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# Seedling Recruitment of *Rhododendron arboreum*: an important NTFP species of North-Western Himalaya, India

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**Abstract.** We examined the recruitment, survival, mortality, growth, and development of *Rhododendron arboreum* Smith, one of the important Non- Timber forest Product species (NTFPs). Ten permanent plots (10 x 10 $m^2$) were created in four sites of mixed broad-leaved temperate forests of Garhwal Himalaya. We measured seedling shoot length and collar diameter at the beginning of the experiment and re-measured at three-month intervals with maximum seedling recruitment recorded in Triguginaryan (36.36 %, during Nov and Aug), and most seedlings were found established either on the boundary or in either partially or fully gaps. While a higher rate of mortality occurred in the winter season. Maximum height increment for seedlings was recorded in Adhwani (1.005 $cm^{-1}$). *R. arboreum* recorded the highest recruitment during post-rainy, with an overall increment of 0.60 $cm^{-1}$. Seasonal variations were seen in the overall relative growth rate for height (RGRH) for *Rhododendron* seedlings. Seasonal variation in temperature and light is a crucial factor in determining growth. Because of the favorable temperature and soil moisture during the rainy season, vigorous shoot growth continued for the longest period of time at all four sites. The current study's findings also show that seedlings develop and survive better in gaps than in the understory. The current study also demonstrates that ideal soil moisture and temperature conditions are essential for seedling growth and development.

**Keywords: c**anopy gaps, growth rate, *Rhododendron*, regeneration, seedling mortality, seedling recruitment.

## 1. Introduction

A population forms by the emergence of new individuals through vegetative or reproductive means it is through seedling recruitment that new individuals emerge into the population (Ribbens et al., 1996). Recruitment, growth, and survival of seedlings are vital in the population and community growth process (Li et al., 1996). From seed production to seed dispersal, from seed germination to seedling establishment, competition within and between seedlings leads to the establishment of seedlings in a forest stand. As part of the recruitment processes, seed dispersal and seed germination play a crucial role because seed dispersal determines how seeds must maneuver through the physical environment (Wenny, 2001) and seed germination determines the number of seeds that germinate after seed dispersal which ultimately influence seed survival percentage. The recruitment of woody plants is inhibited at the number of stages from seed production to seedling survival (Wang et al., 2010). The availability of seed and suitable sites for seedling establishment and subsequent survival limit seedling recruitment (Caspersen & Saprunoff, 2005). Tree species composition, regeneration and other ecosystem characteristics of these other important species have been studied in some parts of Himalaya (Kumar et al., 2022; Negi et al., 2022; Kumar et al., 2022)

Both genetic and environmental factors influence the survival and establishment of seedlings. The former remains effective till the germination of the seed while the latter determines the survival of the species. Both biotic and abiotic elements have an interacting impact on the survival and growth of seedlings. Seasonality affects patterns of seed production; germination, survival, seedling development (Khurana & Singh, 2001), and also the relative growth rate of the seedlings. Seedlings are also at great risk of damage and death from herbivorous animals.

In India, there are 87 species, 12 subspecies, and 8 varieties of Rhododendrons, which belong to Ericaceae family and has around 1200 species worldwide (Tiwari & Chauhan, 2006; Chandra Sekar & Srivastava, 2012). Giant tree in the *Rhododendron* genus can grow to a height of 40 meters and range in size from 2.5 cm to 40 m height (Hora, 1981; Mao et al., 2017). Out of 132 taxa (80 species, 25 subspecies, and 27 varieties) of Rhododendrons reported from India, 6 species, namely *Rhododendron anthopogon*, *R. arboreum, R. barbatum, R. campanulatum, R. lepidotum,* and *R. nivale. Rhododendron arboreum* Smith are found in the western Himalayan. Nepal's national tree and Uttarakhand state tree is *Rhododendron arboreum*. Local dialect calls Burans, 'Bras' and 'Buras'. *Rhododendron arboreum* holds the Guinness Record for World's Largest Rhododendron and as a group of plants having ecologically and economically to temperate forests (Iqbal & Negi, 2017). Rhodo juice/Sharbat, processed juice from its flowers, is popular in Uttarakhand. A variety of natural as well anthropogenic factors disturb Rhododendrons (Mao et al., 2001; Singh et al., 2003). Along with natural threats, various anthropogenic factors, such as unsustainable forest management, clear-felling, logging, and agricultural practices, have contributed to the increase in human pressure on Rhododendron habitats (Mao et al., 2001). Rhododendrons provide ecological stability to the Garhwal Himalayan vegetation (Iqbal & Negi, 2017) and act as an important keystone species here.

