Plant Archives Vol. 18 No. 2, 2018 pp. 1979-1986 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EFFECT OF ALTITUDINAL GRADIENT ON COMMON TREE SPECIES IN DHANAULTI OF GARHWAL HIMALAYA

Maneesh Kumar Gupta*, Sarvesh Suyal[1] and Meena[2]

*Department of Botany, Vardhaman College, Bijnor -246701, (UP), India
[1]Department of Botany, IFTM, Moradabad-244102 (UP), India
[2]Department of Botany, Vivek College, Bijnor-246701 (UP), India

Abstract

Garhwal Himalaya is considered as a hot spot of biodiversity in India and support a large number of plant species. It's wide altitudinal range and variations in other factors like soil texture, climate, rainfall etc., influence the diversity of plant species found in this region, which also supports the life and livelihood of local people in many ways. Many ecologically important trees species like *Quercus floribunda* (oak) and *Rhododendron arboreum* etc. occurring in such forest, are also being used in many ways like as fuel wood etc. But, due to different kind of existing pressure the Himalayan forest is being degraded and become less productive. The present study was carried out in Dhanaulti forest of Garhwal Himalaya to reveal the impact of altitude gradient on common occurring tree species to analyze the change in the dispersion behavior along the altitudinal gradient for proper management, sustainable utilization and conservation of the forest resources. The vegetation analysis was carried out using 10 quadrats (10×10 m^2) at five different altitudes (Forest types; FT-1, FT-2, FT-3, FT-4, FT-5). The results indicated that *Cupresses torulosa* was dominant along all selected forest types except, FT-1 and FT-5 where *Quercus floribunda* was found to be dominant. Interestingly, most of the tree species showed contagious distribution at different altitudes, indicating insufficient mode of seed dispersal (Richard, 1996) or large gap created by the death of trees encouraging the recruitment and growth of new saplings (Armesto *et al.*, 1986). Moreover, J-shaped DD curve of common occurring tree species (poor or no regeneration) in most of the selected forest types, indicate alarming situation. Therefore, it is very essential to develop proper management and conservation strategies for maintenance of such economically useful species and their sustainability in the forest of the region.

Key words: Himalaya, altitude, importance value index (IVI), keystone species, dispersion pattern.

Introduction

Nature has given to us the most precious gift in the form of vegetation which provides food, fodder, fuel, medicine, timber, resins, oils etc. (Gaur, 1999). Plant community plays a significant role in sustainable management by maintaining the biodiversity and conserving the environment (Farooquee and Saxena, 1996). The Indian subcontinent is rich in biodiversity and constitutes one of the 12 mega-diversity countries in the world. The Garhwal Himalaya is one of the hot spots of biodiversity situated in the western part of Central Himalaya, showing wide altitudinal range, rapid change in altitudinal gradient even at small distances and high endemism (Singh & Singh, 1992; Zobel & Singh, 1997; Chandra *et al.*, 2010). The elevation range from 300-2200 m in Garhwal Himalaya comprises three vegetation zones, *viz.*, *Shoea robusta* in sub-montane zone (upto 1000 m), *Quercus leucotrichophora* (>1500) in low montane to mid montane zones and *Pinus roxburghii* regime in between first two zones. A dense canopy of *Quercus floribunda* is found between 2200 and 2800 m whereas above 2800 m oak-conifer association occurs with dominance of *Q. semercarpifolia*, *Abies pindrow*, *Rhododendron barbatum*, *Taxus wallichiana* and *Viburnum* spp. (Bhandari *et al.*, 2000).

In Himalayan region, elevation and climatic factors are important factors for regional differences in species composition (Lee and Chun 2016; Sharma *et al.* 2016). The vegetation diversity of forest ecosystems of Himalaya is influenced by many factors such as topography, soil,

***Author for correspondence :** E-mail : aadimaneesh@gmail.com

climate and geographical location (Chandra *et al.*, 2010). There is a great diversity in the floristic pattern due to altitudinal variation and rainfall (Arora, 1995). Ellu and Obua (2005) have also reported the influence of different altitudes and slopes over species richness and dispersion behavior of tree species. Moreover, altitude itself is a complex combination of related climatic variables closely related with many other environmental properties like soil texture, nutrients, substrate stability etc. (Ramsay and Oxley, 1997).

