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Vol. 11(2) pp. 1-8, November, 2020
Available online https://www.interesjournals.org/basic-clinical-studies.html
DOI: http:/dx.doi.org/10.14303/irjps.2020.0013

Full Length Research Paper

Tree species composition, diversity and distribution along an elevational gradient in oak dominated forests of pir panjal range in Jammu and Kashmir

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Abstract

The present study was conducted to evaluate the impact of altitude on composition and diversity of Oak dominated forests in Rajouri district of Jammu and Kashmir (India). A total of 32 woody species were encountered in the study area lying between 1200m and 2500m elevation. Three species of Oak viz. *Quercus leuchotrichophora*, *Q. floribunda and Q. semecarpifolia* were found to be dominant or co-dominant in the area. *Q. leuchotrichophora* shared the maximum acreage at all elevations. Its associate species, however, remained changing across the elevational gradient. Results revealed that the phytosociological characteristics of the studied forests vary remarkably in response to changes in altitude. Stem density decreased while as total basal area was found to increase with altitude. No of species was maximum at lowest altitude and steeply decreased with rise in altitude. Diversity indices (Margelef Index, Menhinik Index, Shanon Wiener Index, etc.) showed evident decline in their values with altitude. However an unexpected dip due to anthropogenic pressure at middle elevational range was also observed. These forests demand urgent attention for their conservation and management.

Keywords: Ecosystem, Forest, Elevation, Biodiversity, Community composition, Environmental factors.

INTRODUCTION

Forest ecosystems are believed to be the great storehouses of biodiversity (Thompson, Okabe, Tylianakis, Kumar, Brockerhoff, Schellhorn, & Nasi, 2011). They are evolved and influenced by a multitude of environmental factors. Vegetation in a forest ecosystem is a function of time (Kharkwal, Mehrotra, Rawat, & Pangtey, 2005), but its ecological attributes (like community structure, floral composition, diversity, etc.) are mainly determined by its geographic location, climatic regime, soil conditions and other environmental factors. Vegetation complex, even within a particular region, does not remain uniform in time and space. It fluctuates in a cyclic way with changing seasons and in a successional manner over the years (Heady, 1958). Flora of a place responds to and gets shaped by the changes in factors like altitude, climate, soil conditions and natural and anthropogenic disturbances. Variation in community characteristics across environmental gradnients is a major topic of ecological investigations and has been often described with reference to climate, biotic interaction, habitat heterogeneity and history (Givnish, 1999; Willig, Kaufman, & Stevens, 2003; Currie & Francis, 2004; Qian & Ricklefs, 2004; Amissah, Mohren, Bongers, Hawthorne, & Poorter, 2014; Bohra, Athokpam, Garkoti, Das, & Hore, 2014; Khaine, Woo, Kang, Kwak, Je, You, & Yang, 2017). Elevation is recognized as a fundamental factor that influences forest community structure, species composition, diversity, density, regeneration and other ecological attributes of vegetation (Sharma, Ghildiyal, & Gairola, 2009; Gairola, Sharma, Ghildiyal, & Suyal, 2011; Kessler, 2001; Scmidt, Zebre, & Weckesser, 2006; Zhang, Ru, & Li, 2006). It is one of the most important governing factors responsible for regional differences in species composition particularly in the Himalayan region (Sharma, Mishra, Krishan, Tiwari, & Rana, 2016). Altitude in itself represents a complex combination of many related factors like topography, water availability, soil characteristics, climate, etc. (Ramsay & Oxley, 1997) which greatly affect floral composition of an area (Holland & Steyn, 1975). As geographic and climatic conditions change abruptly along an altitudinal gradient (Kharkwal *et al*., 2005), they affect the presence, density, dominance and distribution of plant species.

