DRAFT ON

MARKETING OF SANDAL WOOD GROWN ON PRIVATE LANDS

Introduction to the Species:

The sandalwood tree is a semi-evergreen tree, that has a diphylic origin of both Timor (Indonesia) and peninsular India. There are diverse views on its origin; while Fischer (1928), Thirawat (1955), and Rajagopal Shetty (1977) are of the view that Sandal was introduced to India from Timor in Indonesia, Krishnappa (1972) Majumdar (1941) and Ramaswamy (1956) have reported that Sandal is indigenous to India. Approximately 10 species of *Santalum* are distributed throughout South Eastern Asia and the islands of the South Pacific. But only the *Santalum album* contains 80 to 96 percent of Santalol in its heartwood, whereas the rest of the nine species yield very negligible quantities of Santalol.

In India, the *Santalum album* is distributed all over the country and more than 90 percent of the Sandal tract is situated in Karnataka and Tamil Nadu over 8600 sq km of the area; the balance 10 percent is scattered over Andhra Pradesh, Telangana, Kerala, Maharashtra, Madhya Pradesh, Orissa, Rajasthan, Uttar Pradesh, Bihar, and Manipur.

Sandal was regenerated naturally through root suckers and also through seed dispersal by birds. Sandal being a semi–root parasitic tree species, needs the physiological support of host plants for its' survival and initial establishment. Species of *Ficus*, *Acacia*, *Albizia,* and *Casuarina* serve as effective hosts for Sandal. Silviculturally, Sandal is intolerant to overhead shade during the middle and later years but needs lateral shade during the early years of establishment.

Sandalwood saplings are affected mainly by grazing. So, the Sandal plants that grow in bushes get protection in their initial years of establishment from grazers and browsers. Drought and fire are other

major factors that affect their survival in their initial years of establishment. Smugglers cut the trees and dig the roots also, and it eliminates the chances of getting regenerated through root suckers.

Uses of Sandal Wood:

(A) Fragrance

Sandalwood contains essential oil which is in great demand and is widely used in the cosmetic industry.

Oil extracted from closely related species like *Amyris balsamifera* (West Indian Sandalwood), which, belongs to the family of Rutaceae is used as a substitute for sandalwood oil.

(B) Religious use:

Sandalwood is often used by Hindus in ceremonies. It is used as an embalming paste in temples on idols. In Buddhism, Sandalwood is considered to be of the Padma (lotus) group and attributed to the Bodhisattva.

Sandalwood, along with agarwood, is the most popular and commonly used incense material by the Chinese and Japanese in worship and various ceremonies. It is also used extensively in Indian incense, religiously or otherwise.

(C) Medicine:

Sandalwood essential oil was popular in medicine up to 1920-1930, mostly as a urogenital (internal) and skin (external) antiseptic. Its main component beta-santalol (90%) has anti-microbial properties. It is used in aromatherapy and to manufacture soaps. Due to this anti-microbial activity, it can be used to clear skin from blackheads and spots.

(D) Immersion Oils

Due to its low fluorescence and optimal refractive index, Sandalwood oil is often employed as immersion oil within ultraviolet and fluorescence microscopy.

(E) Food:

Aboriginals in Australia eat the seed kernels, nuts, and fruit of Sandalwood.

(F) Handicrafts:

Sandalwood is one of the finest woods for carving and ranks high in its smoothness, uniform fibres, straight, close grains, and freedom from knots which make it easy for intricate workmanship.

Sandal Ecology:

Sandal prefers an altitude of 700 meters above MSL, where the heartwood formation takes place in commercial quantities and value. Sandal spreads to lesser altitudinal zones also through natural regeneration which of course develops only into non – commercial scales. Altitude has the greatest effect on size of tree growth and heartwood formation.

Even though Sandal grows up to an altitude of 1800 meters above MSL and areas with rainfall range of 300 mm to 2540 mm, good heartwood formation is obtained only at altitudes between 600 – 900 meters and a rainfall range of 850 to 1350 mm.

It is found that the Sandal trees growing on infertile gravely soil have high oil yield and better fragrance. In ideal sites, a mature tree attains a maximum height of 18 meters and a girth of about 250 – 300 cm.

Influence of Soil on the growth of Sandal Wood trees:

This species is frequently found on rocky ground and stony, gravely, and shallow soils. The Sandal grows well on red ferruginous loam soils (with underlying metamorphic and gneiss rock formations). It grows best on fairly moist fertile soil with good drainage. However, this species has high adaptability and comes up well on most soils except on saline, calcareous, and black cotton soils.

