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Vegetation Structure and Regeneration status of *Rhododendron arboreum* sp. in the forests of Western Himalayas: Study of Van-Panchayat and Reserve forests in Chamoli District of Uttarakhand, India

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ABSTRACT

One of the known indicators of forest health is regeneration of trees, their diversity and the age class structure. Forests which are subjected to unsustainable harvest of its products are in particular vulnerable and stressed. The present study was conducted to study the vegetation structure and regeneration status of *Rhododendron arboreum* in the van-panchayat and reserve forests of Uttarakhand, Western Himalaya. *R.arboreum* (Family Ericaceae) is an important keystone species in the region, and any significant change in the species composition due to anthropogenic pressures may also impact the forest community structure. Regeneration status of this species in the study area was enumerated with relative density of seedlings, saplings and mature tree individuals. Regeneration with viable seedling population indicates good forest health and is also a critical part of forest management. Vegetation analysis revealed a total of 13 tree species belonging to 10 families in the forest sites of the study area. Species density (ind/ha) varied from 469-525 (trees), from 322-385 (saplings), and from 435-464 (seedlings) in the van-panchayat forests and 525-572 (trees), 325-350 for (saplings) and 108-275 for seedlings in the reserve forests. Species diversity (H') value in the van-panchayat forests ranged from 2.04-2.16 (trees), 1.52-1.86 (saplings), 1.32-1.54 (seedling) and from 2.36-2.45 (trees), 2.04-2.18 (saplings), 1.22-1.34 (seedling) in the reserve forest sites.The tree species richness and density in the reserve forests were found to be marginally higher than the van panchayat forests due to low anthropogenic pressure and limitations on the community's extraction of forest-resources. However, fewer number of individuals of seedlings and saplings indicate less regeneration capacity of *Rhododendron* sp. in the reserve forest sites, which might be due to reduced seed germination of canopy species or maturation of the forests.

Key words: *Himalaya, Rhododendron arboreum, Vegetation structure, Rgeneration*

Introduction

The Indian Himalayan region with total geographical area of about 530,795 km^2 representing 16.16% of the total geographical area of India (Singh, 2006) is a biodiversity hotspot (Myers, 2005). The state of Uttarakhand in Western Himalaya has around 24,305 sq.km of forest cover reported by IFSR (2021),

of which about 15% forest area is under the community managed forests commonly known as the '*Van Panchayats*' (Pharswan *et al.*, 2020). These community managed forests provides a co-management system which not only benefits the local communities with livelihood but also conserve the indigenous traditional knowledge in forest management (Nagahama *et al.*, 2016). Community management of forests enhances opportunities for responsible use of forest-resources (Bisht *et al.*, 2021).

Rhododendron arboreum Sm. (Family Ericacae) is distributed in an altitudinal range 1500-3000 m in the Himalayas and is locally called as '*burans*. The flowers are harvested by the local communities for making of Rhododendron juice/squash rich in antioxidant properties with high bioprospecting potential in the state of Uttarakhand (Negi *et al.*, 2013). *R.arboreum* with its varied domestic, ecological and medicinal benefits acts as an ecological as well as an important cultural keystone species (Garibaldi and Turner, 2004) and also caters to a large amount of other biodiversity components like the lichens, bryophytes, and pteridophytes, providing an efficient role in the micro-ecosystem (Mamgain *et al.*, 2017).

The risk of anthropogenic pressures on the forest structure and concern on biodiversity conservation has emphasized upon the need for vegetation studies at both the regional and small scale (Brown *et al.*, 1988) form maintenance of forest health. The present study was conducted to analyze the vegetation structure and the regeneration status of *R.arboreum* sp. in the community managed 'Van-Panchayats 'and government managed 'Reserve forest' sites of the Uttarakhand State of India, our study area. The regeneration status of *R. arbourem* sp. was enumerated as an indicator of forest health as regeneration of species is strongly impacted by anthropogenic factors (Barik *et al.*, 1996) and good regeneration of the floral elements of the forests is vital for desired species composition. Therefore, the present study will provide an overview on the vegetation structure and regeneration potential of *R.arboreum* sp. for the health of the *Rhododendron* rich forests in the study area.

