

Seed Germination, Seedling Survival and Growth of *Rhododendron arboreum* – a High Altitude Tree Species of Meghalaya, Northeast India

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ABSTRACT

The present study was carried out to understand the regeneration behaviour of *Rhododendron arboreum* in terms of seed germination and seedling survival and growth in different microsites i.e., open, periphery and interior of Swer and Sohararim forests under natural condition and also along light gradients (high, intermediate and low) under net house conditions. The germination percentage at room temperature in the laboratory was 54 %. The seeds of the species showed 15 % viability after two years of storage. The survival of the seedlings were high in the open microsites of both the forests (72 - 76%) as compared to periphery (31-40%) and forest interior (11 - 33%). The seedling mortality was high during rainy season. The RGR_H and RGR_w of the species were high during spring and rainy season as compared to dry season. Similarly, the survival and growth of the seedlings was better under high light condition. Results of the study indicate that besides temperature, soil moisture and nutrients, light was the key factor for seedling survival and growth in different microsites of the two forests.

Key Words: *Rhododendron arboreum*; Seed Germination; Seedling Survival; Growth; Northeast India.

INTRODUCTION

Regeneration is a key process for the existence of species in the community. This process helps to maintain desired species composition and stocking after biotic and abiotic disturbances (Khumbongmayum et al. 2005). Tree species have different abilities to grow and survive in the forest understorey because of varied biotic and abiotic factors of the environment. Therefore, an understanding of the ecological requirements of plants at seed and seedling stages is useful for developing appropriate conservation strategies. Successful regeneration of a species depends on its ability to produce sufficient seeds, the ability of seeds to germinate, seed viability, seedling survival and growth (Upadhaya et al. 2009). Successful growth and survival of tree seedlings are controlled by a

number of environmental factors, nutrients availability and competition with other plant species (Khurana and Singh 2001a, McLaren and McDonald 2003). It also depends on the ability of the species to withstand different types of disturbances and environmental stresses (Rao et al. 1990).

The species *Rhododendron arboreum* of the family Ericaceae, is distributed from western to eastern Indian Himalaya and its adjacent regions including the state of Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland and Sikkim in northeast India. The species usually occurs in the high altitude (1200-4000m) regions (Chauhan, 1999) and is extremely variable in stature, hardness, flower color and leaf characteristics (Srivastava 2012). The species has attracted the attention of many researchers due to its significant

ecological and medicinal importance (Paul et al. 2010, Sahu et al. 2011, Verma et al. 2013). In Meghalaya, the population of the species is restricted to forest patches at high altitude (1200 m). The population of the species has drastically reduced due to various anthropogenic disturbances. Therefore, the present study was carried out to understand the regeneration behaviour of the species in terms of seed germination and their survival and growth in different microsites of forests and in different light gradients under net house conditions.

STUDY SITES

The study was conducted in two sacred forests at Swer (Latitude 25° 25' N, Longitude 91° 47' E, altitude 1910-1975 m above sea level) and Sohrarim (Latitude 25° 21' N, Longitude 91° 44' E, 1665-1695 m altitude) in East Khasi hills district of Meghalaya in northeast India. The peripheries of both the forests are disturbed due to collection of firewood for funeral purposes, religious rites and also due to grazing. However, a large portion of both the forest is undisturbed.

The soil in both the forest and different microsites were acidic in nature with pH ranging from 4.6 to 5.1. The soil organic carbon (SOC) concentration ranged from 3 to 5 mg g⁻¹, total Kjeldahl nitrogen (TKN) from 0.48 to 1.1%, available phosphorous from 8 to 11 µg g⁻¹, NH₄-N from 18 to 26 µg g⁻¹, and NO₃-N from 12 to 25 µg g⁻¹ (Table 1).

MATERIAL AND METHODS

Seed Germination, Growth and Survival

Rhododendron arboreum seeds were collected from 18 and nine trees at Swer and Sohrarim respectively, during November. Seed morphology was described based on size, shape, colour, length, width, and averages. Germination of freshly collected seeds was studied under laboratory conditions. Five thousand seeds of the species were kept for germination immediately after collection. The number of germinants was recorded daily after the emergence of plumule/hypocotyl. The newly germinated seedlings were transferred to polythene bags for growth studies under different light conditions in the net houses and transplanted to different microsites in the two forest stands. Remaining seeds were kept at room temperature for testing seed viability at an interval of every 3 months.