The Himalayan forest supports the life and livelihood of local people in different ways (Patnaik, 1986; Dhyani *et al.*, 2011). Many tree species such as oak provide many ecosystem services and act as lifeline for local people, have considerable conservation significance in this region (Saxena and Singh, 1982; Singh and Singh, 1986, 1987; Upreti *et al.*, 1985). Many oak species are associated not only with agro-ecosystems but also with the life support systems of the inhabitants of the hills in the Himalaya. The oak forests are source of fuel wood, timber and can be correlated with natural springs and wildlife (Singh, 1981). Likewise, *Rhododendron arboreum* is considered as an ecological keystone species (Paine 1969). But over the past few decades, the Himalaya has experienced unprecedented land use changes due to rapid population growth and human activities (Pandit *et al.*, 2007). Moreover, limited employment opportunities and poverty have increased the dependency of local people for fuel wood, fodder, building material and non-timber forest products on adjacent forests. As a result of this extra pressure, most Himalayan forest has become less productive (Saxena *et al.*, 2005).

The present study was carried out to reveal the impact of altitude on common occurring tree species in various forest types of temperate region of Garhwal Himalaya for assessment and analysis of change in the dispersion behavior along the altitudinal gradient for proper management, sustainable utilization and conservation of the forest resources.

Study Area

The present study was carried out along five different altitude gradient in the forest of Dhanaulti region at elevation range of 2,286 meters above sea level (m asl). (fig.1). Dhanaulti region is located in Garhwal Himalaya of Uttarakhand between 30^{0}27' 0" N78^{0}15' 0" E. Five selected forest types of the study area were named according to the composition of dominant tree species as per (Ram Prakash, 1986) *viz.*>75% as pure, 50-70% as mainly, 25-50% as mixed and<25% miscellaneous and categorized as forest type-1 (FT-1), forest type-2 (FT-2), forest type-3 (FT-3), forest type-4 (FT-4) and forest type-5 (FT-5) (table 1). The soils of this region change according to aspect, altitude and climate. These belong to mollisols and of Satengal to inceptisols. All these polypedons are members of fine sandy loam, mixed, messic family. These soils developed from different parent materials are in equilibrium with geogenic factors. The soils are generally acidic in nature with pH increasing with depth (*Saha et al.*, 2016). The climatic data of the study area are given in fig. 2. The temperature in this region is cool throughout the year. The summer months are cool and winters are not very freezing but provide a misty view of distant mountains. The summer temperatures range from 25^{0}C to 16^{0}C while the winter temperature ranges from 13^{0}C to 2.8^{0}C. Four ecologically and economically useful tree species *viz. Quercus floribunda*, *Cupresses torulosa*, *Rhododendron arboretum*, *Betula alnoides*, were common to all selected

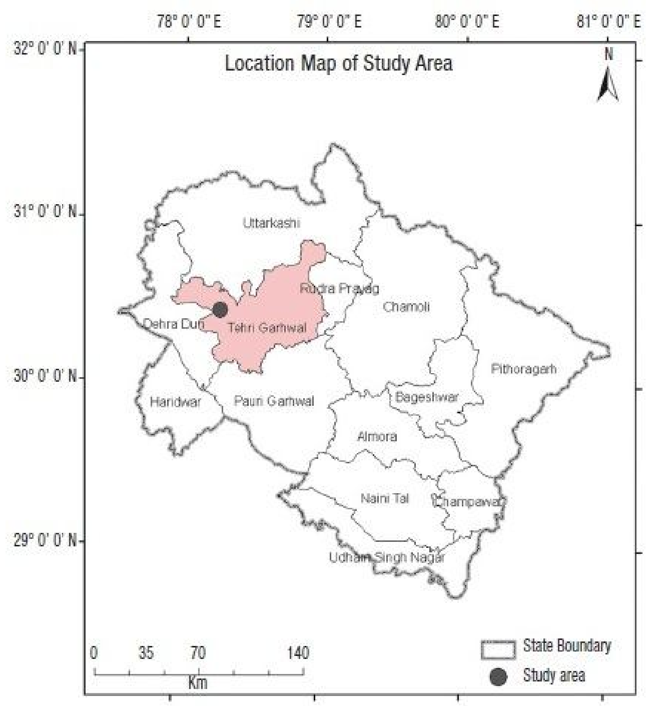

Fig. 1: Location map of the study area in Uttarakhand

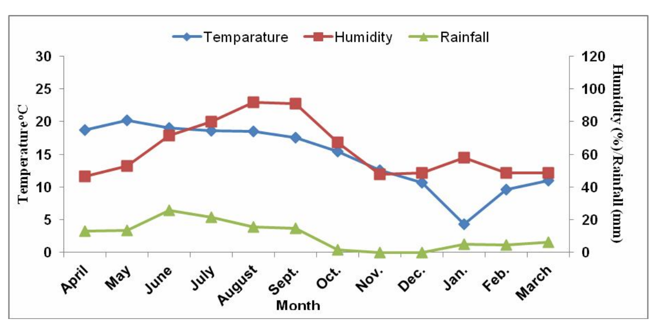

Fig. 2: Metrological data of the study area

Table 1: Location of study area

S. No.	Forest Type	Name of Forest Type	Elevation (m asl)	Aspect
1	FT-1	Mixed broad leaved Forest Type	2200	SW
2	FT-2	Mixed *Quercus floribunda* Forest Type	2400	W
3	FT-3	Pure *Quercus semecarpifolia* Forest Type	2600	SW
4	FT-4	Mixed *Cupressus torulosa* Forest Type	2700	NW
5	FT-5	Pure *Cupressus torulosa* Forest Type	2800	N

forest types (FT-1 to FT-5), selected for present study.

