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Treeline Species : Regeneration Status and Seedling Dynamics in Western Himalayan Region

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ABSTRACT

The seedling phase is the most crucial phase and very sensitive stage because seedlings grow with in the most severe micro environments and have limited tolerance due to short-shallow roots and minimal capacity of resource storage. The aim of the present study was to assess the regeneration status and growth and survival of main treeline forming species in the western Himalayan region between 3145-3467 m across treeline sites. The study were conducted in Tungnath, Bedni and Aali treeline areas of western Himalayan region of Uttarakhand. The mean annual temperature of the sites varied from -8.91 and 25.6°C. Vegetational analysis was carried out by placing quadrats and regeneration status was assess based on number of seedling, sapling and adults. For seedling dynamics study newly recruited seedling were tagged individually in l m^2 quadrat and the growth and survival of the tagged seedling subsequently monitored for 22 months. The total tree density varied between 590 ind. ha^{-1} and 760 ind. ha^{-1}, the individual density was maximum for *R. campanulatum* and *A. spectabilis* was the dominant tree species in terms of IVI. Across all the treeline sites *R. campanulatum* showed good regeneration and *R. arboreum* showed moderate to poor regeneration. Across the sites initial mean number of newly recruited seedlings m^2 was 0.41-0.48 of *A. spectabilis*, 0.38-0.45 of *B. utilis*, 0.50-0.68 of *Q. semecarpifolia,* 0.73-0.95 of *R. arboreum* and 0.55-0.91 of *R. campanulatum. Rhododendron* species appeard to be surviving better in the high altitudes sites.

Keywords Density, Mortality, Regeneration, Seedling dynamics, Treeline.

INTRODUCTION

The seedling phase is the most crucial phase and very sensitive stage in the plants life cycle, at alpine region where temperature, snow cover and other anthropogenic disturbance restrict the seedling survival (Singh 2019). Deedlings grow within the most severe micro environments and have limited tolerance due to short-shallow roots and minimal capacity of resource storage. Microsites variability is likely to play an important role in how the survival-drought relationship evolves with changing climate. Seedling dynamics of plant species can be described by

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demographic characteristics, such as the recruitment, mortality and growth rates of individuals (Choudhary et al. 2014) and they can cause drastic changes in populations. Canopy cover, influences levels of light, soil moisture and nutrients in forest understory, all of which are limiting factors for seedling performance (Augspurger 1984).

The potential regenerative status of tree species often depicts the future composition of forests within a stand in space and time (Henle et al. 2004) and species existence and recruitment process mostly depends on its regeneration potential under varied climatic factors, competition betwen species, predation and anthropogenic disturbances. The presence of sufficient number of young trees, saplings and seedlings in a specific forest population indicates that the tree species are able to regenerate successfully (Singh et al. 2014). Inadequate regeneration is the main problem of forests in mountain forest (Krauchii et al. 2000) as well as treeline areas and thick litter generally reduces the rates of germination and of seedling estabilishment.

The species composition and structure determines the status and functional conditions of forests (Gairola et al. 2014). The mechanisms where by survival, growth and reproduction of trees are limited at the treeline are not properly understood (Tranquillini 1979 and Grace et al. 2002). A number of anthropogenic disturbances are commonly observed in the treeline aras or sometimes lack of regeneration in treeline species is attributed to the effect of climate change (Gaire et al. 2017). Climate is one of the most powerful factor which controls the broad-scale distribution of plant species and vegetation. Temperature is the influencing predictor variable of treeline formation and maintenance (Harsch et al.2009). The aim of the present study was to assess the regeneration status and growth and survival of main treeline forming species in the western Himalayan region btween 3145-3467 m across treeline sites.