Effects of altitude on vegetation have been analyzed by various workers in different parts of the world (Whittaker, 1972; Pavon, Hernandez-Trejo & Rico-Gray, 2000; Mota, Luz, Mota, Coutinho, Veloso, Fernandes, & Nunes, 2018; Acharya, Chettri, & Vijayan, 2011; Ahmed, Husain, Sheikh, Hussain, & Siddiqui, 2006) and particularly in the western Himalayas (Saxena, Pandey, Singh, 1985; Adhikari, Rawat,. & Singh, 1995; Kharkwal *et al*., 2005; Singh, Kumar, & Sheikh, 2009). A great majority of them has confirmed the decline of biodiversity with increasing elevation. Several studies, however, reported peak values of species richness at middle altitudes (Rahbek, 2004; Grytnes & Vetaas, 2002; Kharkwal *et al.,* 2005). Yet some other studies have shown a linear relationship between species richness and altitude (Givnish, 1999) and have given other explanations for the same. Changes in forest composition along elevational transects in the western Himalayan region are, thus, evident, but they require proper and detailed measurement (Chitale, Behera & Roy, 2014; Sharma, Mishra, Prakash, Dimri, & Baluni, 2014) especially in areas which are ecologically least investigated. Vegetation composition with reference to altitude has been evaluated by several workers in parts of Jammu province (Raina & Sharma, 2012; Sharma & Raina, 2013), Pak administered parts of J&K (Shaheen, Ullah, Khan, & Harper, 2012) and Kashmir valley forests (Rather, 2014). But No such study has been carried out in the Pir Panjal Himalayan range (Rajouri and Poonch districts of Jammu and Kashmir) which forms a distinct region and is even taxonomically underexplored despite its rich flora (Dar, Malik, & Khuroo, 2014). Present investigation was carried out in temperate broadleaved Oak dominated forests of Rajouri (southern slope of Pir Panjal mountain range) to assess the effects of altitude on stand structure, species composition, diversity, dispersion pattern and other ecological attributes of vegetation. Pure or mixed stands of Oak (*Quercus* spp) form the principal floral group on the southern slopes of the range between 1200m and 3500m elevation. The area is dominated at various altitudinal ranges (1300-3500m) by one or the other species of Oak particularly *Quercus leuchotrichophora* which is, ecologically as well as socio-economically, a highly valued plant of the region. These forests are also the main representatives of the temperate broadleaved Himalayan forests in Jammu and Kashmir. The approach adopted in this investigation is direct gradient analysis in which aspects of community composition, structure, diversity and dynamics are simply analysed with reference to the changes in evident ecological factors. The present work would be helpful and fundamental in generating baseline data and developing sound conservation and management strategies for the region. It may also help in understanding and predicting the biological impacts of the climate change.

MATERIAL AND METHOD

Study area

Pir Panjal Mountains, extending in a northwest to southeast direction across Jammu and Kashmir in India, form the largest range in the western Himalayas and support wide range of vegetation including grasslands, scrubs and luxurious coniferous and broadleaved forests. The present study was carried out in Oak-dominated broadleaved mixed forests of Rajouri Forest Division (district Rajouri) of Jammu and Kashmir (India). The division, forming a part of southern slope of the Pir Panjal Himalayan range, lies between 740 11′ 03.03″E and 740 40′ 21.95″E longitude and 330 08′ 47.77″N and 330 35′ 05.16′′N latitude with its altitude ranging from 1000-6000 m above sea level. Topography of the region is mountainous and varies from gentle slopes to very steep ridges. It is characterized by the presence of rich coniferous and broadleaved forests between 1000m to 3500m elevational range. Fourteen percent (13.96%) of total forest cover in the region (Rajouri Forest Division) comprises of broadleaved forests in which Oak is, by and large, the principal species (Anand, 2014). Major slope of the catchment area is towards south and southwest and is drained by river Ans and other tributaries of the Chenab. Climate is generally mild in lower parts and harsher and cold with heavy snowfall in upper hillocks. Average annual rainfall is 1150 mm which is mainly received through southwest monsoon during July-September. Division is, administratively, divided into three forest ranges viz. Kalakote, Kandi and Rajouri. Kandi forest range, for it sufficiently representing the entire division in terms of topography, soil, climate and vegetation type, is selected for the present work Figure 1

Sampling and data collection

After preliminary surveying in the area, three forest sites across a wide altitudinal range (from 1200m to 2500m) were selected for the sampling. Sites were named as per their local names (Table 1). Data collection was carried out during 2017-18 using stratified random sampling technique. Twenty quadrates (each measuring 10×10m for trees and 5×5m for shrubs) were laid at each site for collection and subsequent analysis of phytosociological information. Plants with GBH (girth at breast height) >20 cm were considered as trees. Simple measuring tape was used to determine girth of trees. Physiographic features (like elevation, aspect and slope steepness) were recorded using Garmin Etrex 10 GPS device.

Table 1. General profile of study sites.

