Tree Regeneration Pattern And Size Class Distribution In Anthropogenically Disturbed Sub-Alpine Treeline Areas Of Indian Western Himalaya

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Abstract: The position and structure of the treeline species vary from one site to another and in Himalayan region it depends on the snow line or snow cover. The transformation from seedling to adults is important and therefore the regeneration dynamics is a major thrust area of the study. The present study was conducted in the three anthropogenically disturbed treeline areas varying in altitude between 3145 and 3467 m asl in the sub-alpine region of western Indian Himalaya. The cattle pressure was estimated by using questionnaire and direct observation method. 3-5 herds of 800-1000 animals grazing in each studied site during snowless period. Across the treeline sites the total tree density varied between 590 and 760 ind. /ha and seedling density between 200 and 710 ind. /ha. The un-palatable R. arboreum and R. campanulatum showed the maximum seedling density (90-230 ind. /ha and 190-330 ind. /ha) whereas, remaining other species had poor regeneration. R. campanulatum seedling were present 6-20m outside from the actual position of krumholtz and showed an upward movement from actual treeline limit encroaching into alpine meadows.

Keywords: Anthropogenic disturbance, Density, Diversity, Regeneration, Treeline

1 Introduction

Due to heat deficiency at higher elevations, trees fail to grow and are characterized by a clear division of treeless alpine meadows from forests called as alpine treeline [1]. The position and structure of the treeline species also vary [2] from one site to another and in the Himalayan region it depends on the snow line or snow cover. Himalayan treeline are among the highest in the world [3]. The location of treeline in the western part of the Himalayas is at about 3600 m [4], [5]. Very few studies have been carried out on characteristics of treeline on regional scales at Indian Himalaya region [6]. The species composition and structure determines the status and functional conditions of forests. The structure of treelines are not uniform, when viewed globally, the treeline elevation is closely linked with latitude [7], [8]. Regeneration responses and structural changes at the treeline ecotone, would not only influence treeline shifts but can trigger major changes in alpine vegetation [9], [10], [11], [12], [13], [14]. Community structure should be studied together with plant diversity for determining the role of key structuring species that may influenced the entire community [10], [15]. Studied on population structure is important for developing a wider understanding on how species coexistence in natural forest [16], [17]. Dominant status of tree species is determine based on population structure and their expansion [17], [18].

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With the help of population structure one can determine if the population has a stable distribution [19], [20], [21], [22], [23], [24], [25]. Population structures can provide a holistic picture on natural regeneration of tree species which can be used for sustainable management and conservation [25], [26], [27]. The species survival and new recruitment generally depends on its potential to regenerate under climatic irregularities [28]. The transformation from seedling to adults is important and therefore the regeneration dynamics is a major thrust area of the study in terms of regeneration and management of forests [29], [30]. The species existence and recruitment process in a forest mostly depends on its regeneration potential under varied climatic factors, anthropogenic disturbances competition with species and predation. [17], [31]. Natural habitats of several species have become degradation due to heavy grazing pressure which is commonly observed in the treeline areas [32] climate change has also been indicated as a possible factor for lack of regeneration [33], [34]. In Himalayan treeline region knowledge about forest composition, diversity and their natural regeneration is scanty. The objectives of the study were to: i) determine the density, diversity, dominance and IVI of treeline areas tree species, ii) assess the composition of tree species at treeline sites, iii) assess the structure and regeneration patterns of treeline tree species.

2 MATERIAL AND METHODS

Three treeline sites: site I: Tungnath, site II: Bedni and site III: Aali, in the Garhwal region of western Himalaya, varying in altitude between 3145 and 3467 m asl (Table 1) were select for present study. The study sites are situated in the sub-alpine zone, where snow cover remains till April. Physio-graphically the study area is characterized by undulating topographical features, with steep slopes on southern and south-western faces and gentle slope on northern, north-eastern and north-western aspects. Soil is generally brown in colour, sandy loam in texture, with high proportion of sand and silt, and generally acidic with pH value 4 to 5. The climate of the study area is characterized by short cool summers and long severe winters. The mean annual temperature of the sites varied from -8.91 (January) and +25.6°C (May) and mean annual precipitation was 2410.5±432.2mm [35]. The relative humidity percent varied between 60 to 80% throughout the year in the sites. Anthropogenic disturbance in these treeline sites mainly occurs in the form of migratory grazing and tourist activities. Lopping of trees for timber, fuel wood, fodder and removal of litter by local people in the region are other factors.

