people in large scale. Large scale participation, in every likelihood is bound to create greater availability in future along with greater awareness. Channelising this availability to proper market for such private planters would aid in boosting the confidence for such an initiative to be successful.

The State Government had enacted the 'Maharashtra Felling of Trees (Regulation) Act, 1964' for preservation of certain species and preventing soil erosion. The trees scheduled in this Act were accorded specific protection and could not be felled without the permission of the designated 'Tree Officer'. The powers of 'Tree Officer' were vested

with the Collector of the District. For silvicultural management of the trees scheduled herein, powers of 'Tree Officer' were vested with the Forest Department's Range Forest Officer in the year 1989.The species *Santalum album* was included in the scheduled list of this Act on 15th May, 1973 to control unabated exploitation of the existing stock of Chandan trees in private areas. However, threat over Chandan persisted. The large scale theft has resulted in seizure in large quantities by the enforcement agencies which include the enforcement personnel of the Forests and the Police Departments. No legal exploitation from the 'forests' have been carried out in near past however, the department has a stock of more than 75 MT of sandalwood and about 200 litres of sandalwood oil and bulk of this is stuck in sub-judice matters. Besides this about 18 MT of sandalwood was provided to the Karnataka Soap and Detergent Factory, Bengaluru as advised by the Central Government vide its advisory dated 19.05.2005 and revenue of more than 107 lakhs has been remitted to the State Government.

The earlier policy of largely laying restrictions to control illicit felling and its trade was relooked into with advent of the National Forest Policy, 1988 and further discussions thereon. The Central Government, in its Guidelines brought out on18.11.2014, had sought to encourage private participation for increasing the area under tree cover to attain the stated target of having 33% tree cover in the country. Accordingly, in view of the vanishing population of sandalwood tree, State Government has relaxed the earlier stringent policies on sandalwood cultivation and harvest. *Santalum album* was delisted from the schedule of the 'Maharashtra Felling of Trees (Regulation) Act, 1964' on 23rd March, 2021 to further encourage sandalwood cultivation by the farmers and entrepreneurs.

The Central Government, through MoEF&CC, has brought out the 'Wood-Based Industries (Establishment and Regulation) Guidelines, 2016' in compliance of the order dated 05.10.2015 passed by the Hon'ble Supreme Court in Writ Petition 202 of 1995 wherein all States and Union Territories have been directed to suitably amend the State rules since the Acts and Rules relating to 'forest' are under the ambit of the respective State or Union Territory. This shall enable in providing uniform rules and regulations across the country that shall encourage hassle free harvesting and marketing of Sandalwood and its products which would also support in its better utilisation and conservation. However, establishment of any wood-based industry dependent upon sandalwood, being covered under the Central Government's 'Wood-Based Industries (Establishment and Regulation) Guidelines, 2016', shall be subject to regulations stated in the State Rules. This regulatory mechanism shall prevent overexploitation and smuggling of this species and products derived therefrom.

With the huge demand for its wood and oil in the national and international market, in the last decade, extensive private plantations are now being established across the State which, in a way, shall pave the way for reviving the past glory of sandalwood in India. Some of the measures needed for its conservation and sustained utilisation could be listed as follows:

- Establishing regional level seedling/clonal seed orchard of superior genotypes for obtaining quality seedlings and seed material.
- Proper assessment of its tree population at the State and National level for equitable management to profit the concerned agriculturist and the entrepreneur.
- Encouraging mass production of seedlings and distribution within the country so that sandalwood cultivation is extensively encouraged.
- Developing proper package and practises for sandalwood cultivation that would enable in bringing financial gains to the farmers which can also help in conservation of the population.
- Role of genetics and environmental influences on the heartwood and oil quality needs to be extensively studied.

Natural Distribution and Cultivation Status of Sandalwood Trees *(Santalum album)* in Gujarat State, India

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Distribution in Gujarat: Sandalwood trees are naturally well distributed in Saurashtra, North, Central and parts of South Gujarat regions and frequently occurring in and outside forest area including Gir & Girnar Forests of Junagadh, Banaskantha, Sabarkantha, Gandhinagar, Kheda, Panchmahal, Dahod, Narmada, Bharuch, Surat, etc., districts and river banks of Sabarmati, Banas and Mahi. The Kachchh & Valsad and Dangs District of South Gujarat region are not suitable for its natural growth due to soil pH and rainfall. This tree grows in the different zones of Gujarat in the pH range of 6 to 7.5, rain fall from 750 to 2000 mm and temperature 15 to 40°C.

Sandalwood Cultivation: Farmers of Gujarat are very progressive and innovative and are always in search of new models of business. Farmers successfully grow large scale plantations of clonal Nilgiri (*Eucalytus hybrid*), Malabar Neem (*Melia dubia*), Ardusa (*Ailanthus excelsa*), Desi Babul (*Acacia nilotica*), etc. in different parts of Gujarat to cater the need of wood based industries. Considering the future financial benefits of growing sandalwood, farmers have started cultivation of Sandalwood from last 10 years. They purchase quality seedlings from private and forest department's nurseries. Gujarat Forest Department provide all technical know how and subsidy under Agroforestry and Vrukshkheti schemes. The farmers of Gujarat have formed a registered national body named 'ChandanVikas Association'. As per the Association information around 1500 farmers of Gujarat are associated and cultivating Sandalwood trees in around 3000ha. of land. The Sandalwood cultivation is carried out in whole Gujarat except in Dangs district. As per the information of Social Forestry wing of Gujarat Forest Department, 674 farmers raised 330543 Sandalwood trees under Agroforestry and Vrukshkheti schemes (Table.1).

Table.1: District wise list of beneficiaries who have grown Sandalwood trees under Agroforestry and Vrukshkheti schemes in Gujarat.

Sr. No.	District	No. of Beneficiaries	No. of Trees raised	Sr. No.	District	No. of Beneficiaries	No. of Trees raised
1	Ahmedabad	4	1305	17	Panchamahal	6	1844
2	Kheda	6	10440	18	Mahisagar	9	3384
3	Surendranagar	16	6815	19	Dahod	35	4815
4	Anand	18	10270	20	Vadodara	4	4080
5	Kachchh	1	1000	21	Chottaudepur	7	3365
6	Patan	13	7240	22	Junagadh	6	2841
7	Bharuch	22	16123	23	GirSomnath	6	2783
8	Surat	16	24706	24	DevbhumiDwarka	13	7390
9	Tapi	4	1965	25	Jamnagar	60	24004
10	Navsari	12	303	26	Porbandar	2	812
11	Valsad	6	431	27	Botad	1	350
12	Narmada	1	800	28	Bhavnagar	74	32170
13	Mehsana	76	25542	29	Amreli	46	35750
14	Banaskantha	3	3450	30	Rajkot	49	37611
15	Sabarkantha	67	26023	31	Morbi	23	17087
16	Arvalli	57	11774	32	Gandhinagar	11	4070
					Total	**674**	**330543**

FellingRegulation: Sandalwood tree together with Teak (*Tectona grandis*), Kher (*Acacia catechu*), Sisam(*Dalbergia sissoo*) and Mahua(*Madhuca longifolia*) trees or their after growth, is the right of Government and these trees have been reserved under the provisions of the Bombay Land Revenue Code, 1879, or rules made thereunder. These trees either naturally grown or cultivated on private lands, their ownership remained with state Government. The state Government has authorized the Forest Department and Deputy Conservator of Forest to grant permission for felling of sandalwood trees in his area of jurisdiction as per existing guidelines. The transit pass is issued by the Forest Department under the provisions of the Indian Forest Act, 1927.

Case Study of Sandal Cultivation and its theft: The biggest challenge is to protect naturally and cultivated trees of more than 15 years of age and about 45 cm of girth from the thieves involved in illicit felling. For instance, two farmers namely Shri Dahyabhai Patel and Shri Khemabhai Patel of Laloda Village, Idar Taluka in Sabarkhantha District have cultivated 700 Sandal trees each in the year 2007. They procured quality seedlings @ Rs.50/- from the private nursery and planted at the spacing of 6x6 meters in one hectare each with Neem seedlings (*Azadirachta indica*) as the host plants. The author supported them in getting subsidy from National Medicinal Plants Board, New Delhi. Both the farmers worked very hard and grew Sandalwood trees for the first time in this area successfully. In the year 2017 i.e. after 10 years of age, these trees attained average girth of25-30cm. and about 5 meters of height. These trees started developing fragrance and heartwood. However, even after taking all protection measures, 90 trees of Shri Dahyabhai Patel and 110 trees of Shri Khemabhai Patel were cut down illicitly from the year 2017 to 2020. Ultimately, during the year 2021, Shri Dahyabhai Patel opted for the disposal and got the permission from Forest Department. He harvested 95 trees of 31-39 cm. girth at breast height and 2-3 meter of merchantable height and produced 546 kg. of firewood and 1.365 cmt. of timber. The firewood and timber was sold to an Agency of Kannauj, Uttar Pradesh on lump sum amount of Rs.7 lakhs. Shri Khemabhai Patel is also in process of getting permission to dispose the remaining Sandalwood trees.

Case study of Protection of Sandal from Ayurvedic Garden: The Government Ayurvedic Garden, Gandhinagar was developed in 1980 in 12 hectares of area by the Gujarat Forest Department. In the year 1982, this Garden was handed over to the Director, Indian System of Medicine and Homeopathy, Department of Health and Family Welfare. Presently, this Garden is looked after by the Gujarat Medicinal Plants Board (GMPB). As per the recent enumeration there are 2414 Sandalwood trees existing out of which 2056 trees are of less than 30 cm. of girth, 328 trees in 30-60 cm. girth class, 25 trees in 60-90 cm. girth class and 5 trees over 90 cm. of girth and all these trees are facing problem of theft. From the year 2005 onwards around 60 mature trees were repeatedly cut down illicitly by the trained gangs of Rajasthan. The Sandalwood trees in the Garden are being protected by the trained policing manpower in three shifts and around Rs.19 lakhs are spent annually. The auctioning of illicitly cut Sandalwood was carried out by the GMPB. From three auctions from 2015 to 2020, a total of 13586.49 kg of wood was sold with an average price of Rs.1039 per kg.

Suggestions for Future Prospects: The protection of naturally grown and cultivated mature trees is very challenging. Therefore, promotion of large scale Sandalwood plantations might reduce pressure on naturally grown sandalwood trees, as supply of sandalwood in market increases from plantation grown sandalwood. The farmers are also facing problem in getting felling permission and transit pass from Forest Department due to existing restrictions imposed by the state forest department and hence, the cultivated Sandal wood required to be exempted from these regulations. After harvesting, marketing is another challenge for the sandalwood growers, hence, the ban on export need to be lifted and proper marketing network needs to be established to encourage the famers to raise sandalwood plantations under agroforestry schemes. Sandalwood being high value tree species, Government of India and State Governments should start centrally sponsored /state sponsored schemes for its conservation and large scale cultivation.

Acknowledgement: Author is thankful to Addl. PCCF Social Forestry, CCF Working Plan (Surat) and Member Secretary, GMPB for providing requisite information on cultivation of Sandalwood trees under various schemes for writing this article.

Need for a State Sandalwood Policy in Karnataka – A new vision

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Karnataka known as 'Srigandha Nadu' because of largest extent of sandalwood bearing forests in the country and the fragrance of the sandalwood grown in the State. Because of its very high demand and consequent challenges encountered in its protection, the State monopolised its cultivation, felling, conversion and trade through strict provisions vide Chapter X of the Karnataka Forest Act 1963 (Section 23 to 87), which after amendment in 2001 bestowed legal ownership of sandalwood trees grown on private land on the land owner. Earlier, the Act had stipulated that sandalwood trees are the exclusive property of the Government. Further, the penalty for offence related to Sandalwood was raised to 10 years of imprisonment and the amount of fine was enhanced upto Rs. One lakh (section 86). Section 87 stipulates license for possession, storage and sale of sandalwood or for processing it for oil etc.

Rules 103 to 123 of Karnataka Forest Rules 1969, Chapter XIII deals with powers of forest officers to grant permission to extract mature sandalwood trees, after due verification of ownership and title of sandalwood trees on private Land. Rule 108 as amended in 2001, allowed owners may get extracted sandalwood to be transported to the Government Sandalwood Depot for disposal. It also provides for Depot officer to receive sandalwood and convert it, as per its classification and dispose by auction and retails sell.

Rule 118 provides for application for grant or renewal of License for possession, storage and sale. Further, Government of Karnataka order notification dated 11-07-2008 under 100 (1) Karnataka Forest Rule 1969 notified Karnataka Soaps Detergents Limited (KSDL) and Karnataka State Handicrafts Development Corporation (KSHDC) as Public Sector Undertakings permitted to purchase sandalwood from the Owner at prices negotiated by them.

Provisions of Section 77 to 84 of the Karnataka Forest Code, 1976 gives the procedure for exploitation of Sandalwood. Rules 95-97 of Karnataka Forest Manual 1976 provides for classification of Sandalwood into 18 classes. The first 6 are for heartwood and remaining 12 classes are for woods, chips, mixed heartwood, white wood, saw dust or powder (Rule 95). Rule 96 and 97 deals with supply of Sandalwood to Government Sandalwood oil factories and to temples and Muzrai institutions respectively.

1.1 Existing schemes to promote Sandalwood cultivation in Forest land and Private Land:

To augment the resource base, sandalwood has been promoted through

a) Siri Chanada Vana: a state sector scheme launched since 2013-14 to cover an area of 5000 ha. of natural sandalwood bearing forests. It also aims to cover 3500 ha. of degraded forests with sandalwood plantations as well as to maintain older sandalwood plantations, as sandalwood estates. Protection activities such as chain link fencing, dog squads, watch and ward etc are provided under the scheme.

b) Krishi Aranya Protshah Yojana (KAPY): for providing seedlings at subsidized rates and for providing incentive on survival of plants @ Rs. 125 over 3 years. Through the scheme is primarily meant to promote Agro-forestry, which includes sandalwood as well. Farmers in Kolar, Chikkaballapura and few other dry districts are showing tremendous interest for planting sandalwood trees in their land.

c) Raising of seedlings for public distributions: Provides subsidizes seedlings to growers, including farmers who do not register or those who are not eligible under KAPY.

d) Horticulture department supports sandalwood cultivation by farmers under National Ayush Mission and Nurseries under NAM as well as National Horticulture Mission.

1.2 Issues to be addressed to enhance the availability of sandalwood

There is huge gap in supply of quality sandalwood compared to its demand. Therefore, there is huge requirement to increase resource base of sandalwood by encouraging its cultivation by farmers through various policy interventions.

A. supply of Quality planting material from known superior population and standardizing package of practices with respect to treatment of seeds, preparation of beds, transplanting with suitable host plants, providing shade initially etc.

B. Protection from smuggling of mature sandalwood (with heartwood) is a huge challenge for both the Government as well as Private growers. Use of chain link fencing/CCTV/Dog squad is practiced for protection. There is requirement of developing newer solutions using innovation and technology, because farmers are requesting felling of even 12-15 years old sandalwood trees in their land, as they are fearing smuggling of trees from that age, as well as threat to their life.

C. Credit mechanism from National Bank for Agriculture and Rural Development (NABARD) and other commercial Banks and insurance instruments for the sandalwood plantations are also being proposed to be developed to help commercial cultivation of sandalwood plantations as well as for its risk mitigation.

D. Felling Restriction: Presently, after receipt of application for felling, Forest Department after physical verification and after obtaining revenue opinion about ownership of the land and trees, accord felling permissions. After felling, the material is inspected and then permit issued for transit to either Government Sandalwood Depot for conversion and disposal or to Karnataka Soap & Detergent Limited or Karnataka Handicrafts Development Corporation Limited based on the choice of the grower.

There are some delays in the process, despite ICT application rolled out for the felling and its storage under Seva Sindhu portal of Karnataka Government. Farmers are, therefore, demanding exemption from felling regulations; the pros and cons of which are being considered for simplification of the procedure and for processing the application through an online system.

E. Trade: Presently, the trade of Sandalwood is either with the Forest Department through the three Government Sandalwood Depots or KSDL or KSHDC Karnataka State to whom it is permitted in 2002.

F. Conversion: There is a felt need for capacity building and use of latest machineries for faster and precise conversion of Sandalwood into various classes. It is also being discussed to allow conversion at cluster level through trained private individuals.

G. Classification: Presently, Sandalwood classification is in Persian language and into several classes. It is discussed that Sandalwood could be classified based on the purpose of its usage i.e., different classification could be for bonafide, handicraft or industrial purposes into not more than 8-10 classes.

VISION: *The policy on sandalwood is aimed to encourage and promote the private stakeholders along the value chain of sandalwood production from cultivation of sandalwood tree to extraction and its trade. The policy also envisions restoration and rejuvenation of the sandalwood populations in the natural sandalwood bearing forests of Karnataka.*

2.1 Policy interventions to promote cultivation of Sandalwood

The following policy interventions are therefore suggested to increase the availability of quality planting material:

a. Production of Improved Planting stock

A special program is proposed to be implemented for production of Improved Planting stock covering various aspects including (a) selection of Plus trees, (b) identification of seed stands, (c) scientific collection, processing, storage of seeds from identified plus trees and seed stands, (d) establishment of clonal seed orchards, (e) progeny trials, (f) creation of database of Plus trees and geo-tagging these trees, (g) creation of GIS database of all Plus trees, and (h) promotion of tissue culture. The primary outcome of the program will be augmentation of availability of improved seeds from known and improved genetic sources from within and outside Karnataka.

b. Promoting Sandalwood seedlings in Forest Nurseries:

To scale up the availability of Sandalwood seedlings to farmers and to increase the extent of Sandalwood plantations in forest areas, the convergence opportunities under various programs shall be coordinated. Additionally, it is proposed that Sandalwood seedlings may be mandatorily raised at a certain percentage of seedlings raised under existing schemes, particularly in Sandalwood bearing areas.

c. Promotion of Sandalwood in Private Nurseries:

The Department of Horticulture has been supporting Sandalwood cultivation under National Ayush Mission. National Horticulture Mission provides subsidy for establishment of quality nurseries. National Medicinal Plant Board also promotes Sandalwood cultivation. Convergence with various existing programs/schemes of various departments/ institutions will be coordinated to grow Sandalwood seedlings in recognized private nurseries as well.

2.2 Intervention for Improving Protection of Sandalwood trees

Identification and protection of Sandalwood Plantations, Sandalwood estates in forest areas and providing them with chain-link fencing supported by solar fences, adequate manpower, vehicles, dog squad, arms and ammunition etc. Accordingly, either the existing Sandalwood cultivation scheme (Siri ChandanVana scheme) shall be strengthened / redesigned with higher allocation of funds or a new scheme will be formulated and implemented for achieving above objectives.

2.3 Proposed policy intervention for private land owners/farmers

The proposed policy aims to facilitate translating the high market value of sandalwood into commensurate remunerative profits for sandalwood growers through:

Innovative cultivation models

The growers may not be sufficiently aware about plantation technique and on farm protocols to be followed for optimizing the heartwood formation. It is therefore proposed to have a unified portal to provide information about innovative cultivation models, intercropping patterns to optimize economic gain, economics of raising Sandalwood, site suitability criteria, success stories in the form of case studies, short videos, involving various aspects of planting, harvesting, conversion etc., The interested growers will be required to register for training by IWST/Forest Department and field visits to successful plantations in private / forest land, among others.

Sandalwood Growers – Corporate Joint Venture

The sandalwood growers would be encouraged to have joint venture with corporates to enable sharing of ownership of sandalwood plantations, returns, risks and other shared interest, where corporate may come forward to fund the projects, provide technological inputs, surveillance equipments and have joint protection measure with the grower, carry out extraction and sale of sandalwood or make annual payment to the grower, who in return makes available his land, nurtures trees, may cultivate other crops and receive annuity from the corporate or receive share of Sandalwood sale proceeds.

Sandalwood cluster development

In order to promote cultivation of sandalwood trees and to realize its benefits, in high potential areas growers in a cluster would be encouraged to come together and organize in the form of Sandalwood Growers Co-operative Society or even producers company for the purpose of shared interest related to all aspects of sandalwood cultivation including accessing credit, ensuring common protection, its harvesting, conversion and trade etc.

2.4 Proposed policy intervention in extraction, transportation and trade of sandalwood.

a. Process of felling and transportation.

In continuation of amendment of 2001, further simplification and liberalization of the process of felling, transportation, conversion and trade and storage license would be brought to help growers in cutting the present delay encountered through an online portal to be developed by the department.

b. Sale of sandalwood handicrafts by artisans through e-marketing would also be encouraged.

c. Trade relaxation: Present policy of permitting growers to sell the sandalwood trees to Government Sandalwood depots or Karnataka Soaps and Detergents Limited / Karnataka Handicrafts Development Corporation Limited only, would be relaxed to allow sale to other entities through online portal registered with the Department.

d. Application for Geographical Indication (GI) for Sandalwood grown in identified districts of Karnataka would be facilitated to enable growers to have distinct identity and to fetch better prices within and outside country.

3. Proposed institutional Framework

3.1 Setting up of a Sandalwood Board or Council

A State Level body viz. Karnataka Sandalwood Board/Council is proposed to be set up to oversee all issues related to sandalwood cultivation by private growers, other than regulatory functions being dealt by the department. The Board / Council will have panel of institutions and technical experts of growing, managing and marketing of sandalwood and its produce to meet requirement of all stakeholders.

3.2 Constitution of Monitoring Committee headed by Principal Chief Conservator of Forests (Head of Forest Force) and including heads of department of Horticulture, Agriculture, Commerce & Industries, Ayush, KSDL, KSHDL and to be convened by head of Forest Resource Management wing of the Department to review and monitor on the implementation of the policy, as well as provide guidance and support to all concerned stake holders.

4. Way Forward

The Policy is being proposed for next 30 years, with a provision of comprehensive review every 5 years to assess its impact in realizing the vision and objectives of the policy and based on which suitable changes in policy framework and required interventions can be brought.

Karnataka Soaps and Detergents Ltd., for the support of Sandalwood from the Century and more...

Mahesh B. Shirur,
MD, Karnataka Soaps and Detergents Ltd.
Bengaluru.

Sandalwood oil is known for cure against venereal diseases for which it was used during early 20th century, till the arrival of Sulfadrugs in 1930's.During the 1st World War, the shipment of Sandalwood to distillers in Germany was affected leading to piling up of Sandalwood stocks in Mysore State. So, it was felt by the Government at that time to establish Sandalwood Distillation facility in the State. As the technology for distillation was not available locally at that point of time, help was sought from the scientists working at Indian Institute of Science (IISC) namely Dr. Watson & Dr. Sudbrough to come up with the methods to obtain Sandalwood oil of Pharmacopoeia grade acceptable to European buyers.

During those days, Mysore state was under the rule of His Highness Sri. Nalwadi Krishnaraja

Wodeyar and Sir. M. Visvesvaraya was working as Dewan in Wodeyar's court. Industrialization of the state was one of the major priority of Mysore Wodeyars. In this endeavour, establishment of soap factory to manufacture soap, a daily necessity was conceived. Sri. S. G. Sastry a young scientist was deputed to UK for higher training in oil technology. After returning from UK, trials were conducted not only to manufacture soaps but also the creation of

famous Mysore Sandal soap using Sandalwood Oil as base. The birth of Mysore Sandal Soap took place in 1918.

Mysore sandalwood is reputed all over the world for its quality and fragrance. The Mysore sandal soap is manufactured by the Karnataka Soaps and Detergents Ltd., (KS&DL) Company, which utilizes the original sandalwood oils. Sandalwood has a therapeutic effect on skin problems and is endowed with antiseptic properties. The essence of the Mysore sandal soap has also aided the company in gaining popularity in the soap market. The company produces various products of sandalwood. Increased use of sandalwood has led to the tree being endangered from extinction. The tree has been declared as the protected species leading to the rise in the prices of the rare Sandalwood.

Legal aspect of cultivation of Sandalwood:

Sandalwood plants are widely distributed in the southern states like Karnataka, Tamil Nadu, Andhra Pradesh and Kerala. The legal hassles faced by the Sandalwood trade regulation are that there is no comprehensive regulation applicable to the entire country. As per the Karnataka Forest Act (Amended), the grower himself is the owner. Further, Govt. of Karnataka made amendment on the

sale of Sandalwood through Forest Department and Government Departments to eliminate the clandestine trade and to encourage farmers to take up cultivation of Sandalwood on commercial scale during the recent years. The Government of Karnataka vide Notification No. FEE 21 FSW 2008 dt.11.07.2008 notified KSDL and Karnataka State Handicrafts Development Corporation as the Nodal Agency to buy Sandalwood directly from the Growers. As per the Notification, the Public Sector Undertakings/Defence Departments/Para Military Organizations on whose land Sandalwood is cultivated or has grown naturally are treated as 'Owner' as per Rule 103 (C) of1 Karnataka Forest Rules 1969 (2002 amendment).

As per the amended rules, the Farmers/Growers can approach our Company for harvesting the Grown-up Sandalwood Trees. Once harvesting, the rough sandalwood is allowed for natural drying for about 3 months. To maintain transparency in processing, the dressing of rough Sandalwood and classification of sandalwood will be done in presence of the 'Owner". Hence, the 'Owners' of Sandalwood trees shows much interest in selling the Sandalwood to KSDL. Our Company will also give every kind of support to the Growers for harvesting the grownup Sandalwood for mutual benefit of both the organization and growers with the permission of Forest Department. Further, the Government vide Official Memorandum No.A6.SDL.GL-5184/04-05/08-09 dt.16.07.2008 has fixed administrative price for variousclasses of Sandalwood and revises price from time to time for various classes of Sandalwoodbased on the average price of auction sales of Sandalwood. The Company has extended the administrative price to the growers as and when the Company has directly sourced the Rough Sandalwood since 2008. So far KSDL has harvested morethan150 MT'sof Rough Sandalwood from the Growers/Institutions directly and released the payment in most transparent method as per the price fixed by the Company. Since the Company is finding difficulty in getting sufficient quantity of sandalwood, it is making all out effort to source the sandalwood from all available sources like buying directly from the growers as well through Auction sales conducted by the State Forest Departments. At present,Company is procuring dressed Sandalwood through e-auction sales from Marayoor (Kerala), Shimoga, Mysuru and Dharwad.

Dressed Root class of Sandalwood

Role of KSDL in "Grow More Sandalwood" Programme

KSDL works in partnership with sandalwood growers on a 'Share & Prosper' basis in scientific and commercial cultivation of sandalwood for the benefit of both Growers and the Company. KSDL is having MoU with many farmers for ensuring buyback arrangements for Sandalwood on commercial plantation spread over more than 3000 Acres in the state. So far more than 500 farmers of the state have entered into Bi-partite agreement with the Company for commercial cultivation of Sandalwood and equal number of farmers/growers have shown keen interest for growing Sandalwood trees. Further, several hundreds of Farmers have availed consultancy services for commercial cultivation of Sandalwood.This momentum has been growing steadily in the state of Karnataka and even spreading to the neighbouring states.

Measuring Girth of Sandalwood Tree

Role of Government

It is prudent to simplify the regulatory regime related felling and transit of tree species grown on non-forest areas and farmlands. Special incentives are to be given to the growers in the form of subsidies for cultivation, protection and technological upgradation of security systems.

Vision and Mission of KSDL

- Our vision is to make India to regain the glory of the past, the largest producer of *Santalum album* in the coming years by making buy back arrangement with the potential growers, farmers & entrepreneurs by giving scientific & marketing support from time to time on Indian Sandalwood Industry and the Global scenario.
- Our vision is to produce the best quality natural Sandalwood and Oil from the legal and ethical sources on sustainable basis towards National Prosperity through commercial cultivation of natural Sandalwood to produce the best quality natural Sandalwood oil-based products like soaps, cosmetics, beauty aids, perfumes through continuous revolutionize innovations for both new and existing product lines to meet the global standards.
- KSDL business of business is for more than business: business is more transparent, sustainable, legal & ethical by means of care, nurture & earn.
- KSDL basic philosophy is to Share & Prosper together with sandalwood growers.
- Effectively working on sustainable, ecologically sound & ethical supply of Sandalwood in a socially responsible manner.
- KSDL Research centre's constant endeavour is continuously working on upgrading the products quality formulation of all the products viz., Soaps, Detergents, Cosmetics, Agarabathis, including newer products with the heightened regulatory measures to meet the highest international quality standards with fully integrated product life cycle management ensure the compliance of FDA & REACH.
- The major thrust of R&D is committed for developing the natural essential oil based products using the natural Sandalwood oil as base to achieve the new paradigm of competitiveness, maximize customer satisfaction, to meet the customer requirements & expectations.

Santalum album Linn Tree

List of consultancy services offered by

Institute of Wood Science and Technology

The Institute has the following facilities and expertise for rendering services to user industry and Government and non-government organisations:

- Xylarium with authentically identified Indian and foreign wood samples, with expertise to identify timber species.
- Authentic identification of wood-decaying fungi, insects, marine wood borers and foulers.
- Cultures of wood-decaying fungi for reference and laboratory bioassay purposes.
- Accelerated laboratory bioassay of candidate wood preservative chemicals against wood-deteriorating fungi and insects.
- Testing of timber and timber products (untreated and treated)
- Testing of timber and timber products for determining the strength properties.
- Xenotestweatherometer for accelerated weathering experiments.
- Timber seasoning kiln and expertise for setting up solar seasoning kiln.
- Pressure-treatment plant for preservative-treatment of timber.
- T.L.C., G.L.C., and H.P.L.C.
- UV, IR and Atomic Absorption Spectrophotometer
- X-ray Fluorescence Analyzer
- Flow Injection Analyzer
- Nitrogen Analyzer
- Bomb Calorimeter
- Chemical analysis of oils, gums, tannins and other non-wood forest products.
- A seed orchard of sandal for supplying quality seeds.
- Advice on nursery practices, silviculture and plant protection against fungal and insect attack.
- Transfer of technology for improved agroforestry systems.
- Advice on protection and management of mangrove ecosystems from biodeterioration point-of-view.
- Advice on simple, inexpensive wood-preservation techniques (sap displacement method).
- Advice on timber utilisation for catamaran, other fishing crafts and marine structures.
- Model nursery at Nagaroor in collaboration with State Forest Department has been established.

INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY
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New Initiatives for Sandalwood Cultivation in Telangana

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In India, more than 90% of the sandalwood is distributed in the states of Karnataka (70%) and Tamil Nadu (20%) covering around 9,000 km2. In Telangana, Sandalwood cultivation is being promoted since 2018 only. Though returns on sandalwood cultivation are very high, naturally grown sandalwood tree takes 30 years to be ready for harvesting. However, intensive cultivation in organic methods gives quick results in 10 to 15 years.

Agro-climatically, few parts of Telangana are suitable for Sandalwood cultivation. Telangana covers 48% by red Soil, with larger part in Mahabubnagar, Nalgonda, Karimnagar, Khammam, Rangareddy, Nizamabad districts. The average rainfall in Telangana is 900 to 1100 mm and average temperature between 10 to 35-40o c.

Telangana Government has established two Hi-Tech Nurseries under Sub-Mission on Agro Forestry at Centre of Excellence (CoE), Mulugu, with a production capacity of 2.00 lakhs plants per annum @ Rs. 40 lakhs each. CoE, Mulugu is established in an area of 55 acres having the following facilities:

(i) **Demonstration of Fruit crops:** Demonstration of new crops and varieties of Fruit crops.

Iii) **Demonstration of Agro Forestry crops:** Demonstration of new varieties of Agro Forestry crops like Casuarina, Bamboo, Sandalwood etc.

(iii) **Demonstration of latest production technologies:** Demonstration of Ultra High Density Plantations (UHDP), High Density Plantations (HDP), Raised bed with weedmat Fertigation, Automation, Integrated Pest and Nutrient Management.

(iv) **Production of quality Planting Material:** Production & supply of high quality grafts/ budlings/ seedlings of Fruit crops/ Agro Forestry Sps to the farmers.

(v) **Capacity building of farmers:** Creating awareness to the farmers through Training and capacity building.

(vi) **Demonstration of water use efficiency:** Farm ponds, drip irrigation, Water harvesting & storage structures

Production of Sandalwood and host plants seedlings at Hi-Tech Nursery, CoE, Mulugu

Since 2018, with the active support of the Telangana government, sandalwood plantations are being raised in an area of 3363 acres covering 1928 farmers.

Inspiring story of innovative farmer:

Sri. P. Istharapu Reddy a farmer from Pasnour village in Nalgond district has reaped huge profit from raising Sandalwood plantation. His success has given inspiration to many small and marginal farmers in Telangana State to take up Sandalwood plantation. He planted sandalwood on boundary of sweet-orange orchard during the year 2002 with host crop as Sweet Orange. After the plantation has attained 15 years, he felled trees in 2016 and got yield of 33 kg heartwood per tree, and total harvest of 600 kg heartwood from 18 trees. The yield of softwood was 50 kg per tree and 900 kgs from 18 trees. From selling heart and softwood he earned an income of Rs. 37.50 lakhs in 15 years. The details of cost benefits associated with raising sandalwood plantation is given in Table 1

Table 1: Cost-benefit analysis of raising sandalwood

Sl. No.	Particulars	Details
1	No of sandalwood plants	18 plants (Border plantation)
2	Host crops grown	Sweet orange
3	Year of planting	2002
4	Year of Harvesting	2016 (Age: 15 years)
5	Size of plant during harvest	Height: 20-25 ft, diameter: 3 ft
6	Contact No.	6304391957
7	Yield (per tree.) / total yield from 18 plants	
	Softwood kgs	50 kg / 900 kgs
	Heartwood kgs	33 kg / 600 kgs
8	Total Expenditure (for 36 plants for 15 years) 18 SW + 19 Sweet orange	Rs. 1,50,000/-
9	Sale price (Rs. per kg.)	
	a. Softwood	Rs. 500 per kg
	b.Heartwood	Rs. 5500 per kg
10	Total value of Sandalwood crop (for 18 plants after 15 years)	Rs 4,50,000 SW + Rs. 33,00,000 HW = Rs. 37,50,000/-
11	Additional income from Host species (from 18 Sweet orange plants for 3 years) @ Rs. 300/- per plant per year	Up to 3 years Rs. 20,000 (Negligible only)
12	Gross income obtained SW+ Sweet orange after 15 years	Rs. 37,50,000
	Net Income from 36 plants after 15 years	Rs. 36,00,000

Another farmer Sri. Ravinder Reddy from Bacharam village in Rangareddy District has taken up Sandalwood plantation in 32 acres in block plantation in 2016 with Casuarina as host plants and *Melia dubia* as intercrop. Farmer is planning to harvest *Melia dubia* in 2022. As on today Sandalwood plants are very healthy with good girth of main trunk. Farmer is expecting an income of Rs. 5.00 Cr per acre (Rs. 160 Cr. from 32 acres) after 2030.

Role of Government in promotion of Sandalwood cultivation:

To promote Sandalwood plantation in Telangana, Government has launched "Sub-Mission on Agro Forestry" during 2018-19. Department of Horticulture, Govt. of Telangana has established a nursery for supply of quality planting material along with primary and secondary host plants. Conducts awareness on cultivation of Sandalwood in Telangana.

Opportunities for Farmers to Generate Higher Income through Cultivation of Sandalwood in Rajasthan and Gujarat.

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In India, about 53 % of land area of country comprises two important eco-regions: the arid and semiarid regions. The arid zone of India alone occupies an area of 3.2 lakhs km2 which is about 13% of the geographical area of the country. More than 80% of total arid land areas of the country are present in Rajasthan (61%) and Gujrat (20%)(Kalsi, 2007). The main problems of agriculture in these areas are low availability of rainfall and irrigation water and high frequency of droughts, adversely affecting the crop growth. Under these circumstances raising crops successfully is a gamble for farmers often with high rate of failures. However, here agroforestry which brings in cultivation of trees along crops has the ability to stabilize the farm income to some extent.

Agroforestry has significant potential to provide employment to rural and urban population through production, industrial application and value addition ventures. Current estimates show that about 65 % of the country's timber requirement is met from trees grown on farms. Agroforestry also generates significant employment opportunities (National Agroforestry Policy 2014). Given the fact that land-holding size is shrinking, tree farming combined with agriculture is perhaps the only way forward to optimize farm productivity and thus, enhancing livelihood opportunities of small farmers, landless and the women.

The National Agriculture Policy of India (2000) had pointed out that, "agriculture has become a relatively unrewarding profession due to generally unfavorable price regime and low value addition, causing abandoning of farming and increasing migration from rural areas." One of the goals of the policy is 'Improving the productivity; employment, income and livelihood opportunities of rural households, especially of the smallholder farmers through agroforestry'. Further the Policy recommended that "Farmers will be encouraged to take up farm/agro-forestry for higher income generation by evolving technology, extension and credit support packages and removing constraints for development of agroforestry".

High value trees like sandalwood and red sanders-based agroforestry and farm forestry have the potential to improve the income of farmers to levels hitherto unheard by the farmers. The very high price and high demand for the wood and wood products of these two species are encouraging the farmers to cultivate these species in their land.

Commercial cultivation of sandalwood has gained substantial momentum in India since liberalization of rules regarding sandalwood cultivation in 2001 and 2002 in traditional sandalwood growing states of Karnataka and Tamil Nadu. In recent times there has been a spurt in sandalwood farming in states like Maharashtra, Telangana, and Andhra Pradesh. However, sandalwood farming has taken off in a bigger way in non-traditional sandalwood areas in states like Gujarat, Rajasthan, and Madhya Pradesh. Farmers in arid and semi-arid parts of western Indian regions like Gujarat, Rajasthan and Maharashtra are cultivating sandalwood intensively to maximize the returns. In Gujarat alone more than 20, 000 ha are under sandalwood cultivation in 2017 as per Gujarat Sandalwood Growers Association (Mishra *et al.*, 2018b). Sandalwood farming especially, sandalwood based agroforestry has immense potential in terms of revenue generation and optimal utilization of land and resources. The high-income potential of sandalwood agroforestry or farm forestry has encouraged some corporate business groups venture into raising sandalwood plantations in arid and semi-arid areas.

Sandalwood in Rajasthan

In Rajasthan, natural sandalwood is restricted to the southern and eastern part of the state. Good Natural regeneration is found in Haldighat forest of Nathdwara range Rajasmand Forest Division), Bhavarmatha block of Choti Sadri range (Pratapgarh Division). Natural host associated is found to be Acacia nilotica, *Acacia catechu, Acacia senegal, Prosopis cineraria, Prosopis juliflora, Pongamia pinnata* etc. Even grass Imperata cylindrica is found as host. Larger girth size (>30cm girth) found missing in forests, however, larger trees found in protected areas , old havelis, circuit house etc., Sandalwood trees are also found in trenches and mounds in agricultural fields (Jain et al., 2007).

A survey was carried out in 12 locations across various districts/forest divisions in Rajasthan for sandalwood populations and trees were sampled for estimating heartwood content and oil through core wood sampling (Jain *et al.*, 2007). The results revealed that oil content varied between 0.9%-3.0% across various girth classes which was slightly lower compared to similar girth trees in natural forests of southern India. The growth rate of trees and heartwood content were comparable with that reported in various studies in southern India. This study confirmed the tremendous scope of arid and semi-arid regions of Rajasthan growing quality sandalwood plantations.

Mishra et al (2018a) studied heartwood and oil content in various girth class trees ranging between 30 to ≥ 80cm from 22 locations across seven states during 2015-2016. Their study included trees from four locations namely, Jodhpur, Udaipur, Pali and Sadri. The heartwood content varied from 46% in 30-40cm girth classtrees to 78% in > 80cm girth class trees. The heartwood content in sandalwood trees grown in Rajasthan was comparable to heart wood content in trees grown in other states including natural sandalwood. However, oil content varied from 0.58% to 1.6% in various girth class trees and it was significantly lower than oil content found in natural trees of Marayoor (Kerala). It was comparable to the oil content found in trees grown in Madhya Pradesh, Maharashtra, Karnataka, Orissa and Punjab.

The above studies indicated that sandalwood can profitably be cultivated in non-traditional areas like Rajasthan and Gujarat and heartwood and oil content in cultivated sandalwood may almost be comparable with that in cultivated traditional areas like Tamil Nadu and Karnataka.

Legal aspects of Sandalwood cultivation in Gujarat and Rajasthan.

As recently as 2002, state governments, especially in Karnataka and Tamil Nadu, had a monopoly over the control of all sandalwood resources. State laws specified that all sandalwood trees growing on any land, including private lands, belonged to the government. However, the landowners were responsible for preserving the trees on their respective lands. Only the government had the right to sell or trade the wood. This system neither deterred the illegal and indiscriminate harvesting of sandalwood by smugglers, nor did it help conserve the species in its natural habitat. Moreover, the monopolistic laws acted as a huge disincentive for planting of sandalwood on private lands. Farmers even destroyed the saplings that naturally grew on their lands (Viswanath et al., 2009).

Two major producer states in India- Karnataka and Tamil Nadu relaxed the existing forest rules and regulations related to sandalwood in 2001 and 2002. The goal of modified policies was to encourage private cultivation of sandalwood by farmers. However, landowners cannot fell the sandalwood trees without government permission or use them for personal purposes, and they can sell them onlyto government agencies through prescribed procedures. Farmer is entitled for only 80% of the auction value of the wood in Tamil Nadu and 70% in Karnataka.

In Gujarat five tree species namely Sag (*Tectona grandis*), Sisam (*Dalbergia latifolia*), Khair (*Acacia cetachu*), Chandan (*Santalum album*) and Mahudo (*Madhuca indica*) have been designated as "Reserve Trees" which require permission for cutting and transport from competent authority. During 2015, Gujarat has revised the procedure regarding permission from forest department for cutting trees to encourage cultivation and supply of timber from agricultural land. The procedure is online and consists of several steps which are time bound. These

online application and permission procedures are aimed at removing bureaucratic hassles for farmers and merchants.

Issues/problems in Sandalwood cultivation

1 Sandalwood cutting, possession and transit rules vary from state to state in the country. Most of the states have their own rules and some states do not have sandalwood cutting rules. Thus, the present policy regime the financial profitability of sandalwood cultivation is varied by the restrictive policies which deny farmers the full market value for their produce and compel them to go through elaborate bureaucratic procedures to receive the benefits. Hence, revamping of legal provisions related to sandalwood uniformly throughout the country is urgently needed to facilitate free trade and markets to ensure higher and speedy returns to farmers, thereby encouraging private cultivation of sandalwood (Viswanath *et al.* , 2009).

2 Quality Planting Stock (QPM) is not available for farmers in Rajasthan and Gujarat states and private nurseries sell seedlings from unknown sources. There is an urgent need to create improved seed sources of sandalwood for producing quality planting stock.

3 Scientific management inputs are lacking in raising sandalwood plantation and obtaining maximum heartwood and oil yield. Research gaps also exist regarding the optimum age of harvesting under plantations, heartwood yield, factors affecting yield, age of heartwood initiation, and relationship between tree girth and heartwood content under managed conditions and effect of seed sources on all these aspects.

4 Currently, there is paucity of data on sandalwood growth under various climatic and edaphic factors, espacement and various hosts under agroforestry situations in Gujarat and Rajasthan. Effect of hosts on heartwood and oil yield is largely not understood. Cultivation packages also need to be standardized according to the area's agro climatic situation, existing cropping pattern, and compatibility of sandalwood with other annual crops.

5 Raising sandalwood plantation using seedlings from seeds would result in variations in growth, heartwood, and oil content as these traits are largely genetically controlled. For large scale production of uniform planting stocks of high yielding clones tissue culture is the only option as other micro propagation techniques are not feasible in sandalwood. However, tissue culture protocols have only been standardized under laboratory conditions in research institutions and these protocols have not yet reached field conditions.

6 Sandalwood is highly prone to theft and smuggling after 4-5 years of planting and until its maturity (14-15 years). Protecting the sandalwood trees from smugglers is a major problem for farmers as well as government agencies throughout India.

7 There is an urgent need to establish joint tree protection force by the state/central governments by involving both police and forest department personnel to help protect and gather intelligence data regarding smuggling of valuable forest tree resources both in government and private land.

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FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

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Present scenario and prospects of Sandalwood (*Santalum album* L.) cultivation in Rajasthan and Gujarat

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Introduction

Tag of royal tree to the sandalwood coupled with cumbersome rules/policies were against farmers and industries, led the biggest setback for taking up of sandalwood plantations in private land. It was only after amendment of policies/rules related to the cultivation of sandalwood harvest and trade in 2001 and 2002 by the Karnataka and Tamil Nadu State Governments, respectively, rights were given to the farmer /industries to own sandalwood plantation. This reformation has promoted cultivation of S. album in private land. There is a huge demand of quality planting stock of S. album in India by the farmers. The Institute of Wood Science and Technology (IWST), Bangalore has played an important role in development of package of practices for the raising of quality planting stock (QPM), plantation technology and through training, trained human resource for promotion of sandalwood cultivation in India.

After reformation of sandalwood cultivation practices plantations are raised by the farmers in most of the states in the country. Estimated area under cultivation of Sandalwood is around 15,000-20,000 ha (conservative figure). Semi-arid areas of Gujarat and Rajasthan are suitable for Sandalwood cultivation. In Gujarat about 1000 ha area is under cultivation of Sandalwood in farmer's field with different host. Similarly, there is growing interest of Sandalwood cultivation in Rajasthan as a agroforestry species. Due to suitable climate and interest of farmers. There is immense potential of Sandalwood cultivation and value addition in these states.

2.0 Host Requirement

Sandalwood is hemi root parasite tree species, require primary host at nursery and plantation stages, and support growth for 1-2 years. Intermediate host is essential to support Sandalwood growth after primary host for 3-4 years till it establishes haustorial connection with long term host species. Host provides mainly nitrogen, potassium, phosphorous major source of essential elements. Apart from this, host also provides other element and readymade food to support growth of Sandalwood.

It has been observed in Rajasthan that *Zizyphus mauritiana, Acacia senegal* and *Acacia nilotica* favoured good growth of *S. album* and can be used as a long term host, apart from these these, *C. equisetifolia* and *Emblica officinalis* (Anwala) are good host. In Gujarat (Mehsana), *Casuarina equisetifolia* and *Punica granatum*, *Citrus aurantifolia* and *Acacia catechu* were used as a long term host. Though, the best growth was observed with (lemon), but after 6th year entire plantation of Citrus was wiped out by the *S. album*. *Casuarina equisetifolia* favoured good growth of *S. album* in line plantation, but suppressed growth in block plantation in Gujarat, due to over growth of *C. equisetifolia* as a result of more competition for light, water and nutrients. *Emblica officinalis* and Mango can be used as a long term host. In Rajasthan Prosopis cineraria can be good long term host of Sandalwood.

3.0 Management of plantation

As such there are no systematic studies on management practices of Sandalwood cultivation. Based on the field observation, split dose of compost about 5-10 kg per plant twice in a year (i.e. Feb. and Sept.) favoured good growth of host and *S. album*. Biofertilizer viz; AM, PSB,

Azotobactor and *Azospirillum* favoured better growth. Application of *Trichoderma viride* or *T. hazeanum* act as a bio-control agent against collar rotting fungi. Irrigation is very important particularly during summer and winter. Drip irrigation is better than flood irrigation to maintain proper drainage. Weeding and soil working are essential periodically or as and when required.

4.0 Sandalwood cultivation in Gujarat

In Gujarat *S. album* plantation started at small level in around 2004-2005 in Surat, Baroda and Ahmedabad. The first large scale plantation was established at Mesana in 2007-2008 in about 6ha area using *C. equisetifolia*, *Punica granatum* (Pomegranate) and *Citrus aurantium* (Lemon) as long term host. Survival, height, collar diameter, crown size and clear bole of S. album trees at the age of 6 years was greater with *C.arantium* than the other two host species. Heartwood formation was initiated in the trees >9 cm diameter at breast height (DBH) irrespective of host species. (Singh et al.,2018). However, *C.arantium* was wiped out by the *S. album* after 7 years. The *P.granatum* favoured greater value of DBH, height ratio as a long term host, but it required to be verified in replicated trials. Sandalwood plantation in Gujarat has increased after 2010 and it is estimated that total plantations of different age groups is about 1000ha area in Himatnagar, Banas Kanta, Mehsana, Ahmedabad, Baroda, Anand, Surat etc. Gujarat Sandalwood growers association, Gujarat State Forest Department and Anand Agriculture University are promoting and supporting Sandalwood cultivation in Gujarat.

