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Regeneration status of spruce (*Picea smithiana* Wall. Boiss) along the altitudinal gradient in South Kashmir Himalayas (India)

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Abstract
The regeneration status of Spruce (*Picea smithiana*) was assessed with the major focus on regeneration pertaining to the poor recruitment and seedling establishment in south Kashmir of western Himalayas. The study was concentrated along the three altitudinal gradients *viz*. 2,200 - 2,400 m (Anantnag), 2,400 - 2,600 m (Lidder) and 2,600 - 2,800 m (Shopian), at each altitude two sites were randomly selected for the study. The regeneration at all the sites was poor to fair, but did not show any definite trend along the altitudinal gradient. The maximum density of recruits (1031.25 ha^{-1}), number of un-established regeneration (562.50 ha^{-1}) and number of established regeneration (273.44 ha^{-1}), maximum height of un-established regeneration (5.80 m), weighted average height (99.32 m), stocking index (0.16), establishment stocking per cent (5.64) and regeneration success (17.19%) was recorded at middle altitudinal gradient (2,400-2,600 m), whereas the minimum regeneration was recorded at upper altitudinal gradient (2,600 – 2,800 m).

Keywords: *Picea smithiana*, regeneration, spruce, South Kashmir, Western Himalayas

Introduction
In Himalayas, the three conifer species especially *Pinus*, *Cedrus* and *Picea* are distributed on an altitudinal line one above the other in tires, in pure or in mixed species combination. Four genera *Abies*, *Cedrus*, *Picea* and *Pinus* form extensive forest of great economic value in the Himalayas. Spruce (*Picea smithiana* Wall. Boiss) commonly referred as high level conifer, It produce good seeds at an interval of 4-6 years (Singh and Singh, 1984) [21]. The *P. smithina* occurs throughout the western Himalayas from Afghanistan eastwards at least as far as Kumaun, Uttrakhand in India chiefly at elevation of 2,100-3,350 m amsl, though occasionally descending lower on northern aspects and ascending higher on southern aspects.
Regeneration is the key feature of the forest dynamics, progress and restoration of degraded forest lands. It depends on number of seedlings, saplings and their distribution pattern in the region. Forest reveals variation in pattern of regeneration both through differences in their constituent species and the environmental variables in which they grow (Demel, 1997; Denslow, 1987) [4, 5]. With the increase in population, both human as well as livestock, the forests of J&K state are under tremendous pressure due to open grazing, heavy exploitation and other excessive biotic pressures. The situation has become so alarming that in most of the areas the forests are lacking in natural regeneration and are at different stages of degradation.
The augmentation of natural regeneration and eco-restoration of degraded forests with a view to increase productivity are the major concerns. The assessment of natural regeneration is an important aspect which influences the production and management system in many forest species. This is most relevant especially during working plan preparation/revisions. The main object of such survey is to assess whether or not there is adequate regeneration (established and unestablished) in the forest area/species. The basic elements necessary for successful natural regeneration are a sufficient supply of viable seeds, a respective seed beds, favourable climatic conditions for germination and establishment and protection from damaging agents. Therefore if any of these elements is missing, regeneration is unlikely to be successful (Boyer, 1998; Janusz and Winston, 2004; Juntunen, 2006) [2, 11, 12]. Natural regeneration in Himalayan spruce is, however, generally deficient and conspicuous in many areas by its absence.
The problem of natural regeneration in the species is constantly engaging the attention of the forest scientists. Thick layer of humus, accumulation of debris, dense weed growth and continuous grazing (Hafizullah, 1970; Kaul, 1970) [9, 13], are considered responsible for the absence of natural regeneration.

Allelopathy may be one of the reasons that inhibit the regeneration of the spruce. Fisher (1987) [7] showed that allelopathy in many instances played a major role in the natural regeneration failure. Infrequent seed years and low germination capacity of the seeds are also important factors contributing to the absence of natural regeneration in this species. Keeping in the ecological importance and vulnerability of this species the present study was carried out with the objective to quantify the regeneration status of *Picea smithiana* along the altitudinal gradient in South Kashmir Himalayas (India).

Material and Methods

The study on natural regeneration status of *Picea smithiana* was conducted along the three altitudinal gradients (each having 2 sites) ranged of 2,200-2,400 m, 2,400-2,600 m and 2,600-2,800 m in south Kashmir Himalayas (Table 1) during the years 2013 & 2014. The study sites was located between 32˚17/ and 37˚6/ North and 73˚26/ and 80˚36/ east.