Table 1. *Physiographic features of the selected study sites*

Site Name	Altitude (m)	Latitude (N)	Longitude (E)	Aspect	Dominant tree species
Site I (Tungnath)	3145-3355	$30^{0}29'45$-$30^{0}29'54$	$79^{0}12'45$-$79^{0}13'24$	South-East	A. spectabilis, Q. semecarpifolia, R. arboreum and R. campanulatum
Site II (Bedni)	3284-3467	$30^{0}12'22$-$30^{0}12'09$	$79^{0}39'26$-$79^{0}39'36$	South-West	A. spectabilis, Q. semecarpifolia, R. arboreum and R. campanulatum
Site III (Aali)	3302-3446	$30^{0}11'17$-$30^{0}11'02$	$79^{0}39'13$-$79^{0}39'28$	South-East	A. spectabilis, Q. semecarpifolia, R. arboreum, R. campanulatum and B. utilis

Quadrats were place for carrying out the phytosociological analysis of tree species for all the three layers of forest vegetation i.e. trees, saplings and seedlings in selected sites. The quadrats were laid randomly at each site. In each study site all individual were measured by placing 40 quadrats of 10 x 10m for trees, 80 quadrats of 5 x 5m for saplings and 200 quadrats of 1 x 1m for seedling following [36]. The vegetational data were quantitatively analyzed for density, abundance and total basal area [37], [38], [39], [40], [41]. Species diversity was computed using Shannon and Weiner diversity index (H') [42]. Concentration of dominance was calculated by using the Simpson's index [43]. The population structure of different tree species was assessed as seedling, sapling and tree. In each studied treeline site individuals of each species were measured for CBH (1.37m from the ground) with a girth measuring tape. The trees were sampled as above: 30cm, sapling: 11 - 30cm and seedling: < 10cm CBH. The individuals in each tree species were grouped into ten arbitrary CBH classes (A: <10, B: 11–30, C: 31–60, D: 61–90, E: 91–120, F: 121–150, G: 151-180, H: 181-210, I: 211-240, J: > 240 cm) [44]. The population structure were developed and represented by a bar diagram as the relative density percentage was plotted against corresponding girth class for each seedling, sapling and adult tree class following [45]. The regeneration status of treeline species was determined based on the relative proportion of adults, saplings and seedlings [46]. To assess the regeneration status of species following categories were created.

Good Regeneration: $= Seedling > Sapling > Adult$
Moderate Regeneration: $= Seedling \geq Sapling \geq Adult$
Poor Regeneration: $= Adult > Sapling \lesseqgtr Seedling$
Absent Regeneration: $= Seedling \multimapboth Sapling \Longmapsto Adult$
Fresh Regeneration: $= Adult \multimapinv Seedling \veebar Sapling$
*(Symbol**:** **> =** more than, $\geq$ = either more than or equal, $\lesseqgtr$ = either more than or less than or equal, $\multimapboth$ = absent both the end, $\Longmapsto$ = only, $\multimapinv$ = absent one end and $\veebar$ = either).*

The cattle pressure was estimated by distributing questionnaire to 30% of the households in the surrounding villages located within the periphery of 12 km from the treeline sites. Information regarding the size of the herds, duration of stay was gathered from the herders accompanying the herds. Participatory rural appraisal methods was followed for the re-verification of the information gathered through questionnaire and direct contact with the herders. Direct count of the herds size was also done whenever possible following [47].

3 RESULTS

A total of eight tree species were recorded from the three studied treeline sites. Six species were recorded from the Site I (Tungnath) and seven species each from Site II (Bedni) and Site III (Aali). Out of these eight tree species, five species were common at all the three treeline sites, seven species were common at Site II and Site III. The total density of all the tree species at Site I was 760 ind. /ha, at site II it was 590 ind. /ha and at site III it was 710 ind. /ha (Fig. 1 D). R. campanulatum showed the minimum and maximum density among species and varied from 40 ind. /ha at site II to 260 ind. /ha at site I (Fig. 1 A). The total basal cover across all the tree species was maximum (75.40 m^2 /ha) on site III and minimum (52.36 m^2 /ha) on site I (Fig. 1 D). The total basal cover of individual tree species across all the treeline sites was maximum for A. spectabilis = 29.98 m^2 /ha and minimum for R. campanulatum = 0.45 m^2 /ha (Fig. 1 A). The total density of all the saplings at Site I was 570 ind. /ha, at site II it was 200 ind. /ha and at site III it was 370 ind. /ha (Fig. 1 D). R. campanulatum sapling % was 57.89% (330 ind. /ha) at site I, 65.0% (130 ind. /ha) at site II and 78.38% (290 ind. /ha) at site III. The density of sapling ranged from 70 ind. /ha (R. arboreum at site II) to 330 ind. /ha (R. campanulatum at site I) (Fig. 1 B). The total basal cover of saplings was maximum (2.03 m^2 /ha) on site I and minimum (0.55 m^2 /ha) on site II (Fig. 1 D). The total basal cover of individual sapling species across all the treeline sites varied between 0.13 m^2 /ha and 1.05 m^2 /ha (Fig. 1 B). The value of the total density of seedling at Site I was 580 ind. /ha, at site II it was 200 ind. /ha and at site III it was 710 ind. /ha (Fig. 1 D). The percentage of R. campanulatum seedling was 56.90% (330 ind. /ha) at site I, 38.0% (190 ind. /ha) at site II and 64.07% (320 ind. /ha) at site III, similarly the percentage of R. arboreum seedling was 15.52% (90 ind. /ha) at site I, 44.0% (220 ind. /ha) at site II and 46.0% (230 ind. /ha) at site III. Across all the treeline sites in many places the seedling of R. campanulatum were found 6-20m outside from the actual position of krumholtz that make the treeline limit. The density of different seedling species varied from 20 ind. /ha (each for A. spectabilis and T. baccata at site I and site III) to 330 ind. /ha (R. campanulatum at site I) (Fig. 1 C). The total basal cover was maximum (0.13 m^2 /ha) on site I and minimum (0.055 m^2 /ha) on site II (Fig. 1 D). The total basal cover of individual seedling across all the treeline sites was maximum for R. campanulatum = 0.11 m^2 /ha and minimum for Q. semecarpifolia = 0.00003 m^2 /ha at site I (Fig. 1 C).

