Original Research Article

Variation In Heartwood And Oil Content Of *Santalum album* L. In Assam And Karnataka

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Abstract : *Santalum album* L. (East Indian Sandalwood) which is naturally distributed in the three South Indian states (Karnataka, Tamil Nadu and Kerala), has an important place in the culture and heritage of Karnataka state since ages. The economic value of *Santalum album* L. arises from the oil present in heartwood of older age classes. However the value of the tree in terms of heartwood and oil content when grown outside its natural distribution range is not well known. Six girth classes of sandalwood trees were selected to estimate heartwood percent and oil yield for all the four locations viz. Assam (Diphu) and Karnataka (Bangalore, Shivamogga and Mysore). Core samples were taken at the level of breast height (1.76 m) using Haglof increment borer and oil content was estimated by simple hexane extract method (Shankaranarayana *et.al.*, 1997). From the current study it was observed that the sample trees from all the locations showed heartwood initiation at the girth class 41-50 cm. More than 50% heartwood was noticed in the girth class of trees 51-60 cm and 70% heartwood in the girth class 71-80 cm and the oil content of these trees were around 1.5 to 3.0 %. Maximum oil content of 4% was noticed in the trees of girth class 91-100 cm. The rate of heartwood formation, trend of increase in heartwood and oil content percent from the Assam populations showed more or less similar pattern to the populations found in Karnataka.

Key words: Assam, Heartwood, Karnataka, Oil content, *Santalum album*

Introduction

Santalum album L. (East Indian Sandalwood) has an important place in the culture and heritage of Karnatakastate.The heartwood of the sandalwood tree is considered as the finest material for carvings and the fragrance of its oil has been exploited by the perfumery industry worldwide and was a much sought item of trade since the Vedic period, during period of Vijayanagara Empire and Kings of Mysore subsequently (Ganeshaiah *et.al.,* 2007). 'Chandana' or 'Srigandha' regarded as a state tree of Karnataka, since time immemorial, has been its culture, heritage and pride. 'Kannadigas' (people of Karnataka) call Mysore as "temple of sandalwood" (Gandhada Gudi) and Karnataka as the land of Sandalwood (Srigandhanaadu) (Adkoli, 1977). It can be said that sandalwood finds its use in human life particularly in Indian culture and civilizations from cradle to cremation (Arun *et al.*, 2012). East Indian Sandalwood grows well under the rainfall conditions of 500-2000 mm and at the elevations of 600-1200 m. It can also grow beyond these ranges, but under high rainfall conditions the growth is rapid yet with heartwood formation being slow (Rai, 1990).

Sandalwood is an evergreen tree which can grow upto a height of 20-25 meters and attain a girth of 1.5 to 2.5

meters. It starts flowering two times in a year during March-April and September-October with seed production being good in September-October season. Certain trees flower once in a year and some twice in a year and the quantity of seed production from a tree may also vary from season to season. Distribution of East Indian sandalwood extends from 30°N to 40°S from Indonesia in the east to Juan Fernandez Islands (Chile) in the west and from Hawaiian Archipelago in the north to New Zealand to the south (Srinivasan *et al.*, 1992).

The genus *Santalum* consists of 19 species, which are *S. accuminatum*, *S. album*, *S. austrocaledonicum*, *S. boninese*, *S. ellipticum*, *S. fernandezianum*, *S. freycinetianum*, *S. haleakalae*, *S. insulare*, *S. involutum*, *S. lanceolatum*, *S. macgregorii*, *S. murrayanum*, *S. obtusifolium*, *S. peniculatum*, *S. pyrularium*, *S. salicifolium*, *S. spicatum* and *S. yasi*. Among these *S. fernandezianum* once found in Chile has been declared as extinct (Skottsberg, 1922). *S. lanceolatum* of Australia has been listed as a threatened taxon under Schedule II of the Victorian Flora and Fauna Guarantee Act, 1988 (Trueman, 2001) and the endemic Indian *S. album* is placed under vulnerable category of the IUCN Red List. The wood, commercially known as "East Indian Sandalwood" has pungent fragrance and superior quality heartwood due to the presence of essential oil also known as "East Indian Sandalwood oil". It is distributed in an area of over area 9000 km^2 covering the states of Tamil Nadu, Karnataka and Kerala and more than 90% used to be in Karnataka and Tamil Nadu covering about 8300 km^2 (Rai, 1990).