Large scale production of sandalwood seedlings in private nurseries

Mehsana

Himmatnagar

Anand

5.0 Sandalwood cultivation in Rajasthan

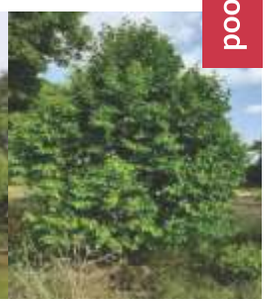
Sandalwood is found naturally in Southern and Eastern Rajasthan, particularly in Aravalli ranges from Sirohi to Pratapgarh in semi-arid regions. Apart from Forest, *S. album* is also found naturally in agriculture land, temples premises, old havellis etc. Small plantation was also established and oil content varied from 0.9 to 3 percent (Jain *et al.*, 2007). Natural regeneration is common in forest and private lands in Aravalli ranges. Trees of small girth can be observed in Sirohi, Sadari, Desuri, Udaipur and Pratapgarh areas. Due to illicit cutting > 40 cm girth trees are rare to locate. Central Arid Zone Research Institute (CAZRI, Jodhpur) planted few trees in their campus nursery, which induced heartwood and oil content. In Arid Forest Research Institute (AFRI), Jodhpur Campus few trees of 8-10 years old are growing luxuriently. During past 8 years plantations of Sandalwood have been established by the farmers in agriculture field as boundary plantations as well as block plantations with different host plants like; Anwala (*Phyllanthus emblica*), *Zizyphus mauritiana, Acacia nilotica, Casurina equisetifolia, Gmelina arborea* and *Melia dubia*. Plantations have been established in agriculture land in Pali, Sirohi, Rajasmand, Udaipur, Jodhpur, Barmer, Nagaur, Sikar, Jaipur, Alwar and Ganga Nagar area. Arid Forest Research Institute, Jodhpur is conducting training of farmers for the

cultivation of Sandalwood. The AFRI, Jodhpur has also established multi locational trials of *S. album* with different host plants in Rajasthan and Gujarat. The Rajasthan State Forest Department should come forward to help farmers in promoting Sandalwood cultivation and liberalize policies on harvest and sale, which is very essential in motivating farmers. National Medicinal Plant Board and Agroforestry Mission are promoting Sandalwood cultivation. As compare to Gujarat, level of Sandalwood cultivation in Rajasthan is very less (about 100 ha). But, there is a great potential of *S. album* cultivation in semi-arid regions of Rajasthan where rainfall is about 500-800 mm and irrigation facilities are available. In addition, Rajasthan has favorable climatic conditions for early heart wood formation. Scope of value addition is immense in Rajasthan due to large number of wood based handicraft industries.

Sandalwood Plantations in Rajasthan

AFRI Campus Jodhpur (10 years old)

Chota Guda, Pali (1.5 years old)



Khimel, Pali (3 years old)

6.0 Future prospects

The Sandalwood has wide adaptation to various types of soil and climatic conditions, which provide scope for cultivation in the area facing temperature from subzero to semi-arid regions (45°C) in Rajasthan with irrigation facilities. Sandalwood is one amongs three tree species (Agarwood, Redsandes and Sandalwood), which are highly prized and sold by weight. In past, plantations were raised by the State Forest Departments particularly, in Karnataka, Tamil Nadu, Andhra Pradesh and Kerala. After liberalization of cultivation policies/rules by the Karnataka and Tamil Nadu State Governments in 2001 and 2002, respectively, Sandalwood is largely cultivated by the farmers and Sandalwood based industries like; DS Group, Surya Vinayaka in Katni and Shivani in Madhya Pradesh, Karnataka Soaps and Detergent Ltd. (KSDL) in Karnataka. Presently, farmers of most of the states in India are cultivating Sandalwood in their farmland. Estimated demand of Sandalwood is about 4000-5000 MT and oil about 100 MT, which is likely to increase drastically due to wide and expanded uses of Sandalwood and its products in international as well as national markets. Pharmaceutical, aromatherapy, handicraft are few examples where scope of demand will be more.

Gujarat and Rajasthan are most suitable states, where large scale commercial cultivation of *S. album* can be carried out by the farmers as well as industries. This is mainly due to availability of land, suitable climatic conditions and entrepreneurships. Both the state governments must be pro-active to to provide all possible support to the farmers and industries to remove hurdles of harvest and sale of Sandalwood and its value added products. Medicinal Plant Board and Agroforestry Mission should continue their support in Sandalwood cultivation to farmers. Niti Ayog, Government of India has already constituted a Committee on Sandalwood development in India and hopefully, of which outcome will take to bring back glory of Sandalwood in India.

7.0 Issues in promoting Sandalwood cultivation and their possible solutions

i Lack of genetically improved seed and clonal material **:** The erstwhile Sandalwood Research Centre, Bangalore has taken up tree improvement programme of Sandwood by selection of plus tree based on commercial traits, established germplasm bank, clonal seed orchard etc. In past due to illicit activities these were damaged. The IWST, Bangalore had restocked germplasm bank and established progeny trails. However, there is a lack of quality seed and most of the planting materials raised by the private nurseries are from undefined or unimproved seed. Only Maryoor Forest Division has protected mature trees as a known source of seed, which can be used till improved seed is available.

ii There is a need of selection of candidate plus tree (CPTs)/ plus trees (PTs) based on commercial traits (growth, heartwood and oil content) from the various plantation from the country and establish germplasm bank, progeny trials and clonal seed orchards at highly protected sites as a source of future genetically improved seed and clonal material for plantation programme. This will fulfill requirement of quality planting material.

iii Lack of knowledge of good host species based on different agro-climatic conditions: currently farmers are using long term host based of scattered information or with their own vision. There is a need to identify the best compatible species of long term host which favour maximum growth of Sandalwood. Possible solution may come out from the All India Coordinated project being implemented by the ICFRE, institutes.

iv Ideal spacing between plant to plant and row to row : Presently farmers are following spacing like 3mX3m, 3mX4m, 4mX4m, 5mX5m based on the local advise of the private nursery persons. Based on Scientific studies, farmers need to be educated for standard spacing for Sandal wood cultivation for maximum financial return.

v Lack of complete package of practices for cultivation: There is a need to generate Scientific data on package of practices for the cultivation and management of Sandalwood plantations for the maximum financial return.

vi Variable policies/rules/norms of the state forest department in the country: Government support farmers and Sandalwood based industries by liberalizing Sandalwood cultivation, harvest and sale rules/policies on the lines of the states of Karnataka and Tamil Nadu. The Ministry of Environment, Forests and Climate Change, Government of India should take initiative to regulate uniform rules/norms/act across the country in all the states. Every State Forest Department should take lead in this matter to promote farmers in Sandalwood cultivation to increase their income and employment by liberalizing cultivation, harvest and sale policies.

vii Protection from illicit cutting and smuggling of Sandalwood: This is the most serious issues to be faced by the farmers. Possible solution lies in insurance of plantation like crop insurance, sensor based alarm system, keeping watch dogs, social fencing, guarding at the age of 10-15 years of age etc. Government may impose long imprisonment, and heavy financial penalties on the smugglers and illicit Sandalwood cutters.

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Prospects and Opportunities of Sandalwood Cultivation in Uttar Pradesh

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Introduction

In India more than 90 % of Sandalwood production is concentrated in Karnataka and Tamil Nadu, however the species occurs all over the country with varied growth, heartwood production and oil contents. The tree flourishes well from sea level up to 1800 m altitude in different types of soil like sandy, clayey red soils, lateritic, loamy and even in black cotton soils. Trees growing on stony or gravelly soils are known to have highly scented wood. Sandalwood tree can grow from moderate rainfall of 600 to 1600 mm, in places with long periods of drought. The species can withstand temperatures from 4- 460C providing immense adaptation plasticity which can be utilized while introducing it to non-traditional areas.

Due to its high value and the demand, attention is being given for establishing sandalwood plantations in the tropical region by the farmers, NGOs, and private sector companies. Sandalwood tree adapts well in terms of growth, heartwood and oil content under diverse locality factors. Thus, survival and establishment in Uttar Pradesh and adjoining areas will not be difficult if appropriate site selections and management interventions are done.

Scope of Sandalwood Cultivation in Uttar Pradesh

Generally *S. album* is found in the dry deciduous forests of Deccan Plateau, mostly in the states of Karnataka and Tamil Nadu, The evergreen tree regenerates naturally when conditions are favorable and has been spreading its distribution.

In Uttar Pradesh also a large area covers dry deciduous forest type. The mains regions of these forests are the plains of Ganga, Yamuna and their tributaries. These forests are found in all parts of the plains and usually in Eastern, Central and Western regions which include Lucknow, Raebareli, Unnao, Ghaziabad districts of the state. Large tracts of deciduous forests have been cleared for cultivation in the state. One research study has also reported occurrence of sandalwood (*Santalum album*) in the forest reserves of Bundelkhand forest division, district Jhansi. On reviewing the literature it was found that some well grown trees of Sandalwood already exist in various districts of Uttar Pradesh.

Since ancient period India has been known for its sandalwood, however during the last decade farmers have developed interest in cultivation of the plants. Earlier, it was mainly confined to the forests of Karnataka, Tamil Nadu and Kerala and state government's plantations. There was lack of cultivation on private agricultural land in other parts of the country. However a policy change in Karnataka and Tamil Nadu allowed people to grow sandalwood which has later inspired other states.

Despite a growth in Sandalwood cultivation, India is far behind to regain its leadership position in global sandalwood trade anytime soon. In fact, growers are unable to meet the domestic demand. To meet out the demand of sandalwood tree, suitable cultivation practices at non-traditional areas is necessary. Identification and mapping of potential habitats in different parts of country is necessary so that the declining native population may be conserved.

As per an estimate, during last decade lot of plantations have come up on private and agriculture land in north Indian states like Gujarat, Andhra Pradesh, Madhya Pradesh, Maharashtra and Uttarakhand, to promote the sandalwood trade in country. In eastern Uttar Pradesh, most of the farmers have very small land holdings, therefore block plantation would not be preferred by them where the waiting period yields no results at all. However, sandalwood agroforestry in the form of bund plantation may be better option, where farmer may get income for seven to eight years. Organic management of the sandalwood also attracts farmers as it reduces the management cost of cultivation.

Status of sandalwood cultivation in Uttar Pradesh

Sandalwood is capable of growing in different kinds of soils like sand, clay, laterite, loam, and black-cotton soil (avoiding water-logged conditions). Even very poor and rocky soils can support sandalwood. A pilot study was conducted on seed germination potential of *Santalum album* at Forest Research Centre for Eco-rehabilitation, Padila Research Nursery, Prayagraj. It was observed that seed germination of *Santalum album* was 40% under the normal condition. Further studies on growth patterns and Sandalwood based agroforestry are also being conducted in various research organizations and universities. The apprehension of low heartwood production and oil content seems cautionary and unsound in the light of scanty and insignificant scientific investigation been carried out on the aspects. It is known that both heartwood production and oil content increases significantly with increasing age. Therefore, it is possible that a higher harvestable age may be prescribed for plantations in non-traditional areas compared to native growth range. The activity will still be beneficial for the farmers.

A recent study recorded overall oil content ranging from 1.0 - 4.0 % in Madhya Pradesh. Natural populations in the girth class of 70-80 cm in. As per Arun Kurmi , Chairman, Progressive Chandan farmers Association, Punjab studies has been conducted to assess the oil content of sandalwood plants in Punjab and the results show that 3% oil content were available in the north India trees which is comparable to south Indian average.

Farmers engaged in Sandalwood Plantation

Based on available information it may be concluded that since last few years farmers have initiated sandalwood planation at their fields as block and bund plantation. Farmers of Pratapgarh, Varanasi, Kaushambi, Sultanpur, Kannauj and Ayodhya districts are engaged in sandalwood cultivation. Mr. Utkrist Pandey, a progressive farmer has started large scale farming of Sandalwood at Pratapgarh district of Uttar Pradesh in 2018 after getting training on cultivation techniques of Sandalwood at IWST Bengaluru. In general farmers are planting Sandalwood seedlings on their field bunds. However, block plantations are also being adopted by large farmers with 220-230 plants per acre. Farmers have established on farm nursery of sandalwood.

Fragrance & Flavour Development Centre (FFDC), a premium institute of Govt. of India has been established in Uttar Pradesh with an aim to serve as an interface between essential oil, fragrance and flavour industry and the R & D institutions both in the field of Agro Technology and chemical technology. Sandalwood is one of the main species on which FFDC is focusing to upgrade the status of farmers and industry engaged in the aromatic cultivation and its processing. Seedlings of sandalwood are also provided by FFDC for promotion of sandalwood cultivation among the farmers In future FFDC may be a potential buyer for sandalwood in the north India region due to which large scale plantations are also coming up in Kannuj district. Farmers in the Teria districts are also engaged in sandalwood cultivation.

Planting Stock

Quality of planting stock is a major concern among farmers. They have a hitch during procurement of seedlings as its source and quality is not well known to them and they feel that may have future repercussions in terms of quality of end product at the time of selling FFDC has standardized technologies for Sandalwood plant nursery in the region Seedling of sandalwoods plants were sold to the farmers and their queries and advance bookings for planting material reflects the future prospects of its cultivation among farmer's/ growers' interest.

Famers feel that a lot of financial viability exists in sandalwood cultivation and continuous increase in

prices of sandalwood and oil. This is the reason behind that Sandalwood cultivation is slowly gaining pace in non-traditional northern India states like MP, Gujarat, and Punjab etc. However some farmers are concerned about security for protecting a mature sandalwood tree would be tough task for a farmer. They feel that lot of money will be required in future for protection of plants. It will attract theft once the trees are ready for harvest as lots of incidents are reported from Lucknow, Sitapur, Barabanki and other districts where mature sandalwood trees were chopped off by the smugglers. Therefore farmers expect government to help by providing suitable protection measures so that more farmers may take up sandalwood cultivation in future.

Concern about Legal Issues:

In Uttar Pradesh a list of 29 species has been released by government for which prior permission is required for harvesting of the tree. However, Sandalwood is not mentioned in that. However there is a feeling among cultivators that sooner or later some policy may come up from State govt. for promoting sandalwood cultivation and its legal nitty gritty.

Liberalization of rules for sandalwood cultivation in southern states has promoted its commercial cultivation throughout the India. Sandalwood cultivation has been initiated in non-traditional sandalwood areas in north India states like Gujarat, Rajasthan, and Madhya Pradesh As per research reports and survey conducted on sandalwood plantations in Northern and Central, parts of the country, it is found that heartwood formation happens generally between 6-9 years of age Farmers have a feeling that sandalwood based agro-forestry practices has immense potential in terms of income generation and suitable utilization of land and resources.

Institute of Wood Science and Technology, Bangalore
Publications for Sale

IWST PUBLICATIONS FOR SALE
BOOKS

Sl. No.	Name of the Books	Language	Rate
1.	Gem of Peninsular India Sandalwood	English	1,500
2.	Endemic Possession of Eastern Ghats: Red sanders	English	150
3.	Biodeterioration of Timber and its Prevention in Indian Coastal Waters - 3rd Progress Report (1982-2005)	English	250
4.	Anatomy and Properties of Lesser Known Timbers of North-East with particular reference to Nagaland	English	175

PROCEEDINGS / ABSTRACTS

Sl. No.	Name of the Books	Language	Rate
1.	Forestry, Forest Products and Coastal Population	English	200
2.	Wood Preservation in India: Challenges, Opportunities and strategies	English	250
3.	Conservation, Restoration and Sustainable Management of Mangrove Forests in India	English	250
4.	Intellectual Property in Forestry issues	English	250
5.	Bamboo Reserve Management & Advances in Utilization Options	English	200
6.	Indian Sandal wood. Compendium Abstracts of Research carried out English	400	
7.	Abstracts of the Published Research Papers (1998-2007)	English	Free

TECHNICAL BULLETINS /BROCHURES

Sl. No.	Name of the Technical Bulletin	Language	Rate
1.	Sandalwood	English/Kannada	100
2.	Sandalwood Tree (Pests, Diseases and their Management)	English	80
3.	A Guide to some important timbers in South Indian markets	English	150
4.	Arbuscular Mycorrhizal (AM) fungi as biofertilizer in forestry	English	30
5.	Teak Heartwood Borer. AlcterogystiaCadambae (moore) and its management	English	50
6.	Whitefly pests in Forestry and their management	English	30
7.	Wood Polymer Composite: New age Material	English	50
8.	Protection of Wood from Weathering	English	80
9.	Flower Gall Inducer of PongamiaPinnata and its management	English	60
10.	Cultivation prospects of edible bamboo shoots in South India	English	100
11.	Ficus Tree in Semi-arid. Agro Ecosystem of Karnataka	English	150
12.	Bamboos of India	English	200
13.	GuaduaanguistifoliaKunth: A Vegetable Steel Bamboo Species	English	150
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16.	Micro propagation of Bamboo Species	English	150
17	Disease Alert on Eruption of Sandal Spike Disease in Conservation and Cultivation of Indian Sandalwood	English	100
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21	Phytoplasma: Thrust for developing effective management strategies	English	100
22	Sandal oil: Adulteration and detection techniques	English	100
23	Bamboo Lumber: A sustainable alternative to solid wood	English	100
24	Utilization Potential of Palmyra Palm Wood (Borassusflabellifer L.)	English	100

My Glorious years at Sandalwood Research Centre

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Introduction

I am delighted to write on the nine glorious years (1977-1985) of Sandalwood Research. During this period several significant contributions were made on sandalwood research especially on the Tree Improvement aspects under the leadership of Shri. K. R. Venkatesan IFS., Conservator of Forests. Sandalwood Research Centre, Bangalore.

The Forest Research Institute (FRI), Dehra dun in 1977 had set up 12 Tree based research centers in India and one of them was Sandalwood Spike Research Centre. Considerable research work was carried out on sandalwood spike disease since its discovery in 1899 by McCarthy while, research on other aspects of sandalwood was neglected. Hence, Shri. K. R. Venkatesan IFS., took out the word 'Spike' from the title and renamed it as Sandalwood Research Centre (SRC) to facilitate research work on all aspects of sandalwood. Later in 1986, SRC was merged with Institute of Wood Sciences and Technology (IWST).

In the first step more than 45 projects were identified which consisted of All India sandalwood survey, biosystematics, physiology, genetics and tree breeding, pathology, entomology, silviculture, Nursery and plantation Package of Practices, Organic chemistry on sandalwood oil and other aspects. This paper reviews the major research work carried out during that period.

All India sandalwood survey

The first authentic sandalwood survey revealed that it occurred over an area of 9040 sq km in India of which 5245 sq km in Karnataka and 3040 sq km in Tamil Nadu were the major sandalwood bearing areas. Sandalwood areas in Andhra Pradesh (Telangana & Andhra Pradesh) 175 sq km, Kerala 63 sq km and Madhya Pradesh (Madhya Pradesh and Chhattisgarh) 33 sq km were recorded. In other states the sandalwood bearing areas were less than 1 sq km (Srimathi, et. al., 1995). Over the years the sandalwood stock in the natural forests decreased considerably due to rampant smuggling, in adequate management, lack of natural regeneration, felling of green trees, pests and diseases.

Tree improvement

Seed Stands and Seed production Areas

Five Seed stands (SS) at Marayoor (Kerala), Chitteries and Javadhis (Tamil Nadu), Rayalpad and Tangli (Karnataka) were identified and converted into Seed Production Areas (SPAs). Nearly 1325 to 2500 seed bearing trees were retained in SPA.

Provenance trials

Sandalwood occurs mostly in southern India but it has spread beyond southern states due to its introduction in the past. Provenance variation in the same species have been recognized when the species moved from one geographical region to another.

Around 11 provenances were identified with specific characteristics.

S. No.	Name of the provenance	Apparent characteristics
1	Maryoor, Kerala	Seed size is big, yellow / light brown heartwood Full of heartwood and sandalwood oil,
2	South Seoni, Madhya Pradesh	Lush green leaves, dark brown bark, heartwood light brown in colour, medium heartwood and oil content
3	Hardanhalli, Chamrajnagar, Karnataka	Medium size ovate leaves and seeds, with high amount of heartwood and sandalwood oil
4	Honnehatti in Bhadravathi, Karnataka Chandrakala in Shikaripura Sagar, Karnataka Tangli, Chikamangalure, Karnataka	Lush green leaves, seeds varying in size, heartwood is light brown or yellow in colour, full of heartwood and sandalwood oil

5	Thindlu, Hoskote, Karnataka	Small diameter trees, Full of dark brown heartwood, sapwood width is 2 to 4 mm. Oil content is around 2 to 3%
5	Chittor, Andhra Pradesh	Yellowish green leaves, yellow, yellow brown heartwood colour.
6	SFRC, Coimbator, Tamil Nadu	Varying seed size. Trees with medium heartwood and sandalwood oil, Heartwood colour dark brown
7	Kumbakonam (Sholapuram), Tamil Nadu	Trees with ovate, lanceolate leaves, Heartwood colour is yellow predominantly. Contains good amount of heartwood and oil
8	Kurumbapatty, Chitteris Javadhis, Salem, Tamil Nadu	Varying seed size. Trees with small size leaves, heartwood light brown to yellow brown. Full of heartwood and oil.
9	FRL (IWST), Bangalore, Karnataka	Varying leaf and seed size and shape. Heartwood colour yellow, yellow brown, brown and dark brown.
10	NZP, Hyderabad, Telangana	Leaves thick, yellow green, varying seed size. Trees with less or no heartwood, Sandalwood oil content is around 2%.
11	Janiguda, Koraput, Orissa	Trees with ovate - elliptic leaves, seed medium in size, heartwood colour predominantly yellow, yellow brown. High heartwood and oil content.

Seed source (SS) or provenance trials were established in 1981 at Nallal (Karnataka) with 21 seed sources (3.14 ha) and Kuderu (Andhra Pradesh) with 10 seed sources (0.24 ha) in 1982.

Plus trees and propagation

Totally 79 plus trees were selected – 39 in Karnataka, 31 in Tamil nadu, 6 in Andhra Pradesh and 3 in Kerala and the plus trees were vegetatively multiplied by scion derived from them by cleft grafting. The plus trees thus multiplied were planted in Germplasm Bank (GB) and Clonal seed Orchards (CSO).

Vegetative propagation through rooting of stem cuttings (mist propagation / macropropagation) was not successful as only 3 to 5 % rooting was achieved. Tissue culture plants though easily produced in the laboratory were not successful in field out planting hence, one cannot see large scale tissue culture sandalwood plantations in India.

For selection of plus trees the author and team use to visit sandal forest areas along with the senior forest officials of Karnataka. The officials use to make fun saying "you are making the job of smuggler easy as they may knock off the selected tree with heartwood (plus tree) leaving other trees with less or no heartwood". Hence, as soon as the tree was selected, seed and scion material were collected for multiplication and the germplasm was conserved in the germplasm bank.

Germplasm and Clonal Bank

The Germplasm bank / Clonal bank were planted at Gottipura (Karnataka) with 60 clones in 1980 and 1982, Karvatnagar with 10 clones and Kurumbatty with 15 clones (Tamil Nadu) in 1983. Nearly 35 different biotypes of sandalwood were also planted in Gottipura (Karnataka) in 1982. (Fig. 1)

Clonal Seed Orchards

Clonal seed orchards (CSO) was established at Nallal (Karnataka) in 1982 with 25 clones in 1.35 ha (Fig. 3) The second CSO was planted at Akkarampalli, Tirupati (Andhra Pradesh) in 1983 with 30 clones in 1 ha area. The 3rd CSO was planted in 1984 with 30 clones in 1.5 ha area. The first CSO had permutated neighbor design with single ring isolation while, the other two CSO's had permutated neighbor design with double ring isolation.

Open pollinated half-sib progeny trials

Seeds collected from 79 plus trees were germinated and seedlings planted in 2.05 ha area in 1980 at Nallal, Bangalore, Karnataka. Singletree plot design with triangular spacing was followed in establishing this half-sib progeny trials. The plot was assessed after planting at 18 months and majority of trees attained 1 to 1.5 m height and were flowering and it was the first report of precocious flowering in sandalwood as normally trees start flowering after 4 years after planting in the field.

Release of Sandalwood Clone

SRC clone -1 was released in 1982 in a function held at SRC/FRL, Bangalore and this SRC-1 clone was handed over for cultivation to shri. S. Shyam Sunder IFS., Principal Chief Conservator of Forests, Karnataka. This clone was derived from plus tree T-01 Sholapuram Pudukottai, Tanjavur, which was 8 year old in sandalwood planation having 8 kg of heartwood. This plus tree was exceptionally fast growing (GBH 59 cms) and height of 9.8 m with good amount of heartwood and sandalwood oil.

The estimates of the expected genetic gains from Tree improvement are (a) afforestation by SS seeds is 2 % (b) By SPA seeds is 5 % (c) by CSO seeds is 15 % and (d) by advance generation seed orchards is 25 %. These gains although look marginal are substantial when considered in the context of overall growth and annual yield of heartwood and sandalwood oil content (Srimathi, et. al., 1995)*.

Methods developed and perfected for plus tree selection,

1) A simple method of using Pressler's increment borer on live sandalwood trees for heartwood estimation was evolved and operation standardized. A new term was coined "CORE GRAM" to compare cores derived from various sandalwood trees with respect to sapwood width and heartwood colour. Earlier, only 2 to 3 samples per day use to be taken and the person operating the increment borer was to apply his might and use to get exhausted. With the rope technique per day more than 50 core samples were taken. This rope technique helped in quick assessment of sandalwood population for heartwood and oil and the person operating the increment borer was not tired/exhausted (Kulkarni, et. al., 1995)*.
2) A simple method (Micro-method) for estimation of sandalwood oil in small quantity (1gr.) of material through extract-oil correlationship was developed. Core samples were used for estimation of sandalwood oil for selection of plus trees (Shankaranarayana, *et. al.*, 1995).
3) Some time it becomes difficult to differentiate the sapwood and heartwood portion from the core samples as well as from the wood disk portion due to similar colour pattern. A colour tests method was developed for differentiating sapwood and heartwood (Fig. 2). The sapwood width was considered as an important parameter for selection of plus trees. Out of 20 reagents tried, four colour tests viz. Vanillin – HCl, Benedict's solution, HCl – Methanol solution and Bromocresol Green were effective. When core sample were treated with Vanillin – HCl solution, a sharp pink ring was observed at the heartwood and sapwood boundary area thus clearly demarcating the sapwood and heartwood portions clearly (Kulkarni, 2004).
4) For multiplication of plus trees and allied germplasm, cleft grafting method was adopted. The success rate achieved was 75%. This was the only method which came handy for multiplication of the elite germplasm while, other methods such as air layering (gutti), rooting of stem cuttings, tissue culture etc., did not give the required success rate. Propagation through root suckers however was easy but the rate of multiplication was very low. Graft incompatibility was recorded and methods to overcome such maladies were evolved. A case of total sterility in sandalwood was first time reported and vegetative propagation through grafting was successfully attempted (Srimathi, *et. al.*, 1995)*.
5) A computerized permutated neighborhood design with single and double ring isolation was developed to achieve panmixis in clonal or seedling seed orchard (Sekar, *et. al.*, 1984).
6) Preliminary studies on the effect of gamma irradiation on sandalwood seeds revealed the

Around 20,000 trees were tested with Presslers Increment Borer by the all India sandal survey team and the author has taken more than 15000 core samples and was referred jocularly as "Head Borer". When the author use to complain about the chest pain due to borer operations, Shri K. R. Venkatesan IFS and R. A. Srimathi, SRO & HoD of Genetics & Tree Breeding Branch of SRC use to say, we will recommend you for Gunnies book of world record for highest number of boring samples obtained!

LD50 dosage is at 30 Kr at 6% moisture level in seeds. Mutants such as chlorine, xantha and albina were observed in seedlings obtained from irradiated seeds apart from linear curved leaves, bifurcated stems etc., (Srimathi, *et. al.*, 1995)*.

Hybridization and Mutation breeding is considered as the last resort in sandalwood tree breeding as the best Indian germplasm of sandalwood if cross breed with other Australian and pacific sandalwood species (which are inferior in heartwood and oil content) will lead to dilution of high quality germplasm.

Genetic variation in half-sib progeny seedlings of sandalwood plus trees

The seed and seedling characteristics belonging to 24 plus trees of sandalwood revealed significant genetic differences. Seedling characters like long hypocotyl, root and shoot length, number of haustoria and leaves associated with 1000 seed weight contributed to genetically vigorous seedlings. High heritability (H) estimates associated with high Genetic advance (GA) were recorded for 1000 seed weight, germination per cent, hypocotyl and shoot length. While, hypocotyl diameter, number of haustoria, and leaves showed low heritability. The D2 analysis of 24 plus trees derived from diverse populations congregated only in 2 clusters implying that the genetic diversity is more intrinsic than due to geographical reasons. Based on varietal indices plus trees KL-3, KL-2, KL-1, K-5, K-7 and TN-25 were shortlisted for further breeding programme (Kulkarni, *et. al.*, 1998).

Varieties in Sandalwood

1). Anchety variety of sandalwood: This variety of sandalwood was growing in Anchety Forest Rest House, Hosur Division, Tamil Nadu. This tree had 51 cm Girth and 6 m height. The fruit shape was very different compared to normal sandalwood trees. This tree showed graft incompatibility suggesting that it is a different germplasm. Seedlings were raised from this tree and then cleft grafted to overcome graft incompatibility. This variety was multiplied successfully in large numbers to be planted in germplasm bank and clonal seed orchards (Srimathi, et. al., 1995)*.

2). Pinhole variety (Pitted variety): Occurrence of pin hole variety (Fig. 3) on an average was 5% in any given population. The pinholes were found on the entire tree (root, stem and branches). The concentration of pinholes ranged from 5 to 28% per 100 cm2. Anatomical studies revealed that the pin holes are due to presence of giant multi-seriate medullary rays (256 to 965 µm in length and 57.6 to 266 µm in width). Normally uni and bi-seriate medullary rays (68.5 to 428.4 µm in length and 15 to 35.78 µm in width) are commonly seen in sandalwood while, occurrence of multi-seriate medullary rays is a new report for sandalwood.

Other stem forms such as twisted (spiral grain), stem with prominent and persistent branch knots, crooked stem were also observed and nearly 3% such trees occurred in any given population. These characters were considered as negative characters and such trees were discarded during plus tree selection. Sandalwood timber is seldom entirely free from defects which affect the strength, durability, colour and economic value. Most of the wood characters mentioned above are heritable and use of seeds and clonal material devoid of such defects is suggested for raising quality plantations (Kulkarni, 2004).

3). Thindlu variety: This variety was characterized by small diameter class (4 to 8 cm DBH) with brown bark in irregular flakes. The most distinguishable character is that the sapwood width is very narrow (2 to 10 mm). The heartwood is dark brown in colour with distinct annual rings. The sandalwood oil content is around 2.5% with 85% santalol content. This variety was first found in Thindlu reserve of Hoskote range of Bangalore division and later in Ammenkatte of Hassan division of Karnataka. This variety was also observed in Bhor in Maharashtra and Valliyur of Tamil Nadu. For in-situ conservation of Thindlu variety, an area of 10 ha was fenced with chain link mesh in Thindlu forests of Hoskote range, Bangalore division.

4). Chickballapur variety: This variety is characterized by the presence of small bluish green leaves with sparse crown. This variety may correspond to the Noganur variety described by Griffith in 1937.

5). Robust variety: This variety usually have a compact crown with lush green foliage. The stem is usually straight and cylindrical with rust brown bark. The sapwood width is wide (around 5 cms). This variety is considered as a fast growing sandalwood type in even aged plantations (Srimathi, et. al., 1983).

6). Other types based on leaf shape and size:

Ovate type (Ovata): This is a normal type found in most of the sandalwood populations with the average length/breadth ratio of 2.3.

Lanceolate type (Lanceolata): The length of leaf is 4 to 6 times more than the breadth. The average length/breadth ratio is 3.

Elliptic type (Elliptica): The length of leaf is twice its breadth. The length/breadth ratio is 1.71.

Linear type (Linerata): The leaf is characterized by parallel long margins. The leaf length is 8 times more than the width. The length/breadth ratio is 5.15.

The leaf size is big (Macrophylla) and small (Microphylla) and these two types are associated with the above leaf shape types (Kulkarni, 1995).

Homoplastic and Natural grafts

Natural stem grafts in sandalwood were observed in Valparai, Sholapuram and Chitteri hills in Tamil Nadu and Cubbon Park in Bangalore, Karnataka. Such type of grafts were technically termed as "Natural Approach Grafts" and the natural root grafts in sandalwood were more common (Kulkarni and Srimathi, 1985).

A unique Homoplastic (Multiple) grafts was made on a well grown 4 year old sandalwood plant with 1.5 m height maintained in a pot (Fig. 4). Cleft grafts were made deriving the scion material from ovate, elliptic, lanceolate and linear leaf types with green and copper coloured leaf. Even after 2 years of making grafts, the ten types maintained their identity and survived. Lanceolate green type showed 77.8% success while, Linear red showed 16.7% success. This experiment confirms the interspecific varieties in sandalwood as the grafts maintained their clonal identity (Kulkarni, 1995).

Sandalwood and horticulture

Sandalwood besides its traditional usage in cosmetics, perfumery and handicrafts industry can be used as a horti-silviculture species. Sandalwood with variegated leaves (greenish leaves with yellow patches, Pinkish / copper coloured foliage) leaves are horticultural novelty. Sandalwood responds to topiary and is grown in gardens (Srimathi, et. al., 1995).

Sandalwood bark with chemo-sterilant properties

A chemo-sterilant compound "triterpene palmitic ester" was isolated from sandalwood bark which was proposed to be used as a third generation pesticide in controlling insect pests on forest plants (Shankarnarayana, et. al., 1995).

S. No.	Sandalwood Leaf type	Grafts made	Number of Grafts established	Graft success (%)
1	Ovate, big, red	6	4	66.70
2	Ovate, small, red	6	2	33.30
3	Ovate, small, green	9	5	55.50
4	Elliptic, green	9	4	44.40
5	Lanceolate, red	9	6	66.70
6	Lanceolate, green	9	7	77.80
7	Linear, red	12	2	16.70
8	Linear, green	11	3	27.30
9	Pendulous	07	3	42.90

Future research work:

1. It is quite essential now to conduct sandalwood survey in order to record the spread of sandalwood in natural forests as well as on private lands / private plantations as the survey conducted is more than 40 years old. The survey should include parameters for heartwood and oil content, pest and diseases, delineation of provenances and selection of plus trees.
2. Multi-locational provenance trials and clonal trials.
3. Clonal propagation through stem cuttings and standardization of macro-propagation protocol.

   Research on macropropagation is to be undertaken and protocol developed / standardized which will pave the way for raising quality and high productive sandalwood clonal plantations like poplar and eucalyptus. This technique has the potential to totally change the scenario on sandalwood cultivation.
4. Standardization of hardening process of tissue cultured sandalwood plants and their field trials.
5. Karyomorphological (Cytogenetics) studies on sandalwood species / varieties and biosystematics.
6. Release of sandalwood varieties and varietal descriptors.
7. Fresh studies on spike disease transmission and fixing the correct vector for transmission involving modern methods.

It was a happy moment that both Mr. K. R. Venkatesan IFS and Mrs. R. A. Srimathi were felicitated for their noble contributions on sandalwood research conducted during 1977 – 1985 period in the sandal seminar held on 19th December 1997 and 2nd March 2014 respectively organized by IWST (ICFRE) and Karnataka Forest Department at Bangalore.

8. Control of heartwood borer *Aristobia octofasciculata Auruvillius* a silent robber of precious heartwood of sandalwood.
9. Breeding resistant varieties against spike disease and heartwood borer.

Short term projects such as delineation of provenances and their trials, clonal propagation (stem cuttings / tissue culture), cytogenetics and sandalwood survey should be pursued vigorously. While, for long term projects a sound research foundation be laid.

I wish to conclude with a quotation from J. M. Lydgate of Hawaii "Sandalwood trees have grown in the past, why should they not grow in the future, if they are only spared and protected! What nature has produced so willingly, may she not be persuaded to produce again with a little intelligent help". Now that the farming community has taken up sandalwood cultivation in India, it builds optimism on the revival of sandalwood wealth so that its availability is made on continuous and sustainable basis to everyone.

Acknowledgments

Thanks are due to Shri. Chennegiaiah grafter and his team who relentlessly worked for multiplication of elite germplasm and establishment of orchards. Thanks are also due to Range Forest officers, Foresters, scientists and technical staff of SRC who made the Tree improvement program a great success. Author is also grateful to Forest officials of Karnataka, Tamil Nadu, Kerala, Andhra Pradesh who contributed a lot on sandalwood tree improvement.

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Fig. 1. Grafted clonal seed orchard of sandal, Nallal, Bangalore.
A. Ramet of Clone K-5. and B. Ramet of Clone T-1.

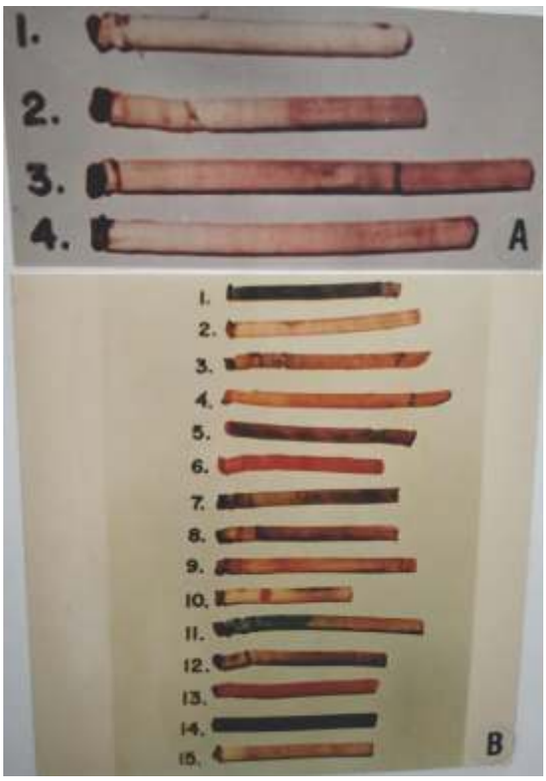

Fig. 2. Colour tests for differentiating sapwood and heartwood in sandal

A- 1. Full sapwood sample.
2. Sapwood and heartwood zones
3 & 4. Sapwood and heartwood boundary not clear
B. 1. Ferric chloride
2. Hydrochloric acid-methanol
3. Iodine
4. Methyl orange
5. Perchloric acid
6. Benzidine
7. Fehling's solution
8. Benedicts solution
9. Potassium Iodide-Iodine
10. Vanillin-Hydrochloric acid
11. Bromocresol green
12. Bromophenol blue
13. Phosphomolybdic acid ethnol-HCl
14. MAULE test (KMnO4 HCl NH4OH)
15. Sudan IV

Fig. 3. Anatomy of Pin hole variety of sandalwood A. Biseriate medullary rays B. Multiseriate medullary rays C. Sandal billet with pin holes

Fig. 4. Homoplastic grafts of Leaf biotypes in sandal.

1. Ovate red
2. Lanceolate red
3. Linear green
4. Lanceolate green
5. Elliptic green
6. Pendulous type
7. Normal ovate green

(stock plant with Pongamia host plant)

Sandalwood - Seed handling and Propagation

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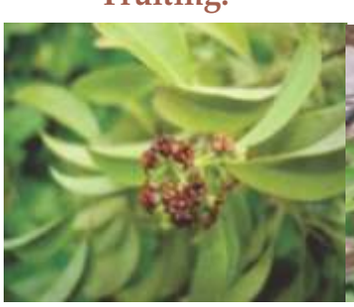
Introduction

A sandalwood plants are produced through seeds. Seeds are easy to propagate. In nature, sandalwood seed are dispersed through bird droppings and germination occur easily when it gets a favourable environment viz. good soil and good rainfall. Germination that occurs naturally is called as regeneration. All the seeds germinated do not survive unless otherwise it gets continuous good environment in the initial period. Though many seeds germinate, only few seedlings become tree in nature. Production of seedling of sandalwood in more quantity is required to meet the demand of public to raise plantations. This article deals about the sandalwood fruit, its maturation, collection and raising of seedlings in nursery. This knowledge is very much essential to produce seedlings in large quantity.

Sandalwood flowering and Fruiting:



Flowering in Sandalwood trees occurs twice in a year. It starts flowering during February to March and during the month of July to August. Fruits mature after 90-110 days. Mature fruits are available during May to June and September to November. Mature fruits can easily be identified by the colour of the fruits. The colour of the fruit is dark pinkish in colour.

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Collection of fruits and processing of Seed:

The fruit size varies resulting in 4000 to 6000 seeds for one kilogram. Mature fruits either fall on the ground or stick to inflorescence and dry up. These fruits can be handpicked from the tree or collected from the ground. Fruits should be collected from the ground regularly. Allowing the fruits to stay on the ground for long time leads to insect attack in fruits, which affect germination.

The collected fruits should be processed by soaking in water for 6-8 hours and the fruit coat removed manually by rolling the fruits with hand and regularly adding water to remove the fruit coat. Clean seeds are obtained by repeated cleaning of fruit, twice or thrice by the above mentioned procedure. The cleaned seeds are dried under sunlight for one or two days to remove excess water. It is then stored at room temperature in a cloth bag. Seeds can be stored for two to three months.

The quality of seeds can be tested by three methods; by floatation test wherein seeds are soaked in water and the floating seeds can be rejected; by germination test wherein seeds representing the lot can

Fruit de-pulping

Seed drying

be sown and percentage germination can be obtained; by cutting test wherein seeds are cut to observe the presence of healthy embryo.

Raising of Seedlings:

Preparation of Nursery bed: The ideal nursery bed size for large quantity of seedling production is 10 (L) x 1 (w) metre. All sides of the bed need to be arranged with single line of bricks with a height of 4-5 bricks (16 to 20 inches height). The bottom of the bed has to be filled with 2 to 3 layer of gravels (size 20 mm) for easy percolation of excess water. Above the gravel, river sand has to be spread for about 6 to 9 inches height.

Bottom layer with gravel

Bricks for preparation of bed

Filling with Sand

Elevated bed

Elevated bed: In elevated type of bed bricks are not used as lining for the bed instead a heap of sand is made to a certain height and then the top of the heap is levelled. Sowing can be done on the flat top of the elevated bed.

Medium for sandalwood seed growing: Sand is found to be the best media for sandalwood seed germination and temperature of 25° to 30°c is found to be ideal.

Management of bed: Thimmet 10G granules @500gm/bed of 1X 10mt can be added along with the bed mixture. Watering has to be done twice daily based on moisture content of the bed. In case of fungal infection spraying of Bavisitin 0.01% is advised.

Preparation of seed for sowing: Germination of sandalwood seed starts at 45 days after sowing and

takes upto150 days. If the seeds are treated with GA3 (Gibberellic acid), they start germinating after 20 days and completes within 60 days.

Treating the seed with GA3: 500 ppm of gibberellic acid solution is prepared by dissolving 1 g of gibberellic acid in 2 litres of water. Initially, gibberellic acid solution has to be dissolved in 5 to 10 ml of 40 to 50% alcohol. Once Gibberellic acid is completely dissolved in alcohol, water is added to prepare two litre of solution. Seeds should be soaked in GA3before sowing in bed.

Sowing of seeds: These GA3 soaked seeds are spread on the nursery bed, leaving spaces between seeds and later covered with thin layer of sandalwood seed. Seeds should not be sown closely.

Watering of nursery bed and Germination: Watering has to be done twice in a day using flower

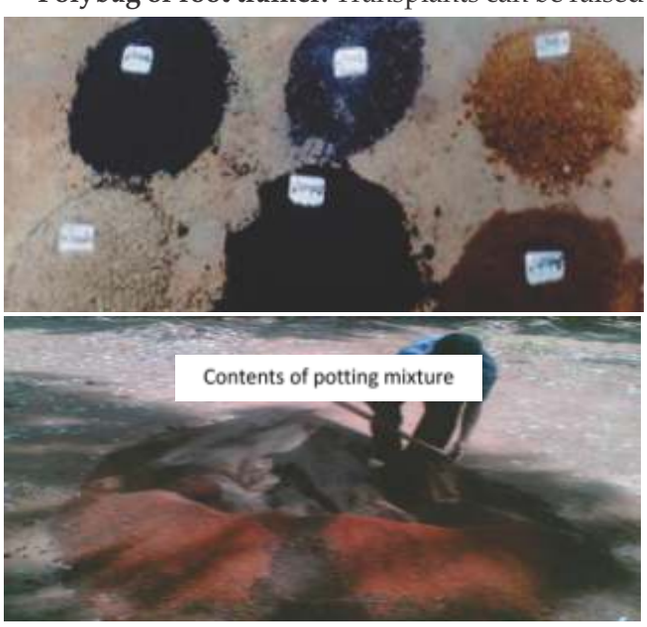
pot from the day of sowing the seeds.

Germination of seeds and transplantation of seedling: Seeds start germinating from 20 days after sowing. Once the seedlings reach the stage of 2-4 leaves (30-40 days after germination) they are ready for transplantation. If seeds are sown in December then transplanting is done in January which can be extended upto February. Transplanting in the afternoon hours is preferred. The transplantation is completed by evening then transplants are not

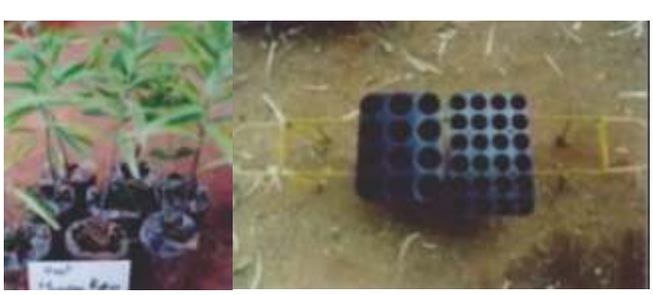
exposed to harsh sunlight and higher temperature. Transplanting care should be taken to avoid root coiling. Transplanted seedlings are kept in shade for about 5-6 days to avoid transplanting shock. They can be exposed gradually to sunlight for hardening the seedlings. Transplantation is done in polythene bag or root trainer filled with potting mixture.

Potting mixture: Potting mixture is the media for planting of transplants. Potting mixture for polybags or root trainer can be prepared by mixing Sand, Soil, Compost, Burnt rice husk and charcoal (optional) in the ratio 25:15:50:5:5. or Sand soil and compost in 35:15:50 ratio can also be preferred.

Polybag or root trainer: Transplants can be raised either in polybags or in root trainer. Polybags of size 5 x 8 inches are preferred as optimum size for sandalwood transplants to maintain them for 9 months. Bigger size polythene bags can be used if the seedlings are to be retained for more than one year. For mass propagation 270cc block type root trainers are recommended with density of 160-200 cell/sq mt.



Preparation of potting mixture



Poly Bags **Root Trainer**

Root trainers provide proper aeration for the roots and the ridges present on root trainer train the root in proper direction thus robust root system is

Seedlings transplanted into Root trainer

Seedlings transplanted into Polybgas

Sandalwood with *Cajanus cajan* as host

produced.

Providing of Host plant: As Sandalwood is a partial root parasite it should be provided with suitable host. Touch me not plant (*Mimosa pudica*) or Pigeon pea (*Cajanus cajan*) can be provided as host plant immediately after transplanting. These host plants have to plant 7 to 10- days after transplanting the sandalwood seedling. Mimosa pudica is propogated easily by cuttings. It can be grown along with the sandalwood plant by inserting a small stem cutting near to the sandalwood plant. In case of Cajanus cajan, one or two seeds need to be sown near the plant.

Host management: Pruning of Mimosa pudica should be carried out at 30 days interval and Cajanus cajan at 15 days interval to avoid overgrowth of the host.

Nutrition supplements: Spraying of NPK soluble solid fertilizers at 0.5% along with multiplex of 0.25% can be followed for 15 days interval if required. Application of vermicompost (5- 10 g) in polythene bag once in 45 days, will boost the growth of the plant.

