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Plant Diversity and Regeneration Potential of Three Different Forests of Central Himalaya

VIJYETA MANRAL, KIRTIKA PADALIA* and HIMANI KARKI

Department of Botany, DSB Campus, Kumaun University, Nainital- 263001, Uttarakhand, India.

Abstract

Plant diversity is essential for human survival and economic well-being and also for the ecosystem function and stability. The total number of accessible seedlings and saplings in a forest community indicates the regeneration status/potential of a species or a forest. In this study, composition, diversity and population structure of three different forests (Banj oak, Chir-pine and Mixed oak-pine) was assessed around Nainital town of Uttarakhand state. Species richness and diversity were maximum in Banj-oak forest (9 species and 1.970, respectively) and minimum in Chir-pine forest (4 species and 0.634, respectively). The total tree density ranged from 1670 (Chir pine forest) to 1830 ind.ha^{-1} (Mixed oak pine forest) and the total basal area ranged from 87.22 (Mixed oak pine forest) to 208.37 m^{2}ha^{-1} (Banj oak forest). Population structure revealed dominancy of mature trees and less number of seedlings evidently indicated the poor regeneration across the forests type. Viability of seeds, disturbances brought by frequent fire incidence, erosion of soil and water, uncontrolled grazing by animals, lopping/cuttings of under canopy plant species by villagers for fuel and fodder are the possible causes of the poor regeneration of the forests.

Article History

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Keywords

Species diversity, Regeneration, Distribution pattern, Population structure

Introduction

The Himalayan chain of mountains extending from west to east for about 2500 km and the width varying between 150 to 450 km, is known to be the youngest, largest and highest chain of mountain in the world[1]. High diverse compositional pattern of the forests is characteristic of this region[1]. The Central Himalayan forests are covered by oak, pine and their associated species. In Indian Himalayan region, most of the temperate forests are occupied by Oak species. Oak considered as the dominant and climax tree species and nearly 35 species of *Quercus* are present in this region[3,4,5]. The pine forests occur in between 500 to 2000 m and the oak forest in between 1000 and 3500 m elevation[6]. Between these ranges mixed oak-pine forests are also present. According to Champion and Seth[7], in Western and Central Himalayan region three common oak species viz. *Quercus leucotrichophora*

CONTACT Kirtika Padalia kirtika.padalia89@gmail.com Department of Botany, DSB Campus, Kumaun University, Nainital-263001, Uttarakhand, India.

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(1800-2300 m) *Q. floribunda* (2000-2500 m) and *Q. semecarpifolia* (2500-3300 m) and pine species mostly *Pinus roxburghii* and other species like *P. wallichina, P. bhutanica, P. gerardiana* and *P. densata* etc. provide a simple and convenient basis for sub division of the altitudinal zones. From the ecological point of view, Nainital and its surroundings become interesting because altitudinal variation over short distances result in the occurrence of forests representing all the above species of oaks and pine[8,9]. These species substantial noteworthy in this region since they serve as lifeline by providing generous ecosystem services to the associated communities[10]. The oak forests are distinguished in comparison to the other forests in reference to containing and maintain higher number of species diversity, litter production and enhance soil quality and fertility[3,11].

The distribution of age structure in a population can predict the status of regeneration in forest ecosystem[12,13,14]. The interaction of a species with biotic or abiotic factors affects their regeneration markedly[15]. For the better growth and to sustain their regeneration in a plant community, it is necessary to have the balanced between the presence of older trees, number of younger age tree/sapling and seedlings[16]. The successful regeneration of a forest might be depends on: (i) capability to produce seedlings, (ii) endurance of seedlings and saplings (iii) growing probability of seedlings and saplings[17].These above mentioned constraints give an imminent into regeneration potential of a species in a natural ecosystem. Several researchers[18,19,20] have already envisaged the regeneration status according to diameter and age structure of tree species in their population.

Numerous noticeable changes are appearing in the Himalayan forest especially in their composition, structure and ability to regenerate. The major causes behind these changes are listed as biotic pressure and uncontrolled anthropogenic activities. The unrestrained lopping, cutting and felling of trees for the requirment of fodder and fuel disturbed the forest ecosystem significantly[21,22]. Grazzing of young seedlings by the animals also promote the degradation therefore, adversely affacts the regeneration of the forest. To keep all these things in view, this study was design with the following objectives: (i) to provide the quantitative details of tree composition and structure of different forests (ii) to assess the population structure and regeneration potential of trees associated with different forests of Nainital, Uttarakhand. This study will be helpful to know the present scenario of forest ecosystem of Central Himalayan region and their future prospective to develop the strategy of conservation in this region.

