

# Survival and growth of seedlings of a few tree species in the four sacred groves of Manipur, Northeast India

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**Vegetation in the sacred groves is protected and conserved because of religious beliefs and cultural practices of local people. Regeneration of species in the groves is largely influenced by micro-climatic conditions. Differences in growth response of nine tree species in terms of relative growth rate for height (RGRH) and relative total leaf area (RGRA) were studied in the gaps and understorey of the four selected sacred groves of Manipur, Northeast India. Seedling survival, RGRH and RGRA were higher in the gaps than in the understorey. This clearly indicates that tree species differ in their response to light environment and the growth of seedlings was influenced by canopy openness. Seedling mortality was greater during February and lower during June, which is a wet month in Manipur. RGRH and RGRA revealed interaction of season and attained the higher relative growth rates during the wet and moist season (summer season) and lower rates during the cool and dry period (winter season), while temporal changes are caused by physiological parameters. Progressive increase in growth rates during the wet season may be attributed to the increased availability of nutrients due to rapid decomposition of litter on the forest floor and also to higher moisture content of the soil during the summer season experiencing rainfall. Peak seedling growth during the rainy season in all the species could be attributed to favourable temperature and soil moisture conditions. Results of the study indicate better growth and survival of species in the gaps than the understorey. Variation in height growth and leaf area of the seedlings of different species may be partly responsible for the difference in growth behaviour and species-specific attributes for efficient utilization of resources under a given set of environmental conditions.**

THE patches of green forest left untouched from various developmental activities and population pressure because of social fencing by local people signify the concept of 'sacred groves'. A sacred grove is a tract of virgin forest, harbouring rich biodiversity and protected traditionally by the local communities as a whole. The area of sacred groves ranges from few square metres to several hectares<sup>1</sup>. There exist some intriguing examples of forest patches harbour-

ing native vegetation, which has been intertwined with the aspects of various indigenous cultural and religious practices along with the associated taboos. Sacred groves provide a good deal of ecological and genetic services by protecting and conserving the primitive cultivators and other wild flora and fauna. Besides these, sacred groves play an important role in maintaining the micro-climate of the region. Conservation of groves located in different ecological units helps in the conserved water, soil and nutrient, and facilitates the regeneration of tree species in terms of seed germination, growth and survival of seedling in the particular habitat.

Regeneration is a key process for the existence of species in the community. It is also a critical part of forest management, because regeneration maintains desired species composition and stocking after biotic and abiotic disturbances. Various studies on regeneration of threatened and medicinal plants have been carried out in informally managed sacred groves<sup>2,3</sup>. The process of seedling development and growth of forest trees largely depends on gaps/canopy openings in the forest created due to natural disturbance, thus influencing the regeneration and species composition of the forest. Natural disturbances generated by tree or limb falls in tropical rainforests cause a great degree of spatial heterogeneity<sup>4</sup> both within and among the gaps, making the gap phase regeneration a complex phenomenon within the forest. Canopy gaps are characterized by temporary increase in light availability<sup>5,6</sup>. The importance of gaps in the regeneration of tree species in undisturbed forest community has been investigated<sup>7,8</sup>, and the significance of natural gap dynamics in the management of forest ecosystem by maintaining its biological diversity has been studied by several workers<sup>9-11</sup>. It has been suggested that 75% of the tree species at La Selva Biological Station, Costa Rica is dependent on gaps for germination or growth before and beyond the sapling stage<sup>12</sup>. Several workers also reported better growth and survival in tropical<sup>13</sup> and subtropical<sup>14,15</sup> forest trees in sunny areas. There is considerable difference in the response of tropical forest tree species to irradiance, particularly in photosynthetic response<sup>16,17</sup> and relative growth rate<sup>18,19</sup>. Performance of seedlings also depends on resource availability and their physiological ability to efficiently use the higher level of resources present in gaps<sup>4</sup>.

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The recruitment, survival and growth pattern of tree seedlings in forest understorey and treefall gaps in the tropical forests have been studied in different parts of the world<sup>20,21</sup>.

