Santalum album Distribution in Sri Lanka and the Variation of Oil Content and Constituents

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ABSTRACT

Santalum album has a cultural and economic attraction mainly because of its fragrant oil produced in the heartwood. Due to this reason, the demand and value are increasing which has created a high market interest.

Early studies indicated that S. album showed a highly localized distribution in Sri Lanka. However, recent studies have proven that it has a wider distribution in the country. According to the literature, sandalwood oil content and quality vary within the trees growing in the same area. Therefore, this study was designed to identify the oil content and oil quality variation in three districts of Sri Lanka, namely, Badulla, Kurunegala and Hambantota. All three districts belong to the Intermediate zone, however, with different rainfall, temperature and elevation figures.

Core samples and whenever possible, cross sections were extracted from randomly selected trees in each district. Oil was extracted by hydro-distillation and the different compounds present in oil were measured by gas chromatography analysis.

The results showed a large variation of oil contents present in the sampled trees. Selected oil compounds, i.e., cis-α-santalol, cis-β-santalol, epi-β-bisabalol, epi-β-santalol and t,t-farnesol showed little or no variation between the three selected districts. However, cis-t-bergamotol was high in the sampled trees of Hambantota district. Those compounds did not have significant correlations with tree parameters, geographic and topographic parameters, i.e., dbh, heath and heartwood content.

Key words: Santalum album, oil quantity, oil constituents, cis-α-santalol

Introduction

The genus *Santalum* embraces some 28 taxa of trees and shrubs, hemi parasitic on roots, from Sri Lanka to Pacific Islands (Barrett and Fox, 1995). However, among those species, only a few produces highly fragrant oil which fetches to a very high price in the international market. *S. album* is considered as the best quality oil yielding species among all. McKinell (1990) stated that a significant variation exists in heartwood oil content between the commercially utilized species. According to his findings, oil contents of *S. album* and *S. yasi* varied by 5-7%, while it varied in *S. austrocaledonicum* by 3-6%. The average oil content of *S. spicatum* stayed around 2%. Sandalwood oil is graded and priced according to the levels of alpha and beta santalol levels using a standard derived from *S. album* and invariably the market prices reflect the relative species average quality.

S. album is naturally distributed in India, Indonesia and Sri Lanka and it is believed to be indigenous to Sri Lanka. However, S. album plantation establishment has recently been started in Sri Lanka before about six years and therefore knowledge of oil content and quality in standing trees is being required by the plantation industry. Even in the global scenario, sandalwood has developed into a commercial timber crop over the past 10-15 years, with substantial sandalwood plantations established in India, China and Australia, and more modest plantings being established in Fiji, Vanuatu, Hawaii and Indonesia (Hettiarachchi et al, 2010).

The study conducted in Sri Lanka by Subasinghe et al (2013) on *S. album* in Sri Lanka showed a higher variation of oil content than the findings of McKinell (1990). Further, Subasinghe et al (2013) found significantly high oil content, i.e., 6.36% in some *S. album* trees tested. It is encouraging for the sandalwood growers in Sri Lanka to find the sandalwood trees with high oil contents. This study is being conducted further in larger extents to identify more variations and the reasons under the funding of the National Research Council of Sri Lanka.

Growth and germination of S. album in Sri Lanka

Growth rate of *S. album* present in natural stands of Sri Lanka varies from 0.3 to 1.0 cm in diameter and 0.5 to 1.0 m in height per annum at young stage. The germination rate of sandalwood seeds is very low under the natural conditions and therefore regeneration and resource increase in the wild has become slow showing the signs of extinction locally. Due to the low natural germination and high illegal harvest, *S. album*, has been identified as a threatened species in Sri Lanka since 1964. It was been declared as a protected species under the Flora and Fauna Act of 1964. This recognition was re-stated at the most recent amendment (Fauna and Flora Protection Amendment Act No. 22, 2009). It has also been mentioned in the same act that this law, however, can be overruled if another regulation become more effective.

