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TREE SPECIES RICHNESS AND REGENERATION PATTERN ALONG THE ANTHROPOGENIC DISTURBANCE GRADIENTS IN MONTANE FORESTS OF GARHWAL HIMALAYA, INDIA

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Abstract

We examined the pattern of tree regeneration of two montane forests across the anthropogenic disturbance gradients in Garhwal Himalaya, Uttarakhand, India. Vegetation data was collected from 60 sample plots using a stratified random sampling technique during the years 2015 and 2016. Circumference (C) was used to differentiate three layers of a species into adults (C $\geq$ 31.5 cm), saplings (C 10.5–31.4 cm) and seedlings (C< 10.5 cm). A total of 25 tree species belonging to 22 genera and 18 families were recorded in the present study. Species richness at the study sites varied from 7 to 15 species. The proportion of trees (0.90%), saplings (6.80%) and seedlings (92.30%) in both the forests indicated a good regeneration status in general. The increasing trend of density observed from the highly disturbed sites to least disturbed sites in both the studied forests which indicated that the density has negative relation with the anthropogenic disturbances.

Key words : Species richness, density, regeneration pattern, anthropogenic disturbances and Montane forest.

Introduction

Montane Himalayan forests are integral part of the life and livelihood of people inhabiting this fragile mountain ecosystem. Collection of fuelwood and fodder from the forest is the main mark that turns the cycle of economy and livelihoods of the rurals over Indian Himalayas (Patnaik, 1986; Dhyani *et al*., 2011). The dependence of the continually growing population on finite forest resources has resulted into degradation and change in species composition of forests. Diverse changes in the Himalayan forests are emerging in terms of structure, density and composition on account of environment degradation and overexploitation of forest resources (Gaur, 1982; Bargali *et al*., 1998). In Garhwal Himalaya anthropogenic disturbances like, deforestation, cattle grazing, fodder collection, litter collection, *etc*. are affecting the forest structure, composition and regeneration status (Gaur, 1999; Ballabha *et al*., 2013).

The natural regeneration of the forest is an imperative process in which elderly population of a species is replaced by the juvenile over the time. Regeneration of plant species is restricted to a particular range of environment of locale and the degree of these environments is a major determinant of its geographic distribution (Grubb, 1977). With the differentiation in species such as the growth features and nature of disturbance the mechanism of regeneration may change (Pandey and Shukla, 2003). In a forest, older trees serve as seed banks which produce young ones and the process continues in time and space (Pokhriyal *et al*., 2012). Although, the obscure interaction between the booming establishment of seedlings and site factors is the basis of the slow and capricious procedure of natural regeneration, yet anthropogenic disturbances have an undeviating consequence on successful endurance of regeneration.

Lack of sufficient regeneration, land degradation *viz*. soil degradation, adverse effects on water resources, deforestation and lowering of the productive capacity of rangelands are major problems in the Himalayan forests (Krauchii *et al*., 2000). Regeneration is a cost effective natural process by which plants re-establish themselves and this strategy helps the plants to maintain their diversity and genetic identity (Hanief *et al*., 2016). The presence of sufficient number of young trees, saplings and seedlings