Understanding seedling recruitment and seedling survival of *Rhododendron arboreum* including associated tree species in mixed broad-leaved temperate forests are essential for conservation in Garhwal Himalaya. Its purpose is to provide information on Rhododendron arboreum regeneration strategies, including recruitment, survival, growth rate, and mortality of seedlings which are experiencing pressures on high-altitude forests. Besides, until today, no in-depth studies have been carried out on seedling recruitment of Rhododendron species, especially in Garhwal Himalaya.

## 2. Materials and methods

### 2.1. Study site

The present study was carried out in two districts of Garhwal Himalaya i.e., Pauri and Rudraprayag (Fig. 1), from two districts four stands (sites) were selected for detailed study. Four sites were Adhwani and Phairikhal in Pauri district and Mohankhal and Triyuginarayan in Rudraprayag district. Under the influence of cool and moist weather conditions, the soils of the districts have been developed from rocks like granite, schist, gneiss, phyllites, slate. Rhododendrons are found to prefer moist areas with calcium-poor schists (Puri, 1960). The mean January temperature varied from 0.5°C to 2.2°C. Among four sites, two sites of Rudraprayag are cooler than the two sites of District Pauri. The study sites show three distinct seasons in a year, summer, rainy and winter. April to mid-June constitute the summer season which extends up to last week of June, followed by rainy season up to September depending upon the climatic variations. October to February constitute the winter season and is characterized by a rapid dip in temperature after mid-October reaching to a minimum during January (Fig. 2).

### 2.2. Sampling Design and Data Collection

This study investigated the dynamics of seedling population dynamic, including natural recruitment, mortality, and growth behavior (Barik et al., 1996). Ten permanent quadrats, each of 10 x 10 $m^2$, were laid down at those places where enough seedlings were found at each site during May, 2014. Until May 2016, the seedlings from each quadrat were marked with water-resistant labels, and their survival was checked every three months. The seedlings that were present in permanent plots were monitored for growth (shoot length and collar diameter) during the study time. The seedling population's age-specific mortality rate (Qx) was calculated using the formula provided by (Poole, 1974):

$$Qx = \frac{dx}{lx}$$

where *lx* is the initial number of individuals in the population and *dx* is the number of individuals dying after census period.

For every site initial height and collar diameter (hereafter termed as diameter) of the seedlings were measured at the beginning of the experiment, and re-measured at three months interval for two years. The observed seedlings were divided into five collar diameter classes based on their collar diameter to monitor the growth.

Relative growth rate (RGR) was calculated to see how much each seedling had grown over a period of time. The relative growth rate for each three month interval was

