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Influence of Site Characteristics on Natural Regeneration of *Rhododendron campanulatum* D. Don Bearing Forests in Alpine Region

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***Abstract*:** The present investigation was carried out on influence of site characteristics on natural regeneration of *Rhododendron campanulatum* D. Don bearing forests in alpine during 2017-19 with the aim to study the effect of site characteristics (aspect, elevation, solar influx, soil N, P and K) in Dodra Kwar and Khashdhar Forest Ranges of Himachal Pradesh India. The study area was divided into three elevation zones, E1=3000-3200 m, E2 =3200-3400 m and E3 = 3400 m above m in northern and southern aspect. Available N, P, K was highest on northern aspect as compared to southern aspect. Maximum solar influx per cent was reported on southern aspect as compared to northern aspect in both forest ranges. The main factors responsible for adequate regeneration of *R. campanulatum* were ample amount of snowfall, soil moisture, available N, P, K, solar influx, aspect, and elevation.

***Keywords*:** Aspect, Elevation, Regeneration, Solar influx, Site characteristics

The genus *Rhododendron* (Family- Ericaceae) was first described by Carl Linnaeus in 1737 in Genera Plantarum. Over 900 species of Rhododendrons have been discovered with most of them distributed from South to Southeast Asia, ranging from the Himalaya through India, Tibet, China to Vietnam, Malaysia, Indonesia, Philippines and New Guinea. In India, there are about 80 species of Rhododendrons, mainly found in Arunachal Pradesh, Sikkim, Manipur, Nagaland, Himachal Pradesh, Jammu and Kashmir and Uttarakhand (Bhattacharya 2011). In spite of their larger distribution many Rhododendrons are classified as rare, endangered and threatened and may therefore become extinct if proper conservation initiatives are not taken up. Moist alpine forests occur throughout the Himalayas particularly on higher altitudes limited to sheltered sites on northern and western aspects. The chief site characteristics consist of ample snowfall, wet soil with thick layer of black humus. The predominant species of the herb, small tree and shrub genera varies with the effect of microclimatic conditions. Edaphic properties play an important role in determining local to regional plant distributions but are often missing from predictions of future species ranges (Lafleur et al 2010). With the view that future establishment may be constrained by non-climatic processes, our expectation was that forest soils, collected from areas where trees are already established, would be more amenable to seedling success than soils from the transition or alpine zones. In the case that transition and/or alpine soils host less successful tree seedlings, high-elevation soil properties would be viewed as limiting to future upslope tree line advance. Given that tree line expansion has the potential to modify habitat conditions (Theurillat and Guisan 2001, Greenwood and Jump 2014, and to alter ecological processes at various scales (Beniston 2003), identifying locally defined limitations to tree seedling regeneration is an important objective when considering where alpine tree line advance will occur in the future (Rosbakh et al 2015). Therefore, keeping in status of conservation and significance of this species, a study was carried out in Rohru Forest Division of Himachal Pradesh.

MATERIAL AND METHODS

The present research was conducted between 31° 12' 36" and 31° 14' 24" N latitude and 78° 01' 27" E and 77° 59' 44" E longitude in the Dodra Kwar and Khashdhar Range of Himachal Pradesh's Rohru Forest Division. The various site characteristics included were: Elevation, Aspect, Solar influx and Soil physico chemical properties.

The study area was divided into two ranges (Dodra Kwar and Khashdhar) and each range was further divided into three elevations (E_1= 3000-3200 m, E_2= 3200-3400 m and E_3= above 3400 m) and two aspects (North and South). For

each study site, eighteen sample plots were laid out and samples were taken for further analysis.

Solar influx: Light illumination was recorded using luxmeter under and outside the Rhododendron canopy in selected sites of each location separately during day time and the value in percentage of light intensity under canopy to that in open canopy was calculated as under (Rao 1998).

$$\text{Solar influx (\%)} = \frac{\text{Total solar radiation beneath the canopy}}{\text{Total solar radiation in open}} \times 100$$

Soil physico-chemical properties of the site: Composite soil samples (0-30 cm) from each sampling plot at different elevations and aspects were collected. Samples were air dried in shade, grinded in iron pestle, passed through 2 mm sieve and stored in poly bags for further laboratory analysis. Available nitrogen (kg ha^{-1}), phosphorus (kg ha^{-1}) and potassium (kg ha^{-1}) were determined as suggested by Subbiah and Asija (1956), Olsen et al (1954) and Merwin and Peach (1951), respectively.

