*Indian Journal of Agricultural Sciences* **87** (7): 911–6, July 2017/Article
https://doi.org/10.56093/ijas.v87i7.71836

# Regeneration status of bhojpatra (*Betula utilis*) forest in north western Himalayas of Kashmir valley, India

NASEER A MIR[1], T H MASOODI[2], SYED MAQBOOL GEELANI[3], AKHLAQ AMIN WANI[4] and P A SOFI[5]

*Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal, Jammu and Kashmir 191 201*

Received: 29 November 2016; Accepted: 3 January 2017

ABSTRACT

The regeneration status of bhojpatra or Himalayan birch (*Betula utilis* D. Don) was assessed in the two forest divisions of Kashmir with the major focus on regeneration status pertaining to the poor recruitment and seedling establishment in north western Himalayas along the different altitudinal gradient. The regeneration in both the forest divisions was poor and decreased further with increasing altitude but did not show any definite trend along the altitudinal gradient. Density-diameter and regeneration success curve for *Betula utilis* was not continuous and displayed typical reverse J-shaped structure depicting un-sustainable regeneration success along the altitude. Density of recruits was greater than the density of seedlings (un-established regeneration) indicating anthropogenic interference in terms of grazing and lopping of mature trees for fodder and other uses. The overall regeneration successes varied between 3.38-10.95% on south eastern aspect and 4.47 to 11.16% on south western aspect in Sindh forest division and between 4.84-11.53% in Tangmarg forest division. The diversity index (H/) *Betula utilis* decreased within the upper diameter classes with maximum diversity in lower diameter (0-25 cm). The correlation between soil parameters, viz. pH, EC, carbon, nitrogen and phosphorus depicted the significant positive as well as negative trends with regeneration parameters.

**Key words:** *Betula utilis*, Density-diameter, Regeneration status, Sindh forest division, Tangmarg forest division

The natural regeneration; as a process of re-growing or reproducing new individual plants in a forest stand, is in particular the most important process to maintain the stable structure of the plant species in a community (Singh and Singh 1992). The population structure of a species in a forest is characterized by the presence of sufficient population of seedlings, saplings and adults that determine its regeneration behaviour and the future composition of a community. Regeneration status of trees can therefore be predicted by the age and structure of their populations (Khan *et al*. 1987). The study of regeneration of trees has important implications for the management of natural forests and is one of the thrust areas of research in modern ecology as studies have shown that regeneration of tree species in a forest is affected by its canopy density, community structure soil moisture and anthropogenic pressures (Murthy *et al*. 2002) although the role of these functional dimensions in high elevation ecosystems is still unfamiliar.

The spatial patterns of vegetation composition and seedling recruitment bhojpatra or Himalayan birch (*Betula utilis* D. Don) in India particularly in Jammu and Kashmir is yet to invite the attention of researchers. The lack of information on community attributes of this treeline species and its ecology are the two major concerns to devise a management plan for restocking these high mountain forests (Shrestha *et al*. 2007, Krauchi *et al*. 2000). The ease and suitability of propagation methods for this species are also not well documented in the literature. With these shortcomings in view the present study was undertaken to document the regeneration status of two prominent *Betula utilis* dominated forest stands comprising treeline in two high altitude forests divisions of Himalayas of Kashmir.

## MATERIALS AND METHODS

The present study was carried out along the three altitudinal gradients of 3000–3200 m, 3200–3400 and 3400–3600 m amsl in different *Betula* stands at Sonamarg in Sind forest division and Gulmarg in Tangmarg forest division. The Sindh forest division with the total area of 37901 ha lies between 34°72.04′ and 34°28.25′ north 74°42.32′ to 75°26.57′ east. The tract of the selected site in this forest division is extremely mountainous and full of ridges with rugged terrain. The altitude of this forest division ranges from 1587 m to 5248 m with dominant *Betula* stands forming their niche between 3000–3750

