J. Farm Sci., 37(3): ( ) 2024

RESEARCH PAPER

Assessment of host trees on heartwood and oil content in fourteen-year-old sandalwood plantations in Chitradurga district of Karnataka

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(Received: November, 2023 ; Accepted: June, 2024)

DOI: 10.61475/JFS.2024.v37i3.20

Abstract: A study was conducted during the year 2018-2021 at College of Forestry, Sirsi for studied on Assessment of host trees on heartwood and oil content on fourteen year old sandalwood plantations in Chitradurga district of Karnataka. The important objectives of this study was screening of secondary host plants on heartwood and oil content of sandalwood tree in different agroforestry systems of Karnataka in Chitradurga district, the results revealed that 32.54 per cent increase in clear bole height of sandalwood tree with *Melia dubia* followed by 31.20 per cent in *Emblica officinalis* as a host plant in fourteen year old sandalwood plantation. Sandal tree volume of main stem was improved 41.50 per cent increased with *Emblica officinalis* followed by *Casuarina equisetifolia* (34.84%). 42.48 per cent enhancement in sandal heartwood content with *Punica granatum* over 40.28 per cent in *Emblica officinalis*. 31.69 per cent increased in oil content was observed with *Melia dubia* followed by 21.55 per cent in *Acacia nilotica* and 21.55 per cent in *Dalbergia latifolia* as a secondary host plants for sandalwood trees. Significantly higher oil content was noticed with *Swietenia mahogani* (2.22%) on par with the other secondary host of *Psidium guajava* (2.38%), *Murraya koenigii* (2.40%) and *Emblica officinalis* (2.45%) as compared to other field hosts.

Key words: Clear bole height, Heartwood, Oil content, Sandalwood

Introduction

Indian Sandalwood tree (*Santalum album* L.) one of the world's most valuable commercial timbers and is currently valued globally for its heartwood and oil. The tree being used by humans from time immemorial and it is one of the first items traded with other countries from India (Rai and Sarma, 1990). It is popularly known as "Dollar earning parasite" (Krishnappa, 1972; Durairaj and Kamraj, 2013). According to the predictions of Thomson 2020, the local demand for sandalwood oil in India will rise to a minimum of 250 tonnes in 2040. Wild sandalwood might yield ~100 tonnes of oil in 2040 and based on recent data Sandalwood plantations were taken up in a massive scale at around 2019 (~30000 ha) in India.

An individual growing tree can put an increment of 1.0 kg of heartwood per year and can attain a girth of over 1.5 meters (Rai and Sarma, 1990). The heartwood of sandalwood trees is estimated to be fetching approximately 9 lakh per tonne in the international market (Ananthapadmanabha, 2000). As per 2010 auction in Marayoor, Kerala, fifth class sandalwood tree was sold at rupees 7390 kg^{-1}. In the international market, sandalwood is fetching about US$2000 per kg of Sandalwood oil (Pullaiah and Swamy, 2021). Nearly, 150 tonnes of Sandalwood oil is produced per annum worldwide (Goswami and Jagatpati 2018). Most of the Sandalwood demand in the world met through Australian Sandalwood (*Santalum spicatum*) (Pullaiah and Swamy, 2021). However, over-exploitation, illicit felling of sandalwood trees has resulted in decline in population and genetic erosion (Annapurna *et al.,* 2006).

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 is hard and nonliving, which is usually dark in color. Initiation and heartwood formation in Indian sandalwood usually begins from the age of 6-7 years (Kulkarni and Srimathi, 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).