Yield of essential oil in the *S. album* tree varies from 1.0 to 8.0% depending on age of the tree, girth, soil, climatic and genetic factors (McKinnel, 1990; Jain *et al.*, 2003). The oil currently sells at a price of 1.5 - 3 lakh/kg in the international market (Arun *et al.*, 2012). The fixative property and tenacious aroma of the oil are attributed to the major odoriferous (sesquiterpenic alcohols - ~ and β santalols (70 - 90%) besides ~ and β santalenes and esters of santalols. Due to stringent policies and large scale unauthorized extraction, sandalwood production has come down from 2000 metric tons (MT) in 1984-85 to less than 100 MT in 2000-01 in Karnataka while in Tamil Nadu it has been dropped from 2200 MT in 2001-02 to less than 200 MT in 2004-05 (Dhanya *et al.,* 2010; Viswanath, 2014). However, the cultivation of sandalwood has fast picked up in recent time in the states of Rajasthan, Gujarat and Himachal Pradesh. There are also reports of cultivation picking up in Assam especially in the lower hills of Karbi Anglong autonomous region of north east India. Apart from Karbi Anglong, sandalwood cultivation is also seen in Doboka, Hojai and Lanka in Nagaon district, Barpothar and Morongi in Golaghat district, Guwahati in Kamrup district, Jamuguri in Sonitpur district and Jonai in Dhemaji district (Raju Gogoipers.com).

Although the news of success stories in sandalwood plantations from other parts of the country has been emerging along with farmers' increased interest for sandalwood production, more information on heartwood percentage and oil yield of trees growing in these areas is required because of the wide geographical variation. In general, value of sandalwood is determined by the volume of heartwood and oil percentage and quality produced by the trees (percentage of sesquiterpenic alcohols - ~ and β santalols). Heartwood from mature sandalwood trees of north east India contains 5 to 7 % oil (McKinnel, 1990). The relationship between girth and oil content in sandalwood growing areas and the effect of girth increment on oil yield is debatable with contrasting reports on this (Venkatesan, 1980; Jain *et al.,* 2003). Heartwood from young trees under 10 years age whose girth is less than 50 cm may contain 0.2 to 1.0 % of oil, while mature trees of 30 to 50 years of age whose girth is around 100 cm may contain 2.8 to 6.2 % of oil while the older aged trees, 50-80 years of age having girth more than 125 cm may contain 4.5 to 8.0 % of oil (McKinnel, 1990).

Sandalwood can grow in different kinds of soils like sand, clay, laterite, loam, black-cotton soil (avoiding water-logged conditions) and very poor, rocky soils can support sandalwood growth and has been said that best quality sandalwood with finest odor can be found in driest region especially on red or stony ground (Gunther, 1952; Jayaram, 1973 and Rajagopal Shetty, 1977). Sandalwood although requires

good drainage and does not stand water logged ground, but the best growth of tree is on rich fairly moist soil as garden loam and well drained deep alluvium on the river banks.

The objective of the current study was to access the heartwood formation and yield of oil in different girth class of sandalwood populations grown in the lower hills of Karbi Anglong and its comparision with that of the three sandalwood grown regions of Karnataka (Bangalore, Shivamogga and Mysore). There are also variable reports on the rate of girth increment in natural populations in forest and cultivated sandalwood in farmlands and homesteads. Under cultivated conditions, the growth rate (Mean Annual Increment) of trees is relatively higher, and even upto 5 cm/ year have been reported (Viswanath *et al.,* 2010) while in natural forest average growth rate reported is only 01 cm/ year (Rai, 1990).

Materials and methods

A survey was conducted in various parts of Assam comprising Diphu urban and suburban areas as well as in Bangalore, Shivamogga and Mysoreto identify suitable *Santalum album* trees belonging to different girth classes (Fig. 1). The trees were selected from outside of natural forests and grown at premises of Government and nongovernmental institutions or homesteads (Fig. 2 and Fig. 3). Six girth classes of sandalwood trees were identified viz., 41-50, 51-60, 61-70, 71-80, 81-90, 91-100 cm respectively to estimate heartwood percent and oil yield for all the four locations of Assam (Diphu) (Fig. 2 and 3) and Karnataka (Bangalore, Shivamogga and Mysore) (Fig. 4). Data from three replicates/ sample trees in each girth class have been 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 (Fig. 5). The core sample extracted was used to estimate the bark, sapwood, transition region and heartwood percentage (Fig. 6). The heartwood portion of the core sample was used for oil content estimation.

