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PHYTODIVERSITY AND STAND CHARACTERS OF SIX OAK (*QUERCUS LEUCOTRICHOPHORA* A. CAMUS) FORESTS IN GARHWAL HIMALAYA, UTTARAKHAND, INDIA

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Abstract

A plant quantitative investigation was carried out at six oak (*Quercus leucotrichophora* A. Camus) dominated stands in different locations of Gahrwal Himalaya. A total of 28 tree species with 17 families, 41 shrub species with 21 families and 50 herb species with 22 families were observed in all studied oak stands. In tree layer maximum 15 genera were recorded in Chaurangikhal oak stand and minimum number of genera (11) was found in Chadrabadani, Diwalikhal and Ghuttu oak stand. For shrub layer highest number of genera (25) was observed in Ghuttu oak stand and lowest (18) – for Chadrabadani, Chaurangikhal and Makku oak stands. Herb layer showed maximum 32 genera, found at Ghuttu oak stand and minimum genera (15) – at Chandrabadani oak stand. Comparatively *Quercus leucotrichophora* have greater values of density, basal area and Important Value Index (IVI) among all studied oak stands to the rest of associated dominant tree species. Highest density (823.6 plant·ha^{-1}) and IVI (170.8) for *Quercus leucotrichophora* was observed at Diwalikhal oak stand, while, lowest density (176.7 plants·ha^{-1}) and IVI (126.3) was found at Makku and Chaurangikhal oak stands, respectively.

Key words: altitudinal range, basal area, density, Important Value Index, sapling, seedling.

Introduction

Plant diversity analysis is an important part for determining the quantitative information, species composition, regeneration, species richness, etc., of a forest stand. Forest diversity is the main source of livelihood of rural mass with different needs as well as various ecosystem services. Oaks in the Himalayan region are intimately linked with subsistence hill agriculture as they protect soil fertility, watershed and local biodiversity. They also supply fodder, leaf litter, firewood and timber. They are also one of the most over-exploited species and fail to regenerate adequately either in disturbed or undisturbed natural habitat (Shrestha 2003). Oaks dominate the canopy in many temperate forests of the Himalayan region. In comparison to

other forests such as pine, oak forests are characterized by higher species diversity, stratification, litter production and soil fertility (Shrestha 2003). Various studies and informative literature in Garhwal Himalaya have been conducted regarding oak forests. Recently Prasad et al. (2017) analyzed the relationship of disturbance with aspect and altitudes in oak belt of Garhwal Himalaya. Some other studies have been also done along altitudinal gradients for population structure, vegetation status and diversity by Chauhan et al. (2014), Pokhriyal et al. (2012) and Singh et al. (2015) in Garhwal region. Six forest types of Uttarakhand have been explored by Ram et al. (2004) for plant diversity analysis in *Quercus leucotrichophora* A. Camus and *Pinus roxburghii* Sarg. forests and advocated for the conservation and management of these forests.

Structural characteristics of the Himalayan oak forests have been studied by various workers (Upreti et al. 1985; Singh and Singh, 1986, 1987, 1992; Singh et al. 1994, Rathore et al. 1997, Kumar et al. 2009, Uniyal et al. 2010, Chauhan et al. 2014, Singh et al. 2015). A well-known multiple use value of *Quercus leucotrichophora* makes this species preferable at research front by the researchers and scientists from various parts of the world. Present study focuses not only oak species but emphasiz on associate tree species, as well. Therefore present study is an effort to investigate oak forest stands of different locations and altitudinal difference with the following objectives: i) phytodiversity and stand characters of oak stands, ii) diversity of associate species, and iii) status of sapling and seedling density of major dominant species.

Methodology

Study area and sample plots

This study was conducted in Garhwal (West Himalaya) in six oak stands at different altitudinal ranges: Chandarabadani 1700–2100 m, Ghuttu 1800–2300 m, Dewalikhal 1500–2200 m, Makku 1800–2300 m, Chaurangkhal 2100–2500 m, Khirsoo 1600–2100 m from Tehri, Chamoli, Rudraprayag, Uttarakashi and Pauri districts of Uttarakhand, respectively (Fig. 1). Systematic random sampling was done, two sample plots (0.1 ha each) in each site were randomly identified and 10 quadrats 10 × 10 m for tree sampling were placed at random on each plot. In each 10 × 10 m quadrat, nested quadrat of 5 × 5 m was used for shrub and sapling sampling and 1 × 1 m quadrats – for herb and seedling sampling. All six oak forest stands were explored for vegetation analysis, sapling and seedling density and diversity parameters (Table 1).