Supplementary nutrition: Osmocote slow release fertilizer 0.25g/ seedling can be provided (if N status of potting mixture is 1-1.5%). Osmocote slow release fertilizer 0.50g/ seedling can be provided (if N status of potting mixture is low)

Pest and disease management: Bavistin (Wettable powder) @0.25% and Ekalux 0.1% can be applied at fortnight intervals in case of fungal and pest attack respectively.

Factors affecting quality of seedlings:

Season of nursery: Establishing nursery during right season helps the plant to grow healthily when they are in nursery bags.

Source of seed: Seed should be collected from known sources which means trees from seed orchards or from plantations maintained for seed collection with broader genetic base should be chosen for seed collection.

Stage of transplanting: Transplanting should be when the seedling are in 2-4 leaves stage delay in transplanting beyond 2-4 leaves stage allows the plant for its shoot and root growth which may lead to damage to roots while transplanting or difficulty in transplanting seedlings with lengthy root.

Type of container: Polybag/root trainer: Root trainers provide proper aeration for the roots and the ridges present on root trainer train the root in proper direction thus robust root system is produced. Root pruning is easy in root trainer.

Size of container: volume of the container: It is important to choose the container with proper size depending on how long the seedlings are retained in nursery before planting in the field.

Nutrition: The health of the plant needs to be monitored regularly and additional nutrition should be provided to maintain good growth of the seedlings.

Host and pest management: Seedlings should be observed regularly for attack of insect/pest. In case of attack, treating with insecticides/pesticides should be followed for obtaining quality seedlings.

Tissue Culture of the Scented Tree, *Santalum album* L.

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Introduction

Santalum album L., commonly known as Sandalwood or Chandan is being generally propagated through seeds. However, due to its out-breeding nature, the seed based progenies are highly variable. While vegetative propagation through grafting and root suckers is less successful for S. album, micropropagation can aid in long-term conservation and clonal propagation of valuable germplasm. In vitro cloning is the only method for rapid and mass production of clonal planting material. In order to exploit the full worth of superior clones containing high oil content or heartwood, researchers have invented tissue culture techniques for mass propagation of sandalwood. Various factors like type of explant used, season of explant collection, nutrient medium, plant growth regulators & other additives incorporated in the medium, incubation conditions, and duration of sub culturing, play an important role in the success of in vitro propagation of any plant species. IWST, Bangalore has developed micropropagation protocols for *S. album* through axillary shoot induction from nodes, adventitious shoot induction from leaf and somatic embryogenesis from callus.

Axillary shoot proliferation

The axillary bud is an embryonic shoot which lies at the junction of the stem and petiole of a plant. These axillary buds are usually dormant, inhibited by auxin produced by the apical meristem, which is known as apical dominance. Nowadays, axillary shoot proliferation has become more popular in commercial micropropagation. The main reason is that it isthe most reliable method of propagation, producing direct shoots and avoiding the risk of genetic variation, thereby guaranteeing clonal stability. Although the rate of multiplication is generally less than that which can be brought about through shoot culture, there is less likelihood of associated callus development or the formation of adventitious shoots, so that subculture carries very little risk of induced genetic irregularity. For this reason, axillary shoot culture has been increasingly recommended by research workers as the most appropriate micropropagation method.

Axillary shoot initiation from nodes of sandalwood

During 1997 Sanjay a first established the tissue cultured sandalwood cultures at IWST for three selected clones by collecting explants from established germplasm banks. Success in shoot induction in explants from mature trees of sandalwood has been reported by Sanjay et al. in 1998.Later in 2002 and 2003, Mamatha and Biniya established in vitro cultures for four other promising genotypes. Sanjaya *et al.* (2006) and Rathore *et al.* (2008) observed multiple shoot induction from nodal shoot segments derived from mature tree on MS medium with additives, IAA and BAP. Low rate of rooting on MS/4 medium with IBA was also observed. Biniya (2007) studied the effect of media, PGR's, additives, genotypes and polyamines on in vitro shoot multiplication in *S. album* and reported that MS medium with NAA, BAP and additives favoured shoot multiplication. Joshi (2012) and Sushant (2020) studied the *in vitro* and *ex vitro* rooting, as well as hardening in sandalwood; the latter also studied the effect of bio-fertilizers on tissue culture raised *S. album* plantlets at nursery stage.

Somatic embryogenesis

Somatic embryogenesis is defined as a process in which a bipolar

structure resembling a zygotic embryo develops from a non-zygotic cell, without vascular connection with the original tissue. Somatic embryogenesis occurs through a series of stages characteristic of zygotic embryogenesis. Somatic embryos can differentiate either directly from the explant without an intervening callus phase or indirectly after a callus phase. The mass propagation of plants through multiplication of embryogenic propagules is the most commercially attractive application of somatic embryogenesis. In addition, it permits the culture of large number of reproductive units, and plants derived from somatic embryos are less variable than those derived by the way of organogenesis.

Somatic embryos of *Santalum album*

Bapat & Rao (1984) and Rathore *et al.* (2008) reported embryogenic callus induction in *S. album* from the leaf segments obtained from multiple shoot culture of mature trees on MS medium with additives and 2,4-D.Though initial growth of callus was slow, from the second subculturing onward fragile and soft embryogenic callus was produced which required subculturing on fresh medium within four weeks period. Maturation and germination of the somatic embryos in appropriate media gives rise to whole plantlets which can then be hardened.

Adventitious shoot regeneration

Adventitious shoot regeneration is the direct organogenesis of shoots from adventitious plant parts like leaves and internodes lacking meristematic cells. This is an efficient and reliable technique of plant tissue culture, unless it fails in the regeneration of shoots from cells and tissues which is a hurdle in its application for the regeneration of forest species. Rathore *et al.* (2008) and Sushant (2020) reported direct adventitious shoot formation from explant of mature sandalwood tree with pulse treatment of leaf segment using TDZ in MS liquid medium for a week, followed by transfer to hormone-free MS medium with additives. The shoots thus regenerated can be further multiplied and rooted, before acclimatisation .

Adventitious shoot regeneration from leaves of *S. album*

In-Vitro rooting

The rate of shoot multiplication and frequency of rooting have a direct impacton the application of a micropropagation protocol for mass production. It is easy to induce rooting from the shoots of seedling origin, but quite often frequency of rooting reduces with increase in age of the source plants particularly in tree species. Rooting frequency also depends on the level of rejuvenation during multiplication stage and quality of the shoots. Nutrient media, auxin source and their concentration and incubation conditions play an important role in the frequency of rooting, root number, root length and shoot length. Apart from these, the other factors like Carbon source, Coumarin and Polyamines also play a major role in adventitious rooting in sandalwood.

In *S. album,* Sanjaya *et al.* (2006) used various auxins and found that micro shoots treated with IBA for 48 hr followed by subculturing on MS/4 agar gelled medium with 2% sucrose favoured maximum rooting of 41.6%. *In vitro* rooting was also observed by the pulse treatment of shoots with IBA for 30min followed by planting in soilrite medium; but this method too resulted in no more than 50% rooting. Rathore et al. (2008) also used various auxins either alone or in combination in MS/4 medium, and found that

In vitro roots induced in sandalwood shoots

combined use of IAA and IBA proved to be the best for in vitro rooting. They also reported rooting from microshoots which were pulse treated with IBA, but the rooting

frequency varied with the genotypes.

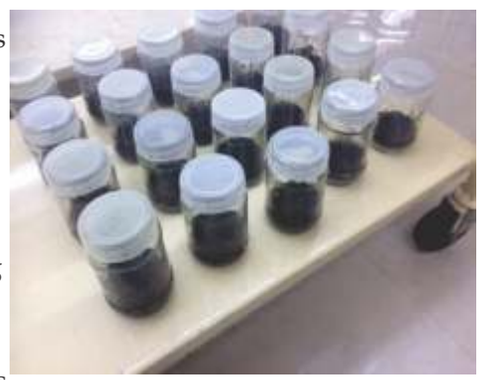
Ex Vitro rooting

Ex vitro rooting reduces one step of in vitro rooting, thereby reducing the cost of production and also improves the survival rate of plantlets. It also helps to save time required for getting the plantlets through time consuming in vitro rooting technique from lab to field. To avoid the hurdle of hardening, most of the time the *in vitro* propagated shoots are directly treated with auxins (alone or in combination) to encourage rooting of the shoots in *ex vitro* conditions. In that way the crucial step of *in vitro* rooting and hardening of the plantlets are merged, and we can get *ex vitro* rooting while the plantlets are also partially acclimatised to the outside environment which will result in better survival rate in the field condition. Auxin type, its concentration and duration of treatment, rooting medium and incubation conditions are the factors which influence *ex vitro* rooting. Goyal (2007) and Sushant (2020) reported that maximum *ex vitro* rooting was obtained in soilrite and vermiculite medium when micropropagated shoots of *S. album* were pulse treated with different concentrations of IBA.

Hardening and acclimatisation

The success of micropropagation on commercial scale depends on the ability to transfer plants from lab to land on a large scale, at low cost and high survival rates. Micropropagated plants under in vitro condition are partially autotroph, lack cuticle and waxy layer on the leaf surface. In addition, stomata are not fully functional, and sometimes the roots are weak or brittle. This heterotrophic mode of nutrition and poor mechanism to control water loss render micropropagated plants vulnerable to transplantation shocks and wilting of plants. Therefore, hardening or acclimatisation is essential before keeping them in open nursery. Hardening conditions and duration may vary with the species for its high rate of survival. Although, considerable efforts have been directed to optimise the conditions for the in vitro stages of micropropagation, scant attention was paid to understand the process of acclimatisation of micropropagated plants to the soil environment. Consequently, the transplantation stage continues to be a major bottleneck in the micropropagation of sandalwood.

In *S. album,* hardening is very important and it is difficult also because of its hemi root parasitic nature. *In vitro* rooting of micropropagated shoots and somatic embryogenes is resulted in the formation of single root, because of which direct hardening in potting medium is very difficult combined with initialcollar rotting. Hence, IWST has worked on the two stage hardening method i.e., primary and secondary hardening techniques, by using different media in combinations for potting mixture preparation and in different growth conditions.



Primary hardening of *S. album* in soil rite

Field establishment of micro propagated plants

The ultimate success of any micropropagation technique relies on the survival of the plantlets in field conditions. The transition from in vitro to an ex vitro environment is one of the most important and critical steps in the field performance of tissue culture raised plants after hardening, which is measured by its survival in soil. Poor survival of a plant under ex vitro conditions is mainly due to poor development of cuticular waxes, non-functional stomata, water loss due to excessive transpiration, poor root system and susceptibility to pathogens.

S. album trees out of test tube

The following work has been carried out by other research institutes or organizations in India, using biotechnological approaches in the production of quality planting material of sandalwood:

S. No.	Organisation conducting research in Tissue culture	Technique employed
1.	Delhi University; IISc, Bangalore	Endosperm culture
2.	BARC, Mumbai; IISc, Bangalore; Hamdard University, New Delhi	Cell suspension culture and somatic embryogenesis from seedling explants
3.	BARC, Mumbai	Protoplast culture and regeneration of plants from seedling explant
4.	BARC, Mumbai; IIT- Kharagpur	Application of bioreactor for production of somatic embryos and synthetic seed. Secondary metabolite production using bioreactor and somatic embryogenesis
5.	IWST, Bangalore	In vitro cloning (micro propagation) of sandalwood from mature trees/clones/plus trees
6.	IWST, Bangalore	Somatic embryogenesis from mature trees/ clones/plus trees
7.	IWST, Bangalore	Evaluation of genetic fidelity of micropropagated plants through axillary shoot proliferation and somatic embryogenesis
8.	RVS Agricultural University, Gwalior; JNAU, Jabalpur	Somatic embryogenesis using suspension cultures
9.	Anand Agricultural University; IWST, Bangalore	Plant regeneration from leaf explants
10.	RVS and RVSKVV Agricultural University, Gwalior; TNAU- Mettupalayam; Centre for Pacific crops and Trees (CePaCT)	*In vitro* cloning of sandalwood

Unlike with herbaceous plants, culturing trees in a test tube poses significant challenges. It is not feasible to assess quality in a short time. Tissue culture studies in sandalwood are mainly confined to regeneration from seedling explants or somatic embryogenesis through callus with low germination frequency (Rao and Bapat, 1978; Lakshmi Sita *et al*, 1979). Success is restricted to R&D level for production of clonal planting material from mature and superior genotypes through micropropagation. The hardening of micropropagated plantlets of sandalwood is still a bottleneck in its large scale production. Since trees take a long time to mature, establishing the tissue cultured plants of sandalwood into soil is a delicate process. In order to meet the growing need of sandalwood at the national and international markets, there is an urgent need to carry out studies on the critical factors for successful establishment of tissue cultured plants in the field. Therefore, IWST has taken up studies for field trials of micropropagated plants of selected promising sandalwood genotypes under an All-India coordinated project on sandalwood.

Conclusion

Trees are generally slow growing, and the same slow growth is observed during in vitro culturing also. Hence, each step in the micropropagation protocol for sandalwood takes more time as compared to fast growing plants like bamboos. Obtaining maximum response without casualties, starting from aseptic culture establishment to the production of hardened plants ready for transplanting, is yet to be achieved in sandalwood. This is another obstacle in the large scale production of quality planting material of sandalwood through tissue culture. The

present research is directed towards overcoming this, and protocols developed by IWST, Bangalore can be used for the large scale production of clonal planting material of desirable clones for mass plantation. Till date there is no production of elite material of sandalwood through tissue culture. Even though various companies or nurseries claim that they are producing and selling tissue culture raised sandalwood plants, their origin might not be from superior genotype selected for high oil yield or heartwood content. Since research at IWST is focused on developing protocols for selected promising genotypes with field trials, quality planting material of sandalwood raised using *in vitro* techniques can be outsourced to various cultivators, nurseries, farmers, general public etc. in the near future.

Suggested reading

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Reproductive Phenology and Natural Regeneration of Indian Sandalwood: An Ecological Implication

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Introduction

Indian sandalwood (*Santalum album* L.) is one of the commercial tree species of genera *Santalum*. Although it is indigenous to peninsular India, it is distributed many parts of the country which includes Andhra Pradesh, Orissa, Maharashtra, Madhya Pradesh, Rajasthan, Gujarat and also in Uttar Pradesh, Bihar and Manipur states. In many places it is naturalized and races of sandalwood population are showing great variation in terms of many morphological, growths, formation of heartwood and oil content.

Ecology of this species play vital role in adoption and survival population in newly introduced area, since it is semi-root parasite, which need host plants for their survival, growth and establishment. Successful plantation of sandalwood is mainly depends upon the healthy & genetic potential of seedling lots, availability & performance of host plants, initial care and periodic management practices like soil working, weeding, watering, application of manure/fertilizer, etc. Planting sandalwood not only fulfils the commercial value; but also paying importance of ecological services like food/ forage, pollination, dispersion, carbon sequestration, etc. in the growing habitat. This paper emphasises the importance of life history parameters like reproductive phenology, plant-animal interaction and natural regeneration in sandalwood along with artificial regeneration.

Reproductive phenology

From commercial point of view, the knowledge of phenology play a vital role in the time of seed collection from the forests or plantations. Foresters and nursery man use to note the fruiting time for large scale seed collection for raising quality seedlings in the nurseries. Sandalwood breeder's point of view, reproductive phenology, in terms of time and duration of flowering/ peak flowering among individuals with a population or between genotypes growing in different habitats or provenances, provide a basic data base about flowering synchrony, which helps during crossing programme as well as while establishment of seed orchards for production of genetic quality seed lots.

Commencement of first flowering in sandalwood usually starts from 3-5 years age and full blooming and fruiting starts during 5 to 8 years of age, depending upon the locality and management practices carried out during cultivation. Rarely some plants flowers at the early age of sapling stage. Three out of sixty saplings of sandalwood established in the Navsari Agricultural University (NAU) campus started flowering at the age of 10 months (i.e., during Sept. to Oct., 2021). Very few fruits were set in those plants. These sandalwood plants were established along with host plants viz., *Alternanthera dentata,* (Ornamental groundcover plant) near the sandalwood plant and *Acacia mangium* hybrid in between two sandalwood plants.

Flowering pattern is recorded to vary among the natural populations. Usually, sandalwood trees flowers during February to April (hot weather) and fruits ripen during May to June and coincide with rainy season. It is also recorded that some of the sandalwood trees flowers continuously about eight to ten months with two peaks in flowering (i.e., Dec. to Jan. and Jul.to Aug.) and fruiting (Apr. to May and Sept. to Oct.) in Dharwad condition. Unusual flowering and fruiting in some of the individuals within a population have also been noticed and such kind variation may be attributed to the genetic factors.

On other hand, environmental factors also play a vital role in seasonal

variation in reproductive phenology viz., time of initiation and length/duration of flowering, as well as overall fruit yield in many tropical tree species including sandalwood. It is observed that fluctuation in fruit yield from one season to other is highly affected by temperature, rainfall, soil moisture and relative humidity of that particular season. It is also reported that fruit set and yield vary from one season to others, which affects the seed germination and seedling vigour in sandalwood.

Duration of flowering and fruiting in sandalwood always helps the insects and birds for food/forage resources viz., pollen, nectar, flesh-fruit pulp and seed. In fact, frugivores are highly dependent on the abundance and nutritional composition of fruits; further, small seeded fruits are ingested and are likely to be deposited at greater distances from the parent tree. Fruits of sandalwood having such qualities; hence, many birds act as potent dispersal agents in sandalwood and provide good regeneration in natural habitat. It is reported that birds like Koel, Common Myna, Brown-headed Barbet, White-headed Babbler and other bird species act as dispersal agent in this species. Other side, insect visitation and pollination also favours the cross pollination in sandalwood that also improves the seed set and genetic quality of seed lots. Insect visitors like honey bee, butterfly and ants encourages the pollination in the sandalwood. Activities of pollinator during flowering season also decide the overall fruit set and seed yield. Further, spider visitation to sandalwood flowers in young plantation was also recorded (see plate). By looking into all these, Sandalwood, play a great role on ecology and ecosystem services.

Natural Regeneration

The natural regeneration pattern of sandalwood in different natural populations/ plantations is determined by the local habitat environment and genetic potential of that population. Among tropical species, the natural regeneration of sandalwood is found to be good and sometime excellent, depending upon the natural population. Sandalwood trees are grown well under partial shade, under canopy and they need partial shade during early age of seedling to sapling condition; however, it needs light at the later stage of tree growth and establishment. Since sandalwood is semi-parasite (root), they require host plants for their growth and establishment. Therefore, successful regeneration is obviously depends upon the neighbouring plants those really act as host plants for sandalwood. Natural regeneration of sandalwood study carried out in the Dharwad region showed that, out of various ecosystems studied like natural forest, medicinal plants garden, Bamboo plantation, Nilgiri plantation, Karanj plantation and Acacia auriculiformis plantation located within in the campus, good regeneration was recorded in the medicinal plants garden, followed by natural forest and bamboo plantation as compared to plantations of Nilgiri and Karanj. The possible reason could be due to presence of more number of sandalwood trees in these ecosystems, which might have attracted several bird species during fruiting season; moreover, bushy plants, scrubs, small trees, hedges in the medicinal garden and natural forest favours the birds for dispersal of sandalwood seeds. Since the seedlings are easily browsed and damaged by cattle and other animals, protection given to medicinal plants, natural forests favours the natural regeneration of sandalwood.

Conclusion

Flowering and fruiting phenology varyat individual level as well as provenance level; in fact two seasons of flowering and fruiting within a year help the nursery man for large scale seedling production both in on and off season. Further, such pattern of flowering and fruiting is an advantage for pollinator and frugivores. Both sandalwood trees and other organisms viz., insects, birds including small mammals, have mutualism in the sandalwood ecosystem. Hence, they are more fruit set and good pattern of recruits under the forests and plantations wherever sandalwood trees are distributed

Santalum album L. - Root Parasitism: Enigma of Host-parasite Interaction, and Host selection

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The interactions among plants and their consumers, pollinators and dispersers are of paramount importance in the ecosystem and in evolution, and so are interactions among plants themselves (Thorpe et al, 2011). The plant-plant interactions can be positive or negative, intra-plant or inter-plant interaction. Among the negative interactions, parasitism and the chemical cross talk between host-parasite is much less studied field and should be getting more attention by researchers. The word parasite is derived from two Greek words Para means beside and sitos means food. Parasitic plants are characterized by the ability to feed directly on other plants, invading either the roots or shoots of their hosts through parasitic structures called haustoria (Kuijt et al., 1968). Based on the status of photosynthesis, parasitic plants are hemiparasitic (photo synthetically competent, though the efficiency of photosynthesis varies considerably between different species) and holoparasites (lack of photosynthetic activity and obtains all their reduced carbon through haustorial connections with a host) (Irving and Cameron, 2009).

Problems of Silviculture of sandalwood:

For the plants having high economic value, sustainability needs to be maintained through the efforts of regeneration. Production of sandalwood can be increased by extensive plantation of this species after properly understanding the host-parasite relationship, proper production of planting materials and knowledge of silviculture of this species. Being hemi – parasite the silvicultural requirements are unique and there is no adequate understanding of the same. Its regeneration and establishment have been problematic because of the poor understanding of host – parasite relationships. Only a few literatures are available indicating the relation of host in field grown sandalwood tree.

This species shows different growth patterns with different host species. It was also reported that sandal requires a primary host at nursery stage, secondary long term host and permanent host in the field (Annapurna et al., 2006). The parasitic nature of sandalwood was reported by John Scott in 1871. The importance of sandalwood parasitism was realized after Barber (1902) reported in detail about haustorial formation, growth and development of haustoria. But the host selectivity of sandalwood is not yet understood properly like in other aerial parasites.

Superior hosts for Sandalwood?

In nature, the establishment and survival of sandalwood trees is entirely dependent on other woody plants in its vicinity which serve as hosts. Legume plants seem to act as superior hosts for *Santalum* (Radomiljac et al., 1998) indeed, direct haustorial establishment on root nodules have been reported (Subbharao et al., 1990). However, some contrary evidence demonstrated that host N is not always a reliable predictor of parasite performance (Jiang *etal.*, 2008).

Nge et al., 2019 studied the host requirement of *Santalum acuminatum* (quandong) and found strong host specificity with *Acacia saligna* as growth of quandongs were stronger when they were paired with Acacia saligna than when grown with other legumes and non-legumes, indicating that some plants are better hosts, and implicating host specificity. The best sandalwood seedling height was attained by the plants grown with *Desmodium triflorum* up to the 24th week and then the plants grown with *Mimosa pudica* attained the same height. The best root collar diameter growth and the highest number of leaf whorls were produced by the plants grown with *M. pudica* and *D. triflorum* respectively. Control experiment and the fertliser treatment produced poor results. (Subasinghe et al., 2011). Das and Tah (2017) conducted experiment in different soil environment of South West Bengal both in nursery and field condition after transplantation of sandalwood saplings with

different hosts singly and in combination of hosts and found that Arhar (*Cajanus cajan*) is the best host followed by Arhar & Tulsi (*Ocimum sanctum*) combination followed by Tulsi singly.

Deepa and Yusuf, 2015, examined the morphological and anatomical features together with biochemical parameters of sandalwood haustoria developed with roots of five host species from leguminous (*Mimosa pudica* L., *Clitoria ternatea* L., *Capsicum pubescens Benth*. and *Arachis glabrata Benth*.) and non-leguminous (*Vetiveria zizanioides* L.) plants. The plants attached with the roots of *Mimosa. pudica* showed better growth (total chlorophyll, protein and carbohydrate content) compared to sandalwood plants attached with other hosts.

S. album L. growth and heartwood contents of trees aged 6 years cultivated on farm land in association with *Citrus aurantium, Punica granatum* and *Casuarina equisetifolia* as host species, were studied to identify the most suitable host. Survival, height, collar diameter, crown size and clear bole of *S. album* trees were greater when grown with *C. aurantium* than the other two hosts.

Secondary metabolite signalling in host–parasitic plant interactions has been studied in several parasitic weed plants as they are a threat to crop production (Runyon et al., 2006). Parasitic plant Cuscuta pentagona (dodder) uses volatile cues for host location. *Cuscuta pentagona* seedlings exhibit directed growth toward nearby tomato plants (*Lycopersicon esculentum*) and towards extracted tomato-plant volatiles present in the absence of other cues (Runyon et al., 2006). Strigolactones (SLs) are the best-characterized class of germination stimulants. At least 20 different SL molecules identified in plants and plant families produce varying forms such that parasite seeds are able to differentiate among hosts on the basis of the identity of exuded SLs as in case of parasite Striga.

There is a complete lacunae in our understanding of the biomolecules involved in sandalwood-host selection and downstream signaling pathways. Earlier Dr Veena Anil's work has demonstrated that somatic embryogenesis in sandalwood was a calcium regulated process, involving calcium dependent Protein kinase (Anil and Rao 2001). It is not far-fetched to assume complex signaling and molecular events control parasitism of *S. album*. But no such study has been conducted so far.

Proper understanding of the host-parasite relationship, proper production of planting materials and deeper knowledge of silviculture of sandalwood are necessary to increase sandalwood plantation in view of extensive sandalwood production. In this context we are investigating the variation in the response of sandalwood towards two different host plants, *Alternanthera* (nonlegume) and *Cajanus* (Legume). The increment in growth, biomass, and the chlorophyll content observed in sandalwood with two hosts compared to the control plant grown without any host clearly indicates the requirement of a host, and in this case Cajanas as the better host. The differences in molecular response towards the two hosts implicates varied response of sandalwood plant towards different host plants.

Conclusion

S. album L, a root hemiparasite, is valued for its heartwood and faces over-exploitation in the forests of Southern India. Moreover, the cultivation of sandalwood is challenging due to its complex silvicultural requirements. Among the host species, legume species have been found to better benefit Sandalwood growth, however there are also reports of non-legumes being effective hosts for S. album. In addition, some observations suggest that, under well fertilized conditions, *S. album* can survive reasonably well without a host. An understanding of whether *S. album* can discriminate and select a preferred host is lacking. Would *Santalum album* select a host plant even under well fertilized soil conditions? these are questions that have not been addressed. The secondary metabolites involved in host-parasite cross talk and the initiation of a parasitic developmental program have been well understood in several plant parasites (such as cuscuta, Scrophulariaceae etc) of economically important crops. An understanding of plant-plant cross talk, signaling events and host induced transcriptome and metabolome changes is lacking for the root parasite, *Santalum album*. This basic understanding of Santalum's parasitism would help both conservation and cultivation efforts.

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Sandalwood Based Agroforestry Systems

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Introduction

Agroforestry is a land use system in which trees and shrubs are intentionally grown in combination with food crops or forage crops. Agro Forestry systems (AFS) vary among the communities since it has been evolved in response to social, economic, cultural, ecological, ethical, and institutional factors. The indigenous management of AFS evolved through trial and errors over a long period of time in tropical and subtropical areas of the world. Indian sandalwood (*Santalum album* L.) is one of the world's most valuable tree species woven into our culture and heritage of India. Now a days, farmers are widely cultivating sandalwood based AFS (SAFS) in their farm lands due to high demand and high price, for the wood and it can be easily cultivated with other agricultural and horticultural crops. The sandalwood-based agroforestry system is viable option to address the current challenges viz., food, wood, health security and environmental security.

To address the declining share of sandalwood in international markets, conserve it in natural areas and promote sandalwood farming, the major sandalwood producing States, Karnataka and Tamil Nadu have relaxed the existing rules and regulations on sandalwood cultivation in 2001 and 2002 respectively. Recently, Maharashtra and Goa are also amended its State Forest Acts on the similar line. Thus, policy changes led to domestication of sandalwood in India. Landholders now have legal rights over the sandalwood trees on their properties and growers can receive as much as 100 percent of the value of the tree as determined by the forest department. Cultivation of sandalwood on private lands has since become an attractive option. As sandalwood tree is semi-root parasite, it is cultivated with different combinations of food and fruits crops as host plants without interfering regular farming systems. Sandalwood based agroforestry system offers opportunities for inter-cropping and generation regular income through host plants and intercropping still maturation of sandalwood tree. Large scale commercial sandalwood plantation is being established even in non-traditional sandalwood growing states viz., Andhra Pradesh, Telangana, Maharashtra, Gujarat, Assam and Punjab.

Sandalwood - an ideal agroforestry tree

Sandalwood is being considered as a suitable species for agroforestry systems due to following features:

- Small – medium size tree
- Narrow and light crown
- Easy to propagate by seeds
- Easily amenable tree
- Good coppicer
- Grows well in a variety of soils
- Not demanding much nutrients
- Hardy and drought tolerant
- Leaves easily decompose.

Sandalwood plantation and its management

Farmers are cultivating sandalwood in different forms such as pure block plantation, boundary plantations, and agroforestry systems (e.g. sandalwood + horti system, sandalwood + agri system, sandalwood + sericulture, sandalwood + apiculture) based on availability of land, host plants, market and other prevailing socio-economic conditions. As the sandalwood tree requires host plant mandatorily for its normal growth and development, its management differs from that of agri-crops and horticultural crops. The establishment and management of sandalwood plantation involves various steps that are discussed below,

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Selection of site

Selection of site depends on edaphic and climatic conditions, viz., temperature, rainfall, soil depth and drainage conditions. Although, sandalwood tree grows well at elevation 650 – 1200 m above MSL(Mean Sea Level) with rainfall of 500-1600 mm. Sandalwood requires partial shade or umbrella shade during young and lateral shade with full over-head sun light for fast and straight growth during later stage. In high rainfall areas, sandalwood growth will be luxuriant but with negligible or no heartwood and low oil content. Even if, sandalwood can be grown in a variety of soils, for high quality sandalwood, the site should have fertile soil with neutral pH, good sunlight, well drain soil and distinct annual seasons. Usually, the moderately sloppy land most preferred for sandalwood. In case of the undulating and sloppy ground, the plantation should be raised along contours to prevent erosion and to conserve moisture during growing period.

Land preparation

Land preparation involves leveling, ploughing, marking of pits with recommended spacing, digging of pits and fencing. Ploughing helps to get well developed root system, improve soil aeration, water infiltration, remove of weeds and expose pests and spores for sunlight. Usually, site preparation will be done 3-4 months before planting, just before onset monsoon (June – July).

Land is cleared and ploughed during summer season. Marking should be done for digging pits with desired spacing. After marking, pitting should be done with size 45 × 45 × 45 cm. Spacing and planting design vary with choice of hosts, intercrops and presence of existing vegetation. Insecticide/ fungicide may be applied in pit to kill the harmful organisms during planting. At the time of planting, 2-3 kg of well decomposed farm yard manure is added in each pit.

Planting

Use healthy seedling with a single leading shoot, (>1ft height), having collar diameter more than 3.0 cm for raising plantation. While planting sandalwood seedlings, right host plant should be planted since sandalwood requires haustorial connection through which sandalwood gets required nutrients. Sandalwood can be planted in different planting system like square planting, rectangular and line planting (Fig 3a, 3b, 3c & 3d). Trench planting method (Fig 4a) is used in arid regions where as in high rainfall areas; ridge planting method (Fig 4b) is employed.

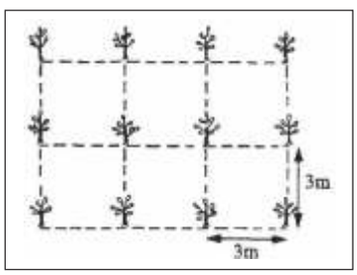


Fig 3a Square planting

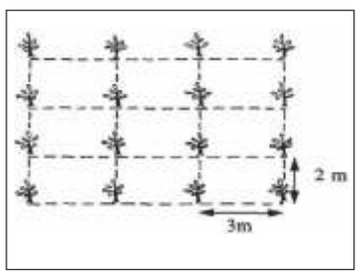


Fig 3b Rectangular planting

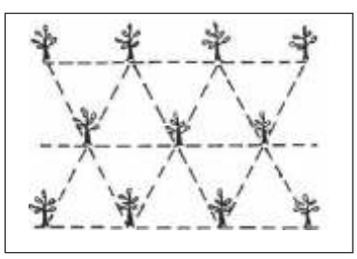


Fig 3c Triangle planting

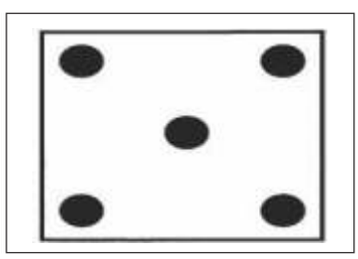


Fig 3d Quincunx planting

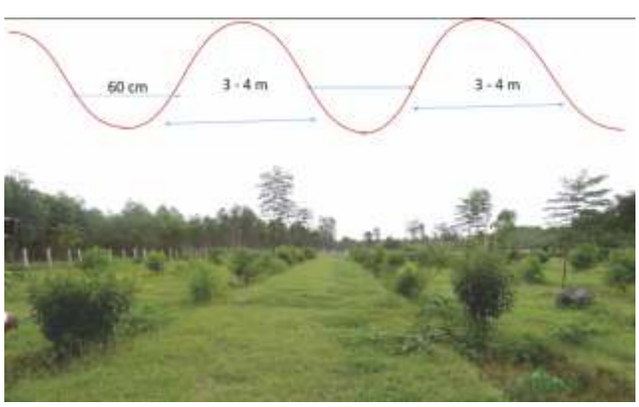


Fig 4a Trench planting in semi-arid and arid regions

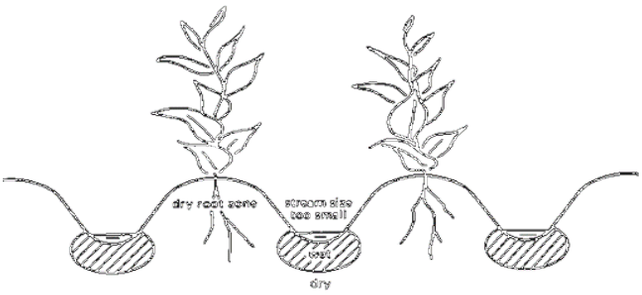


Fig 4b Ridge planting in high rainfall regions

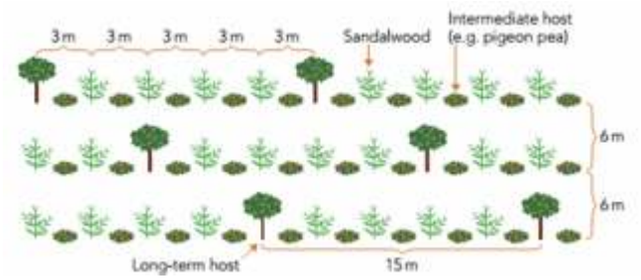


Fig 5a Typical planting layout for sandalwood

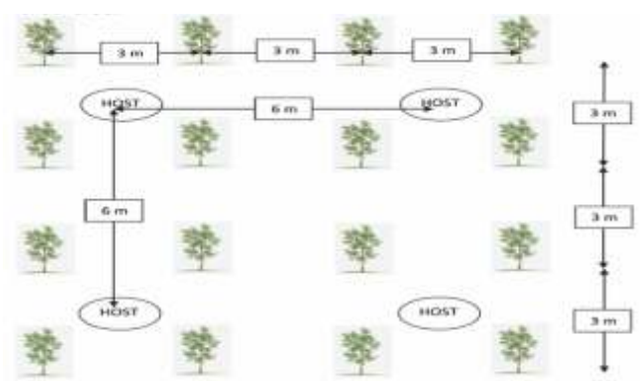


Fig 5b Planting layout of sandalwood at Tirumala (AP)

Selection of host plants

Sandalwood being sandalwood is a (partial) root parasite which requires host for its normal development till the harvest. A lot of research has been carried out on identification right host plants, its interaction with sandalwood species and sandalwood-host haustorial connection in India, Australia, Indonesia, and New Caledonia. The lateral roots can grow beyond 20m from the sandalwood tree. As long as the lateral root grows, the roots of the sandalwood that the potential to associate with the roots of the host plant. More than 70 species are identified as suitable permanent hosts based on the influence on growth of sandalwood trees. Sandalwood needs primary host plants to absorb nutrients through haustoria, which makes a direct link to the xylem of sandalwood tree. More than 300 species are listed as primary host plant species. While choosing primary host, one should keep in mind that the selected primary host should be small, succulent, and easy to grow back after being trimmed and also live long, locally available and not compete with sandalwood plant. The role of the secondary host is to replace the primary host which may die at the age of 1-3 years after being transferred from the nursery to the field. In addition, the secondary host helps to supply nutrients. Secondary hosts can survive for 6-8 years. The replacement of secondary host with tertiary host should be considered when both primary and secondary host plants are dead. Common tertiary host plants are *Cassia siamea, Dalbergia latifolia, Casuarina junghuniana, C. equisetifolia* and *Albizia falcataria.* In fact, non-browsable, Nitrogen fixing and high coppicer host plant species should be given preference. *Capsicum frutescens, Alternanthera* sp, *Acacia* sp., *Duranta repens, Solanum melongena* (eggplant), *Lycopersicon esculentum* Mill. (Tomato) and *Mimosa* sp. are short term host. Tree species such as *Citrus* sp (orange), *Acacia vilosa, Cassia siamea, Acacia auriculiformis, Gliricidia sepium, Tamarindus indica, Citrus aurantifolia, Ziziphus mauritiana, Ficus elastica.* Among these hosts, *Alternanthera* sp. and vegetable crops such as *Capsicum frutescens, Solanum melongena, Lycopersicum esculentum* and *Musa paradisiaca* are identified best hosts for sandalwood based on growth, number of leaves and number of haustoria. It is reported that Alternanthera is most suitable host for high growth of sandalwood. The cuttings of Alternanthera are planted together with sandalwood seedlings in polybags. Among 32 hosts, *Casuarina equisetifolia, Melia dubia, Pongamia pinnata, Acacia nilotica* and *Termianlia alata* are reported as best permanent hosts.

Fig 2. Sandalwood with haustorial connection with tur dal

Fig 3. Nutrient translocation between sandalwood and hosts (casuarina + sandalwood; teak + sandalwood; coconut + casuarina + sandalwood)

host plants attention should be given to the size, shade nature, economic value of host, and its contribution to the growth and development of Sandalwood. Besides, other factors must also be taken into account that the growth of hosts should not exceed the growth of sandalwood because it will cause competition to the elements of nutrients, light and space.

Anatomical studies indicated that a vascular connectivity, haustorial connections developed between the host and sandalwood. The haustoria is functioned as a physiological link that supporting nutritional requirements of sandalwood. It is further confirmed with presence of translocated 32P in sandalwood tree after six hours of injecting 32P isotope in the host plant. The extent of translocation from hosts to sandalwood (Fig. 3) varied from 28.9% (coconut + Casuarina + rubber as host) to 78.5% (Casuarina + rubber as hosts). Reverse translocation of 32P from sandalwood to host was also observed. The translocation from sandalwood tree to host Casuarina was 26 % and to teak was 34.89 % (Rocha *et al*. 2017).

Irawan (2004) reported that when the association between host and the sandalwood is good and compatible, the sandalwood crown appears thick, the leaves are wide and dark green color. On other hand, if the association is not suitable or host not found, then the appearance of the canopy is thin, leaves are small and yellowish with chlorosis (Fig 4). A good host plant should have a thin and watery skin root. eg. members of Leguminosae. While selecting

Fig 4a. Sandalwood + Sesbania (live host)

Fig 4b. Sandalwood + Red gram (dead host)

Table.1 Suitable host plants for sandal wood agroforestry

Primary host	Intermediate hosts	Long/Secondary hosts
Red gram (*Cajanus cajana*)	Papaya (*Carica papaya*), Drum stick (*Moringa oleifera*)	Causurina
Mimosa pudica at nursery stage	*Sesbania grandiflora*	Grafted Tamarind (*Tamarindus indica*),
Horse gram (*Macrotyloma uniflorum*)	Guava (*Psidium guajava*)	Melia-dubia, Silver Oak,
Field bean (*Lablab purpureus*)	Pomegranate (*Punicum granatum*)	Indian Goose berry (*Emblica officinalis*)
Alternanthera sp.,	Sugar apple (*Annona squamosa*)	Mango (*Mangifera indica*)

Irrigation

On the day of planting in field, flood/drip irrigation is recommended. From the day of planting, the watering should be done on daily for early establishment at a rate of 8 to 10 L per plant and thereafter watering should be done every four days once for 3 to 6 months depending on soil moisture availability. As sandalwood is hardy and drought tolerant, it does not need much water. Normally watering is done during summer season. Watering should have applied during early morning and late evening, most preferably in evening. Shallow stony soil requires frequent watering during summer season (Fig 5a & b).

Fig 5a. Drip irrigation **Fig 5b. Lack of moisture in shallow stony soil**

Manure and fertilizer application

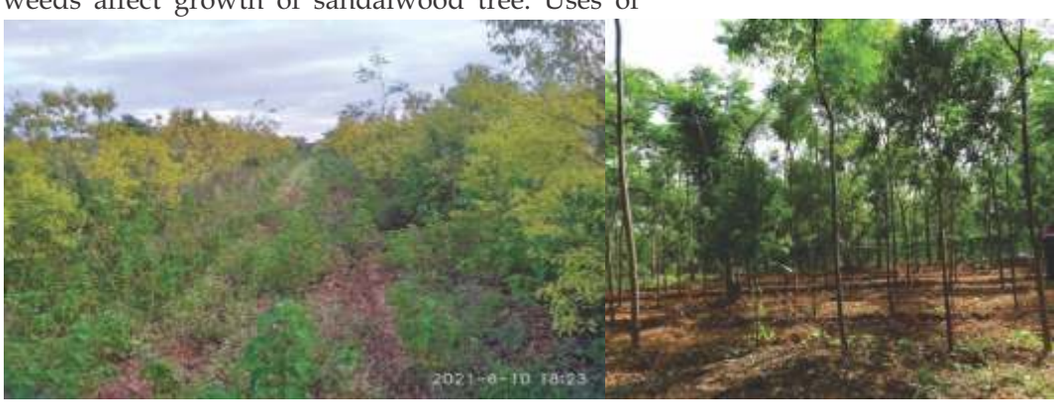
Sandalwood is not requiring any fertilizers during first year of planting. Fertilizers may be applied based on the deficiency of nutrients in the soil. However, DAP (Di-ammonium phosphate) at a rate of 50 gm to 100 gm shall be applied once a year just before the monsoon and after soil working. Application of well decomposed manure is recommended after soil working at the rate of two Kg per plant during planting and 5 kg/plant on 2nd year onwards. Nitrogen (N), phosphorus (P) and amino acids are obtained from host plants, while calcium (Ca) and potassium (K) are taken from the soil. The host plants will greatly affect the quality of the sandalwood oil produced from its heartwood since its quantity and types of nutrients varied.

Weeding and cleaning

Weeding and cleaning should be done when the weeds affect growth of sandalwood tree. Uses of herbicides must be avoided as it sometimes disturbs the growth of sandalwood and other host plants. It is always better to have manual and mechanical weeding/cleaning. Growing of Crotalaria species around young sandalwood plants is not only providing additional nutrients but also reduces weed growth, enhance soil moisture because it is act as cover as well as nurse crop.

Sandalwood based agroforestry models

As sandalwood is partial root parasite, it should be cultivated in combination with other crops as host in different planting design and spacing according to prevailing local socio-economic, environment, market conditions and farmers preference. Even if, it is suitable for bund planting, and block plantation, sandalwood based agroforestry system is most preferred one by the farmers since it provides intermediate income and fodder to the farmers. Spacing adopted for raising pure plantations is 3 x 3m - 5 x 5 m. The IWST, Bangalore has developed 3 sandalwood based agroforestry models viz., sandalwood block plantations, Silvi-Hort system (sandalwood + amla), Silvi-Agri (sandalwood+ horse gram). According to IWST studies, sandalwood farming is highly profitable when compare other farming systems. On trial and error basis, the farmers are also developed different sandalwood



6a. Sandalwood in in-fertile stony soil **6b. Sandalwood growth in manured soil**

based AFS viz., Silvi-Horti (sandalwood+mango; sandalwood +tamarind; sandalwood + lemon), Silvi-Silviculture (sandalwood +silver oak; sandalwood +melia). There are more than 20 sandalwood based agroforestry models with different hosts and spaecing were have been recorded (Fig 7).

sandalwood + mahogany

sandalwood + mango+ pumkin

sandalwood + drumstick

sandalwood + pomegranate

sandalwood + arecanut

sandalwood + papaya

sandalwood + silver oak + bengal gram

sandalwood + soffee + silver oak

Fig 7. Sandalwood based agroforstry models in Karnataka

Canopy opening and shade management

As three or more components co-exist in the sandalwood based agroforestry system, it cause competition among components for light, space, water and nutrients. Since sandalwood tree is strong light demander, manipulation of its canopy and canopy of its host in such a way that both sandalwood and intercrops/host plants would get sufficient sun light and space for normal growth and development. Canopy manipulation (prunning) should be done judiciouly based on habit and crown architecture of host plants. .

While growing sandalwood trees under the shade of existing vegetation, it does not require any pruning. However, when it is grown in open space and have number of low-lying branches, the pruning should be done judiciously up to 10 feet during 2-4 years. Pruning should be done with sharp knife during dormant season. Always the cut branches as much as possible close to main stem from the bottom to avoid split. Prune only those branches which are less than little finger size and branch whorl in a year. Never prune the tree more than 1/3 of the tree height and should maintain at least 40-50% canopy (Fig 8). As sandalwood trees are highly sensitive to physical injury at the early stage, at-most care should be taken while considering pruning. The pruning should be at right time/season and right age by the right person. Otherwise, it would cause irreversible damage to the trees and also may invite pests and pathogen to invade.

Sandalwood trees in un-balanced shade-light ratio

Sandalwood in about 50% shade-light ratio

Fig.8 Canopy manipulation by pruning

Rightly pruned tree

- A sandalwood tree rightly pruned should have:
- Single trunk and a leading shoot at top.
- Canopy extends approximately 2/3 of the tree height, providing good area for photosynthesis for good growth.
- Canopy that tapers towards the top, providing good balance (a low centre of gravity).

Incorrectly pruned tree

- An inappropriate shape "a lollypop" because too many lower branches have been removed.
- A reduced canopy with reduced photosynthetic capacity and low vigor of the tree.
- Many branches at top which make tree top too heavy and unstable, particularly in wind.

Growth and harvest of sandalwood

As secondary xylem ages, water conducting tissues stop functioning when the tree ages, which may lead to heartwood formation (Jones et al 2006). Heartwood formation varies within and between stands. For example, Srimathi and Kulkarni (1995) reported that heartwood is formed at 4th year, Liu and others (2012) noted in 6th year, Brand and others (2012) 7th year and Rai (1990) found in 10th year. The mean heartwood yield per year is varies 1-2.5kg/year/tree (Brand *et al.*, 2012). The harvesting age lies between 15 - 30 years. The expected harvest period in shallow or stony soil is 15 - 20 years whereas in fertile soil, high rainfall areas is 30 - 40 years. Modest commercial quantities of heartwood are produced after 15–20 years. On deep rich soils in moist areas, trees grow luxuriantly but the heartwood formation is slow and the oil content is low, while the slower-growing trees on dry sites at elevations between 600-900 m and rainfall 500-1000 mm develop maximum heartwood with high oil content. There is a strong association between heartwood development and soil type, rainfall and the level of sun exposure on the canopy of the sandalwood has been reported. However, about 13-20% of sampled trees in the population failed to produce heartwood even at the age of 10-14 years old (Brand et al, 2006). Thus, yield of heartwood varies according to age and locality. As there are significant variations between tree in heartwood content and oil yields, considerable scope for selection and improvement of sandalwood.

Conclusion

The sandalwood based agrforestry is viable option to all categories of farmers as low inputs requirement and it has wide adaptabilty. Policy changes on sandalwood cultivation, help to boost sandalwood domestication and cultivation in India. However, systematic research needed to fill the gaps related to optimum harvesting age, heartwood yield, age of heartwood initiation, suitable host plant, allelopathic effect on crop plants and nutrition demand of sandalwood when intercroppped with agriculture crops in different agro-climatic situations.