Fifteen months-old seedlings (since the seedlings were very small) were transplanted at three microsites viz., in open area adjoining the forest, forest periphery and forest interior of both the forest stands. A total of 900 seedlings were transplanted during June, in each of the two forest stands. Similarly, the seedlings were also grown under three light conditions i.e., full sunlight (100%), intermediate sunlight (50%) and low light (30%) in the net house at the North-Eastern Hill University Campus, Shillong (Latitude 25°34' N and Longitude 92°54' E, 1450 m altitude).

Table 1. Microenvironmental variables and soil physico-chemical properties in three microsites at Swer and Sohrarim forests (the values are the mean of four seasons across two years; ± SEM, n = 24)

Parameter	Swer			Sohrarim		
	Open	Periphery	Interior	Open	Periphery	Interior
Light intensity (µmol m ⁻² s ⁻¹)	91920 ± 3.59	37960 ± 1.73	306.4 ± 2.64	84070 ± 2.51	38105 ± 1.36	1026.7 ± 5.59
Air temperature (°C)	23.00 ± 0.09	20.74 ± 0.1	17.19 ± 0.09	24.68 ± 0.07	23.5 ± 0.09	19.32 ± 0.07
Soil temperature (°C)	18.06 ± 0.06	16.74 ± 0.08	14.67 ± 0.078	19.79 ± 0.13	18.8 ± 0.08	16.23 ± 0.08
Relative humidity (%)	43.33 ± 0.79	51.48 ± 0.67	68.52 ± 0.87	42.69 ± 0.57	48.79 ± 0.51	66.18 ± 1.44
Soil moisture content (%)	45.0 ± 0.03	50.0 ± 0.18	58.0 ± 0.2	32.0 ± 0.02	35.0 ± 0.05	31.0 ± 0.06
pH	4.6 ± .2	4.8 ± .12	4.9 ± .15	4.7 ± 0.08	5.0 ± 0.18	5.1 ± 0.2
SOC (mg g ⁻¹)	4.0 ± 0.1	4.6 ± 0.01	5.0 ± 0.03	3.0 ± 0.06	3.8 ± 0.02	4.0 ± 0.01
TKN (%)	0.88 ± 0.002	1.1 ± 0.002	1.0 ± 0.001	0.48 ± 0.001	0.51 ± 0.001	0.6 ± 0.001
Available P (µg g ⁻¹)	9.0 ± 0.03	10.0 ± 0.04	11.0 ± 0.03	8.0 ± 0.01	8.0 ± 0.02	10.0 ± 0.02
NH ₄ -N (µg g ⁻¹)	23.0 ± 1.0	26.0 ± 1.2	28.0 ± 2.1	18.0 ± 1.0	24.0 ± 0.9	25.0 ± 2.0
NO ₃ -N (µg g ⁻¹)	18.0 ± 0.2	24.0 ± 0.2	25.0 ± 0.3	12.0 ± 0.03	16.0 ± 0.1	18.0 ± 0.2

Growth and survival of the seedlings were monitored at three months interval. Growth performance was measured in terms of their height, leaf area and dry weight by harvesting 10 randomly selected seedlings from the three microsites of the two forest and light regimes. The harvested seedlings were thoroughly washed with water to remove soil particles. Leaf area was measured using a LICOR-3000A leaf area meter (LICOR, USA). Dry matter yield was determined by drying the plant material (roots, stems and leaves) at 60°C to a constant weight and weighed. Relative growth rate (RGR) of seedlings was calculated following Beadle (1985) as:

$$\text{Relative height growth rate (RGR}_H) = (\ln H_2 - \ln H_1) / (t_2 - t_1) \text{ (cm cm}^{-1}\text{month}^{-1}\text{)},$$

$$\text{Relative dry mass growth rate (RGR}_W) = (\ln W_2 - \ln W_1) / (t_2 - t_1) \text{ (g g}^{-1}\text{month}^{-1}\text{)}$$

where, $\ln H_2$ and $\ln W_2$ = natural logarithm of final height and weight and $\ln H_1$ and $\ln W_1$ = natural logarithm of initial height and weight taken at time t_2 (final) and t_1 (initial).

The effect of forests, microsites, light regimes and seasons on the growth of the transplanted seedlings was analysed using ANOVA (fixed model effect). SYSTAT version 10 was used for statistical analysis.

RESULTS

Seed Characteristics and Germination

Seeds of *R. arboreum* were very small (weight 1.0 mg, length= 0.01 mm and diameter = 0.01 mm) and brown to brownish black in colour with variable shapes. It had hypogeal type of germination. Seed germination at room temperature in the laboratory was 54 percent. The seeds showed a progressive reduction in viability during storage at room temperature. After two years of storage, there was 15 % viability (Figure 1).