Table 1. Studied oak stands with their geographical locations.

Stand No	Oak stands	District	Altitudinal range, m	Latitude	Longitude
1	Chandrabadani	Tehri	1700–2100	30°18’58.1’’ N	78°36’18.4’’ E
2	Chaurangikhal	Uttarkashi	2100–2500	30°38’30.7’’ N	78°28’59.2’’ E
3	Diwalikhal	Chamoli	1500–2200	30°05’29.9’’ N	79°14’30.4’’ E
4	Ghuttu	Tehri	1800–2100	30°32’02.6’’ N	78°49’15.2’’ E
5	Khirsoo	Pauri	1600–2100	30°08’17.4’’ N	78°50’47.4’’ E
6	Makku	Rudraprayag	1800–2300	30°29’11.4’’ N	79°07’32.0’’ E

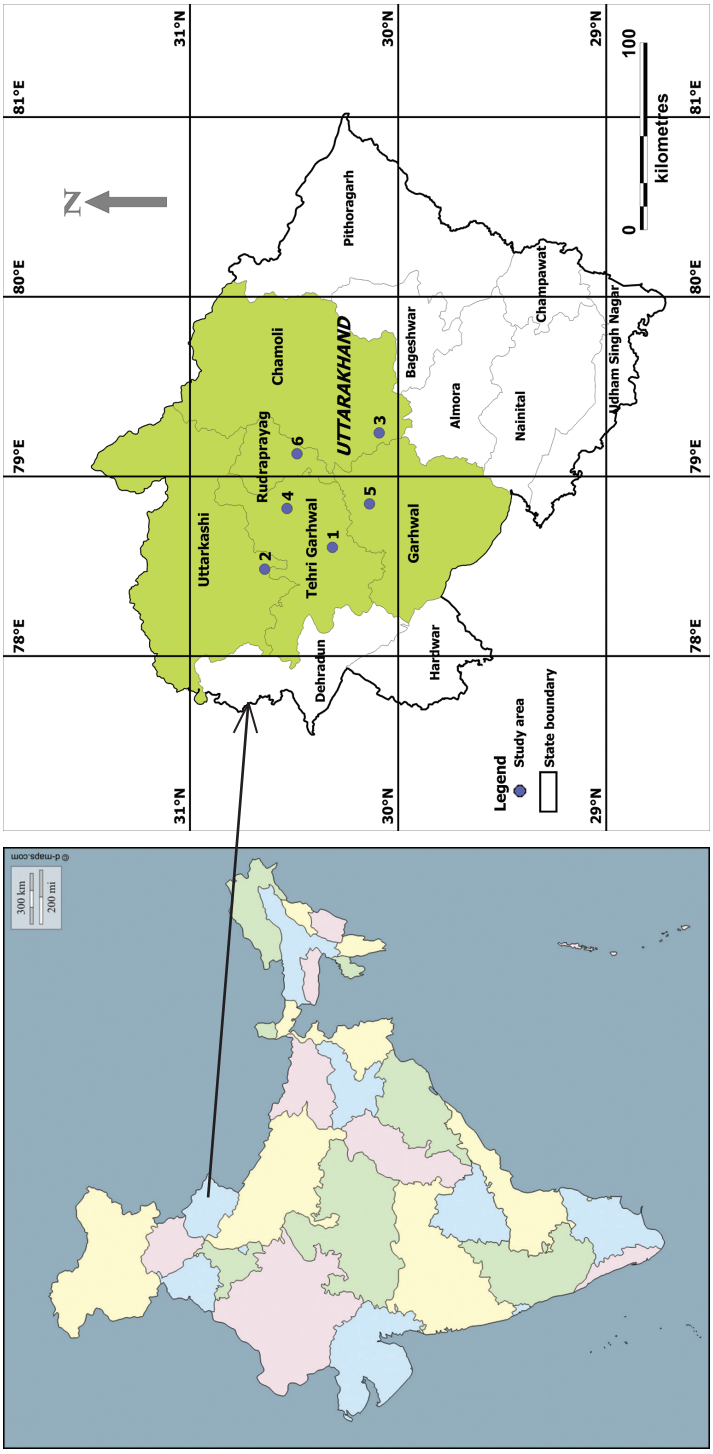

Fig. 1. Location map of study area.
Studied oak stand by numeric: 1 – Chandrabadani (Tehri district), 2 – Chaurangikhal (Uttarkashi district), 3 – Diwalikhal (Chamoli district), 4 – Ghuttu (Tehri district), 5 – Khirsoo (Pauri district), 6 – Makku (Rudraprayag district).

Phytosociological analysis

The phytosociological status was determined as per Mueller-Dombois and Ellenberg (1974) and Mishra (1968). The frequency, density, dominance and relative values for each species of the community were calculated. Different diversity indices were calculated using the following equations of Shannon Index (Shannon and Wiener 1963) (eq. 1), Simpson's index (Simpson 1949) (eq. 2), Margalef Index (Margalef 1968) (eq. 3):

$$H^{'} = -\sum p_i \cdot I_n \cdot p_i \quad (1),$$

$$CD = \sum (n_i / n) \cdot 2 \quad (2),$$

$$SR = S - 1 / I_n(N) \quad (3),$$

where: H' – the Shannon-Weaver index; p_i – the proportion of individuals belonging to species; I_n – the natural log; CD – the Simpson's index; n_i– total sum of an individual species; n – total sum of all species; SR – the Margalef index of species richness; S – the number of species; N – the total number of individuals.

Results

Vegetation composition