MATERIALS AND METHODS

Study suites : The study area, lines between $30^0$11’02–$30^0$2954 N latitude and $79^0$12’45 - $79^0$39’36 E longitude in treeline areas of Garhwal Himalaya, Uttarakhand in the North of India. This is a high mountain area with elevations greater than 3, 000 m above sea level (Table 1). After a through survey of different treeline areas in Garhwal Himalayan region of Uttarakhand, three treeline sites namely, Tungnath, Bedni and Aali were select for the study. In all these selected sites, the main treeline forming species were Fir (*Ais spectabilis*), Birch (*Betula utilis*), Kharsu-oak (*Quercus semecarpifolia*), Buransh (*Rhododendron arboreum*) and Semru (*Rhododendron campanulastum*). *R. campanulatum* occured in the small tree/ sub tree/shrub or krummholtz form in treeline areas.

Climate : The study sites are located in the alpine zone, where snow cover remains till April. Soil is generally brown in color, sandy loam in texture, with high proportion of sand and silt and generally acidic with pH value 4 to 5 (Singh et al. 2019). The climate of the study area is characterized by short cool summers and long severe winters. The mean annual temoperature of the sites varied from -8.91 (January) and 25.6°C (May) and mean annual precipitation was 2410.5 ± 432.2mm (Singh et al. 2019).The relative humidity percent varied between 60 to 80% thoughout the year in the sites.

METHODS

Phytosociological analysis : The phytosociological analysis of trees species were done by placing quad-

Table 1. Physiographic features of the selected study sites.

Site Name	District	Elevation (m)	Latitude (N)	Longitude (E)	Aspect
Tungnath	Rudraprayag	3145-3355	30°29´45-30°29´54	79°12´45-79°13´24	South–East North–East
Bedni	Chamoli	3284-3467	30°12´22-30°12´09	79°39´26-79°39´36	South-East South-West
Aali	chamoli	3302-3446	30°11´17-30°11´02	79°39´13-79°39´28	South-East North-East

rat. In each study site all individual were counted for each tree species by placing 20 quadrats of 10 × 10 m. The size and number of the samples were determined following Saxenaand Singh (1982) and Singh et al. (2014). The quadrats were laid randomly. The vegetational data were quantitatively analyzed for frequency (%), density, abundance and total basal area (Mueller-Dombois and Ellenberg 1974). The importance value index (IVI) was determined as the sum of the relative frequuency, relative density and relative dominance (Ambasht and Ambasht 2002).

Regeneration Pattern : The regeneration status oftreeline species was determined based on the relative proportion of adults, saplings and seedlings. To assess the regeneration status of specis were categorized as; good, moderate, poor absent and fresh regeneration following Singh et al. (2019).

Seedling dynamics :To assess the seedling dynamics of the studied treeline tree species, 40 quadrats of l ×l m^2 size were placed in different locations of each study site. Newly recruited seedlings were tagged individually (using numbered tape flags) in l m^2 quadrat in all studied treeline sites and the survival of the tagged seedling subsequently monitoried for seedling mortality at two months interval during the study period following Joshi and Rawat (1996) and Joshi and Tewari (2009). The newly recruitd seedling of *Q. semecarpifolia* were tagged in October 2016, *R. arboreum* were tagged in May 2017 and *A. spectabilis, B. utilis and R. campanulatum* were tagged in April 2017 individually on 1 m^2 quadrat and subsequently monitored upto June 2018 (*Q.semecarpifolia*) and February 2019 (*A.spectabilis, B. utilis, R. arboreum and R. campanulatum*). The newly recruited tagged seedlings were clearly identifable from older seedlings by their height, number of leaves and absence of leaf scars on the stem due to leaf drop. The dynamics of seedling calculated on the basis of survival and mortality of seedling of the studies species.

RESULT

Phytosociological analysis :Across the treeline sites the total tree density varied between 590 ind. ha^{-1} and 760 ind. ha^{-1} while the total basal area ranged between 54.31 m^2 ha^{-1} and 7542m ha^{-1}. At Tungnath site the individual density of trees varied from 60 to 260 ind. ha^{-1}, it was maximum for *R. campanulatum* and minimum for *Q. semecarpifolia*. At Bedni site the individual density of trees varied from 40 to 170 ind. ha^{-1}, it was maximum for *A. spectabilis* and minimum for *R. campanulatum*. At Aali site the individual density of trees varied from 50 to 190 ind. ha^{-1}, it was maximum for *R. campanulatum* and minimum for *A. caesium*. Across all the studied treeline sites *A.spectabilis* was the dominant tree species in terms of IVI (Table 2).

