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Status of Sandalwood (*Santalum album* Linn.) in Low Hills of Himachal Pradesh

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Abstract

The present investigation on the status of Sandalwood (*Santalum album* Linn.) in low hills of Himachal Pradesh was carried out in the Department of Silviculture and Agroforestry in the laboratory at the main campus of the Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan and in the field at Bilaspur and Jawala Mukhi varying in altitude from 500–850 m. The growth behavior of sandals was studied through the selection of 10 ha sampling plot at Bilaspur and 5 ha sampling plot at Jawala Mukhi based on tree density. The investigations revealed that the trees have covered an area of 15 ha at Bilaspur and 30 ha at Jawala Mukhi. The total number of trees growing at Bilaspur and Jawala Mukhi was found to be 1076 and 815, respectively. Further, average oil content was about 3.86 and 3.90% in the heartwood of *S. album* growing at Bilaspur and Jawala Mukhi. Phytosociological parameters of vegetation in sandal stand at Bilaspur revealed *Santalum album* as the dominant tree species with its maximum IVI value which corresponds to its higher frequency, basal area, and density.

Keywords: Basal area, essential oil, host, importance value index

1. Introduction

The Sandal (*Santalum album* Linn.) is one of the most important commercial tree species of India (Sandeep and Manohara, 2019). It is called the 'Royal tree' because its distribution is restricted, its oil is unique and of high value and the santalol in the sandalwood makes the wood impenetrable by termites (Sundararaj et al., 2019). It is commonly known as East Indian sandalwood or Chandana, belonging to the family *Santalaceae* (Sandeep et al., 2020). It is valuable for its fragrant heartwood (Tah, 2021). It is an evergreen tree attaining a height of 12 to 15 m and girth of 1 to 2.4 m with slender, dropping as well as erect branching (Chitra and Jijeesh, 2021). It flowers and fruits twice a year during March-April and September-October (Rao and Bapat, 1992) which are purplish-brown in color while the fruit is a drupe, purple brown when fully ripe and is single-seeded (Roy et al., 2017). The Sandal tree is a rare marvel of ecology, springing up in a forest where it was never seen before. It happily coexists with all kinds of other plants. Its roots entwine with the roots of other plants in the soil presents a complex system of coexistence. However, it does not harm the host plant. But when man tries to force it to grow in large numbers, it gradually disappears (Anonymous, 1997). It is a semi root parasite species. Its parasitic nature was first time reported by Scot in 1871 (Da Silva et al., 2016). It can parasitize over 300 species from grass to another sandal plant. Under gregarious growing conditions, self-parasitism is common (Doddabasawa and Chittapur, 2021). Its host during its nursery stage is different than in its plantation stage. *Cajanus cajan* and *Casuarina equisitifolia* proved to be their best host during nursery and plantation stages, respectively (Rocha et al., 2014). It is economically very important as it provides fragrant heartwood. Besides its vital importance on the economic ground, it is one of the ingredients of Indian culture and heritage. It has been used as an object in ritualistic offerings, and also an ointment for beauty. Its heartwood is closely grained and thus found to be the best wood for carving purposes such as the carving of idols, cabinet panels, chess boards, pen-holders, paperweights and picture frames (Nurochman et al., 2019). It is distributed between 30°N and 40°S from Indonesia in the West to Juan Fernadez Islands in the East and from Hawaiian Archipelago in the North to New Zealand in the South (Srinivasan et al, 1992). It is further reported that in India, Sandal is found distributed all over the country and more than 90% lies in Karnataka and Tamil Nadu covering 8300 km^2. Venkatesan et al. (1995) reported a state-wise assessment of sandal in India. They reported that sandal is distributed in 9040 km^2 area in India. In Karnataka, Tamil Nadu, Andhra Pradesh, Madhya Pradesh and Maharashtra, sandal trees are distributed over an area of

5245, 3045, 175, 33, and 8 km^2, respectively. Sandal trees are found growing in Kangra Valley near Jawala Mukhi of Himachal Pradesh. The area is about 30 to 35 ha. This contains nearly 4000 trees some of which are stated to be 30-35 years old.

