REGENERATION PATTERN OF TREE SPECIES ALONG AN ALTITUDINAL GRADIENT IN PITHORAGARH DISTRICT, WEST HIMALAYA

Anjali Barola*, Kamini Durgapal and Amit Bahukhandi

G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand, India

***Correspondence**: barola.anjali@gmail.com

ABSTRACT

Regeneration is an important process for maintaining biodiversity, however, several anthropogenic factors influence the pattern of regeneration in forest ecosystem of west Himalaya. The present investigation highlights, the regeneration pattern of dominant tree species namely *Pinus roxburghii*, *Querus leucotrichophora, Myrica esculenta, Pyrus pashia, Querus gluaca, Lyonia ovalifolia, Rhododendron arboreum* and *Terminalia chebula* along the altitudinal gradient (1000-1700m asl) of Pithoragarh district (Uttarakhand). Irregular distribution of the species recorded in the study sites, and maximum species showed "good" (55 %), "New" (22%), "Fair" (18%), "No" (3%) and "Poor" (2%) regeneration trend between 1000m and 1700m asl. At 1500m asl best regeneration was found with maximum species richness as compared to other elevations. However, most of the species are showing 'fair' regeneration, which needs an immediate attention for conservation. Therefore, their management and conservation strategies are required for future regeneration and their plantation will be helpful for biodiversity conservation.

Keywords: Regeneration, Tree species, Altitude, Pithoragarh district, West Himalaya

INTRODUCTION

Regeneration is a key process for the existence of any species in a forest community under varied environmental conditions and also an important indicator of sustainability of forest stock (Baland *et al*., 2010). This is cost effective natural process by which the plant species re-establish themselves and help in maintaining their diversity as well as genetic identity (Hanief *et al*., 2016), and also indicate possible changes in near future (Sharma *et al*., 2014). Presently, inadequate regeneration is the main problem of forests in hilly regions of Himalaya (Rawat *et al*., 2014), however, previous reports indicate that population structure and regeneration pattern of the tree species is influenced by several factors (Gairola *et al*., 2014). Many researchers, highlighted information on richness and diversity of forest ecosystems in the Western Himalaya (Rawal *et al.,* 1994; Dhar *et al*., 1997; Rawal *et al*., 2012; Lodhiyal *et al*., 2013; Singh *et al*., 2016; Negi 2019) however, more data on the regeneration pattern and population structure of diverse tree species along the altitudinal gradient is still required, particularly economically important tree species. This study generates base line data and pattern of species regeneration that will be helpful for developing strategies for future conservation to supplement the subsistence need of the local communities.

METHODOLOGY

The study was carried out along the altitudinal gradient (1000-1700masl) in different forest types of Pithoragarh district, Western Himalaya, Uttarakhand, India (Table 1).

Table 1. Characteristics of the study sites Pithoragarh district, west Himalaya

S. No.	Location	Latitude	Longitude	Altitude (masl)	Aspect
1	Gobrari	29°44'36.9"	080°09'21.4"	1000	SE
2	Tuniyar	29°48'35.9"	080°10'07.2"	1100	SE
3	Tapradhar	29°50'27.8"	080°09'36.5"	1200	NW
4	Gartil	29°47'03.0"	080°05'36.8"	1300	NE
5	Humkapita	29°51'17.6"	080°13'48.2"	1400	NE
6	Hattrap	29°47'14.0"	080°15'30.0"	1500	NE
7	Ankot	29°47'15.9"	080°14'33.0"	1600	Ridge top
8	Devradi pant	29°45'41.5"	079°54'53.1"	1700	SW