[1,2,3,4,5]Faculty of Forestry (email: naseer.mir1@gmail.com) SKUAST of Kashmir, Benkama, Ganderbal, Jammu and Kashmir 191 201. [3]Devision of Environmental Science, Sri Pratap Singh College, Srinagar, J & K 190021.

m asl. The study site is located between the altitudes of 3000–3600 m. The whole forest division forms a catchment area which drains into Sindh river with many smaller nallas from side valleys tributing to it. The Special forest division Tangmarg is spread over an area of 76585 ha and located between 34°011.23′ north latitude and 74°22.03′ east. The birch stands in this forest division at Gulmarg lie on steep to very steep south facing slopes with an average inclination of 40º. The Birch stands with an altitudinal range of 3000–3700m is surrounded by high mountains of Nanga Parbat and Harmukh mountains. The study sites exhibits temperate climate experiencing four distinct seasons: a severe winter (December to February), a cold spring (March to May), a mild summer (June to August) and an autumn (September to November. The mean annual minimum (January) and maximum (July) temperature along the selected timberline ecotone ranges from –8.1 to 19.01°C and –4.4 to 17.6°C at Sonamarg and Gulmarg respectively. The mean temperature of the warmest month is July with 22.0°C. The average annual precipitation at Sonamarg and Gulmarg varies from 932–1050 mm and 1049–1100 mm out of which about 73 and 69% is recorded during winter and spring and the rest during autumn, respectively. The snow cover at the selected sites lasts for about 195 and 180 days/year.

The major portion of Sindh forest division is covered by massive panjal traps with little vegetation, while as the recent alluvium and karewa deposits cover the remaining area leaving very small portion occupied by Triassic limestone and other formations of the older age. The main litho units exposed are traps, slates, quartzites, limestone and shales besides the alluvium and karewa clays (Wadia 1953). At the study site the strata dips steeply and is followed by great thickness of upper Trias limestone and Jurassic formation. The underlying rock determines various soil formations. The depth of the soil depends upon the slope and the dip of the rock. In general steeper the slope shallower the soil.

The soil in *Betula* stands at Tangmarg forest division comprises glacial deposits, lacustrine-deposits and moraines of pleistocene era covering shales, limestones, sandstones, schists and other varieties of rocks. The study site comprises rugged slopes and is spread out under the grandeur of Apharwat Range. The soils are loam or silty loam with snowmelt water being main source of soil moisture for forest growth which is mostly confined to the moist slopes of the valley. The area offers skiing and other winter sports generally carried out on the slopes of Apharwat peak at the height of 4267 m (13999 ft) which displays panoramic view (Table 1).

The prominent forest vegetation is mostly confined to the moist north-facing slope and the valley floor in both the study sites. However, isolated trees and small stands of *Juniperus* spp at lower elevations and *Betula utilis* at higher elevations are found on the sunny slope. On the north-facing slope the lower belt (3000–3500 m) has blue pine and juniperforests, while the upper belt (up to 3300 m) has fir (*Abies pindrow*) and birch (*Betula utilis*) forests up to the treeline (3600 m). *Betula utilis* has descended to the valley floor (3000 m) along the moist water course. It is also found in isolated stands on the southwest-facing slope of the valley where soil moisture is relatively high. The moist alpine scrub above the treeline on the north-facing slope is dominated by *Rhododendrons* and *Juniperus* spp. On the dry southern slope alpine scrub has dwarf and prostrate junipers, *Rosa* spp. and *Berberis* spp.

The regeneration survey was carried out in all the sample plots on each elevation at both the selected sites. In each major plot of 30×30 m, twenty quadrates measuring 2×2m were laid. Twenty five hundred (2500) established plants/ha were considered to express satisfactory regeneration. Similarly, the quadrate was considered fully stocked when it contained at least one established plant (Chacko 1965).