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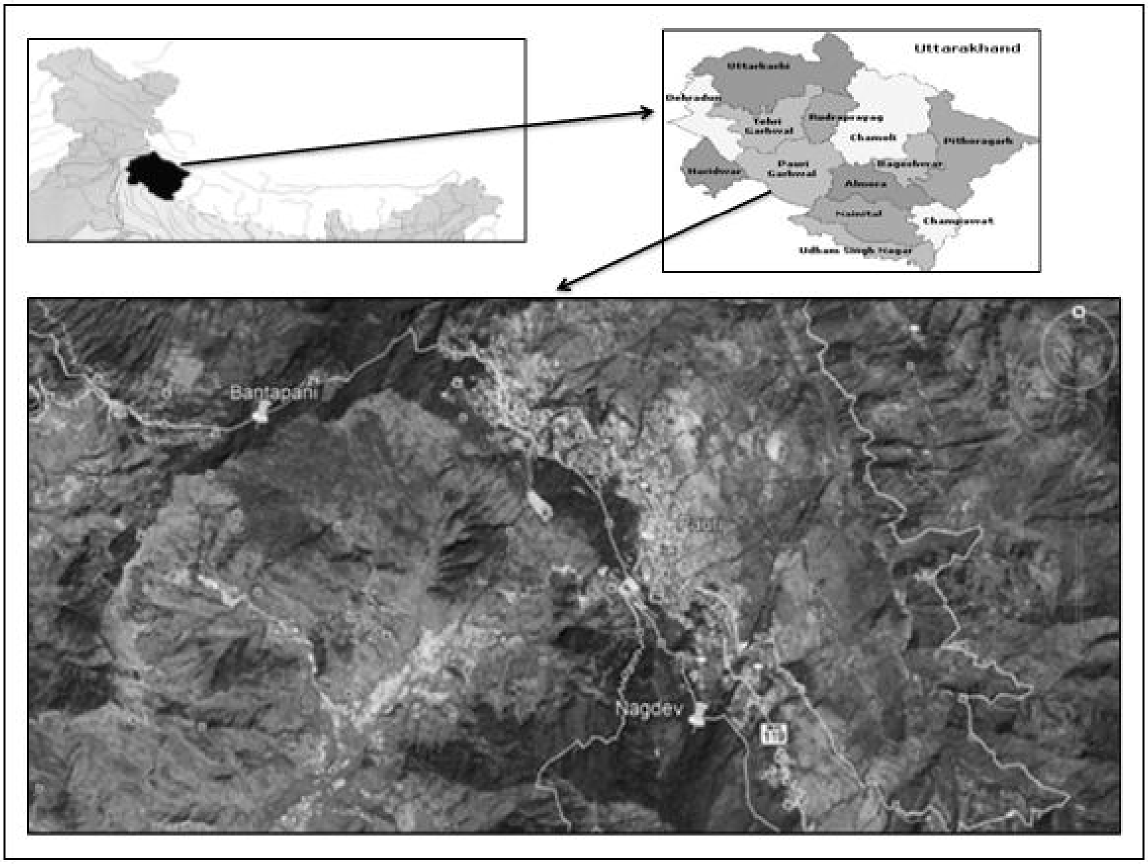

Fig. 1 : Location of the study sites.

in a specific forest population indicates that the tree species are able to regenerate successfully (Khan *et al.*, 1987). Keeping the above in mind, the present study was aimed to evaluate the tree species richness and regeneration status along the anthropogenic disturbance gradients in two montane forests of Garhwal Himalaya.

Materials and Methods

Study area

The study was carried out in two montane forests *viz*. Nagdev and Bantapani forest, of the Garhwal Himalaya, Uttarakhand state during the years 2015 and 2016. Geographically, the selected forests are situated between 30° 072' to 30° 092' N latitudes and 78° 442' to 78° 462' E longitudes with altitudinal range from 1600 m to 2200 m asl (fig. 1). The area experiences a cold temperate climate, with distinct summer, rainy and winter seasons. Temperature of the area ranges between -2°C to 20°C in January and 24°C to 36°C in June. The maximum rainfall takes place from July to September and minimum in the months of December and January.

Site selection

Each of the selected forests was divided into three sites *viz*. least disturbed (LD), moderately disturbed (MD) and highly disturbed (HD) on the basis of different disturbance attributes as suggested by Murali *et al*. (1996).

$$\text{DI TBC} = \frac{\text{TBS of cut stumps in the forest ha}^{-1}}{\text{TBC of all the standing stems in the forest ha}^{-1}} \times 100$$

Where, DI TBC is the disturbance index on total basal cover of cut stumps per hectare (ha^{-1}). The details of study area and forest types are given in table 1.