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Sandalwood Spike Disease: A Rising Threat to the Conservation of Indian Sandalwood

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Introduction

Indian sandalwood (*Santalum album* L.), which is acknowledged as "Royal Tree" in subcontinent is one of the most economically important tree species (Sundararaj, 2008). India has been the traditional leader of sandalwood oil production for perfumery and pharmaceuticals. Its trade has started as early as 17th century. Indian rulers maintained monopoly on the sandalwood resource to ensure financial strength for dominance and trade warfare. Realizing the value of sandalwood Tippu Sultan, King of Mysore declared it as a 'Royal Tree' in 1792. It is perhaps the only wood in the world sold by weight but not by volume and is the second most expensive wood in the world (Arun Kumar *et. al.* 2012). The price of Indian sandalwood and its oil has risen significantly in the past decade mainly due to depletion in productions annually at the rate of 20% since 1995 (Anantha padmanabha, 2000). India's production during 1930s through 1950s was around 4000 tonnes of heartwood per year which had decreased to an average of 300 tonnes per year. Correspondingly the wood price from 1996 to 2012 has increased in arithmetic progression reached Rs. 60,00,000 per ton in 2013. It has impacted the oil export as the maximum quantity of 27,930 kg sandalwood oil exported in the year 1997-98 has reduced to only 10 kg in 2015-16 (Export-Import Data Bank V.7.1 Trade Stat, 2016). The present government rate of sandalwood ranges from Rs. 12,000/kg to as high as Rs.29,500/ kg for the best quality.

Factors for the depletion of sandalwood resources

The decline in sandalwood production is mainly due to the depletion of sandalwood trees in its natural habitats of forest. The depletion is attributed to factors like illicit felling, smuggling and pests and disease. Among these factors Sandalwood Spike Disease (SSD), is the most destructive of disease of sandalwood and is one of the major causes for the decline in sandalwood production as the quantum of trees extracted due to SSD is enormous. Over a million of sandalwood trees had been removed in Coorg and Mysore states during 1903-1916 (Rangaswami and Sreenivasya, 1934) and 98,734 trees were extracted during 1917-1925 in Salem alone due to SSD (John, 1957). In Karnataka the growing stock has been reduced to 25 percent of its initial level in the last two decades of 20th century (Swaminath *et. al.* 1998). All these mass extractions due to SSD in natural habitats pushed the sandalwood to be first classified as vulnerable by the International Union for Conservation of Nature in the year 1998.

Sandalwood Spike Disease (SSD) the real causative agent

SSD is the most destructive disease of S. album and it is characterized by extreme reduction in the size of leaves and internodes accompanied by stiffening of the leaves. In advanced stage, owing to the progressive reduction in leaf size and internodes, the whole shoot looks like a 'spike inflorescence'. Foliage also becomes stiff, resulting in a crowded appearance on twigs and a bushy appearance (Fig.7 and 8). It was first reported in Coorg, South India in the year 1899 (McCarthy, 1899) and it was initially considered as viral disease and then as the disease caused by Mycoplasma Like Organisms (MLO) (Parthasarathi et.al.1966). In 1969, a breakthrough was achieved by three independent research groups that confirmed the causal agents are phytoplasmas. Phytoplasmas are large group of obligate, endophytic, cell wall-less bacterial parasites which are classified within the class Mollicutes and they infect the phloem cell of plants and transmitted through insect vectors.

Chronology of the symptoms and death of SSD affected tree in Marayoor

Fig.1. No symptom of SSD on 17.09.2017

Fig.2. Suspected symptom of SSD on 19.12.2017

Fig.3 Tree with distinct symptom of SSD on 05.03.2018

Fig.4 Tree fully dried due to SSD on 06.07.2018

Fig.5Tree showing 50% of SSD

Fig.6 Tree dried due to SSD

Rising threat to the natural population of Sandalwood at Marayoor

The situation in Marayoor sandalwood reserve of Kerala that had a density of about 1000 sandalwood trees per hectare (Nayar, 1988) was considered relatively free from SSD till 1980 (Prasad, 2011). It recorded 21.4 per cent density of sandalwood in 2005-06 (Sundararaj and Sharma, 2010) which is now reduced to 1.92 per cent mainly due to the death of trees by SSD and consequent extraction on annual basis. At present, natural populations of Sandalwood are mainly available at Marayoor in Kerala and some patches of reserve forests in Karnataka. Recently it is confirmed that in these natural habitats the trees are heavily infected with SSD associated with Candidatus Phytoplasma asteris and 1 to 5% trees are dying annually. Recent investigation carried out by the Institute of Wood Science and Technology (IWST) Bengaluru, revealed that a tree showing symptom of infection of SSD dies within 18 months and it kills even very young naturally regenerating saplings before reaching the age of heartwood formation (Fig.1 to 4). As per the Working Plan of Marayoor Forest Division even a single sandalwood is not there in Sandalwood Reserve 51 (SR 51) as all the trees were extracted due to SSD (Prasad, 2011). In other heavily infested areas like SR 52 and SR 54 most of the trees are in various stages of infection and dying and the dreaded disease is spreading very fast to other Sandalwood reserves like NSR 1, NSR 2, VSR1 and VSR 2 (Fig. 5 to 6). Similar situation of dying of naturally regenerating trees is happening in the natural habitats of sandalwood in Karnataka. The present increased phase of spreading of the infection is primarily due to the fact of restriction on green felling in forests, which allow the infected tree to serve as inoculums till it dies and spread the phytoplasma pathogen to the maximum extent to the healthy trees by the potential vectors. Realising the sharp decline in the sandalwood population in the states and having realised that they cannot be the custodian of sandalwood any more, Karnataka and Tamil Nadu forest departments have amended the Sandalwood act in 2001 and 2002, respectively and made grower himself an owner of the sandalwood as per the Amended Acts. The purpose of the amendment is to encourage farmers and corporate bodies to grow sandalwood plantations to meet the growing demand.

Roadmap to contain SSD

Considering the impact of SSD in the past, it is imperative to protect the sandalwood populations in its natural habitats from SSD and contain its spread to the farmer's field before it causes colossal damage. Unlike other crops, loss of a single tree is crucial for the sandalwood growers as every plant needs to be survived for better monetary returns and hence extraction of trees cannot be taken as an option any more to control the SSD. Hitherto, many attempts have been made to counter spike disease of sandalwood, but the ability to curb the rapid spread of disease in India has been unsuccessful mainly due to the lack of knowledge about vector identities and not having any resistant varieties/populations of the host. Hence, there is a lot of scopes to expand research on the management of SSD by the production of disease-free plants using tissue culture from, superior genotypes. There is no natural resistance against SSD but genetic modification could be applied to produce plants with reduced phytoplasma titers or with insect resistance. Thus, there is a need for substantial research and development to produce SSD- resistance in trees by applying biotechnological advancements. For over 100 years, significant advances have been made in the area of plant pathogenic viruses and their transmission by insect vectors. Regrettably, progress in phytoplasma diseases and their transmission by insect vectors did not keep pace. Consequently, vectors of most of the phytoplasma diseases are unknown, which is evidenced by the fact that so far no insect is authentically confirmed as a phytoplasma vector of SSD, though this disease is more than a century old. Identification and diagnosing the insect vectors of SSD and their behaviour are the need of the hour to evolve effective vector management measures, which will play a prime role in containment and avoiding the spread of the disease. Also the role of seeds in the transmission of SSD has to be ruled out. Hence breakthroughs are required to manage the SSD which will ensure protection of sandalwood from SSD thereby the conservation and sustainable utilisation of this valuable bio-resource in India and safeguarding the expectations of the sandalwood growing farmers.

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Fig.7. Young tree with symptom of SSD

Fig.8. Matured tree with symptom of SSD

Compartmentalization of Damage in Trees (CODIT) with a glimpse on Sandalwood

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Trees are among the most successful life forms to have evolved in terms of longevity, size and ecological dominance. By and large the dominance is a consequence of a unique ability to form highly specialized tissues. Nevertheless, like other organisms, trees are exposed to a wide variety of biotic and abiotic stresses throughout their long life span. Trees and woody plants modulate their phenotypes to cope with harshening environments (phenotypic plasticity, Nicotra et al., 2010). One such phenotypic modulation is Compartmentalization, which can be further elucidated as Compartmentalization of Damage in Trees, (CODIT). Compartmentalization is an efficient defence mechanism that limits or curtails the spread of infection or injury caused by numerous biotic and abiotic stresses in trees (Shigo, 1970). Else, the effect of infection or injury accumulates throughout the lifespan and scavenges the survival of woody species (Shigo and Marx, 1977).

Living cells in trees and CODIT:

The role of living wood cells in the defence (active / pre-formed) mechanism of trees was well explained by the CODIT model, i.e., Compartmentalization of Decay in Trees, where 'D' symbolizing 'Decay', however "Decay" was superseded by 'Damage or Dysfunction' in light of later findings related to tree defence processes (Shigo, 1970). Alex Shigo created the CODIT model in the 1970s, who wanted to make the science of tree compartmentalization accessible to practitioners within forestry and arboriculture for giving them a sound scientific foundation prior to carrying out work on trees (Shigo and Marx, 1977). Later, the simplicity of the model embraced insightful scrutiny by scientific community, where the scrutiny was mostly linked on what caused the tree to compartmentalize, whether that is injury / wound (decay fungi / biotic) or any damage of the tree defence system (Boddy and Rayner, 1983) in trees of great longevity.

Tree Longevity and Compartmentalization:

The great longevity in plants are characterized by a greater degree of modularity, which is apparent in defense systems that compartmentalize injuries and biotic attackers, apart from root-to-shoot connections and bark stripping (Larson et al., 1993). Tree longevity would therefore rely on vegetative vigor (to compartmentalize / over grow the pathogen) and disease resistance (to prevent invasion of pathogen) (Lanner, 2002).

Compartmentalization in tree species:

Tree species compartmentalize the decay / damage in unique ways and with a range of effectiveness, exhibit a variety of CODIT profiles, while some species like the Oaks can inhibit the spread of pathogens within their organism by creating both chemical and anatomical boundaries (Shigo, 1984). Conversely, other tree species like the poplars (*Populus spp.*) are less able to protect themselves and wood decay can quickly affect a larger part of the trunk, thus creating, for example, wide rot-holes (Shigo, 1984).

Fast-growing broadleaved species (pioneers), are good at colonizing open areas and competing with low ground/shrub vegetation, but they generally have a weak compartmentalization capacity of wounded branches since their investment in defence barriers is very low and they are short-lived. The time for branch occlusion after wounding is important as the stem wood is exposed to humidity and fungal infections before closure occurs (Shigo, 1989). Our concern here is how the slow growing species respond (for compartmentalization / occlusion) to injury / wound, very particular to species like sandalwood, where pruning (deliberate wound) is a systematic practice.

In addition, there is very little information on pruning and wound occlusion / compartment alization in tropical trees, most of the literature focuses on conifers (Hein, 2008). In general, trees may have the ability to compartmentalize deleterious somatic mutations, and escape senescence if the negative consequences are restricted to that module (Bernard et al., 2020), which signifies the defence mechanism of trees in nature.

Compartmentalisation / occlusion of the defective portion in broad leaved tree species

Compartmentalization in Sandalwood:

Depending on tree species, wounds (specific to pruning) of more than 5–10 cm diameter (up to 10 cm for trees species with good compartmentalization potential and up to 5 cm for trees with poor capacity) were found to be a significant factor in discoloration, decay and cavities (Schwarze, 2001). Plantation sandalwood production is complex with multiple hosts required through the life of a sandalwood tree. Due to the complexities of the parasitic/host relationship, at times it was difficult to ascertain if the cause of the sporadic deaths was due to fungal disease or lack of host relationships (Barbour et al. 2010), which further augments the available little information regarding disease or damage to sandalwood (Burgess, 2018). Nevertheless, the wounds caused by pruning facilitated fungal niche in the affected / pruned area of sandalwood. Barbour et al. (2010) isolated endophytes, cankers and rot fungi from heartwood from S. album in Western Australia where fungal infections occurred via pruning wounds.

Response of Sandalwood to wounding (pruning):

The wood exposed by wounding is available for infection by many microorganisms, where a relatively small number actually do infect and spread into the wood from the exposed surface of the wound (Shigo 1967). Sandalwood tree response to pruning was significantly affected by age, where the average wound diameter was much greater for the older trees. Over 80% of all pruning wounds on younger trees were occluded by 12 months (leaving wounds of 0.5 mm diameter on average), with 97% occlusion by 18 months, however, in the 5-year-old trees most wounds were still exposed at 18 months (Burgess, 2018). The season of pruning did have some effect on the microbial niche, where, pruning during dry season was dominated by Ascomycetes while in wet season Basidiomycetes were much more common (Burgess, et al., 2018). Some decay fungi are specialists and can degrade only certain components of the wood cell wall and associated structural

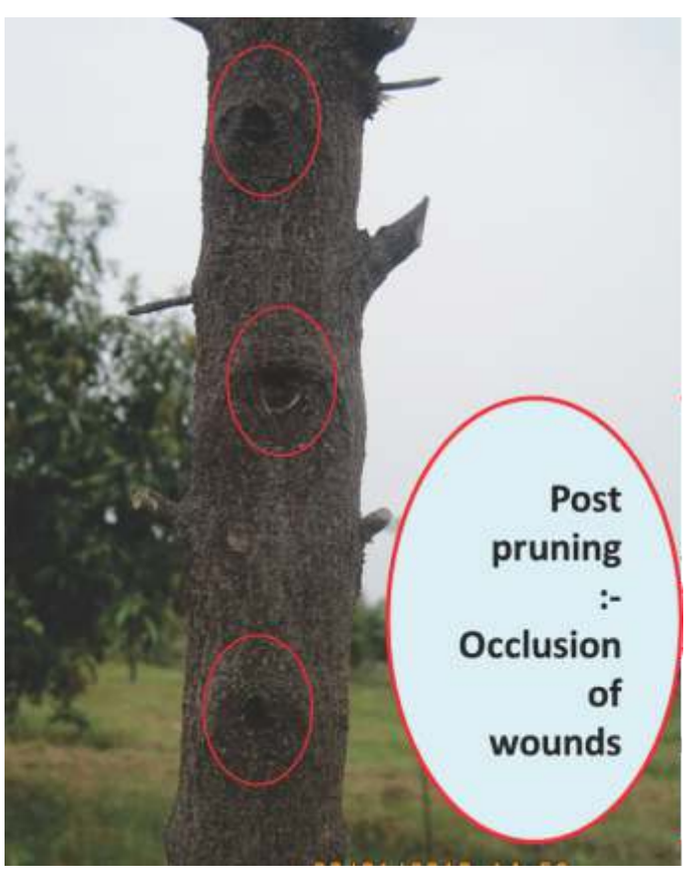
materials, other decay fungi are generalists and can degrade most or all of the wood substance. This pattern of succession is not absolutely fixed and will vary from place-to-place with circumstance and age of the tree (Smith, 2006). Young age sandalwood trees had a lower decay rating than the older trees, due to a higher occlusion rate, where most of the wounds created in the younger trees often appeared to have occluded completely with new bark on the surface. Additionally, the tree response to the pruning wounds resulted in a significant reduction in the discoloration (stain fungi) observed 18 months after pruning for the younger trees, regardless of the season of pruning (Burgess, et al., 2018).

Interpretation:

This little knowledge on defence mechanism of trees clears some facts about compartmentalization / occlusion of the pathogen within the reaction / barrier zone (infected portion), in order to protect themselves from the pathogen and arrest further spread of pathogen. However, this phenomenon of compartmentalization / occlusion varies from species to species of trees. Pruning in sandalwood is practiced as a strategy to augment the commercial bole value of the tree, although appropriate pruning regime to optimize sandalwood heartwood yield is critical. Burgess, et al., 2018, reported pruning wounds remains as an entry path for a large diversity of canker and rot fungi as well as saprophytes and endophytes, however, successful disease/decay free cultivation of sandalwood will depend on pruning stage, where pruning could be practiced early in the tree's rotation i.e., when the tree is at its most vigorous state.

The physiological mechanisms (parenchyma and vessel inter connectivity, synthesis and transport of SMs etc.) involving host-pathogen interaction needs further investigation, as pathogens constantly challenge the defence processes and compartmenta lization is not always successful due to pathogen virulence, time or stress factors which weaken the host defences enabling disease outbreaks in future. For example, canker formation is strongly affected by host physiology (El-Hamalawi and Menge, 1994). Therefore, in order to reduce infection risk, pruning should be done on the faster responding younger trees (Burgess, et al., 2018), appears teleological.

Apart from physiological mechanisms, anatomical components also need further investigation in sandalwood. In general, literature says, after proper pruning, one of the constitutive boundaries that contribute to compartmentalization after branch pruning is the branch protection zone located at the base of the branch. The protection zone is encircled by the stem and contains constitutive chemicals (SMs) that resist the spread of infection. In addition, the protection zone provides a framework for the induced formation of a reaction zone (Pearce, 2000) that further resists the spread of infection. Research shows that the presence of a pronounced branch collar is associated with effective compartmentalization following branch removal (O'Hara, 2007).



Compartmentalization / occlusion (red circles) in sandalwood

Reference: Contact the author at iwst.muthukumar@gmail.com

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Conserve Entomophily Paradise of Indian Sandalwood *(Santalum album L.)*

Where wise actions are the fruit of life, wise discourse is the pollination

- Bryuant H Mc. Gill

R. Sundararaj*, K.N. Manjula, S. Padma, N. Kavya and R. Raja Rishi,
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Pollination is a biological wonder for gene recombination in Angiosperms that plays a vital role in generating a nutritive and more immanently diverse plant population that is indirectly responsible for ecological consistency, community endurance, and ecosystem stability. Pollination is facilitated by insects, wind, water, birds and animals, thus referred to as agents of pollination. Animal pollinators especially bees, butterflies and moths, birds and bats, and beetles and other insects pollinate three-fourths of the world's flowering plants and about 35 per cent of the world's food crops. Entomophily is a form of pollination whereby pollen grains of plants, is disseminated by insects. Dobbs and Muller are the first to discover the role of insects in pollination, and hence called as father of pollination ecology (McGregor 1976). Pollinators visit flowers in search of nectar and pollen as their food source. During this process, they accidentally brush against the floral reproductive parts and pollens get deposited on their body and thus help the plants to achieve pollination for successful production of fruit and seed. Globally 33 per cent of food production and 80 per cent of pollination is bestowed only by honey bees. Other non-bee insects also, contribute over 39 per cent of worldwide pollination. The co-evolution of these pollinators and flowers has favoured the sustainability of life on the earth. Hence, there is a need to understand the overwhelming glory of entomophily and our dependence on these insects for sustaining agricultural and natural habitats worldwide. But, widespread diminishing of these insect pollinators is a key illustration of a loss of crucial ecosystem service due to their deprivation of natural habitats.

The sandalwood tree is self-incompatible and adapted for cross-pollination by insects and dispersal of fruits by birds and bats. The innate range of phenotypic and genotypic variations in terms of morphology, size, and colour of heartwood, growth rate, and years of commencement of the heartwood is primarily due to its strict cross-pollination phenomena (Bhaskar, 1992). Early anthesised flower are pale green and are coincident with pollen maturity and later completely anthesis flower gradually change from reddish white into maroon, along with the receptivity of the stigma, while the anthers gradually shrink and pollen started to lose viability. Thus the sandalwood flower is a protoandrous type of flower development.

According to Sundararaj *et al*. (2020) indicated that the pollinator guild of *S. album* consists of 82 species of insects which includes 6 species of Diptera, 20 species of Hymenoptera, 55 species of Lepidoptera, and a species of Odonata in the natural forest ecosystems. Among the pollinator guild the visit of honeybees viz. *Apis cerana indica and A. florea* were dominant and in abundant and probably be playing a key role as pollinators of sandalwood. The hourly activity of insects visiting sandalwood flowers indicated that most of the insects were active from 10 AM to 4 PM with peak activity from 12 noon to 1 PM. In the natural forest ecosystems the sandalwood trees are not pruned, hence with required lateral branches which harbours foraging habitat of numerous beneficial insects like pollinators which are getting missed in pruned trees. The agro-forestry models of cultivating sandalwood also support apiculture practices that built the economy and improve the productivity of crop. Hence, we have the greater responsibility to grow sandalwood in its natural way without pruning and creating bee-friendly environment for conserving the entomophily paradise, thereby sustainable

cultivation and conservation of Indian sandalwood is ensured.

Recently ecosystem has encountered perilous transformation viz., urbanisation, deforestation, monoculture, indiscriminate use of pesticide and fertilisers affecting health and wealth of the nature. Due to this, the magnificent mobile ecosystem service provider's like pollinator's life is in risk, simultaneously threatening the food security and natural capital as global agriculture has become more pollinator-dependent. An estimated five billion people may experience losses in crop production due to insufficient pollination (Kramer et al., 2019). The ubiquitous nature of pollinators made them to interact with human influenced landscapes which lead to frequent interference with anthropogenic chemicals like pesticides, herbicides and fungicides. These chemicals have a devastating effect on soil health, forms a principle driver for declining of non- target living creatures like pollinators due to a loss of floral diversity and abundance (Hall and Martins 2020). In combination with the excessive use of agrochemicals along with detrimental pruning of sandalwood has a negative effect on the foraging ability and life span of pollinator's, which leads to the colossal loss of pollination in the cultivation of sandalwood and apiculture.

Sandalwood is adopted for cross pollination, thus the health and growth of plant depends on the viability and genetic fitness of the seed. The production of such seeds is totally dependant on the pollinators due to out-breeding nature of sandalwood. Thus the diversity and abundance of pollinators and status of sandalwood plantation is inter-related. Hence, it is an urgent need to conserve the pollinators in the sandalwood based ecosystems.

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Heartwood Estimation in Standing Trees of *Santalum album* L.

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Introduction

Santalum album L. is one of the species in genus *Santalum* producing high quality heartwood and oil. Sandalwood has increasingly focused on describing heartwood based on its biochemical, physiological and structural characters that influence its performance. Heartwood formation in sandalwood varies under different environmental conditions, interaction with host and influences the ecosystems where it is grown. Estimating heartwood formation within the standing tree trunk could significantly improve the understanding of heartwood quantity. Percentage of heartwood increases significantly with age but also differs within same Diameter at Breast Height (DBH) class from one geographical location to another. Studies indicates that though sandalwood grows well across different states in India, there is no uniform pattern in heartwood formation with the increasing age of the tree which may be attributed to varying edapho-climatic conditions and source material. The main purpose to carry out estimation for heartwood is to know the presence of heartwood in sandalwood, if present what is the amount of heartwood volume in standing tree.

Why to estimate heartwood in sandalwood

Sandalwood is emerging as significant agroforestry tree crop which is mainly harvested for its heartwood as it is highly valued as the flagship species that yields a good revenue for a grower. There is a huge demand-supply gap for Indian sandalwood where the prices are flaring day by day. This offers, openings for countries to dominate the trade by upscaling sandalwood farming among farmers and various stakeholders. Employing tools to estimate the formation of heartwood in standing trees prior to harvesting, mainly for sandalwood can be regulated thereafter if known that the inner growth is still slow. This way of finding the heartwood and its growth status without felling will help the farmer to retain the tree until good heartwood growth is attained which in turn benefits him to reap full worth of tree.

How to estimate the heartwood

Heartwood formation in sandalwood trees generally starts around 8 – 12 years of age, but what activates this process has not been very well understood. Certain factors, generally relating to stress, such as gravelly dry soil, insolation, and range of elevation (500 – 700 m), seem to provide favourable environment for the formation of heartwood, irrespective of the size of the stem after 8 years of age. Before estimation of heartwood, some of the morphological clues may be checked by looking at the bark condition all-round the tree as shown in the figure1.

Figure1. Morphological identification of heartwood formation in standing trees of *Santalum album* L.

Therefore, there is need for a more accurate and spontaneous technique which can quantify the heartwood content in the trunk. In general, heartwood estimation is done through following few methodologies:

1 Increment boring method
   a Manual increment boring method
   b Power increment boring method
2 Electric Resistance Tomograph (ERT)

1. Increment boring method

In this method, a specialized instrument known as increment borer is used for heartwood assessment by extracting the core sample from a standing tree trunk. Increment borers are generally operated manually, however, power operated increment borers are also available and are in use.

a. Manual increment boring method

Traditional method of measuring the tree's heartwood is by boring manually, as it is a reliable way to estimate its growth; this method has been adopted for living trees for a long time now. This sampling instrument is most common and widely used across the world. The instrument extracts a small, pencil-sized piece of wood or core sample, from the trunk of the tree to validate the heartwood and sapwood content. This tool uses a tapered cutting thread with 2 to 3 – threading at one end, which drives the borer into the tree when turned. A mini-auger is drilled by hand from the bark to the centre (pith) of the tree. The resulting core sample extracted from the hole displays the growth of heartwood and its demarcation with sapwood at that point in the tree which can be visually observed. The hole bored in the tree is then concealed by filling with wax, to avoid future infection to trees. Increment borers are tidy instruments that consist of a handle (that serves double duty as a case also), a bit and an extractor. The bit is locked onto the handle, making a "T" shaped instrument, then twisted into the tree. Once the bit has reached a little more than half-way through the trunk's diameter, the extractor, a thin metal sleeve, is used to retrieve the core sample. Removing of the core sample is done with shallow extraction spoon. The most frequently employed increment borers extract cores of 4.35 – 5.15 mm in diameter. However, diameters of 8 mm, 10 mm and 12 mm are also available for studies needing a higher amount of wood sample. Small-diameter borers tend to break easily and can often exhibit substantial distortions as a consequence of the boring process.

b. Power increment boring method

Manual method of heartwood estimation which is tedious, and time consuming, pave a way for new future oriented better technology to ease the work. Increment borers come in a great variety of models, lengths, core diameters and sizes. The mechanism of cordless drills has upgraded impressively, making them a substitute for driving and removing increment bore bits. High torque cordless drills can condense the time required to extract cores by a third and substantially lessen the effort required. The borer bits are made from hardened steel with Polytetrafluoroethylene (PTFE) coating for protection and reduced friction. The extractors are made of stainless steel with metallic head and special design for easy core extraction of the wood. A well maintained increment borer can very well stand up to thousands of borer tests. The instrument consists of battery, gearbox, reaction bar, and increment core driller. The battery is charged fully and connected to the borer, by turning on the test switch the drilling bit starts rotating, then placed on the tree to make a hole and the heartwood core is extracted from the trunk.

Core sample extracted from power increment borer

Power increment borer

2. Electric Resistance Tomograph (ERT)

Electric Resistance Tomograph (ERT), is an advanced innovation used to detect and characterize the internal formation of heartwood in standing trees non-destructively. This method gives high resolution and more precision in estimating the heartwood content by displaying a 3D image of the heartwood. Using this technique the estimations can be conducted for large number of trees at various heights unceasingly. Earlier this method was employed in the field of geophysics, later in 1998 Just and Jacob, applied this method to detect the inner growth data of the trunk with altered mathematical algorithms. Tomograms obtained by this equipment are based on electric conductance and resistance.

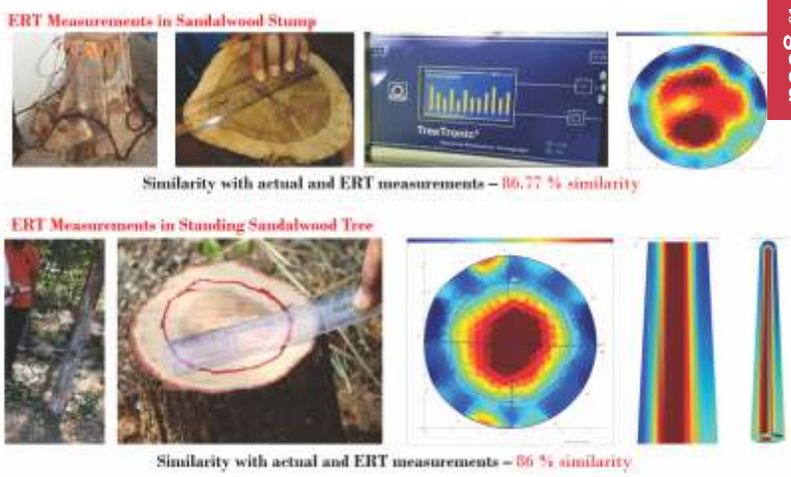

Plate 4. Estimation of Heart Wood in Sandalwood Using Electric Resistance Tomograph (ERT)

In this method, the point electrodes/nails are hammered or pierced around the tree in a circumferentially even manner at a specific height of the tree trunk and then the multi-electrode sensors of ERT are connected to it by alligator like clips. Closer the nails better the accuracy and all the nails should be conducted evenly across the trunk touching sapwood. The maximum number of nails that can be connected to the trunk is 24 and the minimum is 8, based on the size of the tree trunk. The other side of the sensors are connected to the equipment, once the test switch is on, electric impulse is generated and passed on to the tree, the device scans the inner conductance and resistance of the wood and displays a histogram in the device, the file of a particular tree at specific height is saved. Later, the data acquired from the tree is uploaded to tree-specific Picus Treetronic software for conducting further analysis. The software displays the 3-D image tomogram of the heartwood-sapwood demarcation, through which the resistance and the growth diameter of the heartwood can be obtained accurately.

When girth value of the tree is available,

The radius of the tree is calculated at breast height using the formula;

Circumference/girth = $2\pi r$, where, r = radius of the tree

$r = girth/2\pi$

Once the radius of the tree is known by above mentioned method, then,

Radius of the heartwood at breast height, is calculated using the formula;

Heartwood radius = Radius of the tree - (Sapwood depth + Bark thickness)

Heartwood Diameter = 2r

r = Heartwood Diameter/2

Heartwood diameter is expressed in terms of area using the formula;

Basal area (BA) of heartwood = πr^2 (cm^2)

Where, r = radius of the heartwood (cm)

Volume of heartwood (V) is estimated using the formula; V= BA*H

Where, BA = Basal area, H= Height of the bole.

Conclusions:

Sandalwood is valued for its heartwood, efficaciously up keeping and maintaining scented heartwood is very significant. As scarcity is looming globally, proper way of growing this species with maximum heartwood content can yield huge revenue for a farmer, therefore quantification should be conducted to analyze its growth, to stall the harvest at wrong time. Various equipment have emerged in research field to conduct the analysis which a farmer can make use of. In case he can't afford these devices he may contact Institute of Wood Science and Technology, Bangalore for further assistance and guidance.

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Anatomical, physical and mechanical properties of *Santalum album* Linn. (Sandalwood) and its various uses

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Wood properties:

General characteristics:

Heartwood of Indian Sandalwood (*Santalum album* L) is light brownish in colour when freshly cut and it turns to brown on exposure. Wirth further aging, it becomes reddish brown. The specific gravity of the heartwood varies from 0.87 to 0.91. Texture is very fine and even; grain straight, sometimes wavy; dull to somewhat lustrous, with oily feel; heartwood with a strong fragrant scent that persists, without characteristic taste.

Anatomical properties:

The photomicrographs showing the anatomical structure of sandalwood in cross (transverse), tangential longitudinal (TL) and radial longitudinal (RL) sections are displayed in Figure 1. *S. album* is a diffuse porous wood with small vessels visible under hand lens. Growth rings are indistinct although faint, closely spaced, concentric markings are discernible on the transverse surface of the wood. Vessels are exclusively solitary and are circular to oval in cross sectional view. Heartwood vessels more commonly open without much deposits. However, some vessels contain tyloses. Microscopic observations showed exclusively solitary vessels, perforation of vessels is simple and pits alternate. Diffuse and diffuse-in-aggregate parenchyma, chambered crystals in parenchyma only. Pits to parenchyma and rays minute. Fibres non-septate, inter-fibre pits numerous, bordered. The rays are bi-seriate and heterocellular composed of procumbent and upright and/or square cells.

Physical and mechanical properties:

Very limited data is available on different physical and mechanical properties and seasoning behaviour of Sandalwood in the open literature. A few physical and mechanical properties such as weight (at 12% moisture content), static bending strength (modulus of rupture-MOR), compressive strength parallel to grain (maximum crushing stress) and nail holding power of sapwood of sandalwood are reported by Purkayastha (1985) in green and air-dry conditions and reproduced in Table 1. It may be seen from this table that different wood properties in air-dry condition are generally higher compared to those tested in green condition. The wood may be classified as heavy, hard and strong in the dry condition. The sandalwood is reported to be moderately refractory for air seasoning. The timber seasons slowly without any visible faults. The heartwood is rated as extremely durable while sapwood is reported as treatable using the boric acid diffusion process. The wood saws without much difficulty and also works to a smooth, satin-like finish. The sandalwood turns well and it is an excellent wood for carving and inlay works.

(a) (b) (c)

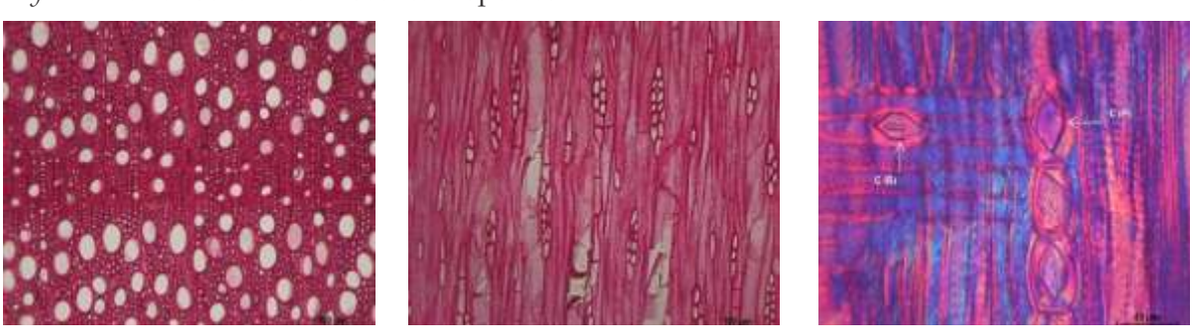
Figure 1: Anatomical structure of sandalwood (a) cross, (b) TL, (c) RL sections (*arrow in photomicrographs indicate the presence of crystals in parenchyma cells*)

Table 1: Properties of sapwood of sandalwood grown in Karnataka ation by pruning

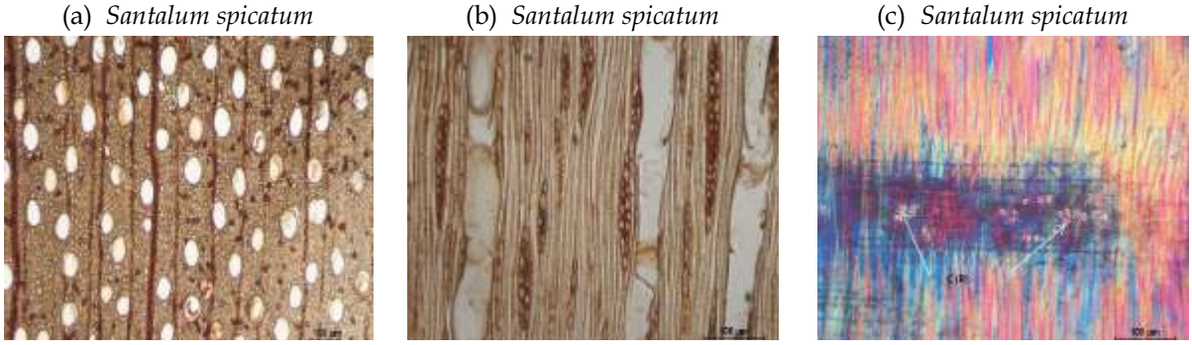
Sl. No.	Physical and mechanical properties		Condition at test Green	Air-dry
1	Basic specific gravity (oven-dry weight / green volume)		0.75	-
2	Weight at 12% moisture content (kg/m3)		-	827
3	Static bending strength: modulus of rupture (MOR) (MPa)		85.12	107.38
4	Max. crushing stress (MCS) under compression parallel to grain (MPa)		37.66	51.58
5	Surface hardness (kN)	Radial	6.84	7.40
		Tangential	6.69	7.55
		End	7.69	743
6	Nail holding power (kN)	Side grain	1.32	1.42
		End grain	1.23	1.38

Sandalwood and its adulterants:

Woods from different plant species referred as sandalwood due to their external appearance, odour and colour are passed on to the consumer in the name of sandalwood by spraying or application of sandalwood oil to the inferior woods due to its high economic value. Other than *Santalum album*, some of the oil yielding species of *Santalum genus* are *S. spicatum* (from Australia), *S. haleakalae, S. paniculatum, S. ellipticum, S freycinetianum* (from Hawai), *S. austrocaledonicum* (from New Caledonia) and S. yasi (from Fiji). Various unrelated plant species having scented wood like *Erythroxylum monogynum* (bastard sandal), *Mansonia gagei* (kalamet), *Ximenia Americana, Lansium anamallayanum* and other non- scented species having similar external appearance to that of *S. album* from other genus like *Amyris balsamifera, Haldina cordifolia, Buxus wallichiana, Drypetes porteri, Gardenia latifolia, Mitragyna parvifolia* are also referred as *S. album* (sandalwood). The other potential adulterant of sandalwood is *Osyris* species (*Osyris lanceolata* and *O. tenuifolia*) from *Santalaceae* family. Many of these species can only be differentiated from *S. album* under microscope in wood anatomy laboratories. The anatomical structures of different adulterants of sandalwood are displayed in Figure 2. Although, *Osyris* spp. has similar external resemblance and gross structure/macroscopic structure, it can be differentiated from *S. album* through minute anatomical structure when viewed under microscope.



(a) *Santalum spicatum* (b) *Santalum spicatum* (c) *Santalum spicatum*



(a) *Osyris* spp. (b) *Osyris* spp. (c) *Osyris* spp.

(a) *Buxus wallichiana* (b) *Buxus wallichiana* (c) *Buxus wallichiana*

(a) *Erythroxylum monogynum* (b) *Erythroxylum monogynum* (c) *Erythroxylum monogynum*

Figure 2: Anatomical structure of adulterants of sandalwood (a) cross-section (b) TL section, (c) RL section (*Symbol 'C' in photomicrographs indicates the location of crystals*)

Some of the wood or oil yielding trees such as Amyris balsamifera, *S. yasi, S. austro-caledonicum, S. spicatum, S. lanceolatum* are also mixed with genuine sandalwood/oil. Only *S. album* trees yield high quality sandalwood and oil whereas other species from Santalum genus though yield oil, but the quality of the wood and oil are not comparable with Indian sandal wood/oil (Srinivasan, *et.al.* 1992). The wood from *S. album* and its potential adulterants can be differentiated by examining and comparing various anatomical characters.. There is a need to create database of wood anatomical features of Santalum species available worldwide along with other methods like chemical profiling, DNA fingerprinting to distinguish the wood samples at species level with more authenticity. This will not only help in authentication of wood, to check the malpractices being used in the markets, its trade and also minimise the economic losses to the end users. *In this context, it is worth to specify that Institute of Wood Science and Technology (IWST), Bangalore has the well-equipped laboratories to identify and authenticate the sandalwood (S. album) using wood anatomical characterization techniques (IAWA standards). This institute also has the facilities to test quality of sandalwood oil from solid wood blocks as well as increment cores using wet chemistry techniques as per IS standards (IS 326).*

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AGRO FORESTRY

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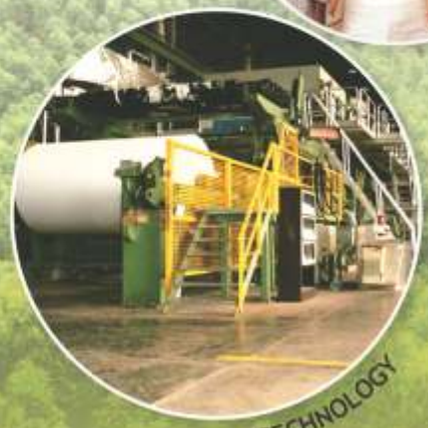

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Wood structure of Indian Sandalwood: Its adulterants and Key to Identification

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Introduction

Over the years, the annual production of sandalwood has declined significantly in India, while the global demand has increased. This growing gap between demand and supply has raised the national and international market price of sandalwood. The Indian sandalwood commands highest price per tonne of wood due to its superior oil quality. However to meet the growing demand of market for common traders after adulterate the oil with cheaper substitutes of this treasured tree species. Unfortunately, due to hike in price of sandalwood, some dealers are even using polished and scented wooden sticks of the most inferior quality. Many timbers similar to sandalwood in external look are passed off by the temporary application of sandalwood oil. The buyer cannot know, so frequently gets cheated. Because of these problems, it is essential to look for some reliable means of identification of wood of this valuable tree species from its adulterants. Wood anatomy, a branch of wood science and technology which is generally used to identify the timbers in order to settle legal disputes besides many applications. The macroscopic and microscopic wood structures including their general features are the common basis of timber identification (Plate1). In the present article, the details of general properties and gross structure of sandalwood, its adulterants and key for identification are described.

Wood structure

The sapwood colour of sandalwood is white to pale yellow, non-fragrant and sharply distinguished from yellowish-brown to dark brown, fragrant heartwood. The colour of heartwood turns darker reddish-brown over time. Due to presence of oil in the heartwood, it has very pleasant smell which lasts for several years. Wood is hard, heavy (specific gravity of 0.87-0.92), dull to lustrous with oily touch, tasteless, straight-grained to slightly wavy, very fine and even-textured.

The stem wood generally is diffuse-porous with very small to extremely small pores/vessels, 25-50 per mm^2, 26-50 µm in diameter, mostly solitary and visible only under the microscope. Growth rings are distinct or indistinct; when distinct, most evident at low magnifications, 8-10 rings per inch, delimited either by thick-walled latewood fibres or crowded pores of small diameter alternating with scattered pores of large diameter. Vessel members are 100-570 µm in length,

Intervascular pitting small 2-7 µm, perforation simple, empty or occasionally filled with tyloses. Fibres are libriform and non-septate, 909-1517 µm in length, 13-22 µm in width with 3-6 µm cell-wall thickness. Rays are fine to very fine, 7-11 per mm, heterogeneous, uniseriate to biseriate, composed of procumbent cells, square and upright cells, 22-41 µm in width and 107-373 µm in height. Axial parenchyma is mostly apotracheal, diffuse to diffuse in aggregate, occasionally filled with rhomboidal crystals either solitary or in 4-6 locules. Crystals are usually absent in rays and fibres.

Root wood is diffuse-porous with very small to extremely small pores/vessels, 50-90 per mm2, 24-80 µm in diameter, mostly solitary, round to oval and invisible by naked eyes in cross section. Growth rings are indistinct. Vessel members are 144-512 µm in length, perforation simple, intervascular pit size 3-6 µm, tyloses absent and no other deposits. Fibres are libriform and non-septate, 661-1632 µm in length, 12-20 µm in diameter with 2-5 µm cell-wall thickness. Rays are fine to very fine, 4-8 per mm, heterogeneous, uniseriate to biseriate, composed of procumbent and upright cells, 24-41 µm in width and 140-272 µm in height. Axial parenchyma is mostly apotracheal, diffuse to diffuse in

aggregate, infrequently filled with rhomboidal crystals in chambered cells. Crystals are absent in both rays and fibres.

Adulterants of Sandalwood

Due to high demand and soaring price for Indian sandalwood, it is often adulterated with imported or indigenous cheaper substitutes. These substitutes are flooding into our Indian sandalwood oil industry and affecting the superior quality of oil. Therefore, the Indian government had to coerce a ban on import of sandalwood. However, it is really difficult to replace the sandalwood oil with a synthetic or cheaper substitute due to presence of unique and large number of essential oil molecules in the Indian sandalwood.

The common fragrant sandalwood adulterants available in commercial market of India are 'Tanzanian or African sandalwood' (*Osyris lanceolata Hochst. & Steud*), Nepal sandalwood (*Osyris wightiana* Wall. Ex Wight), Indian bastard sandalwood (*Erythroxylum monogynum* Roxbs.) and Bastard sandalwood (*Mansonia gagei* J.R. Drumm). Moreover, some non-fragrant timbers are also adulterated with sandalwood due to their fine texture are Haldu (*Haldina cordifolia* (Roxb.) Ridsdale), Kalam (*Mitragyna parviflora* (Roxb.) Korth), Indian boxwood (*Gardenia latifolia* Ait), Himalayan box (*Buxus wallichiana Baill*) and Indian Dryptes (*Drypetes porteri* (Gamble) Pax & K. Hoffm.). These species are passed through the temporary application of sandalwood oil to make them fragrant. As a result of these problems of adulteration, wood identification key could be important to resolve such issues.

Key to Identification

It is difficult to differentiate between Indian sandalwood and similar adulterants based on its physical appearance. However, some unique wood anatomical structures play a key role in identifying the Indian sandalwood from its adulterants (Table 1). Among fragrant adulterants of sandalwood, *O. lanceolata* is distinguished from *S. album* due to the presence of abundant rhomboidal crystals in ray cells and dense accumulation of faint reddish extractives in axial parenchyma of heartwood. In *S. album* rhomboidal crystals are rarely found in ray cells and heartwood extractives are yellowish and scanty in axial parenchyma. The wood structure of *O. wightiana* and *E. monogynum* are very similar to S. album and they are rather difficult to distinguish on the basis of wood anatomical structures and fragrance. The heartwood aqueous extract of *O. wightiana* is slightly reddish and the extract of *E. monogynum* is almost colorless with faint reddish-brown tinge; however, the aqueous extract of *S. album* is yellowish without any traces of red. The wood of *M. gagei* is sweetly scented and differentiated from *S. album* on the basis of presence of storied rays, vessels, fibres and axial parenchyma.

Considering non-fragrant adulterants of sandalwood, the heartwood of *H. cordifolia, M. parviflora, G. latifolia* is odourless and vestured intervascular pitting is present on the vessels, while the heartwood of *S. album* is scented and non-vestured intervascular pitting is found on the vessels. In case of *B. wallichiana* and *D. porteri,* the heartwood is also odourless but the perforations in vessels are *scalariform*. However, the perforations in vessels of *S. album* are simple.

Key for identification of sandalwood from its adulterants

1	Wood fragrant	2
1	Wood non-fragrant	3
2	Rays, vessels, parenchyma and fibres storied	*Mansonia gagei*
2	Rays, vessels, parenchyma and fibres not storied; rhomboidal crystals present in axial parenchyma and heartwood aqueous extract yellowish	*Santalum album*
2	Rays, vessels, parenchyma and fibres not storied; rhomboidal crystals present in axial parenchyma and heartwood aqueous extract colorless but with faint reddish-brown tinge	*Erythroxylum monogynum*

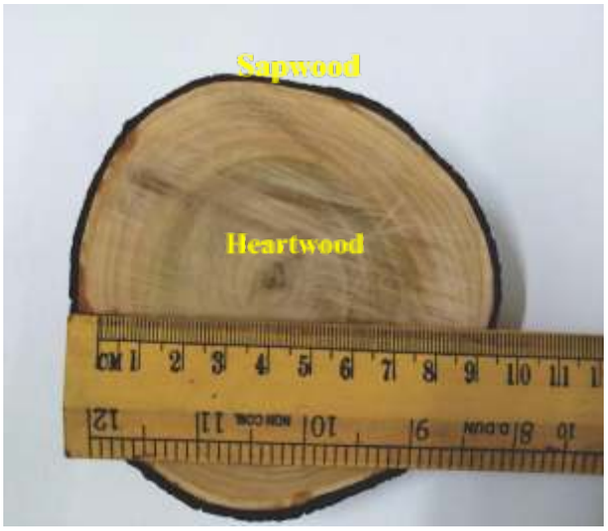
2	Rays, vessels, parenchyma and fibres not storied and rhomboidal crystals present in ray cells only	*Osyris lanceolata*
3	Vessel perforation mostly scalariform; intervascular pits non-vestured	4
3	Vessel perforation exclusively simple; intervascular pits vestured	5
4	Vessels very small, very numerous; crystals absent in parenchyma and rays	*Buxus wallichiana*
4	Vessels small, very numerous; crystals present in rays and rarely present in axial parenchyma	*Drypetes porteri*
5	Silica in rays frequent	*Mitragyna parviflora*
5	Silica in rays absent	6
6	Vessel frequency less than 40 per mm^2; perforated ray cells present	*Haldina cordifolia*
6	Vessel frequency more than 60 per mm^2; perforated ray cells absent	*Gardenia latifolia*

Conclusion:

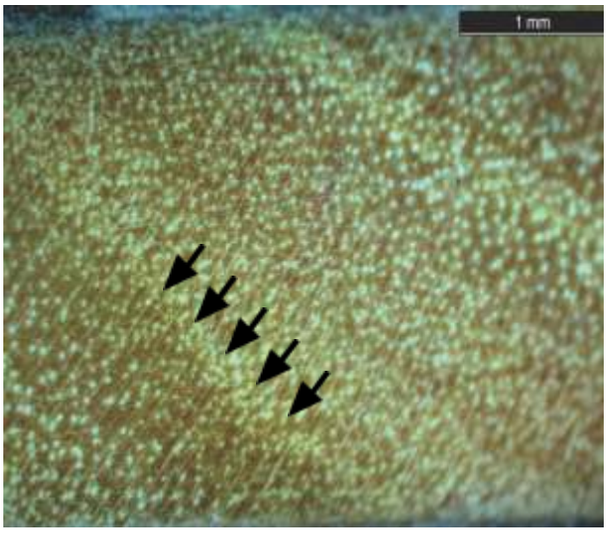
Wood structure of stem and root of sandalwood looks anatomically similar except that in rootwood vessel diameter is slightly bigger and more frequent. The wood of sandalwood can be differentiated from its adulterants by analyzing the anatomical structures. It can usually be distinguished from *Osyris lanceolata, O. wightiana* and *Erythroxylum monogynum* by absence of reddish tinge in aqueous extract of heartwood; *Mansonia gagei* by absence of storied rays, vessels, fibres and axial parenchyma; Buxus sempervirens, *Drypetes porteri* by the absence of scalariform perforations in vessels; and *Haldina cordifolia*, *Mitragyna parviflora* and *Gardenia latifolia* by absence of vestured intervascular pitting.