Sandalwood trees can't withstand water logging and need good drainage. Sandal requires the support of host plants for the intake of potassium, phosphorus, and magnesium and can draw other nutrients directly from the soil.

The incidence of spike disease in Sandal trees is caused by to deficiency of nitrogen in the soil, thus the soil plays an important role in the survival and growth of sandalwood trees.

Climate and its influence:

Climate is the most important deciding factor that decides the distribution, growth, and development of Sandal trees.

In drier localities, heartwood formation takes place well. This species grows well at an altitude of 500-1000 mts and in the areas that receive mean annual rainfall of 800-1000 mm.

Considering the Geography, altitude, and rainfall received in the State of Telangana, it is expected that Sandal Wood trees will yield oil with high commercial value.

Silvicultural System

During the early stages works like tending and intercultural operations improve the quality of sandalwood trees. Sandal trees regenerate profusely through their root suckers. The root suckers can be activated through an intercultural operation which supplements natural regeneration. The sandal trees are to be protected from Grazing and fire.

Phenology of Sandal Wood trees.

The Sandal normally flowers, and seeds from 3rd or 4th year onwards (Troup 1921). The seeds which are dormant initially for two months retain their viability for 10 months.

They profusely germinate and colonized the area during this period. In such areas, a good distribution of different age classes occurs, and

management of such a stand is done in **the natural forests under a "uniform system" of management.**

Rotation:

In the natural forest settings, the rotation period for the Sandalwood trees is not fixed, as the natural forests are maintained under a **Selection System**, so only the dead, dying, and diseased trees be removed**.**

But, in the plantations, based on the experiences gained the rotation period can be fixed at 25 years as it will be the minimum time required for heartwood formation in Sandal trees.

Harvestable diameter

In the natural forests, the harvestable diameter is not fixed only dead and diseased Sandal trees are removed by following a natural selection system as a silvicultural system in the management of Sandal forests.

But, in the plantations raised on private lands, harvestable diameter differs from place to place. The ideal girth is about 30-40 cm. If possible, the heartwood formation in the sandal trees can be accessed through the **Increment boring method and/or by Electric Resistance Tomograph (ERT) methods**, and accordingly the suitable trees can be harvested.

Limiting Factors for the Sandal Wood Trees:

Spike disease that is transmitted by insects is the limiting factor for its existence. The factors that promote the occurrence of spike disease are low availability of soil nitrogen, heavy infestation of *Lantana* weeds, death or damage to host plants through suppression by weeds, and occurrence of fire and drought.

Spike Disease in sandalwood trees was first noticed in 1898 and the Sandal trees died a few months after getting infected. Even though the

disease kills the trees, it does not affect the value of heartwood already produced before infection.

Tending and weed removal:

Growth in Sandal trees gets suppressed due to factors like overhead shade or due to the presence of weeds and climbers. Therefore, it is proposed to carry out the following tending operations. Tending operations are to be done between November to March.

1. Making Sandal seedlings free from climbers: Judicious pruning of overhead trees that are causing shade is done to ensure proper light to Sandal seedlings. Tending shall consist of cutting down climbers and overhanging branches on all green Sandal trees over 1.5 meters in height.
2. Removing the obnoxious weeds that hinder the growth of seedlings is to be done for the proper growth of Sandal trees. Weeds can be easily controlled by using weedicides, and herbicides. For the control of weeds, ploughing the field by using of rotavator at regular intervals is recommended. If the budget allows, the corporation can go for using weed mats. A 5-10 cm layer of wood chip mulch also prevents weeds from growing in the field. Gravel can serve as inorganic mulch, but can prevent weed growth.

Regeneration

In the natural forests, the regeneration of Sandal Wood is achieved through the sowing of sandal seeds mixed with the seeds of other species (preferably the species that can fix atmospheric nitrogen) on the ridges of contour trenches.

The dimensions proposed for the trenches are 3mt x 45cm x 30cm with a distance of 3 meters end-to-end between one trench and another along the same row or contour (6 meters apart center-to-center). The soil of the mounds formed on the lower side of the trenches should be well-

loosened and broken up and should be free of clots. Overhead shade for the ridge should be provided to the extent possible by retaining trees near them. The preparatory works should be completed by the end of May

Dribbling of seeds in the bushes is also one of the techniques practiced (for artificial regeneration of Sandals) with successful results all over forests in India. In the areas where regeneration is attempted through the dribbling method, naturally growing bushes should be retained to avoid invasion of weeds such as lantana and Sandal seeds should be dibbled under these bushes. These will provide effective protection against browsing and function as hosts to young saplings of Sandals.