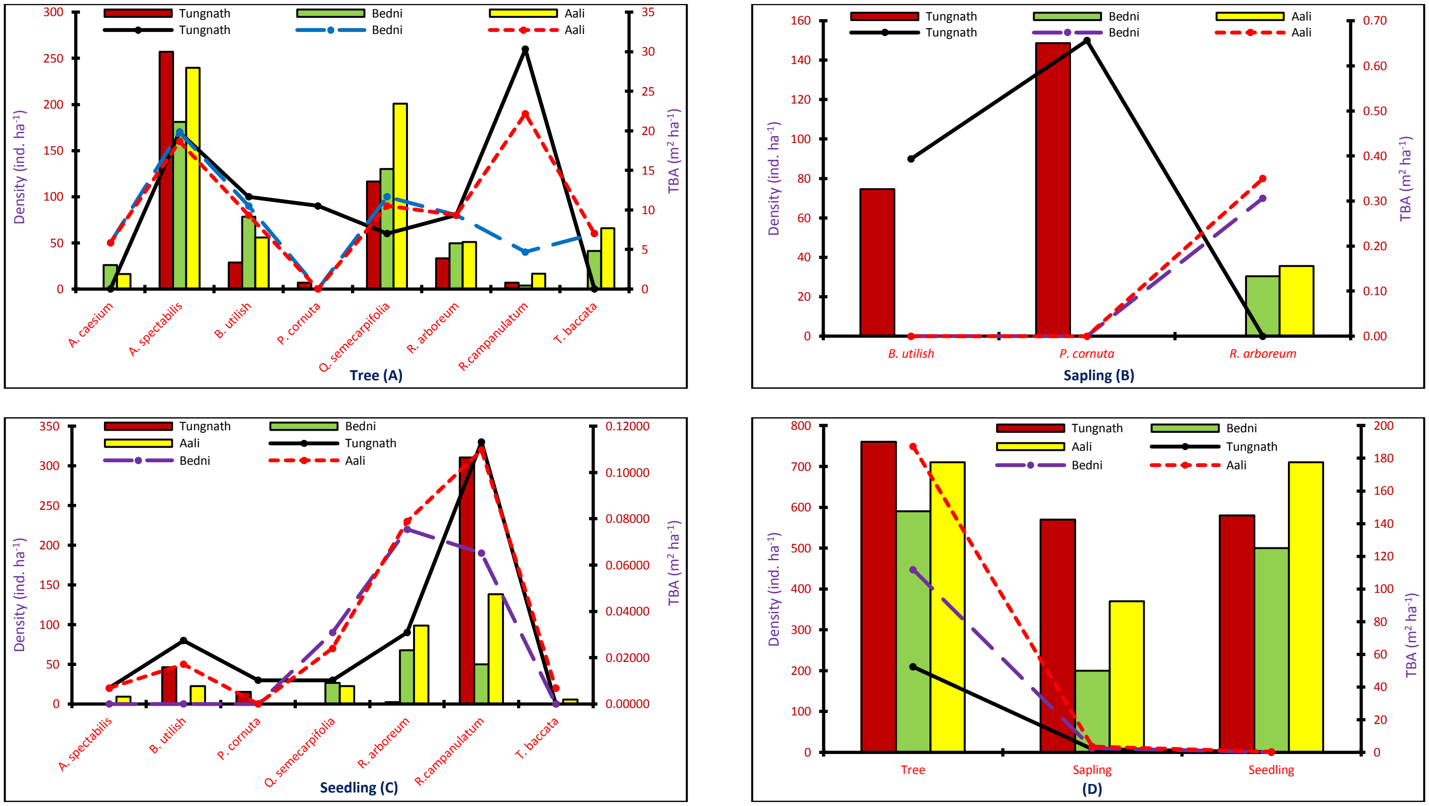
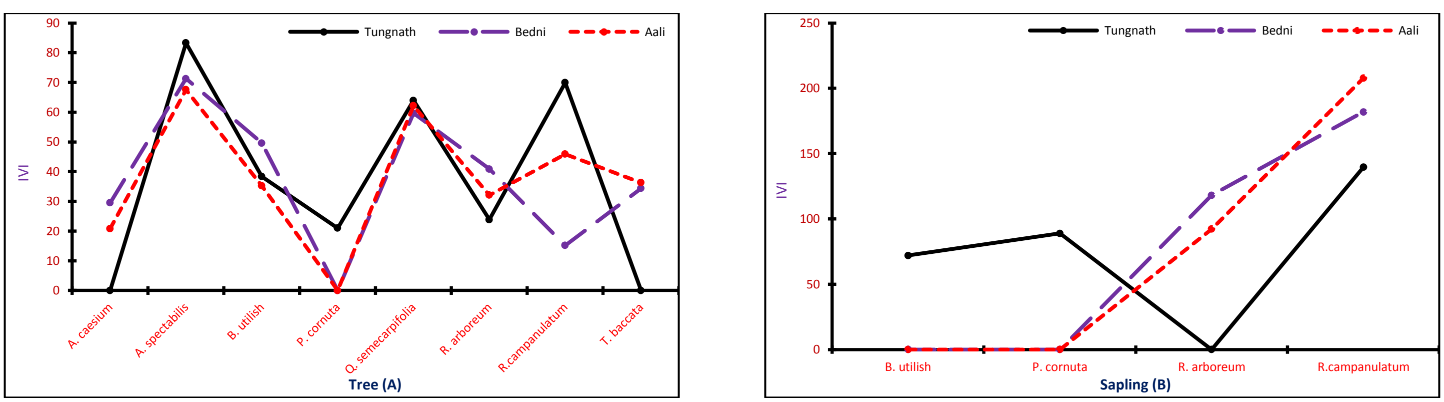