Table 1: Distinguishable wood characteristics to identify Indian Sandalwood from its adulterants

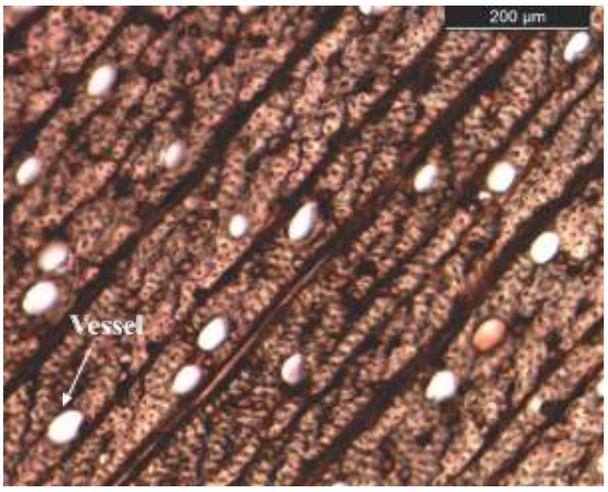
Species	Tangential vessel diameter (µm)	Vessel frequency (per mm^2)	Type of perforation plate	Ray structure	Ray frequency (per mm)	Ray height (µm)/ No. of cells	Rhomboidal Crystals
Indian Sandalwood (*Santalum album*) **Stemwood**	26-50	25-50	Simple	1-2 seriate	7-11	107-373/ mostly 10-18 cells	Present in axial parenchyma
Indian Sandal (*Santalum album*) **Rootwood**	24-80	50-90	Simple	1-2 seriate	4-8	140-272	Present in axial parenchyma
Fragrant adulterants of sandalwood							
African sandalwood (*Osyris lanceolata*)	60-90	-	Simple	1-3 seriate	-	Mostly 7-10 cells	Present in ray cells
Indian bastard sandalwood (*Erythroxylum monogynum*)	50-80	26-52	Simple	1-3 seriate	-	Mostly 12-20 cells	Present in axial parenchyma
Bastard sandalwood (*Mansonia gagei*)	35-65	85-96	Simple	Biseriate	9-13	210	Present in ray cells
Non-fragrant adulterants of sandalwood							
Haldu (*Haldina cordifolia*)	60-110	25-40	Simple	1-3 seriate	13-16	300-670	Absent
Kalam (*Mitragyna parviflora*)	60-120	20-25	Simple	1-4 seriate	12-17	450-650	Absent
Indian boxwood (*Gardenia latifolia*)	30-60	60-90	Simple	Uniseriate	12-16	400	Absent
Himalayan box (*Buxus wallichiana*)	45-50	130-180	Scalariform	1-3 seriate	9-14	450	Absent
Indian Dryptes (*Drypetes porter*)	30-55	100-180	Scalariform	1-3 seriate	16-18	-	Present in ray cells



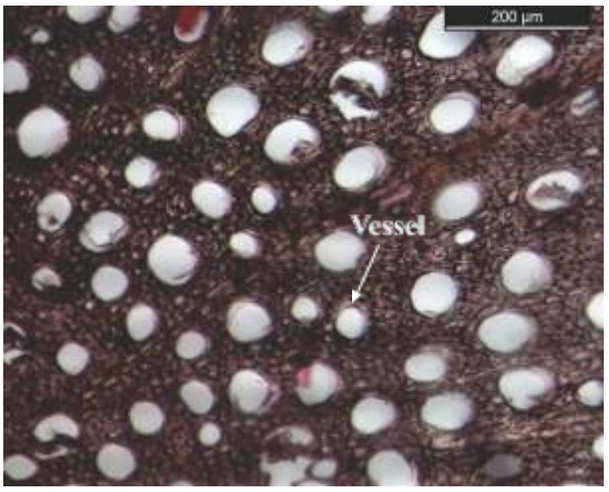
Macroscopic view of transverse section of disc



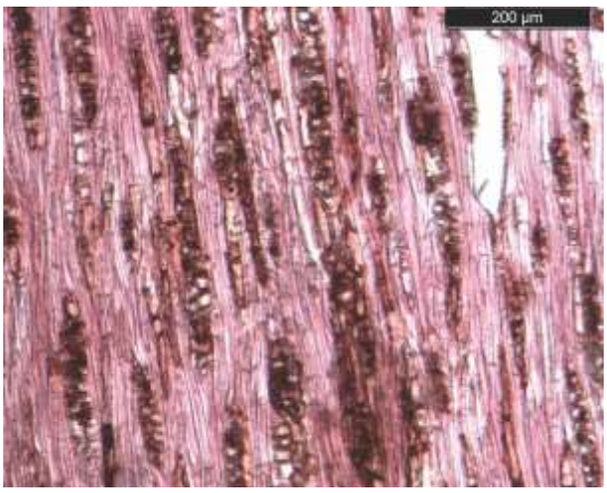
Growth-ring delimited by thick-walled fibres and crowded pores



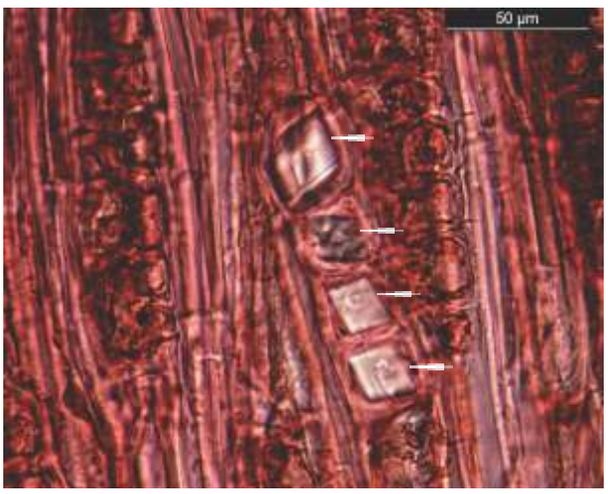
Transverse section of stemwood (10x)



Transverse section of rootwood (10x)



Tangential longitudinal section of stemwood (10x)



Rhomboidal crystals present in chains of axial parenchyma (40x)

Plate 1: Macroscopic and microscopic wood structures of Indian sandalwood

E- Protection System for valuable Sandalwood Trees

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Sandalwood trees are being targeted by smugglers causing huge losses to the forest department and farmers. The development of protocol for microchip based e-protection system for Sandalwood will help to conserve and enhance the status of these precious bio-resources of the country. In this endeavor a collaborative research project was initiated between the Institute of Wood Science and Technology (IWST), Bengaluru and Hitachi India Private Limited for finding the solution for protection, detection and prevention of illicit felling of high value tree species through e-Protection system under Hitachi's Corporate Social Responsibility (CSR) funding. A Memorandum of Understanding (MoU) was signed between the Institute of Wood Science and Technology (IWST), Bengaluru and Hitachi India Private Limited, Bengaluru at IWST to develop a protocol for microchip based e-protection system for sandalwood trees to protect, conserve and enhance the status of these precious bio-resources of the country.

The Government of India estimates the sandalwood market to be Rs 10,000 Crores annually (approximately US$2 billion) and losing Crores of rupees in smuggling as reported by police department. Government is designing various methods to control this menace of sandalwood smuggling. In recent days, dog squads are used to control illicit felling and smuggling of this precious species. Due to over exploitation from the wild, and lack of initiatives to raise the Sandalwood plantations, sandalwood resource declined worldwide. For monitoring large areas, using dog squad is not giving expected results in combating the smuggling activity and protect of sandalwood trees. Karnataka, Tamil Nadu, Kerala, Andhra Pradesh and other state forest department are protecting sandalwood trees through their own forest staff. However, due to shortage of manpower the smuggling of Sandalwood is continued to be a big challenge for the cultivation of Sandalwood. Special steps for protecting the high value trees from being cut and smuggled is the need of the hour. On these strings of thinking there is a need for an automated system for long lasting solution.

New idea of inserting microchip in sandalwood trees is feasible for the protection of trees from illicit felling. If there is any attempt to fell these precious trees, an alert should come to the control station and soon security official would reach the crime scene. This technology has immense possibilities in the field of research and development to produce more useful security and monitoring system for security applications (Soundararajan and Ravi Kumar, 2018).

Internet of Things (IoT) is the network of devices contains electronics, software, actuators, and connectivity which allow these things to connect, interact and exchange data (wikipedia.org). The convergence of IoT is expected to spread rapidly over the coming years and this will unleash a new dimension of services that improve productivity as well as the quality of life of end users. The IoT has the capacity to be a transformative force, positively impacting the lives of millions worldwide (Porkodi and Bhuvaneswari, 2014)

The IoT enables an opportunity for new commercial security models to support mass global protection system with which it can enable the next string of wave in life-enhancing services across several fundamental sectors. Device and application behaviour will place new and varying demands on mobile networks.

Long Range wide area network (LoRa) is a patented digital wireless data communication technology developed by Cycleo of Grenoble, France, and acquired by Semtech in 2012. LoRa enables very-long-range transmissions with low power consumption (Ramon *et al*., 2018). LoRa can

be used over a wide range of frequencies from 137 MHz to 1020 MHz. This includes numerous license-free ISM bands like 169 MHz, 433 MHz, 868 MHz and 915 MHz. This is a key enabler for inexpensive, world-wide deployments and interoperability. In India, the 865 MHz to 867 MHz license free band, as per the Ministry of Communications and Information Technology directions (loriot.io; ensembletech.in; thethingsnetwork.org).

Institute of Wood Science and Technology has been initiated for saving sandalwood tress through the microchip based e-protection system. This microchip based solution is initiated to monitor trees remotely using web interface and mobile app. Any unauthorized attempt made to fell/damage a tree will result in alarm to all registered devices. Protection system required components are Sensors (Tags), Gateway, Server with Web Admin Interface and Mobile App (Android). Pictorial diagram showing e-protection system is shown in Fig. 1.

Sensor (tags) means that it is part of a larger system which will be provides input to a main control system (like a Gateway, Sever, Processor or Microcontroller) (electronicshub.org). Sensor is designed based on microcontroller with accelerometer and customized algorithms. It is designed to detect various parameters of the assets

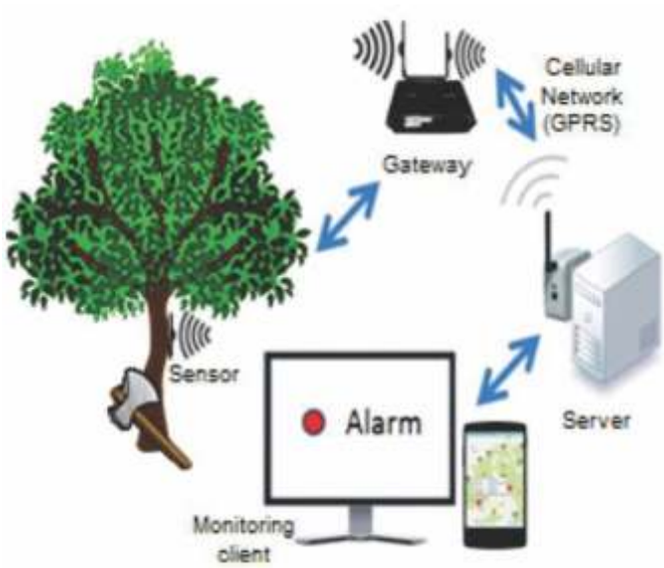

Fig 1: Pictorial diagram showing e-protection system

Institute of Wood Science and Technology has been initiated for saving sandalwood tress through the microchip based e-protection system.

such as vibration and tilt and to communicate the same with Gateway. Sensor also send daily health message to Gateway.

A gateway is a hardware device that acts as a "gate" between sensor and server. Gateway collects the information such as Tree cut/tilt alerts, daily attendance, etc. from the sensors and relay to the Server.

A server is a device or a program that is dedicated to managing network resources of protection system. Servers are often referred to as dedicated because it carry out hardly any other tasks apart from their server tasks. Server is built with state of the art technologies. Server software has capability to handle more than one million trees. Server will configure and monitor the WSN (Wireless Sensor Network) and collect the information from the Gateways and processes for the users.

A mobile app or mobile application is software application designed to run on a mobile device such as a phone/tablet. Mobile applications for monitoring the trees for users (Administrators) are built on Android technology. Mobile App will be downloaded from Google Play store. Mobile Application is also having similar Graphic User Interphase (GUI) interface as Server Web interface.

The microchips were initially been assembled and installed in various tree species at IWST campus and the parameters were optimized. Further refinements were made as per the suggestions given by the stakeholders. E-protection system was developed in two phases.

In the first Phase, as a pilot study, 50 sensors have been installed on sandalwood trees in the 25-acres of IWST campus Malleshwaram, Bangalore and 25 sensors were installed at farmer field at Nelamangala, Bangalore. The IoT sensors installed on the trees are already sending information about

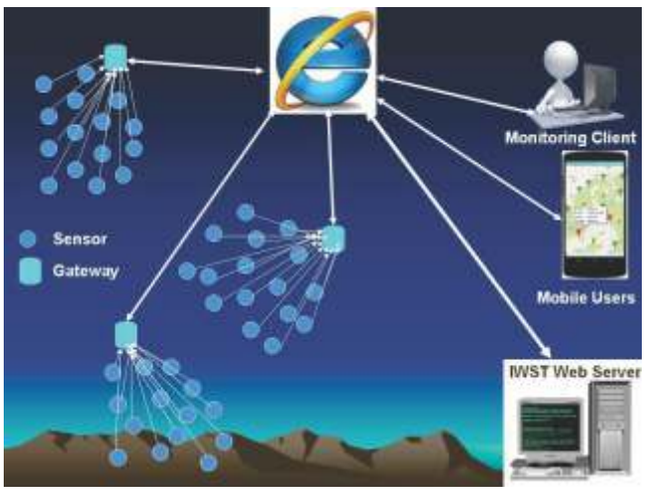

Fig 2: Microchip based Protection System Architecture

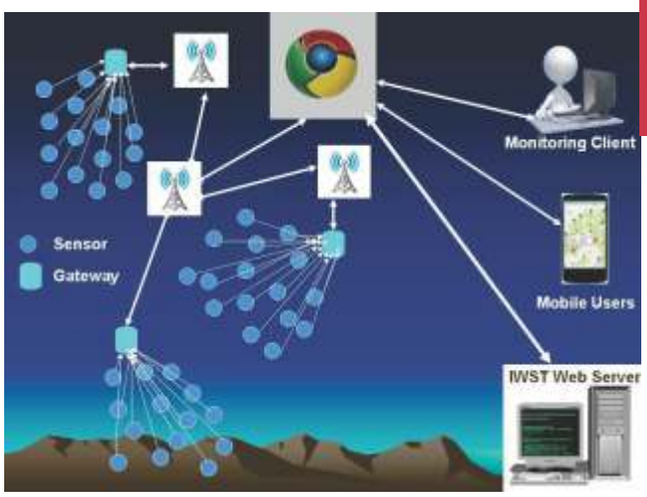

Fig 3: Microchip based Protection System Architecture (With Cellular Network)

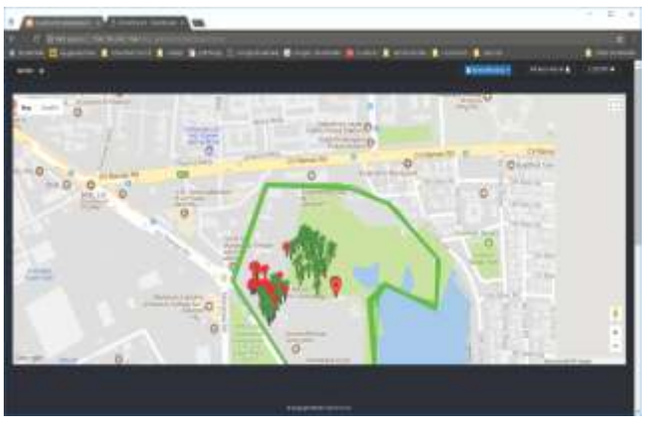

Fig 4: Installation of sensors on Sandalwood Trees in (IWST Campus)

any disturbance and their location to users; the green line shown in the picture depicts the outer boundary of the campus. Communication protocol between the Gateway and Microchip is working fine (Fig. 4).

In Second Phase, the sensor efficiency has been effectively upgraded and the size of the microchips has been reduced (65 × 45 × 10 mm to 56.65 × 24 × 6mm) to smallest possible to suit for the high value tree species like Indian Sandalwood.

- Daily attendance feature has been added in the server programme for monitoring the sensor, control of Gateway, auto detection of gateway health and dashboard.
- The Camouflage microchip cover has been redesigned to match almost completely with the tree bark colour.
- The mobile app has been upgraded to suit common sharing to the new version of sensor and redesign the SIM card based gateway. The Communication between the modified microchip and Gateway has been tested. Significant achievement has been made in the ranges of communication between the sensor and gateway which has been increased from the 700 meter to 4 km radius.
- Increased the overall capacity of Gateway which is now capable to handle 100 sensor tags to more than 1000 sensors.
- Feasibility studies of the final version of sensors and gateway at various agro-climatic regions for the feasibility studies like signal range, weather condition, heavy wind alert monitoring, etc. is under progress. The height and depth of the trees for fixing the microchip will be finalized accordingly.
- GPRS module based gateway established for internet (SIM card slot).
- Communication between Sensor and Gateway integration with server and mobile App tested.
- At Present 25 sensors have been installed on sandalwood trees in the 25-acres of IWST campus Malleshwaram, Bangalore.

New Camouflage

New gateway

New sensor installed in the Tree

Road map for future improvements

- Solar based power supply will be added.
- Capacity of the server will be increased and full-fledged system at IT Cell, Institute of Wood Science and Technology, Bengaluru will be established.
- IWST, Bengaluru will provide technical support for safe and better insertion of microchip in sandalwood and other high value trees.
- Around 5000 microchip will be installed in 50 different localities of agro climatic zones of Southern India for checking of feasibility of the solution.
- IWST will establish the Data Centre for Hosting e-Protection System for its implementation at the National level which may cost approximately Rs. 1.5 Crore.

The commercialization of technology will be a source of revenue. This will also solve social concern and problem of farmers and others, since it will cater to the problems of the farmers and sandalwood and other high value species growers.

Demo of the Microchip Installation

Conclusion

Real time monitoring of high value trees using e-protection system will be a boon to forest departments and sandalwood growers to protect their valuable trees till their harvest. The Wireless Sensor Network (WSN) system was developed using the protocol (HAD2P) for unusual disturbance of the tree for monitoring and detecting its illegal cutting. The colour code and sound alarm is generated initially on the mobile application and thereby giving sufficient time to the user to prevent theft. Microchip based e-protection system has come out as a practical and user friendly system for protecting Sandalwood trees both in forest and farmers fields. This new idea of inserting chips in sandalwood trees is feasible, if there is an unusual movement of these precious trees, an alert should come to the control station and soon security official would reach the particular place. This technology has immense possibilities in the field of research and development can produce more useful security and monitoring systems in mobile network and security applications.

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Historical and Cultural Significance of *Santalum album* L. in India

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Introduction

Indian sandalwood (*Santalum album* L. Family: Santalaceae) is an evergreen tree commonly found in dry deciduous forests of India. It can reach a height of 20 m and attain a girth of 2.5 m. It can grow from sea level to 5000 m altitude and can associate with more than 300 species of plants. It is an obligate hemi-parasite, hardy species and can adapt well in various agro-climatic conditions. It is popularly known as white sandalwood, also popular as "Dollar earning parasite" (Krishnappa, 1972) and its essential oil is ordained as "Queen of essential oil" (Radomiljac et al., 1998). It is indigenous to peninsular India and exploited rampantly for its high economic worth. Indian sandalwood is a highly valued tree of global fame and is acknowledged as Royal tree (Fox, 2000).

2. Historical and cultural importance of Indian sandalwood

2.1 Importance and uses of sandalwood in different times

Historically, sandalwood is amalgamated with the Indian heritage, culture and tradition (Srinivasan et al., 1992). Sandalwood is closely associated with human civilization since time immemorial that has continued to fascinate artists and craftsmen (Campbell, 1883; Kushalapa, 1998). The single largest market segment for Indian sandalwood are the products and applications meant for religious, ritual and ceremonial purposes. In Indian culture, it is regarded with special reverence. Indians have a strong spiritual association with sandalwood and the heartwood is burnt at weddings and funerals. *S. album* is the state tree of Karnataka and Karnataka is critically acclaimed as land of sandalwood (*Gandhada Nadu*), while the region in and around 'Mysuru' is eulogized as a sandalwood shrine (*Gandhada Gudi*) (Adkoli, 1977; Fox, 2000). Though *S. album* is indigenous to Deccan plateau it is getting naturalized in other parts of India and elsewhere (Sandeep et al., 2016). Indian sandalwood is idolized in most religions especially Hinduism and Buddhism. Sandalwood is used in every aspect of human life, especially in Indian culture and civilizations as it is required from cradle to cremation. In India, it is used in the production of attars from countless centuries. Attar is a blend of sandalwood oil and flower oil, such as rose petal, jasmine, kewda and others. The quality of attar is dependent on the concentration of flower effervescence within sandalwood oil. Varieties of attar products are produced in India and it forms an important constituent for the manufacture of incense sticks and scented tobacco such as Pan Masala, Zarada and Gutka. Its oil is used in perfumeries, soaps and toiletries, ayurvedic and pharmaceutical applications.

2.2 Vedic and Indus valley period

From the times of Harappan civilization tree worshiping was practiced in India. Indians were very well aware of medicinal importance of plants and mastered the art of ayurvedic medicine since Vedic period. Vedic and Indus valley period witnessed utilization of sandalwood in the form of fine woodworking artifact or carving deities (Fig. 1), ritual bathing of Hindu deities, temple construction material and for ceremonial causes (Campbell, 1883; Adkoli, 1977). Its importance in Indian culture is referred in Vedic literature, Puranas (ancient Hindu texts eulogizing various deities), subhashitas (collection of eloquent sayings written by ancient Sanskrit poets), mythology (stories on supernatural beings and events) and in the ancient scriptures (sacred writings). The Sanskrit manuscripts that are more than 4000 years old cite sandalwood oil as the oldest known perfumery material. During the age of Yajur Veda sandalwood was used in sacrificial fires,

while the treaties of loud hymns in Rig Veda and melodious hymns of Sama Veda give indirect evidence of Indian sandalwood. It is cited even in the oldest of Indian literatures such as Milinda Panha (200 B.C.), *Patanjali Mahabhasaya* (100 B.C.), *Dhamma Pada, Anguttara Nikaya* (The teachings of Buddha) and *Vinaya Pitaka* (300-400 B.C.). In *Milinda Panha* (Buddhist doctrine), Buddhist sage while referring to the path of righteousness mentions that *"No flower's scent can waft against the wind, not sandalwood's, nor musk's, nor jasmine flowers. But the fragrance of the good goes against the wind in all directions the good man's name pervades"*. While describing *'nibbana'* in *Milinda Panha* the sage also mentions that *"Like sandalwood, it is hard to get, its fragrance is incomparable and it is praised by good men"*. The medical treatises of Charaka and Susruta clearly gave the detailed description of Indian sandalwood and called it as *'Sweta Chandana'* (white sandalwood). Later the name of *'Sweta Chandana'* was adopted and *S. album* was known by the common name of white sandalwood.

Indian sandalwood was utilized, cultivated and traded by many cultures throughout the world since several hundreds of years.

2.3 Sandalwood in Puranic literature and Indian mythology

Puranic literature occupies an intermediate position and is believed to be between Vedic age and the period of classical literature. Vyasa Rishi mentioned about the usage of Indian sandalwood in *Puranas.* In ancient Hindu culture few trees have been associated with wisdom, knowledge, hidden secrets and considered as sacred. '*Agni Varta Purana*' gives the details of plants and plant materials to be used during homa, havana and other religious ceremonies. It is an important ingredient in 'homa/havana' -a Hindu ritual wherein offerings to the gods are made into a fire on special occasions. *Brahma Vaivarta Purana* considers the importance of Indian sandalwood and narrates that Brahma created it through meditative contemplation. In *Brahma Vaivarta Purana* it is mentioned that *'Goddess Lakshmi'* (Goddess of wealth) resides in sandalwood, thus Indian sandalwood tree is believed to be auspicious and bringer of wealth. Vamana Purana recommends the worship of *'Lord Shiva'* with the beige-colored paste of Indian sandalwood. Indian mythology cites sandalwood in various instances and according to a legend, Goddess Parvati created statue of a child using turmeric and sandalwood paste. Later, the statue was blessed to life and came to be known as *'Lord Ganesha'* (God of intellect). In *Bhagavata Purana,* an appreciation hymn mentions that *Lord Krishna* and *Lord Balarama* on their way to Vrishni Kingdom came across a dwarf named '*Kubja*' carrying paste of sandalwood to a tyrant king named *Kamsa*. It is narrated that the dwarf lady was blessed by Lord Krishna to become a beautiful woman after she applied the sandalwood paste to those two divine brothers. According to *'Panchatantra'* stories (before 5th Century) Indian sandalwood was endemic to the Malaya Mountains of southern India. Indian sandalwood was utilized, cultivated and traded by many cultures throughout the world since several hundreds of years. In the Ramayana while referring to river Tambrapani (*Tamara Parni*) says that "river islands covered with forests of sandalwood goes down the sea as a beloved maid to her lover". In south India, it is believed that possession of healthy Indian sandalwood tree in one's garden would ward off evil spirits, black magic and attract wealth for the owner. Even today some households in south India which are aware of this fact prefer to plant sandalwood in their home gardens to prosper wealth and are considered as a secret age-old tradition.

2.4 Indian sandalwood in various religious practices

Sandalwood has high spiritual significance in ritualistic practices and is used in the sacred fires of Zoroastrian temples with a belief that it soothes the troubles of all humanity. Egyptians and Ceylonese used it for medicinal purposes, religious purposes and for embalming mummies.Indian sandalwood incense is the oldest type of incense used that dates back to 4000 years old (Adkoli, 1977). It is burnt during prayers in Buddhist religion. It is mentioned as an item of toiletry in Buddhist Jataka stories of 7th century B.C.Herbalists believe that the fragrance emitted from the sandalwood incense helps to promote an atmosphere of open-mindedness, peace and spiritual

Lord Buddha described Sandalwood tree as -
"Sandalwood, tagara, lotus, jasmine – the fragrance of virtue is unrivalled by such kinds of perfume"
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awareness. Sandalwood incense is used in Catholic Church and Jewish Synagogues. Indian sandalwood was one among the most treasured item of commerce that was exported from India to Roman Empire. The renown of sandalwood can be realized by the quotes of Lord Buddha and Nobel Laureate Gurudev Rabindranath Tagore. Lord Buddha described Sandalwood tree as - "Sandalwood, tagara, lotus, jasmine – the fragrance of virtue is unrivalled by such kinds of perfume" while Gurudev Rabindranath Tagore as "The sandalwood tree as likely to prove, sweetest that can even conquer hate, love and perfumes the cruel axe that lays it low". The value of this species is underlined with the fact that sandalwood imparts fragrance even to the axe that cuts it. More than half a tonne of Indian sandalwood is required annually by Tirumala Tirupati Devasthanam (TTD)to conduct '*Snapana Thirumanjanam*' (celestial bath), pre-dawn ritual '*Suprabatham*' and last seva '*Ekantha seva*' of *Lord Venkateshwara.* To meet this demand TTD has started growing its own sandalwood spanning an area of 100 hectares near Parveta Mandapam, 3 km from the actual shrine of Lord Venkateshwara in Tirumala, Andhra Pradesh. Likewise, Art of Living Foundation also has plantations of Indian sandalwood in its premises.

2.5 Indian sandalwood during anno domini

Sandalwood was eloquently protected bioresource of India since Vijayanagara Period. Vijayanagara Kingdom the super power and richest empire in the world history had its glory because of its trade of natural resources such as sandalwood, spices and diamonds in exchange of guns and horses. The marvel, glory, splendour, richness and audacity of the empire was so overwhelmed that it started to gather enormous interests among scholars, tourists, travellers and merchants from nook and corner of the world more especially from places such as China, Arabia and Europe. Thus, the global politics of resource exploitation would always render the mantra of sustainable resource use an ineffective strategy. Sustainable use of resources has to be a global mantra; else it would be a myth Kalidasa (5th century A.D.) in his poem 'Raghuvamsa' referred sandalwood at various citations. Trade, economic significance and origin of sandalwood have been cited in the Periplus of the Erythrean Sea (written in the 2nd century), Kautilya described a variety of sandalwood in his Arthasastra (200 B.C.), Panchatantra, Kavya-Mimamsa of Rajashekar (880 - 920 AD). Ilango- Adikal, the Tamil poet quotes that Indian sandalwood originated in the Southern Mountain (Malaya Tenmalai Piranda Chandanam) (Srinivasan et al., 1992). Ramaswamy (1956) reported that India is the native of *S. album* and his observations were based on the recorded history of its occurrence in India which was of 2300 years old. From 13th to 18th century it remained significant economic bioresource that led dynasties for expeditions, warfare's and invasions to India (Ganeshaiah et al., 2007). The TTD, in India, daily requires large quantities of sandalwood paste. A day before the Brahmotsavam festival of Lord Venkateshwara, interiors of the sanctum sanctorum and the small shrines are smeared with a rich paste of sandalwood. During the Brahmotsavam, while the deity is around procession, the priests distribute sandalwood powder used for the rituals to devotees en route. Lord Venkateshwara is referred as *'Chandana Charchita Govinda'* (The English narrative would be "The Lord of the untainted form, The Lord who is beautiful and anointed by sandalwood paste, The Lord who has body tint equal to that of cloud"). This 'woody marvel' was known to Indians for countless centuries and South Western Ghats in India is considered as its natural area of distribution (Ramaswamy, 1956).

2.6 Factors leading to the decline of natural populations of *S. album* in India

Tipu sultan, *de facto* ruler of the kingdom of Mysore, hailing from an Arab migrant tribe (Quraish) used to frequent Turkey and Afghanistan for trade. Some researchers opined that Tipu never hesitated to take the help of Afghans and French's to expel the one he hated and applied all sorts of strategies to get maximum benefit from trades (Lafont, 2001). However, historians and researchers admire him as a progressive king who constantly looked out for best global technology for his Kingdom. Apart from his ground breaking changes in economy from going cashless to modernizing warfare system with rocket technology Tipu introduced a stock yard system for storage of sandalwood known as 'Sandal Koti' in 1799, Koti meaning stock-yard of sandalwood. At present Sandal Koti can be located in Hunsur, Tirthahalli, Srirangapatana, Shivamogga, Bengaluru, Sagara, Hassana, Tarikere, Chikamagalur and Fraserpet. During the times of Tipu sultan, Afghans, French and Turks favored sandalwood. Thus, sandalwood trade to Arabian countries was at its pinnacle during the rule of Tipu sultan. He coined names for various classes of sandalwood using Afghan, Arabic and Turkish terms. Later in 1898, the Governments of Karnataka and Tamil Nadu recognized 18 grades of sandalwood for sale. Nevertheless, to establish a monopoly over Indian sandalwood Tipu Sultan created a dictum in 1792. The decree created by Tipu Sultan in 1792, started monopoly of Indian sandalwood and led to the severe deterioration of sandalwood populations in south India. Under the dictum, Indian sandalwood was declared as Royal tree. The states of Karnataka and Tamil Nadu later ratified the mandate to keep sandalwood under the control of their respective governments. But this decree became a curse than a boon as it brought more harm than good as many legal obligations were imposed on sandalwood cultivation.

Lord Venkateshwara is referred as *'Chandana Charchita Govinda'* (The English narrative would be "The Lord of the untainted form, The Lord who is beautiful and anointed by sandalwood paste, The Lord who has body tint equal to that of cloud")

Apart from this over exploitation, frequent forest fires, grazing, browsing; unconventional monoculture eucalyptus plantations, past cyclic epidemic of spike disease caused by phytoplasma (Mycoplasma like organism) and other biotic interferences (Fusarium, Pythium, Rhizoctonia, nematodes etc.) have further contributed to the dwindling of this species, both in area and density. Its existence in natural stands has declined and is difficult to trace a greater number of commercially exploitable sandalwood trees in the forests of Karnataka (Swaminathan, 1998). Fading populations of higher girth classes can be traced in the protected boundaries of governmental, non-governmental organizations, institutions, farmlands and homesteads in its natural as well as naturalized area of distribution. India for decades dominated the sandalwood oil production, but in the current scenario it is importing sandalwood oil from foreign countries (Dhanya et al., 2010). This alarming condition indicates that there is a need to conserve this species and enhance its abundance.

Conclusion:

Indian sandalwood has been inseparable part of Indian culture and tradition. Its utilization has been witnessed from the Indus valley civilization to the present modern era. Sandalwood tree is being grown in the home gardens of many households in south Indian states. Traditionally, it is believed that growing *S. album* in one's backyard would bring prosperity in life (as Goddess Lakshmi resides in), wards off evil spirits and delete the harmful effects of black magic. Thus, it could be said that this traditional belief knowingly or unknowingly has paved the way for effective conservation of this flagship species. Furthermore, the present era has tremendous commercial value for Indian sandalwood in National and International markets. *S. album* has always held important place not only in Hindu religion but in almost all the religions. The Epics, Scriptures, Vedas, Puranas and Buddhist literatures are contained with reference of the significance of *S. album*. The sacredness of *S. album* in also witnessed in Indian mythology. All these factors signify its importance to mankind and should be considered for conservation in its natural stands.

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Sandalwood (*Santalum album* L.) Oil: Uses, Adulteration and Detection Techniques

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Introduction

The Sandalwood oil is extracted from heartwood of stem and root of Sandalwood (*Santalum album* L.) tree. Sandalwood oil is extracted by different methods such as steam distillation, hydro-distillation, hydro steam distillation and solvent extraction methods. Among them Steam distillation is the most common method being used for extraction of Sandalwood oil. The yield of oil depends upon the age of the tree, method of extraction and part of the tree from which the oil is extracted. Pure Indian Sandalwood oil contains more than 90% w/w of (free) alcohols. The major chemical constituents of Sandalwood oil are Z-α-santalol (41-55 %) and Z-β-santalol (16-24 %). The quality of Sandalwood oil depends on its chemical composition due to which it has the pleasant and characteristic aroma.

Sandalwood oil is colourless to golden yellow, clear, slightly viscous liquid has high value due to its long lasting, pleasant, smooth and woody scent. Sandalwood oil is the key ingredient of Indian attars (or atar, which are oil-based perfumes) because of its unique capacity to absorb the characteristic notes of other perfumes and it also can enhance their perfumery status and stability. The oil is also used as a flavouring substance in food products such as frozen dairy desserts, candy, pan masala, baked food, gelatin, puddings and alcoholic and non-alcoholic beverages (Arun Kumar *et al,* 2012). It has also been approved by the United States Food and Drug Administration (FDA), Flavor and Extract Manufactures Association (FEMA) and Council of Europe (COE) for food usage (Kraft et al, 2000). Its use also has been reported in folk medicine with activities against common colds, bronchitis, skin disorders, heart ailments, general weakness, fever, infection of the urinary tract, inflammation of the mouth and pharynx, liver and gallbladder complaints and other maladies (Mishra & Dey, 2013).

Sandalwood and Sandalwood oil

General Steps in Extraction of Sandalwood Oil from Sandalwood

Adulteration of sandalwood oil:

Excessive harvesting without reforestation of Sandalwood tree has substantially reduced the availability of wood to the Sandalwood based industry, resulting in global shortage and steep rise of market prices of its wood and oil (Arun Kumar *et al,* 2012). As a result, the quality of Sandalwood oil entering the trade is being compromised due to its adulteration including substitution. Adulteration of oil leads to inconsistency in its fragrance, medicinal and aromatherapy properties (Misra & Dey, 2013).

Adulteration in Sandalwood oil is a common problem and comes in

Sandalwood Oil-Based Attar

Mysore Sandal Soap

many ways, such as dilution of genuine oil with a cheap carrier oil or solvent, adding synthetic aroma chemicals, or reconstructed oil with natural or synthetic chemicals. About 25 species, including species in other families (e.g. *Amyris balsamifera L., Rutaceae*) were traded as 'sandalwood'. In addition, *S. album* oil may be substituted with oil from other species for example *S. spicatum* which contains 38.7-46.1 % of total santalol (Lawrence 1991), or the oil may be adulterated with synthetic or semi-synthetic substitutes such as 3-methyl-5-(2,2,3-trimethylcyclo-pent-3-en-1-yl) pentan-2-ol commonly known as sandal pentanol or sandalore (Kraft et al, 2000).

Adulterations by fatty oils such as castor oil, peanut oil are easy to detect. On the other hand, adulteration performed by an expert with the right materials can be very difficult to identify and quantify (Lawrence, 1991). Adulteration of genuine oil with (semi) synthetic additives influences physical and chemical properties of the oil. Health issues such as allergenic potential, carcinogenicity, damaging nervous system and reproductive organs have been associated with the use of such additives. Recently, a total of thirty-eight sandalwood oil samples, including ten samples from heartwood of *S. album* and twenty-eight trade samples of Sandalwood oils were assessed at Institute of Wood Science and Technology (IWST) for refractive index (RI), relative density (RD) and α- and β-santalol content (Bisht et al, 2020). The percentage of α- and β-santalols in these samples ranged from 0 to 54.28 % and 0 to 25.94 % respectively. The oil samples with α- and β-santalol content from 48.2 to 54.28 % and 19.15 to 25.94% respectively were comparable with pure sandalwood oil as described in Indian Standard (IS329-2004). It was observed that, less than one third of commercial oils confirm to IS329:2004.

Nomenclature considerations:

Naming Sandalwood is a challenge for Sandalwood oil producers and traders. Accurate identification of the correct tree species from wood is difficult due to the existence of hybrids, as well as different varieties depending on geographical locations. Notable members of *Santalum* genus are Indian sandalwood (*Santalum album*), Australian sandalwood (*Santalum spicatum*). *S. ellipticum, S. freycinetianum*, and *S. paniculatum,* the Hawaiian sandal woods, which are used and considered as high quality; however, these three species were exploited between 1790 and 1825 before the supply of trees ran out. S. yasi known as sandalwood from Fiji and Tonga, and S. spicatum from Australia are also being used as a source of Sandalwood oil. Various unrelated plants from other genus with scented wood (viz.; Myoporum sandwicense - bastard sandalwood, false sandalwood; *Osyris lanceolata* - African sandalwood; *Osyris tenuifolia* - east African sandalwood etc.) are also referred as sandalwood.

Analytical methods to detect adulteration:

The quality of Sandalwood oil is evaluated by assessment of different physicochemical properties viz., colour and appearance, odour, relative density, optical rotation, refractive index, esters content, total alcohol content, steam-distillation residue, miscibility, the α-santalol and β-santalol content and flash point as per Indian Standard (IS 329: 2004) or International Standard (ISO 3518:2002). Sandalwood oil is having a value in range for above physicochemical properties as per nature of components present. This gives an idea about the nature of particular oil or test sample. Generally, samples not falling in set range of specified limits are doubted for presence of adulterants/mixing of cheap natural materials, or natural variations in composition of a material.

Table 2: Requirement for Sandalwood Oil as per Indian standard &International Standard

S/N	Characteristics	As per IS 329	As per ISO 3518
I	Colour and appearance	Nearly colourless to golden yellow, somewhat viscous oily liquid	Colourless to golden yellow, clear, slightly viscous liquid
ii	Odour	Pleasant, sweet, woody and persistent	Characteristic, sweet, woody & persistent
iii	Relative density	0.963 5 to 0.977 5 at 27 °C	0.968 to 0.983 at 20 °C
iv	Optical rotation	-20° to -15°	-21° to -17°
v	Refractive index	1.500 0 to 1.507 0 at 27 °C	1.503 to 1.509 at 20 °C
vi	Esters, calculated as santalyl acetate % by mass, Max	7	<5
vii	Total alcohol, calculated as santalols % by mass, Min	90	90
viii	Steam-distillation residue for 10 h, % by mass, Max	5	-
ix	Miscibility in ethanol, 70% (volume fraction) at 20° C	-	<5
x	Chemical constituents by GC analysis-		
	α- Santalol %	41 to 55	41 to 55
	β-Santalol %	16 to 24	16 to 24
xi	Flashpoint	-	>200 °F (>93.3 °C)

Conclusion:

Adulteration and substitution of Indian Sandalwood oil is considered to be widespread. There are different reasons for adulteration of sandalwood oil such as high production cost, low production output and composition is easy to replicate by (i) addition of oils from other plants; (ii) addition of synthetic compounds. The quality of Sandalwood oil should be evaluated as per Indian Standard (IS 329: 2004) or International Standard (ISO 3518:2002) for different physicochemical properties viz., colour and appearance, odour, relative density, optical rotation, refractive index, esters content, total alcohol content, steam-distillation residue, miscibility in alcohol solution, the α-santalol and β-santalol content and flashpoint. One or a combination of these methods can be utilised as a quality control procedure to authenticate oil and ensure a high quality ingredient. Further, it is suggested that quality control and authentication for high valued Sandalwood oil should be strictly regulated by regulatory bodies or certifying organisations.

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Raipur - 492009.
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Perfumery and pharmacological importance of Indian Sandalwood and its value added products

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Introduction

The olfactory characteristics of Sandalwood oil from the East Indian sandalwood tree (*Santalum album* L.) is legendary since the beginning of perfumery and even now in the modern fragrant world. The warm, sweet, precious wood notes and the non-dominating fixative characteristics of the oil make it the ideal choice for creating wide varieties of perfumes. The fragrance of the oil and heartwood are considered invaluable in meditation practices. Many substitutes have been tried for sandalwood but in the end one can only say that "sandalwood is the wood" and there is no real substitute for this royal perfume (Baldovini*et al*, 2011).

The value of a sandalwood tree depends on three important characters (i) the volume of heartwood; (ii) the concentration and (iii) quality of its heartwood oil. The amount of heartwood in a tree varies considerably depending on age, soil and climate conditions--and other factors not entirely understood (Brand *et al*., 2012). The essential oil found in the heartwood of the trees start to form at the age of around 10 years, and trees can be usually harvested around 25-28 years to get good yield of oil. The volatile oil distilled from Indian Sandalwood derived from the heartwood is colorless to yellowish viscous liquid with heavy sweet odour. The top note (the first aroma you smell) is very soft with a sweet-woody, balsamic body note and a long-lasting bottom note which makes this oil as a good fixative.

Pharmacological Importance:

Sandalwood

Traditionally, in the realm of mental and emotional therapeutics sandalwood is used for treating stress, depression, stress anxiety and nervous tension as it is both a sedative and tonic. It is thought to naturally control anger and aggression and to act upon subtle emotional centers to promote compassion and openness and enhances meditation, this way; the healing process can be hastened as the person loses their worries and discomfort.

About six novel sesquiterpenoids, two aromatic glycosides and several neolignans identified from heartwood chips of sandalwood were evaluated for both in vitro Epstein- Barr virus early antigen (EBV-EA) activation in Raji cells, for assessing antitumor promoting activity and in vivo two-stage carcinogenesis assays demonstrated its potent inhibitory effect on EBV-EA activation, and also strongly suppressed two-stage carcinogenesis on mouse skin (Kim *et al*., 2006). Two lignans obtained from the heartwood of *S. album*, indicated apoptosis induced tumor cell cytotoxicity against HL-60 human pro-myelocyticleukemia cells and A549 human lung adenocarcinoma cells, where IC50 values were determined to be in the range of 1.5- 19.9 µM (Matsuo and Mimaki, 2010).

Indian Sandalwood encourages a deeper meditative mind, increasing the parasympathetic nervous system of a person, rather than a sympathetic nervous system response. “This relaxing oil has a harmonizing and calming effect which reduces tension and confusion and is ideal for use in depression, hectic daily lifestyles and states of fear, stress, nervous exhaustion, and anxiety.”

Sandalwood oil

The sandalwood oil is one of the most valuable essential oils, valued by perfumers for its woody notes, providing a deep rich base note to perfumes and acting as a natural fixative. Sandalwood oil is known to

have extremely beneficial medicinal properties such as:

Anti-inflammatory	: Reduces pain, swelling
Antiphlogistic	: Useful to cure fever
Anti-septic	: Helps prevents infections
Diuretic	: Increases discharge of urine
Emollient	: Softens and soothes the skin.
Hypotensive	: Reduces blood pressure, memory booster helps improve memory
Sedative	: Has Calming effect reduces anxiety, stress, and irritability (Soundararajan *et al*, 2017).

Sandalwood oil is still one of the main remedies used in the Ayurvedic system of medicine. Asians and Arabs use it in self-treatment for a great number of diseases. Traditionally sandalwood has been used for treating digestive complications arising from diarrhea, nausea, colic and gastritis. It is listed as a carminative and digestive muscle relaxant. Its antiseptic properties have been successfully employed for treating gonorrhea and leucorrhea. It has long been valued for treating these types of genito-urinary infections. Indigenous physicians observed that the oil and heartwood possessed antispasmodic properties and so utilized it for treating bronchitis, coughs, sore throat and related diseases. Its use in treatment of skin problems is legendary. It is an excellent moisturizer and nourishes all skin types. It's astringent, anti-inflammatory, antiseptic, and pain relieving properties have been put to good used in healing wounds, scars, and acne. Applied to the forehead in the form of a paste it has a cooling effect and is used to bring down fevers. In cosmetic preparations it is excellent for reducing wrinkles (Soundararajan *et al*, 2017).

Sandalwood essential oil has a cooling effect on the brain and a calming effect on the mind. The sedative properties of this oil guard the nervous system and alleviate the off-putting effects of stress and other negative feelings. For this invigorating reaction, Sandalwood essential oil is celebrated as a perfect meditation tool for more than thousands of years. When used in the form of incense sticks, in diffusers, burners or vaporizers this oil stimulates sensuality, grants a sense of awareness, invokes tranquillity, awakens the divine thoughts within and promotes profound relaxation.

A detailed study of Sandalwood oil was carried for antifungal activities against eight strains known to be human pathogens and was found to be effective against Microsporum canis, *Trichophytonmenta grophytes* & *T. rubrum*. It has been reported that the replication of Herpes simplex viruses is inhibited in the presence of the sandalwood oil.

It has been reported that the effects of inhalation of Indian Sandalwood essential oil and its main compound, alpha-santalol, increases physiological parameters like blood oxygen saturation, respiration rate, eye-blink rate, pulse rate, skin conductance, skin temperature, surface electromyogram, and blood pressure and self-rated arousal like alertness, attentiveness, calmness, mood, relaxation and vigor in humans.