Distribution of Santalum album in Sri Lanka

The early studies conducted on the *S. album* distribution in Sri Lanka stated that it was naturally distributed in three main administrative districts, i.e., Nuwara-Eliya, Rathnapura and Badulla (Tennekoon et al, 2000). According to the preliminary information received from Forest and Wildlife Officers, one of the objectives of the present study was to identify the current distribution of *S. album* in the country. An extensive survey was conducted for this purpose covering all the areas of the country with the help of Forest Officers working at field level. Based on the information received from the relevant officers and the field observations, other than Badulla, Nuwara Eliya and Rathnapura districts, *S. album* is also naturally distributed in the Hambantota, Jaffna, Kandy, Kurunegala, Matale and Puttlam districts (Figure 1). Further, it was interesting to find out the naturally growing sandalwood in Jaffna district in 2013 because that area was under the civil war for about 30 years until it was over in 2009. The vital climatic and geographic factors of those districts are given in Table 1.

According to Table 1, it was evident that *S. album* is growing in significantly different climatic and geographic areas in Sri Lanka varying from drier areas to wet areas. However, it is important to identify the growth rates and oil content variations of *S. album* in those areas and this study is being carried out at present by the authors of this paper.

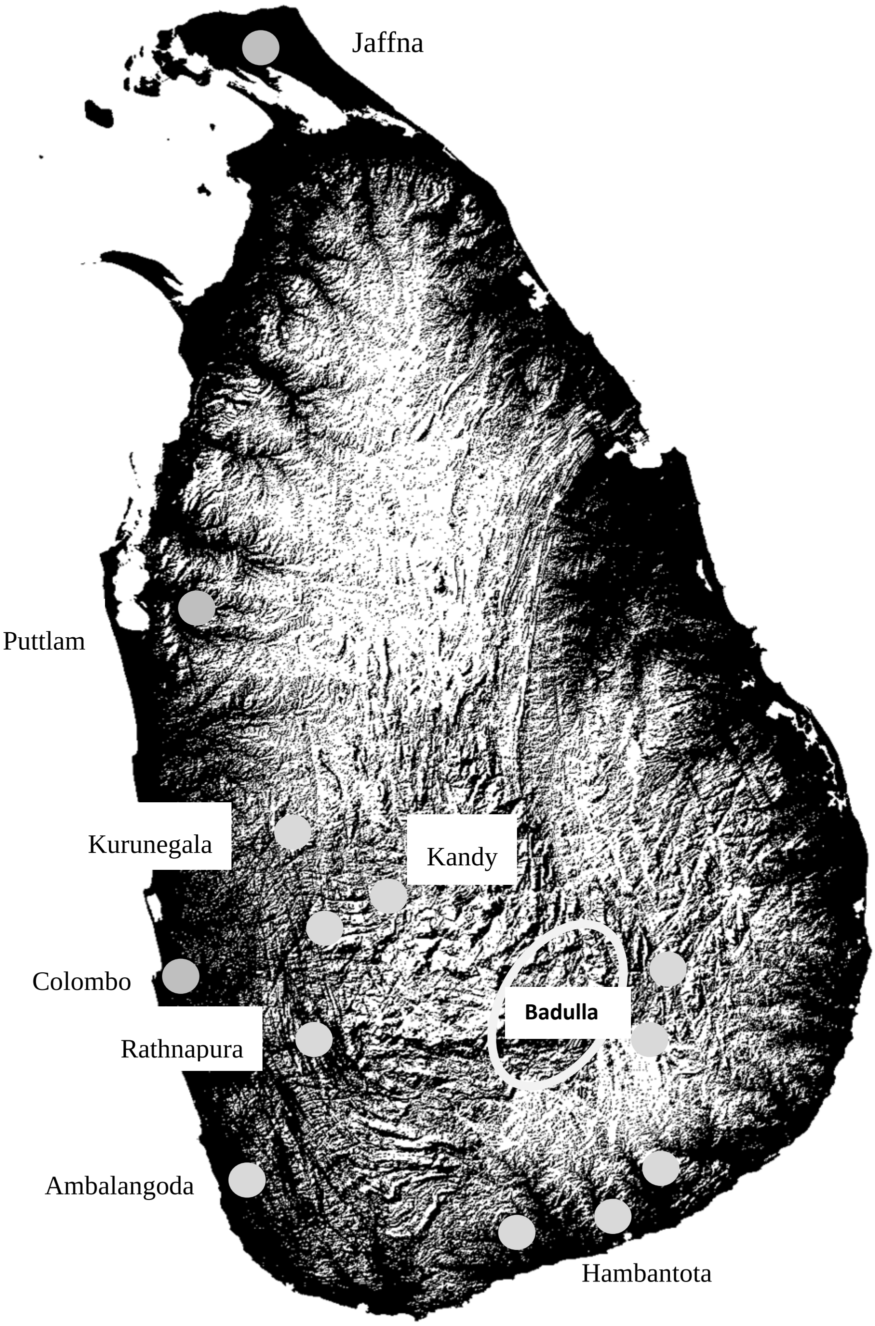

Figure 1: Sandalwood distribution map of Sri Lanka. The circle depicts the most commonly *S. album* distributed area