Germination of sandalwood is profuse and even under relatively inhospitable conditions; Sandal germinates and grows if it gets its significant root connection established with host, as the sandalwood tree is a semi-parasite at an early stage.

Importance of quality of the seed:

The Quality of sandal wood is dependent on the seed source. As on today, the following areas are developed as SPA. Procuring seed from such sources gives quality seedlings:

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.

The QPM can be obtained from the clones like **SRC clone -1**. This clone was derived from **plus tree T- 01 Sholapuram Pudukottai, Tanjavur**, which was 8 years 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.

Seed collection and storage:

Only fruits of the first season (ripening from January to March) should be collected for use in the same year. Seeds should be collected from healthy mother trees of over 40cm. in girth with well-developed crowns and large-sized fruits. Immediately after collection the fruits should be put into water and the pulpy outer portion should be removed. The de-pulped seeds should be washed and dried under shade and stored in gunny bags.

Pre-Treatment of the seed:

Seeds are to be collected from superior trees during April-May and September-October. Fresh seeds weigh about 6000 seeds to a kilogram and take 4-12 weeks for germination after the dormancy period. 80% of the seeds are viable for up to 9 months. Germination is about 80% under control conditions and 60% under field conditions. Germination can be hastened by pre-treatment by acid scarification with concentrated H2SO4 for 30 minutes with stirring and washing in running water or by soaking seeds in 0.05% of Gibberellic acid overnight and then sowing. Soaking seeds in cow dung doesn't improve germination.

Unique traits of Sandal Wood trees:

Traits unique to S. album are: **(a)** being predominantly outcrossing, **(b)** ability to grow under diverse conditions such as very low rainfall and wide variety of soil types, **(c)** innate survival capacity, **(d)** short juvenile phase and flowering by the end of 3–4 years, **(e)** over 60% of plants flower and bear fruits twice a year, **(f)** dispersal of fruits by birds and other animals, **(g)** easy seed establishment and **(h)** profuse coppicing ability.

The above traits of Sandalwood give it a great capacity to adapt to various climatic regions of India. The following table gives information on variation in growth, oil %, and heartwood content of sandalwood plantations with different secondary hosts sampled across 9 locations in

six states, supporting that sandalwood trees have great adaptability, but the formation of heartwood, and oil differs from place to place.

Sl. No.	Location	State	Age Group	GBH	% HW	% Oil	Secondary Host	No of trees sampled in the Age Group
1	Muddanhalli,	Bengaluru Rural	**9**	44.5±10.38	76.85±8.59	81±0.25	*Phyllanthus emblica*	**4**
2	Bevanhalli Chickballapur	Karnataka	8	44±5.08	64.77±9.3	0.794±0.35	Grafted *Mangifera indica*	**10**
3	Gungargatti, Dharwad	Karnataka	**11**	48±9.57	62.89±8.66	1.55±0.49	**Misc**	**7**
4	DSG, Katni	Madhya Pradesh	**9**	48±6.88	37.07±13.88	1.89±1.96	*Phyllanthus Emblica, T.arjuna Pongamia pinnata*	**16**
5	Birsnour, Patiala	Punjab	**20**	80±5.74	62.78±17.76	2.32±0.63	*Leucaena leucocephala*	**5**
6	Mehsana	Gujarat	**10**	54.2±12.74	43.73±20.38	0.64±0.45	Citrus sp	10
7	Mahua	Gujarat	**10**	59.83±7.94	67.95±6.33	4.07±0.80	*Mangifera indica*	
8	Sadri	Rajasthan	**9**	56.2±10.94	48.20±21.43	0.45±0.35	*Azadirachta indica*	**5**
9	Vellore	Tamilnadu	**17**	58.71±7.36	59.09±11.48	3.92±0.38	*NA*	**14**

*(**Source**: Sandalwood Farming In India: Problems And Prospects, By Babita Mishra, Sandeep Chakraborty, Sandhya Mc And S Viswanath published in Indian Journal of Tropical Biodiversity)*

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

Planting Methods:

1. **Planting through dribbling of seed into bushes**:

The soil under the bushes will be raked with a long-handled soil raker over an area of 1'x1'. About 4 to 5 seeds will be dibbled in this area. To keep account of the bush sowing spots, paint-numbered pegs will be erected near the bushes.