Sandalwood on steam distillation yields an essential oil known as 'East Indian Sandalwood Oil' (Tah, 2021). Essential oils are complex compounds or mixtures of odorous and steam volatile nature. They are deposited in the plants in the cell organelle, in the heartwood, excretory cavities and canals. It is also known as "Liquid Gold" (Xiao et al., 2021). The oil contains 90% santalol, 25.5–5.0% santalyl acetate and 1.5–3.0% santalenes.

Knowing its economic and cultural importance, people in the past made some attempts to introduce sandalwood in northern India. The existence of sandalwood at Jawala Mukhi and Bilaspur which falls in the sub-tropical sub-mountain low hill zone (up to 900 m amsl) of Himachal Pradesh is the result of such an introduction. An army officer during World War II, for the first time, planted some trees of sandalwood at Jawala Mukhi (District Kangra) in the late forties. Later on, sandal trees got naturalized but could not spread beyond these sites. However, the entire sub-tropical sub-mountain hill zone covering an area of 9130.37 km^2 suits well to the soil and climate requirements of the species. Therefore, the present study was undertaken to study the status of Sandalwood in the low hills of Himachal Pradesh.

2. Materials and Methods

The present investigation was undertaken in the Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh.

2.1. Experimental sites

2.1.1. Location

Laboratory studies were conducted at Nauni located at 30"51'N latitude and 76°11'E longitude, at 1200 m amsl. Field and nursery experiments were conducted at Jawala Mukhi and Bilaspur varying in altitude from 500–850 m amsl.

2.1.2. Climate

Nauni falls under subtropical to sub temperate climate with an average annual rainfall of about 1250 mm. Generally, May and June are the hottest months and December to February is the coldest. Bilaspur and Jawala Mukhi are in the subtropical sub-mountain low hill zone. The soils of the field sites are shallow, light-textured and loamy sand to sandy loam. The pH of the soils varies from 6.5 to 8.

2.2. Status of Sandalwood

2.2.1. Population dynamics

The general growth behavior of sandalwood occurring in Himachal Pradesh was studied through a selection of 10 ha sampling plot at Bilaspur and 5 ha at Jawala Mukhi. The selection of the site was based on tree density. The trees were marked with white paint. Instruments used to study the population dynamics were metal caliper, vernier caliper, measuring tape and Spiegel Relaskop. Observation recorded were as follows:

a. Number of trees at each site: Total number of sandal trees grown at Bilaspur and Jawala Mukhi were enumerated and numbered with white paint.

b. Diameter of the trees: Diameters of all the marked sandal trees having diameters not less than 5 cm at breast height were recorded in cm with the help of a metal caliper.

c. Height of the trees: The height of all the marked trees having diameters not less than 5 cm were recorded in meters with the help of Spiegel Relaskop.

d. Number of trees in different diameter classes: The marked trees including saplings below five cm (including the nearby regenerated recruits) were classified based on diameter classes. The diameter classes were made as:

Diameter Class	Diameter (cm)
1	<5 cm
2	5–10 cm
3	10–15 cm
4	15–20 cm
5	20–25 cm

2.2. Phytosociological analysis of vegetation

At each site, five quadrates each of 10×10 m^2 i.e., 100 m^2 for trees and shrubs, and five quadrates of 1×1 m^2 i.e., 1 m^2 for herbaceous components were randomly laid out. Percent frequency, density, basal area, relative frequency, relative density, relative dominance, and importance value index were calculated for each species with the formula after the presentation by Mishra, 1968 as follows:

Per cent frequency=(Number of sampling units in which in which the species occurred/Total number of units studied)×100

Density =(Total number of individuals of the species/total number of quadrates studied)

Basal area=πr^2

Where, r=radius

Basal area was measured at 20 cm above ground level for all species

R.F. (Relative Frequency)=(Frequency of individual species/ Frequency of all species)×100