Fig. 1 (A-D). *Density (lines) and total basal cover (bars) of the selected tree species in studied treeline sites. Site I = Tungnath, Site II = Bedni and Site III = Aali. Fig. A: Density and total basal cover of individual tree species. Fig. B: Density and total basal cover of individual sapling species. Fig. C: Density and total basal cover of individual seedling species and Fig. D: Density and total basal cover of all the tree, sapling and seedling species across all the sites.*

On the basis of IVI, the most important tree species across all the treeline sites was A. spectabilis at tree layer and R. campanulatum at sapling and seedling layer (Fig. 2 A, B and C). The value of species diversity (H') was between 0.58 (site II and III) to 0.72 (site I) for tree layer, 1.43 (site I) to 2.20 (site III) for sapling layer and 1.08 (site III) to 1.24 (site I) for seedling layer (Fig. 2 D). Similarly, the value of concentration of dominance (CD) varied from 0.15 (site III) to 0.22 (site I) for tree layer, 0.43 (site I) to 0.66 (site III) for sapling layer and 0.32 (site III) to 0.37 (each for site I and site II) for seedling layer (Fig. 2 D). The H' (r^2 = 0.94) and CD (r^2 = 0.91) correlated positively with density of trees. Similarly, the sapling and seedling density also showed a correlation positively with H' and CD.