Vegetation analysis and regeneration dynamics

Extensive surveys were conducted in the study area for collection of field data and plant specimens. The collected specimens were identified with the help of regional floras (Osmaston, 1927; Naithani, 1984–85; Gaur, 1999) and herbaria (GUH & BSD). Ecological data was collected by laying 10 quadrats (sized 10×10 m^2) in stratified random manner in each site for trees. Within each tree quadrat, 2 quadrats of size 5×5 m^2 and 4 quadrats of size 1×1 m^2 were nested for saplings and seedlings, respectively (Misra, 1968). Circumference (C) was recorded with the help of measuring tape and thread. Individuals of each tree species were differentiated into three layers on the basis of their circumference *viz*. adult tree (C ≥ 31.5 cm at 1.37 m from the ground), sapling (C 10.5–31.4 cm) and seedling (C< 10.5 cm). Further, tree individuals were distributed into successive diameter classes (by converting circumference into diameter) *i*.e., 10–20, 21–30, 31–40 cm, *etc.* and density-diameter curves plotted to discover regeneration pattern at different study sites. The data collected for each layer was quantitatively analyzed following, Mueller-Dombois and Ellenberg (1974).

Regeneration status of each tree species was calculated from density of adult trees, saplings and seedlings at various sites following Shankar (2001). Regeneration status was considered (a) good, if seedlings> saplings> adult trees; (b) fair, if seedlings > saplings d" adults; (c) poor, if the species survives only at sapling stage, but not seedlings (though saplings may be less or equal to adults); (d) no regeneration, if a species is present only in adult form (absent both in seedling and sapling stages) and (e) new, if the species has no adults but is only represented by seedlings or saplings.

Results and Discussion

Species richness and density

A total of 25 tree species belonging to 22 genera and 18 families were recorded from two montane forests of Garhwal Himalaya under the present study, a similar range of species richness was also reported by the earlier workers from other montane forests of Garhwal Himalayan (Negi *et al*., 2008; Bhatt and Purohit, 2009; Gairola *et al*., 2012; Singh *et al*., 2016). The presence of highest species richness recorded at moderately disturbed sites, lowest at highly disturbed sites and intermediate at least disturbed sites of both the forests, were the observation found contrary to the previous findings by Brown and Gurevitch (2004), who reported that the species richness reduces with increase in both natural and anthropogenic disturbances. Highest number of species (3 spp.) was recorded for genus *Quercus* followed by *Pinus* (2 spp.), while rest of the genera were represented by single species. Among families, maximum species belonged to Pinaceae (4 species) followed by Fagaceae (3 species) and Ericaceae (2 species). At Nagdev forest, species richness varied from 12 (NLD) to 15 (NMD) while 7 (BHD) to 9 (BMD) at Bantapani forest. Analysis of the densities showed that the major proportion of total density (trees + saplings + seedlings) were seedlings (92.30%) followed by saplings (6.80%) and trees (0.90%). Tree density varied from 6.9 ind/100m^2 (NHD) to 9.2 ind/100m^2 (NLD), saplings 19.2 ind/100m^2 (BHD) to 105.6 ind/100m^2 (NMD) and seedling 290 ind/100m^2 (BHD) to 1080 ind/100m^2 (NLD). The recorded range of density in present study is similar to the earlier results from different forests of Garhwal Himalaya (Rajwar and Gupta, 1992; Bhandari *et al*., 2000; Mishra *et al*., 2002; Singh *et al*., 2016). The present study reveals that an increasing trend in density was observed from the highly disturbed sites to least disturbed sites in the both the studied forests, which indicating that the density has negative relation with the anthropogenic disturbances. The level of disturbance due to anthropogenic interference in the forest changes the species diversity and tree density (Rao *et al*., 1990). Density and regeneration status percentage of each tree species at different sites has been shown in figs. 2 and 3, table 2 while density–diameter distribution (d-d curves) patterns are presented in fig. 4 (A-F).