R.D. (Relative Density)=(Density of individual species/Total basal area of all species)×100

R.D (Relative Dominance)=(Total basal area of the species/ Total basal area of all species)×100

I.V.I (Importance Value Index)=Relative Frequency + Relative Density+Relative Dominance

2.3. Quality characteristics

2.3.1. Percentage of oil content

To confirm the existence and determine the quantity of oil in the heartwood of sandal trees growing in Himachal Pradesh conditions, preliminary studies were conducted. The heartwood samples were taken from sandal trees growing at Bilaspur and Jawala Mukhi with the help of Pressler increment borer. For extraction studies, 4 samples of 10 gm each of sandal heartwood were taken. These samples were dried and grounded to powder. The dried power of heartwood was soaked in water in a 1000 ml round bottom flask for 48 hours and then distilled with water for 72 hours. Thereafter, the floating oil in the distillate was mechanically skimmed off and was further refined by filtration.

2.4. Physical and chemical characteristics of soil

To study the physical and chemical characteristics of soil, soil samples (0-30 cm depth) were collected from the natural sandal growing areas of Bilaspur and Jawala Mukhi. Soil samples were air-dried in shade. Crushed and sieved through a 2 mm sieve and stored in cloth bags for chemical analysis. Soil texture, soil pH, organic carbon, available N, P and K were determined. The methods used to determine these soil chemical properties are given below:

Sl. No.	Parameter	Method
1.	Soil texture	International pipette method (Piper, 1966)
2.	Soil pH	1:2:5 soil: water suspension, with the help of digital pH meter (Jackson, 1973)
3.	Organic carbon (%)	Vegetative method for determining organic carbon (Walkley and Black, 1934)
4.	Available nitrogen (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
5.	Available phosphorus (kg ha^{-1})	Estimation of available phosphorus (Olsen et al., 1954)
6.	Available potassium (kg ha^{-1})	Flame photometer analysis (Merwin and Peech, 1951)

2.5. Leaf chemical analysis

Leaf chemical analysis was carried out to determine different leaf mineral nutrients content of *Santalum album*. The methodology followed is as below:

2.6. Preparation of samples

Leaf samples of *Santalum album* trees growing naturally at Bilaspur and Jwala Mukhi were brought and washed with tap water. The washed leaves were first air-dried in shade and subsequently in an oven at 60±5°C till constant weights were found and stored in butter paper bags for chemical analysis. For the estimation of total N, 0.02 gm of plant sample was digested in H_2SO_4 using digestion mixture K_2SO_4, $CuSO_4$ (3.5:0.4). After digestion N was estimated in Kjeltec auto 1030 Analyzer. For the estimation of total P, K, and Ca, the wet digestion of plant samples was carried out in a Di-acid mixture consisting of Nitric acid and Perchloric acid in the ratio of 4:1. Ground sample of a plant weighing 0.5 g was digested with 10–15 ml of the di-acid mixture. To have a complete transfer of digested material, three piles of washing of digestion flask were given with distilled water and the final volume of the digestion was made to 100 ml. Phosphorous in the digested sample was determined by Vanado-molybdo phosphoric yellow color method using Spectronic 20-D, whereas, K and Ca were estimated flame photometrically.

3. Results and Discussion

Data on the status of Sandalwood in the low hills of Himachal Pradesh have been presented in Tables 1-5. Data in Table 1 indicates that Sandalwood was found distributed at two sites viz. Bilaspur (Site-I) and Jawala Mukhi (Site-II). The total number of trees at Site-I and Site-II were found to be 1076 and 815, respectively. Maximum average height and diameter of trees at Site-I were found to be 15.50 m and 22.50 cm., respectively. At Site-II, the values for these parameters were, however, recorded as 14.25 m and 20.25 cm. At Site-I, the maximum number of trees (502) was found in diameter class 5-10 cm and minimum (3) in diameter class 20-25 cm. Whereas, at Site-II maximum number of trees (386) were found in diameter class less than 5 cm and minimum (6) in diameter class 20–25 cm. The heartwood oil content of trees was found to be 3.86 and 3.90% at Site-I and Site-II, respectively. It is comparable to the variations found in the