Sandal cultivation has so far been restricted to government-controlled lands, reserve forests and protected areas but liberalized policies suggested to grow *Santalum album* in the farmer's field. Hence, information is lacking on growth, heart wood formation and compatibility with horticultural crops when grown on private lands under intensively managed conditions. The potential of the tree in existing farming with horticultural plants as secondary host for improving livelihood and creating employment opportunities and enhancing farm income is quite huge especially in semi-arid zones due to the less demanding climatic and edaphic requirements of this species. The present research is being undertaken to know the variation in heartwood formation and oil content of sandal wood trees in Chitradurga District of Karnataka. Since, the research on these aspects is very meager. There is a vast scope in the agroforestry system to promote *Santalum album* in the farmer's field. Keeping these points in view, the investigations was carried out on Assessment of host trees on heartwood and oil content in fourteen-year-old sandalwood plantations in Chitradurga district of Karnataka

Material and methods

Survey was undertaken in different locations in Chitradurga district of Karnataka. The basic information was collected with help of questionnaires. In each location/AF systems five trees were selected randomly for estimation of heartwood and oil content. (Table 1)

Table 1. List of predominant secondary hosts identified and their sample size of Chitradurga district

Secondary host plants	Common name	Age (Yrs)	Sample size
Punica granatum	Pomegranate	6.5	4
Citrus reticulate	Orange	7.5	3
Melia dubia	Hebbevu	9.5	4
Emblica officinalis	Amla	5.0	3
Manilkara zapota	Sapota	8.0	2
Murraya koenigii	Curry leaf	4.5	3
Psidium guajava	Guava	5.0	3
Casuarina equisetifolia	Beef wood	5.0	3
Dalbergia latifolia	Beete	6.5	3
Swietenia mahogany	Mahogany	4.5	3

Observation were recorded during the survey

- Name of the location
- Age of the tree (years)
- Name of the secondary host introduced
- Method of planting
- Spacing adopted (m)
- Growth parameters
- Percent heartwood formation
- Percent oil content

Site characteristics: Location, latitude, Altitude (m) longitude, Rainfall (mm), Temp. soil type (Table 2 and 3)

Canopy volume

Canopy volume was estimated using the following formula (Thorne *et al.,* 2002).

$$V = \frac{2}{3} \pi h \left(\frac{a}{2} \times \frac{b}{2}\right)$$

Where, h is the height of the canopy; a and b are spread of mid canopy at perpendicular axes.

Volume of the main stem

The main stem volume indicates the dry matter accumulation in the sandalwood tree and marketable yield. It was calculated considering the main stem as cylinder using the formula as a non-destructive observation.

$V = \pi r^2 h$

Where h is clear bole height and r is radius derived from tree girth

To estimate heartwood per cent and oil yield from the identified locations of Chitradurga district. Data from three replicates/ sample trees in each girth class was recorded. Girth at breast height (GBH) and height of the trees were recorded. The core sample from each tree was extracted using a Haglof increment borer. The core sample was extracted by using the bark, sapwood, transition region and heartwood percentage. The heartwood portion of the core sample used for oil content estimation and the collected core samples was collected at breast height level and its wrapped with blotting paper and kept in a desiccators.

From the core samples, bark thickness, sapwood radius, transition region and heartwood radius was estimated (by converting tree girth to tree diameter) accordingly percentage of heartwood has been calculated. Sandalwood oil was being estimated from the core samples using the method developed by Shankaranarayana *et al*. (1997). This non-destructive method has been found to be very convenient for quick screening of plants for their oil content from the standing trees. The heartwood portion was then cut into fine pieces using a blade. 100 mg of the sample was weighed on a weighing balance and then 100 ml of hexane (60-700 boiling points) was added to the 100 ml standard flask. The samples were kept aside for 18 hours with periodic shaking. The supernatant was taken in quartz cell and optical density at 219 nm (maximum) was measured by UV Spectrophotometer (Shimadzu-240). The mean values are worked out and the data expressed as mean ± SE.

Results and discussion

Influence of host trees on growth, heart wood initiation and oil content in fourteen year old sandalwood plantations at Chitradurga district

The influence of host trees on growth, heart wood initiation and oil content showed significant difference between the different secondary hosts is given in Table 4 and Fig.1.

Significantly higher clear bole height was observed along with the host of *Melia dubia* (2.55 m) which was on par with the other secondary host of *Emblica officinalis* (2.50 m), *Acacia nilotica* (2.30 m), *Casuarina equisetifolia* (2.28 m), *Citrus reticulata* (2.17 m), *Dalbergia latifolia* (2.17 m), *Psidium guajava* (2.12 m) and *Murraya koenigii* (2.10 m). The lowest sandal wood tree clear bole height was recorded with *Swietenia mahogani* (1.72 m) which was on par with the host of *Punica granatum* (1.88 m).