The proportion of trees, saplings and seedling individuals in both the forests indicated the good regeneration status in general. Majority of the tree species showed good regeneration at all the six sites. Fair, poor, not and new regeneration status were also recorded for some species, however, regeneration status of a species often varied from one site to another. Similar trend for a particular species in different montane and sub-montane

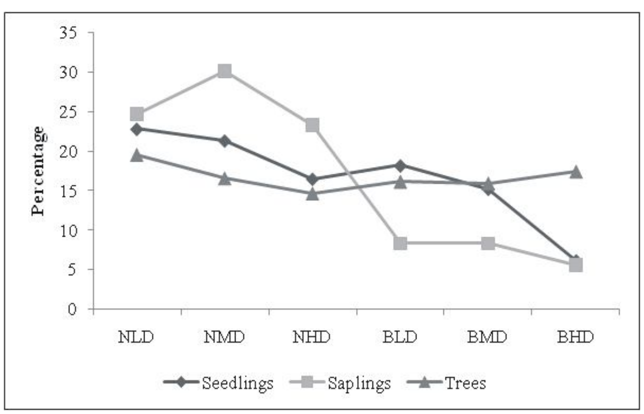

Fig. 2 : Density per cent of seedlings, saplings and trees at different studied sites.

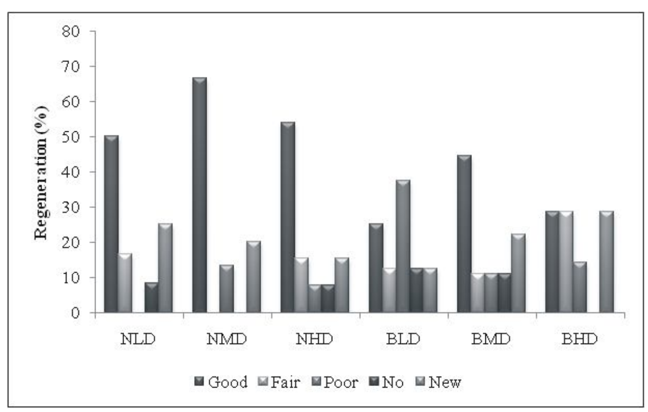

Fig. 3 : Regeneration status of dominant tree species in the study area.