Regeneration pattern : Across all the studied treeline sites *R.campanulatum* showed good regeneration pattern as represented by presence of sufficient number of seedling, sapling and trees with a pattern of seedling > sapling>adult. *R.arboreum* showed moderate to poor regeneration and followed the pattern of seedling>sapling ≤adult or adult >sapling < seedling. *A. spectabilis, A. caesium, B. utilis, Q.semecarpifolia,*

Table 2. Phytosociological analysis of tree species at studied treeline sites.

Sites	Tungnath			Bedni			Aali		
Species	Density (ind.ha^{-1})	TBA (m^2 ha^{-1})	IVI	Density (ind.ha^{-1})	TBA (m^2 ha^{-1})	IVI	Density (ind.ha^{-1})	TBA (m^2 ha^{-1})	IVI
A. spectabilis	170	29.98	83.28	170	21.11	71.25	160	27.98	67.84
A. caesium	-	-	-	50	3.04	29.48	50	1.88	20.84
B. utilis	100	3.35	38.33	90	9.15	49.59	80	6.51	35.21
P. cornuta	90	0.79	20.99	-	-	-	-	-	-
Q. semecarpifolia	60	13.59	63.95	100	15.16	59.61	90	23.43	62.16
R. arboreum	80	3.86	23.81	80	5.79	40.85	80	5.96	32.09
R. campanulatum	260	0.79	69.93	40	0.45	15.17	190	1.94	45.87
T. baccata	-	-	-	60	4.79	34.35	60	7.70	36.29
Total	**760**	**54.31**	**300.2**	**590**	**59.50**	**300.3**	**710**	**75.42**	**300.3**

Table 3. Regeneration status of dominated treespecies in the studied treeline sites.

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

P. cornuta and *T. baccata* hadpoor regeneration with pattern of adult>sapling>seedling or adult>sapling-seedling or adult <sapling >seedling (Table 3).

Seedling dynamics

A. spectabilis : The initial mean number of newly recruited seedlings of *A. spectabilis* in l m^2 quadrat varied between 0.41 ± 0.04 and 0.48 ± 0.09 seedling m^2 in the months of April in yrl across all the studied treeline site. The mean number of seedling in l m ^{2}quadrat was maximum at Tungnath site and minimum at Aali site. The seedling number declined to 0.06 17 ± 0.01 seedling m^{-2} at Tungnath and Aali site and 0.08 ± 0.02 seedling m^{-2} at Bedni site in the third year of study. The maximum 22–27% seeding mortality was observed from November to February (winter season) in the initial period of study. The survival percentage of seedling declined from 100% to 12.50% at Tungnath site, 19.05% at Bedni site and 14.63% at Aali site from April of yrl to February of yrl 3 (Fig. 1A).

B. utilis : The initial mean number of newly recruited seedling of *B. utilis* in l m^2 quadrat varied between 0.38± 0.06 and 0.45 ± 0.14 seedling m^{-2} in the months of April in yrl across all the studied treeline site. The mean number of seedling in l m^2 quadrat was maximum at Aali site and minimum at Tungnath site. The seedling number declined to 0.0 ± 0.0 seedling m^{-2} at Yungnath and Bedni site and 0.04 ± 0.01 seedling m^{-2} at Aali sites in the third year of study. The maximum 27–31% seedling mortality was observed from November to February (winter season) in the initial period of study. The survival percentage of seedlings declined from100% to 0.0% at Tungnath and Bedni site and 8.89% at Aali site from April of yrl to February of yrl (Fig. 1B).