The quadrate sampling approach was followed and we laid down 105 sample plots for trees and saplings, and 350 plots for seedlings in the studied forests. Random vegetation sampling was conducted and 3 sample plots (50×50m) were marked. In each plot, 5 quadrats (10×10m) for enumeration of trees and saplings were laid and each individual 10×10m sub quadrates was further sub-divided into 1×1m for seedlings. Circumference at breast height (cbh at 1.37cm height from ground) was measured for trees. The tree population structure was developed based on density distribution across size classes. Individuals: >31cm CBH were considered trees, 10-31cm CBH as saplings and <10cm CBH as seedlings. The individuals of tree species were recorded from each quadrate and grouped in to seven girth classes (A: 0-10; B: 11-30; C: 31-60; D: 61-90; E: 91-120; F: 121-150; G>151cm). Class A and B represent seedling and sapling, respectively and Classes from C-G represented tree species. Relative density in a size class was calculated as a percentage of the total number of individuals in all size classes. The quadrat data were pooled for plots for calculation of various quantitative measures such as density, frequency, abundance, abundance/frequency ratio and Important Value Index (IVI) (Rawal *et al.*, 2012; Rawat *et al.*, 2014). The provenance value (PV) index was calculated for seedling by using the values of relative density (RD) and relative frequency (RF). The diversity (H') was determined using Shannon - Wiener index as $H= -\Sigma (ni/n)^2 \log2 (ni/n)$, where ni is the density of a species and n is the sum of total density of all the species of that forest. The Simpson's diversity index was calculated as D= 1- Cd, where D is Simpson's diversity and Cd is Concentration of dominance. Species richness was considered as number of species per unit area. The regeneration status of tree species was determined on the basis of population size of seedling, sapling and tree; (a) Good regeneration i.e. if number of seedling >sapling >adults, (b) Fair regeneration i.e. if number of seedling > or <sapling <adults, (c) Poor regeneration i.e. if the species was found as sapling, but no seedling (number of sapling may be more, less or equal that of adult) (d) No regeneration i.e. if individuals of species are present only as adults, and (e) New regeneration i.e. if individual of species have no adult but present as seedling or sapling (Hanief *et al.*, 2016).

RESULTS AND DISCUSSION

The total 18 tree species belonging to 14 families were recorded from the study area from which 17 species belonged to angiosperm (16 genus, 17 species and 13 families) and 1 belonged to gymnosperm (1 genus, 1 species and 1 family). Ericaceae and Rosaceae (2 genus and 2 species respectively) were reported as dominant family followed by Fagaceae with 1 genus and 2 species (Fig. 1).

TREE, SAPLING AND SEEDLING LAYER

Tree density was recorded range 147-547indi/ha along the altitude (Table. 2) and *Quercus leucotrichophora* reported maximum tree density at 1200m asl. The highest IVI (300) was found in *Pinus roxburghii* at 1100m and 1700m, however, lowest (9.5) found at 1500m in *Prunus cerasoides*. The