Table 2: The vital climatic and geographic factors of Sandalwood growing districts in Sri Lanka

Characteristic	**District***								
	Badulla	**Hambantota**	**Jaffna**	**Kandy**	**Kurunegala**	**Matale**	**Nuwara-Eliya**	**Rathnapura**	**Puttlam**
Elevation, m	500-1,000	5-10	5-10	500-1,000	50-100	100-500	1,000-1,500	100-750	5-10
Temperature, ^{0}C	22.5-25.0	25.0-27.5	>27.5	22.5-25.0	25.0-27.5	22.5-25.0	17.5-20.0	22.5-25.0	25.0-27.5
Ann. rainfall, mm	1,000-1,500	1,000-1,500	500-1,000	2,000-2,500	1,000-1,500	1,500-2,000	2,000-2,500	2,500-3,000	750-1,000
No dry months	6	5 ½	8	2 ½	5	5	2	1 ½	7
Major soil types	Red yellow podsoil/ Mountain regosols	Reddish brown earth/ Low humic gley	Red yellow latosols/ Regosols	Reddish brown latosolic/ Brown loams	Red yellow podzolic/ Low humic gely	Reddish brown earth/ Brown loams	Red yellow podzolic/ Mountain regosols	Red yellow podzolic	Red yellow latosols/ Regosols

* Information were mainly used for the areas where sandalwood is grown in these districts

Variation of oil quality and constituents

In order to identify the variation of oil contents and major oil constituents, samples were collected from wild-grown trees from three administrative districts in Sri Lanka, i.e., Badulla, Hambantota and Kurunegala. The climatic and geographical variations of these three districts are given in Table 1.

Core samples were extracted for this study from the selected *S. album* trees using an increment borer. Breast height diameter (dbh) and height were taken as tree measurements. In addition, the location details were recorded by using a high-quality GPS (Garmin Montana 650). During the study, it was also possible to obtain cross sections from the left-over butt regions of the illegally harvested trees.

The heartwood of the samples was carefully separated from the sapwood and heartwood oil extraction was done using hydro-distillation. Since the sample size was small, hexane was used to wash the tubes to collect the maximum oil after none-hour distillation. The oil content was calculated based on the weight of the heartwood sample used (w/w). Table 2 illustrates the variations of the tree parameters, heartwood contents and oil contents of the trees tested from three sele ted districts.

Table 2: Variatin of tree parameters, heartwood and oil contents

District	Dbh, cm	Height, m	Heartwood %	Oil %
Badulla	8.0-18.3	5.0-19.5	16-77	0.67-4.28
Kurunegala	6.5-10.5	4.5-6.0	12-66	0.14-2.56
Hambantota	5.2-9.5	3.5-6.5	6-54	0.21-0.80

Selected major oil constituents were then analysed by using gas chromatography method (GC2010, Shimadzu Scientific, Japan) equipped with a flame ionisation detector. 95% phenyl siloxane coated capillary (AT-5, Alltech, USA) column was used for this purpose. The injector was kept at 220^0 C and the oven had a 1^0 C per min gradient temperature from 120^0 C to 180^0 C. Data were processed by Labsolutions© software (Shimadzu Scientific, Japan). Identification of specific compounds within the oil was verified by using mass spectroscopic data and Kovat's indices (Hettiarachchi et al. 2010). Prior to the injection of the samples into the gas chromatography instrument, extracted sandalwood oil were dissolved in n-hexane to produce 1% w/v solutions.

The results of the oil content variation in different dbh classes are given in Figure 2. According to Figure 2, the highest average oil contents were observed for the trees of Badulla district which is famous for producing high quality sandalwood trees. The lowest oil contents were observed for the trees growing in Hambantota district (Figure 2). Oil contents of the trees in Kurunegala district had the values in between Hambantota and Badulla. However, trees with large diameter trees were not found at the time of sampling from Hambantota and Kurunegala districts mainly due to high rate of illicit felling.