Table 1: Details of the study area

S. No.	Name of Forest Division	Sites	Altitudes (m)
1.	Anantnag	1. Ahlan 2. Daksum	2,200-2,400
2.	Lidder	3. Pahalgam 4. Aru	2,400-2,600
3.	Shopian	5. Mughal Road 6. Aharbal	2,600-2,800

Regeneration survey

The regeneration survey was carried out in all the sample plots on each elevation at selected sites. In each major plot of 40×40 m forty quadrates measuring 2×2m were laid. Two thousand and five hundred (2,500) established plants ha^{-1} were considered as satisfactory regeneration (Chacko, 1965) [3].

Regeneration assessment

The regeneration status of *Picea smithiana* was analyzed by counting the plants as number of recruits (r), established (e) and un-established (u) in each of the sampling unit.

Recruits: Recruits (r) are the current year's seedlings or plants less than 10 cm in height. (r) / **ha** $= 2500 \sum_{i=1}^{n} \frac{r_i}{m}$

Established regeneration: Established regeneration (e) is the number of Plants with height of more than 2 meter. (e)/ **ha** $= 2500 \sum_{i=1}^{n} \frac{e_i}{m}$

Un-established regeneration: Un-established regeneration (u) is the number of seedlings other than recruits which have not yet established and with height of less than 2m. **(u)/ha** $= 2500 \sum_{i=1}^{n} \frac{u_i}{m}$

Where:
n – Number of sampling units,
m – Total number of recording units in survey
r_i – Total number of recruits in each sampling unit
u_i – Total number of un-established plants in each sampling unit
e_i – Total number of established plants in each sampling unit
From the above estimates, the following indices were calculated

$$\textbf{Weight Average height (m)} = \frac{\text{Total height of unestablished regeneration} + (\text{No.of established plants x establishment height})}{\text{Total unestablished plants} + \text{total established Plants}}$$

$$\textbf{Establishment Index } (I_1) = \frac{\text{Weight Average height (m)}}{\text{Establishment height}}$$

$$\textbf{Stocking ex } (I_2) = \frac{1}{2500} \times \frac{\text{unestablished regeneration ha}^{-1}}{4} + \textit{Established regeneration}$$

Established stocking per cent = $100 \times (I_1 \times I_2)$
Regeneration Success (%) = Stocking index $(I_2) \times 100$

Result

Natural regeneration status of Picea smithiana

The assessment of regeneration is a vital aspect to estimate stocking index, composition, competition and problems of forests under management. The present study on natural regeneration status of *Picea smithiana* was assessed along the altitudinal gradient in South Kashmir J&K, India (Western Himalayas). The species was found mixed with Pine at lower altitude and with *Abies* at upper altitude. While as the well established stands of the species were found in the middle altitude.

Significant variation in the regeneration was recorded along the altitudinal gradients with respect to various parameters of regeneration, *viz*. number of recruits, number of un-established regeneration and number of established regeneration. Maximum number of recruits (1031.25 ha^{-1}), number of un-established regeneration (562.50 ha^{-1}) and number of established regeneration (273.44 ha^{-1}) was present at middle altitude (2,400-2,600 m). In terms of individual sites the maximum number of recruits, un-established regeneration and established regeneration with 1093.75, 593.75 and 281.25 plants ha^{-1} respectively was recorded at Pahalgam. Whereas the minimum number of recruits (562.50 ha^{-1}), number of un-established regeneration (328.13 ha^{-1}) and number of established regeneration (171.88 ha^{-1}) was recorded at Aharbal which represented the upper altitude (2,600-2,800) m (Table 2).

Establishment and stocking data of regeneration of Picea smithiana

The critical examination of the data on establishment and stocking of regeneration of *Picea smithiana* forest (Table 3) exhibited significant variation along the altitudinal gradients in South Kashmir Himalayas. The maximum height of un-established regeneration (5.80 m), weighted average height (99.32 m), stocking index (0.16) and establishment stocking per cent (5.64) was recorded at middle altitudinal gradient (2,400-2,600 m). Whereas the maximum establishment index (0.35) was recorded at upper altitude (2,600-2,800 m). In case of individual sites at different altitude the maximum height of un-established regeneration, stocking index and establishment stocking per cent of 6.08 m, 0.17 and 5.76 respectively was recorded at Pahalgam, while the maximum weighted average height of 99.69 m was recorded at Aru and highest establishment index (0.36) at Aharbal. Whereas the minimum un-established regeneration (4.74 m), weighted average height (85.44 m), stocking index (0.10) and establishment stocking per cent (3.73) was recorded at an upper altitudinal gradient 2,600-2,800 m while minimum establishment index of 0.33 m was recorded at lower altitudinal range (2,200-2,400 m).