However, significantly higher tree girth was recorded with *Emblica officinalis* (35.67 cm) which was on par with *Casuarina equisetifolia* (35.37 cm), *Dalbergia latifolia* (35.00 cm), *Swietenia mahogani* (33.90 cm) and *Citrus reticulata* (33.75 cm)

The lowest tree girth was recorded under the secondary host of *Melia dubia* (30.55 cm) which was on par with the other host of *Psidium guajava* (30.87 cm), *Murraya koenigii*

Table 2. Soil type, spacing and management practices followed in sandalwood trees and host plants in Chitradurga district of Karnataka

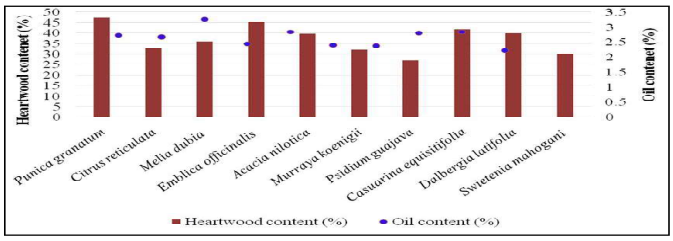
District	Location	Soil Type	Spacing adopted (m)		Management practices followed
			Sandal	Sandal to host	
Chitradurga	Hariyabbe	Red clay	4 x 5	2 x 3	Irrigation, pruning, weeding
	Hiriyuru	Red soil	4 x 2	1 x 1	Pruning
	Hosadurga	Sandy loamy	5 x 3	2 x 3	Irrigation, pruning, weeding

Table 3. Effect of locality factors on per cent oil content in sandalwood trees in Chitradurga district of Karnataka

District	Location	Latitude (North)	Longitude (East)	Elevation (m)	Mean Annual Rainfall (mm)	Mean Annual Temperature (°C)	
						Maximum	Minimum
Chitradurga	Hariyabbe	14.05	76.81	592.89	573	30.94	21.37
	Hiriyuru	13.99	76.69	584.06	569	29.98	20.83
	Hosadurga	13.79	76.28	716.85	551	30.45	21.04

Table 4. Influence of host trees on growth, heart wood initiation and oil content in fourteen year old sandalwood trees at Chitradurga district

Secondary host plants	Sandal clear bole height (m)	Tree girth (cm)	Volume of main stem (dm^3)	Heart wood content (%)	Oil content (%)
Punica granatum	1.88	31.72	14.81	47.12	2.72
Citrus reticulata	2.17	33.75	19.69	32.67	2.67
Melia dubia	2.55	30.55	15.52	36.17	3.25
Emblica officinalis	2.50	35.67	25.32	45.38	2.45
Acacia nilotica	2.30	33.42	20.32	39.72	2.83
Murraya koenigii	2.10	31.42	16.50	31.98	2.40
Psidium guajava	2.12	30.87	16.06	27.10	2.38
Casuarina equisetifolia	2.28	35.37	22.73	41.85	2.80
Dalbergia latifolia	2.17	35.00	21.09	39.83	2.83
Swietenia mahogani	1.72	33.90	15.53	30.28	2.22
S.Em±	0.14	1.10	1.28	3.19	0.18
C.D.@ 5%	0.45	3.52	4.09	10.21	0.58



(31.42 cm) and *Punica granatum* (31.72 cm) as compared to rest of host trees.

Various secondary hosts' plants influenced sandalwood tree growth differently with respect to varied climatic conditions. Among various secondary sandal host, *Punica granatum, Emblica officinalis, Casuarina equisetifolia, Murraya koenigii, Acacia nilotica, Melia dubia* contributed higher growth and improving of clear bole height and tree girth in sandalwood. The similar study was conducted by Bilas *et al* (2018) and reported that *Citrus aurantium*, *Casuarina equisetifolia, Punica granatum* showed the greater height, girth, crown size and clear bole length of *S. album* trees. Similarly Srikanta prasad *et al,* (2022) reported that secondary host exhibited better growth in terms of tree height, canopy spread, canopy volume, stem girth and volume in sandal cultivation in farmers field of northern dry zone of Karnataka.