Core samples taken at the level of breast height (1.76 m) were wrapped in blotting paper and kept in a dessicator (to avoid absorption of moisture) for further experimental studies. Oil content was estimated in the laboratory of Institute of Wood Science and Technology, Malleswaram, Bangalore.

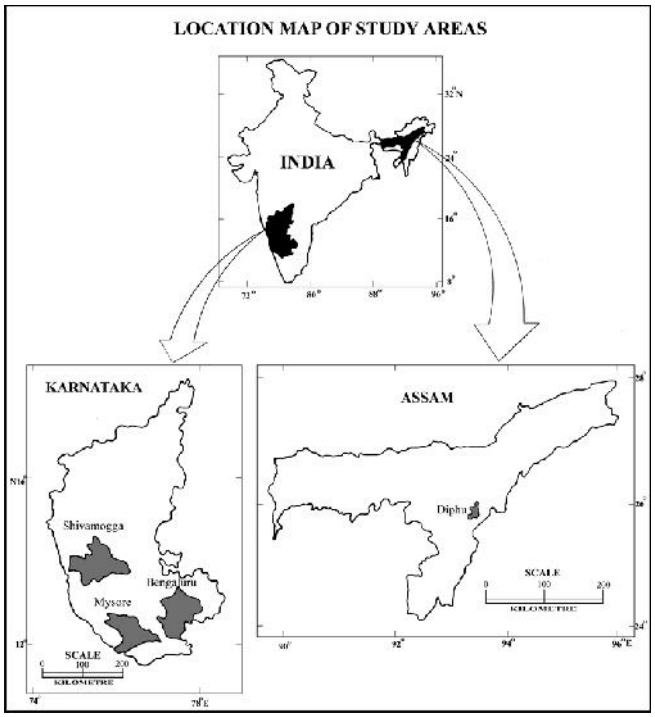

Fig. 1. Location map of study areas in Karnataka (Bengaluru, Shivamogga and Mysore) and Assam (Diphu).

Fig. 2. Mature Sandalwood tree(30 years) in Diphu, Assam.

Fig. 3. Commercial sandalwood plantation (8 years) in Diphu, Assam.

Fig. 4. Core sampling of heartwoodin sandalwoodtree using Haglof increment borer in Diphu, Assam.

Fig. 5. Extracted core sample from sandalwood tree in Diphu, Assam showing heartwood formation.

From the core samples, bark thickness, sapwood radius, transition region and heartwood radius was estimated (by converting tree girth to tree diameter) and the percentage of heartwood was calculated.

Sandalwood oil was 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

Fig. 6. Mature Sandalwood tree (> 50 years) in Shivamogga, Karnataka.

was weighed on a weighing balance and then 100 ml of hexane (60-70^0 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 were worked out and the data expressed as mean ± SE. Statistical significance was determined using Student t-test in Microsoft Excel 2010 at 95% probability level ($P<0.05$)

Results

The present study was conducted to document and compare the variability of heartwood and oil yield among *Santalum album* trees belonging to different girth classes in various parts of Assam comprising Diphu urban and suburban areas as well as in Bangalore, Shivamogga and Mysore districts of Karnataka. The *Santalum album* trees selected for the study were not from the natural forests. Measurements were recorded for girth at breast height (GBH) and from the core samples extracted. The core sample normally contains radial

lengths of bark (bark thickness), sapwood (sapwood thickness), transition zone (region of enzymatic activity usually dark pinkish in color) and a portion of the heartwood. Six girth classes of sandalwood trees were identified viz., 41-50, 51-60, 61-70, 71-80, 81-90 and 91-100 cm respectively to estimate heartwood percent and oil yield. Girth data was collected from 72 trees and oil yield was also estimated from the core samples of same trees. Of the 72 trees sampled in all the six girth classes, 100% of the trees in all the four locations showed heartwood formation.

