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Floristic Diversity of *Santalum album* L. Populations in Mid Hill Zone of Himachal Pradesh

Ankush Garg, Dushyant Sharma[1*] and Kumari Shiwani[2]

Department of Tree Improvement and Genetic Resources, Dr. Y. S. Parmar University of Horticulture and Forestry Nauni, Solan-173 230, India
[1]Department of Tree Improvement and Genetic Resources, College of Horticulture and Forestry Dr. Y. S. Parmar University of Horticulture and Forestry, Neri, Hamipur-177 001, India
[1]Department of Vegetable Science, College of Horticulture and Forestry Dr. Y. S. Parmar University of Horticulture and Forestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Thunag, Mandi-175 048, India
**E-mail: sharmadus@gmail.com*

***Abstract*:** The ecological study of a species is an essential requirement for its long -term survival in a particular area. Keeping in view the socioeconomic importance of the Indian sandalwood and existence of few natural populations to restricted sites in mid hill zone of Himachal Pradesh, India, the study on phytosociology and natural regeneration status of *Santalum album* L. was carried out in five locations of district Kangra. In every natural population, ten quadrats of 10 m × 10 m (100 m^2) size determined by species area curve method were randomly laid to study this tree species. In each quadrat, a sub-quadrat of 5 m × 5 m (25 m^2) and 2 m × 2 m (4 m^2) for size for shrubs and regeneration study were selected, respectively. Studies showed the dominance of *Santalum album* L. tree species in all the five natural populations. Among shrubs, *Lantana camara* L. was observed growing in close association with *Santalum album* L. whereas, natural regeneration of this species in all the studied natural populations was limited due to the lack of good mother trees and human interference to a greater extent.

Keywords: *Santalum album*, Floristic diversity, Natural regeneration, *Lantana camara*

Santalum album L. commonly referred as sandalwood is widely accepted valuable tree belongs to family Santalaceae. This family consists of 29 genera and 400 species, out of which 19 species are specific to genus *Santalum* (Teixeira de Silva et al 2016). This genus (*Santalum*) is distributed across South and Southeast Asia, Oceania and Australia (Harbaugh and Baldwin 2007, Page et al 2020). *S. album* L. is native to the tropical belt of peninsular India, Eastern Indonesia and Northern Australia (Venkatesa 1980). It is indigenous to India covering an area of 9600 Km^2 (Gairola et al 2007), mostly (90%) grown in states like Karnataka and Tamil Nadu (Kumar et al 2012, Kausar et al 2014 and Rocha et al 2017). In Himachal Pradesh, Sandalwood cultivated in some areas of district Bilaspur and Kangra mainly at Jawala Ji region. Sandalwood is an evergreen, hemi root parasite tree which can parasitize over 300 species ranging from grass to another sandalwood species (Ananthapadmanabha et al 1984, Nagaveni and Vijayalakshmi 2007, Rocha et al 2017). Hosts of this tree are different, both in nursery and plantation stages. *Cajamus cajan* and *Casuarina equisetifolia* are recorded as the best host plants during nursery and plantation stages, respectively (Doddabasawa and Chittapur 2021). Sandalwood tree is mainly exploited for its heartwood which yields the renowned East Indian Sandalwood oil, valued for its sweet fragrant, persistent, spicy, warm, woody note, tenacious aroma and fixative property (Krishnappa 1972). Growing sandalwood tree under natural conditions can produce an increment of one kg of heartwood/ year and a girth of one cm/ year (Rai 1990). The timber of Sandalwood is the world's second most expensive timber (Kumar et al 2012).

The existence of sandalwood populations in some particular areas of Kangra and Bilaspur districts of Himachal Pradesh was results of introduction. In late 1940s, Sandalwood trees were first introduced in Jawalamukhi area of district Kangra by an army officer during World War II (Dutt 2000). Later on, sandalwood trees got naturalized but could not spread beyond these confined sites besides the fact that, the entire sub-tropical sub montane hill zone has well suited soil and climate requirements of this tree species. The ecological study of this species is an essential requirement for its long-term survival in a particular area. In this lane the survey was accomplished on phytosociological and natural regeneration status of Sandalwood in five locations of district Kangra, Himachal Pradesh with objectives of studying the distribution pattern, natural regeneration status, ecological status and woody plant association of this tree species.