Materials and Methods

Study area

The study was conducted in Chamoli district (Fig.1) which is the second largest district of the Uttarakhand, state of India (30.2937° N, 79.5603° E). The Western Himalaya with its diverse vegetation structure and forest sub-types are sensitive to anthropogenic pressures and rampant extraction for its

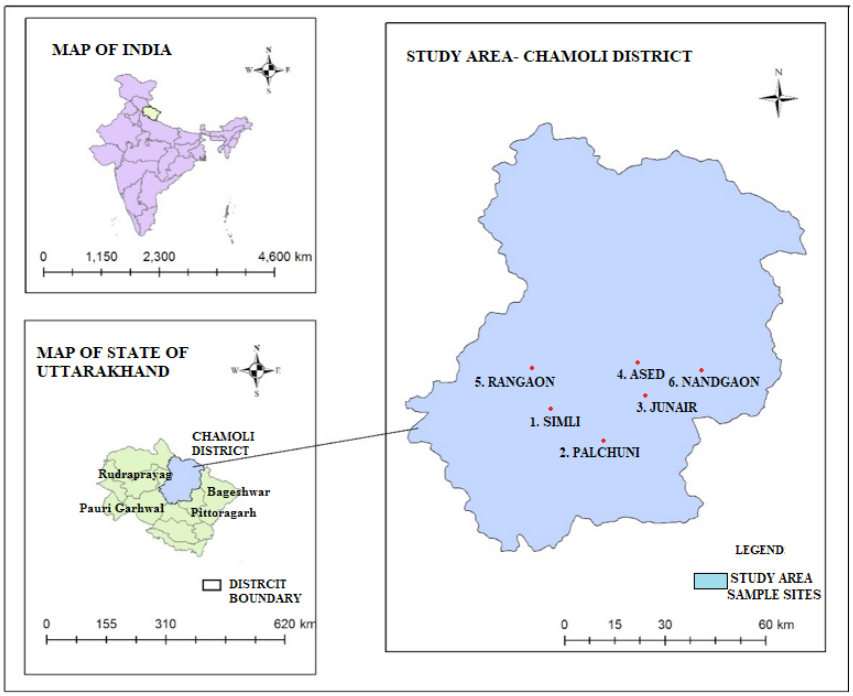

Fig. 1. Map of study area with sampling sites

resources can lead to a risk of overexploitation (Gairola *et al.*, 2011). The district's total geographical area is about 8030 sq.km out of which around 2709 sq.km area is under forest cover (FSI, 2019) and the climate of the region varies from tropical upland to sub-tropical monsoon. *R. arboreum* is harvested for its medicinal values and domestic purposes with the dominant use of *R.arboreum* flowers for its juice and squash production (Singh *et al.*, 2020). The Chamoli district in Uttarakhand was selected for the present study due to its *Rhododendron* dominated forests and an active harvest of *R.arboreum* sp. by the communities. The total tree density of Rhododendrons has been reported around470-580 Ind/ha^{-1}(Chauhan *et al.*, 2017). The sites selected for the regeneration studies *viz; van-panchayat* and reserve forest are placed in (Table 1). *R.arboreum* sp. is harvested from these *Rhododendron* rich forests and also has an established market value-chain of the cottage industries (Singh *et al.*, 2022) supporting the local communities livelihood.

Vegetation sampling

The vegetation analysis was carried in the study area during 2019-20 by stratified random quadrat sampling with 45 quadrats of 10 m × 10 m size in the van-panchayat and reserve forest sites.The sampling design consisted of quadrats of 5 m× 5 m and 1m × 1m for the composition of saplings and seedlings that were laid within the 10 m × 10 m quadrats for trees respectively. The sampling methods were based on the vegetation sampling methods by (FSI 2019). As the overall structure and function of the forest ecosystem is determined by its plant-based components in the ecosystem (Richards, 1996) the vegetation data for the various phytosociological parameters was determined using Curtis and Mcintosh (1950). For regeneration, in each quadrat of 10 m × 10 m, individuals having >31.5 cm CBH (circumference at breast height, i.e. 1.37 m above the ground) were considered as trees, which were measured individually. Individuals having <10.4 cm CBH were considered as seedlings and individuals having CBH from 10.5 cm to 31.5 cm were considered as saplings (Knight, 1963) to study the regeneration potential of *R.arboreum* in the study area.

