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Composition, Population Structure and Regeneration of *Rhododendron arboreum* Sm. Temperate Broad-Leaved Evergreen Forest in Garhwal Himalaya, Uttarakhand, India

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Abstract

The present studied was carried out in four districts of Garhwal Himalaya. Survey and sampling of vegetation were completed used standard ecological method with aim to study of plant composition, population structure and regeneration at different site in the four districts viz. Pauri, Rudrapryag, Tehri and Chamoli of Garhwal Himalaya. Each district represents two sites, falls an altitude in Pauri (1850-2070 m), Rudrapryag (1775-2147 m), Tehri (1938–2459 m) and Chamoli (1711–1960 m). Among the altitudes over all range is (1711-2459 m) altitudes in all eight sites, total 16 tree species has been recorded. Total tree density varies from 670-1510 Ind ha^{-1}, total seedling density from 220-1540 Ind ha^{-1} and total sapling density 165-1300 Ind ha^{-1} was recorded in all sites among the attitudes. Species diversity (H^{-}) was observed between 0.12-0.19 for trees, 0.04-0.40 for seedling and 0.07-0.15 for sapling in all sites among the attitudes.

Keywords: Community; Population; Regeneration; *Rhododendron arboreum*

Introduction

The composition of the species like trees, shrubs, herbs and climbers are indicating present status of the forest biodiversity. Composition of the forest is diverse and different from place to place because of different land form of the sector have different climate, soil and topography and supports tropical, sub-tropical, temperate and alpine and in certain areas even arid or semi-arid vegetation. Any species regenerate in any area or habitat plant diversity and regeneration status of various forest communities is base line study for management and conservation plant diversity. The population structure like seedling, sapling and adult trees on the basis of age and diameter in any forest stand or patch and forest area to determine regeneration status of forest area [1-11]. If seedling and sapling number less are as compare to adult incase consider poor regeneration [12-16]. The regeneration study has most important study to indicate future of forest as well as implication for the natural forest management which will forest, or species survives and dominant in these areas [1]. The distribution pattern is most important of species in which form grown up species in the forest areas an understanding of the distribution of tree species, seedlings, saplings, shrubs and herbs and their assemblages must play an important role in elucidating the larger patterns of distribution of biodiversity in forest areas [17-20].

Rhododendron is a large genus with many of its 1000 species in the world and covered highland area like Nepal, India, China and Malasiya [21-26]. Recent study showed that 06 species of *Rhododendron* was reported in Uttrakhand, Western Himalaya such as R. arboreum, *R. anthopogon* [3], *R. campanulatum* [27], *R. barbatum* [8], *R. lepidotum* [5] and *R. nivale* Hooker [7] or *R. rawatii* is new species reported by Rai and Adhikari [18]. It is belong from Ericaceae family has many superior characteristics for its wide acceptance as fuel, timber, fodder and flower for preparation of very common and pleasant drink (highly medicinal) juice and squash throughout the Himalaya. Among these species, many are dominant tree/shrub species of Garhwal and Kumaun Himalaya [14]. The broad-leaved forests in the Himalaya *Rhoodendron* are considered to the next of *Quercus*, to provide the most effective for soil and water conservation. Owing to multifarious nature of this genus most of the species are over exploited for various purposes [21]. Among these species *Rhododendron arboreum* is one of the most exploited species. Major area under *Rhododendron arboreum* forest is surrounding by local inhabitants of hilly areas in Garhwal Himalaya, therefore, present status of population and regeneration of forest are not available. Keeping in view the afore mentioned facts, this paper deals to investigate the variation of community composition, tree diversity, population structure and regeneration in six *Rhododendron arboreum* forest stands of Garhwal Himalaya.

Methodology

Study area and sample plots

The study was conducted in Garhwal region (Western Himalaya) from 2014 to 2016 in potential site of three districts. After reconnaissance survey was carried out for initial few months, finally based on the presence of *Rhododendron arboreum* species eight sites were selected for detailed study. Systematic data collection was carried out in eight sites with different altitudes: Ghimtoli (1950–2147 m), Kharpatya (1775–1934 m) in Ruraprayag district; Khirsu (1850–1969 m), Pharakhal (1858–2070 m) in Pauri District; Ranichauri 1938–2023 m), Jadipani (2292–2459 m) in Tehri district and Nauti (1750–1900 m), Nadasain (1711–1960 m) in Chamoli district for phytosociological studies of *Rhododendron arboreum* forest and other associated species (Figure 1). Systematic sampling was carried out in selective patches in

each site two sample plot 1000 m^2 or 0.1ha size in each site were randomly identified, and ten 10 × 10 m or 0.01 ha size quadrats were placed random on each plot. 10% of the total area was selected for sampling and at least 0.1% of this was used for complete enumeration. Population structure of all the woody species occurring in each site was studied using quadrate method. Density, frequency and different life stages of the species were determined from the sampled area. Individual tree of *Rhododendron arboreum* within quadrate were marked with paint to determine the quadrate boundaries.