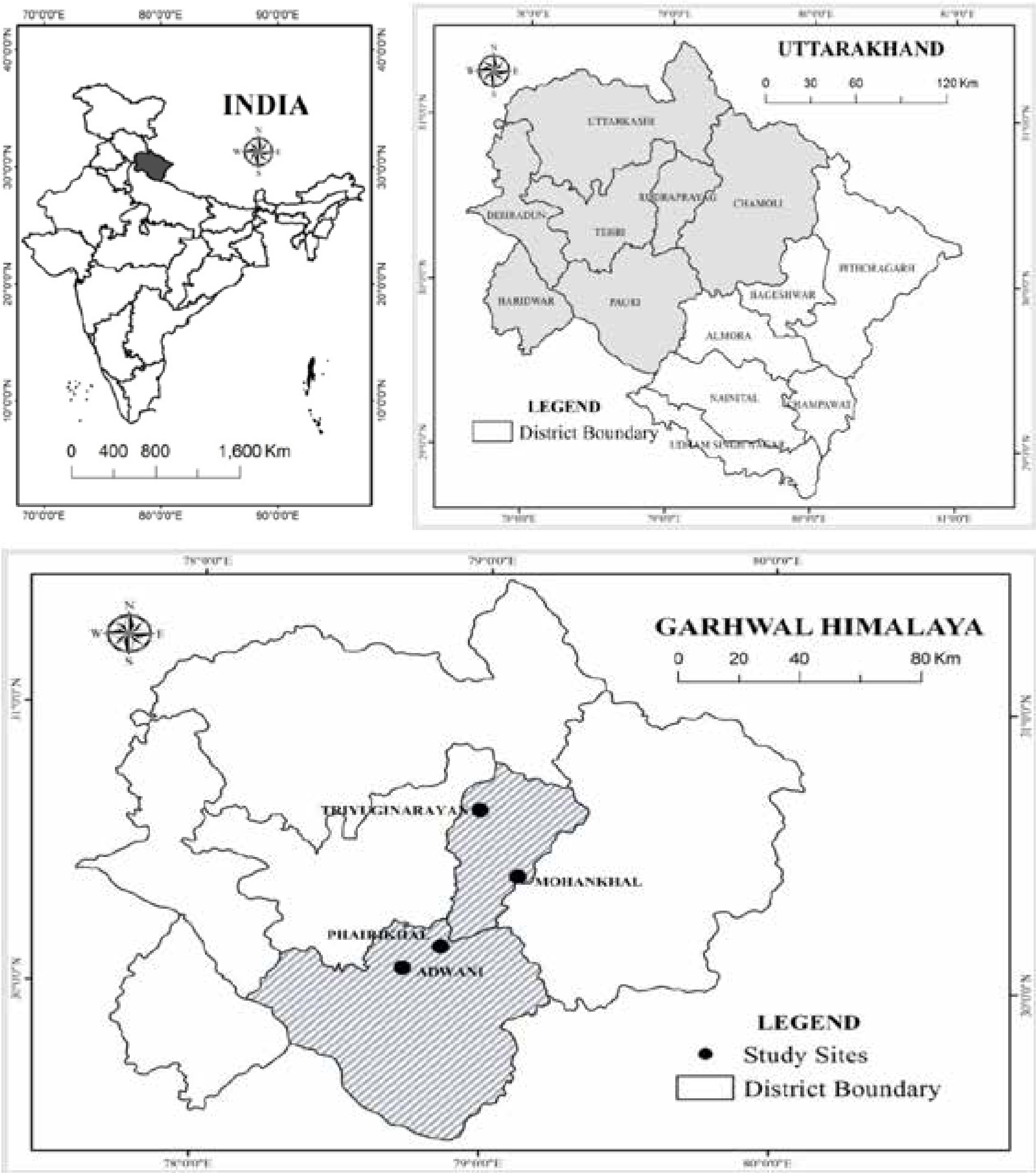


**Figure 1.** Map of the study area

calculated according to (Coombs et al., 1985). The relative growth shoot/ collar diameter) was calculated as

$$RGR = \frac{lnX_2 - lnX_1}{t_2 - t_1}$$

where $X_1$ is the initial height/collar diameter of the seedlings at the time $t_1$ (beginning of the first month), and $X_2$ is the height/collar diameter of the seedlings at the time $t_2$ (end of the third month).

There were at least three potential sources of error in our estimates of survival and mortality: (1) as we may have lost track for some seedlings because their tags were either removed by animals or destroyed during logging (as in case of Mohankhal), (2) Before they were tagged and counted, some seedlings in every quadrat of every site undoubtedly perished; 3) as a result of our erratic sampling schedule, the interval from time t to time t + n occasionally extended by 5 to 10 days.

**2.3. Statistical analysis**

Multivariate ANOVA was performed to test effect of different sites and seasons on the recruitment and mortality of *Rhododendron arboreum* seedlings. Different seasons and different sites were considered as independent factors and seedling growth, mortality and recruitment as dependent variable. First overall effect of sites and seasons on dependent variable was calculated and then sites wise effect was calculated. The ANOVA was performed using SPSS (IBM).

## 3. Result and discussion

### 3.1. Recruitment in permanent plots

Seedling recruitment of *Rhododendron arboreum* and other associated species in permanent plots varied with season and sites. The overall seedling recruitment of *R. arboreum* and other associated species is shown in Table 1. *R. arboreum* recorded the highest recruitment during the post-rainy and spring seasons. Among four study sites, maximum seedling recruitment for *R. arboreum* was recorded in Triguginaryan (36.36%, during November and August), followed by Adhwani (33.33% during August), and most of the seedlings were found established either on the boundary or in the either partially or fully gaps. Shade intolerance of seedlings has also been reported by Nongbri et al. (2014) while working on seedling germination of Rhododendrons in Meghalaya (India). Seedlings are greatly influenced by forest gaps/canopy openings, which affect regeneration and species composition (Khumbongmayum et al., 2005; Brokaw, 1987; Welden et al., 1991). Nagamastu et al. (2002) reported that canopy openness influences the survival rate of seedlings of different species. The relatively higher temperature in gaps and larger exposure to solar radiation may be the cause of better germination of *R. arboreum* seedlings.