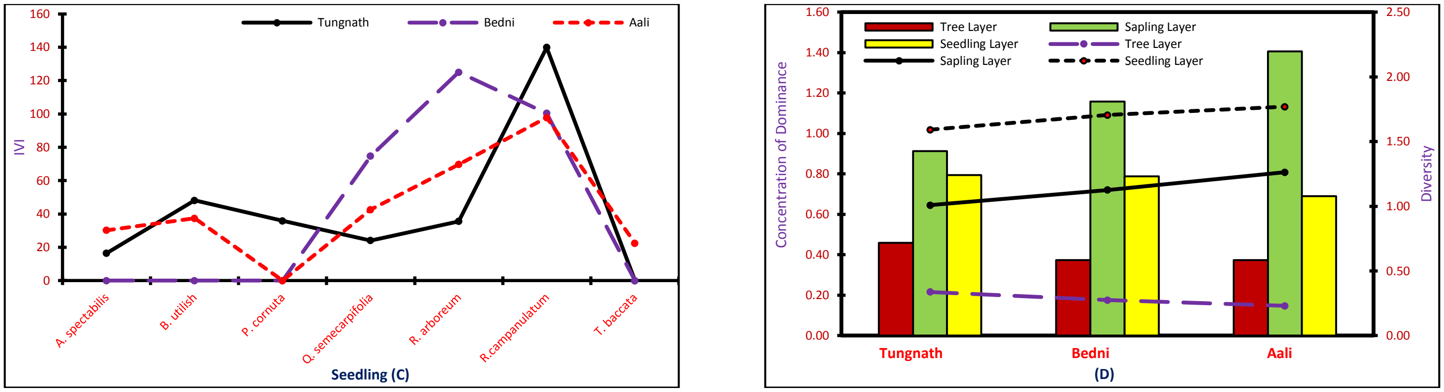
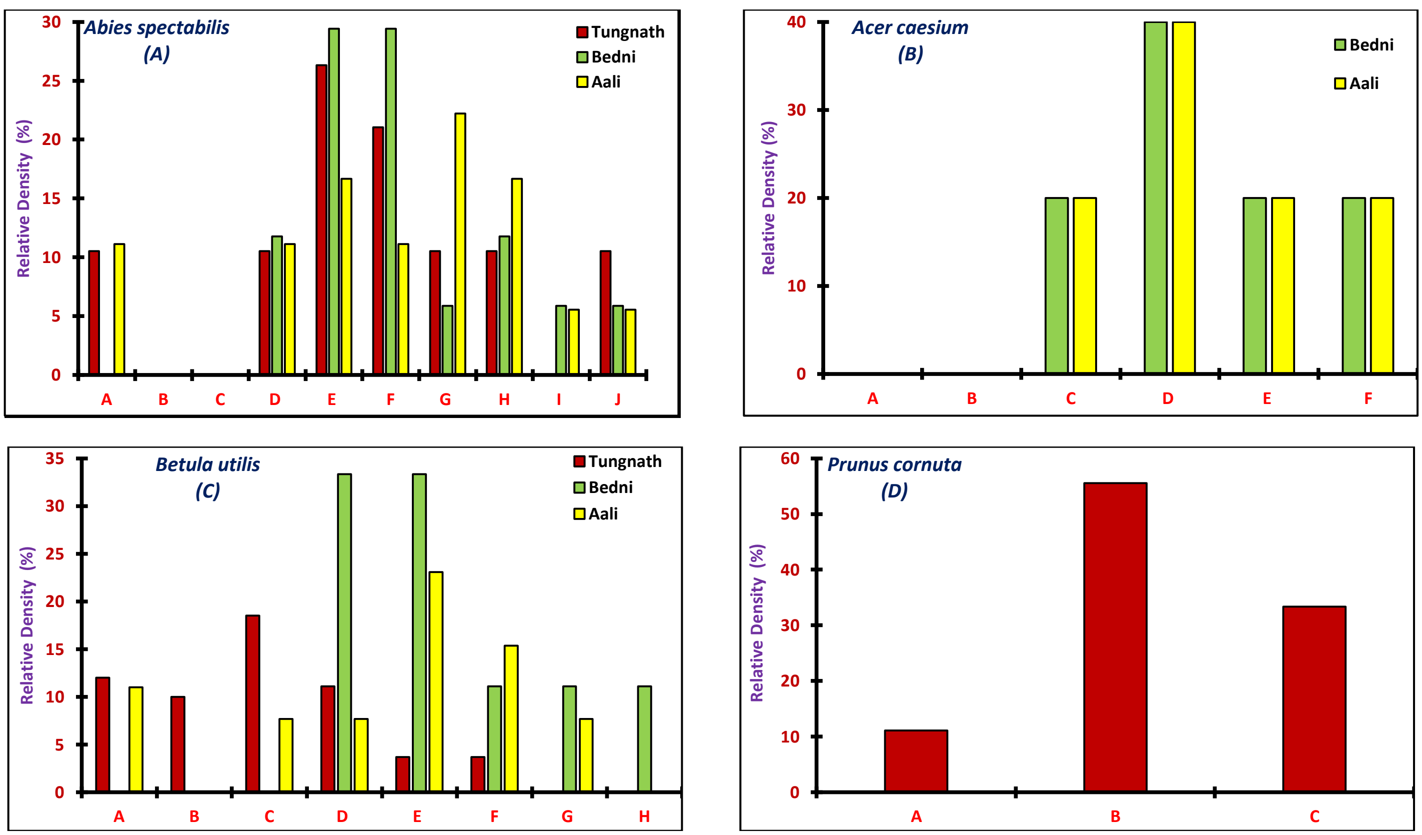


Fig. 2 (A-D). *Important value indices of the studies species across the selected treeline sites. Fig. A: Important value index of tree layer, Fig. B: Important value indices of sapling layer, Fig. C: Important value indices of seedling layer and Fig. D: Species diversity (bars) and concentration of dominance (lines) of tree, sapling and seedling layer in the selected treeline sites.*