Indian Sandalwood encourages a deeper meditative mind, increasing the parasympathetic nervous system of a person, rather than a sympathetic nervous system response

Sandalwood Bark

The aqueous extract of air dried powdered bark of Indian sandalwood in concentration of 25 to 1000 µg/ ml in phosphate buffer showed good inhibition against virulent species, *Staphylococcus aureus* (Shankaranaryanaet al, 1986).

The Triterpenoid- urs-12-en 3 β-ylpalmitate (m.p 115-1160, (α) D 24 +200, C46H80O2) compound has been isolated from sandalwood bark. The tropical application of triterpenoiod on fresh pupae of forest insects viz: *Attevafabriciella, Eligma narcissus, Eupterote geminate* etc produced morphologically defective adults indicating growth inhibition activity of the compound. The extract of bark observed the chemosterilant activity on freshly emerged moths of *Attevafabricella* (Shankaranaryanaet al, 1986).

Sandalwood seed oil

Sandalwood seed oil is fatty oil produced from the seed kernel of the Sandalwood tree having different properties than the essential oil obtained from the heartwood of tree. Sandalwood seed oil is a natural blend of Ximenynic acid and oleic acid with minor quantities of other common fatty acids. Seed oil is a reliable source of Santalbic acid (Ximenynic acid) which is well known source of anti-inflammatory lipid. *Santalum album* seed oil possesses excellent stability and favourable physicochemical characteristics and also pharmacological values with great potential for various applications in cosmetics and others such as anti-inflamatory creams. Sandalwood seed oil finds use in treatment of skin diseases. On pharmacological screening it exhibited diuretic activity, antitremorogenic activity and antiviral activity.

Conclusion

Sandalwood, its valued oil and other sandalwood based value added products possess interesting Pharmacological and perfumery potential. Future studies should pay attention to the possible use of essential oils for specific purposes and also for various other valued uses. It has been recently stressed that, traditional documented use, tribal non-documented use, and exhaustive literature search should be applied to synergize efforts in drug discovery from plant sources and identification of appropriate candidate plants. Besides, drug discovery and development need not always be confined to new molecular entities, but traditional herbal formulations and botanical drug products with robust scientific evidence can also be alternatives, thus accelerating the clinical candidate development using reverse pharmacology approaches.

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Short term Courses offered by the Advanced Woodworking Training Centre (AWTC)

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Security Deposit	:	Rs.5,000/- (Refundable)
Intake	:	Maximum 5 Candidates per Batch

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Intake	:	Maximum 5 Candidates per Batch.

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Potential Utilization of Sandalwood Seed Oil

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Introduction

In India, the heartwood of sandalwood has divine status. The divine fragrance of the sandalwood is said to be very pleasing to the almighty, hence it is used in anointing the divine idols in Indian culture. The fragrance of sandalwood and the religious life of most of the Indians can hardly be separated as it is required right from sacred ceremonies to the last rites of devote. In India, it's been valued for at least 2,000 years as one of the most sacred trees--an important part of devotional rituals and also as one of the most important ingredient of a funeral pyre in Hindu culture. The Indian Sandalwood is known worldwide because of its distinctive fragrant oil and wood considering large genetic distance between provenances, it is concluded that under diverse locality factors Sandalwood adapts very well in terms of growth, heartwood and oil content (Jain *et.al,* 2003).

Sandalwood seed oil is a reliable source of santalbic acid (Ximenynic acid) which is well known source of anti-inflammatory lipid. *S. album* seed oil possesses excellent stability and favourable physicochemical characteristics and also pharmaco logical values with great potential for various applications in cosmetics and others such as anti-inflammatory creams. sandalwood seed oil finds use in treatment of skin diseases.

The seed oil on reaction with zinc chloride yields a dark plastic solid which when dissolved in benzene forms an ideal base for insulation tapes. Seed oil reacts with sulphur at 220°C yielding a dark sticky rubber like product and hence is classified under vulcanisable oils. Resins like colophony (rosin) copal; shellac etc. could be dissolved in seed oil at 200°C to produce an orange coloured varnish. The highly resinous unsaponifiable matter constituting 7 to 17% of oil could be easily separated byshaking seed oil with cold dilute alkali and ethyl acetate (Shankaranarayana, 1988). By partial hydrogenation i.e. reduction at the acetylenic bonds, using Lindlar's catalyst, sandalwood seed oil could be converted into semi-drying oil (Shankaranarayana, 1979). Four surface active products having good foaming capacity and foam stability were prepared by reaction of (i) dimethyl sulphate on sodium santalbate (Shankaranarayana and Krishna Rao, 1982), (ii) seed oil with diethanolamine, gelatinhydrolysate or sodium-ammonia (Shankaranarayana and Parthasarathi, 1986). On pharmacological screening, sandalwood seed oil was found to possess diuretic hypotensive, antitremorogenic and antiviral activities (Desai and Shankaranarayana, 1990). Seed oil finds use in treatment of skin diseases (Kirtikar and Basu, 1987).

Chemistry of Sandalwood seed oil

Sandalwood seed oil is fatty oil produced from the seed kernel of the Sandalwood tree having different properties than the essential oil obtained from the heartwood of tree. Sandalwood seed oil is a natural blend of Ximenynic acid and oleic acid with minor quantities of other common fatty acids. Sandalwood seed oil contains 55-60% of a drying oil highly rich in unsaponifiable matter (7-17%) rich in one of the rarest fatty acids found in the plant kingdom. Sandalwood seeds from young trees (aged around 10years) are as much potentially rich in fatty oil, proteins and minerals as the seeds from the mature trees (age more than 30years) (Shankaranarayana, *et al*., 1990;Shankaranarayana and Parthasarathi, 1985). It is viscous, slimy, pale greenish yellow, Refractive Index. 1.479-1.488, Specific Gravity 0.9304-0.9430 Unsaponifiable matter 7-17%, Acid value 9-15, iodine value 145-159, Saponification value 185-195.

Sandalwood seed oil contains a fat rich in santalbic acid (Ximenynic acid), which is an acetylenic acid. Partial hydrogenation using Lindlar's catalyst has yielded an oil containing 80% of C18:1 and C18:2 fatty acids, 13% of C18:3, 6% C20 fatty acids and traces of Lauric acid(C12), Palmitic acid (C16) Stearic acid (C18) fatty acids making it more semi drying oil in the process (Shankaranarayana, 1979).

Pharmacological Importance

Initial pharmacological studies of seed oil of *S. spicatum* reveal that it does not cause any toxicity or pathological damage to mice, but reduces fat deposition in adipose tissue. However increased aspartate amino transferase enzyme in plasma suggested an increased hepatic activity. Increased n-3 and n-9 fatty acids and decreased arachidonic acid (n-6) were also observed which suggested a stimulation of the delta 9- desaturase enzyme. Isolated ximenynic acid from *S. acuminatum* was reported to have anti- inflammatory properties on several rat peritoneal leukocytes. Further studies of Ximenynic acid found it to alter the cytochrome P-450 enzyme in rats, indicating a pharmacological change in the hepatic metabolism (Dhanushka, et al., 2012).Studies have also found that rats and mice that consumed sandalwood seed oil deposited less fat on adipose tissue (under the skin) than the control group. Researchers have identified that ximenynic acid produces micro-vascular constriction activity or otherwise increased blood circulation in the skin. The ethyl ester of ximenynic acid has been associated with micro-vascular kinetic properties which could be beneficial in treatment of cellulitis, hair loss and varicose veins (Dhanushka, *et al.*, 2012). Studies have also shown that a highly purified ximenynic acid increases cellular detoxification and anti-oxidation capacity. It leads to a strengthening of the Extra Cellular Matrix (ECM), increases dermal strength and improves skin elasticity(Vasundhara, *et al.*, 2015).

Santalbic acid (trans11-octa-decen-9-yonic acid), a major constituent of the seed inhibits gram positive bacteria and several pathogenic fungi (Misra and Dey, 2013). Studies on unusual acetylenic fatty acids of Santalum seed oil genus began in the 1930s and most of them were identified by comparison with those found in seed oils of the Ximeniagenus (Oleaceace), such as ximenynic acid, E-11- octadecen-9ynoic acid, a long chain acetylenic fatty acid. This rare ximenynic acid previously named santalbic acid, was then identified and reported in various genera of Santalaceae. Proximate and fatty acid composition changes in developed sandalwood (*S. spicatum*) seeds and separation and identification of ximenynic acid isomers in this seed oil as their 4,4-dimethyloxazoline derivatives have also been studied (Butaud, et al., 2008).

Conclusion

On pharmacological screening sandalwood seed oil exhibited diuretic activity, anti tremorogenic activity and antiviral activity. It produced prolonged fall in carotid blood pressure and increase in respiration when administered intraperitoneally to adult healthy morgrel dogs anesthetized with pentobarbitone sodium (Desai, *et al.*, 1991).As the global demand for novel cosmetic agents is ever increasing, sandalwood seed oil could enter the market as a cosmetic ingredient that could also act as a vehicle for other oil-soluble agents. Studies continue on oxidative stability and pharmacological effects such as anti-inflammatory and cytotoxicity to extend knowledge of sandalwood seed oil as an acceptable pharmaceutical and cosmetic ingredient (Dhanushka, *et al.*, 2012). Acetylenic acids such as ximenynic acid are known to interfere with fatty acid metabolism in a variety of tissues. Seed oil of *S. album* may be a good source of ximenynic acid for cyclo-oxygenase and lipoxygenase enzyme studies (Butaud, et al., 2008).

Research interest to evaluate its pharmacological and cosmetic potential has developed recently perhaps on realization that sandalwood seed oil may contain novel chemicals that exhibit a wide range of pharmacological cosmetic effects. Hence, more studies are required on phytochemical, cosmetic and pharmacological importance of seed oil of this important species. This rare active oil can be formulated and delivered in a manner similar to normal carrier oils. Having excellent stability and favourable physicochemical characteristics, Sandalwood Seed Oil may offer the personal care formulator an exciting ingredient with anti-inflammatory activity on skin together with the known emollient and nourishing properties of oleic acid (Hettiarachchi, et al., 2013).

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Variations in Growth, Heartwood and Oil Content of Commercial Sandalwoods

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Introduction

Indian sandalwood (*Santalum album* L.) is recognised as one of the most valuable wood in the world. Due to dwindling of mature sandalwood trees in its natural range, the demand and price of sandalwood products is increasing year to year. It is reported that the global sandalwood oil market will be double in value over the next five years, to USD 197 million by the end of 2026. Since, both heartwood and oil of sandalwood are marketable products and its quality depends on age of trees, determination of right harvesting age is crucial for maximum returns. Early studies indicate that the harvesting age lies between 15 and 30 years. The harvesting age vary with site, climate and genotypes of plant. The paper aims to review the variations in heartwood and oil content of commercial sandalwoods.

Growth statistics of sandalwood

S. album is capable of growing in all types of soils up to elevation of 1800 m from mean sea level, with rainfall range, 500-5000mm. Sandalwood grows very slow in in natural habitat at rate of about 1.0 cm girth per year. However, sandalwood trees can grow from 5-6 cm in girth per year in fertile soil with moisture conditions. The growth rate of sandalwood trees in known age planation varies from 1 to 6 cm in wet site and 0.6 - 2.5 cm in dry sites. Sandalwood can grow more than 5 feet height in a year when high inputs of water and manures provided (Fig 1). Further, a study revealed that both height growth and survival per cent of plants, produced from 10 different seed sources did not differ significantly. A study revealed that Indian sandalwood trees, intensively managed with fertiliser and suitable hosts, had highest growth rates, whereas the trees grown in old fallow land had lowest growth rates.

The differences in early growth in trees (<10 years old) are likely to continue in later years. The highest mean height, basal diameter and diameter at breast height of 6-year-old sandalwood plantations are 6.0m, 12.7cm and 10.3cm, respectively, reported in south China. The mean height and bole length of 16 years old trees grown in Vanuatu is 6.8 and 2.2 m, respectively. Mean stem diameter of the same is tapering at rate 2.0, 0.2, 2.9, and 0.3 cm at five tree heights viz., 15 cm, 30 cm, 1.00 m and 1.30 m from ground levels, respectively. *S. album* plants (2.5 x 2.5 m spacing) have attained 3.14m height and 11.0 cm gbh at age of 6 years old in Madhya Pradesh, India.

Fig 1(a). 1-year old sapling in field

Fig 1(b). 1-year old sapling in nursery

Heartwood formation and its variations

The price of sandalwood is largely determined by its heartwood quality and santalol content of the oil. Knowing the time of heartwood formation and its development in sandalwood tree is important, as it helps to decide the rotation age for harvesting. Currently, very little information is available on these aspects, especially for the sandalwood trees grown in farm lands. The current knowledge on heartwood formation suggests that as the secondary xylem ages, water conducting

tissues stop functioning when the tree ages, which may lead to heartwood formation.

There is a misunderstanding that wounding can initiate early heartwood in sandalwood trees. But the wounding cause stress-induced development rather than age-related development that forms true heartwood. Among chemicals tested for heartwood formation, ethylene is the only treatment, which produced santalols on treated branches, this confirmed the presumption that sandalwood oil is produced by a regulated senescence process. Further, it is suggested that 10-year trees are ideal choice for heartwood initiation by artificial means. However, environment induced stress plays vital role in the promotion of heartwood development in *S. album*. Though heartwood is found in all kinds of soils, elevations and climates, certain trees produced heartwood earlier than others in the same environment and quantity of heartwood increase steadily with girth classes. On an average, the following heartwood yield is expected from different girth classes under forest conditions (Table 2).

Table 2 Girth and heartwood yield in Indian sandalwood

SL No	Girth class (cm)	Mean girth	Heartwood yield (kg)	Rate of Increment (kg)
1	1-15	8	2.4	-
2	16-30	23	6.0	3.6
3	31-45	38	16.5	10.5
4	46-60	53	39.0	22.5
5	61-75	68	74.0	35.0
6	76-90	83	127.0	53.0

An earlier study reported that a sample tree of 10 cm girth at breast height had a good percentage of quality heartwood and another sapling, just 30 cm away from the above, of the same girth, did not have heartwood at all in Shenkottai forests, Tamil Nadu. In a known age plantation, 5-10% of trees formed heartwood at an early age of 8 years while 15-20% of trees did not form heartwood even after 20 years. This strongly indicates that differences in growth, yield and colour of heartwood is mainly due to genetic makeup of individual trees. However, it is not clear that to what extent the climatic and edaphic factors cause variations in heartwood and oil content. The mean girth and heartwood increment per year at breast height is 1.0 cm and 0.2-1.0 kg per year, respectively.

An Australian study too confirmed that there is a strong association between the rate of heartwood development and soil type, rainfall and the level of sun exposure on the canopy of the sandalwood found. *Albeit* as early as 1894 it had been recognized that the tree attains a commercially profitable size between 27 and 30 years, subsequent studies showed interesting but contrasting results. The heartwood is formed earlier in sandalwood trees where the trees grown in a shallow soil or soil with high proportion of stones, together with a distinct annual dry period, and exposure to full sun. In a population, about 15-20% of *S. album* trees have formed heartwood naturally at age of 6th year. It is reported that a few *S. album* trees in a plantation have developed heartwood even at the age 4th year at Sholapuram, Tanjavur, Tamil Nadu, of which one of them was selected as a superior plus tree, a clone, SRC-I of which was released for cultivation. The clone had produced 8 kg of heartwood at age of 8 years old. It is predicted that heartwood development may begin at 7.5 years, and increase at a rate of approximately 2.5 kg per year thereafter in *S. album*. As 8 years old tree (Coleroon river banks, Tamil Nadu) produced 10kg of heartwood and a 20 years old tree (Araku Valley, Andhra Pradesh) had 40kg, it is presumed that an average a tree can produce at least 1kg of heartwood per year.

Rotation age of sandalwood varies with soil type. For example, the expected harvest period is 15–20 years in shallow soil or stony soil and 30-40 years in deep, fertile soil, high and evenly distributed rainfall and a shaded canopy condition. Under suitable growing conditions, heartwood formation starts before trees attaining 10 years old, and produce modest commercial quantities after 15–20 years. In forest conditions, heartwood initiation starts at around 10th year in *S. album* trees in India and to reach their full maturity size at age 30–60 years. In Australia, some private companies plan to harvest the *S. album* trees at age 15 years due to high maintenance cost and investors agreement.

Significant variation is found in heartwood content, colour and quality within and between

sandalwood trees, which are influenced by the growing environment1 and genotype. The heartwood development and its quality are most pronounced in the roots and base of the tree, and gradually decrease towards the trunk and branches. About 52% of heartwood is contained in the bottom third of the 16-year-old tree bole (0 -1.00 m), while 17% of the same is recorded in the butt portion. Quantity of heartwood production is not uniform in all trees in a plantation, for example 3 trees had 24.3–30.2 kg of heartwood, 6 trees had only 0.3–1.0 kg heartwood and another 3 trees had no heartwood.

About 22% of 16-year-old trees grown in Kununurra (Australia) had heartwood at all five sampling heights from ground level (0m) to 3 m stem height and heartwood presence decreased up the stem from 19.2 % at 0 m to 2.8% at 3 m height. The mean air-dry weight of the same age trees is 5.8kg heartwood tree−1 and 43.7 kg sapwood tree−1 at 12% moisture content. The heartwood content is highly variable between trees of a population. For example, mean heartwood weight of largest trees is 24–30 kg, while mean heartwood of other trees is 1kg/ tree. The total predicted heartwood yield of S. album plantation (260 trees/ha) at age 16-years is 1.5 tonne ha−1 and sapwood 11.41 t/ha. Mean heartwood yield of a 35 years old *S. album* tree (mean height =10.20 cm and gbh = 83 cm) in West Bengal, India is 214.51 kg and mean price of the same age tree in 2010 is Rs 1,90,000/- and a largest tree fetches highest price, Rs 4,35,000/- with heartwood yield of 415 kg. The earlier studies revealed that about 70%, 13% and 20% of sampled trees in the population failed to produce heartwood even at the age of 10-14 years old.

Although, sandalwood is grown in almost all states of India, the heartwood formation and oil content are not uniform with increasing tree age due to difference in environment and planting material. Sometimes, growing habit of sandalwood trees determine time of heartwood formation and its quality. Low level branching is not only restricting the development of the heartwood into the canopy of the sandalwood tree, but also it reduces the potential value of the tree due to presences of knots at time of harvest. However, pruning at an early age (years 2-3) can substantially increase clean bole height and commercial value of tree at harvest, by reducing the incidence of low branching.

As heartwood and rotation age of sandalwood differ environment, especially local climate and soil1, the heartwood data and prediction model developed of one location is not applicable to other areas for *S. austrocaledonicum* and *S. album* stem diameter of *S. album* trees at 30 cm above the ground is highly correlated with total heartwood and heartwood diameter of 16-year-old trees (r^2 = 0.87), which indicates that large-diameter trees had markedly higher heartwood weights, but no clear correlation was found between ground diameter and heartwood proportion (r = 0.28) in 21-year-old sandalwood plantation. Similarly, moderate correlation is developed between heartwood (area and diameter) and stem diameter of *S. album* natural populations grown in West Timor, Indonesia. There is a strong positive relationship between tree diameter and heartwood diameter have been reported. However, the stem diameter-heartwood relationship should be used as guide only for *S. album* trees within a narrow age range (15–17 years) with stem diameters between 10 cm and 35 cm at 30 cm above the ground due to heartwood formation being a function of age, small size of sample trees and genetics and environment would also presumably play a part in heartwood formation. However, sometimes, the yield of sandalwood is un-predictable since surviving trees contain as little as 10% of heartwood as against 50-60% in the good trees.

Fig 2(a) Core extraction in 10-year-old tree

Fig 2(b) Core of 10-year-old tree

Fig 2 c) & d) Wood cores of sandalwood grown in agroforestry system in Karnataka (age: 3-11-year)

Variations in oil yield and its quality

Sandalwood oil, regarded as the queen of essential oils and it is used in perfumes, cosmetics, flavours and religious functions. Significant variation was found in oil yield, colour and α and β santalol content of sandalwood oil collected from different locations. The yield and compositions of any essential oil are strongly influenced by species, the age of the tree, colour of heartwood, organ maturation, individual tree, location within the tree, the environmental cues and genotype. The brown colored heartwood of *S.album* contains lesser oil (1.4-2.5% than light coloured one (3.0-6.0%). However, it is yet to confirm that whether these variations could be attributed by tree age, genotype, environment or combinations with certainty.

The higher quantity of finest fragrance sandalwood with high oil content is obtained from the driest region particularly on red or stony ground than those grown in fertile tracts. It is found that sandalwood trees growing on rocky soil and in association with xerophytic conditions have higher proportion of oil-bearing heartwood than those growing on fertile soil enjoying good rainfall and nourished by vigorous hosts, are not comparable since rate of growth is exceedingly slow in the first case while growth increment is rapid in the second site. The oil content of heartwood of 6-year-old sandalwood ranges from 0.66% to 1.76% and its oil quality (santalols, 34.13% to 37.91%) failed to meet the ISO standard for *S. album* oil. The heartwood of young *S. album* trees (10years old; girth at breast height (gbh) <50cm; ht. <10m) contains 0.2 – 2.0 % oil and that from the mature trees (30-50 years old; gbh >100cm; ht. 20m) contain 2.8 – 6.2%, with mean oil content of *S. album* provenances (Bangalore, Thangli and Marayoor) in India is nearly constant, 4.0% at 80cm gbh onwards and increase marginally beyond 80cm gbh. Generally, younger trees (<8 years old) yielded lower oil and fragrance with santalol content than that from mature wood (14-17-year-old). The total oil yield in central and transition zone was fairly consistent at 3.1% to 3.6% dry wt. Transition zone contained an average of 36 mg/g dry wt. of oil while central heartwood yielded 30 mg/g wt. of oil and no difference was observed in either the yield or composition of oil from both zones. The mean range of α-santalol (44.4–50.1%) and β-santalol (18.3–20.4%) concentrations in oil of 16 year old trees at the five different heights from the ground are not significantly different, but good enough to meet the bench mark ISO standard of *S. album* (ISO 3518 2002E). Overall, the heartwood oil contained 46% α-santalol and 19.2% β-santalol, whereas the sapwood oil had containing 58.5 % α-santalol and 19.5 β-santalol37. Total oil yield derived from sandalwood trees vary from place to place, for instance, the expected oil yield of *S. album* trees is 240kg/ha, 800kg/ha in Australia and 400 kg /ha from natural forests in India. These differences may be partly due to the choice of host species, watering regime and tree density, age and growing environment.

The mean oil concentrations in the heartwood of 16-year-old trees at the five different bole heights varies from 6.2% at 0 m and 2.9% at 3.00 m stem height from the ground level with mean oil concentration of 5%, this figure is close to that (6–7%) obtained from mature natural trees growing in India, and greater than that previously recorded near the base of 14-y-old S. album trees growing at Kununurra (2.9–4.4%) and Carnarvon (1.9–2.9%). The estimated oil yield of 16-year-old trees ranged from 0 to 1.61 kg oil tree–1, with a mean of 280 g oil tree–1 and mean oil yield per ha is 73 kg oil ha–1, whereas the mean sapwood of the same age trees had 0.1% oil concentration.

In fact, *S. album* contains relatively high oil content (6-7%) compared with other sandalwood species, *S. yasi* (5%) and *S. austrocaledonicum* (3-5). Oil quality of *S. album* is also superior than other species with more than 70% of total santalol, which give the distinct aroma. The oil of 14-y-old S. album trees had 45 - 47%

α-santalol and 21–22% β-santalol. Although the oil content of 14-y-old Australian sandalwood is relatively low, it is still encouraging large scale plantations in Australia as its oil quality meets the ISO standards, ISO 3518 2002E. Similar variations in heartwood diameter and oil content have found in the 20-year old *S. album* trees due to interaction of genotype and environment. The oil content of 21-year-old sandal plantation in Hainan at 30 cm above ground was 4.36% and its quality is on par with the ISO standard, ISO3518:2002. Mean yield (%) of heartwood and oil of 8–26 years old *Santalum spicatum* trees (grown 400-600mm mean annual rainfall) increased significantly with sandalwood age. Even if, the α-santalol content is less age-related, but it was noted high in 26-year tree. Normally, both oil and α-santalol concentrations are relatively high in the butt, roots and 1st grade wood of mature trees (14-26 years old). Among sandalwood grades, 1st grade accounts for the 33–46% of the total weight of commercial wood and rest is 10–23% of the total. Based on the above-said results, it is suggested that sandalwood tree may need retained at least 25 years to get maximum quantity of high-grade heartwood and prime quality oil.

Although both Indian and Australian sandalwood oils contain similar chemical constituents, the Australian Sandalwood oil differ with low level of α-santalol and β-santalol and presence of E, E-farnesol and α-bisabolol. Qualitative co-occurrence alpha-santalol and β-santalol was found in sandalwood oil and both have a strong positive linear correlation (r=0.99) when peak area used. Sapwood contained almost no extractable oil and α- santalol occasionally present in oil. The extractable oil yield was compared to the proportion of heartwood in cores. Despite the general trend, many samples of even 15-year-old trees yielded very little fragrant heartwood. Therefore, there are several factors involved in formation and development of oils within heartwood undoubtedly contribute to these variations in this relationship and these in turn may be related to growing conditions, host plants and genotype. If the mean weight of heartwood per tree and oil concentration are known, yields and the potential value of other trees grown in similar environment can be estimated.

Conclusions

While natural sandalwood reserves are dwindling very fast in almost all sandalwood growing areas due to overexploitation and illegal harvesting, the area under commercial sandalwood cultivation is being increasing rapidly in all sandalwood growing countries. The plantation grown sandalwood would replace or supplement the wild supply of sandalwood in near future. As the quality of farmland grown sandalwood is inferior than that grown in wild, it is suggested to have the longer rotation, i.e., 20-30 years to improve yield and quality of sandalwood oil. Earlier reports say that about 13% - 70% of sampled trees in the population failed to produce heartwood even at the age of 10-14 years old. Sandalwood trees growing on rocky soil with xerophytic conditions have higher proportion of oil-bearing heartwood than those growing on fertile soil. The heartwood formation and oil quality of sandalwood depend upon edaphic, climatic factors and genetic makeup of sandalwood.

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- Super Heavy Duty Both Side Calibrating Machine
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- Single Head Calibrating Machine
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Sandalwood Resources in India: A Review on Conservation and Policy Issues

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Introduction

Santalum album, the Indian Sandalwood, produces highly aromatic oil and the price of which is skyrocketing in the global perfumery market. The oil has an important place in the indigenous system of medicine. Markets worldwide are currently facing a serious shortage of this increasingly expensive, high quality Indian sandalwood (*Santalum album*) – largely as a result of unsustainable harvesting of the species over a long period of time in its native environments of India. East Indian sandalwood, *S. album* is sought after by perfumery and allied industries for the supreme quality essential oil.

Conservation status of sandalwood species

Sandalwood is widely distributed in Southern parts of peninsular India. The value of sandalwood was realized as early as 1792 when Tipu Sultan the then ruler of Mysore declared it as a "Royal Tree". Due to this historical reason sandalwood has ever since remained under government control. It is defined as a "forest produce", although it does not have any special provisions under "Indian Forest Act". Sandalwood resource in India especially wild population is currently threatened mainly because of illicit felling, forest fire and grazing and to a certain extent spike disease coupled with heavy domestic and international demand with inadequate uniform regulation in the Southern states especially in Karnataka, Tamil Nadu, and Kerala. Smuggling of Sandalwood has created socio-economic and law and order problems in all Sandalwood producing states.

Recent policy initiatives of sandalwood

The legal hassles created by sandalwood trade regulation results from the fact that there is no comprehensive regulation applicable to the entire country. Hence, clandestine trade is flourishing and sandalwood population declining to the extent that it is on the verge of extinction. Sandalwood is included in the Red List of International Union for Conservation of Nature (IUCN) as vulnerable and sandalwood growing states of India have stated that it faces extinction. India realised the value of sandalwood trade and took positive steps to protect the natural population of sandalwood. Measures to sustain this valued bio resources, took prominence and flaws in policy which endangered the species were amended. Government of Karnataka promulgated an amendment to Karnataka Forest Act in 2001 to encourage private domestication of sandalwood as a means to conserve and enhance the status of this resource. The amendment gave landowners full legal right to trees on their land, made them eligible to receive full value on extraction and made amendments on the sale of Sandalwood through Forest Dept. & Govt. Departments. Tamil Nadu followed path with the Tamil Nadu Forest (Amendment) Act in 2002, the landowners were given the right to trees (Dhanya *et al*, 2010). Subsequently, Kerala Forest (Amendment) Act in 2010 regulated cutting and possession of sandalwood. India thus remains competitive in its attempt to grow more sandalwood both in-situ & ex-situ by inter plantation methods to bring back its lost glory. It is hoped that this initiative will meet both domestic and international market demands.

Production and utilization of sandalwood

Ecologically sandalwood has adapted to various agro climatic and soil conditions for in-situ regeneration. Heartwood yield again depends upon locality and age of tree. There has been a significant reduction in production of sandalwood during the past years. Production of heartwood during 1930s through 1950s was around 4000 tons a year,

which decreased to a meagre 500 tons of wood a year or even less. It is estimated that the global demand for Indian sandalwood is around 5000 – 6000 tonnes/ annum and for oil it is around 100 – 120 tonnes/annum (Dhanya *et al*, 2010).

Variations of sandalwood oil contents

The valuable fragrant oil of the sandalwood tree is concentrated in its heartwood. Compared to other sandalwood species growing elsewhere, Indian sandalwood oil tops the list in the world for its superior oil content (Table 1). *S. album* or Indian Sandalwood has the highest oil content of Sandalwood species (6-7% oil content) compared to other commercially exploited species elsewhere in the world including *S. spicatum* (2%) and *S. lanceolatum* (1%). This explains the reason Indian Sandalwood is the most highly demanded of the Sandalwood species. Several non-Santalum species such as *Osyris tenuifolia, O. laceolata* from East Africa and *Amyris balsamifera* L. from West Indies are also used as sources of "Sandalwood" type. However, the wood has less fragrance and the distilled oil are different when compared to true sandalwood.

Table 1. Comparison of oil content among different Santalum species

Species	Origin	Oil content (%)	Santalol content
S. album	India, Indonesia	6–7	α-santalol: 41-55% β-santalol: 16-24%
S. yasi	Fiji	5	α-santalol: 37-39% β-santalol: 26-28%
S. austrocaledonicum	Vanuatu, New Caledonia	3–5	α-santalol: 48-49% β-santalol: 20-22%
S. spicatum	Western Australia	2	α-santalol: 15-25% β-santalol: 5-20%

Source: AAG (2006)

The market value of a given volume of heartwood will depend primarily on the concentration and quality of its oil that is, the quality of sandalwood in the marketplace is typically determined by the relative proportions of α- and β-santalol as recognised in the international standard for Indian sandalwood (*Santalum album*) oil (ISO 3518:2002). Heartwood oil concentration and quality in sandalwood vary between species and can also be influenced by genetic, environmental and agro climatic factors. However, one of the most important concerns among the sandalwood growers is about quantity and quality of oil that can be obtained from a harvested tree when compared to the oil obtained from wild sources of Indian origin.

In general, older sandalwood trees have more heartwood and produce higher quality of oil since santalol contents are higher. High-quality sandalwood oil comes from trees that are at least 30 years old. Trees that grow in shallow soil or in soil with a high level of stone inclusions, with distinct annual dry period and exposure to full sun develop heartwood more rapidly and could be harvested after at least 15-20 years.

Measures to encourage sandalwood cultivation in Karnataka

To encourage cultivation in large scale in private and farmers lands the Government of Karnataka took positive step by introducing many incentive programs like (1) Krishi Aranya Protsaha Yojane from 2011 in which each individual is paid a Rs of 125/-per plant over a period of 3 years in 3 instalments, first year Rs 35/-, second year on surviving plant Rs.40/- and third year on surviving plant Rs.50/-. (2) Sub-mission on Agroforestry from 2016 in which each individual is paid a Rs of 35/- per plant over a period of 4years in 4 instalments, first year Rs14/-,second year Rs 7/-, third year Rs 7/- & fourth year Rs7/-. (3) MGNREGA in which a land holder with a NEREGA job card will be paid as per the costs fixed by Rural Development and Panchayat Raj (RDPR) department annually for each plant planted. (4) Raising of Seedling for Public Distribution scheme (RSPD), in which any farmer or

individual is supplied with subsidised poly bag seedlings with nominal rates Rs. 3/- from forest nurseries.

Apart from the above incentive programs, liberalization of existing policies & regulations also been thought to encourage individual/ farmers to grow more and more sandalwood trees. A new Karnataka Sandalwood Policy 2020 has been drafted & placed before government for notification with many liberalisations including free marketing. In this context National Rainfed Area Authorities, Food and Agricultural Organization of United Nations (FAO-NRAA) also making efforts to bring the sandal wood marketing through the countries prestigious e-NAM platform with specified tradable parameters to encourage cultivators to trade directly. Efforts also being in place during current year to establish a Sandalwood Farmer Producer Organization (FPO) in Kolar District of Karnataka through NABARD which is first of its kind in the country.

The policy of Government of Karnataka to abolish control over sandalwood cultivation has paved the way for community and private entrepreneurs to cultivate sandalwood which is in high demand. Karnataka Forest (Amendment) Bill, 2001 allows cultivation of sandalwood trees in private lands. This comes as a major policy change as far as sandalwood cultivation is concerned. A uniform policy for the entire Country on conservation strategies and transport policies of Sandalwood may help in improving overall status of the precious wealth of India. Raising large scale plantations in natural Sandalwood bearing areas will add to the resource building of this valuable tree species.

Perspectives in popularizing Sandalwood

Highest priorities for Indian Sandal wood research has been evincing globally in the field of conservation, understanding plant physiology and genetics to maximize oil production and minimize maturation period, processing, markets mainly focusing to the industrial needs. Considering the large-scale demand for quality planting material for domestication, there is an urgent need for establishing germplasm banks, clonal seed orchards and sandal nurseries to ensure quality planting material to the aspirant farmers/sandalwood growers.

Certification system and product standardisation are critical elements of supplier–buyer chains, particularly in high-value European sandalwood markets.

Certification system and product standardisation are critical elements of supplier–buyer chains, particularly in high-value European sandalwood markets. Development of certification programs and product standards should therefore be a priority for Indian sandalwood industry and could be championed and coordinated by prime research institutions like Institute of Wood Science and Technology, Bengaluru with the support Ministry of Environment, Forest and Climate Change, Government of India. Institutional efforts for saving this valuable resource from depletion should be definitely entailed to strengthen traditional conservation measures backed by a multitude of strategies by providing the requisite incentives to the farmers/sandalwood growers for its conservation and development.

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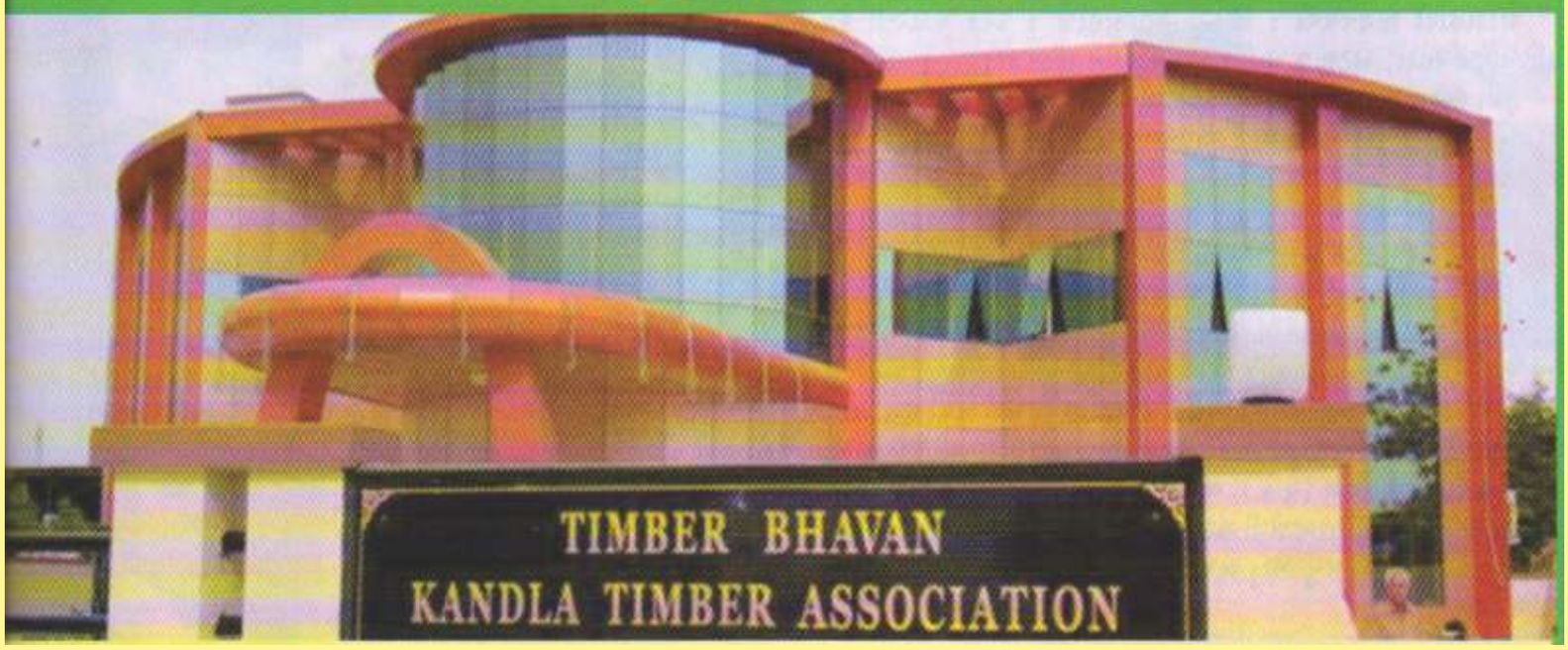

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Production and Trade of Commercial Sandalwoods – An Overview

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Introduction

The East Indian sandal wood (*Santalum album* L.) is recognised as the most valuable wood in the world due to its high heartwood, quality of oil and high demand in international markets. . Many state governments have liberalized the policy to promote sandalwood cultivation due to dwindling of mature sandalwood trees in forests. As a result of recent policy changes in respect of liberalization on sandalwood cultivation in India, many progressive farmers and tree growers have started cultivating sandalwood in large scale since 2001. Although global sandalwood market has been strong for many centuries and its price has gone up manyfold, prospective farmers and sandalwood growers are sceptical about future market trends with respect to its price. Considering the ambiguities among farmers with respect to trading of sandalwood, in this paper, an attempt is made to review production and market outlook of sandalwood.

Commercial sandalwood species

There are 17 species, 14 varieties, and one extinct species reported under the genus, "*Santalum*". The sandalwood species are generally distributed in tropical South Eastern region of Southern hemisphere between 30°N and 40°S. Of these, *S. album, S. austrocaledonicum, S. insulare, S. lanceolatum, S. macgregorii, S. spicatum* and *S. yasi* are commercially important species. Among all, *S. album* is highly demanded and priced one in the international market due to its high-quality oil and used as a primum standards to compare that of other sandalwood oils. The information on distribution and trade status of commercial sandalwood species is given in the Table 1.

Table 1 Commercial sandalwood species in international trade

Sl No	Species	Distribution	Trade status in the market
1	*Santalum album* (East Indian sandalwood)	Indonesia, India, Sri Lanka and Timor-Leste	Most highly regarded species. Oil used for International Standardization (ISO – 3518:2002)
2	*Santalum spicatum* (West Australian sandalwood)	South-western Australia	One of the most traded sandalwoods. Oil (ISO 22769:2009) has relatively low santalols, and high E, E farnesol content (allergen in cosmetics).
3	*Santalum austrocaledonicum*	New Caledonia and Vanuatu	Oil quality varies with some populations. High-quality oils is similar to *S.album*
4	*Santalum yasi*	Fiji, Niue and Tonga	Produces excellent quality heartwood and high-quality oil (α-santalols:34-40% and β-santalols: 29–31%) Oil quality is slightly lower than *S.album*
5	*Santalum paniculatum*	Hawaii	Oil quality is satisfactory and high proportions of α-santalols (up to 40%) and β-santalols (up to 16%)
6	*Santalum macgregorii*	Papua New Guinea	Poor quality oil
7	*Santalum insulare*	French Polynesia and the Cook Islands	Overall oil quality is satisfactory

Despite *S. album* and *S. yasi* are distributed in the large geographic disjunction, they are closely related and presumed to have developed from a common ancestor in northern Australia about three million years ago. Further, it is reported that both closely related species (*S. album and S. yasi*) as well as quite distantly related species (*S. album* and *S. austrocaledonicum*) species freely hybridize readily each other when they grow together.

Production of sandalwood

There is a paradigm shift underway in all traditional sandalwood growing areas, such that domestic sandalwood plantations will replace sandalwood resources in the natural habitats due to commercial extinction of most widely traded sandalwood species in its native range with exception of *S. spicatum* (Western Australia) and *S. austrocaledonicum* (New Caledonia). Supply of sandalwood from commercial plantations of *S. album*, *S. austrocaledonicum*, *S. spicatum* and *S. yasi* may overtake and supplement the supply of sandalwood from natural habitat in the next 10-15 years. However, the production and prospect of sandalwood trade differ from country to country due to prevailing socio-economic and political conditions (Table 5).

East Indian sandalwood

India

Among commercial sandal woods, *S. album* is regarded as most valuable one since ancient times due to its inherent quality of high α-and β-santalol content in the oil. Currently, *S. album* account for about 95% of total global production. However, the supply of *S. album* has declined over the past 10-15 years, reportedly due to illegal harvesting and the prevalence of spike disease in India. Tamil Nadu, one of the main producer states in India, was produced about 2000 MT of heartwood per year during the early 1980s and the auctioned heartwood has declined to 1400 MT in 2003 and further to 300 MT in 2013 due to dwindling of mature sandal trees in the natural habitat. India currently produces about 400 MT of sandalwood annually supply from India remains variable, even though supply fell to just 250 tonnes of wood a year in 2016 from almost 4,000 tonnes a year in 1970 (www.bloomberg.com). According to Thomson (2020), sustainable harvest from wild sandalwood stands in Tamil Nadu, Karnataka and Kerala is likely to be modest (e.g., 2000 MT of heartwood per year, but more likely only 1000 MT).

8	*Santalum lanceolatum*	Northern Australia	Oil is inferior quality
9	*Santalum leptocladum*	Southerly subpopulation (latitudes above 20°S) of S. lanceolatum	-
10	*Osyris lanceolata*	Southern, eastern and northern Africa and also in southern Europe and in Asia, from China to India, and on Socotra, Yemen	Inferior quality heartwood with low santalols (<10%)

The monopoly of Karnataka and Tamil Nadu over sandalwood may end in near future, as other states are keen in taking up cultivation in large scale. Already, Government of Karnataka, Tamil Nadu, Maharashtra and Goa state have relaxed the centuries-old restrictions on sandalwood cultivation and other states are in line for promoting sandal wood cultivation in farm lands. Due to high market price and the pro-sandalwood policy, the farmers are keen to cultivate sandalwood in large scale in farmlands along with food crops, horticultural crops and timber species as sandalwood-based agroforestry. Many private agencies, especially real estate developers and progressive farmers started in raising sandalwood plantations in large scale in India including non-traditional sandalwood areas, viz., Andhra Pradesh, Telangana, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan.

Currently, the area under sandalwood in farm lands has grown dramatically to an estimated 30,000 ha in 2019, with the majority of the plantings in Gujarat (20,000ha) and Karnataka (12,000ha) States. The area under sandalwood cultivation is growing at rate of 600 ha per year (Pallavi, 2015). The estimated yield is 8 MT heartwood per ha on a 25–30-year rotation. Of late many real estate or property developers are also showing keen interest in establishment of large-scale sandal plantations (100 acres) in A.P., and Telangana as it enhances value of the properties. India would once again become a major producer of *S. album* in the world, if plantations are established with superior genotypes and improved silviculture and re-emergence of spike disease controlled.

Indonesia

In Indonesia, sandalwood reserves in natural forest areas have declined significantly due to lack of management and over exploitation. Further, interest in establishing new commercial sandalwood plantations is low due to the perceived long rotation period and lack of policy initiatives by the government to promote plantations. Timor-Leste exported about 30 tons of sandalwood oil annually during the 1960s, which reduced to 7 tons in 1994 due to over exploitation of *S. album* in the past. It has been reported that there are difficulties in establishing S. album plantations, but the reasons for this have not been clearly identified.

China

Although China has started establishing plantations very recently, it has been made significant progress over the past 5–6 years and about 60,000 seedlings are being planted annually. These planting will greatly increase the supply of Indian sandalwood to meet the growing domestic demand to some extent in China.

Australian sandalwood

Now, Australia is the largest producer and exporter of S. album wood and oil in the world. Large scale plantations have been raised in Northern Australia. Quintis, the largest Indian sandalwood (*S. album*) Company in the world, currently it manages an area of about 12,564 ha (with about 5.5 million S. album trees) in northern Australia. The other major S. album producer in Australia, are Santanol Pty Ltd., and TFS. The TFS plans to increase output by 30-fold to 10,000 tons of timber a year from its 30,000 acres of plantations in Western Australia and completed its first commercial harvest in 2014 according to its website. The total Indian sandalwood area has increased from 50 ha in 1999 to 7,000 ha in 2012.

Australia is also a major producer of low quality sandalwoods such as *S. spicatum* and *S. lanceolatum*. The Forests Products Commission, Australia has harvested about 2,150 MT each year and about 1,500 MT of powdered sandalwood is exported to agarbatti industry in Asia and Middle East. Besides this, about 500 MT sandalwood exported as pre-grind, and unprocessed for carving and furniture. In 2008, about 12,000 ha of *S. spicatum* had been planted and by 2014 this had increased to 20,000 ha. The commercial rotation period for *S. spicatum* in arid zones in likely to be 30-35 years (cf. 15-17 years for irrigated *S. album*) with a yield of 3-4 MT of heartwood per ha. The guesstimated current annual production of *S. lanceolatum* from the wild is 150-250 MT of heartwood. However, the surge of illegal harvesting and dumping of low-grade *S. spicatum* powders into the market are major challenges for sustainable production of wild *S. spicatum*. The estimated supply of marketable oil from recently established plantations is expected to rise substantially from 2019 when harvesting begins. Although, the santalol content in *S. spicatum* is lower than that in *S. album,* there is still strong demand for its oil. Further, the oil quality of heartwood derived from its future plantations is likely to be improved with help of improved planting materials.

S. austrocaledonicum, *S. macgregorii* (listed on the IUCN Red as endangered), *S. insulare, S. yasi, S. ellipticum, S. freycinetianum, S. haleakalae* and *S. paniculatum* are commercial sandalwood species in the Pacific region. Of these, *S. yasi* and *S. austrocaledonicum* produce high-quality sandalwood

products like *S. album* from India and Indonesia. The quality of Pacific island's sandalwood oil generally lies somewhere between Indian and Australian sandalwood. While many sandalwood species in the Pacific region are approaching commercial extinction in their native habitats, both small and larger scale sandalwood plantations are being established in many parts of the Pacific region, which will increasingly substitute the dwindling supplies from wild sources.

African sandalwood

Osyris spp., especially *O.lanceolata,* belongs to same familyas that of *S. album* i.e., *Santalaceae*. It is a multi-stemmed African tree that produces a heartwood oil with similar fragrant properties to *Santalum* species. African sandalwood is harvested from natural populations of *O. lanceolata* in Chad, Sudan, Ethiopia, Uganda, Kenya and Tanzania and much of the wood is sold in the international market and subsequently mixed with and sold as Indian sandalwood. The average santalol content is typically much lower than that of *S. album*. As result of exploitative harvesting of this species, its wild reserves have declined in some regions and approaching disappearance in some areas. The adulteration of Indian sandalwood products with imported African sandalwood has partly eroded market confidence in sandalwood products originating from India. African sandalwood is, however, expected to remain part of the global resource for the next 5-10 years.