Site	Forest	Elevational range (m)	Aspect	Slope/terrain
I	Gadyog-Kanthol	1200-1600	South western	Gentle
II	Jaglaanoo-Perinar	1600-2000	South eastern	Steep
III	Badhal-Nangathub	2000-2500	Western	Gentle

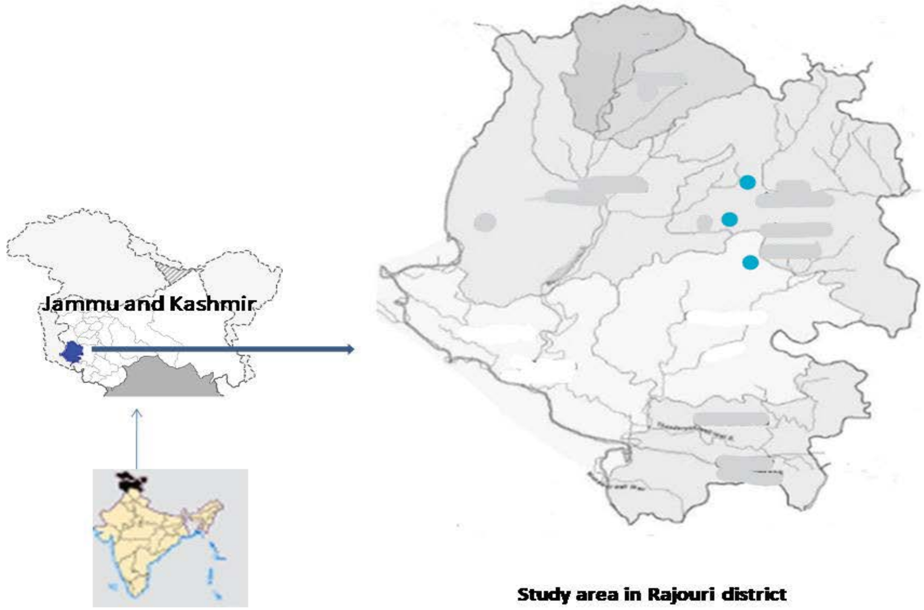

Figure 1: Sampling sites in the study area.

Data analysis

Density, frequency and abundance were calculated using standard methods. Basal area was estimated using formula:

Basal area= $\frac{(cbh)^2}{4\pi}$

Where, cbh=circumference at breast height

Basal areas calculated for species were multiplied with densities of the respective species to obtain total basal area ($m^2\ ha^{-1}$). Calculation of Importance Value Index (IVI) for trees and Provenance index (PI) in case of shrub species was done as below:

IVI=Relative Density+ Relative Frequency + Relative Dominance (for tree species)

PI= Relative density + Relative frequency (for shrubs)

Distribution pattern of all the tree species was determined by abundance/frequency (A/F) ratio (also known as Whitford Index) and was categorized as regular (if A/F < 0.025), random (if A/F between 0.025 – 0.05) or contagious (if A/F > 0.05). Number of species present in a forest was taken as Species Richness (SR). Margalef index (MI) and Menhinik index (MeI) of richness were calculated as MI= S-1/log N and MeI=S/√N where S=number of species and N= total number of individuals. Shannon–Wiener diversity index (H´) and Simpson's diversity index were calculated using the formulae:

$$\text{Shannon–Wiener diversity index } (H') = -\sum_{i=1}^{s} pi \ln pi$$

$$\text{Simpson index of diversity (SI)} = 1 - \left(\sum_{i=1}^{s} (pi)^2\right)$$

where, pi is the proportion of i th species and S is the number of individuals of all the species. Simpson index of diversity was expressed as 1-Cd to avoid confusion.

Peilou's index of evenness (e) was calculated as e=H´/log N, where H´ is Shannon Wiener index and N is total number of species present.

RESULT AND DISCUSSION

Results

Composition: A total of 32 species of trees (20) and shrubs (12) belonging to 30 genera were recorded from the entire study area. Three species of Oak viz. *Quercus leuchotriphora, Q. floribunda* and *Q. semecarpifolia* showed their dominance and/or co-dominance all across the study area. It was observed that 14 species of trees were found growing at site I, 6 at site II and 7 at site III. 8, 6 and 4, while species of shrubs were found at sites I, II, III respectively. Total density (individuals/ha) of trees and shrubs was observed to be 975 at site I, 840 at site II and 770 at site III and 380, 270 and 225 at sites I, II and III respectively. Total basal area (m^2/ha) of trees was calculated to be 68.84, 133.04, 100.33 and 72.66 at sites I, II, III and IV respectively. Whitford Index (Abundance/Frequency ratio) ranged between 0.01 to 0.20 for trees and 0.03 to 0.69 for shrubs (Table 2, Table 3 and Table 4).