Data analysis

Field data were analyzed for species richness, and the index of diversity was computed by using Shannon-Wiener information (H′) from (Shannon-Wiener, 1963) and the concentration of dominance (Cd) was measured by Simpson's index (Simpson 1949). The Shannon–Wiener diversity index is measured as $H' = -\Sigma (ni/n)^2 \log_2 (ni/n)$, where *ni* is the density of species and *n* is the sum of total density of all species in the forest. The Simpson's concentration of dominance was measured as $Cd = \Sigma Pi^2$, where $\Sigma Pi = \Sigma ni/n$, where *ni* and *n* were same as used for (*H′*). Simpson's diversity index was further calculated as D = 1– *Cd*, where D is Simpson's diversity and *Cd* is Simpson's concentration of dominance.

Results

1. Species composition and vegetation structure

a) Van-Panchayat forests

Species composition and vegetation structure of the van panchayat forest sites *viz*; Simli, Junair and Palchuni is presented in Table 2. *Rhododendron arboreum* along with other dominant tree species like *Quercus, Myrica esculenta, Alnus nepalensis, Lyonia ovalifolia* and *Pinus roxburghii* were recorded from the study area. Ericaceae was found to be the dominant family followed by Fagaceae and Rosaceae. The Importance Value Index (IVI) was recorded from the forest sites and the highest IVI value was

Table 1. Details of the forest sites

Sampling sites	Altitude (m)	Category	No. of plots sampled	Coordinates
1. Simli	1480	Van Panchayat	8	30.2787° N, 79.2183° E
2. Junair	1650	Van Panchayat	7	30.2587° N, 79.5583° E
3. Palchuni	1280	Van Panchayat	6	30.2987° N, 79.2883° E
4. Ased	1600	Reserve Forest	9	30.2677° N, 79.2193° E
5. Raingaon	1900	Reserve Forest	8	30.2787° N, 78.2183° E
6. Nandgaon	1850	Reserve Forest	7	30.2887° N, 79.2583° E

No. of plots calculated by center point quadrat method by Kent and Coker (1992).

found to be for the *Quercus sp.* like *Q.semicarpifolia* (60.3) followed by *Rhododendron arboreum* (57.6). The minimum IVI was found to be for the *Prunuscerosoides sp.* (3.0). Tree species density was recorded between 469-525 (ind/ha) and the basal area between 1.2-21.5 (m^2 ha^{-1}) in the van-panchayat forest sites of the study area.

b) Reserve forest sites

Species composition and vegetation structure recorded from the reserve forest sites *viz*; Ased, Raingaon and Nandgaon is placed in Table 3. The dominant family in the Reserve forest sites were found to be Ericaceae, Fagaceae and Pinaceae with species like *Quercus leucotrichophora, Rhododendron arboreum, Myrica esculenta,* and *Lyonia ovalifolia* being dominant in the reserve forests. The highest IVI value was recorded for the *Quercus leucotrichophora* sp. (55.5) whereas the minimum IVI is recorded for *Machilusduthei* (2.0). The IVI for *Rhododendron arboreum* tree sp. in the reserve forest sites were found between 40.5 and 50.5 respectively. Tree species density varied between 525-572 (ind/ha) and the basal area between 0.2-25.5 (m^2 ha^{-1}) in the Reserve forest sites of the study area.