Tree species in each sample plot or quadrate were recorded and CBH (circumference at breast height, 1.37 m from the ground level) measured. Individuals were categorized as trees (>31 cm CBH), sapling (11-30 cm CBH) and seedlings (<10 cm CBH) within the quadrate size of 100^2 m for trees, 25^2 m for shrubs and 1^2 m for herb.

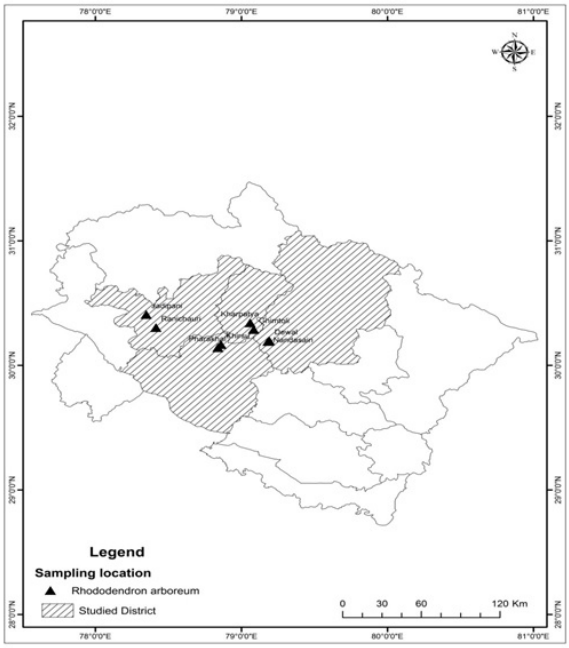

Figure 1: Sampling locations and study area map of Garhwal Himalaya.

Ecological and regeneration study

Stratified sampling technique was conducted in natural growing areas and planted areas of *Rhododendron arboreum* forest. Study area was divided based on presence of the species. A standard size sample plot or quadrate (10 × 10=100 m^2 for tree, 5 × 5=25 m^2 for shrub, seedling and sapling and 1 × 1=1 m^2 for herb) was used in each site for data collection.

Data analysis has been analyzed following standard ecological methods by Curtis and McIntosh, Grieg-Smith and Kersaw [9], Muller-Dombois and Ellenberge [4,6,13]. The following phytosociological parameters were studied using different formulae [12].

Species diversity H^- was computed by the Shannon and Weiner [23] information index as follows:

$$H^- = -\sum_{i=1}^{s} \frac{N_i}{N} \log 2 \frac{N_i}{N}$$

(Where, Ni is the total density value for species i and N is the sum of the density values of all the)

$$Frequency\% = \frac{Total\ number\ of\ Quadrates\ in\ which\ species\ occured}{Total\ number\ of\ quadrates\ studies} X100$$

$$Density = \frac{Total\ number\ of\ individual\ of\ a\ species\ quadrate}{Total\ number\ of\ quadrates\ studied} X100$$

$$Abundance = \frac{Total\ no\ of\ individual\ of\ a\ species}{Total\ number\ of\ quadrates\ in\ which\ species\ occurred}$$

$$IVI = Relative\ frequency + Relative\ density + Relative\ dominance$$

Statistical analysis

Statistically have been applied one-way ANOVA and correlation by SPSS software.

Results

Physical characteristics of study sites

Physical characteristic of study sites was given in Table 1. There were total 08 sites reported inventory. These sites fall between 30°24'25" N and 30027'66" N latitude 79°18'66" E and 78°33'56" E longitude and covered altitudinal range between 1711 -2459 masl. Among the sites four sites represent each open/easy and open/moderate respectively equally access to resources.