This planting method is adopted in open scrub jungles with lot of bushes. The seeds are sown during monsoon. A long bamboo pole of 4 to 6 cm internal diameter and 1.5 m long can be used to sow the seeds. The septa at the nodes are to be removed and one end of the pole is

sharpened, or a hollow metal piece is attached to rake the soil. The pole is introduced at the base of the bush and through the hole four to five seeds (a mixture of seeds) are transferred to the base of the bush. Fairly success has been achieved by this method.

2. **Dribbling of Seeds in Pits or Mounds:**

The usual trench mound technique adopted for afforestation for other species of trees can also be adopted for Sandal, but here a perennial host plant is also grown along with Sandal either on the mound or by the side of the pit.

Sowing should be done on the mounds in about mid-June or earlier according to the onset of the southwest monsoon. Seeds of the following species may be mixed with those of Sandal at the time of sowing: different species of Acacias like Senegal catechu (A. sundra), umbrella thorn (A. planifrons), *Senegalia ferruginea, Albizia amara, Albizia lebbeck, Cassia siamea, Cajanus cajans, and Calotropis gigantea, etc.* The seeds of these host species will require pre-treatment by soaking in just-boiled water for a minimum of 12 hours.

(iii) Planting Container-Raised Seedlings in Nurseries:

Raising of nursery: Sandal and host seed may be sown in two different beds. Seedlings of sandal trees can be grown equally well in Sunken and raised beds.

Seed beds are formed with sand and red earth in a ratio of 3:1 and they are thoroughly mixed with nematicides like- thimet @ 500 gms per bed of 10mx1m size. Around 2.5 Kg of seeds collected from plus trees are broadcasted uniformly over the bed and the bed is uniformly covered with straw, which should be removed when the leaves start appearing after germination.

Seed beds are sprayed with a fungicide (dithane –Z-78) 0.25% once in 15 days to avoid fungal attack and thimet granules at the rate of 10 Kg. per ha. once a month to avoid nematode attacks.

When seedlings have reached the 4-6 leaves stage, they are transplanted to poly bags along with the host plant like *Feronia elephantum* (wood apple) or along with the seed sowing of *Cajanus cajan* as the primary host for better growth of Sandal.

Seedlings are carefully removed from beds after copious watering and the roots should be intact while planting in the poly bags. Shade can be provided immediately after transplanting. Watering is to be done once in a day, but excess watering should be avoided. Host plants shall be pruned as and when necessary, so that they do not grow over Sandal and hamper its growth.

Poly bags should contain soil mixture at the ratio of 2:1:1 (Sand, red earth farmyard manure) and the size of the poly bag is 30 cm x 15 cm. To avoid nematode attack, thimet at the rate of 6 gm per poly bag shall be applied along with soil mixture and it should be thoroughly mixed before filling the bag. Shifting of bags shall be done once in two months.

Planting technique: Soil testing for suitable soil for growing of Sandal seedlings shall be taken up before planting and adequate pesticides may be used for pits and soil at the planting stage.

Escapement: 3m x 4m

Pitting: 60cm^3 pits are to be dug out during May. A weathering period of at least 30 days shall be allowed before planting. Before planting, bio-fertilizers (like Rhizobium, Aspergillum, and Phospho-bacteria), and vermicompost are added according to soil testing report. In the pits, SSP 50 gms, 1/5 cft of FYM are added.

Planting: Planting shall be done in June-July immediately after the receipt of South west monsoon. No planting should be done after July. Taller and

healthy seedlings of at least 60 cm. height and one-year-old seedlings can be planted. Host plants shall also be planted in the same pit. At the time of planting, the seeds of host plants like Alternatha and red gram are sown and the host plants are to be maintained along with sandal plants. Pruning of red gram is to be done regularly.

Host species: At the time of planting of Sandal, planting of the perennial host is required, otherwise Sandal growth will be stunted with pale yellowish leaves and ultimately the plant may die within a year. Sandal has as many as 150 host plants out of which some of the good host plants are: *Cassia siamia, Pongamia pinnata, Melia dubia, Wrightia tinctoria, Casuarina equisetifolia, Cajanus cajan, Bursera penicillate, Mundulia sobarosa, Cassia occidentalis, Mimosa pudica, etc.*

Casualty replacement: Casualties will be replaced during the month of September-October on the onset of the North-east monsoon in the first year as well as during June-July in the second year.