The regeneration status of *Betula utilis* forest stands 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.

$$(r)\ /\text{ha} = 2500 \sum_{i=1}^{n} \frac{r_i}{m}$$

*Established regeneration:* Established regeneration (e) is the number of Plants with height of more than 2 meter.

$$(e)/\text{ha} = 2500 \sum_{i=1}^{n} \frac{e_i}{m}$$

*Un-established regeneration:* Un-established

Table 1 Altitude wise geographical attributes selected sites at Sonamarg and Gulmarg

| Site | Altitude | Longitude | Latitude | Soil type | Slope |
|---|---|---|---|---|---|
| Sonamarg | 3000m-3200m | 340 17.98′ N | 0750 17.39′E | Clay Loam | 32.28o |
| (South East) | 3200m-3400m | 340 18.12′ N | 0750 18.72′E | Loam | 42.23o |
| | 3400m-3600m | 340 18.89′ N | 0750 18.96′E | Silt Loam | 43.17o |
| Sonamarg | 3000m-3200m | 340 17.39′ N | 0750 15.88′E | Clay Loam | 39.33o |
| (South West) | 3200m-3400m | 340 18.09′ N | 0750 16.20′E | Loam | 42.11o |
| | 3400m-3600m | 340 18.76′ N | 0740 16.82′E | Silt Loam | 43.23o |
| Gulmarg | 3000m-3200m | 340 01.98′ N | 0740 21.30′E | Loam | 38.41o |
| (South West) | 3200m-3400m | 340 02.09′ N | 074021.25′E | Silt Loam | 45.56o |
| | 3400m-3600m | 340 02.685′ N | 074022.68′ E | Silt Loam | 41.06o |

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

$$\text{Weight average height (m)} = \frac{\text{Total heights of unestablished regeneration + (No. of established plants × established heighs)}}{\text{Total unestablished plants + total established plants}}$$

$$\text{Establishment Index } (I_1) = \frac{\text{Weight average height (m)}}{\text{Establishement height}}$$

Stocking Index ($I_2$) =

$$\frac{1}{2800} \times \frac{\text{unestablished regeneration ha}^{-1}}{4} + \text{Established regeneration}$$

Established stocking per cent = 100 × ($I_1$ × $I_2$)

Regeneration Success (%) = Stocking index ($I_2$) × 100

The soil samples were air dried and processed through a 2 mm sieve whilst twigs, roots and gravel were removed. The sieved fraction of soil was homogenized and used for analysis of different physico-chemical parameters as per standard procedures described by Jackson (1967) and Misra (1968).

## RESULTS AND DISCUSSION

### *Natural regeneration status of* Betula utilis

Assessment of natural regeneration is an important aspect to evaluate stocking, and composition, competition, problems of forests under management. In the present study, mean natural regeneration status of *Betula utilis* was assessed in two forest divisions in Jammu and Kashmir, India (Western Himalayas). The distribution of *Betula utilis* in western Himalayas is purely restricted to sub-alpine region with a mixed stands at lower altitude between 3000-3300 m amsl and pure stands at upper altitude (3300-3600) with occasional stems of *Abies pindrow* on Southern aspects. The well established stands of the species were found in the middle altitude (3200-3400 m amsl).

Significant variation in the regeneration was recorded along altitudinal gradients at Sonamarg and Gulmarg (Sindh and Tangmarg forest divisions) with respect to various parameters of regeneration, viz. number of recruits, number of un-established regeneration, number of established regeneration and height of un-established regeneration (Table 2). Maximum number of recruits (1 375 and 1 368/ha), number of un-established regeneration (343.75 and 353.75/ha), number of established regeneration (187.81 and 190.63/ha) and height of un-established regeneration (4.70 and 4.94 m) was present at middle altitude and minimum number of recruits (593.75 and 656.25/ha), un-established regeneration (187.50 and 196.88/ha), established regeneration (37.50 and 62.50/ha) and height of un-established regeneration (1.71 and 1.88 m) on upper altitudinal gradient on south eastern and south western aspects at Sonamarg (Sindh forest division). Similarly at Gulmarg (Tangmarg forest division), the maximum number of recruits (1 031.25/ha), un-established regeneration (359.38/ha) established regeneration (198.44/ha) and height of un-established regeneration (5.06 m) was recorded on middle altitudinal gradient. The minimum number of recruits (531.25/ha), un-established regeneration (193.88/ha), established regeneration (65.63/ha) and height of un-established regeneration (1.93 m) was recorded at upper altitudinal gradient.