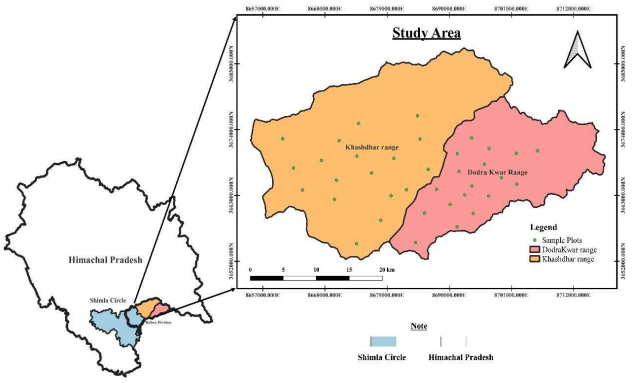

Fig. 1. Study area

RESULTS AND DISCUSSION

Solar Influx (%): The elevation, aspect and range caused significant effect on solar influx (%) (Table 1). The maximum solar influx (24.08 %) was at elevation range 3200-3400 m and minimum solar influx (13.12 %) was at elevation range above 3400 m. Among aspect, highest value for solar influx (20.16 %) was observed on southern aspect and lowest (18.07 %) was on northern aspect. In forest range, highest solar influx (19.42 %) was recorded in Dodra Kwar and minimum (18.82 %) in Khashdhar. The interaction effect of E×A showed that highest solar influx (24.94 %) at elevation range 3200-3400 m on southern aspect and lowest was reported at elevation range above 3400 m on northern aspect (11.79 %). In the interaction effect of E×R, maximum amount of solar influx (24.17 %) was at elevation range 3200-3400 m in Dodra Kwar which was statistically at par with solar influx per cent at elevation range 3200-3400 m (23.99 %) in Khasdhar. The minimum solar influx (12.44 %) was at elevation range above 3400 m in Khashdhar. In the interaction of A×R, highest solar influx (20.43 %) was on southern aspect in Dodra Kwar which was statistically at par with on southern aspect in Khashdhar. However, the interactions between E×A×R were non-significant. The present study reflects that solar influx per cent is higher on southern aspect than northern aspect. The solar influx values obtained in the current study are supported by the findings of Giertych (2000) and Mahajan (2010) for regeneration and survival of *Taxus baccata* and *Pinus roxburghii*.

Available Nitrogen (kg ha^{-1}): Available nitrogen of soil was significantly influenced due to elevation and aspect (Table 2). Significantly maximum available nitrogen (314.17 kg ha^{-1}) was at elevation range 3000-3200 m and minimum (289.26

Table 1. Solar influx (%) at different aspects along the elevations in *R. campanulatum* bearing forest

Elevation (E)	Solar influx (%)								
	Dodra Kwar			Khashdhar			Range average		
	North	South	Mean	North	South	Mean	North	South	Mean
E_1 (3000- 3200 m)	18.87	21.26	20.07	19.51	20.93	20.22	19.19	21.10	20.14
E_2 (3200-3400 m)	23.61	24.72	24.17	22.83	25.15	23.99	23.22	24.94	24.08
E_3 (Above 3400 m)	12.71	15.30	14.01	10.86	13.61	12.24	11.79	14.46	13.12
Mean	18.40	20.43	19.42	17.73	19.90	18.82	18.07	20.16	
CD (p=0.05)	Elevation (E)		0.49						
	Aspect (A)		0.40						
	Range (R)		0.40						
	E X A		0.69						
	E X R		0.69						
	A X R		0.56						
	E X A X R		NS						

kg ha^{-1}) was reported at elevation range above 3400 m. Among aspect, the highest available nitrogen (312.78 kg ha^{-1}) was on northern aspect whereas; lowest available nitrogen (281.18 kg ha^{-1}) was on southern aspect. In the interaction effect of E×A×R, the maximum available nitrogen (334.70 kg ha^{-1}) was at elevation range 3000-3200 m on northern aspect in Khashdhar. Minimum available nitrogen (280.08 kg ha^{-1}) was recorded at elevation range above 3400 m on southern aspect in Khashdhar However, the effect of R and interactions between E×A, E×R, A×R were non-significant.

The available nitrogen decreased as the elevation increased. The lower altitudes in present study were moister as compared to the higher elevation. N is mostly present in the form of nitrates in the soil, which is very mobile and gets moved freely with the moisture (Gupta and Sharma 2008). The soil organic carbon is higher in lower altitudes as compared to upper altitudes. The high amount of organic matter in the lower elevation may also be the reason for richness of N.