The seeds of *R. arboreum* are too small, and they get easily dispersed by the wind, and regeneration is not limited by seed production or dispersal. It has also been observed that seedling recruitment is limited by the seed limitation factor (Clark et al., 1998), i.e., the section of sites where seeds arrived but seeds do not grow into seedlings. However, the recruitment of *Rhododendron arboreum* seedlings in the field conditions indicates that seeds have the potential to germinate. Although, a lower number of seedlings were found during the study period, and most of the recruitment was observed in the section of sites that were either in gaps or at forest boundaries that were exposed due to forest cutting. Thus it may be safe to conclude that small seeds require moisture and light for seedling recruitment. Our statistical analysis shows that there is insignificant variation in the recruitment of the seedlings with different seasons of the year (Table 2). Seed size plays an important role in germination, as large size seed produces large-sized seedlings which have an initial size advantage (Kidson & Westoby, 2000), while small sized seed produces small seedlings, having initial disadvantage as have been observed during the study for *R. arboreum* with a lower number of seedlings.

In all four sites and during the entire study duration maximum recruitment was recorded during the post-monsoon season and minimum during winter (or ending winter season). The seedlings of *R. arboreum* showed high mortality during the winter season while the mortality rate was low during other seasons. In the temperate broad-leaved forest of western Arunachal Pradesh, Paul (2008) has reported that high mortality of *R. arboreum* seedlings during the dry season. Similar to this, seasonal mortality has

**Table 1.** Recruitment status of *Rhododendron arboreum* and other associated species in studied sites (in percentage)

| | 2014 | | 2015 | | | | 2016 | |
|---|---|---|---|---|---|---|---|---|
| **Adhwani** | | | | | | | | |
| **Species** | **AUG** | **NOV** | **FEB** | **MAY** | **AUG** | **NOV** | **FEB** | **MAY** |
| *Myrica esculenta* Buch.-Ham. ex D.Don | 18.18 | 18.18 | 0.00 | 9.09 | 18.18 | 9.09 | 27.27 | 0.00 |
| *Quercus leucotrichophora* A. Camus | 5.26 | 21.05 | 0.00 | 0.00 | 10.52 | 63.15 | 0.00 | 0.00 |
| *R. arboreum* | 33.33 | 0.00 | 13.33 | 0.00 | 20.00 | 20.00 | 13.33 | 0.00 |
| **Phairikhal** | | | | | | | | |
| *M. esculenta* | 13.33 | 6.67 | 13.33 | 13.33 | 20.00 | 20.00 | 13.33 | 0.00 |
| *Q. leucotricophora* | 6.25 | 34.37 | 3.12 | 0.00 | 6.25 | 50.50 | 0.00 | 0.00 |
| *R. arboreum* | 0.00 | 30.77 | 15.38 | 23.08 | 0.00 | 30.76 | 0.00 | 0.00 |
| **Mohankhal** | | | | | | | | |
| *M. esculenta* | 0.00 | 37.50 | 0.00 | 25.00 | 12.50 | 25.00 | 0.00 | 0.00 |
| *Q. leucotricophora* | 7.40 | 33.33 | 3.70 | 0.00 | 11.11 | 44.44 | 0.00 | 00.00 |
| *R. arboreum* | 30.00 | 10.00 | 0.00 | 20.00 | 20.00 | 20.00 | 0.00 | 0.00 |
| **Triyuginarayan** | | | | | | | | |
| *Q. leucotricophora* | 17.39 | 17.39 | 0.00 | 0.00 | 47.82 | 17.39 | 0.00 | 0.00 |
| *R. arboreum* | 0.00 | 36.36 | 0.00 | 0.00 | 36.36 | 27.27 | 0.00 | 00.00 |