Methodology

The analysis of trees was carried out in the year 2017 in tree layer by using 10×10 m^2 quadrats in five different forest types. The size and number of quadrats were determined by the species area curve method (Mishra, 1968). 10 randomly placed square shaped quadrats were laid for analysis of tree species at each altitude. Diameter at breath height (dbh) of all trees falling with in the sample plot was also measured.

Frequency, Density and Abundance was calculated following (Curtis and Mclntosh, 1950). Frequency expresses the distribution or dispersion of species in a community and was calculated as follows:

$$\text{Frequency E\%F} = \frac{\text{No. of quadrates in which the species occured}}{\text{Total No. of quadrates studies}} \times 100$$

The density is defined as the number of individuals per unit area or volume and calculated as:

$$\text{Density EDF} = \frac{\text{Total No. of individuals}}{\text{Total No. of quadrates studies}}$$

$$\text{Dominance} = \frac{\text{Total basal area of a species}}{\text{Total No. of quadrates studies}}$$

Abundance refers to density of individuals of a species in those sampling units only, in which a given species occurs and was calculated as follows:

$$\text{Abundance} = \frac{\text{Total basal area of individuals}}{\text{No. of quadrates occurence}}$$

Abundance to frequency ratio (A/F ratio) for different species was used to determine the distribution pattern in terms of regular (<0.025), random (0.025-0.05) and contagious (>0.05), as described by Curtis and Cottam (1956).

Girth at breast height (GBH) was measured at 1.37 m above ground level.

Basal area πr^2 (circumference GBH=$2\pi r$)

$$\text{Mean Basal Area} = \frac{\text{Basal area of All individuals of species}}{\text{Total No. of individuals of species}}$$

Total basal cover (TBC) refers to the mean basal cover multiplied with respective density to obtain total basal cover (TBC m^2 ha^{-1}).

Total basal cover (TBC) = Mean basal area of species × density of species.

The importance value index (IVI) was determined as the sum of the relative frequency, relative density and relative dominance (Curtis, 1959).

$$\text{Relative frequency} = \frac{\text{Frequency of species}}{\text{Total Frequency of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Dominance of species}}{\text{Total dominance of all species}} \times 100$$

IVI= Relative frequency + Relative dominance + Relative density.

Results

The composition and structure of tree species were studied in selected forest types at five different altitudes namely- FT-1, FT-2, FT-3, FT-4 and FT-5. For comparative study the common tree species found in these forest types such as *Quercus floribunda*, *Rhododendron arboreum*, *Cupressus torulosa* and *Betula alnoides,* were analyzed for different parameters like Frequency, Density, Abundance, Dominance, Relative frequency, Relative density, Relative dominance, IVI, A/F ratio, TBC.

In FT-1, based on IVI values *Quercus floribunda* was reported dominant species followed by *Rhododendron arboreum* and *Cupressus torulosa*. The maximum value of frequency was recorded for *Quercus floribunda* and *Rhododendron arboreum* followed by *Cupressus torulosa* whereas, the maximum value of density was recorded for *Rhododendron arboreum* followed by *Quercus floribunda* and *Cupressus torulosa*. The maximum and minimum values for total basal cover were observed for *Quercus floribunda* and *Cupressus torulosa*, respectively (table 2). All the tree species in this forest type were distributed contagiously (table 3).

In FT-2, *Cupressus torulosa* was reported as dominant with highest IVI value followed by *Quercus floribunda, Rhododendron arboreum* and *Betula alnoides*. All the species in this forest type have shown maximum value of frequency except, *Betula alnoides*. The maximum value of density was recorded for *Quercus floribunda* followed by *Cupressus torulosa, Rhododendron arboreum* and *Betula alnoides*. The maximum and minimum values for total basal cover were observed for *Cupressus torulosa* and *Betula alnoides*, respectively (table 2). All the tree species in this forest type were distributed contagiously (table 3).