Recruitment and survival of naturally emerging seedlings of dominant tree species in gaps and understorey of a subtropical broadleaved climax forest of Meghalaya were also analysed<sup>15</sup>. But limited information is available on such studies in sacred groves, especially in Northeast India. Moreover, no such studies have been reported so far from the sacred groves of Manipur. Therefore, a study on the survival and growth of seedlings in the understorey and gaps of the four selected sacred groves of Manipur was undertaken. The present study on regeneration in terms of the survival and growth of naturally emerged seedlings of a few selected tree species in the understorey and gaps of the four sacred groves of Manipur will fill in this gap in knowledge. The study may also help in formulating the conservation strategies of the sacred groves of Manipur.

### Study sites

Manipur lies in the extreme northeastern corner of India, between 23°50'–25°42'N lat. and 92°58'–94°45'E long. The state can be divided into two major regions, namely the central valley (Manipur valley) and the surrounding mountains. Manipur valley comprises four districts, i.e. Imphal East, Imphal West, Bishnupur and Thoubal. On the basis of size, vegetation and location, four sacred groves, namely Konthoujam Lairembi, Mahabali, Langol Thongak Lairembi and Heingang Marjing were selected in Imphal East and Imphal West districts. The selected sacred groves are situated between 23°50'–25°41'N lat. and 93°2'–94°47'E long. and they all have sub-tropical forests as their dominant vegetation. Konthoujam Lairembi and Mahabali are located in the valley while Langol Thongak Lairembi and Heingang Marjing are located on the hills. Konthoujam Lairembi is situated in the Konthoujam village, about 11 km west of Imphal city at the elevation of 711 m, covering an area of 1.41 ha. The Mahabali sacred grove is situated in the midst of Imphal city at 710 m altitude, covering 5.05 ha. Langol Thongak Lairembi is located in the Langol hill ranges, covering 5.05 ha. The altitude ranges from 800 m at the foothills to 1050 m at the peak. Heingang Marjing is located in Heingang village to the north of Imphal city, at the elevation of 834 m covering an area of 7.08 ha. The four groves represent the rich vegetation of native species having ethnobotanical importance. Human interferences are regulated by the caretaker and the village authorities through religious proscription and prescription imbued with the cultural beliefs and taboos. Therefore, the regeneration process of tree species in terms of germination, seedling survival and growth and development up to and beyond the sapling is largely determined by the forest micro-climate, which in turn might be altered due to various physico-chemical variables, canopy openings and change in seasons.

Four layers of vertical stratification were observed in all the four sacred groves. *Ficus benjamina* Linn. and *Saprosma ternatum* Hk. f were the dominant species in Konthoujam Lairembi sacred grove where the canopies are close to each other, while *Persea macrantha* Nees and *Ficus glomerata* Roxb. dominate in the Mahabali sacred grove, which have a sparse topstorey layer. The two sacred groves located in the hill ranges are dominated by *Pinus kesiya* Royle ex. Gordon. and canopy coverage is relatively closed.

The climate of the study area is monsoonic with warm moist summer (mid-May to September), experiencing heavy rainfall and cool dry winter (December to February). The mean maximum temperature varied from 22 (January) to 30°C (August) and mean minimum temperature varied from 5 (January) to 23°C (July). The average relative humidity ranged from 58 (March) to 82% (October). The mean monthly rainfall was minimum in December (2.5 mm) and maximum in June (236 mm). The average annual rainfall was 1482 mm. The period between March and mid-May, and that between October and November represents spring and autumn season respectively.

The soil of the two sacred groves situated in the plains is blackish in colour, while it is yellowish-red to pale brown in the other two sacred groves which are located in the hilly area. The type of the soil is Entisol<sup>22</sup>, which is alluvial in nature and its texture is loamy sand. The soil is acidic with pH ranging from 5.4 to 6.59. The organic carbon content ranged from 4.85 to 5.37%, while the total kjeldhal nitrogen (TKN) ranged from 0.01 to 0.04%. In general, the soils are poor in nitrogen<sup>23</sup>.