Q. semecarpifolia : Across all the studied treeline sites the initial meannumber of newly recruited seedlings of *Q. semecarpifolia* in l m^2 quadrat varied between 0.50 ± 0.01 and 0.68 ± 0.06 seedling m^{-1} in the months of october in yrl. The mean number of seedling in l m^2 quadrat was maximum at Aali site and minimum at Bedni site. The seedling number declined to 0.00 ± 0.00 seedling m^{-2} at Tungnath and Bedni site and 0.05 ± 0.01 seedling m^{-2} at Aali site the third year of study. The maximum 20 -24% seedling mortality was observed during the months from December to February during winter season in the initial period of study. At Aali site 7.35% seedlings had survived, while at Tungnath and Bedni site no tagged seedling had survived during the study period (Fig. 1C).

R. arboreum : The initial mean number of newly recruited seedlings of *R. arboreum* in 1 m^2 quadrat varied between 0.73 ± 0.09 and 0.95 ± 0.11 seedling m^{-2} in the months of May in yrl across all the studied treeline site. The mean number of seedling in 1 m ^{2} quadrat was maximum at Aali site and minimum at Bedni site. The seedling number declined to 0.40 ± 0.01 seedling m^2 at Aali site and 0.30 ± 0.01 seedling m^{-2} at Tungnath and Bedni sites in the third year of study. The maximum 18–30% seedling mortality was observed from November to February (winter season) in the initial period of study. The survival percentage of seedling declined from 100% to 36.59% at Tungnath site, 41.10% at Bedni site and 42.11% atAali site from May of yrl to February of yr3 (Fig. 1D).

R. campanulatum : The initial mean number of newly recruited seedlings of *R. campanulatum* in 1 m^2 quadrat varied from 0.55 ± 0.08 to 0.91 ± 0.13 seedling m^{-2} in the month of April in yrl across all the studied treeline sites. The mean number of seedling in 1m^2 quadrat was maimum at Aali site and minimum at Bedni site. The seedling number declined to 0.35 ± 0.04 seedling m^{-2} at Tungnath site, 0.30 ± 0.02 seeling m^{-2} at Bedni site and 0.47 ± 0.07 seedling m^{-2} at Aali site in the third year of study. The maximum 20-22% seedling mortality was observed from November to February during winter season in the initial period of