**Table 2.** Results of Multivariate ANOVA for effects of different sites and seasons on recruitment and mortality of seedlings

| Source | Variable | F | Sig. |
|---|---|---|---|
| Corrected Model | Recruitment | 1.637 | .033 |
| | Mortality | 1.422 | .094 |
| Intercept | Recruitment | 46.873 | .000 |
| | Mortality | 30.100 | .000 |
| Site | Recruitment | .174 | .914 |
| | Mortality | .082 | .969 |
| Season | Recruitment | 2.684 | .013 |
| | Mortality | 4.448 | .000 |
| Site x Season | Recruitment | 1.518 | .085 |
| | Mortality | .633 | .886 |

been documented by numerous studies from both natural environments (Swaine et al., 1990; Lieberman & Li, 1992; Granhus et al., 2008) and from experimental circumstances (Gerhardt, 1993; Bowers & Turner, 2002). The overall results of seedling recruitment of *R. arboreum* in study sites show that although the process of seed development starts from mid-February or early march but initiation of seed germination starts after the monsoon season. Several factors that can influence the transition of seed into seedlings are the availability of moisture, temperature, and anthropogenic factors (grazing and trampling of seedlings). The main cause of peak mortality of seedlings during the winter season is low temperature and moisture stress conditions (Barik et al., 1996). Numerous studies have documented the impact of low soil moisture on seedling survival and growth (McLeod & Murphy, 1977; Mueller-Dombois et al., 1980; Schulte & Marshall, 1983). Our results of higher mortality during the seedling stage are also supported by some studies e.g., Peters et al. (2003), Hsia and Francl (2009), which pointed out that mortality rates during the seedling stage often exceed 50%. As *R. arboreum* produces abundant seeds but seedling's survival percentage is very low, it is possible that even little variations in seed size and seedling death rates will have a significant impact on the rate of establishment of seedlings and ultimately their transition into adults (Hall & Bawa, 1993).

Among four permanent sites, the highest seedling recruitment for *Quercus leucotricophora* was recorded in Adhwani site (63.15%) during November, followed by Phairikhal (50.50%), with the lowest recruitment in Triguginaryan (17.39%) while for *Myrica esculenta* highest recruitment was observed in Mohankhal (37.50%) during November, followed by (27.27%) during February in Adhwani (Table 1).

### 3.2. Seedling survival and mortality

Higher mortality of *R. arboreum* and the other two species occurred during the winter season (November - February) at all sites. During rainy months (May - September) mortality of seedlings was very low and in some months (August, September, and October) no seedlings were found dead or damaged except in Mohankhal where the mortality of *R. arboreum* seedlings was observed due to logging of trees. According to reports, the survival percentage of seedlings gradually rises during the wet season (Lieberman & Li, 1992). Likewise, peak mortality was observed in the second year, due to harsh winter conditions with no snowfall and rainfall followed by a forest fire (Phairikhal and Adhwani) during the early dry spring season (Fig 2a, b, c and d).