Available phosphorus (kg ha^{-1}): The maximum available phosphorus (27.13 kg ha^{-1}) was observed at elevation range 3000-3200 m (Table 3) and minimum (26.08 kg ha^{-1}) at elevation range above 3400 m which was statistically at par with available phosphorus (26.25 kg ha^{-1}) d at elevation range 3200-3400 m. Among aspect, highest value of available phosphorus (28.40 kg ha^{-1}) was on northern aspect whereas, lowest (24.57 kg ha^{-1}) on southern aspect. In interaction effect E×R, has highest available phosphorus (28.40 kg ha^{-1}) at elevation range 3000-3200 m in Khashdhar whereas, lowest (24.75 kg ha^{-1}) at elevation range 3200-3400 m in Khashdhar. The interaction effect of A×R, revealed that maximum

Table 2. Available nitrogen (kg ha^{-1}) at different aspects along the elevations

Elevation (E)	Available Nitrogen (kg ha^{-1})								
	Dodra Kwar			Khashdhar			Range average		
	North	South	Mean	North	South	Mean	North	South	Mean
E_1 (3000- 3200 m)	325.89	298.64	312.27	334.70	297.43	316.07	330.30	298.04	314.17
E_2 (3200-3400 m)	312.77	289.43	301.10	308.62	291.28	299.95	310.70	290.36	300.53
E_3 (Above 3400 m)	299.88	282.28	291.08	294.79	280.08	287.44	297.34	281.18	289.26
Mean	312.85	290.12	301.49	312.70	289.60	301.15	312.78	289.86	
CD (p=0.05)	Elevation (E)		2.01						
	Aspect (A)		1.64						
	Range (R)		NS						
	E X A		NS						
	E X R		NS						
	A X R		NS						
	E X A X R		4.02						

Table 3. Available Phosphorus (kg ha^{-1}) at different aspects along the elevations

Elevation (E)	Available Phosphorus (kg ha^{-1})								
	Dodra Kwar			Khashdhar			Range average		
	North	South	Mean	North	South	Mean	North	South	Mean
E_1 (3000- 3200 m)	28.10	23.60	25.85	29.40	27.40	28.40	28.75	25.50	27.13
E_2 (3200-3400 m)	29.60	25.90	27.75	26.90	22.60	24.75	28.25	24.25	26.25
E_3 (Above 3400 m)	27.90	23.70	25.80	28.50	24.20	26.35	28.20	23.95	26.08
Mean	28.53	24.40	26.47	28.27	24.73	26.50	28.40	24.57	
CD (p=0.05)	Elevation (E)		0.36						
	Aspect (A)		0.30						
	Range (R)		NS						
	E X A		NS						
	E X R		0.51						
	A X R		0.42						
	E X A X R		0.73						

available phosphorus (28.53 kg ha^{-1}) on northern aspect in Dodra Kwar which was statistically at par with available phosphorus (28.27 kg ha^{-1} on northern aspect in Khashdhar. The minimum available phosphorus (24.40 kg ha^{-1}) was d on southern aspect in Dodra Kwar which was statistically at par with available phosphorus (24.73 kg ha^{-1}) on southern aspect in Khashdhar. In the interaction effect of E×A×R, the highest value of available phosphorus (29.60 kg ha^{-1}) was at elevation range 3200-3400 m on northern aspect in Dodra Kwar which was statistically at par with available phosphorus (29.40 kg ha^{-1}) at elevation range 3000-3200 m on northern aspect in Khashdhar. The lowest available phosphorus (22.60 kg ha^{-1}) was at elevation range 3200-3400 m on southern aspect in Khashdhar. However, the effect of R and interaction between E×A was non-significant. The present study shows that lower elevation (3000-3200 m) and mid elevation (3200-3400 m) were having more density of grasses and recorded high amount of P.

Available Potassium (kg ha^{-1}): The highest amount of available potassium 234.43 kg ha^{-1} was recorded at elevation range 3000-3200 m, whereas, lowest 216.40 kg ha^{-1} was at elevation range above 3400 m (Table 4). Among aspect, maximum available potassium (233.44 kg ha^{-1}) was d on northern aspect, whereas, minimum (217.52 kg ha^{-1}) was on southern aspect. In the interaction effect of E×A×R, the highest value for available potassium (249.00 kg ha^{-1}) was at elevation range 3000-3200 m on northern aspect in Khashdhar. Lowest value for available potassium (209.08 kg ha^{-1}) was at elevation range above 3400 m on southern aspect in Khashdhar. However, the effect of R and interactions between E×A, E×R, A×R were non-significant.