Materials and Methods

Study Site

The studied forests were selected in between 550-2000 m above at mean sea level (between 29°19'-29°28' E latitude and 79°22'-79°38' E longitude) in Nainital district (Uttarakhand state) of Central Himalayan, India (Fig. 1).These forests were categorized on the basis of species composition (i.e., Banj-oak forest, Chir-pine forest and Mixed oak-pine forest). (i). *Banj-oak forest site*: This forest site was situated in Kailakhan village, about 2 km far from Nainital town. The site was located at North-East aspect at 2,084 m (6837 ft.) above sea level between 29°38 E latitude and 79°51' E longitude. The forest exhibits dominance of Banj Oak trees and *Quercus leucotrichophora* was the dominant tree species. (ii). *Chir-pine forest site*: This forest site was situated in Mangoli van panchayat, about 18 km far from Nainital town. The site was located at North-East aspect at 550 m above sea level between 29°38 E latitude and 79°46' E longitude. The forest showed the dominance of Chir-pine trees and *Pinus roxburghii* was considered as the dominant tree species (iii). *Mixed Oak-Pine forest site*: This forest site was located about 7 km away from Nainital town in North-East aspect at 1654 m above sea level in between 29°39 E latitude and 79°45' E longitude. This site exhibits co-dominance of Banj-oak and Chir-pine trees. *Quercus leucotrichophora* and *Pinus roxburghii* were the dominant tree species in this forest site. All these forest sites were again divided into three transit positions i.e., hill-base (HB), hill-slope (HS) and hill-top (HT).Therefore a total of three forest type and nine transit position (3 in each) were studied.

The soil of study site is acidic in nature with an average pH of 5.5. The climate of the study area was considered as monsoon temperate with an annual precipitation of 2347 mm in which, about 75 % rainfall

was occurs during the 3 months of monsoon. The mean monthly temperature ranged from 6 °C to 25 °C during the summer season and from 1.7 °C to 4 °C during the winter season.

Methods

Tree layer vegetation was analyzed by placing 30 random quadrats (10 quadrats in each position) of 10 m x 10 m in each forest type.The size of the quadrat and their sample numbers were determined following Saxena and Singh[23].The tree layer vegetation was categorized into seedling (having girth class < 10 cm), sapling (with girth class 10.1-30 cm.) and tree (with girth class ≥ 30.1 cm). The quantitative analysis of vegetation was computed by following Misra[24].The species richness was calculated merely by the counting of different species present in all the quadrats[25] in each forest type. Shannon Weiner' diversity Index[26] and concentration of dominance[27] were determined for each species at each forest and position.

In order to develop population structure and to understand regeneration of different species, individuals were measured for circumference at breast height (cbh) with a tape. On the basis of cbh, the trees were arbitrarily classified into six size classes in addition to seedling and sapling class[17].

Fig. 1: Map showing the location of studied forests (in red dots) in Nainital district (Uttarakhand state) of India

Results

Species Composition

The detail information about the dominant species of the different forests along with its associated vegetation cover is shown in Table 1 and Table 2. In Banj oak forest, total nine tree species were reported, in which the maximum species richness was occurred in Hill base region (6 species). The total density of tree, sapling and seedling was reported as 1790 ind.ha^{-1} (520 ind.ha^{-1} at HS to 700 ind.ha^{-1} at HB), 80 ind.ha^{-1} (20 ind.ha^{-1} in eachat HB and HT to 40 ind.ha^{-1} at HS) and 90 ind.ha^{-1} (20 ind.ha^{-1} in each at HB and HS to 50 ind.ha^{-1} at HT), respectively. The total basal area of tree was 208.37 m^{2}ha^{-1} (55.72 m^{2}ha^{-1}at HT to 90.83 m^{2}ha^{-1} at HB) and sapling layer was estimated 11.63 m^{2}ha^{-1} (1.16 m^{2}ha^{-1}at HB to 8.82 m^{2}ha^{-1} at HS).