Table 2 Natural regeneration status of *Betula utilis* across the available aspects and altitudinal gradients in *Betula* dominant tree stands at Sonamarg and Gulmarg Forest Ranges

| Site/ Aspect | Altitude (masl) | Recruits (/ha) | Unestablished regeneration (/ha) | Established regeneration (/ha) | Height of unestablished regeneration (m) |
|---|---|---|---|---|---|
| Sonamarg (South East) | 3000-3200 | 937.50 | 218.75 | 125.00 | 2.43 |
| | 3200-3400 | 1375.00 | 343.75 | 187.81 | 4.70 |
| | 3400-3600 | 593.75 | 187.50 | 37.50 | 1.71 |
| Sonamarg (South West) | 3000-3200 | 968.75 | 215.63 | 135.00 | 2.62 |
| | 3200-3400 | 1368.00 | 353.75 | 190.63 | 4.94 |
| | 3400-3600 | 656.25 | 196.88 | 62.50 | 1.88 |
| Gulmarg (South West) | 3000-3200 | 812.50 | 226.56 | 140.63 | 3.05 |
| | 3200-3400 | 1031.25 | 359.38 | 198.44 | 5.06 |
| | 3400-3600 | 531.25 | 193.88 | 65.63 | 1.93 |

### *Establishment and stocking data of regeneration of* Betula utilis

The critical examination of the data on establishment and stocking of regeneration of *Betula utilis* forest (Table 3) exhibited significant variation along the altitudinal gradients

Table 3 Establishment and regeneration per cent of *Betula utilis* across the available aspects and altitudinal gradients at *Betula* dominant tree stands in Sonamarg and Gulmarg forest ranges

| Site/ Aspect | Altitude (masl) | Weighed average height (m) | Established index (I1) | Stocking Index (I2) | Established stocking per cent | Regeneration success (%) |
|---|---|---|---|---|---|---|
| Sonamarg (South East) | 3000-3200 | 74.50 | 0.372 | 0.072 | 2.69 | 7.21 |
| | 3200-3400 | 80.42 | 0.367 | 0.110 | 4.02 | 10.95 |
| | 3400-3600 | 34.76 | 0.174 | 0.034 | 0.59 | 3.38 |
| Sonamarg (South West) | 3000-3200 | 78.40 | 0.392 | 0.075 | 2.95 | 7.53 |
| | 3200-3400 | 86.20 | 0.364 | 0.112 | 4.06 | 11.16 |
| | 3400-3600 | 49.62 | 0.248 | 0.045 | 1.11 | 4.47 |
| Gulmarg (South West) | 3000-3200 | 78.48 | 0.392 | 0.079 | 3.10 | 7.89 |
| | 3200-3400 | 82.59 | 0.370 | 0.115 | 4.27 | 11.53 |
| | 3400-3600 | 47.14 | 0.236 | 0.048 | 1.14 | 4.84 |

at both Sonamarg and Gulmarg (Sindh and Tangmarg forest divisions). The maximum weighted average height (80.42 and 86.20 m), stocking index (0.110 and 0.112) and establishment stocking per cent (4.02 and 4.06) was recorded at middle altitudinal gradient and minimum was recorded at upper altitudinal gradient on south eastern and south western aspect at Sonamarg (Sindh forest division). Similarly the maximum weighted average height (82.59 m), stocking index (0.115) and establishment stocking per cent (4.27) at Gulmarg (Tangmarg forest division) was recorded at middle altitudinal gradient.The regeneration success varied along the altitudinal gradient but did not varied to great extent along the aspects at both the sites, the maximum was recorded at middle altitude and minimum at upper altitude at both the sites, which varied between 3.38 to 10.95% on south eastern aspect and 4.47 to 11.16% on south western aspect in Sonamarg (Sindh forest division). While the regeneration success in Gulmarg (Tangmarg forest division) varied between 4.84 to 11.53%.