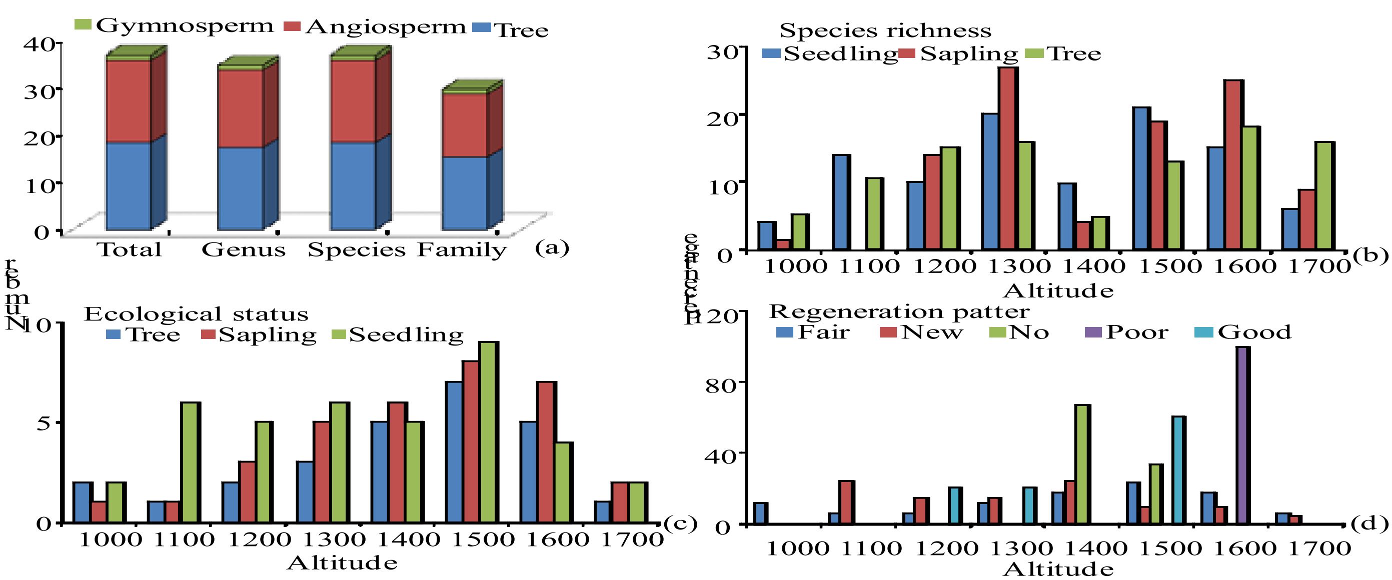

Fig. 1. Forest characteristics along the altitudinal gradient, West Himalaya

Shannon diversity index (H') range= 0.13 to 1.14 was reported maximum in *Myrica esculenta* (0.36) at 1300m followed by *Pinus roxburghii, Quercus leucotrichophora and Rhododendron arboreum,* respectively. Likewise, Simpson diversity index was varied from 0.41 to 3.93 and reported maximum in *Terminalia chebula* (0.99) at 1400m asl. Results reveal that sapling density varied between 7 and 447 indi/ha along the elevation range and was reported maximum in *Q. leucotrichophora* (213indi/ha) at 1300m. The lower altitude forest indicated highest IVI for *P. roxburghii* (1100m) and *P. pashia* (1300m). Similarly, sapling of *M. esculenta* (0.36) showed maximum diversity at 1300m and minimum found at 1700m in *P. roxburghii* (0.02). In terms of seedling density (range= 30-181indi/ha), was and reported highest in *Q. leucotrichophora* (66indi/ha) at 1300m as compared to others species. *P. roxburghii* showed maximum IVI in the lowest altitude (1000 m) and minimum in *A. nepalensis* (1400m). The 1300 m altitude was found good for seedlings of *M. esculenta* (0.36), *P. roxburghii* (1) which showed highest Shannon diversity index (H') and Simpson diversity, respectively.

Contagious distribution was shown by maximum species (63-88%) followed by random distribution (13-38%) and regular distribution (13%). The highest percentage of contagious distribution was shown by tree and sapling (50%). Random distribution highest shown by sapling (40%) and tree (23%) at 1600masl where as regular distribution was shown highest by tree (55%) at 1500masl. The tree species number varies in different forest as their seedling/sapling stages are concerned (Fig. 2). The overall seedling density ranged between 31-181indi/ha whereas sapling density varies from 27-407indi/ha. The maximum percentage of seedling (20%) was recorded at 1500masl and minimum (1%) at 1100masl. The highest percentage of sapling (27%) at 1300masl followed by (25%) at 1600masl whereas the maximum percentage of tree (18%) at 1600masl and minimum (5%) at 1000 and 1400masl.