The Chir pine forest was constructed by the 5 tree species, of which the maximum number of species

was recorded in Hill base region (4 species). The values of tree and sapling density were calculated as 1670 ind.ha^{-1} (480 at HB to 620 ind.ha^{-1} at HS) and 160 ind.ha^{-1} (20 ind.ha^{-1} at HT to 80 ind.ha^{-1}at HS), respectively. The seedling density was reported only 10 ind.ha^{-1} at HB while completely absent at HS and HT. The total basal area of the tree layer was 176.54 m^{2}ha^{-1} (43.44 at HS to 83.07 m^{2}ha^{-1} at HB) while sapling layer constructed only 0.66 m^{2}ha^{-1} (0.13 m^{2}ha^{-1} at HT to 0.36 m^{2}ha^{-1} at HS).

Table 1: Status of vegetation composition in different forest sites

Forest sites	Species	TREE						SAPLING						SEEDLING		
		HB		HS		HT		HB		HS		HT		HB	HS	HT
		D	TBA	D	TBA	D	TBA	D	TBA	D	TBA	D	TBA	D	D	D
Banj oak forest	*Acer oblongum*	-	-	10	1.91	-	-	-	-	-	-	-	-	-	-	-
	Cedrus deodara	10	0.37	-	-	-	-	-	-	-	-	10	0.38	-	-	20
	Cupressus torulosa	10	0.99	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lyonia ovalifolia	20	0.54	-	-	-	-	-	-	-	-	-	-	-	-	-
	Myrica esculenta	30	24.50	10	0.46	-	-	-	-	-	-	-	-	10	-	-
	Pinus roxburghii	-	-	-	-	30	0.28	-	-	-	-	10	1.27	-	-	-
	Quercus floribunda	-	-	10	1.15	-	-	-	-	30	7.14	-	-	-	20	-
	Quercus leucotrichophora	620	63.99	490	58.30	540	55.44	20	1.16	10	1.68	-	-	10	-	30
	Rhododendron arboreum	10	0.44	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**700**	**90.83**	**520**	**61.82**	**570**	**55.72**	**20**	**1.16**	**40**	**8.82**	**20**	**1.65**	**20**	**20**	**50**
Chir pine forest	*Cocculus laurifolius*	10	0.22	-	-	-	-	-	-	-	-	-	-	-	-	-
	Lecumeris spectabilis	-	-	-	-	-	-	10	0.01	-	-	-	-	10	-	-
	Pinus roxburghii	430	78.04	620	43.44	570	50.03	40	0.09	80	0.36	20	0.13	-	-	-
	Pyrus pashia	20	1.76	-	-	-	-	-	-	-	-	-	-	-	-	-
	Syzygium cumini	20	3.03	-	-	-	-	10	0.07	-	-	-	-	-	-	-
	Total	**480**	**83.07**	**620**	**43.44**	**570**	**50.03**	**60**	**0.17**	**80**	**0.36**	**20**	**0.13**	**10**	**A**	**A**
Mixed oak pine forest	*Bohermeria olerosa*	20	0.23	20	0.51	-	-	-	-	-	-	-	-	-	-	-
	Myrica esculenta	10	0.27	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pinus roxburghii	400	18.94	360	19.49	440	23.04	50	0.16	60	0.16	40	0.12	10	-	30
	Quercus leucotrichophora	230	12.67	190	7.20	150	4.68	10	0.01	-	-	30	0.08	30	-	-
	Rhus vulgaris	10	0.16	-	-	-	-	10	0.06	-	-	-	-	-	-	-
	Total	**670**	**32.29**	**570**	**27.20**	**590**	**27.73**	**70**	**0.23**	**60**	**0.16**	**70**	**0.20**	**40**	**A**	**30**

HB=hill base, HS=hill slop, HT=hill top, D=density, TBA=total basal area, A=absent

In mixed oak pine forest, collectively 5 tree species were encountered. The maximum number of species were reported in Hill base (5 species) followed by Hill slope region. The total density of tree and sapling layer was reported 1830 ind.ha^{-1}(570 at HS to 670 ind.ha^{-1}at HB) and 200 ind.ha^{-1} (60 at HS to 70 ind. ha^{-1}at HB and HT), respectively. The seedlings were completely absent at HS while highest occurred in HB (40 ind.ha^{-1}). The total basal area of tree layer was estimated 87.22 m^{2}ha^{-1} varied in between 27.20 (HS) to 32.29 m^{2}ha^{-1} (HT) and sapling layer as 0.59 m^{2}ha^{-1} (0.16 m^{2}ha^{-1} at HS to 0.23 m^{2}ha^{-1} at HB).