In FT-3, *Cupressus torulosa* was also reported dominant with highest IVI value followed by *Quercus floribunda, Rhododendron arboreum* and *Betula alnoides*. The maximum values of frequency, density and total basal cover were also recorded for *Cupressus torulosa* followed by *Quercus floribunda, Rhododendron arboreum* and *Betula alnoides*. In other words, the values of all selected parameters were recorded minimum for *Betula alnoides* (table 2). The distribution pattern of *Quercus floribunda* was regular whereas all other species were distributed contagiously (table 3)

In FT-4, *Cupressus torulosa* was again reported as dominant species with highest IVI value followed by *Quercus floribunda, Rhododendron arboreum* and *Betula alnoides*. The maximum value of frequency was observed for *Cupressus torulosa* followed by *Quercus floribunda, Betula alnoides* and *Rhododendron arboreum*. The maximum values of density and total basal cover were also recorded for *Cupressus torulosa* followed by *Quercus floribunda, Rhododendron arboreum* and *Betula alnoides* (table 2). In this forest type *Quercus floribunda* and *Betula alnoides* were random in distribution whereas, *Rhododendron arboreum* and *Cupressus torulosa* were distributed contagiously (table 3).

Table 2: Frequency (%), Density (individuals/hactare), Total basal cover (TBC), IVI and A/F ratio of trees and seedlings in different forest types/altitudes

Forest Type/ Altitude (m asl)	Tree species	Frequency %	Density	TBC	IVI	A/F Ratio
FT-1/ 2200	*Quercus floribunda*	83.33	550	50.06	122.23	0.0792
	Rhododendron arboreum	83.33	553	49.32	119.8	0.076
	Cupressus torulosa	33.33	241	30.56	57.93	0.217
	Betula alnoides	-	-	-	-	-
FT-2/ 2400	*Quercus floribunda*	83.33	576	41.78	92.56	0.074
	Rhododendron arboreum	83.33	358	33.7	76.76	0.051
	Cupressus torulosa	83.33	491	74.73	111.76	0.07
	Betula alnoides	16.66	116	8.15	18.89	0.42
FT-3/ 2600	*Quercus floribunda*	66.66	458	42.64	90.92	0.0103
	Rhododendron arboreum	41.66	291	22.59	54.62	0.168
	Cupressus torulosa	83.33	483	82.72	125.44	0.069
	Betula alnoides	25	150	10.44	29	0.24
FT-4/ 2700	*Quercus floribunda*	91.66	266	22.58	65.65	0.0316
	Rhododendron arboreum	58.33	216	17.77	47.84	0.063
	Cupressus torulosa	100	583	89.89	140.19	0.058
	Betula alnoides	66.66	208	12.75	46.31	0.046
FT-5/ 2800	*Quercus floribunda*	58.33	491	38.13	108.06	0.144
	Rhododendron arboreum	33.33	125	11.03	35.39	0.112
	Cupressus torulosa	100	266	39.33	102.15	0.026
	Betula alnoides	58.33	200	13.18	60.3	0.06

Table 3: Dispersion pattern of tree species along altitude gradient

S.No.	Tree Species	Forest Type/Altitude (m asl)				
		FT-1/ 2200	FT-2/ 2400	FT-3/ 2600	FT-4/ 2700	FT-5/ 2800
1	*Quercus floribunda*	0.079 (C)	0.074 (C)	0.010 (Re)	0.031 (R)	0.144 (C)
2	*Rhododendron arboreum*	0.076 (C)	0.051 (C)	0.168 (C)	0.063 (C)	0.112 (C)
3	*Cupressus torulosa*	0.217 (C)	0.070 (C)	0.069 (C)	0.058 (C)	0.026 (R)
4	*Betula alnoides*	-	0.420 (C)	0.240 (C)	0.046 (R)	0.060 (C)

Abbreviations: R = Random; Re = Regular; C = Contiguous

In FT-5, *Quercus floribunda* was reported as dominant with highest IVI value followed by *Cupressus torulosa, Rhododendron arboreum* and *Betula alnoides.* The maximum values of frequency and total basal cover were reported for *Cupressus torulosa* followed by *Quercus floribunda, Betula alnoides* and *Rhododendron arboreum*. The maximum value of density was recorded for *Quercus floribunda* followed by *Cupressus torulosa, Rhododendron arboreum* and *Betula alnoides* (table 2). The distribution pattern of *Cupressus torulosa* was random whereas all other species were distributed contagiously (table 3).

Betula alnoides was not found in FT-1 while present in all other forest types. Maximum frequency and density of *Quercus floribunda* was found in FT-4 and FT-2, respectively, while abundance of this species was maximum in FT-5. Dominance, TBC, Relative frequency, IVI and A/F ratio of *Quercus floribunda* were found maximum in FT-1 as compared to other Forest type, whereas relative density and relative dominance were found maximum in FT-5.