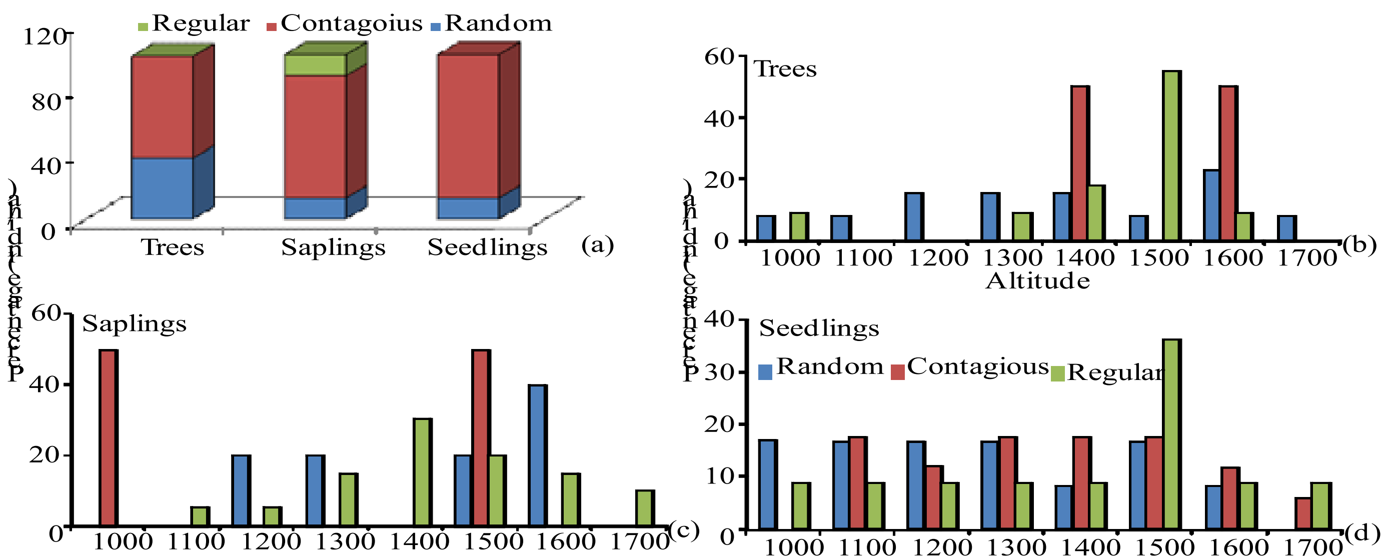

Fig.2. A/F ration of studied forest sites along the altitudinal gradient, West Himalaya

Table 2. Phytosociological analysis of tree species along the altitudinal gradient

	Parameters					
Altitude (masl)	**Density (indi/ha)**	**Frequency**	**A/F Ratio**	**Simpson diversity**	**Shannon diversity**	**Dominant species (IVI values)**
Tree						
1000	160	87	0.043	0.42	0.14	*P. roxburghii* (286.3)
1100	327	100	0.033	0	0	*P. roxburghii* (300)
1200	460	107	0.093	0.41	0.13	*Q. leucotrichophora* (272.3)
1300	500	187	0.103	2.12	0.72	*Q. leucotrichophora* (150.9)
1400	147	100	0.187	2.47	0.83	*P. roxburghii* (175.3)
1500	393	227	0.157	3.93	1.14	*Q. gluca* (133.2)
1600	547	173	0.183	2.76	0.72	*Q. leucotrichophora* (161.6)
1700	500	100	0.050	0	0	*P. roxburghii* (300)
Sapling						
1000	27	13	0.067	0	0	*T. chebula* (200)
1100	7	7	0.017	0	0	*P. roxburghii* (100)
1200	227	80	0.090	0.82	0.26	*Q. leucotrichophora* (244.8)
1300	447	227	0.120	3.27	0.51	*Q. leucotrichophora* (121.4)
1400	73	53	0.097	1.91	0.52	*A. lebbeck* (73.4)
1500	313	140	0.257	4.69	1.39	*Q. gluca* (85.4)
1600	407	207	0.200	3.94	1.12	*Q. leucotrichophora* (120.2)
1700	153	60	0.037	0.38	0.08	*P. roxburghii* (174.1)
Seedling						
1000	81	29	0.093	0.43	0.15	*T. chebula* (200)
1100	117	90	0.460	3.37	0.73	*P. roxburghii* (100)
1200	90	75	0.307	2.87	0.90	*Q. leucotrichophora* (244.8)
1300	177	131	0.443	4.72	1.41	*Q. leucotrichophora* (121.4)
1400	87	72	0.357	0.66	0.88	*A. lebbeck* (73.4)
1500	181	139	0.403	5.11	1.51	*Q. gluca* (85.4)
1600	127	106	0.230	3.27	0.11	*Q. leucotrichophora* (120.2)
1700	30	29	0.073	0.50	0.22	*P. roxburghii* (174.1)