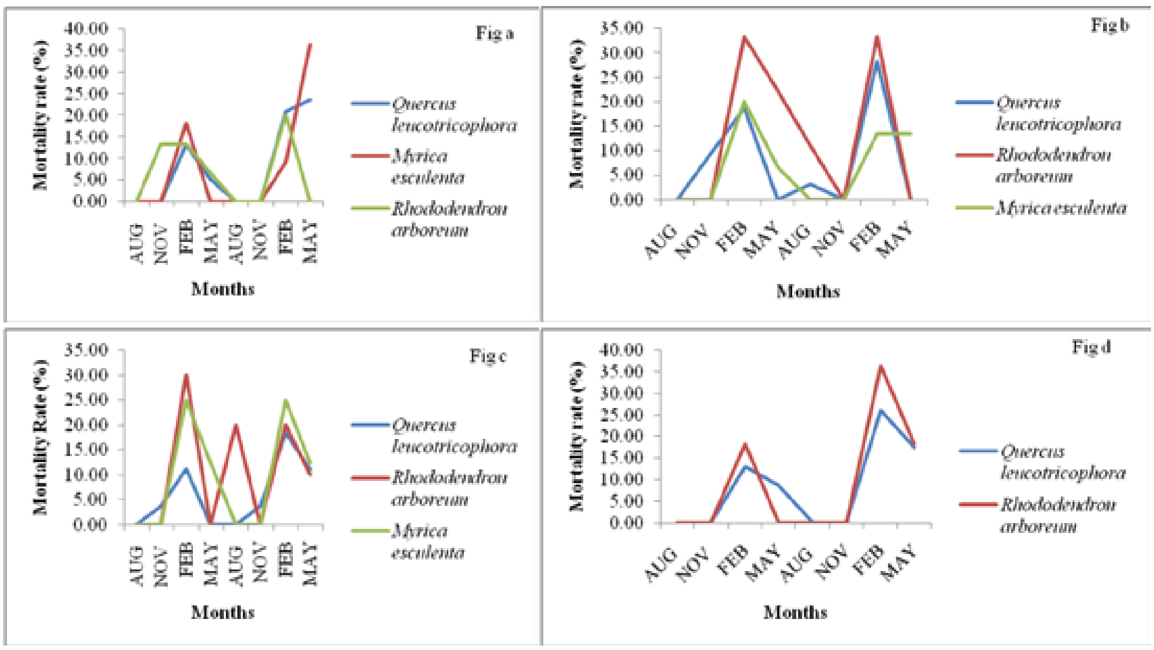


**Figure 2.** Seedlings mortality rate (%) in Adhwani (Fig a), Phairikhal (Fig b), Mohankhal (Fig c) and Triyuginarayan (Fig d)

Multivariate ANOVA was performed to test the effect of sites and season on the recruitment sites. Non-significant effect on the recruitment and mortality (F = 0.174, 0.82, P > 0.001) was observed on *R. arboreum* seedlings. Different seasons of the year have a significant effect on the recruitment and mortality of the seedlings (F = 2.684, 4.448, P < 0.001). The best season for recruitment was recorded from August to November, for the interaction between two factors (season and site) non - significant differences were recorded for recruitment and mortality (F = 1.518, 0.633, P > 0.001, Table 2). All the sites have a non-significant effect on the recruitment and mortality of *R. arboreum* seedlings (Table 3).

### 3.3. Seedling development (Height and Collar diameter Increment)

Seedling development (Fig. 3 a and b) for *R. arboretum* varied in terms of height with sites and with the season. Technically growth of *R. arboretum* seedlings is slow. The growth in terms of height for the present study was 1.05 cm/year (Adhwani), 0.23 cm/year (Phairikhal), 0.43 cm/year (Mohankhal), and 0.72 cm/year in Triyuginarayan with an overall increment of 0.60 cm/year. The increment in collar diameter/year was 0.44 mm in Triyuginarayan, 0.43 mm for both Adhwani and Mohankhal, 0.69 mm for Phairikhal. Because arboreum seedlings are tender and highly nutritious, higher collar diameter increments are most likely to occur in Phairikhal. Consequently, cattle eat the upper part of seedlings more frequently, resulting in a higher amount of food material for the collar diameter alone as herbivores tend to prey more frequently and benefit from their persistence (herbivore). Jackson (1994) reported that Rhododendrons grow a few millimeters in height during the first 1–2 years, which can be further slowed by low temperatures and reduced light availability. The growth and development in terms of height were higher in the early spring season and rainy season. It may be attributed to higher moisture and moderate temperature conditions. According to Khumbongmayum et al. (2005), the gradual acceleration in seedling growth rates during the rainy season may be caused by both the increased moisture content of the soil and the quick decomposition of litter. ANOVA results showed a non–significant effect of season on seedling growth (Table 4), however, Bharali et al. (2012) reported positive effect of different seasons of the year on seedling growth in two *Rhododendron* species of Arunanchal Pradesh.

**Table 3.** Result of Multivariate ANOVA for effects of different seasons on recruitment and mortality of seedlings in four study sites

| | | Adhwani | | Pharikhal | | Mohankhal | | Triyuginarayan | |
|---|---|---|---|---|---|---|---|---|---|
| Source | Variable | F | Sig. | F | Sig. | F | Sig. | F | Sig. |
| Corrected Model | Recruitment | 4.61 | .000 | 7.24 | .000 | 8.15 | .000 | 4.67 | .000 |
| | Mortality | 5.80 | .000 | 8.50 | .000 | 3.78 | .001 | 4.07 | .001 |
| Intercept | Recruitment | 28.09 | .000 | 53.05 | .000 | 57.85 | .000 | 23.01 | .000 |
| | Mortality | 35.60 | .000 | 47.25 | .000 | 26.83 | .000 | 19.06 | .000 |
| Season | Recruitment | 4.61 | .000 | 7.24 | .000 | 8.15 | .000 | 4.67 | .000 |
| | Mortality | 5.80 | .000 | 8.50 | .000 | 3.78 | .001 | 4.07 | .001 |