The regeneration success per cent has also varied significantly along the altitudinal gradients and among all the selected sites. The maximum regeneration success per cent (16.56) was recorded at middle altitude (2,400-2,600 m) and minimum regeneration success per cent (10.78) was recorded at upper altitude (2,600-2,800 m). While as in case of individual sites, the maximum regeneration success per cent (17.19) was recorded at Pahalgam followed by Aru with 15.94 per cent (Table 3).

Discussion

Regeneration is a key feature of the forest dynamics, progress and restoration of degraded forest lands. It depends on member of seedlings/saplings and their distribution pattern in the region. If the seedlings/saplings are less than the mature trees, it indicates declining trend and poor regeneration capacity. Variation in regeneration pattern is observed vis-à-vis differences in the constituent species and environmental variables in which they grow (Denslow, 1987; Whitemore, 1996) [6, 24]. Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of these conditions is a major determinant of its geographic distribution (Grubb, 1977) [8]. Regeneration of forest tree species under natural habitat is important in modern forestry. Working plans for regeneration are carried out to compare the status at the beginning and at completion of the plan, so as to prepare a stock map for the area proposed to be regenerated.

Variation in the regeneration were recorded at all the three altitudinal gradients in South Kashmir with respect to various regeneration parameters *viz*. number of recruits, number of un-established regeneration and number of established regeneration. Maximum number of recruits (1031.25 ha^{-1}), number of un-established regeneration (562.50 ha^{-1}), and number of established regeneration (273.44 ha^{-1}) were recorded at middle altitude (2,400-2,600 m) and minimum number of recruits (617.19 ha^{-1}), un-established regeneration (359.38 ha^{-1}) and established regeneration (179.69 ha^{-1}) were recorded at higher altitudinal elevation (2,600-2,800 m). Regarding individual sites maximum number of recruits (1093.75 ha^{-1}), number of un-established regeneration (593.75 ha^{-1}), and number of established regeneration (281.25 ha^{-1}) were recorded at Pahalgam site.

Maternal effect in trees growing at a particular altitude plays a role through seed mass, which can affect the seedling growth rate during first year (Oleksyn *et al*., 1998) [19]. At higher altitudes seed germination per cent is initially low after seed dispersal, but subsequently the remaining dormant seeds grow in the next season, involving opportunistic, adaptive strategy to take advantage of weather/climatic conditions that subsequently helps natural selection (Isik, 1986) [10].

Establishment and stocking of regeneration of spruce (*Picea smithiana*) exhibited significant variation at all the three altitudinal gradients and individual sites. It was found that maximum height of un-established regeneration (5.80 m), weighted average height (99.32 m), stocking index (0.16), establishment stocking per cent (5.64) and regeneration success (16. 56%) were recorded at middle altitude (2,400-2,600 m) and maximum established index (0.35) were recorded at higher altitude (2,600-2,800 m). Regarding individual sites the maximum height of un-established regeneration (6.08 m), stocking index (0.17), establishment stocking per cent (5.76) and regeneration success (17.19%) were recorded at Pahalgam site. Similarly maximum weighted average height (99.69 m), were recorded at Aru site and maximum established index (0.36) were recorded at Aharbal site. Yashpal (2006) [25] reported that natural regeneration of spruce and fir was poor in all the selected sites of Jubbal forests (H.P). A high of 33.11 per cent stocking was observed at middle elevation, which decreased at higher altitudinal elevations. Mir *et al.,* (2017) [16] also reported the decrease in the regeneration pattern of *Betula utilis* in north western Himalayas of Kashmir with the maximum regeneration success percentage of 11.53 and 11.16%. Thadani and Ashton (1995) [22] and Mir *et al*., (2017) [16] from their respective studies concluded that dense canopy of the forest does not promote satisfactory establishment of the understory, the moderate disturbance appears to benefit the regeneration success, Besides browsing, growth rate and species composition of the natural regeneration success are mainly determined by the light conditions. Malik *et al*. (2012) [15] reported that the maximum established regeneration of *Pinus geradiana* was 291.66 ha^{-1} in Kinaur district of H.P. Overall natural regeneration was poor. Lanker *et al*. (2010) [14] reported that recruitment of *Taxus baccata* was maximum at higher elevation due to reduced anthropogenic pressures, while at lower altitude association species had better recruitment and regeneration.