For *Rhododendron arboretum* all the parameters were found maximum in FT-1, except abundance which is found maximum in FT-3. For *Cupressus torulosa* all parameters were found in FT-4, except abundance, relative frequency and A/F ratio. Abundance and A/F ratio of this species was maximum in FT-1 while Relative frequency was maximum in FT-5 as compared to other forest type frequency and density of *Betula alnoides* was found maximum in FT-4 whereas, abundance and A/F ratio were found maximum in FT-2. Rest parameters studied were found maximum in FT-5 for this species.

As compared to other forest types among all species of these Forest types *Cupressus torulosa* exhibited maximum frequency, density, dominance, TBC, relative density, relative dominance, IVI, in FT-4. However, the abundance and relative frequency of *Quercus floribunda* was maximum in FT-5 and FT-1, respectively. Moreover, *Betula alnoides* showed maximum A/F ratio and minimum all other parameters (except density and abundance). Density of *Rhododendron arboretum* and abundance of *Cupressus torulosa,* was minimum in FT-5 as compared to other species and Forest types. A/F ratio of *Quercus floribunda* was found minimum among all other species (table 2).

Discussion

Gairola *et al.* (2008) have studied forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India at an altitude ranging from 2800-3600m. The results revealed that from low to high altitude strata, size and density of trees declined sharply. Furthermore, it is supposed that in the event of a rise in temperature at lower elevations the movement/migration of vegetation would be toward upper elevation (Chen and Hill, 2011). In the present study, density of common tree species ranged from 1082 to 1541 trees ha^{-1} and total base cover ranged between 101.67 to 158.36 m^2 ha^{-1}. However, the density of common trees and total base cover were gradually decreased with an increase in elevation which is in contrary with the studies conducted in Western Ghats by Pathasarathy and Karthikeyan (1997). Moreover, in a study, Kumar *et al.* (2009) reported the density and total basal cover values between 652 to 1028 m^2 ha^{-1} and 11.38 to 31.70 m^2 ha^{-1}, respectively, in Garhwal Himalayan temperate forest. Bhandari and Tiwari (1997) also reported density values from 1570–1785 trees ha^{-1}. These values reported by above experts for Garhwal Himalayan forests are fluctuating above and below the values of present study, due to different levels of disturbances in the forests. Many researchers (Baduni & Sharma, 1996; Ghildiyal *et al.*, 1998; Sharma & Baduni, 2000; Ram *et al.*, 2004) reported basal area values ranging from 17.9 to 180.1 m^2 ha^{-1} in the temperate forest of Himalaya. The values carried out in the present study fall within the range of values reported by various researchers. For instance, in different forest types of Garhwal Himalaya, Raturi (2012) reported highest value of density (1980 trees ha^{-1}) in the temperate mixed forest and minimum value of density (1090 trees ha^{-1}) in sub-tropical forest. Devlal and Sharma (2008) also reported total density of trees ranging from 1166 trees ha^{-1} to 1826 trees ha^{-1} in natural forest of Gangotri.

In general, in most of the selected forest types *Cupressus torulosa* was found to be dominant species followed by *Quercus floribunda.* Although, oak forests are most extensively distributed between the altitudes 1000m to timberline and represent the climax stage, throughout the Central Himalaya (Champion & Seth, 1968; Upreti *et al.*, 1985).

Dispersion pattern

Hubbell *et al.* (1999) reported that dispersal limitation is an important ecological factor for controlling species distribution pattern and a connection between biotic and abiotic factors. An analysis of dispersion pattern indicated that majority of species had contiguous distribution at the altitude between 2200-2800m asl. Many workers Greig-Smith, 1957; Singh and Yadav, 1974; Kumar and Bhatt, 2006) have also reported contiguous distribution for Himalayan forests. However, the present study indicated that *Quercus floribunda* changed its dispersion from contiguous (2200-2400m asl) to regular at 2600m asl followed by random at 2700m asl to finally contiguous at 2800m asl. *Rhododendron arboreum* was found contiguously distributed between 2200-2800m asl. On the other hand, *Cupressus torulosa* also showed contiguous distribution pattern between 2200-2700m asl whereas random pattern at 2800m asl. *Betula alnoides* was found to be absent at 2200m asl, showed contiguous distribution pattern between 2400-2600m asl followed by random distribution at 2700 m asl and again contiguous pattern at 2800m asl. Odum (1971) suggested that contiguous distribution is common in nature, whereas, random is found only in uniform environment, and regular distribution occurs when severe competition occurs between the individuals. The contiguous distribution of a species may be due to insufficient mode of seed dispersal (Richard, 1996) or large gap created by the death of trees encouraging the recruitment and growth of new saplings (Armesto *et al.*, 1986). The changes in distribution pattern may reflect the reactions of species to disturbance as well as to changes in the habitat conditions (Sagar *et al.*, 2003).