Seedling Survival and Growth

The seedling survival of *R. arboreum* was high in the open microsite at Swer (76%) and Sohrarim (72%) forest after two years of transplantation. The survival was 11 % and 33 % in the forest interior at Swer and Sohrarim respectively. The seedling mortality exhibited a clear

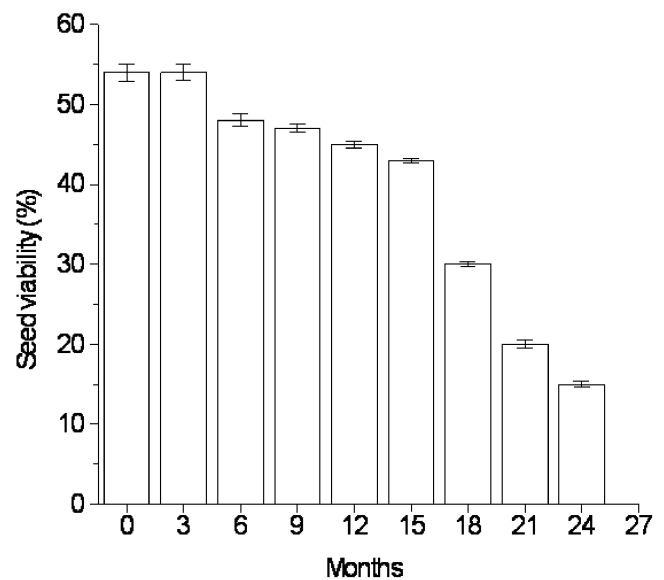


Figure 1. Seed viability (%) of *R. arboreum* during storage at room temperature (\pm SEM, n=100)

seasonal pattern. High seedling mortality was observed during rainy season (June to September) (Figure 2).

Similarly, under net house, after two years, the survival of *R. arboreum* seedlings was high (90 %) in full sunlight. The survival was 40 % and 20% under intermediate and low light intensities respectively. During rainy season, the seedlings showed high mortality in the net houses under intermediate and low light intensity (Figure 2).

After two years of transplantation, the mean height of *R. arboreum* was 40 cm, 30 cm and 5 cm in the open, periphery and interior microsites at Swer. The corresponding values were 16 cm, 11 cm and 3 cm at Sohrarim. Similarly, the performance of the species in terms of number of leaves, leaf area and dry weight was highest in the open sites and decreased towards the forest interior. However, the plants performed better at Swer forest as compared to Sohrarim forest (Table 2). The overall growth of the seedlings under three light gradients in the net house followed a trend similar to that observed in field with higher values in high light as than those under intermediate and low light conditions (Table 2).

Relative Growth Rate (RGR) of Seedlings

The RGR_H and RGR_W of *R. arboreum* varied between the two forests and across the seasons. The RGR_H differed significantly ($F = 13.806$, $P < 0.01$) between the

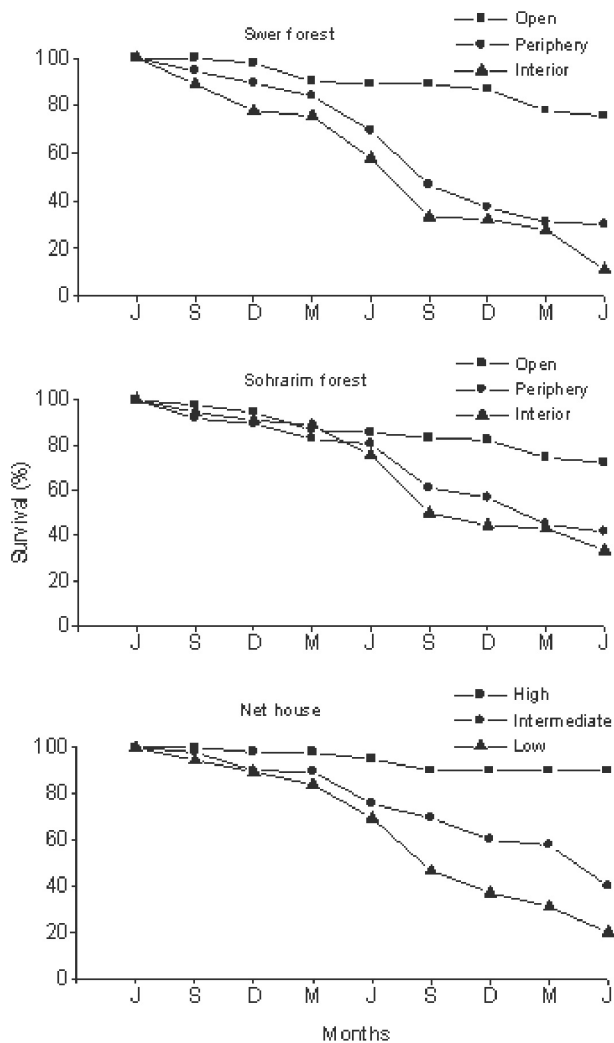


Figure 2. Survival of *R. arboreum* in different microsites of the two forests and light gradient in net house