(iv) Vegetative propagation

The vegetative propagation of Sandal will be tried by four methods.

1) Side Grafting or Cleft Grafting.
2) Root suckers.
3) Rooting of cuttings.
4) Rooting of sprigs**.**

Cultural operations

Soil working (saucer formation) to a radius of 50 cm is done once in six months. The host plants are pruned periodically so that maximum sunlight reaches the Sandal plants.

To facilitate maximum heartwood formation and to obtain clear bole, side branches on the lower half of the main stem are pruned at regular intervals.

Operations in the second year include casualty replacement, weeding, soil working, pruning, etc.

Third year operations are similar except for casualty replacement. Weeds are to be removed in all years.

Pest and Diseases of Sandal Wood Trees:

Spike disease is one of the important diseases of sandal. This disease is caused by **mycoplasma-like organisms (MLO)**. It can occur at any stage of development of the tree. As the disease progresses, the new leaves become smaller, narrower or more pointed and fewer in number with each successive year until the new shoots give an appearance of fine spike. At the advanced stage of the disease, the internodal distance on twigs becomes small, the haustorial connection between the host and sandal breaks and the plant dies in about 2 to 3 years.

Spread of disease is sporadic and the disease is transmitted in nature by insect vectors. It has been found that other insect vectors in addition to Nephotettix virescens may also be responsible for transmission of disease. So far, no permanent remedial measures have been prescribed for control of spike

Stem borers Zeuzera coffease Nietn (red borer) Indarbela quardinotata Walker (bark-feeding caterpillar) and Aristobia octofasiculata Aurivillius (heartwood borer) are some of the pests causing considerable damage to living trees

(Source: IWST, Bengaluru)

Tree Improvement:

Genetically superior trees with good heartwood and a high content of oil have been selected from southern India. Seventy-nine candidate

(plus) trees have been identified. These are maintained at the IWST germplasm bank in Gottipura (Bangalore, Karnataka). Clonal seed orchards of these plus trees are maintained at Nallal and Jarakabande (Bangalore District) and the Andhra Pradesh Forest Department Research Center, BIOTRIM, at Tirupathi (Andhra Diseases and Pests Tree Improvement Pradesh). First-generation plants raised through these seeds showed promising results. Screening for disease resistance and breeding for high-quality of sandal oil and heartwood is underway.

Securing sandalwood plantations:

To save the Sandalwood trees from being felled illegally, technologies like IoT are being developed. Any unauthorized attempt made to fall/damage a tree will result in an alarm to all registered devices. Some of the technologies which are used are:

1. **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 These systems are used for receiving signals from the sandal trees when they are tried to cut.
2. The Institute of Wood Science and Technology in association with Hitachi India Pvt Ltd, developed **microchip-based e-protection system**. This microchip-based solution is initiated to monitor trees remotely using the web interface and mobile app. Any unauthorized attempt made to fell/damage a tree will result in an alarm to all registered devices. Protection system required components are **Sensors** (Tags), **Gateway**, **Server with Web Admin Interface and Mobile App (Android)**. Now the size of micro-chips has been reduced. 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.

Significant achievement has been made in the ranges of communication between the sensor and gateway which has been **increased from the 700 meters to 4 km radius.**

Increased the overall capacity of Gateway which is now **capable of handling 100 sensor tags to more than 1000 sensors**.

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.

Key problems in Sandalwood Cultivation:

- Quality of planting stock used/procured by farmers is of dubious quality and from largely unknown sources which may have serious repercussions in quality of end product at time of selling and disposal.
- Scientific management inputs have been lacking in initial stages of raising sandalwood. There have even been instances in Gujarat where farmers have raised sandalwood plantation without secondary host which has naturally resulted in poor growth of mature plantations.
- In many cases, too close spacing between sandalwood trees and between sandalwood and host plant has happened based on faulty advice of technically incompetent nurserymen/seedling

suppliers which has also resulted in poor growth of sandalwood growing stock.

- Many pest and disease problems in early stages of sandalwood plantations have largely gone undetected or unnoticed by farmers.

Suitability of Sandalwood in the state of Telangana

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 the average temperature between 10 to 35–40 degree 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.