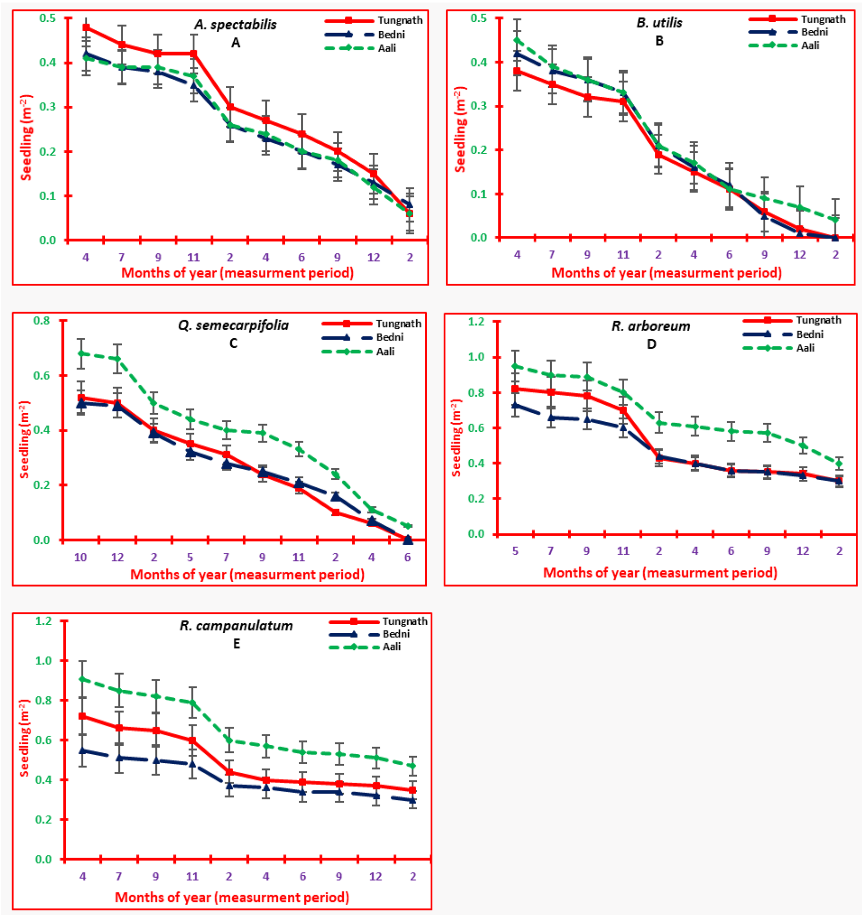

Fig. 1 (A-E). Seedling dynamics (M) of studied treeline species across all the sites during the study period. Fig. (A) *A. spectabilis*, (B) *B. utilis*, (C) *Q. semecarpifolia*, (D) *R. arboreum* (E) *R. campanulatum* 1-12 = Months of year. Error bars indicates ± SE.

study. The survival percentage of seedlings declined from 100% to 48.61% at Tungnath site, 54.55% at Bedni site and 51.65% at Aali site from April of yrl to Frbruary of yr 3. *R. campanulatum* showed the highest survival percentage comparison to other study species across all the sites (Fig. 1E).

ANOVA indicated that the seedling number varied significantly across the species and sites ($p<0.05$), but not-significantly across the months. All the interaction of species × sites, species × months, site × months and species × sites × months were non-significant ($p<0.05$) (Table 4).

Table 4. Analysis of variance for different parameter of seedling dynamics across all the study sites. ** Significant at 0.05% NS (Non-Significant).

Seedling dynamics	Source of variation	Type III sum of squares	DF	Mean square	F-value
	Species	56.94	4	28.47	7.76^{**}
	Sites	104.08	2	52.04	14.19**
	Months	0.48	9	0.24	0.06^{NS}
	Species × Sites	8.46	8	2.11	0.57^{NS}
	Species × Months	0.03	36	0.00	0.00^{NS}
	Sites × Months	5.87	18	1.46	0.40^{NS}
	Species × Sites × Months	0.18	72	0.02	0.00^{NS}

DISCUSSION :

Treelines are part of the mountain habitats where accelerated increasein plant species richness is taking place in a warming world (Steinbauer et al. 2018). Tree distribution and population pattern at the treeline ecotone are highly sensitive to climatic variations (Grace et al. 2002) and most of these treeline species are on the threshold of their climatic limits. At alpine treeline locations exposure, soil, mineral nutrients, water availability, temperature, drought and microclimate change over short distances. Structural changes at the treeline ecotone, including growth and regeneration responses, can not only lead to treeline shifts but are expected to trigger alterations in alpine vegetation (Holtmeier and Broll 2005).Several alpine plant species that are restricted to areas above the treeline would perience severe habitat fragmentation and reduction, resulting in an increased risk of regional extinction (Dirnbock et al. 2003.

In the present study, a total of eight tree specieswererecorded fromthethre studied treeline sites and the total tree density varied between 590 and 760 ind. ha^{-1}. The values of various phytosociological analysis in the present study are close to values reported by Gairola et al. (2008), Zhang et al. (2009), Gaire et al. (2010), Pant and Samant (2012), Gairola et al. (2014), Dutta and Sundriyal (2018), Rawal et al. (2018) and Singh et al. (2019) from different parts of Western Himalaya like Kumaun, Garhwal, Himachal Pradesh, Sikkim, China, Nepal and Pakistan.

Across all the studied treeline sites only *R. campanulatum* and *R. arboreum* were the species regenerating and showed good to moderate regeneration. Due to toxic nature of some *Rhododendrons* species, animals avoid grazing them. This can be major causes of higher regeneration of this species in theses treeline areas. Another cause of good regeneration of *R. campanulatum* could be that it is found in clumps, the species which grow in clumps are, in general, better adapted for intra-specific competition than inter-specific competition, while all other species showed poor regeneration status. Harsh climatic conditions in the alpine zone might restrict the regeneration and survival of treeline trees species (Tranquilini 1979). Seed and seedling demography is affected by many factors, disturbance has been known to play an important role in ecosystem dynamics; for example canopy gap cration can increase the availability of light resources to seedlings in humid forests (Weldn et al. 1991 and Hoffmann 1996). In tropical dry forests, seasonal drought and fire disturbance have a strong influence on seedling demography, though little is known about these factors (Marod et al. 2002).