Vegetation composition of the all six oak stands is present in Table 2. A total of 28 species of trees, 42 species of shrubs and 50 species of herbs were recorded belong to 17, 21 and 22 families respectively. Maximum tree species (17) were found at Chaurangikhal oak stand and minimum number (11) of tree species were recorded at Ghuttu oak stand. *Quercus leucotrichophora, Rhododendron arboreum* Sm.*, Lyonia ovalifolia* (Wall.) Drude and *Myrica esculenta* Buch.-Ham. ex D. Don were dominant species among all oak stands. In shrub strata, Ghuttu and Khirsoo oak stand recorded highest (27) species while, lowest (19) species were found in Chandrabadani oak tand. Dominant shrub species included *Eupatorium adenophoram* (Spreng.) King & H. Rob. and *Berberis aristata* DC*.* Herb strata was composed of 50 species represented by 22 families, of which maximum 37 species were found at Ghuttu oak stand and minimum 16 species were observed at Chandrabadani oak stand. The dominant herb species in all stands were observed as *Andropogon munroi* C. B. Clarke*, Cynodon dactylon* (L.) Pers. and *Fragaria nubicola* Lindl. ex Lacaita*.* Large number of genera in a plant community may have an important role in plant diversity. In tree strata, stands of Ghuttu, Khirsoo and Makku have greater number of genera of respective species, however shrub strata consisted of less number of genera of respective species. In herb strata greater number of gernera was counted for Chaurangikhal, Diwalikhal and Makku oak stands.

Diversity

Shannon, Simpson and Margalef indices were calculated for all sampled species recorded in all oak stands. For tree layer, the highest Shannon diversity (1.23) was obtained in Chaurngikhal oak stand and lowest (1.04) at Ghuttu oak stand. Simpson index of tree strata was found within the range of 0.25–0.45. As far as the Margalef index was concerned, Chaurangikhal oak stand showed the highest value of 1.665, followed by 1.522 at Makku, 1.294 at Chandrabadani and 1.273 at Diwalikhal oak stand. Shrub strata achieved maximum Shannon diversity (1.43) at Ghuttu oak stand, while its minimum (1.13) was found at the Diwalikhal oak stand. Highest value of Simpson di-

Table 2. Vegetation composition of tree, shrub and herb layer in studied oak stands.