*Betula* are prolific seed producers, but there is wide annual variation in the quantity and quality of the seed crop. Abundant seed crops are generally repeated at 2–3 years intervals with good dispersal ability (Wagner *et al.* 2004). Their germination is regulated by the interaction of photoperiod and temperature (Vanhatalo *et al.* 1996). The regeneration behavior of *Betula* is therefore, characterized by their population structure which depends upon the presence of adequate number of mature trees in any given area. Most studies on subalpine forests have reported poor seedling recruitment in under stories of undisturbed old-growth forests (Mori and Takeda 2004). In these habitats canopy gap formation, controlled form of lopping and grazing and a favourable composition of herb layer seems to be highly responsible for successful regeneration (Subedi and Shakya 1999). While dense canopy of the forest does not promote satisfactory establishment of the understory, the moderate disturbance appears to benefit the regeneration, Besides browsing, growth rate and species composition of the natural regeneration are mainly determined by the light conditions (Thadani and Ashton 1995). Populations of *Betula nigra* have been found to regenerate profusely with the result of high seed production, vigorous colonization and early growth in the areas with full sun and adequate moisture (Wolfe and Pittillo 1999). The proceeding pattern of regeneration is often attributed to the better edaphic factors which appear to favour establishment of early successional deciduous broadleaved species like *Betula utilis*, (Shrestha *et al*. 2007). Moreover, opening of canopy increases light intensity in the forest floor and reduces litter accumulation which is suitable for seed germination and seedling establishment of early successional species (Grime 2001).

The opening of canopy also exposes the mineral soils, which might be suitable for seed germination and seedling survival as reported for *Betula alleghaniensis* (Peterson and Pickett 2000). Human impact has been used to explain obtaining best regeneration in the least disturbed sites (Maren and Vetaas 2007). Further, the sites exposed to direct sunlight have been found to be more stable than deep shaded forest floor for seedling growth of *Betula* spp. provided that moisture and nutrients are adequate (Carlton and Bazzaz 1998). Similar results have been reported by Rikhari *et al.* (2000) and Lanker *et al.* (2010) in *Texus* species. Singh *et al.* (1987) reported similar results on natural regeneration process of fir and spruce in Narkanda forests of Himachal Pradesh. The results of present study are also in accordance with the findings of Malik *et al*. (2012) for *Pinus gerardiana* and Lanker *et al.* (2010) for *Taxus wallichiana*. The overall poor regeneration of *Betula utilis* in both the forest divisions might be due to the high anthropogenic pressure, intensive grazing and lopping which reduces seed production that ultimately changes the species composition and even the seral stage of forests in the subalpine zones (Shrestha *et al.* 2007, Shamet and Gupta 2005).

*Diversity index of* Betula utilis *in the different diameter classes*

The analysis of Shannon Weiner diversity index (H′) among the different diameter classes of *Betula* trees revealed that the maximum diversity of 0.361 and 0.352 was observed in lower diameter class (0-25 cm) and lowest diversity of 0.181 and 0.300 in higher diameter class (>50 cm) of Sonamarg and Gulmarg (Sindh and Tangmarg forest divisions) (Fig 1). Further, when the average diversity values were compared across the diameter classes in both the divisions, the diversity of *Betula* trees at Gulmarg (0.323) was found to be significantly higher