Table 1: Status of Sandalwood (*Santalum album* Linn.) in low hills of Himachal Pradesh

Sl. No.	Population dynamics	Site-I (Bilaspur)	Site-II (Jawala Mukhi)
1.	Average maximum height (m)	15.50	14.25
2.	Average maximum diameter (cm)	22.50	20.25
3.	Diameter Classes	No. of trees in different diameter classes	
	<5 cm	423	386
	5–10 cm	502	271
	10–15 cm	121	110
	15–20 cm	27	42
	20–25 cm	3	6
4.	Total number of trees	1076	815
5.	Oil content (%)	3.86	3.90

trees growing in south India, the natural home of sandalwood. The sampling area at Site-I and Site-II was determined based on the density of the sandalwood plantation (Table 1). At Site-I (Bilaspur), a 10 ha area was selected because of its dense stand at one particular place only. At Site-II (Jawala Mukhi), most plantations were found scattered adjoining to the town and farmers' agricultural landholdings. Due to these basic underlying characteristics of sandalwood plantation at Site-II, a patch of 5 ha area could only be selected. There has been no significant difference among the population dynamics because these sites were located in the same agro-climatic zone. Furthermore, these plantations were done almost at the same period. According to folklores, one defense person had introduced *Santalum album* at Jawala Mukhi (Personal Communication, 1989). Venkatesan et al. (1995) reported 4000 trees of sandalwood in Kangra valley near Jawala Mukhi of Himachal Pradesh.

The average maximum height and diameter growth at Site-I were found to be 15.50 m and 22.50 cm, respectively. Whereas, at Site-II, these values were 14.25 m and 20.25 cm. The maximum number of trees at Site-I were in diameter class up to 5-10 cm whereas, at Site-II maximum number of trees were in diameter class <5 cm. Very few trees have attained a harvestable diameter class i.e., 20–25 cm.

The above findings indicate moderate tree growth although these are subjected to heavy biotic and abiotic interferences e.g., browsing by animals, heavy erosion of soils, and cutting/ lopping by local inhabitants. The heartwood oil content of trees was found to be 3.86% and 3.90% at Site-I and Site-II, respectively. It is comparable to the variations found in the trees growing in south India, the natural home of sandalwood. The specific physiochemical characteristics of soils and distinct ecological settings of the present sites bearing sandal stands in the North-Western Himalayas region may also have influenced the oil content. The difference between the minimum and maximum temperatures in Himachal Pradesh is much greater than in the southern states of India where there is a general tendency of temperature remaining around 20–30°C. Temperature variations at the sites under study have been from 5–25°C. This can also be a reason for variations in the oil content of sandalwood in Himachal Pradesh.

The phytosociological parameters i.e., density, percent frequency, basal area and importance value index (IVI) for the vegetation of sandal stand at Bilaspur and Jwala Mukhi have been tabulated in Table 2 and 3. Data tabulated in Table 2 reveals that the sandal forest at Bilaspur was dominated by *Santalum album* followed by *Lannea coromandelica* and *Leucaena leucocephala* with IVI 103.38, 31.50 and 29.09, respectively. *Mallotus philippinensis* and *Bauhinia variegata* have less distribution with IVI 8.77 and 5.42, respectively. *Dalbergia sissoo*, *Albizia lebbeck* and *Caccia fistula* had rare distribution with IVI 4.74, 4.74 and 3.93, respectively. Dominating shrubs were *Carissa carandus* and *Lantana camara* with IVI 30.97 and 29.89, respectively. *Euphorbia* spp, *Zizyphus numularia*, *Phoenix* spp and *Dodonaea viscosa* were having an IVI of 12.78, 11.01, 8.52 and 8.41, respectively. *Agave amerciana* and *Adhatoda vasica* were rarely distributed with IVI 3.49 and 3.31, respectively. Dominating grass was *Chrysopogon montanus* with IVI 186.04 followed by *Dicanthium anulatum* with IVI 113.96. Data presented in Table 4 revealed that *Santalum ablum* was a dominating tree at Jawala Mukhi with IVI 87.51. The associated tree species were *Acacia catechu* and *Dalbergia sissoo* with an IVI of 21.92 and 21.35, respectively. *Mallotus philippinensis* showed a minimum IVI of 13.63. Dominating shrub was *Lantana camara* with IVI 51.99. It was followed by *Adhatoda vasica*, *Carissa carandus*, *Murraya koenigii* and *Agave americana* with IVI 24.14, 20.58, 18.92 and 15.47, respectively. *Zizyphus*