Inspiring story of innovative farmer:

Sri. P. Istharapu Reddy a farmer from Pasnour village in Nalgonda 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 plantations. He planted sandalwood on the boundary of sweet-orange orchard during the year 2002 with a host crop of Sweet Oranges.

After the plantation had attained 15 years, he felled trees in 2016 and got a 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 kg from 18 trees. From selling heart and softwood he earned an income of Rs. 37.50 lakhs in 15 years.

Such inspiring stories will help many others to patronize this species as in their AF systems.

Suggestions to promote sandalwood-based agroforestry across India

Since the challenges faced in sandalwood farming are huge while meeting the expectations of the farming community, only a concerted effort can help in solving some of the technical and management problems faced by farmers and other stakeholders.

Some suggested steps to promote sandalwood cultivation are outlined below

- Only Quality planting material (QPM) stock where the seed source is known should be procured by farmers for planting purposes.
- Sandalwood plants procured should be raised only by certified and accredited nurseries.
- Scientific management inputs should be adhered to in the initial stages of raising sandalwood like spacing, host management, intercropping, pruning of sandalwood trees, fertilization, drip irrigation, and pest management.
- The farmers must be protected from half-baked nurserymen turned 'consultants' masquerading as sandalwood experts.
- The protection of growing sandalwood trees has become a major constraint for farmers. Rather than relying on the physical protection of trees, farmers could explore the possibilities of installing remote surveillance and protection systems that is available and being offered by companies like Hitachi India Pvt Ltd.
- Rules and regulations regarding sandalwood are to be liberalized

- Currently, there are no schemes for sandalwood tree insurance. Maybe some sort of crop insurance scheme will help the farmers in adopting Sandalwood as an Agroforestry species in a big way.

Marketing of Sandalwood:

The genus Santalum belongs to the family Santalaceae and more than 61 variants are known to inhabit the globe. Even though varying numbers of species are being reported by several researchers, only 16 noteworthy species have been identified and categorized. Four species of the genus Santalum are enlisted in the IUCN Red Data List due to overexploitation and illegal harvesting. Only a single species of Santalum (S. album) is found in the Indian subcontinent and in all over Asia. Sandalwood is categorized as Indian sandalwood, Australian sandalwood, Hawaiian sandalwood, and sandalwood of the Pacific islands as per its geographical presence across the world. The price of Indian sandalwood is considered to be several times higher than other sandalwood species and the essential oil obtained from it is of superior quality.

Sandalwood had a rich tradition of trade with the East and was regarded as a highly prized commodity as early as the 5th Century BC (Edwards, 1951).

Tippu Sultan who ruled the Kingdom of Mysore had declared the sandalwood tree as a royal tree and took over the sandalwood trade of the state on a monopoly basis around 1792. This practice was continued by the later Maharajas of Mysore and subsequently by the Karnataka Government until recently. The extraction and disposal of sandalwood came under the jurisdiction of the Forest Department in 1864. The classification of the sorted sandalwood into 18 classes was introduced in 1898.

Due to huge international demand, the prices of Indian sandalwood have skyrocketed and the production has drastically reduced from 4000 tons (1950) to 2000 tons (1990) to less than 1000 tons (1999)

(Ananthapadmanabha, 2002; Viswanath, 2010) with the current production of about 400 tons (Soudararajan et al., 2015).

It was reported that the local market requirement was more than 5000 tons in 2006 and to meet this demand India imported 3000 tons of heartwood from S. album as well as from non-Santalum species (Dev et al., 2014). During 2008-09, India imported nearly 60,000 Kg of sandalwood oil (Viswanath, 2010). Now the imports are around 4000 tons. Sandalwood in logs, chips, powder, and oil form is imported mostly from countries like Australia, Ethiopia, and Tanzania.

The **first survey of Indian sandalwood (1977-78**) deciphered that more than 90% of sandalwood populations were found in Karnataka and Tamil Nadu covering an area of 8300 sq. km of the total 9034 sq km. Karnataka alone contributed more than 50 percent (5245 sq km) of the sandalwood growing area (Jain et al., 1998). Other states with sandalwood trees were recorded in Andhra Pradesh (175 sq km), Assam (8 sq km), Telangana (15 sq km) Gujarat (4 sq km), Rajasthan (2 sq km), Maharashtra (8 sq km), Madhya Pradesh (33 sq km), Orissa (25 sq km), Himachal Pradesh (few thousand trees), Uttar Pradesh (2 sq km), Uttarakhand (few hundred trees), Manipur (few thousand trees), and many private lands across the country (> 500 sq km) (Srinivasan et al., 1992).