MATERIAL AND METHODS

Study area: The study was conducted in five natural populations (Banoh, Khariya, Amb Khatta, Selra and Jawala

Ji) of *Santalum album* L. distributed in district Kangra, Himachal Pradesh. The area located between latitudes 31° 41' 00" and 32° 28' 05"; and longitudes 75° 35' 34" and 77° 04' 46" presents an intricate mosaic of mountain ranges, hills and valleys. It is primarily a hilly district, with altitudes ranging from 350 m amsl to 4880 m amsl in the hills of Dauladhar. Six types of soils are observed in the district including Histosols (snow field, peaty and saline peaty), Ultisols (Brown red and yellow), Alfisols (Sub Mountain), Ardisols (Grey Brown) and Entisols (Younger alluvium). The climate varies from sub-tropical to sub-humid. Winter extends from December to February and summer extends from March to June while July to September are the rainy months. The average annual rainfall of the district is 1751 mm, out of which 83% occurs during June to September. Snow fall is received in the higher reaches of Dhauladhar ranges. The minimum and maximum temperature at Dharamshala varies from 2.9°C in January to 32.9°C in May.

Phytosociological Studies of Natural Populations

Community analysis: The status of plant diversity and regeneration in natural populations of the study area, community analysis was carried out during rainy season, 2020-2021. In every natural population, ten quadrats (10 m × 10 m) determined by species area curve method were randomly laid to study tree species. In each quadrat, a sub-quadrat of 5 m × 5 m and 2 m × 2 m size for shrubs and regeneration study were selected, respectively. The vegetation data was quantitatively analyzed for density (D), per cent frequency (%) and abundance (A). Relative frequency (RF), relative density (RD) and relative basal area (RBA) were determined following methods proposed by Phillips (1959), while Importance Value Index (IVI) was calculated by following Curtis (1959). Indices of similarity and dissimilarity were calculated by using formulae of Mishra (1989) and Sorensen (1948). Species Richness was estimated as per the method named Margalef's index of richness' (D_{mg}) as per Magurran (1988), Diversity as per Shannon-Wiener (1963) and Index of Diversity were estimated as per Simpson (1949).

Natural regeneration study of natural populations: The adequacy of regeneration of *Santalum album* L. within its natural population was judged on the basis of number of established plants in a unit area. According to Chacko (1965), desired number of established plants is 2500/ ha and the quadrate is considered fully stocked when it contains one established plant. Observations on regeneration were made in a quadrat size of 2 × 2 m.

RESULTS AND DISCUSSION

Natural population of *Santalum album* L : The major tree species that represent the natural populations of *Santalum album* L. in district Kangra are *Acacia catechu, Albizia chinensis*, *Albizia lebbeck, Grewia optiva, Leucaena leucocepahla* and *Dalbergia Sissoo*. These species occur mixed with other important/ associated species in the natural populations (Table 1-5). A range of 6-9 tree species and 2-3 shrub species were predominant in all five locations of district Kangra. The maximum number of tree species out of total species were d in Jawala Ji whereas, minimum number of species in Banoh. Maximum values for parameters like density, abundance, basal area, per cent frequency and IVI (Importance Value Index) were observed in *Santalum album* L. in four out of five locations namely, Banoh, Khariya, Selra

Table 1. Floristic diversity of trees and shrubs in Banoh

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/ (cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	90	1.13	0.18	80.00	17.31	25.81	13.92	57.04
Albizia chinensis	60	1.00	0.25	60.00	11.54	19.35	18.83	49.72
Cassia fistula	40	1.33	0.04	30.00	7.69	9.68	3.44	20.81
Ficus religiosa	20	1.00	0.39	20.00	3.85	6.45	28.95	39.24
Santalum album	300	3.00	0.42	100.00	57.69	32.26	31.41	121.36
Syzygium cumini	10	1.00	0.04	10.00	1.92	3.23	3.46	8.61
Total	520	8.46	1.36	310.00	100	100	100	300
Shrubs								
Lantana camara	330	3.30	44.53	100.00	51.56	47.62	56.5	155.64
Murraya koenigii	220	2.75	18.56	80.00	34.38	38.10	23.5	96.00
Rubus ellipticus	90	3.00	15.78	30.00	14.06	14.29	20.0	48.36
Total	640	9.05	78.87	210.00	100.00	100.00	100.0	300

and Jawala Ji. High values of these parameters attributed to the dominance of one species over the other species in their respective habitat. *Santalum album* found to dominant species. In general, *Santalum album* had older crop in their habitat. Minimum values for these parameters were observed for tree species named *Syzygium cumini* in Banoh, Khariya, Amb Katta and Selra. For Jawala Ji, *Ziziphus jujuba* recorded minimum value. This implies that *Syzygium cumini* and *Ziziphus jujuba* are also grow in association with *Santalum album* L. in one or other natural populations. *Santalum album* L. was dominant tree species in all the locations surveyed expect for Amb Katta. *Acacia catechu* (Banoh and Khariya), *Dalbergia sissoo* (Selra and Jawala Ji) and *Santalum album* (Amb Katta) was recorded as co-dominant tree species in natural populations of *S. album.*