### Methods

An opening in the forest extending down through all foliage levels to an average height of 2 m above ground is considered as gaps<sup>24</sup>. The area of gaps was measured by mapping them to scale. Distance from the centre to the margin was measured at 45° intervals around each gap. The approximate gap margins were then sketched onto a scaled drawing. Based on these drawings the gaps were then grouped into different shape (elliptical, circular, trapezoid, etc.) and areas were then calculated using the formulas. Three gaps were recorded in each of the two groves located in the hills, i.e. Langol Thongak Lairembi and Heingang Marjing and two gaps in Mahabali, while no gap was available in Konthoujam Lairembi during the study period (2002–03). The area of gaps varied from 30.55 to 131 m<sup>2</sup>. Different microenvironmental variables such as light intensity, soil moisture, water-holding capacity (%), soil texture and soil pH were determined in the understorey and gaps. Light intensity ( $\mu\text{mol m}^{-2}\text{s}^{-1}$ ) was calculated from the value of illuminance (lux), which was measured with digital lux meter at three different times during the day (8.00 a.m., 12 noon and 4 p.m.) during different seasons and means were calculated. Soil texture was determined by hydrometer method. Water-holding capacity of the soil was measured

**Table 1.** Environmental variables in the understorey and gaps in four selected sacred groves

Variable	Sacred grove											
	Mahabali			Langol Thongak Lairembi			Heingang Marjing					
	Gaps			Gaps			Gaps					
	Understorey	Understorey	1	2	Understorey	1	2	Understorey	1	2	3	
Area of gaps (m <sup>2</sup> )	88.08–	115.20–	131	81	102.36–	76	25.91	51.75	30.55	66.73	32.84	
Light intensity (μmol m <sup>-2</sup> s <sup>-1</sup> )	90.38	124.32	1417.36–	1406.16–	107.69	1335.60–	1281.84–	1342.87–	1493.52–	1487.35–	1547.94–	
pH	5.68	6.59	1482.31	1489.61	5.4	1512.00	1357.99	1388.80	1530.48	1676.09	1574.16	
Water-holding capacity (%)	44.67	40.32	48.65	47.76	42.1	42.54	42.78	42.57	38.84	39.52	39.04	
Soil moisture content (%)	39.45	39.18	39.46	38.89	38.4	38.29	39.01	38.74	32.96	32.78	31.46	
Organic carbon (%)	5.37	5.23	4.97	4.76	4.85	4.88	4.72	4.93	4.88	5.02	4.96	
TKN (%)	0.04	0.04	0.04	0.37	0.02	0.03	0.02	0.02	0.01	0.01	0.01	
Soil texture												
Clay (%)	2	3	4	3	10	11	10	9.5	5.5	4.95	4	
Silt (%)	20	18	16	17	21.5	21	23	21.5	17.25	17.50	18	
Sand (%)	78	79	80	80	68.5	68	67	69	78	77.55	78	

\*No gap was available during the study period in Konthoujam Lairembi sacred grove.

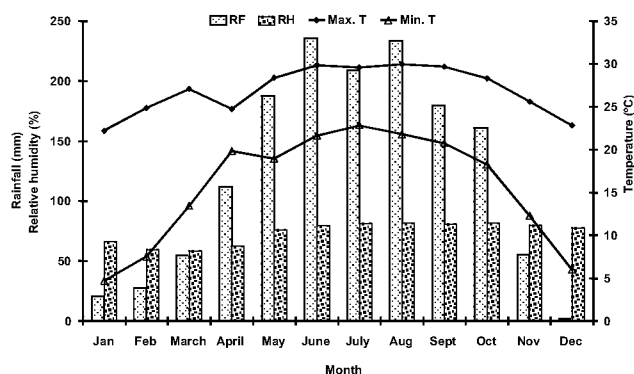
following Keens-up method, while soil pH was measured by a digital pH meter. Values for different variables in the understorey and gaps are given in Table 1.

For studying survival and growth, seedlings of nine important tree species, viz. *Eugenia praecox* Roxb., *Hep-  
tapleurum hypoleucum* Kurz., *Litsea polyantha* Juss., *Litsea  
sebifera* Thumb., *Marlea begoniaefolia* Roxb., *Oroxylum  
indicum* Vent., *Persea macrantha* Nees, *Quercus serrata*  
Thumb. and *Saprosma ternatum* Hk. f were selected from  
the four sacred groves. Among them two species (*E. praecox*  
and *L. polyantha*) were present in all the four groves. *M. be-  
goniaefolia* was common to Konthoujam Lairembe and Maha-  
bali sacred groves. *P. macrantha* was exclusive to Mahabali  
sacred grove, while *H. hypoleucum*, *O. indicum* and *S.  
ternatum* were exclusive to Konthoujam Lairembe sacred  
grove. *L. sebifera* and *Q. serrata* were common to Langol  
Thongak Lairembe and Heingang Marjing sacred groves.