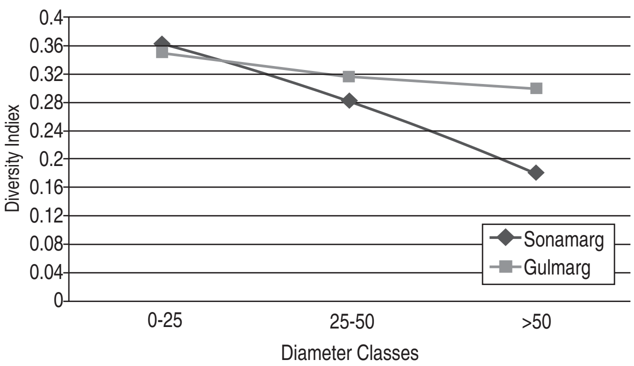


Fig 1 Shannon-Wiener Diversity index (H') of *Betula utilis* in the different girth classes (cm) at Sindh and Tangmarg forest division

than its diversity at Sonamarg (0.275).

The values of Shannon Weiner diversity index (H´) for various diameter classes of *Betula* revealed that the highest diversity (0.361 and 0.352) was observed in lower size classes and lowest diversity (0.181 and 0.300) in higher diameter class in Sonamarg and Gulmarg (Sindh and Tangmarg forest divisions). The diversity values calculated across the girth classes of *Betula* were found to be negatively co-related with each other. The diameter class diversity analysis gives the scenario of the forest stand structure as expanding type with more number of trees in lower size class, reduction in the next subsequent classes and again a slight increase for the highest size class (class >50). The trend of decreasing species diversity density and height with the increasing tree size is similar to that observed by Prasad *et al.* (2007) and Mir *et al*. (2016). A low diversity was recorded in the girth class of >50 cm indicating the low population of mature trees and giving impression of ongoing secondary successional stages within these forest stands. Generally during the early stages of community succession, the number of younger stems will be more and as community becomes older, the number of younger stems decreases and mature trees increase. The girth class distribution for *Betula* in two forest divisions showed the dominance of lower and middle girth classes. The decline in the stem count in highest girth class of >50 cm might be due to high anthropogenic pressure, viz. fuelwood collection, harvesting of small size stems for fencing and other household consumption.

*Correlation studies between soil and regeneration parameters*

Correlation studies between different regeneration parameters and soil parameters at in Sonamarg and Gulmarg (Sindh and Tangmarg forest division) (Table 4) revealed that the pH was negatively (significant) correlated with EC, OC, recruits and un-established regeneration but positively correlated with N and establishment regeneration. Electrical conductivity was negatively correlated with N, un-established regeneration and regeneration success but positively correlated with OC and Recruits, whereas OC was negatively correlated with nitrogen, recruits and un-established regeneration and positively correlated with regeneration success. Available nitrogen exhibited positive (significant) correlation with Recruits and un-established regeneration and regeneration success.

The correlation study between soil and regeneration attributes showed a high synchrony throughout the altitudinal gradients. The species cannot get established in particular area without presence of adequate soil nutrients and proper edaphic condition. Similar relationship between soil variables has been reported by Gupta and Sharma (2008) who attributed the situation to intimate link of soil characteristics with vegetation development and regeneration parameters. According to Jha *et al.* (2002), if the soil is rich in SOM content, it will be definitely rich in total N, P and K contents. Gairola (2012) concluded that organic C showed a positive correlation with total N (0.840), available P (0.520) and available K (0.520). There is considerable evidence that temperate of broad-leaved and conifer tree species alter soil C and N dynamics and are thereby intimately related (Binkely and Giardina 1998). A study by Cote *et al*. (2000) concluded that both organic C and N were significantly affected by factors such as stand type, stand age, and the interaction between age, species composition, diversity, species richness and soil properties. Lanker *et al*. (2010) has found that regeneration parameters and soil has close relationship for the establishment of particular species.