R. campanulatum and R. arboreum were the species regenerating at the treeline sites as represented by presence of sufficient number of seedling and sapling (Fig. 3 F & G). In the remaining species the seedling/sapling density was low or absent. The population structure of the tree species in terms of relative proportion of seedlings, saplings and adults varied [46] greatly in studied treeline sites. Across all the sites A. spectabilis was represented by large size classes but very few individuals in seedling classes (Fig. 3 A). A. caesium was only represented by large size classes (Fig. 3 B). B. utilis was represented by low number of seedlings and saplings but presence of larger individuals (Fig. 3 C). P. cornuta was present only at Tungnath site and sapling size class showed the maximum representation (Fig. 3 D). In Q. semecarpifolia saplings were completely absent and domination was of larger size classes (Fig. 3 E). T. baccata was represented by large size classes but very few in seedling classes while absent in sapling size classes (Fig. 3 H).



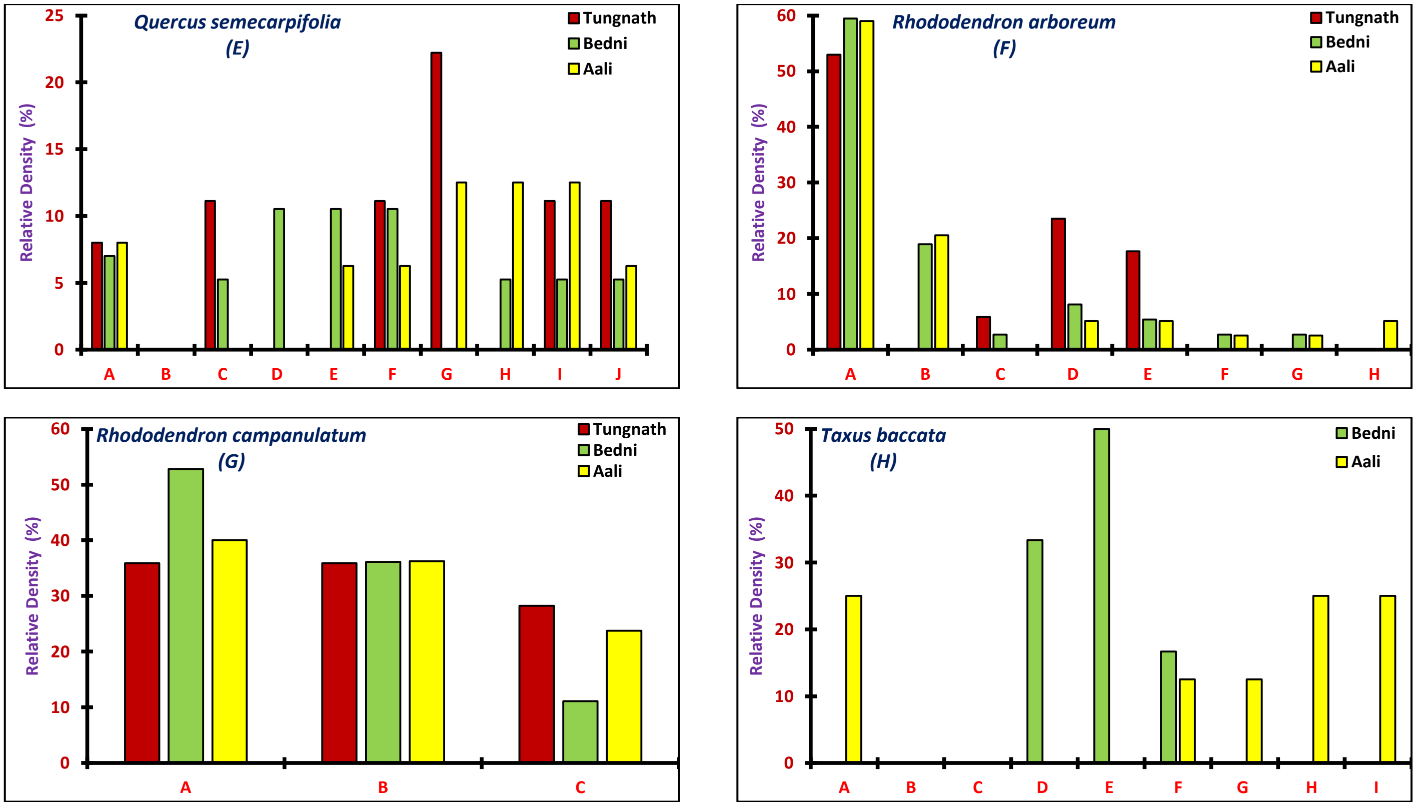


Fig. 3 (A-H). *Population structure of dominated tree species and entire forest stand of studied treeline sites. Fig. A: Population structure of A. spectabilis. Fig. B. Population structure of A. caesium. Fig. C: Population structure of B. utilis. Fig. D: Population structure of P. cornuta. Fig. E: Population structure of Q. semecarpifolia. Fig. F: Population structure of R. arboreum. Fig. G: Population structure of R. campanulatum and Fig. H: Population structure of T. baccata. A-J showed the girth classes.*