Heartwood Content

Variability of heartwood percentage in *Santalum album* trees across different girth classes (cm) in Diphu, Assam and three locations in Karnataka was worked out from the core samples (Table 1). The percentage of heartwood formation in most of the sandalwood populations increased steadily with increase in the girth (Fig. 7). The mean percentage heartwood varied significantly between different populations in different girth classes, the trees growing in Bangalore region were found to have highest percentage of heartwood and the lowest was found in the trees growing in Shivamogga region among the three regions in Karnataka.

Table 1. Variation in heartwood (%) in *Santalum album* L. trees across different girth classes (cm) in Diphu, Assam and three locations in Karnataka.

Location	Girth Class (cm)					
	41-50	51-60	61-70	71-80	81-90	91-100
Diphu	45.08 ± 1.51	47.96 ± 1.65	56.29 ± 1.96	73.94 ± 2.52	74.32 ± 1.95	83.24 ± 1.02
Bangalore	51.50 ± 5.47	55.21 ± 6.77	66.21 ± 8.12	74.91 ± 0.96	76.13 ± 2.39	84.58 ± 1.61
Shivamogga	44.07 ± 1.62	50.94 ± 4.30	55.78 ± 4.09	67.33 ± 11.19	69.12 ± 7.23	73.15 ± 8.87
Mysore	40.53 ± 2.33	55.86 ± 3.76	67.33 ± 3.36	72.02 ± 1.10	77.48 ± 6.90	79.16 ± 3.95

*Mean ± S.E. of heartwood (%) has been reported.

All the *Santalum album* trees in the girth class 41-50 cm corresponding to around 10-12 years age, in all the four locations in Assam (Diphu) and Karnataka (Bangalore, Shivamogga and Mysore) showed heartwood formation. Thus it is evident from the study that the trees with girth class ranging from 41-50 cm had more probability of heartwood initiation. Among all the trees (girth class ranging from 41-50 cm), the lowest heartwood percentage was observed in the sandalwood populations of Mysore region (40.53 ± 2.33 %, $P < 0.05$) and highest was observed in sandalwood populations of Bangalore region (51.50 ± 5.47 %, $P < 0.05$), while the sandalwood populations of Diphu and Shivamogga showed similar percentage (45.08 ± 1.51% and 44.07 ± 1.62 respectively, $P < 0.05$) of heartwood formation. The study also showed that there was a minimum of 40% heartwood formation in girth class of 41-50 cm in all the locations studied.

The percentage of heartwood formation increased gradually from the girth class 41-50 cm until it reached the girth class of 71-80 cm (> 30 years age) in all the four locations of Assam (Diphu) and Karnataka (Bangalore, Shivamogga and Mysore). Minimum heartwood percentage for girth class 71-80 cm being the sandalwood population of Shivamogga (67.33 ± 11.19 %, $P < 0.05$) and maximum being the sandalwood population of Bangalore (74.91 ± 0.96 %, $P < 0.05$) as well as sandalwood population of Diphu (73.94 ± 2.52 %, $P < 0.05$).

It was noticed that in the higher girth class (> 81 cm) the rate of increase in heartwood formation was slow. Minimum heartwood percentage in the girth class 91-100 cm was observed in the sandalwood population of Shivamogga (73.15 ± 8.87 %, $P < 0.05$) and maximum was observed in the sandalwood population of Bangalore (84.58 ± 1.61, $P < 0.05$) as well as in sandalwood population of Diphu (83.24 ± 1.02%, $P < 0.05$) which were on par. The percentage of heartwood formation in sandalwood trees growing in Diphu, Assam was comparable to those found in all the three locations of Karnataka in this girth category. From the study, it may be inferred that considerable variation exists in the heartwood content of sandalwood populations falling under lower girth

classes and rate of heartwood formation is fairly rapid upto girth class of 81-90 cm corresponding to around 25-30 years age.

Oil Percent

The data on variation in oil content (%) in *Santalum album* L. trees across different girth classes (cm) in Diphu, Assam and three locations in Karnataka is presented in Table 2. Mean total heartwood oil percentage differed significantly between different populations in different girth classes, with trees from Shivamogga region yielded the best oil percent though it had lowest mean percentage of heartwood formation. It is evident that oil content was more than 3% in all the locations of Karnataka and Assam for the girth class 91-100 cm (Table 2).