	Chandrabadani (1700–2100 m)	Chauragikhal (2100–2500 m)	Diwalikhal (1500–2200 m)	Ghuttu (1800–2300 m)	Khirsoo (1600–2100 m)	Makku (1800–2300 m)
Tree strata (28 species, 17 family)						
Species	12	17	12	11	14	12
Genera	11	15	11	11	14	12
Dominant species	*Quercus leucotrichophora* *Rhododendron arboreum* *Lyonia ovalifolia* *Myrica esculenta*	*Quercus leucotrichophora* *Rhododendron arboreum* *Lyonia ovalifolia*	*Quercus leucotrichophora* *Rhododendron arboreum* *Lyonia ovalifolia* *Myrica esculenta*	*Quercus leucotrichophora* *Rhododendron arboreum* *Lyonia ovalifolia*	*Quercus leucotrichophora* *Rhododendron arboreum* *Lyonia ovalifolia* *Myrica esculenta*	*Quercus leucotrichophora* *Rhododendron arboreum* *Lyonia ovalifolia* *Myrica esculenta*
Shrub strata (42 species, 21 family)						
Species	19	20	20	27	27	20
Genera	18	18	19	25	24	18
Dominant species	*Eupatorium adenophoram* *Myrisinea fricana* *Caryopteris foetida*	*Eupatorium adenophoram* *Berberis aristata* *Rosa macrophylla*	*Eupatorium adenophoram* *Berberis aristata* *Myrisinea fricana*	*Eupatorium adenophoram* *Berberis aristata* *Leptodermis lanceolata* *Rubus foliolosus*	*Berberis aristata* *Caryopteris foetida* *Eupatorium adenophoram*	*Berberis aristata* *Eupatorium adenophoram* *Rosa macrophylla*
Herb strata (50 species, 22 family)						
Species	16	25	21	37	21	19
Genera	15	25	21	32	20	19
Dominant species	*Andropogon munroi* *Cynadon dactylon* *Fragaria nubicola*	*Andropogon munroi* *Chrysopogon gryllus* *Cynadon dactylon* *Fragaria nubicola*	*Anaphalis adnata* *Andropogon munroi* *Cynadon dactylon* *Fragaria nubicola* *Galium asperifolium* *Herteropogon contortus*	*Andropogon munroi* *Cynadon dactylon* *Fragaria nubicola* *Valeriana jatamansi*	*Anaphalis adnata* *Andropogon munroi* *Cynadon dactylon* *Micromaria biflora* *Valeriana jatamansii*	*Andropogon munroi* *Cynadon dactylon* *Fragaria nubicola* *Valeriana jatamansii* *Vicia tenera*

versity (0.19) was found at Chandrabadani oak stand, followed by Makku (0.15) and Khirsoo oak stands (0.14). In the context of Margalef diversity of shrub strata, the values were recorded within the range of 2.497–3.237. In the herb strata, highest Shanon diversity (1.57) was observed at Ghuttu oak stand and lowest (1.20) – at Chandrabadani oak stand. Chandrabadani and Ghuttu oak stands showed maximum and minimum values of Simpson diversity – 0.21 and 0.08, respectively, in herb strata. Margalef index was observed between the ranges of 1.637–2.085 in all studied oak stands (Table 3).

Table 3. Diversity attributes of tree, shrub and herb layer in studied oak stands.

Oak stands	Tree layer			Shrub layer			Herb layer		
	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef	Shannon	Simpson	Margalef
Chandrabadani	1.08	0.35	1.294	1.28	0.19	2.871	1.20	0.21	1.637
Chaurangikhal	1.23	0.25	1.665	1.30	0.08	2.918	1.40	0.17	2.017
Diwalikhal	1.08	0.45	1.273	1.13	0.09	3.237	1.32	0.12	2.085
Ghuttu	1.04	0.31	1.233	1.43	0.07	2.595	1.57	0.08	1.925
Khirsoo	1.15	0.44	1.170	1.18	0.14	3.112	1.32	0.15	1.858
Makku	1.06	0.30	1.522	1.30	0.15	2.497	1.28	0.18	1.930