Density-diameter curve (DD curve)- All the studied forest types showed J-shape (poor regeneration, that is, seedlings<saplings>adult trees) which indicates that forest types has reproduced well in the immediate past. Although, the forest type 3 and forest type 4 showed reverse J-shaped curve for *Rhododendron arboreum* indicating good regeneration in such forest types (figure 3). Higher densities in lower diameter classes are indicative of mature forest with good regeneration status in general (Rollet, 1978; Blanc *et al.*, 2000). However, the higher percent of J-shaped (poor regeneration) tree species in all the forest sites indicates heavy anthropogenic pressure on forest species for fuel and fodder and need management and conservation.

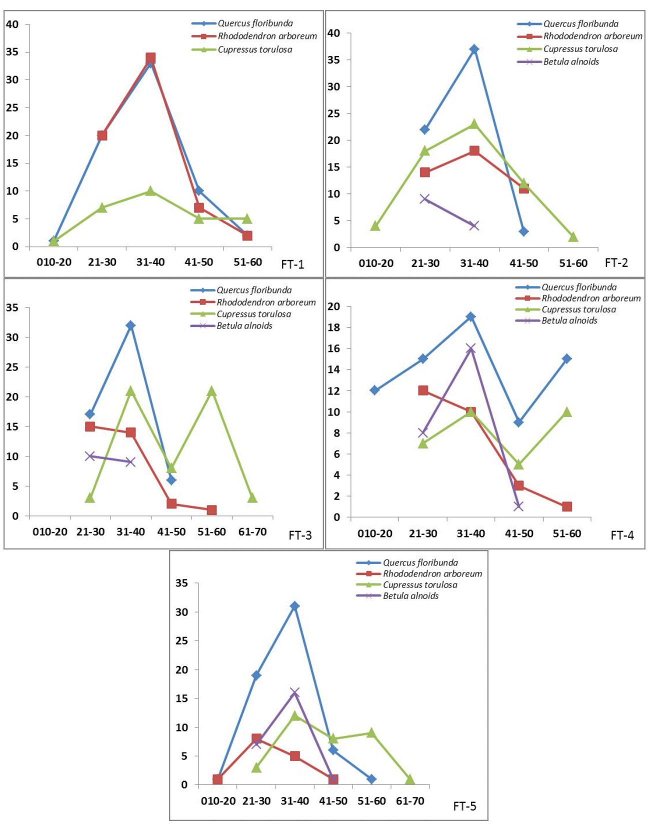

Fig. 3: DBH class distribution of tress in studies sites

Dominance-diversity curve (D-D curve)

The dominance-diversity curve common tree species has been given in figure 4. The dominance-diversity curve fit for the lognormal situation (Khera *et al.*, 2001). The lognormal series describes the partitioning of realized niche space among various species and it is consequence of the evolution of diversity in the niche parameters that is exploits (Whittaker, 1965; Khera *et al.*, 2001). However, in the report of Raturi (2012) dominance-diversity curve for trees prepared on the basis of importance value index, approached to the geometric series for all forest types. The lognormal distribution of the forest layer was due to highly mixed nature of vegetation, whereas, the geometric series confirmed the niche preemption hypothesis of Whittaker (1975).

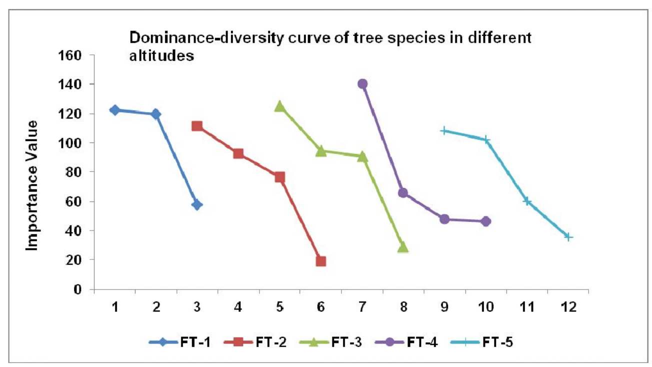

Fig. 4: Dominance diversity curve of trees in different forest types/altitudes

Conclusion

The present study shows that common occurring tree species of all studied forest types are in a very alarming situation as showing J-shaped curve (poor or no regeneration), except *Rhododendron arboreum* in forest type-3 and forest type-4. Therefore, it is very essential to develop proper management and conservation strategies for maintenance of such economically useful species and their sustainability in the forest of the region.