POPULATION STRUCTURE AND REGENRATION PATTERN

A total of 1542 free-standing live individuals (DBH>1cm) were identified belonging to 7 species, 6 genera, 6 families. *Q. leucotrichophora*, *P. roxburghii* and *M. esculenta* were the most abundant, accounting for 36.12%, 33% and 19%, respectively, of the total number of the free standing individuals and identified as dominated species in the forest community. The DBH classes of all species in the sample plot were unimodally distributed, with young trees more abundant than older trees and 59.27% of the individuals were in the DBH class <10cm; indicating abundant recruitment beneath the forest canopy. However, *Q. leucotrichophora*, and *P. roxburghii* had a higher capacity for natural regeneration than rest of the identified species. According to the DBH class of tree species the distribution of *Q. leucotrichophora*, and *P. roxburghii* was unimodal and discontinuous, similar to that of all species in the sample plots, evident discontinuous unimodal distributions, with abundant smaller trees and distinct size deficiencies (2cm<DBH<8cm and 3cm<DBH<10cm), suggesting an adequate number of seedlings, but a lack of saplings under the canopy. A sharp decrease at a DBH of 11-30cm indicated that all the studied species *Q. leucotrichophora*, *P. roxburghii, M. esculenta, T. chebula, R. arboreum, L. ovalifolia, P. pashia* saplings have high mortality under the forest canopy. All the studied spp. at an elevation gradient of 1000-1500m had a low survival rate between the seeding and sapling stages. The presence of sapling and tree stage (DBH<90cm) were exhibited in *R. arboreum* at an altitude of 1600m and *P. roxburghii* at 1700m, respectively (Fig. 3).

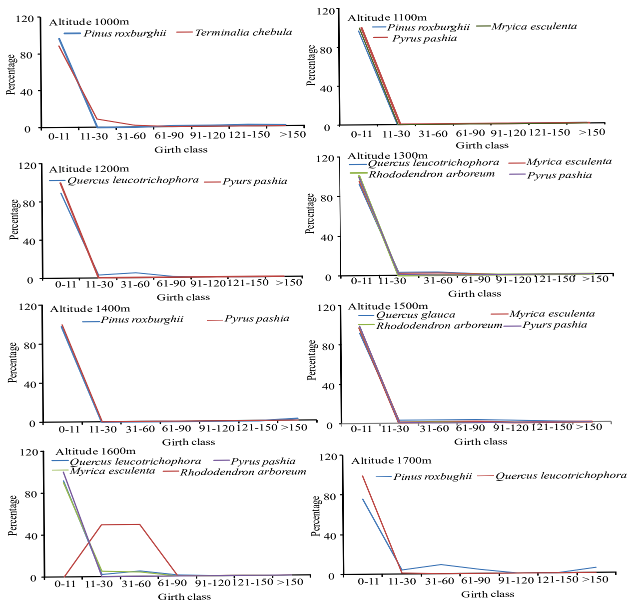

Fig. 3. Population structure along the altitudinal gradient, West Himalaya

Similarly, *P. roxburghii* showed maximum tree density (500indi/ha) at 1700m (Table. 3), however, sapling density of *Q. leucotrichophora* (213indi/ha) was recorded highest at 1300 m and seedling density of *P. roxburghii* (91indi/ha) recorded maximum at 1100m elevation. In the study area, maximum species showed "good" (55 %), "New" (22%), "Fair" (18%), "No" (3%) and "Poor" (2%) regeneration trend at 1000m to 1700m (Fig. 4; Table 3). *R. arboreum,* in north east (NE) facing aspect at 1500m elevation showed "good" regeneration, however, "poor" was found in ridge top of 1600m elevation. *M. esculenta* was reported "fair" regeneration at 1300m, 1500m and 1600m. However, "new" regeneration at 1100m elevation from south east (SE) facing aspect recorded in *M. esculenta*. "New" regeneration was found in *P. pashia* in the elevation range of 1100m to 1600m. However, "no" regeneration was reported by *T. ciliata*, *B. variegata* and *P. cerasoides*.