About 20–25 seedlings (<20 cm height) of each of the  
above nine tree species were randomly selected from the  
understorey and gaps. The selected seedlings were of uni-  
form growth and healthy in appearance without any evidence  
of damage or injury. The selected seedlings were labelled  
with an individually numbered aluminium tag and their  
growth and survival were monitored seasonally over a period  
of 1 year (June 2002 to June 2003) at four months interval.  
Stem height and leaf area of all the tagged seedlings were  
measured in June 2002 ( $t_0$ ), October 2002 ( $t_1$ ), February  
2003 ( $t_2$ ) and June 2003 ( $t_3$ ). The periods from  $t_0$  to  $t_1$ ,  $t_1$   
to  $t_2$  and  $t_2$  to  $t_3$  represented rainy, winter and summer  
seasons respectively. Monthly data on temperature, relative  
humidity and rainfall are given in Figure 1. Leaf area of  
each seedling was measured by portable leaf area meter  
(LICOR 3000A) without detaching the leaves. Relative  
growth rates of the individual seedlings in terms of height  
(RGRH) and total leaf area (RGRA) were calculated<sup>25</sup>.

$$\text{RGR} (t_{n-1} - t_n) = \frac{\ln S(t_n) - \ln S(t_{n-1})}{t_n - t_{n-1}},$$

where  $S$  is the plant size, i.e. height (cm) or total leaf area  
( $\text{cm}^2$ ) and  $t$  the time (months).



**Figure 1.** Mean monthly rainfall (RF), relative humidity (RH) and temperature ( $T$ ) of the study area during the study period.

RGRH and RGRA values indicate the aboveground growth  
of individual plants in terms of stem height and total leaf  
area respectively. Seasonal variation for RGRH and RGRA  
in gaps and understorey of the groves was analysed using  
one-way ANOVA, keeping time as source of variation.  
SYSTAT version 6.0 was used for statistical analysis.  
Calculated RGRH and RGRA values during the period  $t_0$   
to  $t_1$  have been presented as RGRH<sub>1</sub> and RGRA<sub>1</sub>, those dur-  
ing  $t_1$  to  $t_2$  as RGRH<sub>2</sub> and RGRA<sub>2</sub> and those  $t_2$  to  $t_3$  during  
RGRH<sub>3</sub> and RGRA<sub>3</sub>, respectively.

## Results

### Survival of seedling

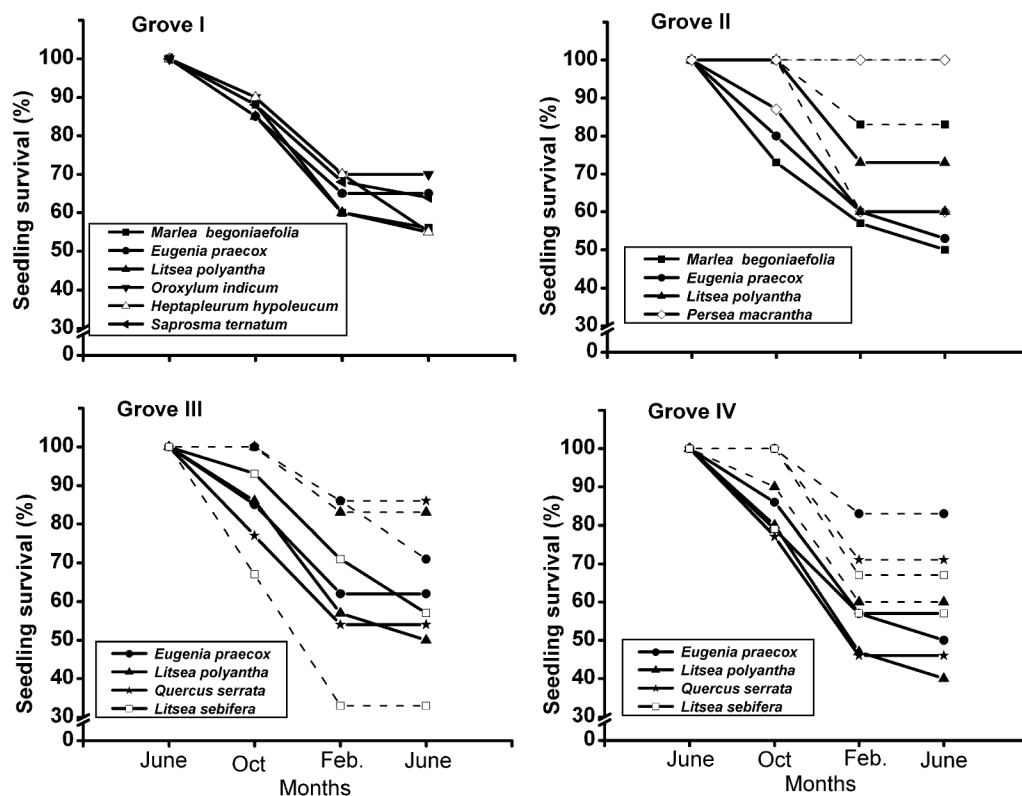
For all the selected species, seedling mortality was high  
during February, which experienced the cool and dry winter  
season. The survival was comparatively high in gaps than  
the understorey (Figure 2). In the gap in Mahabali sacred  
grove (Grove II), seedlings of *E. praecox* and *P. macran-  
tha* did not show any mortality during the study period.