The regeneration status of the species depends on sufficient number of seedling, sapling and adults in the forest. At Tungnath site only R. campanulatum while, at Bedni and Aali site R. campanulatum and R. arboreum showed good regeneration while, all other species at Tungnath treeline showed poor regeneration pattern (Table 2). At Bedni site Q. semecarpifolia and at Aali site A. spectabilis, B. utilis, Q. semecarpifolia and T. baccata showed poor regeneration, in these species the relative proportion of seedling were more than sapling but the relative proportion of sapling were less than adults and species follow the pattern of adult > sapling < seedling. At Bedni site A. caesium, A. spectabilis, B. utilis and T. baccata and at Aali site only one species A. caesium showed absence of regeneration, these species were represented by adult trees, whereas they were completely absent in sapling and seedlings layer (Table 2).

Table 2. *Regeneration status of dominated tree species in the studied treeline sites*

Species	Regeneration status		
	Tungnath	Bedni	Aali
A. spectabilis	Poor	Absent	Poor
A. caesium	-	Absent	Absent
B. utilis	Poor	Absent	Poor
P. cornuta	Poor	-	-
Q. semecarpifolia	Poor	Poor	Poor
R. arboreum	Poor	Good	Good
R. campanulatum	Good	Good	Good
T. baccata	-	Absent	Poor

Anthropogenic disturbance was high in the studied treeline sites. Bakarwal, Gujjars and Pahari people graze their animals like goats, sheep, horses and buffalo in these treeline areas throughout the year. The heavy grazing was observe during snow free period from May to October during day time and these people also collect grasses for stallfed animals from these areas. During study period hundreds of goat and sheep (800-1000 in numbers) were commonly seen grazing these areas. The increase in human pressure and disturbances in these forest is responsible for formation of forest gap (patchy vegetation) [48]. Tourist were regularly trekking, visiting and staying in these areas. The local people in the treeline areas fulfill day-to-day needs like animal fodder, leaf litter, grazing and fuel wood, and the periodical needs [48] for small timber and NTFP's.

4 DISCUSSION

Treeline form varies depending upon abiotic and biotic factors and historical background. Generally, treeline is diffused type, with tree individuals getting gradually sparser and shorter above timberline [1]. Anthropogenic and ecological factors determine species composition and structure [49]. Compositional features of vegetation at treeline ecotones in the Himalaya are relatively less explored [50]. The composition of treeline ecotone in this part of Himalaya varies significantly from other reported compositions in treeline ecotones elsewhere in Himalaya. It is reported that the coniferous species in sub-alpine belt of southern part of the Tibetan Plateau and southern slopes of

Himalaya are highly diverse [50]. J. indica, J. recurva, A. spectabilis, A. densa, A. pindrow, and B. utilis are reported to form timberline on southern slopes of the Himalaya [50], [51], [52]. Furthermore altitude is another important factors which determine the distribution of tree species as they influence the microclimatic habitat conditions [51], [53]. In the present study the total tree density varied between 590 and 760 indi. /ha and total basal cover was between 52.36 and 75.40 m^2 /ha. Earlier several workers like [17], [50], [54], [55], [56], [57], [58], [59] have reported the values of density of tree species varying from 160 to 1470 indi. /ha and total basal area ranged from 2.69 to 87.83 m^2 /ha respectively for other sub-alpine forests in the Himalayan region, which were comparable to our studies (Table 3). The sapling and seedling density was between 70-330 ind. /ha and 20-330 ind. /ha which was comparatively lower than the values reported for similar forest types at Tungnath, Pindari and Lata treeline in western Himalaya by [17]. The sapling density was in the range reported by [50] at Chaudans, Pindari, Bhagirathi, Tungnath, Byans and Nelang treeline sites while the seedling density was similar to Tungnath site and comparatively higher at other sites. The lesser number of seedling and sapling in the site, may be due to severe biotic pressure. Regular human/animal interventions like overgrazing, lumbering and encroachments of forest areas are among the key regulatory factors controlling the distribution of species [41]. Such trends were also reported by [60] in various forest communities in Great Himalayan National Park (GHNP) in north western Himalaya. [17], [61] have reported from other part of north western Himalaya that density of trees decreases with increasing elevation. The species diversity values of tree (0.58-0.72), sapling (1.43-2.20) and seedling layer (1.07-1.24) and concentration of dominance value of tree (0.15-0.22), sapling (0.43-0.66) and seedling (0.32-0.37) in the present study were similar to reported by [62] at Dhanaulti in Garhwal Himalaya and also in the range for most of the Central Himalayan Forests [36], [63], [64].