The *Santalum album* trees of girth class 41-50 cm for all the four locations of Assam (Diphu) and Karnataka (Bangalore, Shivamogga and Mysore) showed variability in the oil percent. The oil percent was ranging from 0.5 to 1.0 % for girth class 41-50 cm. Minimum oil percent was observed in sandalwood populations of Diphu (0.54 ± 0.16 %, $P < 0.01$) and maximum was observed in Shivamogga populations (0.93 ± 0.12, $P < 0.01$). Variability of oil percent was observed in different girth classes selected from all the four locations showed heartwood formation.

Table 2. Variation in oil content (%) in *Santalum album* L. trees across different girth classes (cm) in Diphu, Assam and three locations in Karnataka.

Location	Girth Class (cm)					
	41-50	51-60	61-70	71-80	81-90	91-100
Diphu	0.54 ± 0.16	0.70 ± 0.13	1.52 ± 0.24	1.93 ± 0.26	2.97 ± 0.13	3.08 ± 0.54
Bangalore	0.86 ± 0.06	1.16 ± 0.27	1.62 ± 0.05	2.09 ± 0.15	3.05 ± 0.31	3.81 ± 0.17
Shivamogga	0.93 ± 0.12	1.29 ± 0.13	2.13 ± 0.18	2.67 ± 0.15	2.79 ± 0.31	4.07 ± 0.18
Mysore	0.81 ± 0.15	1.37 ± 0.09	1.58 ± 0.21	2.39 ± 0.13	2.61 ± 0.23	3.52 ± 0.11

*Mean ± S.E. of oil content (%) has been reported.

Overall, the maximum oil content for all the girth classes was found in Shivamogga sandalwood population. About 4.07 ± 0.18 % of oil, belonging to the girth class of around 91-100 cm was observed and it had the highest percentage of oil compared to all other sandalwood populations in all the four locations. Though the sandalwood populations found in Shivamogga region had lower heartwood percentage for most of the girth classes included in the study, it yielded maximum oil content. Percentage of oil yield in sandalwood populations of Diphu was generally comparable to that the three locations in Karnataka across all categories of girth classes, however, due to limitations in obtaining larger sample sizes this aspect cannot be proved conclusively.

Discussion

The value of sandalwood tree depends on the quantity and quality of heartwood it contains. Till date, no study has revealed about the exact age for initiation of heartwood in *Santalum album* and also very little information is available on the rate at which heartwood in *Santalum album* is developed subsequently. It is well known fact that there is large variation in the age at which *S. album* initiates the formation of heartwood (Srimathi and Kulkarni, 1979) and that in some individuals of *S. album* heartwood is noticed only in higher age classes (Rai, 1986).

In the present study, the percentage of heartwood formation in most of the sandalwood populations increased steadily with increase in the girth. The sandalwood trees in the girth class 41-50 cm in all the four locations studied showed good amount of heartwood formation which is an encouraging aspect especially for farmers wanting to grow sandalwood. The edaphic and climatic conditions in all the four locations also seem to favour good heartwood formation. Jain *et al.* (1988) had observed that soil properties and their relationship to the growth of sandal depends on pH, water holding capacity, pore space, volume expansion on wetting, exchangeable calcium, magnesium and available potash, which may exert a positive influence in girth and height in sandalwood populations. The percentage of heartwood formation increased rapidly from the girth class 41-50 cm until it reached the girth class of 71-80 cm in

all the four locations of Assam (Diphu) and Karnataka (Bangalore, Shivamogga and Mysore). Requirement of proper host for sandalwood growth was also emphasized by Ananthapadmanabha *et al.* (1984). However, this aspect has not been properly recorded in the current study. The other limitation has been the difficulty in assessing the correct age of sandalwood based on growth. Based on girth class alone it may be difficult to determine the exact age of the tree. In general, based on past records and discussions with cultivators and Forest department officials, an approximate assessment of age was arrived at in the current study.