Composition and population structure

A total of 16 species were recorded across the study sites. Total tree density maximum was recorded at Pharakhal (1510 Ind ha^{-1}) followed by Kharpatya (1340 Ind ha^{-1}) and Nauti (1060 Ind ha^{-1}). *Rhododendron arboreum* showed maximum Density (930 Ind ha^{-1}; Relative dominance 69.40 and IVI 185.10) at Kharpatya followed by Density (890 Ind ha^{-1}; Relative dominance 60.00 and IVI 170.78) at Pharakhal. Density, Relative dominance and IVI was also recorded maximum (430 Ind ha^{-1}; 27.74 and IVI 89.74) in Quercus leucotrichophora at Pharkhal followed by (280 Ind ha^{-1}; 34.48 and IVI 97.48) at Nauti and Myrica esculenta was maximum Density (180 Ind ha^{-1}); Relative dominance (24.13) and IVI (48.26) at Pharakhal and Nauti respectively followed by Nandasain Density (60 Ind ha^{-1}); Relative dominance (8.00) and IVI (15.46) was given in Tables 2 -4.

Statistically one-way ANOVA was applied on trees density, trees density across the sites were significant difference at P<0.05; P=0.001 and variance ratio was (F=0.974). Tree density of *Rhododendron arboreum* had positive relationship (r =0.897, P<0.01; P=0.002) with total forest tree density across the sites. Tree density increased significantly with total forest tree density across sites may be increased forest biomass.

Sites	Altitudinal range (m)	GPS Location	Access to Resources	Major associates species
Pharakhal (Pauri Garhwal)	1858-2070	30°14'55"-30°16'93" N 078°55'25"-078°57.85" E	Open/Easy	*Quercus leucotrichophora and Myrica esculenta*
Khirsu (Pauri Garhwal)	1850-1969	30°10'036"-30°10'082" N 078°60'71"-078°59'16" E	Open/Moderate	*Quercus leucotrichophora and Myrica esculenta*
Kharpatya (Rudrapryag)	1775-1934	30°28'08"-30°24.85" N 079°09'58"-079°12.88" E	Open/Easy	*Quercus leucotrichophora, Myrica esculenta, Lyonia ovalifolia*
Ghimtoli (Rudrapryag)	1950-2147	30°24'25"-30°21'62" N 079°12.05"-079°11'68" E	Open/Easy	*Quercus leucotrichophora, Myrica esculenta, Lyonia ovalifolia*
Jadipani (Tehri)	2292-2459	300 32'01"-300 27'66"N 0780 34'07"-078033'56"E	Open/Easy	*Quercus leucotrichophora, Quercus floribunda, Lyonia ovalifolia*
Ranichauri (Tehri)	1938-2023	300 21'66"-300 20'85"N 0780 38'58"-078034'98"E	Open/Moderate	*Pinus roxburghi, Cedrus deodara, Myrica esculenta, Pinus wallichiana*
Nandasain (Chamoli)	1711-1960	300 19'88"-300 25'98"N 0790 25'85"-078026'03"E	Open/Moderate	*Quercus leucotrichophora, Lyonia ovalifolia, Myrica esculenta*
Nauti (Chamoli)	1750-1900	300 24'25"-300 25'11"N 0790 18'66"-079014'18"E	Open/Moderate	*Quercus leucotrichophora, Myrica esculenta, Lyonia ovalifolia*

Table 1: Physical characteristics of different forest sites.

Species Name	Sites							
	1	2	3	4	5	6	7	8
Quercus leucotrichophora	430	120	190	360	140	10	240	280
Rhododendron arboreum	830	650	930	620	500	470	470	580
Myrica esculenta	180	50	40	180		20	60	180
Lyonia ovalifolia	10	20	120	20	40	10	60	20
Cedrus deodara	-	-	10	-	-	60		
Cocculus laurifolia	-	-	50	-				
Pinus wallichiana						20		
Pinus roxburghii						80		
Quercus floribunda					40			
Total	1510	840	1340	1180	720	670	830	1060
Abbreviations: 1: Pharakhal, 2: Khirsu, 3: Kharpatya, 4: Ghimtoli, 5: Jadipani, 6: Ranichauri, 7: Nandasain, 8: Nauti.								

Table 2: Site wise total tree density (Ind. ha^{-1}) in different forests.