Stand characters

The dominant species recorded in addition to *Quercus leucotrichophora* were *Rhododendron arboreum, Lyonia ovalifolia* and *Myrica esculenta.* Comparatively *Quercus leucotrichophora* have greater values of density, basal area and IVI among all studied oak stands to the rest of associated tree species. Highest density (823.6 plant·ha^{-1}) and IVI (170.8) for *Quercus leucotrichophora* was observed at Diwalikhal oak stand, while lowest density (176.7 plants·ha^{-1}) and IVI (126.3) was found at Makku and Chaurangikhal oak stands, respectively. *Rhododendron arboreum* was observed as second most dominant species having maximum tree density (160.0 plants·ha^{-1}), basal area (0.24) and IVI (50.4) in Makku oak stand. Least density (41.37 plants·ha^{-1}) of *Rhododendron arboreum* was found at Chandrabadani oak forest. Diwalikhal oak stand showed minimum basal area (0.13) and IVI (31.4) for *Rhododendron arboreum. Lyonia ovalifolia* exhibited as next dominant tree species in all studied oak stands, which achieved its maximum density (149.1 plants·ha^{-1}), basal area (0.26) and IVI (50.6) at Ghuttu oak stand. Minimum density (12.5 plants·ha^{-1}), basal area (0.07) and IVI (23.0) were recorded at Chandrabadani, Diwalikhal and Chaurangikhal oak stands, respectively. *Myrica esculenta* was only found at four oak stands out of six. Khirsoo oak stand is considered most suit-

able for *Myrica esculenta* having highest values of density (165.4 plants·ha^{-1}), basal area (0.17) and IVI (45.5). The lowest density (67.5 plants·ha^{-1}) of *Myrica esculenta* was found at Chandrabadani oak stand but basal area and IVI was lowest recorded at Diwalikhal oak stand as 0.06 and 28.5 (Table 4).

Sapling and seedling occurrence shows the regeneration potential of species present in a forest stand. Higher sapling and seedling density of *Quercus leucotrichophora* was recorded as 2.93 plants/25 m^2 and 1.85 plants·m^{-2}, respectively, at Khirsoo oak stand, followed by Chandrabadani oak stand for sapling density and Chaurangikhal oak stand for the seedling density. *Rhododendron arboreum* displayed maximum sapling density (0.58 plants/25 m^2) again at Khirsoo oak stand, followed by Ghuttu (0.55 plants/25 m^2) and Chaurangikhal oak stands. Higher seedling density of this species was recorded at Chaurngikhal, Diwalikhal and Khirsoo oak stands. *Lyonia ovalifolia* showed greater density at Khirsoo oak stand and was recorded least at Chaurngikhal oak forest stand, while density at seedling stage of this species was found within the range 0.11 plants·m^{-2} – 0.47 plants·m^{-2}. *Myrica esculenta* was absent at Chaurangikhal and Ghuttu oak stands and showed higher sapling (0.58 plants/25 m^2) and seedling density (0.33 plans·m^{-2}) at Khirsoo oak stand (Table 5).

Statistical analysis was carried out using Gen Stat Version-32 and analyzed applying 2-way ANOVA. The analysis of density, basal area and IVI of *Quercus leucotrichophora* and its associate species revealed that species differ highly significantly at the level *P = 0.001 of* probability. The analysis for all the character is shown on Table 6.

Table 4. Tree density (plants/ha), basal area (m^2/ha) and IVI (Important Value Index) of dominant tree species in studied oak stands.

Studied oak stands	*Quercus leucotrichophora*			*Rhododendron arboreum*			*Lyonia ovalifolia*			*Myrica esculanta*		
	Density	Basal area	IVI	Density	Basal area	IVI	Density	Basal area	IVI	Density	Basal area	IVI
Chandrabadani	522.5	1.14	144.7	41.3	0.21	44.6	12.5	0.13	43.2	67.5	0.07	29.1
Chaurangikhal	564.0	1.24	126.3	136.0	0.21	38.1	106.0	0.17	23.0	-	-	-
Diwalikhal	823.6	1.13	170.8	103.6	0.13	31.4	121.8	0.07	31.6	85.5	0.06	28.5
Ghuttu	512.7	1.00	138.7	138.2	0.22	46.5	149.1	0.26	50.6	-	-	-
Khirsoo	798.2	1.17	156.2	123.6	0.21	40.2	58.2	0.17	24.5	165.4	0.17	45.5
Makku	167.7	1.08	135.7	160.0	0.24	50.4	106.7	0.17	38.1	83.3	0.11	28.6

Table 5. Sapling density (plants/25m^2) and seedling density (plants/m^2) of major dominant tree species in studied oak stands.