The higher volume of main stem was observed with secondary host of *Emblica officinalis* (25.32 dm^3) on par with the other secondary host of *Casuarina equisetifolia* (22.73 dm^3). The lowest volume of main stem was recorded under the host of *Punica granatum* (14.81 dm^3) which was on par with the other secondary host of *Melia dubia* (15.52 dm^3), *Swietenia mahogani* (15.53), *Psidium guajava* (16.06 dm^3) and *Murraya koenigii* (16.50 dm^3).

With respect to oil content, the significantly higher per cent oil content was noticed with *Melia dubia* (3.25%) which was on par with the other secondary host of *Acacia nilotica* (2.83%), *Dalbergia latifolia* (2.83%), *Casuarina equisetifolia* (2.80%), *Punica granatum* (2.72%) and *Citrus reticulata* (2.67%).

Significantly higher oil content was noticed with *Swietenia mahogani* (2.22%) on par with the other secondary host of *Psidium guajava* (2.38%), *Murraya koenigii* (2.40%) and *Emblica officinalis* (2.45%) as compared to other field hosts.

The suitability of the host depends upon several factors. In the present experimental study *Punica granatum, Emblica officinalis, Acacia nilotica, Casuarina equisetifolia* significantly contributed to the heartwood content (%) and oil content (%) of sandalwood trees. Some of the literature studies standardize the host for sandalwood trees over in line with present experimental in *Casuarina equisetifolia,* (Delphy, 2011) *Dalbergia sissoo* and *Acacia mangium* (McComb, 2009; Ouyang *et al.,* 2016) *Acacia nilotica* and *Cassia siamea* (Doddabsawa *et al.,* 2020)

The absence of any relationship between heartwood proportion and oil content indicates that heartwood formation and oil accumulation may be two independent processes. Though oil formation occurs only in the heartwood, it is not necessary for oil accumulation to be linearly related to heartwood growth. However, as trees mature and rate of heartwood growth becomes a near constant, oil accumulation continues at a rate independent of the heartwood, leading to increase in oil content with tree age. It is a common feature to

record higher concentration of heartwood extractives among aged trees rather than in younger trees

Results can be used to clarify an existing belief that oil content is higher in trees growing in dry/harsh conditions than those in fertile tracts. Size of the trees (height, canopy and diameter) growing in drier conditions will be usually lower than what is generally expected for a given age. Smaller diameter trees will certainly have smaller heartwood diameter. Given that oil formation is independent of heartwood growth, and assuming constant amount of oil being formed irrespective of tree/heartwood growth, trees of the same age but with smaller diameter may tend to have greater percentage of oil in the heartwood. As the mechanism involved in oil synthesis in this species remains elusive, further deductions are not possible. The present study suggests that plantation managers should look towards maximizing growth. It is important to recognize that a deeper understanding of the relationship between heartwood and oil is hampered by the lack of information on mechanism of natural synthesis of sandalwood oil

Conclusion

Influence of secondary host plants on fourteen year old sandalwood trees in Chitradurga district was 32.54 per cent increase in clear bole height of sandalwood tree with *Melia dubia* followed by 31.20 per cent in *Emblica officinalis* as a host plant in fourteen year old sandalwood plantation. Sandal tree volume of main stem was improved 41.50 per cent increased with *Emblica officinalis* followed by *Casuarina equisetifolia* (34.84%). 42.48 per cent enhancement in sandal heartwood content with *Punica granatum* over 40.28 per cent in *Emblica officinalis*. 31.69 per cent increased in oil content was observed with *Melia dubia* followed by 21.55 per cent in *Acacia nilotica* and 21.55 per cent in *Dalbergia latifolia* as a secondary host plants for sandalwood trees.

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