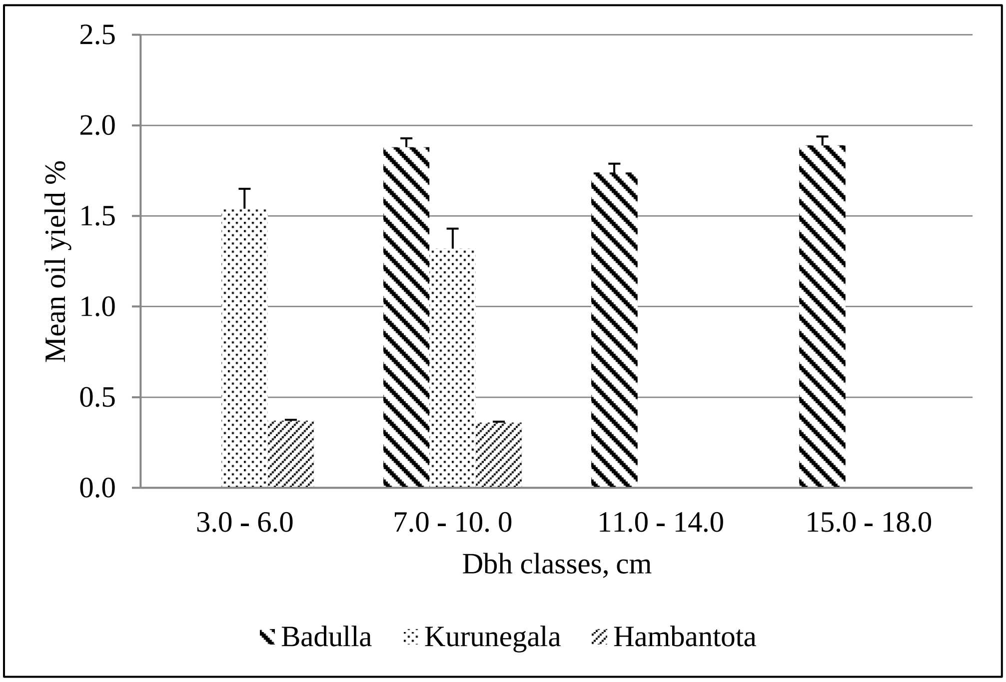

Figure 2: Change of oil content (with standard error) for the sampled locations

The variation of the tested constituents, i.e., cis-alpha-santalol, cis-beta-santalol, epi-beta-santalol and epi-beta-bisabalol showed no significant pattern of the variation with the tree size. It was, however, important to notice that very high values of epi-beta-bisabalol in all four samples tested from Hambantota District. Those values were 25.47, 38.97, 58.53 and 86.47%. The oil contents of these four samples varied from 0.20% to 0.70% and the dbh of those were very low, i.e., 4.0 to 9.1 cm. The average heartwood contents of the four samples of Hambantota district was 31%. Out of these four samples only two trees had cis-alpha-santalol values above 38% and the other two had those values were even below 3.8%.

Out of 35 trees sampled from Badulla district, 18 trees had cis-alpha-santalol above 40% and four trees had the values between 30-39%. Six trees had cis-alpha-santalol content varying from 20 to 29% and the values of the rest of the seven trees were below 19%. Two tees sampled in Badulla District had cis-beta-santalol values above 30% and 16 trees it varied from 20 to 29%. Variation of cis-beta-santalol values for 10 trees were between 10 to 19% and for seven trees, it was below 9%.

Cis-alpha-santalol content was above 40% for three trees out of six sampled from Kurunegala district and it was 19% for one tree. The rest of two trees had cis-alpha-santalol content below 9%. Cis-beta-santalol content was above 30% for one tree sampled in Kurunegala district and for three it varied from 20 to 29%. It was below 9% for the rest of the two trees.

One tree had cis-alpha-santalol content above 40 out of four trees sampled in Hambantota district and another tree had that value between 30 to 39%. It was below 19% for the rest of the two trees. Cis-beta-santalol values for all four trees of Hambantota district had the values lower than 5%.

Discussion

Illegal felling is the main threat to the *S. album* resource in Sri Lanka. Due to the high value of oil and its demand, poachers cut sandalwood trees from the wild and from the homegardens without paying any attention for the size or the maturity of the trees. Therefore the sacrifice of immature trees is high and it results the near extinction of this valuable species.

Commercially the value of any sandalwood tree depends up on its quantity and quality of heartwood oil. According to Brand et al. (2007) and Doran et al (2005) 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.