Table 2: Phytosociological parameters of vegetation in sandal stand at Bilaspur

Name of species	Density (No. 100 m^{-2})	Frequency (%)	Basal area (cm^2 100 m^{-2})	IVI
Trees				
Santalum album	17.60	100	784.09	103.38
Lannea coromandelica	3.50	40	329.79	31.50
Leucaena leucocephala	6.40	100	56.87	29.09
Mallotus philippinensis	3.00	40	19.89	8.77
Bauhinia variegata	2.00	20	29.74	5.42
Dalbergia sissoo	1.00	20	25.72	4.74
Albizia lebbeck	1.00	20	25.72	4.74
Cassia fistula	1.00	20	14.47	3.93
Shrubs				
Carissa carandus	7.60	100	50.42	30.97
Lantana camara	8.40	100	13.58	29.89
Euphorbia spp	4.00	60	8.29	12.78
Zizyphus numularia	2.33	60	10.79	11.01
Phoenis spp	4.00	40	5.51	8.52
Dodonaea viscosa	3.50	40	9.45	8.41
Agave americana	2.00	20	2.91	3.49
Adhatoda vasica	2.00	20	0.40	3.31
Grasses				
Chrysopogon montanus	40.00	60	5.35	186.04
Dichanthium anulatum	32.70	20	4.20	113.96

*Density and the basal area is on a per square meter basis

Table 3: Phytosociological parameters of vegetation in sandal stand at Jawala Mukhi

Name of species	Density (No. 100 m^{-2})	Frequency (%)	Basal area (cm^2 100 m^{-2})	IVI
Trees				
Santalum album	8.80	100	2050.32	87.51
Acacia catechu	3.00	60	382.00	21.92
Dalbergia sissoo	2.33	60	390.27	21.35
Mallotus philippinensis	2.33	60	112.52	13.63
Shrubs				
Lantana camara	17.40	100	152.45	51.99
Adhatoda vasica	12.67	60	42.62	24.14
Carissa carandus	4.25	80	126.02	20.58
Murraya koenigii	3.75	80	95.25	18.92
Agave Americana	4.33	60	92.00	15.47
Zizyphus numularia	2.00	60	63.20	11.86
Dodonaea viscosa	2.00	60	44.36	11.33
Grasses				
Chrysopogon montanus	80.00	60	12.94	145.49
Cymbopogon martinii	20.35	40	12.04	80.51
Heteropogon contortus	25.00	40	8.52	74.00

*Density and the basal area is on a per square meter basis

Table 4: Physio-chemical characteristics of soils

Sl. No.	Parameter	Site-I (Bilaspur)	Site-II (Jawala Mukhi)
1.	Soil Texture	Sandy loam	Silty loam
2.	Soil pH	7.6	7.7
3.	Organic carbon (%)	1.72	0.70
4.	Nitrogen (kg ha^{-1})	481.89	285.38
5.	Phosphorus (kg ha^{-1})	13.39	12.27
6.	Potassium (kg ha^{-1})	264.32	141.12

numularia and *Dodonaea viscosa* showed lowest IVI of 11.86 and 11.33, respectively. Dominating grass was *Chrysopogon montanus* with IVI 145.49 followed by *Cymbopogon martini* and *Heteropogon contortus* with IVI 80.51 and 74.00, respectively.