At the lowest altitude i.e. 1200-1600m (Table 2), it was found that the *Quercus leuchotrichophora* (IVI=148.410) showed highest density, frequency and IVI values and followed by *Quercus floribunda* (IVI=16.470), *Pyrus pasia* (16.470), *Rhododendron arboretum* (IVI=16.369), *Puma granatum* (IVI=15.146), *Ficus palmate* (IVI=13.103), *Pinusroxburgi* (IVI=11.941), *Zanthoxylum armatum* (IVI=9.004), *Celtis australis* (IVI=10.772), etc. Among shrubs, *Berberis lyceum*

(PV=45.744), *Indigofera heterantha* (PV=34.308), *Rubus ellipticus* (PV=31.839), *Sarcococca salinga* (PV=26.901) were the prominent species.

Mid elevation i.e. 1600-2000m (Table 3) showed *Quercus floribunda* becoming more prominent with IVI=39.216 followed by *Aesculus indica* (IVI=22.882) and *Rhododendron arboreum* (IVI=35.423). *Berberis lyceum* (PV=52.020), *Viburnum grandifolium* (PV=34.848), *Elaeagnus umbellate* (PV=32.492) and *Rosa maschuta* (PV=28.114) were prominent in the shrub layer.

At higher elevation i.e. 200-2500m (Table 4), *Quercus floribunda* (54.399) became even more ubiquitous.

Table 2. Vegetation analysis at Site I Gadyog-Kanthol forests.

Species	Density (per ha)	Total basal cover (m^2/ ha)	Abundance/ Frequency (WI)	IVI/PV
Tree species				
Quercus leuocotrichophora	440	55.617	0.054	148.410
Quercus floribunda	40	4.212	0.064	16.470
Rhododendron arboreum	40	1.561	0.025	16.369
Bombax ceiba	20	0.536	0.200	5.329
Grevia optiva	25	0.440	0.063	8.203
Pyrus pashia	110	1.696	0.036	27.495
Pinus roxburgii	50	1.248	0.125	11.941
Puma granatum	70	0.321	0.077	15.146
Ficus palmate	60	1.342	0.150	13.103
Zanthoxylum armatum	35	0.285	0.088	9.004
Celtis australis	35	0.642	0.056	10.772
Morus alba	10	0.103	0.100	3.676
Melia azaderachta	20	0.382	0.050	7.607
Ulmus wallichiana	20	0.464	0.087	6.476
Total	975	68.848		
Shrub Species				
Ellaegnus umbellate	30		0.075	24.107
Zizipus mauritiana	25		0.063	16.699
Berberis lyceum	100		0.063	45.744
Carrisa spinarum	25		0.125	11.436
Indigofera heterantha	75		0.083	34.308
Rosa maschuta	15		0.150	8.967
Rubus ellipticus	65		0.070	31.839
Sarcococcasa linga	45		0.050	26.901
Total	405			

Table 3. Vegetation analysis at Site II Jaglanoo-Perinar forests.

Species	Density (per ha)	Total basal cover (m^2/ha)	Abundance/Frequency (WI)	IVI
Tree species				
Quercus leuocotrichophora	495	87.496	0.010	167.248
Quercus floribunda	90	15.274	0.025	39.216
Aesculus indica	50	8.370	0.056	22.882
Lyonia ovalifolia	25	2.497	0.100	9.108
Rhododendron arboreum	85	16.681	0.033	35.423
Pyrus pashia	95	2.723	0.033	26.122
Total	840	133.041		
Shrub species				
Elaeagnus umbellate	55		0.138	32.492
Berberis lyceum	75		0.047	52.020
Rubus ellipticus	40		0.044	32.997
Viburnum grandifolium	45		0.050	34.848
Rosa maschuta	35		0.056	28.114
Amelocissus latifolia	20		0.050	19.529
Total	270			

Quercus semecarpifolia (IVI=11.924) started appearing at this altitudinal range. *Boxus wallichiana* (IVI=31.210) was another important endemic species of this range. Other associate tree species of this altitude included *Pyrus pasia* (19.345), *Aesculus indica* (11.996) and *Lyonia ovalifolia* (8.259). *Vibrnum grandiflora* (PV=69.048), *Skimmia laureola* (PV=52.540) and *Berberis aristata* (PV=48.571) were present among shrubs.