Sandal Quality:

Normally, heartwood starts producing at the end of about 6-7 years when the trees attain a height of 3 m and a girth at breast height (GBH) of 24cm. Heartwood formation is rapid in about 20 years and reaches its peak when the trees are between 30 and 60 years old when they vary from 40 to 60 cm. or more.

Sapwood and heartwood are sharply demarcated. Sapwood is white to whitish-yellow and devoid of any scent; the colour of the heartwood varies from light yellow to dark brown.

The oil yield from light-coloured wood ranges from 3 to 6%. While the oil yield from brown wood is comparatively less and is not more than 2.5%. Roots contain the highest oil content of up to 8 to 10%. The main constituent of the oil, accounting for 90% of the oil is Santalol ($C_{15}H_{24}O$), a Sesquiterpene Alcohol, it occurs as a mixture of two isomers of x-Santalol and B-Santalol. Other ingredients of the oil are Sentene, Santalene, Santenol, Teresantalol, and Tere-santalic acid.

Heartwood formation in sandalwood trees:

The high economic worth of Indian sandalwood is due to its heartwood and oil content. Heartwood is defined as inner rings of xylem deposited with metabolic byproducts that are hard and non-living, which are usually dark in color. The Heartwood of Indian sandalwood delivers a pleasant, strong smell and is yellow or brownish in appearance. Its color is an indicator of oil content and reported that yellow heartwood has 3-4 % oil; light brown color heartwood has 3-6% oil while brown and dark brown heartwood has 2-5 % oil (Rai, 1990).

Initiation and heartwood formation in Indian sandalwood usually begins from the age of 6-7 years (Srimathi and Kulkarni, 1980), and the best quality heartwood is observed at the age of 30 years whose girth may be around 50 to 60 cm (Sen Sarma, 1982).

The initiation and development of heartwood in Indian sandalwood depends on the planting material, edaphoclimatic conditions, and range of elevation (Rajagopal Shetty, 1977; Rai, 1990).

Heartwood content varies between and within different girth classes of Indian sandalwood (Rama Rao, 1904). The trees in plantations with adequate fertilization and irrigation can perform better than forest-grown

trees in terms of girth increment. The growth and development of sandalwood trees in natural conditions is slow due to the role of several stress factors. Several limiting factors such as plant genotype (Hillis, 1987), rate of growth (Hillis, 1987; Bamber et al., 1985), tree age (Yang et al., 2003), and environment (Climent et al., 1993) were found to be responsible for the variation of heartwood content in other tree species.

Quantifying the onset and variation in heartwood volume is important to determine the possibility of improving these characters through selection.

S. album trees with a height below 10 m, girth below 50 cm, and heartwood diameter between 0.5-2 cm yield 0.2-2 percent of oil content while mature trees with a height between 15-20 m, girth between 0.5-1 m and heartwood diameter between 10-20 cm yield oil content of 2.0-6.2% (Rai, 1990).

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 a favourable environment for the formation of heartwood, irrespective of the size of the stem after 8 years of age. Before the estimation of heartwood, some of the morphological clues may be checked by looking at the bark condition all-round the tree.

In general, heartwood estimation is done through the following few methodologies:

1 Increment boring method

a Manual increment boring method

b Power increment boring method

2 Electric Resistance Tomograph (ERT)

To Sum Up:

1. Heartwood formation starts at an age of 6-7 years, but the heartwood with commercial value can be obtained from Sandal trees, whose age is about 25 years and more.
2. Heartwood formation is rapid in about 20 years and reaches its peak when the trees are between 30 and 60 years old when the girth varies from 40 to 60cm. or more
3. The trees in plantations with adequate fertilization and irrigation can perform better than forest-grown trees in terms of girth increment, but the heartwood formation will be meager. The best heartwood is developed in such plants that grow in stressful conditions
4. The initiation and development of heartwood in Indian sandalwood depends on the planting material, edaphoclimatic conditions, and range of elevation
5. Traits unique to Sandalwood tree
6. Seed sources also play an important role in having saplings with the highest grades of phenotypic characters with good oil content. It is believed that the seeds procured from the Marayoor sandalwood reserve in Kerala, produce the best seedlings and hence there is a lot of demand for seeds from this area. Marayoor sandals have high oil content and huge amounts of hardwood, so they are very much in demand globally. As per the latest estimate, the number of sandalwood trees in 1,460.77 hectares of Marayoor reserve is 57,000.
7. The rules are to be simplified

Experiments on inducing heartwood formation in Sandal trees:

Very few sandal plantations formed aromatic heartwood naturally when they were young (< 10 years old), and the quality of essential oil distilled from those young sandals was quite poor (Liu et al., 2011, 2012).