Studies at both the sites revealed that Santalum *album* was the dominant species with *Lannea coromandelica* and *Acacia catechu* as co-dominants. Maximum IVI value for Sandal is attributed to its higher frequency, basal area and density. *Carissa carandus* and *Lantana camara* were dominant shrubs whereas, *Chrysopogon montanus* dominated the grass species.

At Site-I, *Santalum album* showed maximum dominance followed by *Lannea coromandelica* and *Leucaena leucocephala.* Maximum IVI for *Santalum album* is attributed to its higher frequency, basal area and density. *Dalbergia sissoo*, *Albizia lebbeck* and *Cassia fistula* have low dominance due to their low density, frequency and basal area. Among shrubs, *Carissa carandus* dominated the site, followed by *Lantana camara. Agave Americana* and *Adhatoda vasica* showed the least dominance. *Chrysopogon montanus* was found to be the most dominant grass at Site-I with an IVI Value of 186.04. It was due to its high frequency and basal area. The low distribution of *Dicanthium anulatum* (IVI 113.96) is attributed to its low frequency and basal area.

Data in Table 5 revealed that *Santalum album* dominated the vegetation at Site-II. Its IVI value was 87.51. It was attributed to its higher frequency, basal area and density. *Mallotus philippinensis* had low dominance with IVI 13.63. The most dominant shrub at this site was *Lantana camara* (IVI 51.99). *Zizyphus numularia* and *Dodonaea viscosa* had got low dominance having IVI 11.86 and 11.33, respectively. *Chrysopogon montanus* (IVI 145.49) dominated the different grass species, owing to its high density, frequency and basal area. *Heteropogon contortus* (IVI 74.00) had the least density, frequency and basal area.

Data presented in Table 4 indicates that soil texture at Site-I (Bilaspur) and Site-II (Jawala Mukhi) was sandy loam and silty loam. The sandal is capable of growing in different kinds of soils like sand, clay, laterite, loam and black cotton soils (avoiding waterlogged conditions). Even very poor and rocky soils can support sandalwood (Rai, 1990). Whereas, soil pH at Site-I and Site -II was found to be 7.6 and 7.7, respectively. Organic carbon at Site-I and Site –II was found to be 1.72 and 0.70%. Whereas, Nitrogen, phosphorus, and potassium at Site-I (Bilaspur) and Site-II (Jwala Mukhi) were found to be 481.89, 13.39, 264.32 and 285.38, 12.27, 141.12 kg ha^{-1}, respectively.

Table 5: Leaf mineral nutrients content of *Santalum album*

Sl. No.	Place	N (%)	P (%)	K (%)	Ca (%)
1.	Bilaspur	2.37	0.41	1.89	5.05
2.	Jawala Mukhi	2.38	0.43	2.59	5.63

Data on leaf mineral nutrients content of *Santalum album* trees growing at Site-I (Bilaspur) and Site-II (Jawala Mukhi) has been depicted in Table 5. N, P, K, Ca in the leaves of *Santalum album* trees growing at Site-I and Site-II were found to be 2.37, 0.41, 1.89, 5.05, and 2.38, 0.43, 2.59, 5.63%, respectively.

4. Conclusion

The present investigation concludes that a total of 1891 Sandalwood trees were found to be distributed at both the sites of Himachal Pradesh. Heartwood oil and leaf mineral nutrient contents were found maximum in the sandal trees growing at Jawala Mukhi in Kangra valley of Himachal Pradesh. Phytosociological studies revealed the dominance of *Santalum album* with *Lannea coromandelica* and *Acacia catechu* as co-dominant tree species. *Carissa carandus* and *Lantana camara* were the dominating shrubs, whereas, *Chrysopogon montanus* dominated the grass species.

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