Density of both tree species and shrub was found to be higher (975 and 380) at the lowest altitude (1200-1600m) and then decreased with increase in altitude. While reverse trend was found in the basal area having lowest (68.84m²/ha) at lower elevational range and highest (133.04m²/ha) at the mid altitude.

Species Diversity

Species richness and diversity indices varied across the stands studied, but not much significantly between middle and higher altitudes (Table 5). Shannon-Wiener Index was highest (1.99 for trees) at lower elevation and almost similar at middle (0.93) and higher altitudes (0.96). However, it gradually decreased (1.93, 1.84 and1.34) for shrub layer moving from lower to higher elevation. Simpson's diversity index was minimum (0.70 for tress and 0.73 for shrubs) at 1200-1600 altitudinal range. Margelef index values ranged from 0.74 to 1.88 for trees and 0.73 to 1.17 for shrubs whereas Menhenick index was found between 0.20 to 0.44 for trees and 0.33 to 0.41 for shrubs, with their maximum values for trees and shrubs at lowest altitude. These values showed a decreasing trend from lower to higher altitudes. Peilou's evenness index (J') was calculated to be highest (1.20) at the middle altitude (0.49 to 0.75 for trees and 0.92 to 1.92 for shrubs).

Highest number of species (SR) for trees (14) and shrubs (08) was found at 1200-1600m elevation. However there was no significant difference in this respect between middle and higher altitudes.

Table 4. Vegetation analysis at Site III Badhal-Nangathub forests.

Species	Density (per ha)	Total basal area (m²/ha)	Abundance/ Frequency (WI)	IVI/PI
Tree species				
Quercus leuocotrichophora	420	75.239	0.052	162.868
Boxus wallichiana	115	1.465	0.072	31.210
Pyrus pasia	55	1.095	0.061	19.345
Quercus floribunda	120	16.647	0.033	54.399
Quercus semecarpifolia	25	1.274	0.063	11.924
Aesculus indica	20	1.997	0.050	11.996
Lyonia ovalifolia	15	2.616	0.100	8.259
Total	770	100.333		
Shrub species				
Skimmia laureola	70	-	0.072	52.540
Elaeagnus umbellate	35	-	0.088	29.841
Vibrnum grandiflora	75	-	0.030	69.048
Berberis aristata	45	-	0.031	48.571
Total	225			

Table 5.Phytosociological analysis of study sites (summarized).

Parameter	Site I Gadyog-Kanthol forests		Site II Jaglanoo-Perinar forests		Site III Badhal–Nangathub forests	
	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs
Main(Dominant) species	*Quercus leucotrichophora* (IVI=148.41)	*Berberis lyceum* (PV=45.74)	*Quercus leucotrichophora* (IVI=167.24)	*Berberis lyceum* (PV=52.0)	*Quercus leucotrichophora* (IVI=162.86)	*Viburnum grandifolia* (PV=69.04)
Species Richness (Total Number)	14	8	6	6	7	4
Margelef Index	1.88	1.17	0.74	0.89	0.90	0.73
Menhinik Index	0.44	0.41	0.20	0.36	0.25	0.33
PelioIndex (Evenness)	0.75	0.92	0.51	1.02	0.49	0.96
ShanonWiener Index (H)	1.99	1.93	0.93	1.84	0.96	1.34
Simpson Index of Diversity (SI)	0.77	0.84	0.93	0.73	0.70	0.73
TotalBasalarea (m²/ha)	68.84	-	133.04	-	100.33	-
TotalDensity (indl/ha)	975	380	840	270	770	225