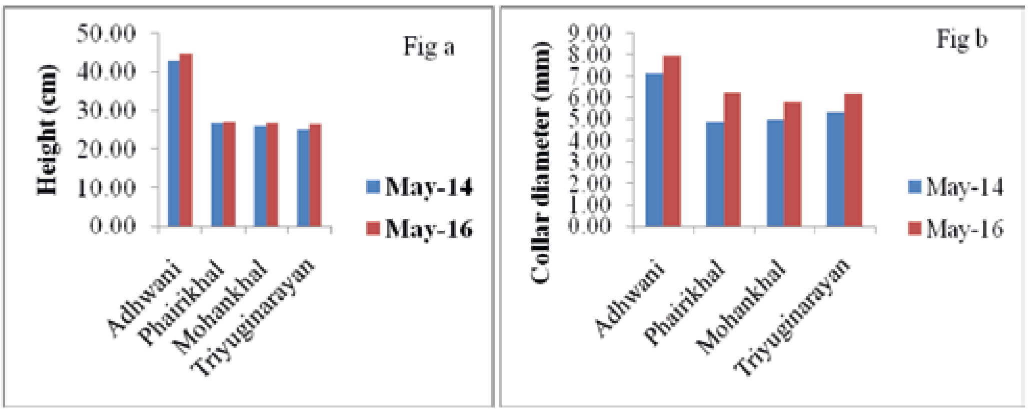


**Figure 3.** Growth of *Rhododendron arboreum* seedlings in terms of height (Fig. a) and collar diameter (Fig. b) in study sites for two years

**Table 4.** Results of Multivariate ANOVA for effects of different seasons on shoot growth and seedling diameter

| | | Adhwani | | Pharikhal | | Mohankhal | | Triyuginarayan | |
|---|---|---|---|---|---|---|---|---|---|
| Source | Variable | F | Sig. | | | | | | |
| Corrected Model | Collar diameter | 0.138 | 0.997 | 0.61 | 0.74 | 0.266 | 0.976 | 0.083 | 1.00 |
| | Shoot growth | 0.014 | 1.000 | 0.004 | 1.00 | 0.004 | 1.00 | 0.008 | 1.00 |
| Intercept | Collar diameter | 662.90 | 0.000 | 678.77 | .000 | 769.34 | 0.000 | 250.64 | 0.000 |
| | Shoot growth | 576.37 | 0.000 | 330.62 | .000 | 254.68 | 0.000 | 167.36 | 0.000 |
| Season | Collar diameter | 0.138 | 0.997 | 0.611 | 0.747 | 0.266 | 0.976 | 0.083 | 1.00 |
| | Shoot growth | 0.014 | 1.000 | 0.004 | 1.00 | 0.004 | 1.00 | 0.008 | 1.00 |