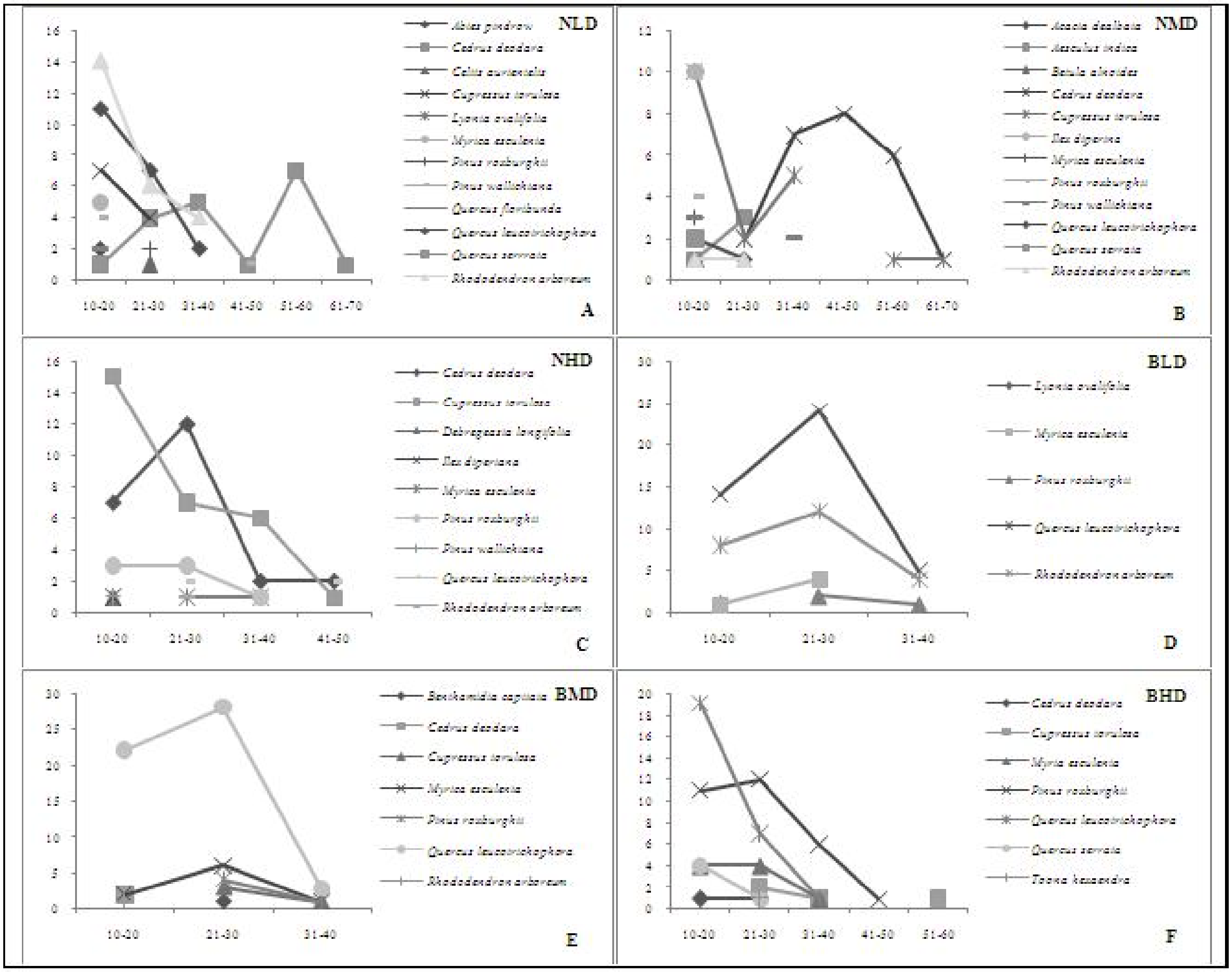

Fig. 4 : (A-F) DBH class distribution of trees in the studied sites.

Table 1 : Characteristic features of study sites

Study sites[1]	Coordinates	Altitude (m asl)	Aspect[2]	DI(%)	Dominant tree species /IVI
NLD	30° 08' 2.99" N, 78°46' 35.7" E	2000–2150	NE	4.88	*Cedrus deodara* (89.44), *Rhododendron arboreum* (69.79), *Quercus leucotrichophora* (54.44),
NMD	30° 07' 57.5" N, 78°46' 44.4" E	1850–2000	NE	7.66	*Cedrus deodara* (124.62), *Cupressus torulosa* (63.1), *Ilex dipyrena* (31.26)
NHD	30° 07' 23.6" N, 78°46' 21.1" E	1700–1850	NE	13.62	*Cupressus torulosa* (121.11), *Cedrus deodara* (104.14), *Pinus roxburghii* (29.53)
BLD	30° 09' 48.4" N, 78°44' 99.1" E	2000–2150	NE	6.76	*Quercus leucotrichophora* (166.09), *Rhododendron arboreum* (95.84), *Myrica esculenta* (24.30)
BMD	30° 09' 51.5" N, 78°45' 02.8" E	1850–2000	NE	29.50	*Quercus leucotrichophora* (205.28), *Myrica esculenta* (40.19), *Pinus roxburghii* (25.93)
BHD	30° 08' 16.4" N, 78°46' 69.8" E	1700–1850	SE	35.64	*Pinus roxburghii* (121.16), *Quercus leucotrichophora* (78.28), *Myrica esculenta* (42.37)

Abbreviations: [1]NLD = Nagdev least disturbed, NMD = Nagdev moderately disturbed, NHD = Nagdev highly disturbed, BLD= Bantapani least disturbed, BMD = Bantapani moderately disturbed, BHD= Bantapani highly disturbed, [2]NE = north-east, SE= south-east.

Table 2 : Seedlings, saplings and trees Density/100m^2.