Among shrub species, maximum number of shrubs

Table 2. Floristic diversity of trees and shrubs in Khariya

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	70	1.40	0.13	50.00	12.96	15.63	10.26	38.85
Acacia nilotica	20	1.00	0.06	20.00	3.70	6.25	5.29	15.25
Albizia lebback	50	1.25	0.18	40.00	9.26	12.50	14.15	35.91
Grewia optiva	40	1.33	0.08	30.00	7.41	9.38	6.88	23.66
Mallotus phillipinensis	30	1.50	0.03	20.00	5.56	6.25	2.34	14.15
Mangifera Indica	30	1.00	0.21	30.00	5.56	9.38	16.72	31.65
Santalum album	270	2.70	0.36	100.00	50.00	31.25	28.87	110.12
Syzygium cuminii	10	1.00	0.04	10.00	1.85	3.13	3.19	8.16
Terminalia chebula	20	1.00	0.15	20.00	3.70	6.25	12.29	22.25
Total	540	12.18	1.28	320.00	100	100	100	300
Shrubs								
Lantana camara	340	3.40	50.10	100.00	46.58	43.48	66.1	156.11
Murraya koenigii	280	3.11	16.46	90.00	38.36	39.13	21.7	99.19
Ziziphus mauritiana	110	2.75	9.29	40.00	15.07	17.39	12.2	44.71
Total	730	9.26	75.85	230.00	100.00	100.00	100.0	300

Table 3. Floristic diversity of trees and shrubs in Amb Katta

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	240	2.40	0.38	100.00	40.68	30.30	37.39	108.37
Bombax ceiba	20	2.00	0.07	10.00	3.39	3.03	7.08	13.50
Leucaena leucocephla	40	1.00	0.03	40.00	6.78	12.12	3.08	21.98
Mallotus phillipinensis	20	1.00	0.01	20.00	3.39	6.06	1.59	11.04
Mangifera Indica	20	1.00	0.16	20.00	3.39	6.06	15.66	25.11
Melia azedarach	20	1.00	0.06	20.00	3.39	6.06	5.95	15.40
Santalum album	210	2.10	0.21	100.00	35.59	30.30	20.73	86.63
Syzygium cuminii	20	1.00	0.08	20.00	3.39	6.06	8.52	17.97
Total	590	11.50	1.03	330.00	100	100	100	300
Shrubs								
Carrisa opaca	110	2.75	14.34	40.00	14.86	18.18	14.3	47.36
Lantana camara	410	4.10	71.47	100.00	55.41	45.45	71.3	172.20
Murraya koenigii	220	2.75	14.37	80.00	29.73	36.36	14.3	80.44
Total	740	9.60	100.18	220.00	100	100	100	300

(three) was recorded in locations like Banoh, Khariya, Amb Katta and Jawala Ji (Tables 1-5). The highest or density, abundance, basal area, per cent frequency and IVI was for shrub species *Lantana camara* L. in all the five locations surveyed. *Lantana camara* and *Murraya koenigii* were observed as dominant and co-dominant shrubs species, respectively in all the five locations. Shrub *Lantana camara* grown in close association with *S. album*. The high density of shrubs may be explained on an account of more space ad tree cover allowing more shrubs to grow on the surface floor. Sharma and Thakur (2015) have reported density value ranging from 270-316 trees per hectare and shrub density of 3440-5120 for different natural populations of *T. chebula* in district Kangra. The high basal area denotes the presence of higher number of matures trees and shrubs in natural populations.

Vegetation indices of trees and shrubs: Population wise descending order of tree species diversity was Khairya,

Table 4. Floristic diversity of trees and shrubs in Selra

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	70	1.75	0.13	40.00	12.73	12.12	11.05	35.90
Dalbergia sissoo	80	1.14	0.25	70.00	14.55	21.21	21.58	57.34
Ficus carica	40	1.00	0.08	40.00	7.27	12.12	7.08	26.47
Mallotus phillipinensis	50	1.67	0.03	30.00	9.09	9.09	3.13	21.31
Mangifera Indica	30	1.00	0.21	30.00	5.45	9.09	18.46	33.01
Morus alba	10	1.00	0.01	10.00	1.82	3.03	1.61	6.46
Santalum album	260	2.60	0.38	100.00	47.27	30.30	32.14	109.72
Syzygium cuminii	10	1.00	0.05	10.00	1.82	3.03	4.94	9.79
Total	550	11.16	1.18	330.00	100	100	100	300
Shrubs								
Lantana camara	410	4.10	61.77	100.00	57.75	50.00	74.8	182.52
Murraya koenigii	300	3.00	20.84	100.00	42.25	50.00	25.2	117.48
Total	710	7.10	82.61	200.00	100	100	100	300