The overall regeneration success of *Betula* at both the sites was poor and did not show any definite trend along the altitudinal gradients. The maximum regeneration success at

Table 4 Correlation matrix between soil parameters and regeneration parameters

| Parameters | Ph | EC μ/Scm$^{-1}$ | C (%) | N kg/ha | Recruits/ha | UER/ha | ER/ha | RS (%) |
|---|---|---|---|---|---|---|---|---|
| Ph | 1 | | | | | | | |
| EC μS/cm | -0.963** | 1 | | | | | | |
| C (%) | -0.988** | 0.989** | 1 | | | | | |
| N kg/ha | 0.900* | -0.983** | -0.947** | 1 | | | | |
| Recruits/ha | -0.263** | 0.378** | -0.307* | 0.431** | 1 | | | |
| UER/ha | -0.080* | -0.033** | -0.061* | 0.020* | 0.842* | 1 | | |
| ER/ha | 0.202* | -0.063 | -0.150 | -0.024 | 0.876* | 0.905* | 1 | |
| RS (%) | 0.190 | -0.076* | 0.149* | 0.008* | 0.878* | .0946** | 0.993** | 1 |

UER= Un-established regeneration; ER = Established regeneration; R= Regeneration Success. *Significant at the 0.05 level, **Significant at the 0.01 level.

both the sites was 10.95 and 11.16% on south eastern and south western aspect at Sonamarg (Sindh forest division) and 11.53% at Gulmarg (Tangmarg forest division) on middle altitudinal gradient and minimum 3.38, 4.47% and 4.84 % on upper altitudinal gradient in both the divisions. The reason behind the poor seedling recruitment along the elevation might be due to the anthropogenic factors especially cattle grazing and logging.

## REFERENCES


Binkley D and Giardina C. 1998. Why do species affect soils? The warp and woof of tree-soil interaction. *Biogeochemistry* **42**(2): 89–106.

Carlton G C and Bazzaz F A. 1998. Regeneration of three sympatric birch species on experimental hurricane blowdown microsites. *Ecological Monographs* **68:** 99–120.

Cavaliere C. 2009. The effect of climate change on medicinal and aromatic plants. *Herbal Gram* **81:** 44–57.

Chacko V J 1965. A manual of sampling technique for forest surveys. Manager Publications, Delhi, p 172.

Cote L, Brown S, Pare D, Fyles J and Bauhus J. 2000. Dynamics of carbon and nitrogen mineralization in relation to stand type, stand age and soil texture in the boreal mixed wood. *Soil Biology and Biochemistry* **32**(8-9): 1 079–90.

Gairola S, Rawal R S and Todaria N P. 2008. Forest vegetation patterns along an altitudinal gradient in sub-alpine zone of west Himalaya, India. *African Journal of Plant Science* **2**(6): 42–8.

Gairola S, Sharma C M and Ghildiyal S K. 2012. Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya. *Environmentalist* **7:** 212–9.

Glatzel G. 2009. Mountain forests in a changing World- an Epilogue. *Mountain Research and Development* **29:** 188–90.

Grime J P. 2001. *Plant Strategies, Vegetation Process, and Ecosystem Properties*, p 51 Wiley, Chichester, United Kingdom.

Gupta M K and Sharma S D. 2008. Effect of tree plantation on soil properties, profile morphology and productivity index I. Poplar in Uttarakhand. *Annals of Forest* **16**(2): 209–24.

Jackson M L. 1967. *Soil Chemical Analysis,* p 498. Prentice Hall of India Pvt Ltd, New Delhi.

Jha M N, Gupta M K and Dimri B M. 2002. Impact of changing natural forest cover and site conditions on the soil resources in western Himalayan region. (*In*) *Natural Resources of Western Himalaya,* pp 23–42. Pandit Ashok K (Ed). Valley Book House, Srinagar.

Khan M, Rai J P N and Tripathi R S. 1987. Population structure of some tree species in disturbed and protected sub tropical forests of northeast India. *Acta Ecology* **8:** 247–55.

Krauchi N, Brang P and Schonenberger W. 2000. Forests of mountainous regions: Gaps in knowledge and research needs. *Forest Ecology and Management* **132:** 73–82.

Lanker U, Malik A R, Gupta N K and Butola J S. 2010. Natural regeneration status of the endangered medicinal plant, *Taxus baccata* Hook. F. syn. *T. wallichiana*, in northwest Himalaya. *International Journal of Biodiversity Science, Ecosystem Services and Management* **6**(1–2): 20–7.