Name of species	Nagdev forest									Bantapani forest								
	NLD			NMD			NHD			BLD			BMD			BHD		
	Sd	Sp	Tr	Sd	Sp	Tr	Sd	Sp	Tr	Sd	Sp	Tr	Sd	Sp	Tr	Sd	Sp	Tr
Abies pindrow Royle	50	4.8	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia dealbata Link	-	-	-	40	3.2	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Aesculus indica (Colebr. ex Cambess.) Hook	-	-	-	70	8	0.4	-	-	-	-	-	-	-	-	-	-	-	-
Benthamidia capitata (Wallich ex Roxb.) Hara	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	-	-
Betula alnoides Buch.-Ham. ex D.Don	-	-	-	40	4.8	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Cedrus deodara (Roxb. ex D.Don) G. Don	10	1.6	1.9	50	-	2.4	90	1.6	2.3	-	-	-	50	1.6	0.2	60	6.4	0.2
Celtis australis var. *eriocarpa* (Decne.) Hook. f.	90	4.8	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupressus torulosa D.Don	130	19.2	1.1	150	32	1.9	110	40	2.9	-	-	-	80	8	0.4	70	8	0.4
Debregeasia longifolia (Burm. f.) Wedd.	-	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Ficus palmata Forsk.	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-
Ilex dipyrena Wallich	-	-	-	130	17.6	1	90	8	0.1	-	-	-	-	-	-	-	-	-
Lyonia ovalifolia (Wallich) Drude	200	3.2	-	140	3.2	-	-	-	-	190	9.6	0.1	50	-	-	-	-	-
Morus alba L.	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-
Myrica esculenta Buch.-Ham. ex D.Don	290	19.2	0.5	90	11.2	0.3	110	6.4	0.2	200	11.2	0.5	150	4.8	0.9	-	1.6	0.9
Pinus roxburghii Sargent	90	6.4	0.2	50	11.2	0.4	140	14.4	0.7	20	-	0.3	70	9.6	0.5	90	1.6	3.1
P. wallcihiana A. B. Jackson	70	9.6	0.5	20	3.2	0.5	50	6.4	0.1	-	-	-	-	-	-	-	-	-
Prunus crasoides D.Don	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-	-	-
Quercus floribunda Lindley ex Rehder	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q. leucotrichophora A. Camus	80	12.8	2	70	9.6	0.3	70	1.6	0.4	170	4.8	4.3	80	4.8	5.3	50	-	2.7
Q. serrata Murray	10	-	0.1	50	-	0.2	50	-	-	-	-	-	-	-	-	-	1.6	0.5
Rhododendron arboreum Smith	40	4.8	2.4	70	1.6	0.2	40	3.2	0.1	170	3.2	2.4	220	-	0.1	20	-	-
Rhus javanica L.	-	-	-	-	-	-	-	-	-	100	-	-	-	-	-	-	-	-
Symplocos paniculata (Thunb.) Miq.	20	-	-	20	-	-	-	-	-	10	-	-	-	-	-	-	-	-
Taxus wallichiana L.	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toona hexandra (Wallich ex Roxb.) M Roemer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4
Total density	**1080**	**86.4**	**9.2**	**1010**	**105.6**	**7.8**	**780**	**81.6**	**6.9**	**860**	**28.8**	**7.6**	**720**	**28.8**	**7.5**	**290**	**19.2**	**8.2**

Abbreviations: Sd= Seedling, Sp= Sapling, Tr= Tree.

zone forests of Garhwal Himalaya was reported by Gairola *et al*. (2012), Pala *et al.* (2012), Ballabha *et al.* (2013), Malik and Bhatt (2016) and Singh *et al*. (2016).