Table 5. Floristic diversity of trees and shrubs in Jawala Ji

Tree species	Density (individual/ha)	Abundance (AB)	Basal area (m^2/ha) trees/(cm^2/ha) shrubs	Percent frequency	Relative density	Relative frequency	Relative basal area	IVI
Trees								
Acacia catechu	30	1.50	0.05	20.00	5.17	6.06	3.91	15.14
Albizia chinesis	50	1.00	0.16	50.00	8.62	15.15	10.99	34.77
Dalbergia sissoo	80	1.60	0.24	50.00	13.79	15.15	16.02	44.97
Eucalyptus spp.	10	1.00	0.10	10.00	1.72	3.03	6.82	11.57
Ficus carica	30	1.00	0.05	30.00	5.17	9.09	3.32	17.59
Santalum album	290	2.90	0.46	100.00	50.00	30.30	30.19	110.49
Tectona grandis	50	1.67	0.18	30.00	8.62	9.09	12.41	30.12
Toona ciliata	30	1.00	0.22	30.00	5.17	9.09	14.90	29.16
Ziziphus jujuba	10	1.00	0.02	10.00	1.72	3.03	1.44	6.19
Total	580	11.67	1.52	330.00	100	100	100	300
Shrubs								
Carrisa opaca	120	2.40	25.86	50.00	14.81	20.00	22.0	56.84
Lantana camara	390	3.90	64.76	100.00	48.15	40.00	55.2	143.31
Murraya koenigii	300	3.00	26.77	100.00	37.04	40.00	22.8	99.84
Total	810	9.30	117.39	250.00	100.00	100.00	100.0	300.00

Table 6. Vegetation indices of trees and shrubs under natural populations of *Santalum album* L.

Population	Vegetation index							
	Shannon – Wiener Index(H)		Simpson's dominance (cd)		Species richness (d)		Equitability (e)	
	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs
Banoh	1.26	0.98	0.25	0.40	0.80	0.48	0.70	0.89
Khairiya	1.66	1.00	0.19	0.40	1.27	0.30	0.76	0.91
Amb Katta	1.48	0.97	0.24	0.43	1.10	0.30	0.71	0.88
Selra	1.60	0.68	0.21	0.52	1.11	0.15	0.77	0.98
Jawala Ji	1.64	1.00	0.20	0.37	1.41	0.30	0.71	0.91

Table 7. Regeneration studies of *Santalum album* L. in its natural populations

Location	Recruits /ha	Un-established /ha	Established /ha	Establishment index (I_1)	Stocking index (I_2)	Established stocking per cent	Regeneration success percentage
Banoh	175.00	125.00	50.00	0.18	0.03	1.91	3.25
Khairiya	125.00	75.00	50.00	0.20	0.03	2.09	2.75
Amb katta	75.00	75.00	25.00	0.10	0.02	1.00	1.75
Selra	125.00	75.00	50.00	0.25	0.03	2.13	2.75
Jawala Ji	75.00	75.00	75.00	0.33	0.04	3.33	3.75

Jawala Ji, Selra, Amb Katta and Banoh (Table 6). Species diversity of shrubs ranged from 0.68 to 1.00, maximum in Selra and minimum in Khairya and Jawala Ji. The high diversity can be attributed to low disturbance, habitat conditions and species characteristics (Zegeye et al 2006). Among all the locations surveyed maximum values for tree species dominance and tree species richness were recorded for Banoh and Selra, respectively whereas, in case of shrubs highest values for dominance and richness were observed for Jawala Ji and Banoh, respectively. The population wise equitability in tree and shrub species was recorded high in Selra (Table 6).

Natural regeneration: In all the natural populations surveyed, Banoh registered maximum number of recruits and un-established regeneration. Jawala Ji recorded maximum for established regenerations, establishment index, stocking, established stocking per cent and regeneration success per cent which was due to the presence of good mother tree and less human disturbance such as grazing, walking over and other human activities, etc., which led to the growth of good flourished seedlings of sandalwood. The rest of the locations were disturbed by human activities. Another reason for presence of good seedlings was the slope of this location as sandalwood needs sloppy areas for good drainage due to which it flourishes well (Padmanabha 2003). These findings are supported by Hanumantha et al (2012). Guleria (2008) observed that sandalwood regeneration is better in the presence of host plants association. These results are supported by findings of Sharma and Thakur (2016) and Singh (2020), where absence of natural regeneration of Harar in its natural populations due to the disturbance in the natural population sites by the humans and other factors which restrict the flourishing of seedling in its natural habitat.

CONCLUSION

The mature and over mature trees of *S. album* L. in limited number were observed growing in selected natural populations. Natural regeneration of S*. album* was negligible in these populations which confirm the urgency of supplementation of natural regeneration with the help of artificial regeneration. The major associated tree species of S. album were *Acacia catechu, Albizia chinensis, Albizia lebbeck, Grewia optiva, Leucaena leucocepahla and Dalbergia Sissoo*, while, *Lantana camara* L. and *Murraya koenigii* were major associated shrub species.

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