Table 2: Diversity parameters of different forest sites

Forest sites	Transect	TREE			SAPLING			SEEDLING		
		SR	H'	Cd	SR	H'	Cd	SR	H'	Cd
Banj oak forest	HB	6	0.660	0.786	1	0	1.000	2	0.996	0.500
	HS	4	0.370	0.888	2	0.796	0.620	1	0	1.000
	HT	2	0.940	0.899	2	0.996	0.500	2	0.956	0.520
Chir pine forest	HB	4	0.634	0.796	3	1.242	0.225	1	0	1.000
	HS	1	0	1.000	1	0	1.000	A	-	-
	HT	1	0	1.000	1	0	1.000	A	-	-
Mixed oak pine forest	HB	5	1.224	0.464	3	1.145	0.543	2	0.811	0.625
	HS	3	1.099	0.507	1	0	1.000	A	-	-
	HT	2	0.821	0.610	2	0.988	0.501	1	0	1.000

SR=Species richness, H'=diversity, Cd=concentration of dominance, A=absent, HB=hill base, HS=hill slope, HT=hill top

Diversity Parameters

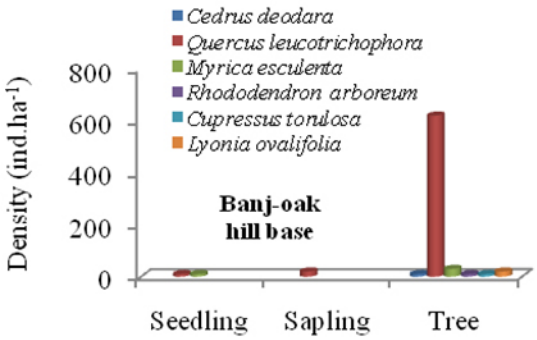
In Banj oak forest, the species diversity of tree, sapling and seedling was reported as 1.970, 1.792 and 1.952 while the concentration of dominance as 2.573, 2.120 and 2.020, respectively. In Chir pine forest, the value of species diversity was calculated as 0.634 for tree layer, 1.242 for sapling layer and nil for the seedling layer. The values of concentration of dominance for tree, sapling and seedling were 2.79, 2.22 and 1, respectively. In mixed oak pine forest, the species diversity for tree was 3.14, for sapling 2.13, and for seedling 0.811. The values of concentration of dominance were 1.58, 2.04 and 1.62 for tree, sapling and seedling, respectively.

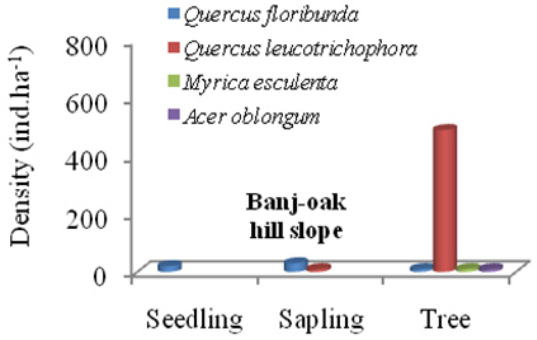
Population Structure and Regeneration Pattern

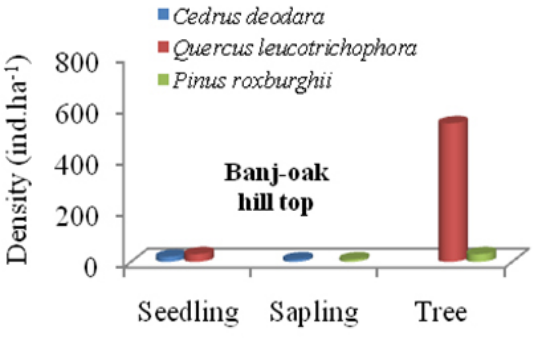
The relative percentage of trees, saplings and seedlings of different size classes at each forest site were calculated to develop the population space structure(Fig. 2). The Banj oak forest showed poor regeneration due to the density of mature tree > sapling > seedling. Across the position, the sapling density was relatively low and contains higher number of old trees. At Hill top *C. deodara* was represented by only seedlings and saplings which indicating that these species are new to this area.