Least disturbed sites

At the least disturbed site of Nagdev forest, poor regeneration was recorded for *Quercus serrata*, fair regeneration for *Cedrus deodara* and *Quercus leucotrichophora* while good regeneration was observed for *Abies pindrow*, *Celtis australis*, *Cupressus torulosa*, *Myrica esculenta*, *Pinus roxburghii*, *P. wallichiana* and *Rhododendron arboreum*. No seedling was recorded for *Quercus floribunda* (no regeneration) whereas; *Lyonia ovalifolia* and *Symplocos paniculata* were represented by seedlings only (new regeneration status). At the least disturbed site of Bantapani forest, poor regeneration was observed for *Pinus roxburghii*, fair for *Quercus leucotrichophora* and *Rhododendron arboreum* whereas, good regeneration was observed for *Lyonia ovalifolia* and *Myrica esculenta*. Two species (*Rhus javanica* and *Symplocos paniculata*) were recorded in seedling stage only.

Moderately disturbed sites

At moderately disturbed site of Nagdev forest, *Cedrus deodara* and *Quercus serrata* showed poor regeneration, *Lyonia ovalifolia*, *Symplocos paniculata* and *Taxus wallichiana* represented their presence at seedling stage only (new regeneration), whereas rest of the species (*Acacia dealbata*, *Aesculus indica*, *Betula alnoides*, *Cupressus torulosa*, *Ilex dipyrena*, *Myrica esculenta*, *Pinus roxburghii*, *P. wallichiana*, *Quercus leucotrichophora* and *Rhododendron arboreum*) had good regeneration. At moderately disturbed site of Bantapani forest, poor regeneration was observed for *Rhododendron arboreum*, fair for *Quercus leucotrichophora*, new regeneration status for *Lyonia ovalifolia* and *Prunus cerasoides* while good regeneration was expressed by *Cedrus deodara, Cupressus torulosa*, *Myrica esculenta* and *Pinus roxburghii*.

Highly disturbed sites

Cedrus deodara showed poor regeneration at highly disturbed site of Nagdev forest, *Quercus leucotrichophora* fair and *Debregeasia longifolia* expressed no regeneration, *Ficus palmata*, *Morus alba* and *Quercus serrata* exhibited new regeneration status while good regeneration was represented by *Ilex dipyrena, Myrica esculenta, Pinus roxburghii, P. wallichiana, Quercus leucotrichophora* and *Rhododendron arboreum*. At highly disturbed site of Bantapani forest, *Cedrus deodara* and *Cupressus torulosa* showed good regeneration; *Pinus roxburghii* showed fair where as *Myrica esculenta, Quercus leucotrichophora* and *Q. serrata* represented poor regeneration. At this site *Toona hexandra* had no regeneration status and *Rhododendron arboreum* showed new regeneration status.

The present study revealed that the density of trees, saplings and seedlings is too low at highly disturbed sites in comparison to moderately or least disturbed sites. The decline in stem density with decreasing altitude might be due to gradual and consistent increase in extraction of fuelwood and fodder. Alterations in the seedling proportions in a forest stand is the result of progression of regeneration mechanism for instance seed production, dispersal and seedling emergence, survival and growth among the species (Streng *et al*., 1989; Schupp, 1990). In addition to anthropogenic disturbance the forest structure and composition in hills largely depends on the altitude and climatic variables like rainfall and temperature (Kharkwal *et al*., 2005).

The forest structure and composition depends on the regeneration potential of species composing the forest stand in space and time (Jones *et al*., 1994). The forests of Oak species "a late successional species" when disturbed by various anthropogenic means are invaded by the "early successional species" such as pine due to changed microclimatic conditions (Champion and Seth, 1968; Upreti *et al*., 1985). The density–diameter distribution (d-d curves) patterns are of 'J' shaped at all the six study sites. Higher densities in lower diameter classes (J–shaped curve), are indicative of mature forest with good regeneration status in general (Rollet, 1978; Blanc *et al*., 2000).

Conclusion

It can be concluded from the present results that (a) both the studied montane forests (Nagdev and Bantapani) have good regeneration in general, (b) density of regeneration layers *viz*. trees, saplings and seedlings are negatively affected by anthropogenic that leading to poor, fair or no regeneration.

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