According to McKinnel (1990), the oil yield in *S. album* tree varies from 1.0 to 8.0% depending on age of the tree, girth, soil, climatic and genetic factors. The oil percentage of sandalwood trees studied varied from 0.54% (Diphu) in lower girth class to a maximum of 4.07% (Shivamogga, Karnataka) in highest girth class though it had lowest percentage of heartwood among the four locations in that category. The oil yield in trees sampled in the highest girth class in Diphu, Assam was lowest when compared to the other locations of Karnataka, though statistically not significant ($P < 0.01$), but the heartwood percentage was highest in that category compared to other regions of Karnataka. Edaphic factors and variation in mean annual rainfall may also be possible explanations for this variation. The average mean annual rainfall in the three locations in Karnataka is also less than 10000 mm with Mysore receiving less than 600 mm mean annual rainfall. Sreenivasaya and Narayana (1948) had observed that sandal growing on rocky soil and in association with xerophytic conditions as having higher proportion of oil bearing heartwood than the one thriving on fertile soil enjoying good rainfall. Puransingh (1911) had also reported that specimens obtained from trees on relatively poor rocky gravelly soils and in semiarid regions had higher oil content than those of specimens obtained from fertile soils.

Viswanath (2014) opined that the edaphic and environmental factors in lower foothills of Assam in north east region appear to be suited for the growth of *Santalum album* as evidenced from the luxuriant growth of trees Golaghat and Diphu, during a survey conducted at that time in Assam. The hot humid climate, annual rainfall of around 2000 mm during summer in the region and elevation of around 650 m msl in the lower hill region of Assam apparently favours the luxuriant growth of this plant. The present growth pattern of the species indicates that the geo-environmental factors of the region are suitable for the growth of Sandalwood. Apart from Karbi Anglong district, sandalwood is largely planted by farmers in Doboka, Hojai and Lanka of Nagaon district; Barpothar and Morongi of Golaghat district; Guwahati of Kamrup district; Jamuguri of Sonitpur district and Jonai of Dhemaji district of Assam. The present preliminary assessment of growth and heartwood formation across this region has revealed that heartwood and oil accumulation is happening in the traditional sandalwood growing areas in Karnataka. Further detailed sampling across the different agroclimatic regions in Assam and other states in northeast

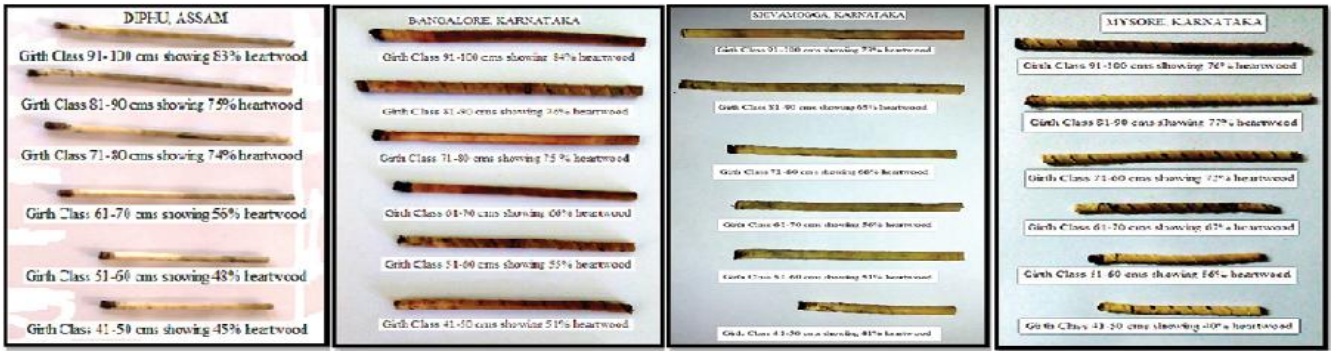

Fig. 7. Core samples of *Santalum album* L. trees from Diphu, Assam and Bangalore, Mysore and Shivamogga in Karnataka showing extent of heartwood formation from pith to periphery in different girth classes.

could reveal a more concise picture and dispel myths about the quality of sandalwood trees being inferior to that in peninsular India. Considering the financial viability of growing sandalwood (Viswanath, 2010) and seeing the growing trend in price of wood and oil in international market, growing this tree is undoubtedly a viable proposition which could boost the local economy. The overall picture that emerges from the study is that the Assam population are not much different from the Karnataka sandalwood population in terms of heartwood or oil percent, rate of heartwood formation and also trend in increase of oil content or formation with age. This preliminary study is expected to instill confidence among sandalwood growers in northeast and encourage more farmers to grow sandalwood by incorporating this tree in existing agroforestry practices.

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