Influence of site characteristics on natural regeneration of *R. campanulatum*: The maximum regeneration (52.78 %) for *R. campanulatum* was at elevation range of 3200-3400 m on northern aspect in Khashdhar (Table 5). Solar influx per cent was 22.83 and available N, P, K were 308.62, 26.90 and (234.76 kg ha^{-1}, respectively). The minimum regeneration success per cent (21.00) was at elevation range 3000-3200 m on southern aspect in Khashdhar. Here, the solar influx per cent was 20.93 and available N, P, K were 297.43, 27.40 and 227.81 kg ha^{-1}, respectively. The highest regeneration success (38.89 %) was r at all the altitudinal range on northern aspect in Dodra Kwar. The available N, P, K were 325.89, 28.10 and 239.80 kg ha^{-1}, respectively. The minimum regeneration success per cent (25.00) was at elevation range 3000-3200 m on southern aspect in Dodra Kwar. Here, the solar influx per cent was 21.26 and available N, P, K were 298.64, 23.60 kg and 221.09 kg ha^{-1}, respectively.

Available N, P, K was highest on northern aspect as compared to southern aspect. The maximum regeneration success for *Rhododendron campanulatum* was d in northern aspect as compared to southern aspect. The main factors responsible for adequate regeneration of *Rhododendron campanulatum* were ample amount of snowfall, soil moisture, available N, P, K, solar influx, aspect and elevation. In mountain ecosystems, slope- aspect plays a key role in regulating insolation, which in turn affects soil moisture, temperature regimes, hydrological precipitation pattern, erosion, species composition and distribution, photosynthetic efficiency and nutrient dynamics that can directly influence the development of local vegetation and ecosystems (Leonelli et al 2009, Sharma et al 2010, Aimme and Normaniza 2015, Yanyan et al 2017). The seasonally wet and poorly drained sites had well developed wet heath communities (Vickers and Palmer 2000). Pandey et al (2018) conducted a study on timberline structure and woody taxa regeneration towards tree line along atitudinal gradients in Khangchendzonga National Park, Sikkim and revealed that humus, elevation and slope

Table 4. Available Potassium (kg ha^{-1}) at different aspects along the elevations

Elevation (E)	Available Potassium (kg ha^{-1})								
	Dodra Kwar			Khashdhar			Range average		
	North	South	Mean	North	South	Mean	North	South	Mean
E_1 (3000- 3200 m)	239.80	221.09	230.45	249.00	227.81	238.41	244.40	224.45	234.43
E_2 (3200-3400 m)	231.65	215.89	223.77	234.76	220.14	227.45	233.21	218.02	225.61
E_3 (Above 3400 m)	227.64	211.12	219.38	217.76	209.08	213.42	222.70	210.10	216.40
Mean	233.03	216.03	224.53	233.84	219.01	226.43	233.44	217.52	
CD (p=0.05)	Elevation (E)		0.70						
	Aspect (A)		0.57						
	Range (R)		NS						
	E X A		NS						
	E X R		NS						
	A X R		NS						
	E X A X R		1.40						

Table 5. Natural regeneration of *R. campanulatum* at different aspects along the elevations

Site	Elevation (m)	Regeneration success (%)	
		N	S
Dodra Kwar	E_1 (3000- 3200 m)	38.89	25.00
	E_2 (3200-3400 m)	38.89	27.78
	E_3 (Above 3400 m)	38.89	27.78
Khashdhar	E_1 (3000- 3200 m)	38.89	21.00
	E_2 (3200-3400 m)	52.78	22.22
	E_3 (Above 3400 m)	38.89	36.11

played an important role in shaping the vegetation composition as well as timberline boundaries of the landscape.

CONCLUSION

Rhododendron campanulatum prefers cooler and moist sites. Available N, P, K was highest on northern aspect as compared to southern aspect. The regeneration status of *R. Campanulatum* was fair in both forest ranges, except in the mid elevation and northern aspect of Khashdhar range, which showed moderate regeneration success rate. The main factors responsible for adequate regeneration of *R. campanulatum* were ample amount of snowfall, soil moisture, available N, P, K, solar influx, aspect and elevation.

AUTHOR CONTRIBUTION

Ankush Moran and Mukesh Prabhakar designed the study; Nilotpal Raj, Himesh Kapoor and Kapoor collected data and developed draft of manuscript; Software- N kengoo and S Balaji Naik; Akshay Kailas Pingale, Tapan Adhikari and Vaibhav Rajesh Rao Jumale added additional data inputs and helped in laboratory.

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