The regeneration was not satisfactory at all the three altitudes in spruce (*Picea smithiana*) which is mainly due to low seed production, wide gap between good seed years, human interference, and grazing by sheep and goat and other climatic factors. Natural regeneration of different tree species through seed depends upon their production and germination capacity and subsequent successful establishment of seedlings/saplings. Seeds from healthy well-formed trees provide greater assurance that the resulting stock will have good form, survival and resistance against stress conditions. Under favorable conditions a higher growth rate increases species competitive ability, survival and long term success. Growth rate is therefore a crucial rate, especially in the first year of establishment (Vitasse *et al*., 2009) [23]. During our study seedlings were found growing in large quantities under shade and moisture availability. The results are in line up with Acharya (2004) [1], in mixed *Abies spectabilis* forest of Manang, where high human interference was the main factor leading to the destruction of species of high girth classes and less natural regeneration of *Abies spectabilis* due to low

moisture and high human pressure. Parkash (1991) [20] indicated that favourable conditions of snowfall, good seed year and soil conditions in respect of raw humus, resulted in profuse natural regeneration in the *Cedrus deodara*. Environmental factors in combination with genetic and physiological ones play an important role in determining a forest tree species potential for seed quality. Depending on the tree species, seed germination response is affected by latitude, altitude, soil moisture, soil nutrient profile, temperature, light, and density of plant cover and decomposition status of humus, thickness of forest litter and degree of habitat intervention by man/animals (Mukherjee *et al*., 2004) [18]. Lack of sufficient regeneration is a major problem of mountain forests and most sub-alpine forests have poor seedling recruitment in under storeys of undistributed old growth forests (Mori and Takeda, 2004) [17].

Table 2: Regeneration status of spruce (*Picea smithiana*) at different altitudes in south Kashmir.

Altitude (m)	Sites	Recruits (ha^{-1})	Un-established regeneration (ha^{-1})	Established regeneration (ha^{-1})
2,200-2,400	Ahlan	921.88	515.63	234.38
	Daksum	796.88	421.88	203.13
Mean		859.38	468.75	218.75
2,400-2,600	Pahalgam	1093.75	593.75	281.25
	Aru	968.75	531.25	265.63
Mean		1031.25	562.50	273.44
2,600-2,800	Mughal Road	671.88	390.63	187.50
	Aharbal	562.50	328.13	171.88
Mean		617.19	359.38	179.69

Table 3: Establishment and stocking data for spruce (*Picea smithiana*) at different altitudes in south Kashmir.

Altitude (m)	Sites	Height of un-established Regeneration (m)	Weighted average height (m)	Established index (I_1)	Stocking Index (I_2)	Established stocking percent (%)	Regeneration success (%)
2,200-2,400	Ahlan	5.78	89.29	0.33	0.15	4.75	14.53
	Daksum	4.38	86.81	0.34	0.12	4.15	12.34
Mean		5.08	88.05	0.33	0.13	4.45	13.43
2,400-2,600	Pahalgam	6.08	98.95	0.34	0.17	5.76	17.19
	Aru	5.53	99.69	0.35	0.16	5.52	15.94
Mean		5.80	99.32	0.34	0.16	5.64	16.56
2,600-2,800	Mughal Road	4.56	85.14	0.34	0.11	3.84	11.41
	Aharbal	4.93	85.74	0.36	0.10	3.63	10.16
Mean		4.74	85.44	0.35	0.10	3.73	10.78

Conclusion

Regeneration status in the natural habitat was poor at all sites across the altitudinal gradients. The number of seedlings, saplings, trees, recruits, un-established regeneration, established regeneration and regeneration success per cent was maximum at middle altitudinal gradient. Anthropogenic/animal interventions need to the minimized. Logging of mature trees should be based on scientific operations to reduce physical damage to the young seeding/sapling population.

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