Trade of sandalwood and its oil

Although Indian sandalwood is being interwoven closely with the Indian culture and traditions for more than 3000 years, its dominance on the international sandalwood trade is waning during the recent past due to various reasons. On the other hand, other countries, especially Australia is emerging as major player in sandalwood trade in the world. However, still, there is a wide gap between demand and supply for Indian sandalwood, which offers great opportunities for the countries to dominate the trade by upscaling sandalwood cultivation using superior genotypes and silviculture techniques.

Oil market

Among all sandalwoods, the east Indian sandalwood has highest average oil content, and it is used as bench mark to grade other sandalwood oils. It is still retaining strong demand and reputation in the international market due to its high santalol content and price (Table 2). As decline of Indian sandalwood supply in the market, Australian sandalwood oil is accepted as an important product in the fragrance market, and a large volume of it is purchased by perfume manufacturers at a discounted price, despite its low quality. It indicates the very diverse nature of the international sandalwood market from both a product development and market segmentation perspective.

Table 2 Oil content in commercial sandalwood species

Sl No	Species	Origin	Oil content (%)	Price (US$ per Kg)
1	*S. album*	India, Indonesia	6-7	74
2	*S. yasi*	Fiji	5	45
3	*S. austrocaledonicum*	Vanuatu, New Caledonia	3–5	38
4	*S. macgregorii* (Brophy et al., 2009) 25	Papua New Guinea	0.5-2.5	
5	*S. spicatum*	Western Australia	2	10
6	*S. lanceolatum* (AAG, 2006)	Queensland (Barbour, 2020)	1	05

Carving logs

The carving or ornamental logs attract highest prices in the market as they are quite rare and very little supply due to overexploitation and harvesting of immature trees. In this case too, the East Indian sandalwood is fetching the highest price in the market (US$74/kg) due to its premium quality. The value of the *S. yasi* carving log is about 60% of *S. album* (Table 3). While modest volumes of *S. macgregorii* are traded internationally, most enters through unofficial channels, and it is difficult to track its price. Further, its price is on par with that of *S. austrocaledonicum* since its oil quality relatively good.

Table 3 Price for sandalwood products from different sandalwood species

Product	US$/kg) in 2008-09				
	S. album	*S. yasi*	*S. spicatum*	*S. lanceolatum*	*S. macgregorii*
Carving log	74	44	13	6	NA
Oil	1250	1050	700	-	NA
Pre-grind heartwood	40-45	30	10	3	NA

– = not applicable; NA = not available

Pre-grind heartwood

Pre-grind heartwood is used for oil extraction and it is priced on a similar basis as that of carving logs and oil, reflecting both the santalol levels and the yield potentials of each species. The balance of the remaining sandalwood logs goes to the agarbatti industry and other products for burning. This part of the industry is highly price sensitive (elastic demand), and the high level of santalol powder get higher price and accounts major share of the market. The price range of agarbatti powder is US$18-1.2/kg. The presence of substitutions in the agarbatti market put pressure on price rise of pure sandalwood products. On 15th March, 2021, the Karnataka Forest Department (2021) has notified the revised price of 18 classes of sandalwood logs and current price of 1st class sandalwood (Villayetbudh, Billet -I) is increased from Rs.10,285 to Rs.12,200/kg (18.6%) from 2019 to 2020 (Table 4). As there is huge variations exist in both oil content and its quality within species, it offers great opportunity to improve the value of sandalwood resource through use of high oil quality producing superior genotypes.

Gaps in supply and demand

Current world market demand for sandalwood sourced from a variety of sandalwood species and aggregate demand is thought to be around 5,000 - 6,000 tonnes per year. While widening the gap between supply and demand of sandalwood over time, the price of its products also increases simultaneously. Due to lack of transparency in the production and marketing of Indian sandalwood, it is difficult to predict the supply and price trend. The problem in determining price trend is also complicated by the extensive trade of illegal wood, as this harvest is not reported. Despite the decline of Indian sandalwood supply, still the demand is relatively constant, and has pushed its price up significantly over the past few years. Legally sourced Indian sandalwood currently trades at between a $ 30,000 and $ 85,000 per tonne, with sapwood prices ranging from $ 1,000 to $ 2,500 per tonne. Sandalwood sells for as little as $13 per kilogram in various Asian black markets, but sells from more than $130 a kilogram in mainland China. During the period between 2001 and 2007, the price of Indian sandalwood and its oil has been increased 17-fold. The price growth for Indian sandalwood is considered to be unsustainable at its current levels, increases at rate of about 23% compounded rate over 15 years. The entry of high-quality synthetics into the market may also reduce the potential for further increase of sandalwood oil price. Over the past 10 years, the continuous price increase of Australian sandalwood indicates an unsatisfied demand for the commodity worldwide. Despite market potential and demand for Australian sandalwood, it still does not attract the premium price of Indian sandalwood. Heartwood prices for Australian sandalwood range between AU$3,000 and $16,500 per tonne. Due to

overexploitation and lack of protection for the sandalwood resource in many countries, both India and Australia are the dominant sandalwood suppliers in the global markets.

Table 4 Current price of Indian sandalwood logs in India

Sl No	Name of Sandalwood class	Description of class	Current Rate/kg (Rs.) (March 2021)
A	Heartwood		
1	Vilayetbudh (Billets- I)	Sound billets weighing not less than 9kg and not exceeding 112 pieces per tonne	12200.00
2	Chinnabudh (Billets-II)	slightly inferior billets weighing not less than 4.5 kg and not exceeding 224 pieces per tonne	10900.00
3	Panjam (Billets- III)	Billets having small knots, cracks and hollows weighing not less than 2.2 kg and not exceeding 448 pieces per tonne	10000.00
4	Gotla	Includes short and sound pieces. There are no limits of weights and number of pieces per tonne	7000.00
5	Ghatabadla	Billets with knots, cracks and small hollows weighing not less than 4.5 kg and not exceeding 250 pieces per tonne	12700.00
6	Bagardad	Consists of solid pieces without limit as regards dimensions, weight or number	10900.00
7	Roots -I	Pieces weighing not less than 6.75 kg and not exceeding 150 pieces per tonne	9700.00
8	Roots-II	Pieces weighing not less than 2.25kg and not exceeding 448 pieces per tonne	8300.00
9	Roots -III	Small and side roots below 2.25 kg in weight.	8500.00
10	Jajpokal -I	Hollow pieces weighing not less than 3.10 kg and not exceeding 320 pieces per tonne	13700.00
11	Jajpokal -II	Hollow pieces weighing not less than 1.30 kg per tonne	10600.00
12	Ainbagar	Solid, cracked and hollow pieces weighing not less than 450g	8900.00
13	Cheriya/China Sali or Large Chilta	Consists of pieces and chips of heartwood weighing not less than 2.25 g	5500.00
14	Ain Chilta	Consists of pieces of heartwood	5400.00
15	Hatri Chilta	Consists of heartwood and chips obtained from plaining billets with Hatri	2850.00
B	**Mixed wood**		
16	Milvachilta	Consists of heartwood and chips having fair proportions of heartwood and sapwood	3400.00
17	Basola buini	Consists of small heartwood and sapwood chips	3600.00
18	Saw dust	Sawn powder obtained while sawing the sandalwood	810.00
C	**Sapwood**		
19	White chips	Consist of chips of sapwood only	105.00
20	Bark and Waste		25.00

(Source: KFD, 2021)

Prospects of sandalwood market

At present, the sandalwood has become a boom market. The price of one-kilogram Indian sandalwood oil is about $3,000, or about five times as much as silver in 2017. Price is rising by at least 20 to 25% a year. Although sandalwood products are consumed globally, Asia is the largest consumer, with China alone accounting for half of expected global demand growth. The demand for sandalwood is expected to increase fivefold (20,000 tonnes per year) by 2025. Factors influencing demand in eastern markets include increasing prosperity, a growing market and consumer preference for natural products, and significant growth in demand from China. The major commercial end uses of sandalwood in western markets are used as a key component in fine fragrances, toiletries, aromatherapy and incense, and as an insect repellent. Factors influencing demand in Western markets include growing consumer preference for natural ingredients; manufacturer preference for sustainable, ethically produced ingredients; and a growing global beauty industry. It is reported that future value of sandalwood plantation from Australia range from 20,000 to 41,000 Australian dollar per tonne for Indian sandalwood and 3,000 to 16,500 Australian dollar per tonne for Australian sandalwood, *S. spicatum.*

Although it is difficult to quantify the actual size of the global market for sandalwood due to a lack of availability of trade data and illegal trade (likely around 33% of the total market), the most reasonable estimate of the annual global sandalwood market in recent times is 6320 Air Dry Tonnes Heartwood (ADTH) during 2011–2012. Price of sandalwood rose rapidly in the 2000 and the price of *S. album* sandalwood in India increased at a compounded rate of 15.1% between 1992 and 2014 and the wholesale price for high-quality East Indian sandalwood oil reached more than or equal to USD 3000 kg−1 (for perfumes and new pharmaceutical uses in the United States) in 2016.

The global sandalwood oil market is predicted to double in value over the next five years, to USD 197 million by the end of 2026. The price elasticity for sandalwood products can be counterbalanced and buffered by both product diversification and regional market diversification with strong economies, such as China, Europe, India, the Middle East and North America. There are growing middle classes with high disposable incomes in China and India, nations with traditional cultural associations with sandalwood, which will maintain upward pressure on price even as supply increases or if individual products or markets face a downturn. Nevertheless, sandalwood is a luxury item, the price of and demand for which would inevitably decline to some extent in a major global economic downturn. It is likely that a range of new uses will be developed and traditional uses will be re-established when more reliable and consistent supplies of high-quality sandalwood oil are generated through sustainably managed plantations. Due to presence of a substantial unmet demand for high- and mid-range perfumes, body-care products, aromatherapy, traditional eastern medicines, new pharmaceutical products, and top-of-the-range solid furniture and associated increased demand in China, India and other Asian economies will help underpin the price of sandalwood oil for the foreseeable future.

On the other hand, the inferior oil quality species such as *S. spicatum*, may struggle to maintain their market share in the future, with lower grades of S. album products. Synthetic santalols are expensive to produce and in lesser demand in the perfume sector, which may help the sandalwood to retain its market. While sandalwood production from wild stands will likely be at low levels (≤100 tonnes per annum−1) in the future, the supply of plantation sandalwood from the South Pacific Islands (Thomson, 2020), Australia and India will gradually increase, as a result of establishment of new sandalwood plantations by smallholders, farmers and private companies. Nevertheless, the biosynthesis of sandalwood oil and other innovations may also affect sandalwood oil production, such as the production of larger amounts of higher-quality heartwood at a younger age through improved genetics and silviculture, including new heartwood stimulation technologies.

Future challenges in sandalwood supply

As result of declining of sandalwood supply in the market, some firms like perfume companies would prefer to go for synthetic ingredients over sandalwood

extracts. The supply, demand and price of substitute products are also important factors in influencing sandalwood market and its products in the future. The low-cost synthetic sandalwood oil products used in budget perfumes and cosmetics likely to limit future price increases for natural products. Further, the shortage of sandalwood has also resulted in adulteration of sandalwood oil with poorer quality blended oils. This has caused a negative impact on buyer confidence and industry credibility. Therefore, a standard certification system is needed to improve buyer's confidence and market credibility.

On the other hand, Australia is already a major contributor to the international sandalwood market, harvesting approximately 2,300 tonnes of Australian sandalwood (S. spicatum). The declining production of premium quality sandalwood in India, and the eventual harvest of Indian and Australian sandalwood from Australian plantations would make Australia the largest global producer of sandalwood in near future. It is expected that about 8,800 tonnes of Indian sandalwood heartwood harvested from Australian plantations would reach annually by 2021, while the harvest of Australian sandalwood heartwood is expected to reach 3,195 tonnes per year. Despite the current strong demand for sandalwood in world markets and supply shortfalls, it is uncertain that how the international market will react when significant volumes of product entered the market from Australian and later Chinese plantations. Thus, increase in global supplies of sandalwood will affect the pricing and marketing of sandalwood in the market. Generally, it is expected that an increased supply will place a downward pressure on prices. For example, as the Indonesian sandalwood oil, at rate of less than US $ 10 of the East Indian sandalwood oil, entered into international market in 1980s and captured nearly 40% of the global market by supplying 5 tonnes of oil per month. As results of this, the export of sandalwood oil from India was declined significantly during that time. At present, the largest threat to sandalwood is not smuggling or extinction of wild reserves, but rather biotech companies taking a lot of efforts to produce santalol rich sandalwood oil by infusing DNA of sandalwood trees into yeast cultures in days (in the lab) instead of years.

Despite the challenges, the Indian sandalwood producers have several advantages, owing to premium quality of Indian sandalwood; there is a great demand in international market. Moreover, the Indian government is promoting sandalwood based farming throughout the country through various schemes and liberalization of restrictions on sandalwood cultivation.

Conclusion

Area under commercial sandalwood plantations is increasing rapidly in all sandal growing countries. The plantation grown sandalwood would replace or supplement the wild supply of sandalwood in near future. Australia has become largest producer and supplier of sandalwood in the world. The oversupply and synthetic substitutions of sandalwood oil may place downward pressure on price of sandalwood and oil. However, the price elasticity of sandalwood products can be counterbalanced and buffered by both product diversification and regional market diversification in the future. Further, it is expected that the East Indian sandalwood market would remain strong for at least the next ten years due to its premium oil quality and expansion of sandalwood area in India due to pro-sandalwood policy changes.

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Diversity Concerns on Scented wood under Intensive Cultivation

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Owing to the huge benefits from cultivation of sandalwood, it is gaining more and more popularity among the farmers. The benefits of Sandalwood cultivation are stupendous. After the age of seven to eight years, the heartwood of a sandalwood tree grows by 1 kg every year, and its market price range between Rs 3,000 and Rs 6,000 per kg. It is the only wood in the world to be sold by weight. According to an estimation of Institute of Wood Science and Technology (IWST), Bangalore, the cost of sandalwood cultivation per hectare is about Rs 30 lakh for the entire crop cycle, but the returns vary from Rs 1.2 crore to Rs 1.5 crore. Institute recommends a 15-year harvest cycle of sandalwood for maximum benefit (Mishra et al., 2018).

The scientific and technological advancement in the cultivation and protection of sandalwood made the people invest in sandalwood cultivation in many parts of India. A large number of private plantations of sandalwood along with government plantations started all over different states even in non-conventional areas (Fig.1) resulting in huge demand for the sandalwood seedlings.

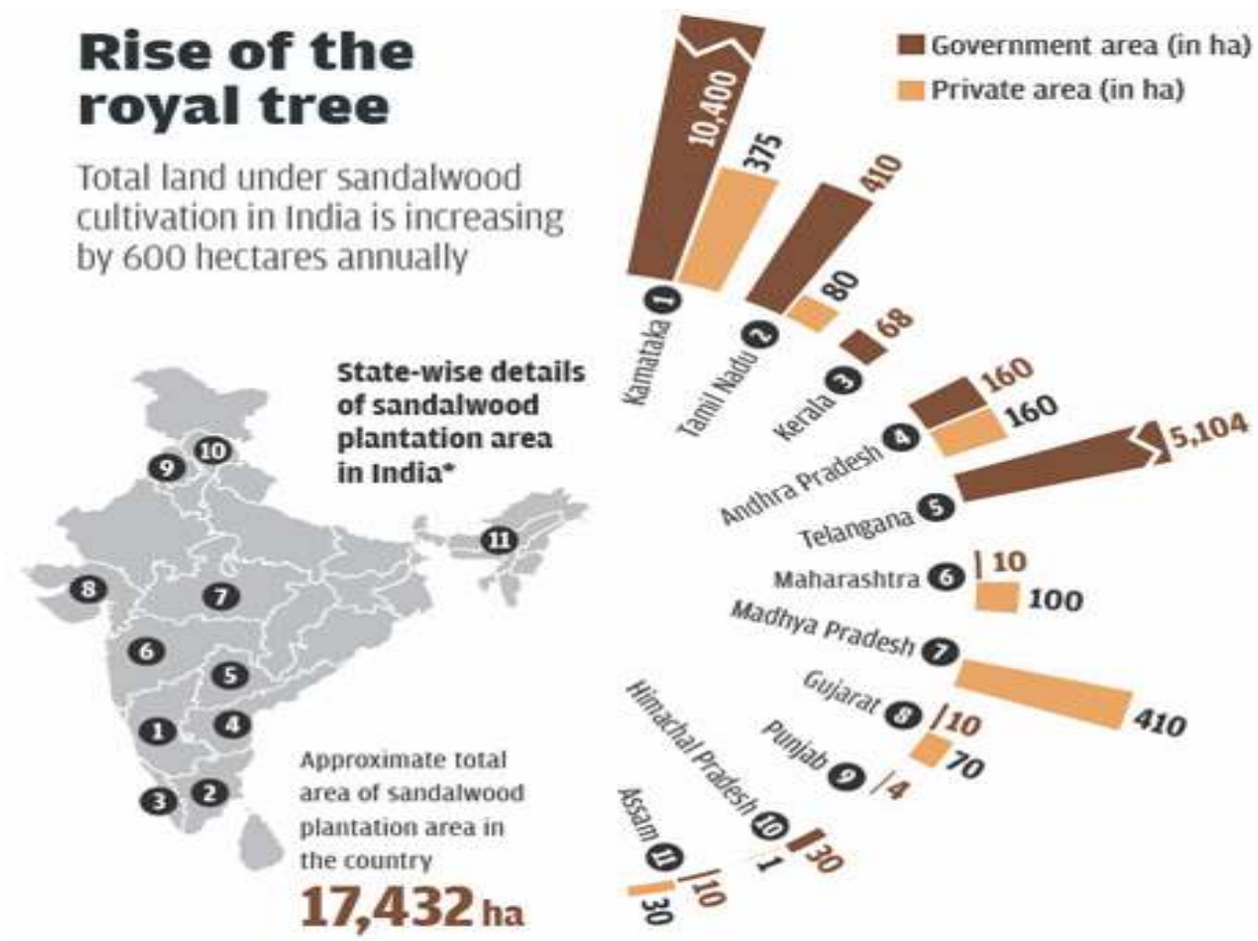

Fig.1 State wise sandalwood plantations in India (Source:Pallavi, 2015)

All these plantations are being established by quality planting materials through seed origin and sandalwood is being cultivated with intensive silvicultural practices on farmlands. However, a large number of these plantations are raised from a few seed sources due to the non-availability of quality seed sources in time for their establishment. Among these, seedlings from the Maryaoor Division of Kerala have piqued the interest of farmers owing to their high yield. Maryaoor now has the highest number of sandalwood trees after the Spike disease destroyed the best trees of Mysore and Tamil Nadu. Superior sandalwood trees or plus trees have good heartwood and high content of oil besides an almost uniform girth. There is a huge demand for the seeds and seedlings of Maryoor Division and most of the plantations in South India have been established using these seeds. This has to be taken into account that Provenance variation in growth has been maintained to conserve a species from its extinction.

We have witnessed the mass destruction of sandalwood plantations from spike disease before and the lessons learned should not be forgotten. The major factors influencing crop failure are regarded as (a) Crop uniformity for the trait susceptible to an environmental hazard and (b) extent of cultivation of the crop (Monoculture). The greater the uniformity for a susceptible trait and the more extensive the area of cultivation, the greater the risk of disaster. In the case of pest or pathogen attack, two additional factors enhance the risks: (1) a highly dispersible disease or insect agent, and (2) favourable environmental conditions for the multiplication of the agent. One of the rationales for crop germplasm conservation is that plant genes have utilitarian value. When they are effectively used, they can decrease crop susceptibility to natural predators, pathogens, and stresses. Further, a single seed source occupying a large area of plantations may pose a higher risk of pest and disease in future (Anon, 1993).

Hence, there needs to be a scientific intervention to avoid the future repercussions of the aforesaid problem. The tragic disappearance of Hawaiian sandalwood is particularly relevant to the discussion of conservation of economically important tree species, where there is often scant regulation, little consumer awareness, complex environmental, social, and economic pressures, and high demand with finite supply (Susan, 2015). Diversifying the seed sources of sandalwood plantations need to be addressed urgently. Researchers should plan for the best tree improvement program in such a way that to identify the best trees from the best populations which can benefit the farmers economically and simultaneously, maintaining the broad genetic base so that breeding for the diseases and pest resistance can go on. The precautions are better than the cure. Superior germplasm sources exhibiting disease resistance, rapid growth, good bole form, early heartwood formation and desirable heartwood oil composition need to be developed for S. album in India. The establishment of Progeny trials, seed stands and clonal seed orchards can pave the way towards safe and successful plantation development of Sandalwood in India.

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Potential for growing Sandalwood (*Santalum album*) tree in the salt affected soils

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Introduction

Modern agriculture covers a range of risks related to production, prices and markets, financial, institutional and social aspects that often are directly or indirectly associated with weather impacts. The studies have shown that by incorporating perennial (tree) component in cropping patterns the projected yield losses under climate change scenarios can be halved. Moreover, the farmers' income from agriculture has remained stagnated due to increasing input cost in one hand and decreasing productivity and low price of output on the other hand. In response so-called 'profitable agriculture' solutions are intended to grow highly profitable/valuable crops by the farmers in their farmland to address the issue of farm distress. One example of such valuable crops is sandalwood (Santalum album Linn.), which is in great demand in national and international market and the dry wood is sold at the high price with rate ranging from Rs 8000-10000/kg. The annual production of sandalwood in India has been declining. Data show that production declined from 4000 MT (metric tonne) per year in the 1950s to 500 MT in 2007. The global annual demand for sandalwood is estimated to be about 5000–6000 MT wood and100–120 Mg oil. The major issues related to depletion of the sandalwood in forests include the illegal felling, smuggling and diseases. The illegal felling and smuggling of Sandalwood resulted from its high demand in the national and international market. However, recent policy change by the govt. has allowed farmers' to cultivate and harvest sandalwood from their farmland, and the species is making inroads into North India.

Scope of sandalwood

Indo-gangetic plain of India is characterized by the dominance of rice-wheat cropping systems. In addition, Eucalyptus and Poplar based agroforestry practices are also well accepted by farmers in their farmland. However, only major issue faced by farmers is the moderate return from these farming systems, and the problem is further exaggerated in the salt affected soils. In India, the estimated salt affected area is currently 6.67 Mha, but the future projections point to an increase to 16 Mha by 2030, due to climatic influences and anthropogenic mismanagement, which could adversely affect the crop productivity and farm income. In order to protect farmers from productivity/price/return related distress, a permanent and long term solution is urgently required. One of the alternatives is to grow low input-high output crops such as Sandalwood to increase farmers' income and reduce salinity induced losses. Due to the widening gap between demand and supply, Sandalwood has a great potential as plantation or as a component in agro-forestry systems. However, large scale planting of sandalwood has not picked up due to lack of awareness among farmers, non-availability of quality planting material, rigid government policies, lack of knowledge on poor establishment resulting from its root parasitic nature and lack of understanding about host–parasite relationships, absence of regional specific plantation technology, and the lack of knowledge on its performance on alluvial soil in general and on salt affected soil in particular. One specific biological property of the sandalwood is the pattern of life that semi parasitic character of the root (Fig 1.). Hence, there is a potential to increase sandalwood production through better understanding of the nature of host–parasite relationship, production of quality planting materials and knowledge of its silviculture. Presently, only a few studies are available on the relation of host plant with sandalwood tree and that too only in Southern Indian states. Moreover, the existing identified salt tolerant trees are less profitable, so identifying highly profitable trees such as Sandalwood for the salt environment is urgently required.

Salinity tolerance of sandalwood

Sandalwood is semi-root parasite, which requires host plant to supply nutrient and water because it absorbs less material from the natural environment. Further, Sandalwood growth is significantly affected in the absence of host plant, while more than one type of host is considered better with preferably the legumes. Beside this number of host plants, spacing between plants and soil type also affects Sandalwood growth. As far as abiotic stress tolerance is concerned, *S. album* is tolerant to moderate (4-8 dS m^{-1}) salinity, alkalinity (pH 9.0), and drought conditions. Sandalwood contains some novel protein-coding genes that impart tolerance to species against various abiotic stresses, such as drought and salinity. However, scarce information is available on the growth and productivity potential of *S. album* under the abiotic stress conditions. Little is known about the mechanisms by which *S. album* adapts to different stresses, specifically the drought and salinity. Being hemi-parasitic nature, identification of host plant for sandalwood could be the first step toward increasing abiotic stress tolerance of *S. album*. A very less information is available on probable effect of salinity stress on the growth and physiology, which will affect its promotion and adoption in the dry lands.

Growth potential of sandalwood in saline soils

An experiment was carried out at ICAR-CSSRI for six months during 2020-21, to observe the effects of saline irrigation (ECiw 9), including control and ten host plant species (*Acacia ampliceps, Azadirachta indica, Citrus aurantium, Casuarina equisetifolia, Dalbergia sissoo, Leucaena leucocephala, Melia dubia, Phyllanthus emblica, Punica granatum, Syzygium cumini*) on the growth potential and physiology of sandalwood. The different salinity levels were considered to determine the threshold level of salinity tolerance in sandalwood. The different host species was considered as sandalwood's ability to form haustorial connections (Fig. 1) varies with the type of host species-which ultimately influence the survival, growth and productivity of sandalwood. Therefore, our aim was to assess the growth potential and salinity tolerance of sandalwood in association with different host plant species.

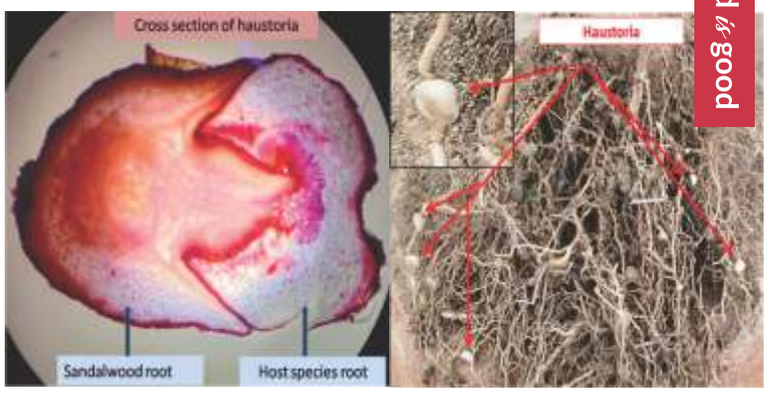

Figure 1. Haustoria formation between the Sandalwood and host root

Figure 2. Effect of salinity and two host species (*Azadirachta indica* and *Melia dubia*) on the growth of Sandalwood.

The results of present investigation showed that under controlled conditions, the maximum ($p<0.05$) height (79.0 cm) and collar diameter (5.4 mm) growth of sandalwood were observed with *Melia dubia* and *Dalbergia sissoo*, respectively. Under saline conditions (ECiw 9), the maximum ($p<0.05$) height (65.0 cm) and collar diameter (4.7 mm) growth of sandalwood were recorded with *Dalbergia sissoo* and *Azadirachta indica*, respectively (Table 1; Fig 1). Similar trends were observed for the other growth parameters, such as number of leaves and branches and total plant biomass in Sandalwood. Salinity stress increased the Na+/ K+ ratio in Sandalwood leaves, and its higher value (3.4) was observed with *Citrus aurantium*, while lower value (0.91) was recorded with *Dalbergia sissoo* (Fig 3). The physiological processes such as photosynthetic rate, relative water content and chlorophyll content decreased by 29, 35 and 67 %, respectively, under salinity stress. Similarly, among 10 host species, Sandalwood grown with *Melia dubia, Dalbergia sissoo* and *Azadirachta indica* showed highest antioxidant enzymatic activities (Apx, CAT, Pox, GR and SOD) under saline condition. The number of haustoria on an average reduced by more than 50 per cent under saline conditions, compared to control.

Table 1. Effect of salinity and different host species on height and diameter growth of Sandalwood

Host species	Height (in cm)		Collar diameter (in mm)	
	Control	EC 9	Control	EC 9
Melia dubia	76.4	60.2	5.82	4.25
Casuarina equisetifolia	64.1	42.0	3.80	3.51
Citrus aurantium	67.2	53.3	4.84	3.60
Phyllanthus emblica	70.8	59.2	5.71	4.21
Syzygium cumini	67.4	60.1	4.04	3.69
Acacia ampliceps	57.5	54.7	4.79	3.96
Punica granatum	69.6	50.4	4.84	3.60
Azadirachta indica	68.2	65.0	5.10	4.60
Leucaena leucocephala	75.2	62.7	4.35	4.00
Dalbergia sissoo	79.0	65.8	5.45	4.80
Mean	**67.4**	**60.1**	**4.82**	**4.00**

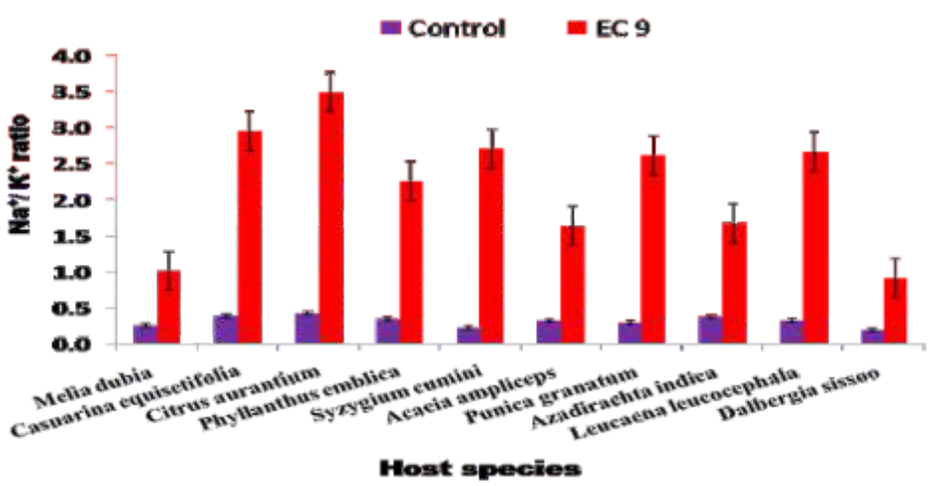

Figure 3. Effect of salinity and host species on Na+/K+ ratio in sandalwood leaves

The results indicated that imposed salinity levels had only slight to moderate effect on the sandalwood growth; however, its growth pattern was mainly governed by the type of host species. The performance of host plant is the single most important criteria for satisfactory growth performance of sandalwood under saline conditions. The results showed that salinity stress resulted in a decrease in number of root-induced haustoria, while increase in leaf Na+/K+ ratio and antioxidant enzymes activities, indicates existence of a salinity tolerance mechanism in the Sandalwood. The sandalwood produced maximum haustorial connections with *Melia dubia* under controlled and with *Dalbergia sissoo* under salinity stress conditions, suggesting the species specific preference of sandalwood for haustorial formations under the contrasting environmental conditions.

Conclusions

Our findings showed that sandalwood growth varied with the host species both under control and saline conditions, and it exhibited a good growth potential under the saline soils conditions. Therefore, based on results obtained so far, sandalwood has shown good prospects of successful cultivation with suitable compatible host species such as *Melia dubia, Dalbergia sissoo* and *Azadirachta indica* in the saline soil environment.

Chandan Vikas Association is an all India trust registered with a charitable trust as per government rules.

CVA has provided free guidance for sandalwood cultivation to 8200 farmers in 24 states across India.
Our objective is to increase the income of farmers by cultivating sandalwood. In the future, we will start a very large sandalwood process industry and also do marketing on the basis of cooperative. Farmers should get money directly from farmers.

CHANDAN VIKAS ASSOCIATION

(All India - NGO)

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Practical Experiences in Sandalwood Cultivation

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Demand for Indian sandalwood is high in the world. Our sandalwood is very different from many other countries in the world, which cannot be compared, in terms of fragrance, anti-bacterial, anti-fungal and other such properties.

In this article, I write about the practical experience on cultivation of sandalwood., so that other farmers will come to know about it. Today, when thousands of farmers in India cultivate sandalwood, farmers need to be aware of the questions that come up regarding problems and benefits of sandalwood cultivation.

I am not writing this article in any scientific language but I am trying to write in a simple language for all to understand.

Problems and Benefits of sandalwood cultivation-

Main Problems

(1) Lack of adequate sandalwood cultivation literature that would give proper guidance for the farmers.

(2) Farmers often incur loss from improper application of fertilizer, water and late treatment of the disease.

(3) The biggest problem is the theft of sandalwood from farmer's field.

(4) The biggest question is the sale of sandalwood and its adequate price.

Advantage/Benefit.

(1) Sandalwood cultivation yields more income than it is earned by the farmer from routine cultivation.

(2) Routine farming results in loss of profits from the natural environment, while long-term cultivation of sandalwood does not have any significant side effects.

(3) Sandalwood cultivation costs (labour, fertilizer, security, etc.) only 5% to 7% of the income.

(4) Growing agro forestry helps climate change mitigation.

(5) Less investment, less effort, and more income.

(6) Other crop cultivation can be done with sandalwood.

Changes in sandalwood cultivation, Govt. Law and training

Since the state governments have relaxed the law on sandalwood cultivation since 2002, farmers have gradually started cultivating sandalwood. Sandalwood cultivation was a new topic for farmers. Since Institute of Wood Science and Technology (IWST) started imparting training on sandalwood since 2005, its awareness has been spreading among the farmers of India. I have also taken training in 2014.

Loss from misdirection/misguidance

Tulsibhai from Mehsana, Gujarat, planted sandalwood in 45 acres in 2007. Tulsibhai planted sandalwood at a distance of 10 x 10 feet. Today, the plantation 14 years old. Tulsibhai had planted lemon as the host tree, all the lemons died in 2011 due to sandalwood. He then started planting Casuarina as host plants but the sandalwood killed the casuarina trees. At the end they planted saptaparna trees. So, the sandalwood growth that should take place in 14 years is relatively low.

Died Lemontrees in Tulsibhai farm

Farmers have been misguided and misled by the state governments for changing the law for cultivating sandalwood and not providing information about it. Nursery owners guide farmers to plant sandalwood plants at 6 x 6, 8 x 8, or 10 x 10 feet in the lure of selling more seedlings and making profit. Farmers are happy with high density plantation for 4, 5 years, but in my experience, after 6, 7 years, the growth of their sandalwood stops. Its girth is not more. I have seen many farms with these problems are in many states like Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra, Gujarat etc..

Sandalwood plantation in Dharmesh bhai farm

The photo above was taken at Dharmeshbhai's farm on 7.4.2016, which is near Dharmaj village in Gujarat, which was planted in 2007. There were 230 sandalwood trees. All are harvested and sold for only Rs 3 lakh in 2021. This sandalwood began to grow into heartwood trees. Who is responsible for the girth of sandalwood and heartwood after 14 years....?. Planting distance not proper, no host, water and manure management. There are many such farms in India even today.

When a farmer cultivates sandalwood, he wish to become a millionaire. In his thoughts, he works hard in the early years to meet his expectations. When the growth of his farm stops / stuck after 5- 6 years then his enthusiasm breaks down, he stops working hard, he spends days and years in despair. Sandalwood cultivation is not bad, but the wrong way of guidance put them in distress.

Sandalwood cultivation in India

India has planted 1,35,00,000 sandalwood trees from 2015 to 2021 (This figure is based on the information provided verbally by the nursery owners who came in contact with us). But there are many nurseries in India which are not in touch with us who have sold sandalwood plants and we do not have statistics on the number of sandalwood plants sold by the state governments. But an estimate of 2.5 crore sandalwood plants has been planted so far, that is 30 lakh sandalwood trees have been planted every year till 2021. So, in terms of income, after 2033, Indian farmers are likely to earn Rs 15,000 – Rs.20,000 crore every year.

The Chandan Vikas Association (CVA) has provided guidance to 7186 farmers through various seminars and webinars. Apart from this many farmers in India may have taken training from IWST. Many farmers might have taken guidance from any other sources whose records we do not have. Thus, thousands of farmers have moved towards sandalwood cultivation.

Production of sandalwood heartwood

Production of sandalwood heartwood will start 300 tons to 400 tons per year from 2027. At least 6,000 to 10,000 tons of heartwood will be produced every year after 2033. The Government of India will open export permission for sandalwood in future. Farmers must come together and start a production unit. Unity has to work. Farmers will have to face a lot of trouble in selling sandalwood if they do not go beyond unity.

To sell sandalwood, first test every tree after 15 years, analyse it, get the cutting permission of the tree to be cut, keep the tree in your house for 4 months, separate its heartwood and then sell it. All this process will take 6 to 12 months.

(1) Mr. Hiralal who is a farmer from At- Javkheda village in Nandurbar, Maharashtra, had planted sandalwood trees on the border of the farm. 11 trees of age 11 to 20 years were cut down with the permission from Forest Department. The heartwood weight of this sandalwood tree was 135 kg, whose record is not written scientifically. In 2021, all these

types of sandalwood were sold for Rs. 8 lakhs by CVA.

(2) Mr. Gamanbhai Vaishya is a farmer of Dahod district/ Tal-Sanjeli village of Gujarat. He planted sandalwood all along the border of his farm. He cut sandalwood trees at the age of 15 to 20 years with forest department permission. It weighed 365 kg of sandalwood heartwood, which sold for Rs 17 lakh.

(3) Mr. B. B. Limbachia, from Mota Garadiya village in Jamnagar district of Gujarat is an ex Forest Officer. He had 9 trees in his farm of about 15-30 years old. Heartwood was separated 4 months after cutting. This heartwood weight was 325 kg. Out of which 100 kg wass sold for Rs. 7 lakhs.

Problems in sale

Selling sandalwood is not easy and often farmers are deceived by middlemen. Farmers do not find the original buyer, if found they show many kinds of defects, such as, this sandalwood does not have the right aroma, is not thick, does not have oil, is not very old, the colour is not right. The trader tries to buy for less money by showing many such defects. If the farmers want full income, price of sandalwood, then in future the farmers together will have to set up a production unit. Without this, you will not get the original income or price of sandalwood in any way.

Manufacturing companies buy stolen wood at Rs 2,000 per kg. The stolen wood are tricked into selling officially, where Forest and GST department does not get to know. This practice runs on a very large scale. At present, the companies trading in sandalwood have come together and decided that we should not buy sandalwood at a higher price than a certain amount.

After the sale of heartwood of sandalwood, TP Questions for the pass

Obtaining Transit Permit (TP) for the transportation of sandalwood from the State Forest Departments is a big challenge for the farmers. Different States have different laws to regulate sandalwood cultivation and trade. Often such regulations cause impediment for sandalwood

cultivation and trade. So, the Central Government and the State Government must make farmer oriented laws to promote sandalwood cultivation. If the government does not amend the law, the farmers will change the law through the Supreme Court, as is in the public interest. There was a time 15 years ago, when farmers had 1% sandalwood and state governments had 99%. Now, State governments will have 10% and farmers have 90%. So, it is right time for the laws of the state governments to be made in the interest of the farmer.

Vigilance for theft

Do not let anyone enter your sandalwood farm after 8-10 years. Allowing anyone to come in means it is most likely to be stolen. When it comes to selling sandalwood, do not take anyone to the farm to show the sandalwood to a trader. Real sandalwood buyers are 1- 2%, the rest are traders sent by commission agents or thieves to study. This is the biggest problem. Before showing sandalwood to someone, ask for their Aadhaar card, sandalwood license, factory address, after seeing all this, show sandalwood only after checking.

If you would like any guidance in this regard, you can contact CVA. Trusting someone in sandalwood would be the biggest mistake of life. The whole life's work will go a waste and I hope it will be useful for the farmers interest in Sandalwood cultivation.

Sandalwood: History, Uses, Present and the Future

Ramakant Harlalka,
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Harshavardhana was considered as one of the most prominent Indian emperors who ruled India during 7th century AD. Kannauj was his capital which is located on Ganges. He built a huge empire that extended from north & north-western India till the Narmada in the South. During Kumbh festival at Haridwar, he was traveling with several boats from Kannauj with full load of various articles for donation and while coming back he used to bring sandalwood logs in all the boats. All sandalwood logs were converted into paste after grinding on stone and which was distilled in Cupper-deg distillation unit to recover sandalwood oil.

Sandalwood is very popular in the Islamic world, where it is used as perfume or burned as "bukhoor" to fumigate rooms and spaces of worship. Sandalwood has been used in several religious practices for centuries in the form of carvings and applied to the body for purification purposes. When Buddha passed away in 543BC, it is said that his body was cremated on a bed of sandalwood, enhancing the well-known belief that sandalwood elevates the user's spirituality. In recent times yoga and meditation have introduced incense culture to the Western world, where sandalwood together with other natural herbs, is burnt as incense to elevate and encourage holistic healing.

Use of sandalwood

Sandalwood has many medicinal uses and hence, it is used in large scale in the manufacture of ayurvedic medicines. Its products have the finest of fragrance, one that lasts for years. Its products are used widely from birth to incineration in various rituals and it is also used in temples as prasadam. The sandalwood oil is used for varied applications because of its unique chemical and physical properties. Further, it has gained a special place in Aroma Therapy, Perfumery, Agarbattis, Soaps and Detergents, Pharmaceutical, Cosmetic and Allied Industries. On a spiritual level, sandalwood supports the experience of inner unity of mind, body, and spirit; awareness of inner soul life, enhancement of higher consciousness and related creativity, relaxation of the conscious mind, meditation, prayer and spiritual practice, peace, and acceptance.

Sandalwood has distinct, high-value end uses that function to underpin its price and maintain demand in different market segments and regions. These uses and markets include essential oil from its heartwood as an ingredient (providing woody base notes and fixative properties) in fine perfumes, exclusive natural body-care products and pharmaceuticals, especially for European and North American markets. It is being used extensively for carvings, traditional medicines and religious uses in China, the Republic of Korea and Japan. The sandalwood based attars are used funeral pyres and chewing tobaccos in India.

Present status

Since liberalization of rules regarding cultivation of sandalwood during 2001 and 2002, there has been tremendous interest among farmers and stakeholders across India in farming this tree. High demand and remunerative prices of heartwood have motivated farmers/stakeholders to take up sandalwood farming especially in non-traditional areas in many states across India like Gujarat, Rajasthan, Andhra Pradesh, Madhya Pradesh, and Maharashtra since the past decade. The potential of the tree in natural and naturalized forested areas, existing farming systems and other silvi-horticultural systems across India have been studied by IWST including heartwood and oil formation using non-destructive methods. The scope of cultivation in current farming systems including economics of cultivation have been critically analyzed and presented. The current problems and

future prospects for increased livelihood opportunities and enhancing farm income levels also discussed along with suggestion for promoting sandalwood farming practices across India.

Future prospects

The markets for sandalwood heartwood and oils from Pacific Island countries have been strong and have continually diversified since exports to China commenced over 200 years ago. The global sandalwood market remains buoyant, with 2019 wholesale prices of Santalum album oil ranging from USD 1750 kg−1 (unlicensed production through Dubai) to USD 2100 kg−1 for licensed production from India and USD 2000–2500 kg−1 as wholesale price for Australian *S. album* plantation oil. The wholesale price for *S. austrocaledonicum* oil is USD 1500–1750 kg−1. The heartwood (air-dried) of S. album is mostly traded by growers for more than USD 100 kg−1. The price for Fiji's *S. yasi* heartwood (partly to fully air-dried, 'village gate' price) for carving, furniture, and oil distillation has increased steadily to USD 50 kg−1 in 2019 while the price for grade-1 S. austrocaledonicum heartwood (partly to fully air-dried; 'on the beach' price) is USD 35 kg−1. The global market for sandalwood products, sustainably sourced from a growing plantation resource in Australia, Asia and the Pacific Islands, is predicted to remain strong up to and beyond 2040.

The high rate of increase in sandalwood prices in recent decades is unlikely to continue, due to both an expanding supply from increasingly better-managed plantations and genetic improvement followed by technological innovations to induce earlier and greater heartwood yields in planted sandalwood. Nevertheless, sandalwood prices will remain sufficiently high to make agroforestry cultivation a commercially attractive proposition for efficient Pacific Island sandalwood growers.

Indian Sandalwood – A Treasure House

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Introduction

Sandalwood is considered as the oldest, precious and commercially significant herbal plant which is also used as timber in India. It is well known for its unique and distinctive fragrance. The heartwood of the plant is very expensive and is associated with great commercial value in the national and international markets as it is enriched with fragrant essential oil. The aromatic essential oil of the plant is used in various perfumes, food products, cosmetics, aroma therapy and pharmaceutical industries. Traditionally, the plant is used in various medicinal systems such as Ayurveda, Unani and Siddha to cure diseases like jaundice, dysentery, gastric irritability and as a tonic for liver, heart, fever, memory improvement, anti-poison and also as blood purifier. It is considered sacred and its importance and usage are also mentioned in Vedas, Puranas, Buddhism, epics and scriptures. In Ayurveda, the sandalwood plant is used as an expectorant, diuretic, astringent, stimulant, coolant and sedative agent. Besides this, the plant is associated with therapeutic and pharmacological properties such as antioxidant, anti-cancerous, anti-inflammatory, antiviral, antibacterial, antifungal, hepato-protective and cardio-protective.

Currently most of the world demand of sandalwood is supplied from Australia using *S.spicatum* known as Australian sandalwood. Due to the high value and the demand, there is a growing attention at present in establishing sandalwood, especially *S. album* plantations in the tropical regions. There is a trend in sandalwood plantation establishment in Australia, India, Sri Lanka, China, and Fiji recently due to the large domestic demand and the existing high demand (Subasinghe, 2013). However, the plantation sector lacks the information on establishing sandalwood plantations, which is identified as a great risk when considering their profit maximising goal. Without the information such as nursery techniques, host suitability, plantation establishment, growth rates and oil characteristics, managers of sandalwood plantations might therefore face difficulties in achieving the expected outcomes.

Global sandalwood market

It is difficult to quantify the size of the global market for sandalwood due to a lack of published and available trade data and also the scale of illegal trade (likely around 33% of the total market). The most reasonable estimate of the annual global sandalwood market in recent times is 6320 tonnes in 2011-2012 (Coakley 2013). It is clear, however, that global demand for sandalwood remains strong and also that demand has considerably outstripped supply, especially for East Indian sandalwood, in the past two or three decades. Consequently, prices raised rapidly. The price of *S. album* sandalwood in India increased at a compounded rate of 15.1% between 1992 and 2014 (Anon 2014), and the wholesale price for high-quality East Indian sandalwood oil reached ≥USD 3000 kg^{-1} (for perfumes and new pharmaceutical uses in the United States) in 2016 and early-to-mid 2017 before dropping back to around USD 2000-2500 kg^{-1}. The global sandalwood oil market in 2020 is estimated at USD 97 million (approx. 50 tonnes) (Global Sandalwood Oil Markets Report 2020).

India

The annual official harvest of sandalwood was 300-370 tonnes in 2008-2012 (Padmanabha 2013) but the total production in 2011-2012 was estimated at 1250 tonnes, with 1000 tonnes associated with illegal harvesting. There has been considerable private-sector interest in developing sandalwood plantations, including northern locations, such as Andhra Pradesh, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan, where the species does not naturally occur and which are free from sandalwood spike disease (mycoplasma). The area currently planted with sandalwood in India is estimated to have grown dramatically in the last five years to an estimated 30,000 ha in 2019, in both agroforestry configurations and plantations. It is considered that about 1000 ha of 25-30-year-old sandalwood plantations will be harvested per year in 2040,

producing 8000 tonnes with an oil content of 2.5% oil, or 200 tonnes of oil. It is estimated that wild stands will produce 2000 tonnes with 5% oil, or 100 tonnes of oil.

Demand in 2040

The local demand for sandalwood oil is estimated at a minimum of 250 tonnes in 2040. It is likely that local S. album plantation wood will mainly be used domestically for agarabatti, funeral pyres and oil, especially for soaps/attars. India will likely be a net importer of sandalwood heartwood and/or oil in 2040, but it is difficult to predict the quantity due to uncertainties in production, quality and maturation times of its recent plantations. These new plantations are mainly in non-traditional sandalwood-growing areas, and the impacts of sandalwood spike and other pests and diseases are unknown and growth rates/ heartwood development rates uncertain. Very much need to entertain sandalwood plantations in natural habitats and forests and rules and regulations should be made convenient.