Maren I E and Vetaas O R. 2007. Does regulated land use allow regeneration of keystone forest species in the Annapurna Conservation Area, Central Himalaya. *Mountain Research and Development* **27:** 345–52.

Mir N A, Masoodi T H, Mir A A, Khan H, Sofi P A, Wani F J and Hameed O B. 2016. Phenology and growth performance of Himalayan birch (*Betula utilis*) in Kashmir Western Himalayas along the different altitudinal gradients. *Indian Journal of Agricultural Sciences* **86** (8): 1 086–91.

Misra R. 1968. *Ecology Work Book,* pp 131-3. Oxford and IBH Publishing Company, Kolkata.

Mori A and Takeda H. 2004. Effects of undisturbed canopy structure on population structure and species coexistence in an old-growth subalpine forest in central Japan. *Forest Ecology and Management* **200:** 89–101.

Murthy I K, Murali K S, Hegde G T, Bhat P R and Ravindranath N H. 2002. A comparative analysis of regeneration in natural forest and joint forest management plantations in Uttara Kannada Dist.,Western Ghats. *Current Science* **83:** 1 358–64.

Peterson C J and Pickett S T A. 2000. Patch type influences on regeneration in a western Pennsylvania, USA, catastrophic windthrow. *Oikos* **90:** 489–500.

Prasad P R C, Reddy C S and Dutt C B S. 2007. Phytodiversity assessment of tropical rainforest of north Andaman Islands, India. *Jornal of Forestry* **1**(1): 27–39.

Rikhari H C, Sharma S, Nadeem M and Palni L M S. 2000. Himalayan yew: stand structure, canopy damage, regeneration and conservation strategy. *Environmental Conservation* **25**(4): 334–41.

Shamet G S and Gupta N K 2005. Survey, regeneration and planting studies in yew (*Taxus baccata*): an endangered medicinal species of Himalaya. Report of National Medicinal Plant Board, GOI, p 25.

Shrestha B B, Ghimire B, Lekhak H D and Jha P K. 2007. Regeneration of treeline birch (*Betula utilis* D. Don) forest in a trans-Himalayan dry valley in Central Nepal. *Mountain Research and Development* **27**(3): 259–67.

Singh JS and Singh SP. 1992. Forests of Himalaya: Structure, Functioning and impact of man. Gyanodaya Prakashan, Nainital, India.

Singh V, Bhagat S, Arya S R. 1987. Litter fall and natural regeneration of spruce and silver fir. *Indian Forester* **113**(9): 616–21.

Subedi M N and Shakya P R. 1999. Productions dynamics, conservation and management implications of *Quercus semecarpifolia* Sm. forest on Mount Phulchoki, Central Nepal. *Indian Journal of Ecology* **26:** 97–106.

Thadani R and Ashton P M S. 1995. Regeneration of banj oak (*Quercus leuchotrichophora* A. Camus) in the Central Himalaya. *Forest Ecology and Management* **78:** 217–25.

Timilsina N, Ross M S and Heinen J T. 2007. A community analysis of sal (*Shorea robusta*) forests in the western Terai of Nepal. *Forest Ecology and Management* **241:** 223–34.

Vanhatalo V, Leinonen K, Rita H and Nygren M. 1996. Effect of prechilling on the dormancy of *Betula pendula* seeds. *Canadian Journal Forest Research* **26:** 1203–8.

Wadia D N. 1953. op. cit., pp. 363-65, a Kosi Dam Project, Preliminary Report, CW1NC 1953, Delhi, p 22.

Wagner S, Walder K, Ribbens E and Zeibig A. 2004. Directionality in fruit dispersal models for anemochorous forest trees. *Ecological Modellinh* **179:** 487–98.

Wolfe C B and Pittillo J D. 1977. Some ecological factors influencing the distribution of *Betula nigra* L. in western north Carolina. *Castanea* **42:** 18–30.