Table 3. *Comparision of tree vegetation composition in different treeline sites*

Study Sites	Density (ind. /ha)	TBA (m^2 /ha)	IVI	Reported
Nanda Devi National Park, Uttarakhand, India	580-820	6.21-87.83	-	[54]
Tungnath, Uttarakhand, India	186-590	5.40-74.5	35-264	[50]
Kedarnath Wildlife Sanctuary, Uttarakhand, India	235-505	10.49-42.92	-	[55]
Kedarnath Wildlife Sanctuary, Uttarakhand, India	690-740	46.94-76.27	9.78-84.33	[56]
Tungnath, Uttarakhand, India	243-634	8.94-69.84	-	[17]
Mandal-Chopta, Uttarakhand, India	330-1470	36.32-84.29	2.41-154.23	[57]
Gangotri, Uttarakhand, India	820	2.69	12.90-83.40	[58]
Nanda Devi National Park, Uttarakhand, India	160-760	4.4-69.6	-	[59]
Tungnath, Bedni, Aali Uttarakhand, India	590-760	52.36-75.40	15.17-83.28	Present study

The occurrence of a sufficient number of younger individuals in a forest population show successful regeneration [65]. Maximum number of individuals in sapling stage and a sharp decline towards both higher tree classes and lower seedling classes results in hill-shaped curves, indicating that the rate of conversion of sapling to tree is not proportional as also indicated in an earlier study [17], [54]. In the present study at Tungnath treeline site there was, a decline from lower girth class individuals to higher girth class while at Bedni and Aali treeline site the forest showed a hill-shaped curves. The regeneration of R. arboreum and R. campanulatum was found higher compared to other species. Due to toxic nature of Rhododendrons species, animals avoided grazing these species, this can be a major cause of higher regeneration of this species in these treeline areas. Some species of the family Ericaceae are a potential source of toxic diterpenes, named grayanotoxins. The encroachment of R. campanulatum seedlings in the alpine meadows area (6-20 m) from the krumholtz of R. campanulatum has also been reported by [66]. Dominance of individuals of smaller size class (seedlings and saplings) has been reported in the treeline areas of Kalchuman Lake area of Manaslu Conservation Area [34], [67] and in Makalu-Barun National Park [68]. [69] Has reported abundance of seedlings above the treeline in A. spectabilis. The species in these areas are showing good regenerate as they are located within protected forest areas in contrast to our anthropogenically disturbed areas. B. utilis formed an abrupt treeline boundary and generally most of the time was found in patches, absence of seedlings and saplings was conspicuous, where tree individuals formed the upper limit. Contrary to the present study treelines of Nepal [70], [71], [72] in Indian region have reported good regeneration in B. utilis. In our treeline sites only R. campanulatum and R. arboreum showed good regeneration status while all other species showed poor regeneration status. R. campanulatum was found generally in clumps, species that usually grow in clumps are generalally better adapted to intra-specific competition [56], [73]. While all other species in these treeline sites showed an inadequate regeneration pattern, [74] in Khokhan Wildlife Sanctuary (KhWLS) also found inadequate regeneration pattern of P. duthiei. The overall regeneration status was poor in these treeline forests. All the treeline species showed about 75-80% relative proportion of adults while only 20-25% relative proportion in saplings and seedlings. [75], [76] have reported similar results in Rajouri and Poonch districts of J&K State by A. pindrow also had poor regeneration. Poor regeneration of Quercus species in Himalayan mountain forests was also reported by other workers from time to time [36], [77] and anthropogenic disturbance was attributed for this. [61], [78] have reported that due to human and animal impact, forest species are showing inadequate regeneration of younger individuals. [79] has reported similar results due to heavy grazing in British Columbia. The livestock grazing pressure in our study area was found to be high. Certain grazing communities during the snow less period migrate to the alpine meadows with large herds of cattle, goats and sheep's. Natural regeneration is hampered due to trampling and browsing which cause large scale mortality of saplings and seedlings.

According to [80], grazing by cattle is the one of the fundamental cause of why oak species are facing to regenerate in the central Himalayan forest.

6 CONCLUSION

The two Rhododendrons, R. arboreum and R. campanulatum had good regeneration in the three anthropogenically disturbed studied treelines. In coming years the domination can be of these Rhododendron species which are un-palatable to the animals. The rest of the species had poor regeneration possibly due to grazing and trampling by large herds to cattle varying between 800-1000 in numbers that stay in these areas for approximately 8-9 months in a year. At most of the studied sites, there were species and site specific shifting patterns with little treeline shifting in more recent years. In our studied treeline area R. campanulatum seedling were present 6-20m outside from the actual position of krumholtz. R. campanulatum which is found in krumholtz form showed an upward movement from actual treeline which would reduce the alpine meadows area. Therefore, treeline forests in the study area along with those in the region require regular proper management, so that the seedlings and saplings could survive and replace adult trees in future.

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