DISCUSSION

Altitude is an important environmental gradient that offers significant variations in vegetation characteristics due to its direct impact on microclimate (Adhikari, Fischer, & Pauleit, 2015) especially in mountain regions for greater and abrupt environmental changes across a relatively small geographic range (Zhang *et al*., 2006). Studies conducted in various parts of the Himalayas have indicated remarkable differences in species composition, distribution pattern and diversity attributable to altitudinal impact (Adhikari *et al.*, 2015; Sharma *et al*., 2009; Sharma, Baduni, & Gairola, 2010; Gairola, Sharma, and Suyal, 2011; Kharkwal *et al.,* 2005; Acharya *et al.*, 2011; Ahmed, 2006; Kharkwal *et al*., 2005; Singh, Kumar, & Sheikh, 2009). Present study was an attempt to assess the effect of altitude on Oak and its associate species along an elevational gradient in forests of Pir Panjal belt which is ecologically still underexplored. It has revealed that three species of Oak viz. *Quercus leuchotrichophora*, *Q. floribunda* and *Quercus semecarpifolia* grow abundantly between 1300m and 2500m. *Quercus leucotrichophora* exhibiting highest frequency (100%), density (420 to 495 individuals/ha), basal cover (55.61 m^2/ha to 87.49 m^2/ha) and IVI (148.410 to 167.248), predominates the vegetation at all the three sites. This is in accordance with the characteristic composition of temperate broadleaved forests throughout the western Himalayas where different species of oak often dominate the vegetation (Troup, 1921**;** Singh, Rawat & Chaturvedi, 1984; Singh and Rawat, 2012)**.** Values on phytosociological aspects obtained in the present study are comparable with those observed by other workers for similar vegetations in Uttrakhand (Lal & Laudhiyal, 2016), Kumaon (Singh & Singh, 1986)**,** Gharwal (Singh, Malik, & Sharma, 2016)**,** parts of Jammu (Sharma & Raina, 2013) and other parts of the Himalayas (Singh and Singh, 1986; Khera, Kumar, Ram, & Tewari, 2001; Ahmed, Husain, Sheikh, Hussain, & Siddiqui, 2006; Paul, Khan, &Das, 2018). Although *Quercus leuchotrichophora* was found dominant all across the study area, it varied in its IVI, density, abundance, frequency, etc. at different altitudinal zones. This indicates wider eceological amplitude of the species and its tolerance to biotic pressures. *Quercus floribunda* and *Q. semecarpifolia*, however, became more conspicuous respectively at middle (1600-2000m) and higher (2000-2500m) elevations. *Pinus wallichiana*, *Aescules indica* and *Boxus wallichiana* were the most important co-dominants at lower, middle and higher elevations respectively. Similar characteristics of vegetation have been reported for the western Himalayan temperate forests by other workers (Gairola *et al*., 2011; Sharma *et al*., 2009; Singh *et al*., 2009). Associate species like *Rhododendron arborium*, *Pyrus pasia*, etc. were found throughout the study area (though exhibiting different values of stem density, frequency and IVI in different stands) and it signifies their wider altitudinal range and greater adaptability to varying situations. Presence of the only conifer species intermixed with Oak at lower altitudinal zone indicated the ecotonal effect which was also responsible for the maximum number of species in this zone. On the contrary certain associate species including endemic *Boxus wallichiana* and *Q. semecarpifolia* were only found at higher altitude owing to their restricted natural range. Decrease in stem density with a rise in altitude was also in accordance with the trend observed by other workers in the Himalayan region (Gairola *et al*., 2011; Acharya *et al.,* 2011; Shaheen *et al*., 2012). Basal cover for individual species as well for entire tree vegetation was, however, found maximum at mid elevation and it is due to presence of old growth forests. Majority of plant species in the study area have shown clumped distribution/dispersion (indicated by WI index values) as it is very common in natural ecosystems (Odum & Heald, 1972).

Diversity is generally believed to decrease with altitude and a similar trend was also found in the present study. The values of diversity indices (Shanon Wiener index, Simpson index of diversity, Margalef index and Menhinik index) calculated for the study area are similar to those reported by other workers in other parts of the Himalayas (Sharma, Gairola, Baduni, Ghildiyal, & Suyal, 2011; Sharma *et al*., 2009; Singh, Malik, & Sharma, 2016; Sharma, Mishra, Tiwari, Krishan, & Rana, 2017). The highest diversity at the lowest elevation may also be attributed to the edge effect as these sites bordered subtropical region on the lower side. However it did not show much difference at middle and higher altitude in diversity of tree species which can be due to intense anthropogenic disturbances at mid elevations in the region.

CONCLUSION

Information on vegetation characteristics of forest areas is important from research, conservation and management point of views. Forest area investigated in the study is dominantly populated by at least three species of Oak almost all across the altitudinal gradient between 1300 and 2500m. Although *Quercusleuchotrichophora* grows abundantly irrespective of elevational zonation, its associate tree and shrub species keep replacing one another while moving across the elevational gradient. All phytosociological characteristics of the vegetation vary remarkably in response to changes in altitude. Tree species diversity decreased with altitude but an unexpected decrease at the middle range is attributed to anthropogenic pressures.

ACKNOWLEDGEMENT

The author is indebted to University Grants Commission, New Delhi (India) for grant of Fellowship under its FDP scheme for this work.

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