The regeneration of a forest is a vital process in which old trees die and are replaced by young ones in perpetuity (Mittal 2018). Over the three year study period the seedling number continuously declined from initial to final observation. The mean survival number after 22 months of observation of seedling in *A. spectabilis* was 0.06 seedlings m^{-2} , 0.01 seedling m^{-2} in *B. utilis* and *Q. semecarpifolia*, 0.35 seedling m^{-2} in *R. arboreum* and 0.37 seedling m^{-2} in *R. campanulatum*. Verma et al. (2015) has reported just 0.67 seedling m^{-2} in *Q semecarpifolia* and Mittal (2018) has reported 4.0 seedling m^{-2} in *R. arboreum* and 0.0 seedling m^{-2} in *Q. leucotrichophora*. Negi et al. (1996) also reported around 53.5% mortality in *Q. floribunda* and Verma et al. (2015) reported 85-95% seedling mortality in *Q. semecarpifolia*. Joshi and Tewari (2009) reported >50% of seedling survival in *Q floribunda* species. Rao and Singh (1986) have recorded higher mortality rate (35.0%) in one year for oak seedlings initiated during rainy season as compared to 20.6% mortality rate for oak (Banj and Harinj) seedlings in which initiation occurred prior to rainy season. Low light reduced seedling emergence of birch (*Betula* spp.) by 43%, seedling growth by 99%, and survival by 94% (Catovsky and Bazzaz 2000). In our studied treeline areas *B.utilis* generally grow in northern aspect, in northern aspect the intensity of light low compare to other aspect.

Difficulty in the regeneration of oaks has also reported by Abrams (1992) and Buckley et al. (1998) from North American forests. The maximum 18-31% mortality of seedling was observed during dry season of the first year of observation from November to February. Marod et al. (2002) observed that the mean survival rate of the first year seedlings for all species is quite high in the rainy season (11.5% per month) and low in the dry season (6.1% per month). Malik and Bhatt (2016) reported the initial mortality may be due to micro site effects and small terrestrial animals during the early stages of development.

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 (Miranda et al. 2018). In all treeline species showed the maximum seedling mortality during winter season. Generally the soil in treeline areas gets frozen during winter and the transpiration rate of seedlings become high this may be a main cause of maximum mortality during winter when the seedlings were under severe water stress during winter (Tewari et al. 2018 and Singh et al. 2019). Moving on to the finer scales, the local environmental conditions including microclimate, edaphic factors (soil, pH, water-holding capacity, nutrient content) and topographic factors (aspect, slope) have control over seedling establishment and growth effecting treeline position or species line position (Holtmeier 2009). Severe biotic and high anthropogenic pressure were also responsible for high seedling mortality in treeline areas. Across all the study site heavygrazing was observe during snow freeperiod from May to October during day time. During study period hundred of goat and sheep (800—1000 in numbers) were commonly seen grazing in these areas. Regular human/ animal interventions like over grazing, lumbering and encroachments of forest areas are among the key regulatory factors controlling the distribution of species (Singh et al. 2019). Suh trends were also reported by Rawat and Singh (2006) in various forest areas in Great Himalayan national Park in North Wstern Himalaya. Cierjack et al. (2008) also stated that plant regeneration is generally limited in harsh environment. Sparhawk (1918) has reported that hardly 0.1-1.0% of seedlings are able to establish themselves under normal condition in forests.

CONCLUSION

Low regeneration survival was a conspicuous features in the treeline species. The seedling number continuously declined during the study periods of 22 months. *Rhododendron* species however, appear to be regenerate better and may dominate in the treeline vegetation in furute. Heavy anthropogenic pressure in the form of grazing animals appears to be one of the major factor responsible for low regeneration and mortality of seedling in these treeline areas coupled with stressful winter conditions.

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