Altitude is one of the most important determinants of tree distribution due to its direct impact or microclimate of the habitat (Rawal *et al.,* 1994). In the western Himalaya, along the altitudinal transect, distinct changes in vegetation types are reported (Gairola *et al*., 2008). The forest health depends on the potential regenerative status of species composing the forest stand in space and time (Jones *et al*., 1994), and the species distribution pattern indicates its adaptability to various environment and forest communities mainly depends on the ecological characteristics of locations, species diversity and regeneration pattern (Gairola *et al*., 2014). Researchers also reported that regeneration status of tree species of any forest is determined by recruitment of saplings and seedlings (Dhar *et al*., 1997; Pant *et al.,* 2012). The outcomes of the study supported by earlier investigations (Pant *et al.,* 2012; Singh *et al*., 2016). In the study, most of the species had contagious distribution, few species had shown random distribution and very few species showed regular distribution. However, in the mid elevation range (1500-1600m) showed maximum regular distribution of trees and saplings. Similar kind of trends also reported in Garhwal Himalaya (Gairola *et al*., 2010; Singh *et al*., 2016). The study reported highest species richness in NE facing aspect of forest of *Q. glauca* (1500m) and three species namely, *Q. leucotrichophora, M. esculenta* and *P. pashia* showed new regeneration at 1100m in the SE aspect (1100m). The poor regeneration was recorded for *Q. glauca* and *R. arboreum* at the ridge top of 1600m, and *T. ciliate*, *B. variegata* and *P. cerasoides* showed no regeneration. The overall status of regeneration of the tree species is unsatisfactory and alarming situation which may affect the population size and forest composition in near future. Few species reported fair regeneration which might be due to anthropogenic pressure such as firewood collection, grazing, poor biotic potential of tree species which either affect the fruiting or seed germination or successful conversion of seedling to sapling stage. Regeneration of the species is also affected due to environmental factor such as temperature, rainfall, moisture content, soil characteristics, aspect, altitude, etc (Gairola *et al*., 2014; Pant *et al*., 2017; Negi 2019). The economically important species those produce wild edibles and other products need to be given prioritize in regeneration and protection of forest that will also serve the purpose of biodiversity conservation in the region.

Table 3. Regeneration status of tree species along the altitudinal gradient, West Himalaya

Altitude (m asl)		Density (indi/ha)							
		Pinus roxburghii	*Quercus leucotricophora*	***Myrica esculenta***	***Pyrus pashia***	*Quercus gluaca*	*Lyonia ovalifolia*	*Rhododendron arboreum*	*Terminalia chebula*
1000	SD	79	-	-	-	-	-	-	3
	SP	0	-	-	-	-	-	-	27
	TR	153	-	-	-	-	-	-	7
	RS	Fair							Fair
1100	SD	91	5	**9**	**6**	-	-	-	-
	SP	7	-	-	-	-	-	-	-
	TR	327	-	-	-	-	-	-	-
	RS	Fair	New	**New**	**New**				
1200	SD	21	54	-	**7**	3	5	-	-
	SP	-	193	-	-	20	13	-	-
	TR	-	440	-	-	20	-	-	-
	RS	New	Fair		**New**	Fair	New		
1300	SD	15	66	**52**	**13**	-	23	**9**	-
	SP	60	213	**147**	**7**	-	20	-	-
	TR	13	333	**153**	-	-	0	-	-
	RS	Good	Fair	**Fair**	**New**		New	**New**	
1400	SD	58	11	-	**8**	-	-	-	8
	SP	7	7	-	-	13	-	-	33
	TR	100	0	-	-	-	-	-	20
	RS	Fair	New		**New**	New			Fair
1500	SD	-	14	**49**	**5**	35	21	**37**	-
	SP	-	47	**67**	**7**	100	20	**53**	-
	TR	-	53	**67**	-	220	7	**33**	-
	RS		Fair	**Fair**	**New**	Fair	Good	**Good**	
1600	SD	-	64	**25**	**29**	-	9	-	-
	SP	-	173	**153**	**7**	20	33	**7**	-
	TR	-	380	**133**	-	13	13	**7**	-
	RS	-	-	**Fair**	**New**	Poor	Fair	**Poor**	
1700	SD	47	5	-	-	-	-	-	-
	SP	147	7	-	-	-	-	-	-
	TR	500	-	-	-	-	-	-	-
	RS	Fair	New						