Total Density, Basal area and Species Diversity

The diversity values, total species density (ind/ha) and total basal area (m^2 ha^{-1}) of trees, saplings and seedlings recorded from the van-panchayat and reserve forests is placed in Table 4. The Shannon diversity (H') values in the van-panchayat forest sites *viz;* Simli, Junair and Palchuniranged from 2.04-2.16 (trees), 1.52-1.86 (saplings), 1.32-1.54 (seedling) whereas the Simpson index (D) values ranged from 0.20-0.26 (trees), 0.12-0.16 (sapling), and 0.10-0.13 for

Table 2. Species vegetation structure and Phytosociological attributes in the Van Panchayat forest sites

Species	Family	Site 1 Simli			Site 2Junair			Site 3Palchuni		
		D	TBA	IVI	D	TBA	IVI	D	TBA	IVI
Quercus semicarpifolia	Fagaceae	163	21.5	60.3	155	20.2	55.5	160	20.5	58.5
Rhododendron arboreum	Ericacaeae	120	11.5	57.6	125	12.5	54.3	115	15.5	55.5
Lyonia ovalifolia	Ericacaeae	60	11.0	48.3	55	9.5	40.3	50	10.5	38.3
Myrica esculenta	Myricaceae	53	3.5	35.5	45	4.3	30.3	45	3.8	28.5
Alnus nepalensis	Betulaceae	28	3.0	15.5	25	3.2	11.5	20	3.5	10.5
Prunus cerosoides	Rosaceae	23	1.2	3.0	20	1.4	4.5	18	1.6	3.5
Pyrus communis	Rosaceae	18	1.2	4.5	15	1.5	5.5	16	1.8	4.0
Juglans regia	Juglandaceae	15	1.3	6.8	12	0.8	5.5	10	0.5	5.5
Pinus roxburghii	Pinaceae	45	3.5	17.5	40	4.2	18.0	35	5.5	18.5
Total		**525**	**57.7**	**249**	**492**	**57.6**	**225.4**	**469**	**63.2**	**222.8**

D=Density (ind ha^{-1}), TBA= Total basal area (m^2 ha^{-1}), IVI= Important Value Index

Table 3. Species vegetation structure and Phytosociological attributes of in the Reserve forest sites

Species	Family	Site 4 Ased			Site 5 Raingaon			Site 6 Nandgaon		
		D	**TBA**	**IVI**	**D**	**TBA**	**IVI**	**D**	**TBA**	**IVI**
Quercus leucotrichophora	Fagaceae	185	25.5	55.5	165	20.5	45.5	175	22.5	50.5
Rhododendron arboreum	Ericacaeae	155	10.5	50.5	150	9.5	40.5	145	7.5	42.5
Symplocosra mosissima	Symplocaceae	25	2.5	15.5	22	2.3	18.3	30	2.0	20.5
Myrica esculenta	Myricaceae	65	4.5	35.5	55	3.5	28.5	45	4.5	25.5
Alnus nepalensis	Betulaceae	15	1.5	10.5	18	2.5	14.6	20	2.0	12.5
Acer caesium	Aceraceae	07	0.2	4.2	08	0.3	3.7	09	0.2	4.8
Machilusduthei	Lauraceae	05	0.5	3.5	07	0.3	2.5	08	0.2	2.0
Lyonia ovalifolia	Ericacaeae	45	3.5	35.5	35	1.5	25.5	38	2.5	28.4
Pyrus communis	Rosaceae	12	1.4	5.8	10	1.5	4.5	15	1.8	5.8
Cedrus deodara	Pinaceae	28	5.5	20.5	30	5.0	22.5	34	4.5	24.5
Pinus roxburghii	Pinaceae	30	4.5	18.5	25	3.5	17.5	30	3.0	18.0
Total		**572**	**60.1**	**255.5**	**525**	**50.4**	**223.6**	**549**	**50.7**	**235**

D=Density (ind ha^{-1}), TBA= Total basal area (m^2 ha^{-1}), IVI= Important Value Index

(seedling). In the Reserve forest sites*viz;*Ased, Raingaon and Nandgaon. Shannon index for diversity (H') values ranged from 2.36- 2.45 (trees), 2.04-2.18 (saplings), 1.22-1.34 (seedling) whereas the Simpson index (D) values ranged from 0.36-0.42 (trees), 0.18-0.22 (sapling), and 0.12-0.18. for (seedling) respectively.