Studied oak stands	*Quercus leucotricophora*		*Rhododendron arboreum*		*Lyonia ovalifolia*		*Myrica esculanta*	
	Sapling	Seedling	Sapling	Seedling	Sapling	Seedling	Sapling	Seedling
Chandrabadani	1.83	1.13	0.49	0.23	0.70	0.28	0.43	0.08
Chaurangikhal	1.20	1.36	0.52	0.50	0.20	0.26	-	-
Diwalikhal	1.02	1.11	0.38	0.48	0.30	0.40	0.40	0.28
Ghuttu	1.09	0.64	0.55	0.37	0.42	0.23	-	-
Khirsoo	2.93	1.85	0.58	0.42	1.05	0.11	0.58	0.33
Makku	1.23	1.27	0.47	0.30	0.47	0.47	0.43	0.33

Table 6. Statistical analysis of density, basal area and IVI.

Variables	Mean density	Mean basal area	Mean IVI
Quercus leucotrichophora	685.9	1.345	149.4
Rhododendron arboreum	144.4	0.202	38.6
Lyonia ovalifolia	129.4	0.136	35.5
Myrica esculanta	63.6	0.041	18.4
Level of significance	$p<0.001$	$p<0.001$	$p<0.001$
CD (LSD)	46.12	0.166	9.26

Discussion

Phytodiversity analysis has been observed by various workers with respect to different environmental factors, altitudinal gradients, disturbance gradients and regeneration status, as well as aspect wise in Garhwal Himalayas. Singh et al. (2015), Sharma et al. (2010), Uniyal et al. (2010) and Pokhriyal et al. (2010) analyzed plant diversity with respect to disturbance and altitudinal gradients particularly of the oak dominated forest in Gahrhwal Himalaya. In present study *Quercus leucotrichophora* was associated with *Rhododendron arboreum, Lyonia ovalifolia* and *Myrica esculenta*, which were also reported earlier by Kumar et al. (2009), Singh et al. (2015), Chauhan et al. (2014) in different parts of Garhwal Himalayas. Absence of *Myrica esculenta* at Chaurangikhal and Ghuttu oak stands may be due to their higher altitudinal ranges, which were beyond of its limited habitat distribution altitudes (1500–2000 m). The distribution range of *Myrica esculenta* was recorded between 1850–2250 m a.s.l., as reported by Sharma et el. (2009). The dominant shrub and herb species, as *Myrsine africana* L. and *Valeriana jatamansi* Jones ex Roxb., were recorded in restricted distribution.

Richness of shrub and herb species is greater at higher altitudinal ranges, particularly from 2000 m up to 2500 m. Giri et al. (2008) recorded the Shannon diversity in the range of 0.27–2.22 in an oak dominated forest, which was more or less similar to pres-

ent investigation (1.04–1.57). As far as the Simpson diversity was concerned, present study yielded almost similar values as reported by Sharma et al. (2010) during their study in seven temperate forest types of Garhwal Himalaya. The diversity index of Margalef was found in similar pattern as reported by Sharma et al. (2009) in a moist temperate forest of Garhwal Himalaya. In context of the density, basal area and IVI of dominant tree species of the studied oak stands were concerned; the greater values were yielded for *Quercus leucotrichophora.* Present study showed that *Quercus leucotrichophora* density range from 166.7 to 823.6 plants·ha^{-1} is more or less similar to earlier reported by Chauhan et al. (2014) at two oak forest stands of Garhwal Himalaya.

Conclusion

In a natural forest stand, the associated or companions of a dominant species can also play an important role for the establishment and sustainability of a particular species/group of species. The broad-leaved character of *Quercus leucotrichophora* and its major associates *Rhododendron arboreum, Lyonia ovalifolia* and *Myrica esculenta* have been reported capable of conserving the moisture at larger amount in hilly areas and also beneficial in erosion control. Study concluded that these species may also be considered for research as same preference of *Quercus leucotrichophora.* Associate species, particularly *Myrica esculenta* and *Rhododendron arboreum,* are extracted for edible products at considerable scale and therefore may be investigated for their conservation point of view. Therefore, a conservative approach for *Quercus leucotrichophora*, as well as its associates, needed research front in the Garhwal Himalayan region.

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