(Whereas: RS-Regeneration status; SD-Seedling; SP-Sapling; TR-Trees)

ACKNOWLEDGEMENTS

The authors thank Director, GBPNIHE for facilities and encouragement. Financial support received from National Mission for Sustaining the Himalayan Ecosystem (NMSHE) (Task Force-3), Department of Science & Technology, India is gratefully acknowledged. The authors also thankful to colleagues of Center of Biodiversity Conservation and Management (CBCM) group for their support.

REFERENCES

Baland JM, Bardhan P, Das S, Mookherjee D (2010). Forests to the people: Decentralization and forest degradation in the Indian Himalayas. *World Development*, 38: 1642-1656

Dhar U, Rawal R S, Samant SS (1997). Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: implications for conservation. *Biodiversity and Conservation*, 6: 1045-1062

Gairola S, Rawal RS, Todaria NP (2008). Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. *African Journal of Plant Science*, 2: 042-048

Gairola S, Sharma CM, Rana CS, Ghildiyal SK, Suyal S (2010). Phytodiversity (angiosperms and gymnosperms) in Mandal-Chopta forest of Garhwal Himalaya, Uttarakhand, India. *Nature and Science*, 8:1-17

Gairola S, Rawal RS, Todaria NP, Bhatt A (2014). Population structure and regeneration patterns of tree species in climate-sensitive subalpine forests of Indian western Himalaya. *Journal of Forestry Research*, 25: 343-349

Hanief M, Bidalia A, Meena A, Rao KS (2016). Natural regeneration dynamics of dominant tree species along an altitudinal gradient in three different forest covers of Darhal watershed in north western Himalaya (Kashmir), India. *Tropical Plant Reserach*, 3:253-262

Jones RH, Sharitz RR, Dixon PM, Segal DS, Schneider RL (1994). Woody plant regeneration in four floodplain forests. *Ecological Monographs*, 64: 345-367

Lodhiyal LS, Lodhiyal N, Kapkoti B (2013). Structure and diversity of tree species in natural forests of Kumaun Himalaya in Uttarakhand. *Journal of Plant Development Sciences*, 5: 97-105

Negi GCS (2019). Forest fire in Uttarakhand: causes, consequences and remedial measures. *International Journal of Ecology and Environmental Sciences*, 45: 31-37

Pant S, Samant SS (2012). Diversity and regeneration status of tree species in Khokhan Wildlife Sanctuary, north-western Himalaya. *Tropical Ecology*, 53: 317-331

Pant M, Negi GCS, Kumar P (2017). Macrofauna contributes to organic matter decomposition and soil quality in Himalayan agroecosystems, India. *Applied Soil Ecology*, 120: 20-29

Rawal RS, Pangtey YPS (1994). High Altitude Forest in a Part of Kumaun in Central Himalaya: Analysis along Altitudinal Gradient. *Proceedings-Indian National Science Academy Part B*, 60: 557-564

Rawal RS, Gairola S, Dhar U (2012). Effects of disturbance intensities on vegetation patterns in oak forests of Kumaun, west Himalaya. *Journal of Mountain Science*, 9: 157-165

Rawat BS, Gairola S, Sekar KC, Rawal RS (2014). Community structure, regeneration potential, and future dynamics of natural forest site in part of Nanda Devi Biosphere Reserve, Uttarakhand, India. *African Journal of Plant Science*, 8: 380-391

Sharma CM, Mishra AK, Prakash O, Dimri S, Baluni P (2014). Assessment of forest structure and woody plant regeneration on ridge tops at upper Bhagirathi basin in Garhwal Himalaya. *Tropical Plant Research*, 1: 62-71

Singh G, Padalia H, Rai ID, Bharti RR, Rawat GS (2016). Spatial extent and conservation status of Banj oak (*Quercus leucotrichophora* A. Camus) forests in Uttarakhand, Western Himalaya. *Tropical Ecology*, 57: 255-262