Species Name	Sites							
	1	2	3	4	5	6	7	8
Quercus leucotrichophora	27.74	14.28	14.17	30.50	28.57	4.34	36	34.48
Rhododendron arboreum	60	77.38	69.40	52.54	47.61	43.47	40	34.48

Myrica esculenta	11.61	5.95	2.98	15.25		8.69	8	24.13
Lyonia ovalifolia	0.64	2.38	8.95	1.69	9.52	4.34	16	6.89
Cedrus deodara	-	-	0.74	-	-	13.04	-	-
Cocculus laurifolia	-	-	14.39	-	-	-	-	-
Pinus wallichiana						8.69		
Pinus roxburghii						17.39		
Quercus floribunda					14.28			
Total	100	100	100	100	100	100	100	100
Abbreviations: 1: Pharakhal, 2: Khirsu, 3: Kharpatya, 4: Ghimtoli, 5: Jadipani, 6: Ranichauri, 7: Nandasain, 8: Nauti.								

Table 3: Site wise relative dominance in different forests.

Species Name	Sites							
	1	2	3	4	5	6	7	8
Quercus leucotrichophora	89.74	50.89	54.02	136.00	50.47	5.86	97.14	97.48
Rhododendron arboreum	168.80	220.50	185.10	118.20	214.13	208.32	163.47	145.45
Myrica esculenta	35.40	21.18	10.05	35.72	-	11.80	15.46	48.26
Lyonia ovalifolia	4.43	7.41	32.24	10.06	15.31	5.92	23.92	8.81
Cedrus deodara	-	-	4.20	-	-	24.72	-	-
Cocculus laurifolia	-	-	14.39	-	-		-	-
Pinus wallichiana					-	11.73	-	-
Pinus roxburghii						31.63	-	-
Quercus floribunda					20.07			
Total	299.96	299.98	300.00	299.98	300	300	300	300
Abbreviations: 1: Pharakhal, 2: Khirsu, 3: Kharpatya, 4: Ghimtoli, 5: Jadipani, 6: Ranichauri, 7: Nandasain, 8: Nauti.								

Table 4: Site wise Importance Value Index (IVI) in different forests.

Total Seedling density had been observed maximum Density (1540 Ind ha^{-1}) at Khirsu followed by (1280 Ind ha^{-1}) at Kharpatya and Density (1120 Ind ha^{-1}) at Ghimtoli (Figure 2). *Rhododendron arboreum* was recorded maximum (Density 900 Ind ha^{-1}) at Khirsu followed by Density (560 Ind ha^{-1}) at Ghimtoli and Density (360 Ind ha^{-1}) at Kharpatya. Seedling density had been recorded maximum at Density (430 Ind ha^{-1}) at Ghimtoli, followed by Density (390 Ind ha^{-1}) at Kharpatya and Density (290 Ind ha^{-1}) at Khirsu for *Quercus leucotrichophora. Lyonia ovalifolia* saw maximum Density (280 Ind ha^{-1}) at Kharpatya followed by (40 Ind ha^{-1}) at Pharakhal and (30 Ind ha^{-1}) at Ranichauri and Dewal. Total Sapling Density had seen highest (1300 Ind ha^{-1}) at Ghimtoli followed by (1250 Ind ha^{-1}) at Kharpatya and (1140 Ind ha^{-1}) at Pharakhal. *Rhododendron arboreum* saw maximum Density (670 Ind ha^{-1}) at Ghimtoli followed by (490 Ind ha^{-1}) at Kharpatya and (480 Ind ha^{-1}) at Pharakhal. *Quercus leucotrichophora* had been recorded highest Density (410 Ind ha^{-1}) at Ghimtoli followed by (360 Ind ha^{-1}) at Kharpatya and *Myrica esculenta* was maximum Density (260 Ind ha^{-1}) at Kharpatya followed by (80 Ind ha^{-1}) at Pharakhal and (60 Ind ha^{-1}) at Ghimtoli was given in Figure 2.

Rhododendron arboreum seedling and sapling density are positive relationship to total species seedling and sapling density. The seedling density was more or less same across the sites except to Kharpatya, Khirsu and Nauti. Whereas *R. arboreum* density comparativily less as compare to *Quercus leucotrichophora. R. arboreum* seedling density was increased significantly (r=0.912, P<0.01; P=0.002) with total seedling density across sites. Sapling density had showed similar pattern significantly (r=0.923, P<0.01; P=0.001) increased with total sapling density across the sites.