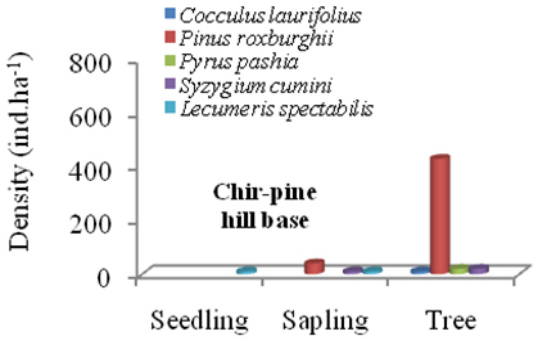
The Chir pine forest showed poor regeneration having the much greater density of trees than the saplings and seedlings. At Hill base, *P. roxburghii* was the dominant tree species while *L. spectablish* found only at sapling and seedling stage which indicated that these are new to that particular area. At Hill slope and Hill top single species *P. roxburghii* was present at sapling and tree stage only.

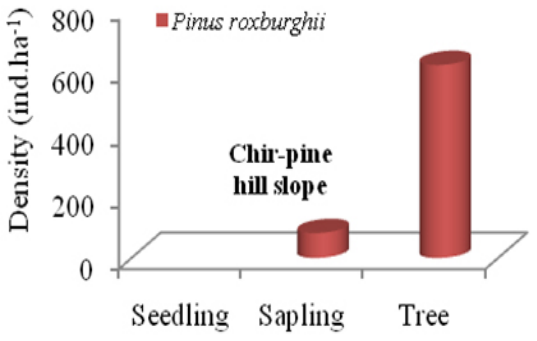
Mixed Oak pine forest also exhibited poor regeneration because tree density was greater in comparison of saplings and seedlings across the positions. Mixed Oak pine forest was dominated by *Q. leucotrichophora* and *P. roxburghii. R. vulgaris, B. olerosa* and *M. esculenta* were the associated species which indicated the diversity status of the forest.

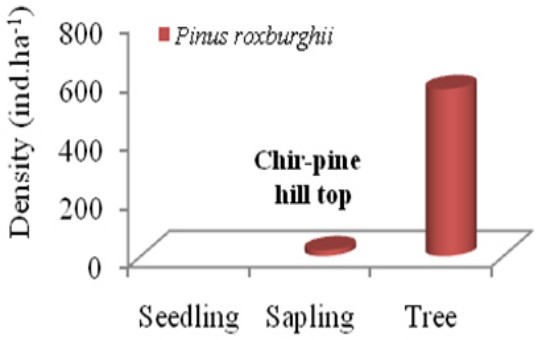

Cedrus deodara
Quercus leucotrichophora
Myrica esculenta
Rhododendron arboreum
Cupressus tonulosa
Lyonia ovalifolia
Banj-oak hill base
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree

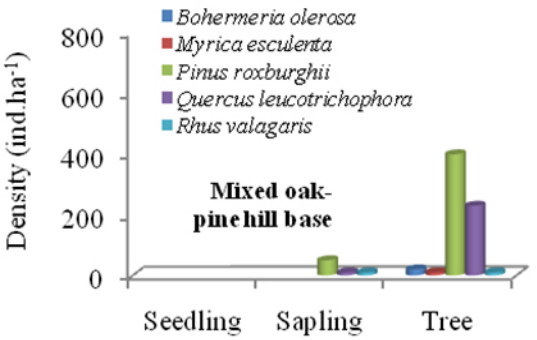

Quercus floribunda
Quercus leucotrichophora
Myrica esculenta
Acer oblongum
Banj-oak hill slope
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree

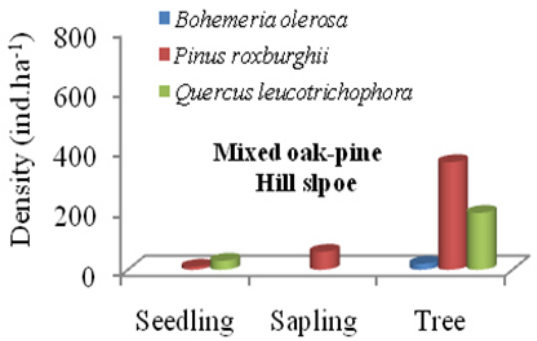

Cedrus deodara
Quercus leucotrichophora
Pinus roxburghii
Banj-oak hill top
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree


Cocculus laurifolius
Pinus roxburghii
Pyrus pashia
Syzygium cumini
Lecumeris spectabilis
Chir-pine hill base
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree


Pinus roxburghii
Chir-pine hill slope
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree


Pinus roxburghii
Chir-pine hill top
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree


Bohermeria olerosa
Myrica esculenta
Pinus roxburghii
Quercus leucotrichophora
Rhus valagaris
Mixed oak-pine hill base
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree


Bohemeria olerosa
Pinus roxburghii
Quercus leucotrichophora
Mixed oak-pine Hill slpoe
Density (ind.ha-1)
800
600
400
200
0
Seedling
Sapling
Tree

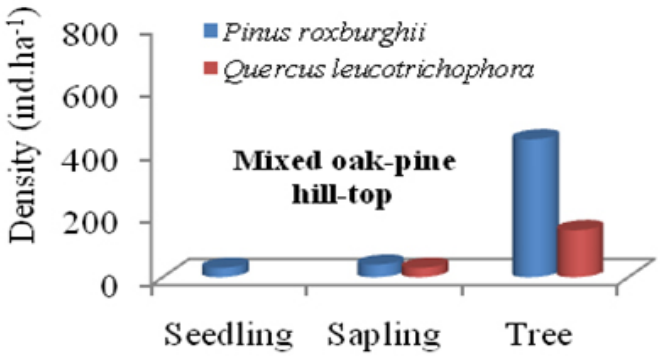


Fig. 2: Population structure of different forest in Banj-oak forest, Chir pine forest and mixed oak-pine forest

Discussion

The Floristic inventory and diversity parameter helps to know the composition and assortments of the forests[28], which also recommend valuable information regarding to conservation aspects. Forest is considered as a complex fragile ecosystem, therefore it is urgent need to know the actual picture of forests in relation to their composition, structure and diversity as well for their conservation and management. Across the forest type, the density varied from 1670 (Chir pine forest) to 1830 ind.ha^{-1} (Mixed oak pine forest). The present tree density was comparatively higher as reported for natural forests of Garhwal Himalaya (1363- 685 ind.ha^{-1})[29], natural (515 ind.ha^{-1})[30] and planted forests (484 ind.ha^{-1})[30], *Q. floribunda* dominated natural forest (1190- 490 ind.ha^{-1})[31], *Q. floribunda* dominated forest (930 ind. ha^{-1})[32] and for disturbed (780- 260 ind.ha^{-1})[33] and protected forests (970-460 ind ha^{-1})[33]. The present values were placed lower than as reported for natural (3429 ind.ha^{-1}) and planted forests (1865 ind.ha^{-1}) 34 of north India region.

Basal area gives an idea of stand volume and considered as a vital indicator of carbon storage. The total tree basal area varied in between 87.22 (Mixed oak pine forest) and 208.37 m^{2}ha^{-1} (Banj oak forest), which is comparatively less as reported for natural forest (216 m^{2}ha^{-1})[35]. The present values were placed higher from the range 25.47 to 19.47 m^2 ha^{-1} and 49.65 to 10.16 m^2 ha^{-1} as reported for disturbed oak forest[33,35] of Nainital catchment, respectively.

The species diversity of a forest is prejudiced by many factors such as altitude, climate, soil, vegetation cover, biotic pressure etc[3]. In the present study, total tree diversity was varied from 0.634 (Chir pine forest) to 3.144 (Mixed oak pine forest), which is comparatively higher as reported for planted forest (0.56)[34] and for natural forest (0.412-1.769)[31]. The present values were lower as reported for sal plantation ((5.53-1.58)[36,37].