References

Armesto, I.J., J.D. Mitzel and C. Villagram (1986). A comparison of spatial patterns of trees in somet ropical and temperate forests. *Biotropica*., **18:**1-11.

Arora, R.K. (1995). Himalayan Resources, Diversity and Conservation. In: U. Dhar (ed). Himalayan Biodiversity. *Gyanodaya Prakashan, Nainital*, **2:** 39-55.

Baduni, N.P. and C.M. Sharma (1996). Effect of aspect on the structure of some natural stands of *Quercus semecarpifolia* in Himalayan moist temperate forest. *Indian J. Forestry*, **19:** 335-341.

Bhandari, B.S. and S.C. Tiwari (1997). Dominance and diversity along an altitudinal gradient in a montane forest of Garhwal Himalaya. *Proc. Indian Natl. Sci. Acad*., **B 64:** 437-446.

Bhandari, B.S., J.P. Mehta and S.C. Tiwari (2000). Dominance and diversity relation of woody vegetation structure along an altitudinal gradient in a montane forest of Garhwal Himalaya. *Journal of Tropical Forest Science*, **12(1):** 49-61.

Blanc, L., G. Maury-Lechon and J.P. Pascal (2000). Structure, floristic composition and natural regeneration in the forests of Cat Tien National Park, Vietnam: an analysis of the successional trends. *Biogeography*, **27:** 141–157.

Champion, H.G. and S.K.Seth (1968). A revised survey of the forest types of India. *New Delhi*: *Government of India, Press*. pp. 404.

Chandra, J., V.S. Rawat, Y.S. Rawat and J. Ram (2010). Vegetational diversity along an altitudinal range in Garhwal Himalaya. *Internat. J. Biodivers. Conservat*., **2(1):**014-018.

Chen, C., J.K. Hill, R.R. Ohlemuller, D.B. Roy and C.D. Thomas (2011). Rapid Range Shifts of Species Associated with High Levels of Climate Warming. *Science*, **333:**1024–1026.

Curtis, J.T. (1959). The Vegetation of Winconsin. An Ordination of plant communities, University Winconsin Press, Madision Winconsin, pp. 657.

Curtis, J.T. and G. Cootam (1956). Plant Ecology Workbook laboratory field reference manual, Burgers Publication co., Minnesota, pp. 193.

Curtis, J.T. and R.P. McIntosh (1950). The interaction of certain analytic and synthetic phytosociological characters. *Ecology,* **31:**434-455.

Devlal, R. and N. Sharma (2008). Altitudinal changes in dominant diversity and species richness in a temperate forest of Garhwal Himalaya. *J. American Science*, **4(3):** 1545-1003.

Dhyani, S., R.K. Maikhuri and D. Dhyani (2011). Energy budget of fodder harvesting pattern along the altitudinal gradient in Garhwal Himalaya, India. *Biomass Bioenerg.*, **35:** 1823–1832.

Eilu, G., J. Obua (2005). Tree condition and natural regeneration in disturbed sites of Bwindi impenetrable forest National Park, Southwestern Uganda. *Tropical Ecology,* **46:**99e111.

Farooquee, N.A. and K.G. Saxena (1996). Conservation and utilization of medicinal plants in high hills of central Himalayas. *Environ. Conserv.,* **23:**75-80.

Gairola, S., R.S. Rawat and N.P. Todaria (2008). Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. *African J. Plant Science*, **2(6):** 042-048.

Gaur, R.D. (1999). Flora of the District Garhwal: North West Himalaya (with ethnobotanical notes) Transmedia, Srinagar Garhwal.

Ghildiyal, S.K., N.P. Baduni, V.P. Khanduri and C.M. Sharma (1998). Community structure and composition of oak forests along altitudinal gradient in Garhwal Himalaya. *Indian J. Forestry,* **21:** 242-247.

Greig-Smith, P. (1957). *Quantitative Plant Ecology,* 2nd edition. *Butterworth, London*.

Hubbell, S.P., R.B. Foster, S.O'Brien, B. Wechsler, R. Condit, K. Harms, S.J. Wright and S. Loo de Lau (1999). Light-gap disturbances, recruitment limitation and tree diversity in a Neotropical forest. *Science*, **283:**554-557.

Kharkwal. G., P. Mehrotra, Y.S. Rawat and Y.P.S. Pangety (2005). Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Current Science,* **89(5):** 873-878.

Khera, N., A. Kumar, J. Ram and A. Tiwari (2001). Plant biodiversity assessment in relation to disturbances in midelevational forest of Central Himalaya. *Indian Tropical Ecology*, **42(1):**83-95.

Kumar, M. and V.P. Bhatt (2006). Plant biodiversity and conservation of forests in foot hills of Garhwal Himalaya. *J. Ecol. Applicat*., **11(2):** 43-59.