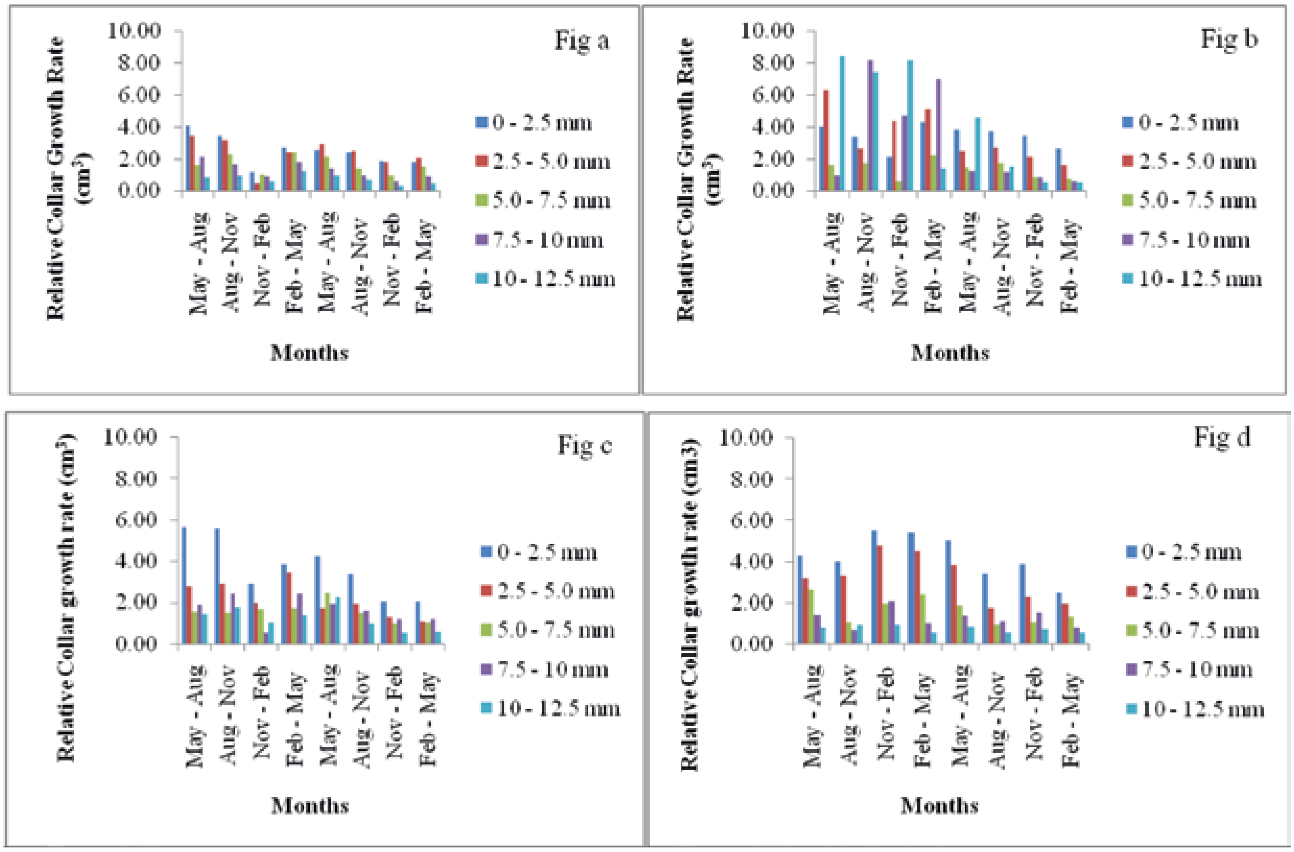


**Figure 4.** Relative collar diameter growth rate of *Rhododendron arboreum* seedlings in Adhwani (Fig. a), Phairikhal (Fig. b), Mohankhal (Fig. c) and Triyuginarayan (Fig. d)

### 3.4. Seedling development (Relative growth rate, Shoot and Collar diameter)

Seasonal variations were seen in the overall relative growth rate for height (RGRH) of rhododendron seedlings. Seasonal variation in temperature and light is a crucial factor in determining growth. RGRH increased throughout the wet season, peaking between February to May and May to August. Winter inhibits the growth of seedlings, resulting in lower seedling growth. While all four sites showed active shoot growth from February to August, the peaks of active shoot growth coincided with different months in each site. Lower collar diameter growth of seedlings was observed during the winter season. The trend of collar diameter growth in all individuals and all sites was higher in the spring season and lower in the winter season (Fig. 4 a, b, c and d). Plant survival and growth are determined by the ability of species to adapt their morphology and physiology to their environment (Rose, 2000). Winter conditions caused low RGRHs among seedlings due to cold, dry weather and low rainfall (Khumbongmayum et al., 2005). In the rainy season, seedling growth is at its peak due to rapid decomposition of litter on the forest floor and higher temperatures and moisture levels. As seedlings grow, the ratio of relative growth declines due to a combination of factors, including the shift from productive tissues to structural tissues and the self-shading of leaves (Turnbull et al., 2012; Evans, 1972; Maranon & Grubb, 1993), as well as a decline in resource availability as seedlings get larger (Ingestad & Agren, 1992).

## 4. Conclusion

The present study is one of the longest experimental studies on *Rhododendron arboreum* in the Garhwal Himalayas. The study revealed that the survival and mortality of seedlings are greatly influenced by the season of the year, with high mortality occurring during cold and dry months of the study. The study also reveals that the growth and development of seedlings are governed by favorable temperature and soil moisture conditions. The wet season of the year was when seedling growth was determined to be the fastest. This variation is caused by the variable light, temperature, moisture, and edaphic conditions at various locations, which leads to the emergence of a variety of microclimatic habitats for species with disparate growth patterns.

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