two forests and microsites ($F = 58.907, P < 0.01$). The RGR_H was maximum in the open and forest periphery and minimum in the forest interior. It showed a distinct seasonality with highest relative height growth rate during spring (March) and rainy (June-September) season and minimum during winter (December) season at all the three microsites of both the forests. Similar seasonal trend was recorded in case of RGR_w ; the peak values being during March and September (Figure 3). Under net house condition also the RGR_H and RGR_w was high under high light intensity and decreased with the decrease of light intensity.

DISCUSSION

The persistence of seed viability in *R. arboreum* for a longer duration suggests that the seeds could be of orthodox type (Ray and Brown 1995, Khurana and Singh 2001b). Better growths of transplanted seedlings of *R. arboreum* in Swer than Sohrarim forest may be attributed to thick soil layer, rich nutrient pool and high nutrient availability. The gradual decline in survival of the species from open to forest interior suggests their intolerance to shade. Along with the shade, high humidity and high soil moisture level were the main causes of seedling mortality of species in the forest interior, since the seedlings got infected by fungi with the onset of rains. Biotic damages caused by herbivores and pathogens are shown to be important factors for seedling mortality in tropical dry forests during the rainy season (Maza-Villalobos et al. 2013). This could also be caused by the depletion of carbohydrate reserves during

Table 2. Seedling height, number of leaves, leaf area and dry weight of *R. arboreum* after two years of transplantation in different microsites at Swer and Sohrarim forest and light gradient in net house (Values are significant at $P < 0.01$ between microsites of each forest, between forests and between light intensity; \pm SEM, $n=10$)

Forests/Net houses	Microsites / Light gradient	Height (cm)	Number of leaves plant ⁻¹	Leaf area (cm ²)	Dry weight (g plant ⁻¹)
Swer forest	Open	39.61 \pm 1.01	83.20 \pm 2.48	617.31 \pm 29.84	31.89 \pm 0.46
	Periphery	30.88 \pm 2.16	26.06 \pm 0.91	92.81 \pm 1.35	8.94 \pm 0.10
	Interior	4.41 \pm 0.01	15.0 \pm 0.21	62.61 \pm 1.10	4.50 \pm 0.01
Sohrarim forest	Open	16.37 \pm 0.10	21.80 \pm 0.42	193.67 \pm 8.85	7.88 \pm 0.06
	Periphery	11.44 \pm 0.12	18.50 \pm 0.37	74.42 \pm 1.59	3.36 \pm 0.03
	Interior	3.22 \pm 0.03	17.60 \pm 0.34	45.07 \pm 0.47	4.16 \pm 0.09
Net houses	High	21.95 \pm 2.71	41.90 \pm 5.81	371.10 \pm 50.54	7.84 \pm 0.35
	Intermediate	8.60 \pm 0.31	14.20 \pm 1.09	71.87 \pm 9.37	5.92 \pm 0.08
	Low	7.89 \pm 0.37	9.10 \pm 0.50	34.16 \pm 1.38	2.45 \pm 0.00