Kumar, M., C.M. Sharma and G.S. Rajwar (2009). The effects of disturbance on forest structure and diversity at different altitudes in Garhwal Himalaya. *Chinese J. Ecology*, **28(3):** 424-432.

Lee, C.B. and J.H. Chun (2016). Environmental drivers of patterns of plant diversity along a wide environmental gradient in Korean temperate forests chang. *Forest,* **7:**19.

Mishra, R. (1968). *Ecology Workbook. Oxford & IBH, Calcutta*.

Odum, E.P. (1971). Fundamentals of ecology, 3rd eds. Philadelphia: *Saunders*. 574.

Paine, R.T. (1969). A note on trophic complexity and community stability. *The American Naturalist,* **103(929):** 91-93.

Pandit, M. K., N.S. Sodhi, L.P. Koh, A. Bhaskar and B.W. Brook (2007). Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. *Biodiversity Conservation*, **16:** 153-163.

Parthasarathy, N. and R. Karthikeyan (1997). Biodiversity and population density of woody species in a tropical evergreen forest in Courtallum reserve forest, Western Ghats, India. *Trop. Ecol.,* **38:** 297-306.

Patnaik, R. (1986). Tribals and forest. In: Desh B. and Garg R.K. (eds.), Social Forestry and Tribal development. *Indian Environmental Society, New Delhi, India*. pp. 105–117.

Ram Prakash (1986). Forest Management. International Book

Distributors, Dehradun, India. pp. 214.

Ram, J., A. Kumar and J. Bhatt (2004). Plant diversity in six forest types of Uttarakhand Central Himalaya, India. *Current Science,* **87 (7):** 975-978.

Ramsay, P.M. and E.R.B. Oxley (1997). The growth form composition of plants communities in Ecuadorian Paramos. *Plant Ecol*.,**131:**173-192.

Raturi, G.P. (2012). Forest Community Structure along an Altitudinal Gradient of District Rudraprayag of Garhwal Himalaya, India. *Ecologia*., **2:** 76-84.

Richards, P.W. (1996). The tropical rainforest 2nd eds. Cambridge University Press, Cambridge.

Rollet, B. (1978). Description, functioning and evolution of tropical forest ecosystems: organization. In: UNESCO, UNEP and F.A.O. (eds.) Tropical forest ecosystems. *UNESCO*, *Paris*, pp. 112–142.

Sagar, R., A.S. Raghubanshi and J.S. Singh. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management*, **186:**61-71.

Saxena, A.K. and J.S. Singh (1982). A Phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. *Vegetation*, **50:** 2-3.

Saxena, K.G., R.K. Maikhuri and K.S. Rao (2005). Changes in agricultural biodiversity: Implications for sustainable livelihood in the Himalaya. *Journal of Mountain Science*, **2(1):** 23–31.

Sharma, C.M., A.K. Mishra, R. Krishan, O.P. Tiwari and Y.S. Rana (2016). Impact of climate on structure and composition of Ridge Top forests in Garhwal Himalaya. *Taiwan*, **61(2):** 61-69.

Sharma, C.M. and N.P. Baduni (2000). Effect of aspect on the structure of some natural stands of *Abies pindrow* in Himalayan moist temperate forests. *The Environmentalist*, **20:** 309-317.

Singh, J.S. and S.P. Singh (1987). Forest vegetation of the Himalaya. *Bot Rev.*, **52:** 80-192.

Singh, J.S and P.S. Yadav (1974). Seasonal variation in composition, plant biomass and net primary productivity of tropical grassland of Kurukshetra, India. *Ecology Monograph*, **44:** 351-375.

Singh, J.S,. S.P. Singh and C. Shastri (1981). *Science of rural development in mountains*. Lyonia, *Gyanodaya Prakashan, Nainital, India,* **11(2):** 43-59.

Singh, J.S. and S.P. Singh (1992). Forests of Himalaya; Structure, Functioning and Impact of Man. *Gyanodaya Prakashan, Nainital, India.*

Sushil Saha, Govind-Singh Rajwar and Munesh Kumar (2016). Forest structure, diversity and regeneration potential along altitudinal gradient in Dhanaulti of Garhwal Himalaya. *Forest System*, **25(2):**e058.

Upreti, N., J.C. Tewari and S.P. Singh (1985). The oak forests of Kumaun Himalaya (India): Composition, Diversity, and regeneration. *Mountain Res. Develop*., **5:** 163-174.

Whittaker, R.H. (1965). Dominance and diversity in land plant communities. *Science,* **147:** 250-260.

Zobel, D.B. and S.P. Singh (1997). Himalayan forests and Ecological generalization. *Bio. Sci.,* **47(11):** 735-745.