Therefore, the induction of fragrant heartwood formation in young sandalwood plantations has great importance in large-scale cultivation practices because the values of sandalwood at harvest will depend largely on the volume and the quality of the heartwood.

Several studies have shown that some chemical elicitors, such as **CuSO4** (Kadambi, 1954), **ethrel** (Li and Chen, 1994), **paraquat** (Radomiljac, 1998), **benzyladenine** (Liu et al., 2013), and **H2O2** (Li et al., 2021), **can induce heartwood formation in young sandals**.

However, all these chemical elicitors were used as liquid solutions, and the induced heartwood was generally formed around the injection holes; moreover, the amount was quite low.

Different Classes of Sandalwood:

In the sandalwood, nothing goes to waste, and every part of it including dust fetches good value to the grower. So, the growers must have preliminary knowledge of the product that they are cultivating and offering for sale. To get better returns, at the time of processing, they should make such pieces which gives more money to them.

To make the farmers understand about **different classes (20 classes) of sandalwood,** a brief introduction is given in the following table:

S No	Class	Description	Current prices/kg (2021)
Heart wood			
1	Vilayat Budh (Class I billets)	Sound billet weighing not less than 9 kg and not exceeding 112 pieces per tonne	12200.00
2	China Budh (Class II billets)	Slightly inferior billet weighing less than 4.50 kg and not exceeding 224 pieces per tonne	10900.00

3	Panjam (Class III billets)	Billets having small knots, cracks and hollows weighing not less than 2.2 kg and not exceeding 448 pieces per tonne.	10000.00
4	Ghotla (billets of short length)	Includes short and sound pieces. There are no limits of weights and numbers per tonne.	7000.00
5	Ghatbadla	Billets with knots, cracks, 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 (Class I)	Pieces weighing not less than 6.75 kg and not exceeding 150 pieces per tonne	9700.00
8	Roots (Class II)	Consists of pieces weighing not less than 2.25 kg and not exceeding 448 pieces per tonne	8300.00
9	Roots (Class III)	Consists of small and side roots below 2.25 kg in weight	8500.00
10	Jajpokal or Badla (Class I)	Consists of hollow pieces weighing not less than 3.10 kg and not exceeding 320 pieces per tonne.	13700.00
11	Jajpokal (Class II)	Hollow pieces weighing not less than 1.3 kg per tonne.	10600.00
12	Ainbagar	Consists of solid, cracked and hollow pieces weighing not less than 450 g.	8900.00
13	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 small pieces of heartwood.	5400.00
15	Hatri Chilta	Consists of heartwood and chips obtained by plaining billets with Hatri or Randha (plane).	2850.00
Mixed Wood			
16	Milva Chilta	Consists of pieces and chips having fair proportions of heartwood and sapwood	3400.00
17	Basola Bukni	Consists of small heartwood and sapwood chips.	3600.00
18	Saw dust	Sawn powder obtained while sawing the sandalwood	810.00
Sap Wood			
19	White chips	Consist of chips of sapwood only	105.00
20	Bark and Waste		25.00

(Source for different classes of sandalwood: Classification of sandalwood sorted before being passed for sale (according to the Karnataka Forest Manual Rule No. 95))

Recommendations:

Growing and Marketing Sandalwood is a highly technical and very difficult process. As explained, the quality and formation of heartwood in Sandal trees varies from location to location. Seed source (QPM) plays a very important role in the development of healthy and vigorous plants, that have good heartwood content in them. Sandal trees are to be protected from various biotic factors, abiotic factors, diseases, and most importantly theft. Spacing, tending, cultural, and silvicultural requirements of the

species warrant a good knowledge of the species and its management. Information on host specificity is a very important aspect of the management of this species. Farmers must be aware of the economic importance of different parts of sandalwood trees.

The growers must be aware of different classes of sandalwood trees, as the market value of the different classes differ,

The best way for the farmers to get a good knowledge of the species and market is by orienting themselves under the umbrella like Sandalwood Growers – Corporate Joint Venture and the Government can help the growth of this sector by organizing Sandalwood clusters.

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