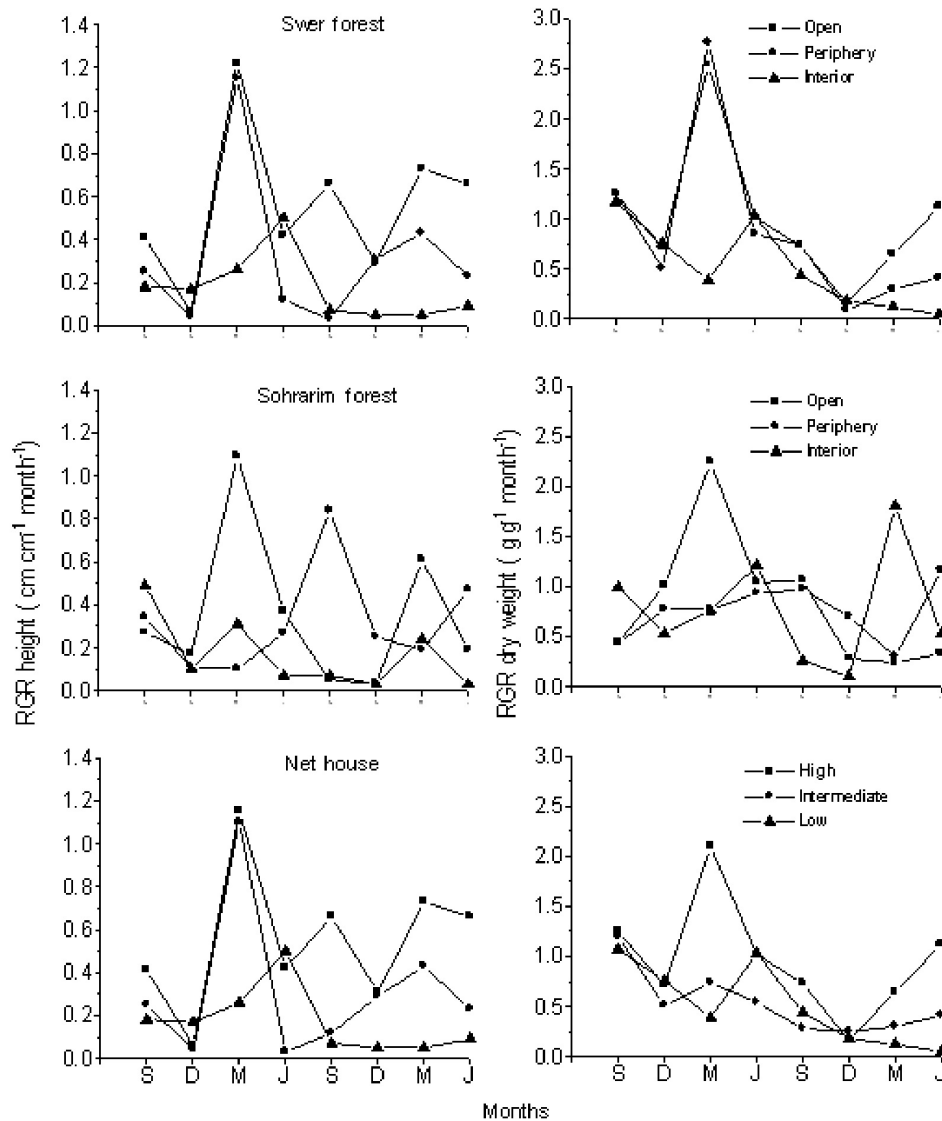


Figure 3. Relative growth rate of *R. arboreum* seedlings in different microsities of the two forest and light gradient in net house

prolonged droughts (November-February) that may have reduced the ability of the plants to defend themselves, or recover from herbivores and pathogens which show high densities during rainy seasons (Maza-Villalobos et al. 2013). Similar observation has been reported by Gomez et al. (2001) in Mediterranean woody species.

R. arboreum seems to be a light demanding species. There were very few seedlings of this species in the forest interior as compared to open places and forest margins in both the forest stands (Nongbri 2007). Similar observations were made by Bharali et al. (2012) in two other species of *Rhododendron* i.e., *R. kenderickii* and *R. grandew* in temperate broad leaved forests of Arunachal Pradesh. This is further supported by better growth of the

seedlings under high light intensity than under intermediate and low light intensity in the net houses. Similar results were observed in a number of tropical species by Balderrama and Chazdon (2005), Benitez-Malvido et al. (2005) and Vieira and Scariot (2006).

High relative growth rate of *R. arboreum* seedlings in the open and periphery during rainy season can be attributed to greater availability of soil moisture in combination with warmer temperature which must have increased the physiological activities. Paul (2008) also reported marked increase in leaf number of *R. arboreum*, *R. arboreum* var. *delavayi*, *R. barbatum* and *R. kesian-giae* during the wet period in temperate forests of Arunachal Pradesh. On the contrary, low growth rate during

the winter (November-February) may be attributed to low temperature and high soil moisture stress.

It may be concluded that the survival and growth of *R. arboreum* seedlings were greatly influenced by light intensity. But high seedling mortality during dry period was due to moisture stress, while pathogens were mainly responsible for seedling mortality during the rainy season. Thus variation in light, temperature, moisture and edaphic factors at different microsites played an important role in influencing growth and survival of tree seedlings in subtropical humid forest of Meghalaya represented by the two studied stands. Therefore, such studies are useful in understanding the habitat as well as microclimatic requirement of a species that would help in developing effective conservation and management strategies of a species.

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