Tree age of sandalwood can be considered as a critical factor for the quality of oil constituents. This could be the reason of having oil constituents different from the expected values in Hambantota district. Proving this finding, although Brand et al. (2007) managed to extract oil from young sandalwood trees contains the main ingredients of sandalwood oil, the content was low compared with 14-year and 15-year old trees planted in Australia. These have not met the current ISO standards of ISO 2002, for S. album oil, which are 41-55% of alpha-santalol and 16-24% of beta-santalol.

Many researchers, e.g., Doran et al (2005), Joulain et al (2012), and Jain et al. (2003) found a high variation of oil between individuals of similar size and growing in the same area. These variations were, however, not properly explained by the authors and therefore it can be suspected that the genetic factors may play a significant role in oil formation. In addition, it may also be due to the climatic and topographical factors.

The percentage of heartwood varied significantly between different populations from 32% to 19% in different *S. austrocaledonicum* populations in Vanuatu (Page et al., 2006). Further, they found that the size of the trees is not directly indicative of the heartwood percentage, which is confirmed by the lack of correlation between them. The age onset for heartwood formation has been reported to be variable in *S. album* ranging from 14 to 46 years in Timor (Haffner, 1993) while Doran et al (2002) indicates approximately 10 years for plantation grown *S. album* in north-western Australia.

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References

Barrett, D.R., Fox, J.E.D. 1995. Geographical distribution of Santalaceae and botanical characteristics of species in the genus Santalum. In Gjerum, L, Fox, J.E.D. and Ehrhart, L. (eds) Sandalwood seed nursery and plantation technology. FAO, Suva, Fiji. Field document No. 8 RAS/92/361.

Brand, J.E., Fox, J.E.D., Pronk G., Cornwell, C. 2007. Comparison of oil concentration and oil quality from Santalum spicatum, S. album plantations, 8-25 years old, with those from mature S. spicatum natural stands. Australian Forestry, 70(4): 235−241.

Doran, J.C., Thompson, L.A.J., Brophy, J.J. 2002. Sandalwood. In Regional workshop on sandalwood research, Development and extension in the Pacific Islands and Asia.

Doran, J.C., Thomson, L., Brophy, J.J., Goldsack, B., Bulai, P., Faka'osi, T., Mokoia, T. 2005. Variation in heartwood oil composition of young sandalwood trees in the south Pacific (Santalum yasi, S. album and F1 hybrids in Fiji, and S. yasi in Tonga and Niue). Sandalwood Research Newsletter, 20:3-7.

Fauna and Flora Protection Ordinance Act, No 22 (Amendment). 2009. Published as a Supplement to Part II of the Gazette of the Democratic Socialist Republic of Sri Lanka of April 24, 2009.

Haffner, D. 1993. Determining heartwood formation within Santalum album and S. spicatum. Sandalwood Research Newsletter, 1: 4-5.

Hettiarachchi, D.S., Gamage, M., Subasinghe, U. 2010. Oil content analysis of Sandalwood: A novel approach for core sample analysis. Sandalwood Research Newsletter, 25: 1−4.

Jain, S.H., Angandi, V.G., Shankaranarayana, K.H., Ravikumar, G. 2003. Relationship between girth and percentage of oil in sandal provenances. Sandalwood Research Newsletter, 18:4-5.

Joulain, D., Nengone, S.N., De Guahma, D., dit Lyo, L. 2012. New insights into the qualitative and quantitative analytical chemistry of sandalwood essential oils New Caledonia, France. Proceedings of International Sandalwood Symposium, 21-24 October, 2012, Honolulu, Hawaii.

McKinnell, F.H. 1990. Status of management and silvuicultural research on sandalwood in Western Australia and Indonesia. USDA Forest Service Technical Report PSW-122.

Page, T., Tate, H., Tungon, J., Sam, C., Dickinson, G., Robson, K., Southwell, I., Russell, M., Waycott, M. and Leakey, R. 2006. Evaluation of heartwood and oil characteristics in nine populations of S. austrocaledonicum in Vanuatu. Sandalwood Research Newsletter, 21, 4-7.

Subasinghe, U., Gamage, M., Hettiarachchi, D.S. 2013. Essential oil content and composition of Indian sandalwood (Santalum album) in Sri Lanka. Journal of Forestry Research 24(1): 127-130.

Tennekoon, K.U., Ekanayaka, S.P., Etampawala, E.R.L.B. 2000. An overview of Santalum album Research in Sri Lanka. Sandalwood Research Newsletter, 11: 1-4.