Girth class distribution in the Van-Panchayat and Reserve forests

The girth class distribution with the proportion of individuals (%) and diameter class distribution of tress (>30 cm), saplings (10-30 cm) and seedlings (0-10cm) in the Van-Panchayat and Reserve forests are graphically represented in (Fig. 2). In the Van-Panchayat forests, the young population from girth class (10-30 cm) and (0-10 cm) were found with sufficient number of sapling (27.6 %) and seedling (34.4 %) population in the community managed forests. In the Reserve forests, individuals from the matured tree population (50.22%) with girth class (>30cm) were found to be more dominant over the young population from the girth class (10-30 cm) and (0-10 cm). The total seedling density in the van panchayat forests were found between 435-464 ind. ha^{-1} and in the reserve forest sites between 108-275 ind.ha^{-1}. The proportion of young population like sapling (CBH 10-31.5 cm) and seedling (CBH <10 cm) was found to be more in the van-panchayat forest sites and the proportion of adult population (CBH >31.5 cm) was

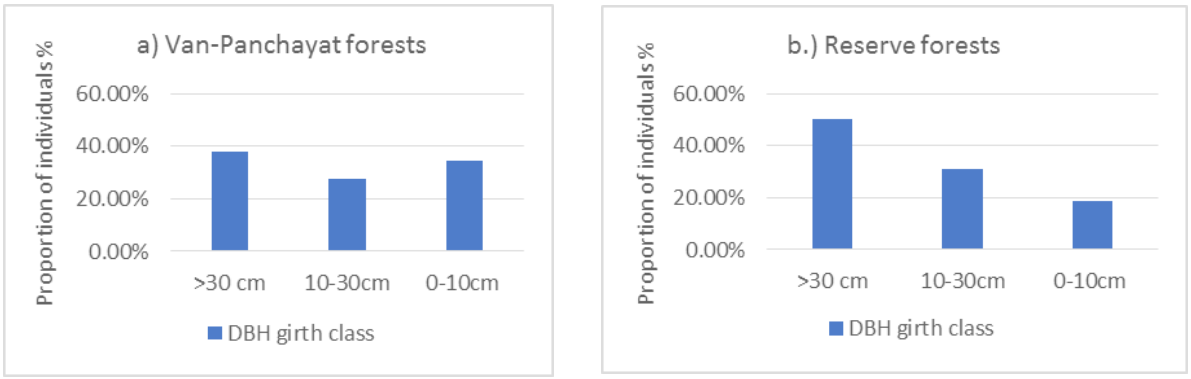

Fig 2. Proportion of individuals (%) and diameter class distribution of tress (>30 cm), saplings (10-30 cm) and seedlings (0-10 cm) in a) Van-Panchayat forests b) Reserve forests.

Table 4. Total density, Basal area and Species diversity of forest sites in the study area

Total Density (ind/ha)	Van-Panchayat sites			Reserve forest sites		
	Site1 Simli	Site2 Junair	Site 3 Palchuni	Site 4 Ased	Site 5 Raingaon	Site 6 Nandgaon
Trees	525	492	469	572	525	549
Sapling	385	322	360	350	325	348
Seedling	464	435	442	275	225	108
Total Basal area (m^2/ha)						
Trees	57.7	57.6	63.2	60.1	50.4	50.7
Sapling	13.5	11.5	10.1	18.0	17.6	15.8
Seedling	0.21	0.15	0.17	0.11	0.06	0.05
Shannon index (H')						
Trees	2.16	2.04	2.11	2.45	2.36	2.40
Sapling	1.86	1.52	1.74	2.18	2.04	2.12
Seedling	1.54	1.32	1.42	1.34	1.22	1.28
Simpson index (D)						
Trees	0.20	0.26	0.24	0.36	0.42	0.38
Sapling	0.12	0.16	0.14	0.18	0.24	0.22
Seedling	0.10	0.13	0.11	0.12	0.18	0.15

found to be more in the reserve forest sites of the study area.

Regeneration status of the *R. arboreum sp*.