The biological and ecological characteristics of a population are reflected by their population structure[38] and the regeneration profile is provided by the pattern of allocation of individuals in different size classes. The ratio of various age groups in a population determine the reproductive status and determine the future course[39] of the population. Population structure of tree species showed the state of forests whether they are sustainable or needs to certain management practices. The overall J-shaped population structure revealed dominancy of trees and lowest number of seedlings across the studied forests (Fig. 3), which undoubtedly indicated that regeneration status is poor in these forests. The less number of seedlings in all the forests may be due to the low viability of seeds, disturbances brought by frequent fire incidence, erosion of soil and water, uncontrolled grazing by animals, cuttings of under canopy plant species by villagers for their domestic cattle etc[12,20,40]. The seedlings, saplings and trees of a plant species exhibit the population dynamic which is used to decide their regeneration status[41,42]. According to Good and Good[17] the soil nutrients, water and sunlight conditions may be the major factors for successful regeneration of the tree species.

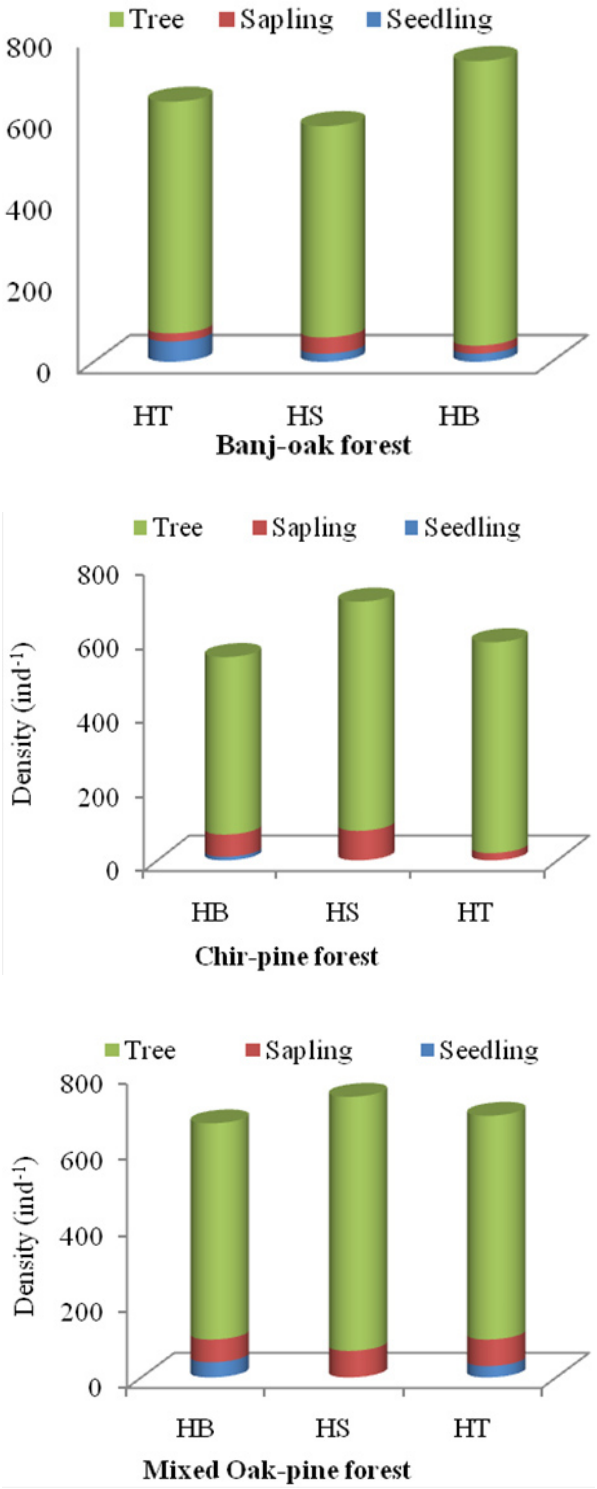


Fig. 3: Regeneration status of studied forests (Banj oak forest, Chir pine forest and Mixed oak-pine forest)

Conclusion

To conclude, present study indicated that distribution of plant species along the altitudinal transact is determined by its own ability to survive and grow in different environmental conditions. The status of the forests in terms of regeneration was not good. With the progress of time if this situation will continue these forests could face the extinction sooner or later. To speculate the future changes in composition particularly in Chir pine forest where the seedlings were generally absent, consequently, the forest of this area may be vanished if the control measured could not be adopted.

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Conflict of Interest

There are no known declared conflicts of interest related with this piece of research work.

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