Species diversity (H-) in all study sites

Shannon diversity index (H index) was calculated in tree, sapling and seedling on site wise was given in Tables 5 and 6. Species diversity across the sites was calculated with different strata, tree species diversity ranged from 0.12-0.19, saplings species diversity from

0.07-0.15 and seedlings species diversity from 0.04-0.40 across sites. The diversity (H-index) of trees was calculated highest (0.19) at Khirsu followed by (0.16) at Jadipani and (0.15) at Ghimtoli site. The sapling diversity recorded maximum (0.15) at khirsu followed by (0.14) at Jadipani and (0.13) at Pharakhal. The diversity (H-index) of seedling have observed highest (0.40) at Ghimtoli followed by (0.24) at Kharpatya and (0.13) at Pharakhal.

Tree density was positive relationship (r =0.874) with species diversity (H^-) across the sites. Tree density increased significantly (P<0.01; P=0.001) with species diversity (H^-) across sites. It indicates that species diversity was increased with tree density across sites.

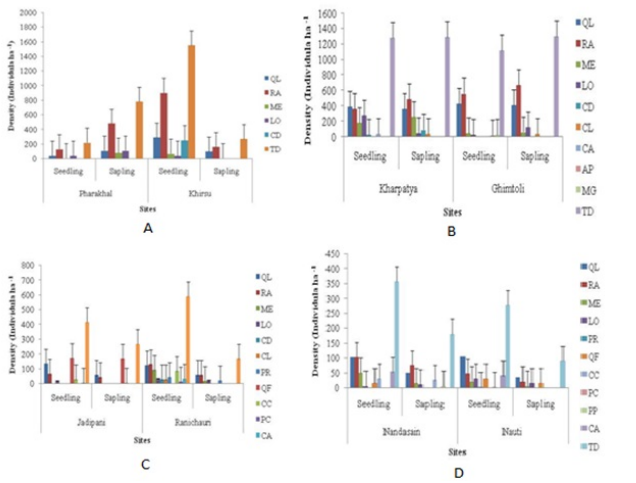

Figure 2: Seedling and Sapling density of different forest sites, QL=*Quercus leucotrichophora,* RA=Rhododendron arboreum, ME=Myrica esculenta, LO=*Lyonia ovalifolia,* CD=*Cedrus deodara*, CL=Cocculus laurifolia, PW=Pinus wallichinan, PR=*Pinus roxburghii,* QF=*Quercus floribunda*, CC=*Cornus capitata*, PC=*Prunus cerasoides*, PP=*Pyrus pashia,* CA=*Celties australis*, AP=*Abies pindrow*, MG=*Mechilus gamblei*, PW=*Pinus wallichiana*, PR=*Pinus roxbrghii*, QF=*Quercus floribunda*, TD=*Total Density.*

Discussion

Present study was carried out on eight study sites in the Garhwal Himalaya Uttrakhand. Geographicaly these sites are located between 30° 10' 36" to 30° 32' 01" N latitude and 78° 26' 03" to 79° 25' 85" E longitude with varied altitudes from 1711 m asl in Nandasain and 2459 m asl in Jadipani (Table 1).

Composition and population structure

A total of 16 species were recorded across the study sites. Total tree density maximum (1510 N ha^{-1}) was recorded at Pharakhal and minimum (670 N ha^{-1}) at Ranichauri. Maximum density observed due to better association and combination of *Rhododenron arboreum, Quercus leucotrichophora* and *Myrica esculenta* etc., species saw at Pharakhal site but Ranichauri site *Pinus roxburghii* is co-dominant with association of *Rhododenron arboreum* species is not support to other species, therefore minimum density was recorded. Density of *Rhododendron arboreum* ranged between 670 N ha^{-1} (Ranichauri) to 930 N ha^{-1} (Pharakhal), Relative dominance ranged between 0.74 (Kharpatya) to 77.38 (Khirsu) and IVI ranged between 4.20 (Kharpatya) to 220.50 (Khirsu). *Rhododendron arboreum, Quercus leocotrichophora* and *Myrica esculenta* mixed forest was observed dominated species having good association of the species across sites. Similar study was conducted by Rawat and Chandhok [19] *R. arboreum* density (80 N ha^{-1}) and IVI (29.99) was observed at Govind Pashu Vihar Wildlife Sanctuaries in Uttarakashi district [10]. *R. arboreum* density (1.23 N ha^{-1}) and IVI (28.69) was observed at J&K, Western Himalaya.