90 percent of sandalwood trees are distributed in Karnataka (5245 km^2), Tamil Nadu (3045 km^2) and the rest in Andhra Pradesh (175 km^2)

Phytochemical constituents of sandalwood

Plant is a rich source of volatile oil isolated from the roots and heartwood of the plant. These volatile oils are extracted from the roots and heartwood after 30 years of its growth. The oil is yellowish, colourless, viscous, with a heavy sweet odour. The main active constituent present in the volatile oil is santalol which is a mixture of two primary sesquiterpene alcohol, beta-santalol (16.0%) and alpha-santalol (19.6%) where alpha form predominates. The minor constituent of the plant includes lanceol, bisabolol, nuciferol and sesquiterpene hydrocarbons like alpha and beta santalenes, beta-bisabolene, alpha, beta and gamma-curcumenes and bergamotenes phenylpropanoids. The major essential oil components of the plant include sesquiterpene alcohols like epi-cis-beta-santalol, alpha-trans-bergamotol, cis-beta santalol and cis-alpha santalol. The minor constituents are comprising of heterocyclics, alpha-isabolol, hydrocarbons antene, alpha-santalene, beta-santalene, epi-beta-santalene, alpha-ergamotene, alpha curcumene, beta-curcumene, gamma-curcumene, beta-bisabolene, alpha-isabolol, transbeta-santalol and cis-lanceo. The other chemical constituents in sandalwood plant oil include teresantalol, santenol, alcohol, aldehydes, alpha santalic acid, beta-santalic acid, ketones, nor-tricyclic santalal, isovaleraldehyde, antenone, santalone and other acids including teresantalic acids. (Shailja and Gitika 2021).

Seed and seed treatment

Seed production generally is good in one of the seasons. Certain trees flower only once a year and some do not flower regularly. About 6000 seeds make 1 kg. Seeds can be collected directly from the tree. The fruits should be de-pulped, washed thoroughly in water, dried under shade, and stored in airtight containers. Soak the seeds in 0.05% gibberellic acid overnight facilitates good germination.

Primary nursery

Seeds germinate best when they are sown in a free-draining medium such as 2:1 mix of river sand and soil. Composted sawdust is also a very good germination medium. Nick the seed shell to expose the kernel. Nicked seed begins to germinate after 2

Compounds present in plant parts

Leaves	Urosilic acid,catechin, vilexin, iso vilein, shilcimic acid, gama aminobutyric acid
Seed	Xymnemeic acid, oleic acid,linoleic acid, stearic acid
Seed cover	Betulinic acid
Bark	Tri terpenoid (3-betayl-palmitate)
Wood oil	α-santalol, β-santalol, bergamotol

weeks, whereas seeds that are not nicked may take 6 weeks to germinate. Sow the seeds in a seedling tray or pot, just (5-10 mm) below the surface of the medium so that the seeds do not touch each other. Water to keep the medium moist but not wet. During the wet season, trays may need to be brought out of the rain. Protect germinating seedlings from full sun and predation by rats and birds

Secondary nursery

Seedlings are ready to be transplanted in poly bags once they develop two leaves. Use a sterilised growing medium in the poly bags that has 50% sand to assist drainage and 50% soil to improve water-holding capacity. Prick out the seedlings (when they are at the 2-leaf stage) by lifting the root system with a cleaned stick and pulling gently on the base of the stem. Plant the seedling firmly in the medium and cover the roots. Place the poly bags on raised benches, particularly during the rainy season, to help drainage.Cover to protect the seedlings during periods of heavy rain to reduce the chance of the growing medium becoming saturated. Grow the seedlings under shade (e.g. shady tree or shade cloth). The pot host Alternanthera should be planted as stem cuttings after the sandalwood is at 4-6 leaf stage. If the pot host is planted too early, it will grow quickly to overtake the young seedling, leading to stunted growth and death of the sandalwood. If the pot host is planted too late, the sandalwood may grow slowly. Seedlings can survive without a host for 3 years but thereafter they tend to die. In a natural population 2 percent of seedlings do not produce haustoria and they fail to survive on their own beyond 3 years of age.

Hardening seedlings

Once the seedlings reach the 10-12-leaf stage, they need to be progressively moved to areas of higher light levels to 'harden' or acclimatize them to conditions in the field. They should have 50% shade in the first month, and then 25% shade for another month, and then one to several months in full sun, before they are planted in the field. Seedlings transplanted directly from the shade to a full-sun position in the field typically have poor survival.

Raising wildlings and management

Seedlings germinated naturally under an existing sandalwood tree can be collected and transplanted in the nursery or another location (such seedlings are called wildlings). This is a simple method of establishing new stands of sandalwood. Select sandalwood trees that are fruiting or are otherwise known to fruit heavily. Clean all undergrowth from beneath the canopy of the selected sandalwood trees.Loosen the soil in the cleared area by shallow digging or cultivating only the top 5 cm of soil. Wildlings begin to germinate in the cultivated area about 1-2 months after the soil is disturbed. Water the cultivated area during dry periods, if possible, or after the first seedlings break through the soil. Keep the cultivated area free from weeds.

When wildlings have reached 4 to 6 leaf stage they are transplanted to polybags along with a seed of *Cajanus cajan, Alternanthera sessilis* (L.), *Cassia fistula* L., *Mimosa pudica* L., etc., the primary host for better growth of sandalwood seed. Polybags should contain soil mixture of ratio 2:1:1 (Sand: Red earth: Fym). Sterilizing the growing medium can help to prevent diseases. The medium can be sterilized by covering black plastic sheet and leaving it in the sun for a day or heating it over a fire in a steel drum. It has been found that polybags of 30 x 14 cm size are the best. Seedlings are carefully removed from beds with all roots intact; roots should not be allowed to dry. Shade can be provided for a week immediately after

transplantation. Watering is to be done once a day, but excess moisture is to be avoided. The watering regime for seedlings raised in a nursery will vary according to the amount of rainfall and the position of the seedling in the nursery (e.g. 50% shade versus full sun). Seedlings in full sun during the dry season may need to be watered every day, but during the wet season shelter from the rain may be necessary. Host plants are to be pruned frequently, so that they do not over grow sandalwood and hamper its growth. Shifting may be done once in two months to avoid root penetrating soil and grading is to be done once in three months. Weeding is to be done at regular intervals. Seedlings of about 30 cm height can be raised in 6-8 months' time. A well branched seedling with a brown stem is ideal for planting in the field.

Problems in nursery

i Low quality of seed

Quality of seed depends on condition of mother trees. The ideal mother tree should be more than 20 years old, healthy and having high santalol.

ii Competition for nutrients

Sandalwood is hemi parasite plant, meaning that the plant should have a host which provides some nutrients to the sandalwood plant. Nutrition competition arises between sandalwood and the host plant.

iii Lack of water

The moisture content of seedling media is an important factor in sandalwood nurseries. High humidity will decrease the aeration which is unsuitable for sandalwood seedling growth. Therefore, regulation of moisture content plays an important role in producing high quality seedlings.

iv Sowing medium of germination

The type of sowing medium can influence the aeration and drainage capacity and both will influence the survival of seedlings. Some treatments about medium factors are explained in following table. Sandy material was the better medium for germination. This factor is related to the aeration, drainage and temperature.

Table: Influence of type of sowing medium on seed germination rate

medium	Germination rate (%)
Soil	30.67
Sand	81.33
Sawdust	77.33
Faecal of cow	70.66

I. (Surata 1993)

v Sunlight Intensity

Sandalwood needs shade in the nursery. High intensity of light can kill the seedling. Surata (1993) reported that shading leads to higher survival rate, except in the case of shading with Acacia villosa.

Table: Influence of shading type on the growth of 8-months old young plantation

Treatment	Height (cm)	Diameter (cm)	Survival rate (%)
Control	43.12	0.61	56.00
Shade with *Imperata cylindrica*	39.54	0.58	71.87
Shade with *maize* and *kacangturis*	56.63	0.59	71.99
Shade with *Acacia villosa*	56.43	0.59	57.81
Shade with *kacangturis*	70.32	0.71	84.38

(Source: Butar 2007)

vi Pests and diseases

The common diseases in nurseries are londoh (a whitish decay fungi), damping off and wilt. The most common pests are defoliators, leaf worm, weevil, grass hoppers, bag worm, sap suckers, coccids and lac insect which can quickly kill a large number of seedlings.

Sandalwood spacing

The distance between sandalwood and host trees is critical to ensure good growth over the entire rotation of the plantation. The minimum spacing of sandalwood trees is 3 m × 6 m or 5 m × 5 m, with large, long-term host trees planted at least every fifth tree within each row. At a spacing of 3 m for sandalwood, the host trees would be spaced every 15 m. It is recommended that each row is 'offset' so that every sandalwood is within 5-6 m of a long-term host. The number of intermediate host trees will depend on the size of the host tree.

Mostly the ratio of host to parasite is 1:1 followed in the field. This ratio is critical for survival and productivity of sandalwood trees as well as the host plants. Equal host to parasite ratio (1 : 1) heavily leaning towards parasite leads to heavy parasitic load, and hence may cause death or decline of the host population, decreasing the ratio further. Therefore, host and sandalwood ratio of 2 : 1 and 3 : 1

Conclusion:

Sandalwood cultivation is a promising venture and with liberalization from governments, commercial production is spreading across the agrarian landscape, however, the production potential is yet unknown and uncertain. Presently, sandalwood is found to survive with a vast array of plants, especially short-rotation species like casuarina and in some instances even with fruit trees like citrus, amla, mango, papaya, pomegranate and other economical horticultural and forestry species.

As a parasite sandalwood inhibits the associated host, but the economical equilibrium between host and sandalwood is not yet ascertained. Perennial trees of long rotational period of 25-30 years would appear beneficial, but there are no long-term studies to confirm this. We need thorough in-depth knowledge for commercial success. Much of the available information particularly on hosts is from pot-culture studies, and upscaling of these results to the field level is rather difficult to comprehend with regard to economical rotation age, selection of hosts, spacing and host-to-parasite ratio. Cultivation practices in farmer fields and natural habitats needs to be standardized with good hosts. However, it is suggested to have multiple hosts of commercial importance comprising both perennial leguminous and non-leguminous tree species.

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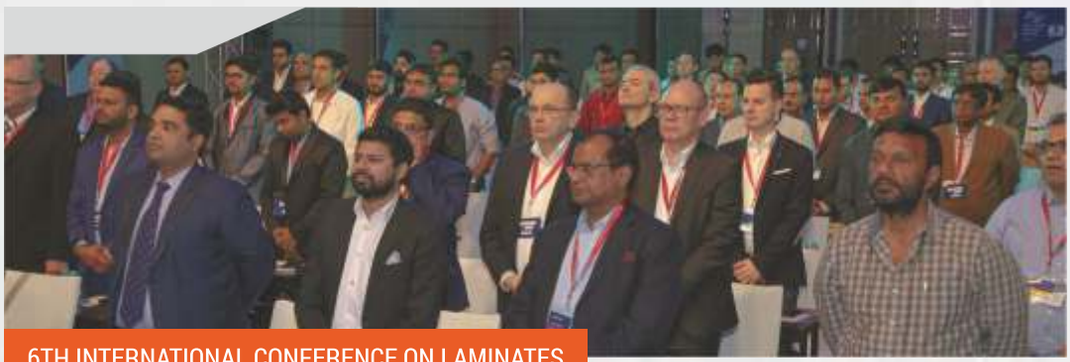

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4. Study on Cleaner Production
5. Launch of Technical book on laminate
6. Catalogue shows at National and International Level
7. Launch of awareness video on Laminate application
8. Networking with members for raw materials, production, market and government policy related issues
9. Export incentive benefits to laminate exporters
10. Support to PM Cares fund during pandemic

Upcoming Events

1. 7th International Conference on Laminates during Delhi wood March 2021
2. Catalogue show at Interzum, Germany 2021
3. Online technical workshop on production and environment aspects during October 2020.
4. Environment clinic with Pollution control board (December 2020)

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Problems and Prospects for Cultivation of *Santalum album* L.

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Sandalwood is losing ground in India, owing to various factors include smuggling of sandalwood, policy paralysis in respect of promoting sandalwood cultivation, forest fire, biotic pressure on forests, prevalence of sandalwood spike disease, etc. Although there are many problems associated with the cultivation of sandalwood in India, in this paper an attempt is made to discuss some of the problems related to establishment of sandalwood plantation in forest area and private plantations.

Problems faced during sandal wood growth

1. Lack of regeneration

Poor regeneration can be attributed to several factors, both natural and anthropogenic. Hurdles to natural regeneration of sandalwood in forests include recurrent annual fires in natural sandalwood areas, lopping of trees for fodder, excessive grazing, hacking, encroachments and spread of sandalwood spike disease. While these factors hinder regeneration in forest areas and diminish the growing stock, the situation is accelerated by human activities of chronic overexploitation and illicit felling.

2. Low seed setting in seed stands

Sandalwood is predominantly an out breeding species. The seeds are produced twice a year and are capable of self-regeneration. Seeds from various seed sources exhibit significant variation morphologically and physiologically. Presence of genotypic barriers for embryo development has resulted in lower percentage of mature fruits in spite of good percentage of fruit initiation (Sindhuveer endra *et al.*, 1999). The tendency for out breeding in sandalwood is reinforced by asynchronous flowering, insect pollination, heterostyly and self-incompatibility. Alternatively, *S. album* regenerates asexually by means of root suckers. Root suckers generally originate as shoot primordia from injured or severed roots and are confined to an area around the mother tree. Studies have shown that natural stands of sandalwood in Sri Lanka have spread clonally by prolific root suckering (Tennakoon *et al.*, 2000).

3. Low seed germination and seedling mortality

Seeds are obtained by removing the fleshy portion of the fruit. Seeds vary in their size and shape. Under normal conditions they retain their viability up to six months and then gradually diminish. Fresh seeds exhibit dormancy for 2 months. Pathogen infection, rabbit and rodent menace, grazing by animals, high atmospheric temperature and excessive moisture content are the major factors which considerably reduce the survival of seedlings. Sandalwood seedlings are prone to attack from insect pests and diseases, which take a heavy toll and sometimes wipe off the whole stock.

Damping off, vascular wilt, web blight, stem infection and seedling blight caused by *Fusarium oxysporum, Phytophthora, Pythium* and *Rhizoctonia* are the most serious diseases that cause severe damage and economic loss in nurseries (Remadevi et al., 2005). Among these *F. oxysporum* is the most serious pathogen which affects seedlings in nurseries as well as in natural forests. Seedling mortality caused by *F. oxysporum* affects sandalwood at various stages causing pre-emergence damping off, collar rot, stem and root infection.

4. Shade requirement

In the early stages of seedling development, sandalwood derives nutrition from the relatively large seed reserves and later, the formation of host attachment through root connection becomes critical for seedling survival and growth (Barrett and Fox, 1997). The duration of dependency on the kernel as the food source needs to be studied. Sandalwood is a sciophile in the seedling stage, becomes more heliophilic once established. Full Sun light is detrimental to the survival of sandalwood germinants and they need to be grown in greenhouse, shade house or in a shady area. Therefore, the level of shade is important for seedling growth. Early growth of sandalwood after seed germination was found to be better in the shades of bushes and clumps of vegetation (Rao, 1942) have shown that some shade is beneficial for the first three year, however, the length of time for optimum benefit has not yet been elucidated.

5. Host plant requirement

Sandalwood, being a hemi-root parasitic tree, root connection with a host species is required for nutrition to young plants as well as to the adult trees. Additionally, host plants can also provide shade required for the healthy growth of seedlings. Sandal wood benefits from a primary host at the nursery stage and from a secondary host (long term) in the field (Fox, 2000). Early nursery growth was found to be more rapid and secure when grown with a pot host which functions both in plant nutrition and water relations of sandalwood and reduces out planting stress when transferred to the field (Fox, 2000). Poor growth without a primary host even after application of supplementary nutrition has revealed that a pot host is important for healthy and robust development of sandalwood. Successful establishment of sandal wood seedlings in plantations requires the appropriate utilization of host and this aspect has contributed to low regeneration, both naturally and artificially.

6. Slow growth of sandalwood

Though sandalwood is considered to be a slow-growing tree under forest conditions (1 cm girth/year), it can grow at a rate of 5 cm of girth or more per year under favorable soil and moisture conditions. The heartwood formation in sandalwood starts around 10-13 years of age. So far the growth data is available only in respect to natural forests, mainly from Javadis in Tamil Nadu and the Dharwad area of Karnataka.

Singh *et al*., (2018) studied the growth and heartwood contents of S. album trees aged 6 years cultivated on farm land in association with *Citrus aurantium*, *Punica granatum* and *Casuarina equisetifolia* as host species, were studied to identify the most suitable host. Survival, height, collar diameter, crown size and clear bole of *S. album* trees were greater when grown with *C. aurantium* than the other two hosts. Heartwood formation in S. album was initiated in trees >9 cm diameter at breast height (DBH), irrespective of host species. Relatively greater value of DBH: height ratio of S. album in the case of *P. granatum* indicates suitability of this species as a long term host.

Assuming about 250 trees are growing well, they can put on an annual increment of 1 kg per year per tree, thus giving an overall increment of 250 kg of heartwood per year. The returns can be increased by adopting intensive practices

Suggestions

- The tissue cultured plant cultivation will benefit farmers as sandalwood is the most economically rewarding crop in the world. Better protection and improved regeneration will result in increased number of healthy plantations and ultimately, will increase the income of the farmers.
- Government should give priority for the research, development and extension to promote sandalwood.

Age (Years)	Girth at breast height (cm)	Yield of heartwood (kg)
10	10	1
20	22	4
30	33	10
40	44	20
50	55	30

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Growing Sandalwood on the Wasteland of Madhya Pradesh: Predicaments and Potential Solutions

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Madhya Pradesh (MP) is the second largest State in India covering 9.38% of total geographical area of the country. The annual rainfall ranges 800 mm to 1,800 mm and the annual temperature varies from 22°C to 25°C with the maximum temperature reaching up to 49° C. The State is drained by a number of rivers, which include Narmada, Tapti, Son, Betwa, Shipra and Chambal. As per the land use pattern report of Ministry of Agriculture, Government of India (2014-15), the total geographical area of Madhya Pradesh is 30,825 thousand hectare. Out of this total area, the culturable wasteland is 1,010 thousand hectare covering approximately 3.29 % of the total geographical area. Now, this wasteland can further be utilized for cultivation of some economically important forest trees and other crops.

Nearly one-third area of the State is covered with forests. Sandalwood is not a naturally occurring associate of these forests. However, it has ecologically adapted as an associate in natural dry deciduous teak forest. Because of its high economic value, sandalwood is being given considerable attention by the State Forest Department.

The earliest recorded sandalwood introduction to the natural forests of Madhya Pradesh dates back to 1880. Since then it has spread to an area of about 2360 ha. The first planting was done in an area of 175 ha during 1979 in Seoni District. Subsequently, substantial plantings were made in revenue lands in Dewas, Indore, and Rajgarh Districts on the Malwa plateau.

Fig: a) Sandalwood plant b) Sandalwood based agroforestry with aonla as host at some private farm in MP

Role of private sectors

There is a growing demand for sandalwood based products. On the other hand there is severe shortage of supply of sandalwood raw material. It has compelled the State Governments to bring changes in rules related to cultivation of Sandalwood. This has encouraged the Corporates to raise Sandalwood plantations. It is estimated that there has been new plantation on as much as 15,000 acres in southern states and parts of western and northern India, in recent years. Companies such as Surya Vinayak Industries and Namdhari Seeds Ltd and a host of individual farmers with large land holdings have taken up commercial plantation of sandalwood in the states of Madhya Pradesh, Rajasthan, Karnataka, Andhra Pradesh, Gujarat and Maharashtra.

Although Sandalwood can be grown on wastelands of MP, raising sandalwood plantations in such lands is a big challenge owing to the following reasons.

1 Identification of Ground water source/Aquifer

In Madhya Pradesh, mostly the wasteland is Stony and rocky, where water availability is the major concern. Except the rainy season which is of 3 months, the whole plantation for their water requirement depends on the ground water. Therefore, identification of aquifer or ground water source is required. This process is cost intensive and more of hit and trial method.

2 Pest and Disease spread at Specific area repeatedly every year

Recurrence of certain diseases like spike disease and insect-pests like scales and mealy bug at some specific area repeatedly every year.

3 Identification of Waterlogging and water stress plants

The wastelands generally have undulated land area, which creates hurdle in even distribution of irrigation water and ultimately results in improper drainage.

4 Bark Cracking problem in Young and old plantation

Bark cracking is a major issue in such plantations. Through literatures, it has been found sun scalding is the main concern for the cause.

5 Plant Nutrient Management System

There are no standard packages of practices for cultivation of Sandalwood and hence it is difficult for the farmers to follow right nutrient management regime to raise healthy plantations.

6 Protection of Sandalwood trees from theft

Sandalwood is highly prone to theft and hence protection of sandalwood trees poses big challenge for the growers.

To combat such challenges the public and private organizations should come together and work in the direction to find out the ways of promoting sandalwood cultivation in remote/wasteland areas.

Suggestions to Promote Sandalwood Farming in Wasteland/Non Traditional Areas:

1 Wasteland under possession of government should be given to corporates or private players to initiate sandalwood plantation. The period for lease should be 50 years so that at least two harvests can be taken. Multiplication of germplasm to be reinforced through tissue culture and raising seedlings from seeds collected from plus trees of sandalwood.

2 Saplings should be made available to farmers at free of cost by agencies like IWST, State Forest Departments and State Agricultural Universities.

3 Sandalwood based agro forestry demonstration plots with horticulture species as secondary host along with short term primary host & annual intercrops for demonstration to farmers and in this way, a farmer will also be ensured with sustainable income to meet out his plantation expense.

4 Nationalized banks should come forward with finance schemes in agro forestry for growers.

5 Legal restrictions should be lifted for sandalwood's harvesting, transport and marketting as it is grown by the farmers.

Conclusion

There has been increased interest among farmers and corporates in growing sandalwood in farmlands and private lands. However, lack of adequate knowledge on sandalwood cultivation and forest legislations hampers the extension of sandalwood cultivation in non-traditional areas. Hence, State agencies have to play proactive role in promoting Sandalwood cultivation in non-traditional areas by liberalizing the existing legal provisions and by providing incentives to the sandalwood growers.

(A-B) Sandalwood idols of Lord Krishna and Radha with decorative frames found in the Salar Jung Museum, Hyderabad.

Fresh Scents of the Ancient Aroma

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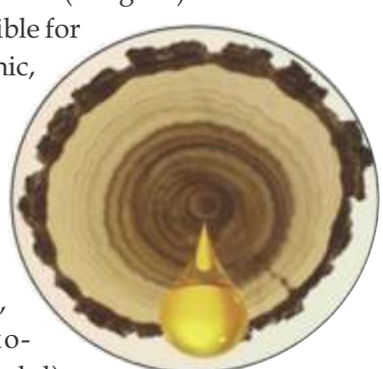
Introduction

The East Indian Sandalwood is one of the most revered gifts of ancient India to the world. It has been an integral part of Indian culture for ages. The sandalwood tree is grown for its heartwood which contains the exquisite oil. Steam distillation of the heartwood obtained from the stem and root portions of *Santalum album* yields a mixture of around 70 constituents which are mostly sesquiterpenoids, and the most prominent among them are the α- and β- santalols. These santalols and many of their oxidised derivatives have been isolated, and proved to have various medicinal properties and impart fragrant odour. Though the other sandalwoods (other species of the *Santalum* genus) can produce comparable levels of these compounds, the oils derived from them are commercially less valuable. However, natural supplies of *S. album* are now virtually non-existing mostly due to illegal felling, and only the trees grown in plantations have salvaged the species from becoming extinct.

However, its cultivation is hindered by many factors. Apart from the silvicultural intricacies, the health and security of the tree are the most concerning. Slow growth rates and variation in sandalwood oil content also hamper sandalwood production. Moreover, the production of the essential oil yielding heartwood in the tree is governed by many unproved factors. All this had led researchers to attempt developing technologies for artificial synthesis of the compounds in the sandalwood essential oil. The efforts to chemically synthesize α- and β- santalols began in 1970s, but the feasibility of chemical synthesis was reported only in the 21st century owing to the structural complexity of these molecules. Nevertheless, devising an industrial mechanism for large-scale production did not seem to be cost-effective, and the quest for alternative approaches still continued.

Constituents of sandalwood oil

The actual composition of the *S. album* essential oil is highly complex. Comprehensive analysis of the oil by Brunke (Dragoco) in 1995 showed that (–)-(Z)-β-Santalol is largely responsible for the highly appreciated creamy, lactonic, sandalwood odour of the oil.



Greater than 90% of the sandalwood oil is composed of α-santalol and β-santalol. The remaining constituents are hydrocarbons (α-santalene, β-santalene and epi-β-santalene), aldehydes (tricycloekasantalal, exo-norbicycloekasantalal and teresantalal), ketones, phenols, acids (teresantalic acid), and heterocyclic compounds. Though they are collectively responsible for the characteristic odour of the oil, the exact quantity of each of these compounds is not the same in oils extracted from different trees. Many factors have been attributed to this difference in composition of sandalwood oil including geographical origin, climatic variation and the extraction method employed.

Chemical synthesis

A wide variety of novel and fascinating odorant structures which are part of essential oils have been isolated from natural sources. (–)-(Z)-β-Santalol enantiomer is the gold standard solely responsible for the esteemed odour and highly reminiscent of the sandalwood essential oil.

Whereas processing and obtaining essential oils is often time consuming, energy and labour intensive, and often requiring solvent extraction, they upsurge the prices of essential oils and their synthetic versions offer sustainable supply at constant quality and reasonable price.

The widespread shortage of mature sandalwood trees and an ever-increasing rise in the price of natural sandalwood oils led researchers to explore for their synthetic substitutes. Devising a synthetic route to the principal constituents in sandalwood oil has challenged chemists for about half a century, as the molecule's right isomer and enantiomer with a specific orientation of the sidechain was required. The structure of α-santalol was precisely identified by Semmler in 1921, and Ruzicka elucidated the exact gross structure of β-santalol, at the end of 1935. In 1967, α-santalol structure was confirmed by Erman, while that of β-santalol was confirmed only in 1970 by Erman and Kretschmar. From then, considerable efforts were made to synthetically develop the natural fragrance compounds of sandalwood oil and semi-synthetic approaches were also tried, mostly for α-santalol and β-santalol. But it was not until 2004, that Dupau demonstrated the four-step sequence from an aldehyde to the installation of the key (Z)-allylic alcohol as catalytic, industrially feasible and efficient.

Advances in genetic, metabolic and protein engineering make use of enzymes to synthesise required chemicals.

Though the chemical synthesis of the santalols was successfully achieved, the manufacture of the synthetic santalols did not become a practical possibility, since the mechanism involved many steps and required the use of difficult-to-handle reagents in the industrial-scale, and the overall yields were also generally low. Consequently, research was then directed towards obtaining synthetic substitute compounds possessing the fragrance of sandalwood by economically and commercially feasible processes using easily available and low-cost starting material. Some important synthetic sandalwood aroma chemicals were thus synthesised viz., Sandranol, Sandalore, Sandela, Santalydol, Osyrol, Polysantol, Brahmanol, Decahydro β-Naphthyl Formate, and various condensates possessing sandalwood odour or structures similar to santalol.

Alternative biological synthesis

Since a method for chemical synthesis of all the sandalwood sesquiterpene constituents is not yet available, the search was still on for an alternative to the naturally extracted sandalwood oil through a more energy and resource efficient process. Research was hence focussed on producing biologically derived synthetic versions of the sandalwood oil constituents. Plant cell and tissue culture techniques, which are employed for the synthesis and extraction of a variety of plant extractives, were thus explored. Crovadore's team of researchers attempted to produce sesquiterpenes of the sandalwood essential oil from *S. album calli,* and their method for in vitro production of β-santalene was patented in 2010. At the end of 2012, Misra and Dey reported the presence of santalols in the extracellular medium when somatic embryos of *S. album* were cultured in air-lift bioreactors. However, sandalwood oil production using in vitro cultures is still in its infancy and has not progressed further, since production of individual compounds has only been achieved so far.

Advances in genetic, metabolic and protein engineering make use of enzymes to synthesise required chemicals. Metabolic engineering of living microorganisms to produce specific sandalwood oil compounds using regio- and stereo-specific enzymes offers a sustainable and environmentally friendly alternative. The genes coding for the enzymes of a metabolic pathway leading to the production of one of the constituents are transferred to another single-celled organism, whose growth and expression of the inserted genes can be controlled using fermentation technology. Escherichia coli and Saccharomyces cerevisiae are easy to engineer heterologous hosts using which the production of santalols and santalenes has been shown to be possible. Large-scale industrial production has also been achieved, and these biologically produced synthetic versions have been traded as syn-bio sandalwood oil, like Isobionics® Santalol.

Conclusion

As early as 1984, Shankaranarayana and Parthasarathi of the then Sandalwood Research Centre, Bangalore rightly stated that, "while a host of considerations led to the development of a multitude of synthetic sandalwood aroma chemicals, none of them is a match to the natural East Indian Sandalwood oil in its sweet, fragrant, persistent and woody odour, or possesses its many medicinal properties". On the contrary, oils produced through alternative biological methods may be labelled "natural", but they are not sourced from the traditionally and biologically natural producer, and most importantly do not contain all the components of the traditional sandalwood oil.

The existing methods of natural sandalwood oil production are not without problems, but it should not imply that synthetic techniques are the only remedy. Though the santalols are individually key molecules that typically recall the odour of the essential oil, the odour of the sandalwood oil is infinitely more rich and complex than those pure odiferous principal compounds. Same holds good for the synergetic medicinal effects rendered by the absolute sandalwood oil, which may not be realised with its individual constituents. Future attempts can focus on carrying forward the preliminary efforts on extracting sandalwood oil constituents from in vitro cultures of the natural source i.e., *Santalum album.* But developing such a technology also has a long way to go, because the mechanism to elicit constitutive in vitro production of all the constituents must first be invented, which is nearly impossible. Right now, we are bound to be satisfied with the fresh scents of chemical or biological synthetic versions, at least until the sandalwood tree regains its past glory with increased populations that remain protected. And then, the ancient aroma will drift afresh.

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A Variant Maneuvers from Aromatic Wood – A Rich Heritage of Vitality Continues

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Introduction

Sandalwood is a valuable aromatic wood produced from trees of genus *Santalum*. Its importance is mentioned in Sanskrit and Chinese manuscripts. It is considered as sacred and symbol of vitality. Sandalwood is often cited as one of the most expensive woods in the world. In India, it is largely distributed in Southern India especially in Karnataka, Kerala and Tamilnadu. The species is recognized due to its fragrance and significant social and economic values. It is apppellated by several vernacular names such as Chandan in Sanskrit and Hindi, Chandanam in Tamil and Malayalam, Gandham in Telugu and Shrigandha in Kannada. The nation has a rich heritage with the Scented tree being prominent in many areas but unfortunately, the production of Sandalwood has decreased because of decimated sandalwood numbers, while the demand continues to increase.

The Scent Finds its Way in Following Stretches

1. Sandalwood in Religious Rituals

In hinduism, it is believed that goddess Lakshmi lives in Sandalwood tree. The essence of the wood spreads positive energies across the place. It is used to worship most of the holy deities preferably god Shiva. The fine paste of Sandalwood powder is intrinsic to rituals and ceremonies as a custom. It is applied on foreheads as a "Prasada" a gracious gift of god after religious tonsure. (Harishankar et al., 2014). In buddhism, it is considered as padma (lotus) and offered to Amitabha Buddha. It is the most popular scent used in incense while offering to guru.

Similarly, It is used to worship Jain deities Thirthankaras. During Jain cremation ceremonies, sandalwood garlands are used. On the occasion of Mahamasthakabhisheka, the statue of Gommateshwara is showered with holy elements and sandalwood is one among of it. As a part of sufism tradition, sandalwood paste is applied on graves to symbolize devotion and respect. This culture is practiced among Tamilians also.

2. Sandalwood in medicine

For centuries, Sandalwood is been included in Ayurveda, Chinese and Tibetan traditional medicines. In Ayurveda the sandalwood oil is treated as a cooling, exhilarating, antipyretic, expectorant and stimulant. It is also used as astringent to the bowels and as an aphrodisiac. In Siddha medicine, sandalwood paste with lime juice is recommended to treat itching, scabies, eczema and other skin problems. During leucorrhea sandalwood paste is consumed with milk as a remedy. In Unani, sandalwood is applied on forehead during fever in order to dissipate the effect of heat and provides coolness to the body. In India specially in south, people do apply "gandha" on their body and on their foreheads during fever, as it is anti-pyretic and lowers the "ushna" (body heat) and offers cooling effect. It is also applied to inflamed sites of body or on boils and effective in curing skin diseases. For genito-urinary problems sandalwood decoction is recommended and for migraines sandalwood paste is applied on nostrils for relief.

Sandalwood scent is mainly known for the benefits of aromatherapy. It promotes mental and physical health by lowering the spasm and contraction of muscles and blood vessels and stimulates sleep with goodness of Santalol, which is an active compound. Along with the anti –inflammatory property, Sandalwood oil is also a good antimicrobial agent. It is broadly active against many drug resistant microbes like *Staphylococcus* (including antibiotic-resistant strains MRSA and VRSA), *Streptococcus*, and some vancomycin resistant gram-negative bacteria (Morris et al., 1979). Through natural means sandalwood paves a way to

treat drug resistant diseases.

Sandalwood is significant in treating dandruff and dermatophytes. In the journal Nature Communications, it is noted that aromatic oil stimulates release of 'hair growth factors" which includes vitamins and hormones essential for promoting hair cell follicles multiplication. Sandalore is thought to promote hair growth by acting on the smell receptor OR2AT4, which is present in hair follicles. (Deccan chronicle 2018). In Thirupathi, devotees who offer their hairs to god 'keshamundana', will apply sandalwood paste on their bald head. This is a traditional practice tagged with medicinal value.

3. Sandal in beauty aids

Sandalwood provides multiple advantages to skin. Traditionally it's been in practice with regular face packs and ailments. Its active key ingredient is alpha–Santalol, which is an inhibitor of tyrosinase, a key enzyme in synthesis of the skin pigment melanin. So it contributes in skin lightening effects. Sandalwood helps in reducing scars, wrinkles, inflammation, psoriasis, acne, eczema and other skin aided benefits. Sandalwood oil nourishes the skin and improves the elasticity of skin and even out skin tone. It also contains antioxidants which prevents free radical formation in skin and helps to maintain buoyancy of skin cells. In India, most home remedies prepared by grandmothers included sandalwood as special element for skin treatment. Sandalwood oil is very popular and widely used. It is often added to soaps and lotions. Sandalwood soap in tropical countries like India is useful as it potentially reduces sunburns. The smooth scented oil imparts hydrating, anti-ageing, cleansing, de-toning and moisturizing effect making it the perfect classic ingredient in most beauty aids especially in soaps and creams. As a tradition, at some places, it is included with regular base oils like almond or jojoba oil for scalp. As hair oil it stimulates hair growth and cools the scalp, eliminates dandruff and contributes a unique fragrance to the hair and smoothens the hair texture. It is also used as body massage oil. Hydrosols of sandalwood is used to smoothen the face and as a hair mist (Reema Patel, 2021).

Sandalwood holds sweet and solid long lasting cologne. Most Indian attars use sandalwood oil as the base because of its inherent capacity to absorb ethereal notes of other whole herbs or flowers and enhance their perfumery status and stability. The goodness of its fixative property is used to make top –class perfumes and essential perfume oil which revivifies mental calmness.

4. Sandalwood in microscopy

It is used as immersion oil with Ultraviolet and Fluorescence microscopy due to its optimal refractive index and less fluorescence property. Immersion oils for UV wavelength range must have extremely low or no fluorescence, serving non hazyto the field and making images distinct. Fluorescence material contradicts this property. Sandalwood oil is classified as "non-fluorescent," hence they are signified in this area (Bannerjee et al.,1981).

5. Sandalwood in food

On FDA approval recommended quantities of therapeutic graded essential oils are used to add flavor and fragrance to many foods and soft drinks. Sandalwood oil is used by many food industries in India as a flavor enhancer. It is used in chewing gum and bubble gum to enhance the taste. It is also used to give intense flavors to products like candies, frosting, butter cream fillings. (Das, 2016).The sandalwood oil is also used as an additional factor in baking aided with moisture retaining capacity with addition of good texture to baked products like cakes, cookies, puddings etc.

The strong sweet and long lasting odor makes sandalwood oil as a preferable ingredient in beverage industry. It is added to vodkas and liquors like brandy as a primary or supplemental flavor. Due to high amount of α-santalol in sandalwood oil it is blended with chocolates under recommended amount in order to reduce anxiety and to provide fine and new taste. (Hongratanaworakit et al.,2004).

It is also used in non-alcoholic beverages like fruit and vegetable juices. Flavored creams are prepared with addition of few drops of sandalwood oil to keep the drink fresh and delicious. They are used in tonic

preparations too. Sandalwood oil is added to mineral water to enhance the flavor and also for its therapeutic value.

Sandalwood oil is used in extending shelf life of food products like meats, fish, cheese, fowl, fruits and vegetables because of their antimicrobial property. They render natural preservative advantage and also mask unpleasant tastes or smells in food products. They also possess good antioxidant property. Sandalwood oil is also used as a flavor stabilizer. Sandalwood produces an edible nut which tastes like almond.

6. Sandalwood as disinfectant and as air refresher

Sandalwood possess a strong endurant smell. Because of this noteworthy feature. It is used in camphors and dhoop in order to spread the smoothening scented fumes around. In ancient practices it was used in order to avoid cockroaches and other infectious agents. This practice has been followed with advanced technology and formulations, resulting as good disinfectant, killing a broad range of bacteria and fungi. Hydrosol or floral water extracted via steam distillation from sandalwood is a pleasant way to refresh small rooms.

Sandalwood as furniture

Due to its hard characteristic, sandalwood exhibits good furnishing property. They are moisture proof and offer compact structure. In the process of using sandalwood furniture, its abrasion resistance is better than other solid wood furniture, so the service life of sandalwood furniture is very long. It possess beautiful oily texture with more decorative effects. With the above mentioned properties, sandalwood is used in many decors like idols, doors, beds, tables and other furnishing items. Due to heavy logging in the past few years, the wood of sandalwood has become increasingly scarce, so authentic sandalwood furniture on the market is particularly expensive.

In India, white sandalwood is majorly used to showcase rich heritage and as a symbol of high respect. Sandalwood garlands made up of sandalwood chips or remnant bark pieces are noteworthy. Among government bound places, the spectacular furniture and decors are displayed. The exquisitely carved sandalwood door leading to the cabinet room of the imposing building at Vidhana Soudha in Bengaluru is magnificent. The carved images of gods and mythological figures have a huge demand in the market.

Conclusion

India was once a world leader in sandalwood production. However, over the year smuggling became rampant due to the wood's high value and demand in the market. Thefts gradually decimated the sandalwood forests. Royal tree status-a tag indicating the exclusive proprietorship of Government, not only hampered Sandalwood tree cultivation, but also indirectly resulted in over exploitation. It has got immense uses in various industries. Some of the potential uses of sandalwood are untapped. Lack of quality sandalwood is still a major constraint for this. Consistent efforts in terms of scientific research are needed for product diversification and value addition.

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SANDALWOOD - The fragrance of the world (Sandalwood species around the world)

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Sandalwood tree belongs to the family Santalaceae, the gnus "*Santalum*" grows naturally throughout the Pacific and EasternIndian Ocean regions. Sandalwood trees are evergreen ranging in size from tall shrubs to large trees. They grow n variety of climates ranging from Australian desert to sub-tropical New Caledonia and at elevations from sea level to 5000 meters. It is distributed in peninsular India, parts of Malaysia, Australia, New Zealand and Polynesia extending to the Hawaiian Archipelago and Juan Fernandez islands, The species belonging to this genus are generally root parasitic plants, equipped with special structures (haustoria) on its root that penetrates the root of host plants to obtain nutrients.

The genera contains sixteen recognized species and more than 12 varieties, distributed throughout the world. Out of them only sevenspecies, produce commercially exploitable scented heartwood and oil (*S.album, S.yasi, S.spicatum, S. lanceolatum, S austrocaledonicum, S.mecgregorii,* and *S.paniculatum*). These are important species for their fragrant scented heartwood and for essential oil. Other species of Santalum also produce fragrant wood and oil, however their contribution to the essential oil industry is limited.

All species occur in natural forest in different habitats. Most of the species are over exploited and are under threat as endangered species. The demand for the scented heartwood and scented natural sandalwood oil is on the increase and the supply is on the decline. Because of inconsistent supply, the price is fluctuating and has gone steeply depriving its use in various industries. The only alternate left is to produce sandalwood commercially with high input and management technique to a short rotation crop.

The genus represented by ***Santalum album***Linn., produce rich heartwood and oil. It is known as "East Indian Sandalwood" and the distilled essential oil from it as East Indian sandalwood oil". East Indian sandalwood oil is the queen of all sandalwood in the world, in quality and fragrance. The heartwood upon distillation yields 4 to 6 percent oil. Its use is in perfumery and medicine. It is naturally found in India, Sri Lanka and Indonesia and introduced to different countries for its lucrative returns. It is highly adaptive to different tropical countries.

S.spicatum, (R.Br.) ADC, popularly known as West Australian sandalwood, it is one of the

important species producing scented heartwood and oil. Sandalwood has been exported to different countries since 1844. The oil has different chemical composition and has better medicinal properties. Compared to other sandalwood oil. The heartwood is dark brown and the sapwood is white and combatively less. The scented heartwood yields about 2 to 2.5 percent oil. The essential oil is used in perfumery, incense sticks, soaps and toiletries and aromatherapy. Wood is used for carving.

S. laceolatum (R.Br) is the second major resource of sandalwood to native Australia. It is known as "Plum Bush" native to Queensland. The sapwood is pale yellow and the heartwood is dark brown. The scented heartwood on distillation yields about 2 to 3 percent oil. Chemical composition of oil is different compared to other Santalum species.

S.austrocaledonicum, The tree is native to New Caledonia NC, and also found distributed in the main island of Archipelago of New Caledonia and Vanuatu of south Pacific. Plants are having greater economic potential, the heartwood is slightly yellow and good material for carving. Scented heartwood yields about 4.5 percent oil on distillation. Essential oil is similar to East Indian sandalwood but not identical, it blends well with other essential oil. Attempts are being made to hybridize with S. album. The oil is highly priced and very much sought after in the perfume industries.

Santalumyasi.It grows in Fiji, Tonga and Papua New Guinea Island, Its scented heartwood and oil is equivalent to East Indian sandalwood. It is capable of growing in various types of soil. In Tonga its best development is on soils derived from volcanic ash overlaying coralline rock. It grows to a height of 15 meters with a maximum bole of 40 to 50cm at GBH. Leaves are typically linear simple and opposite. Scented heartwood upon distillation yields about 5 to 6 percent scented oil.

Hybrid sandalwood is found only Fiji, Tonga and Papua New Guinea islands.

Grafting

One year old root stock of *S. album* has been grafted with mature Santalumyasi clones. Micro grafting trials with scions of *S.yasi* trees grafting on *S.album* germinant has been very successful. It seems the growth performance of these hybrids are more than two folds compared to *S.album or S.yasi*.

Hybrid plants

It has been reported that native Fijian species is able to naturally hybridize with *S.album*. The seeds collected from *S.yasi* trees in a mixed population with *S.album* gave 20% hybrid seeds. Hybrid sandalwood seedlings showed growth rate almost twice to that of *S.yasi*. Scented heartwood on distillation have yielded more than 7 % essential oil. Sandalwood oil is almost equivalent to East Indian sandalwood oil in both physical and chemical properties.

S.macgreigorii. F.V Mullar **(PNG sandalwood).** The tree is endemic to southern Papua New Guinea. Tree size varies from small to medium and grows to a height 8 to 10 meters, often multi stemmed. Morphologically the tree resembles to *S.album*. The commercial value of sandalwood depends on its heartwood content. Heartwood is slightly brown in colour and yields 3 to 5 % essential oil. The quality of oil is low due to lower santalol content. It blends well with other essential oil.

Hawaiian sandalwood (*Santalumpaniculatum*)

The tree is endemic to Hawaii Island. It occurs in in dry wood land forest areas of Lava substrates or in Cinder cones. The trees are grouped under green colored species. The tree is called mountain sandalwood. It is only found in big island. Heartwood is brown in colour and yields about 2 to 3 % essential oil. Sandalwood has a god history behind and is more culturally attached to different religions, and the product derived from it have been in use for several centuries.

Other species of "Santalum" are only of academic interest since their production and contribution to the essential oil industry is limited, however they are the important species of the region contributing to the cultural heritage and use. There are more than 56 species and varieties of "*Santalum*" mentioned in the literature, based on the morphological characters.

Sandalwood Society of India

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Sandalwood Society of India (SSI) is a registered body (vide registration no SOR/GNR/139/2014-15) under Karnataka Society's Registration Act 1960. SSI is also registered with Niti Aayog (no139/2014-15). It is a non-profit organization actively involved promotion of Sandalwood cultivation across the country having headquarters in Bangalore and regional clusters in Tamilnadu, Telangana, Gujarat, Maharashtra, Orissa, Rajasthan and Assam. The society was formed with a mission to promote natural, sustainable, and legal production of sandalwood and its end products to meet global requirements by involving farmers, entrepreneurs, scientists, and end users.

The objective of the society is to meet the aspirations of the farmers, entrepreneurs, and end users, keeping in mind the global demand and supply of sandalwood with the involvement of all stakeholders. Further, focus has been given for the promotion of sandalwood and its allied products to achieve 10-15% of market share particularly in perfume sector. The concept of production of natural sandalwood from soil to oil by utilizing the lab to land and ends up with value added products chain viz. Toiletries, cosmetically, Neutraceuticals, Ayurveda, pharma preparations including high end life style products.

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Key Activities

SSI has taken up initiation to enlarge private plantation to the tune of over 173,000 acres across the country. In Karnataka 49000 acres of sandalwood has been cultivated in their lands. The rate of annual growth of plantation is more than 10%. Society is equipped with senior scientists with more than 30 years of experience in sandalwood and other agro forestry species, retired IFS officers, technocrats and industrialists. The society's knowledge bank is tremendously helping farmers who regularly seek help in all cultivation & preservation aspects.

SSI has already delivered capacity building training to more than 2000 forest officers and field staff of Karnataka Forest Department on sandalwood Seed Technology, Nursery Practices, Sandalwood Planting designs, Plantation Technology, Pests and diseases control, Insect management, Protection of

sandalwood plantations, Value added products developed from sandalwood seed oil, Legal issues of different states, Trade and marketing of Sandalwood. Society has tie ups with Krishi Vigyan Kendras, University of Agricultural Sciences, Vana Vigyan Kendras, IWST and Karnataka Forest Department for establishing different agro forestry models with sandalwood to help farmers maximizing the benefits.

Society frequently conducts training programs for farmers from different states. So far SSI has trained more than 9000 farmers and numbers are growing. SSI is on the verge of developing many products from sandalwood seed oil for the first time in the world. They are anti ageing creams, sandalwood health drink which aims at reducing diabetic levels, Sandalwood Seed husk as animal feed etc. This will generate regular revenue both to farmers and governments.

SSI is capable of acting as coordinating body for growers and end users to meet the emerging demand and supply of sandalwood & its products. This will help farmers, end users to obtain insurance, and banking assistance. SSI is willing to help state governments in building forest infrastructure involving Sandalwood, *Melia Dubia*, and other agro forestry, horticulture and agricultural species as consultants and training partners.

- Sandalwood society of India provides technical input to nurseries to grow healthy saplings.
- The society also conducts onsite training Programs.
- Sandalwood Society of India develop different Agro forestry models.
- To provide a common platform for all sandalwood growers & industries.
- It is non-profit organization with the focus on Production utility, educational, research on sandalwood.

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Published by:

Institute of Wood Science and Technology, Bengaluru
Indian Council of Forestry Research & Education
(An Autonomous body under Ministry of Environment, Forest & Climate Change)
P.O. Malleshwaram, Bengaluru - 560 003, Karnataka, India
E-mail: dir_iwst@icfre.org | Website: https://iwst.icfre.gov.in

For copies, write to:
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Designed by: **Samvida Communications (OPC) Pvt. Ltd.**
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