For regeneration, the relative proportion of seedlings and saplings of the individual tree species is studied in the forest sites. In the present study, the regeneration status for *R.arboreum sp.* were based under the following categories by Uma (2001) :

(1) Good regeneration, number of seedlings> saplings >adults.
(2) Fair regeneration, number of seedlings >or < saplings < adults.
(3) Poor regeneration, if the species survive only at sapling stage, there are no seedlings (Number of saplings may be more, less or equal that of adults).
(4) No regeneration, where the species are found only in adult form.

The regeneration status of *R.arboreum* in the forest sites is tabulated in (Table 5). The findings showed that the van panchayat sites showed 'good' regeneration in Site 1 (Simli), 'fair' in Site 2 (Junair) and 'good' in Site 3 (Palchuni) whereas the reserve forest sites showed 'fair' regeneration in Site 4 (Ased) and Site 5 (Raingaon) and 'poor' regeneration in Site 6 (Nandgaon) respectively.

Discussion and Conclusion

In the present study, the tree density was recorded in the range of 469-525 ind. ha^{-1} in the van-panchayats and 525-572 ind. ha^{-1} in the reserve forests which is comparable to 473-840 tree ha^{-1} reported by (Joshi *et al.*, 2020). The total basal area of the tree sp. in the van-panchayat forests varied between 57.7- 63.2 m^2 $ha^{-1}$and between 50.4-60.1 m^2 ha^{-1} in the reserve forests which is comparable to the total basal area values (43–67.14 m^2 ha^{-1}) reported by (Mittal *et al.,* 2020). Species diversity (H') value in the van-panchayat forests ranged from 2.04 - 2.16 (trees), 1.52-1.86 (saplings), 1.32-1.54 (seedling) and from 2.36-2.45 (trees), 2.04-2.18 (saplings), 1.22-1.34 (seedling) in the reserve forest sites.

The proportion of the number of seedlings, saplings, and large trees in each population help in prediction the future status of forest (Sundriyal *et al.,* 1998). In the present study, the regeneration status of *R.arboreum* sp. were found to be slightly higher in the van panchayats sites than the reserve forest sites. The seedling density in the van panchayat were found to be between 435-464 ind. ha^{-1} and in the reserve forest sites between 108-275 ind.ha^{-1}. The higher number of seedling than to mature tree population showed good to fair regeneration in the van panchayats indicating effective management by the native communities in maintaining the forest health while the reserve forests with less seedling population showed the domination of mature trees. As generally in a forest community, domination of young sapling and seedling population (between mid-lower diameter class) is indicative that the forest is still in developing stage whereas the domination of trees (at mature class) shows the forest has reached its mature stage. The biotic pressures also play an important role in survival of the seedling population (Canham *et al.,* 1985) which can be attributed for the species composition in the study area.

The present study concluded that in-spite of the harvesting of the flowers the diversity of the forest and regeneration status is similar in both the category of forests *viz*., van panchayat and the reserve forests. The reserve forests are marginally richer in terms of tree species richness and diversity than the van panchayat forests because of low anthropogenic pressure for the extraction of forest resources than

Table 5. Regeneration status of *R.arboreum* sp. in the Van-Panchayat and Reserve forest sites

Van Panchayat sites	Density (Ind/ha)			Regeneration
	Trees	Saplings	Seedlings	
Site 1 (Simli)	120	140	160	Good
Site 2 (Jumair)	125	120	145	Fair
Site 3 (Palchuni)	115	135	155	Good
Reserve forest sites	Trees	Saplings	Seedlings	Regeneration
Site 4 (Ased)	155	130	155	Fair
Site 5 (Raingaon)	150	120	125	Fair
Site 6 (Nangaon)	145	125	——	Poor

CBH: circumference at breast height; trees (CBH >31.5 cm); saplings (CBH 10-31.5 cm); seedlings (CBH <10 cm

the community harvested forests. In thevan-panchayat forests with viable seedling population and good regeneration of *R.arboreum* is indicative of good forest health and efficient management of the community forests where the harvest of *R.arboreum* by the local communities is within the sustainable harvesting limits. However, with increasing anthropogenic pressures strong policies and tools like forest certification is needed for encouraging the sustainable forest management practices and for maintaining the long-term health of the *Rhododendron* rich forests in the study area.

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Conflict of Interest

The authors declare no conflict of interest.

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