Sites	Species diversity Shannon index (H-)		
	Trees	Saplings	Seedlings
Pharakhal	1510	1140	220
Khirsu	840	270	1540
Kharpatya	1340	1250	1280
Ghimtoli	1180	1300	1120
Jadipani (Tehri)	720	265	410
Ranichauri (Tehri)	670	165	587.5
Nandasain (Chamoli)	830	180	357.5
Dewal (Chamoli)	1060	90	277.5
Maximum	1510	1300	1540
Minimum	670	165	220

Table 5: Site wise saplings, seedlings, shrubs and herbs density in different study area.

Sites	Species diversity Shannon index (H-)		
	Trees	Saplings	Seedlings
Pharakhal	0.14	0.13	0.13
Khirsu	0.19	0.15	0.12
Kharpatya	0.12	0.09	0.24
Ghimtoli	0.15	0.11	0.40
Jadipani (Tehri)	0.16	0.14	0.09
Ranichauri (Tehri)	0.15	0.08	0.04
Nandasain (Chamoli)	0.12	0.08	0.06
Nauti (Chamoli)	0.12	0.07	0.07
Maximum	0.19	0.15	0.40
Minimum	0.12	0.07	0.04

Table 6: Site wise species diversity Shannon index (H1) of trees, saplings, seedlings, shrubs and herbs in different forest study area.

Total seedling density (1549 N ha^{-1}) was recorded across the sites and in which of *Rhododendron arboreum* was highest seedling density (900 N ha^{-1}) at Khirsu as compared to other sites. Sapling density of *Rhododendron arboreum* had been recorded maximum (670 N ha^{-1}) at Ghimtoli as compared to other site, it is due to maximum seed-

bearing tree at this site, so which is encouraging the regeneration and produced more numbers of seedling and sapling. *Rhododendron arboreum, Quercus leucotrichophora* and *Myrica esculenta* species will replace the other existing pioneering species. It was observed that these species having good association at Khirsu and Ghimtoli sites. The present data supported by earlier study done by Pant and Samant [15] reported that *R. arboreum* seedling density and sapling density (430 N ha^{-1} and 260 N ha^{-1}) respectively at North-West Himalaya.

Species diversity (H^{-})

Tree, sapling, seedling diversity (H-index) on site wise was given in Table 6. The diversity (H') value of trees was calculated highest (0.19) at Khirsu followed by (0.15) at Ghimtoli site, because species dominances are less as compared to other sites to indicate higher diversity in these sites. Higher diversity is also due to moderate resources availability at higher altitude and not to easy accessible areas and fewer disturbances in the sites tends to increase diversity [17,24]. Our observations are conformity with these results. The sapling diversity value was recorded maximum (0.15) at Khirsu and seedling diversity value was observed highest (0.40) at Ghimtoli as compared to other sites. It may be good site there is younger stand which is supported to seedling and sapling.

The observation clearly showed that low diversity sites were situated at lower altitudes and might be the result of high anthropogenic pressure at lower altitudes and most of the habitations in study sites are located near to lower altitudes and these altitudes are more approachable to collect daily needs [2].

Conclusion

The study provides compositional, population structural and regeneration status or phytosociology of *Rhododendron arboreum* at eight sites in four districts of Garhwal Himalaya. In all-natural forest stands the associated or companion of dominant species can also have played important role for the establishment and sustainability of particular species. The broad-leaved character of *Quercus leucotrichophora* major associates *Rhododendron arboreum* have been reported to capable conserve the water moisture at large amount in hill area and also beneficial in erosion control. The study concludes as these species may also be a part of research for their regeneration, establishment and sustenance at same preference of *Quercus leucotrichophora*. *Rhododendron arboreum* are extracted from edible product and small but considerable scale therefore may be investigated for their conservation point of view. The flower of *Rhododendron arboreum* is medicinally important at local and regional level peoples are extracted for making of Juice and Squesh from its flower to serve the upliftment of local economy and livelihood. Lower density, IVI value and regeneration areas indicate for their attention toward future research overcome the upcoming problems. Negligence of the species may be affect the future composition, diversity and regeneration of the existing oak forest mixed stand therefore conservation approach for *Rhododendron arboreum* must be needed as research front in the Gahwal Himalayan region.

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