### Relative growth rate of seedlings in terms of height and total leaf area

RGRH and RGRA of the seedlings of the selected species  
in the understorey of the Konthoujam Lairembe sacred grove  
(where gaps were not available) and in the understorey  
and gaps of Mahabali, Langol Thongak Lairembe and  
Heingang Marjing sacred groves showed seasonal variation;  
the minimum being during October to February (Figure  
3). The cold and dry climatic conditions during these months  
may be responsible for poor growth of seedlings.

In the understorey of Konthoujam Lairembe sacred grove,  
differences in RGRH and RGRA among the species were  
significant (RGRH,  $F = 18.34$ ,  $P < 0.0001$  and RGRA,  
 $F = 21.35$ ,  $P < 0.0001$ ). Variation in relative growth rates  
for height differed significantly between RGRH<sub>1</sub> and  
RGRH<sub>2</sub> ( $F = 29.41$ ,  $P < 0.0001$ ), and RGRH<sub>2</sub> and RGRH<sub>3</sub>  
( $F = 27.14$ ,  $P < 0.0001$ ). Significant differences in temporal  
changes of RGRAs were also recorded between RGRA<sub>1</sub>  
and RGRA<sub>2</sub> ( $F = 31.97$ ,  $P < 0.0001$ ), and RGRA<sub>2</sub> and  
RGRA<sub>3</sub> ( $F = 15.7$ ,  $P < 0.0001$ ). *E. praecox* exhibited the  
highest RGRH and the value was lowest for *H. hypoleu-  
cum*. *S. ternatum* showed the highest RGRA among the  
selected species (Figure 3).

While analysing the growth of two common species (*E.  
praecox* and *L. polyantha*) between the understorey and  
gaps in the case of the three groves, it was observed that  
the relative growth rates for stem height and total leaf area  
differed significantly throughout the study period (RGRH,  
 $F = 33.1$ ,  $P < 0.0001$ ; RGRA,  $F = 215.18$ ,  $P = 0.0001$ ).  
Both RGRHs and RGRAs showed significant differences  
between the gaps and understorey during the study period  
(RGRH<sub>1</sub> and RGRH<sub>2</sub>,  $F = 13.86$ ,  $P < 0.0001$ ; RGRA<sub>1</sub> and



**Figure 2.** Survival of seedlings of selected tree species in the understorey and gaps of four sacred groves. Grove I, Konthoujam Lairembi; Grove II, Mahabali; Grove III, Langol Thongak Lairembi and Grove IV, Heingang Marjing. Continuous lines represent understorey and broken lines represent gaps.

$RGRA_2$ ,  $F = 16.8$ ,  $P < 0.0001$ ;  $RGRA_2$  and  $RGRA_3$ ,  $F = 12.11$ ,  $P < 0.001$ ), except between  $RGRH_2$  and  $RGRH_3$  ( $F = 3.03$ ,  $P < 0.05$ ).

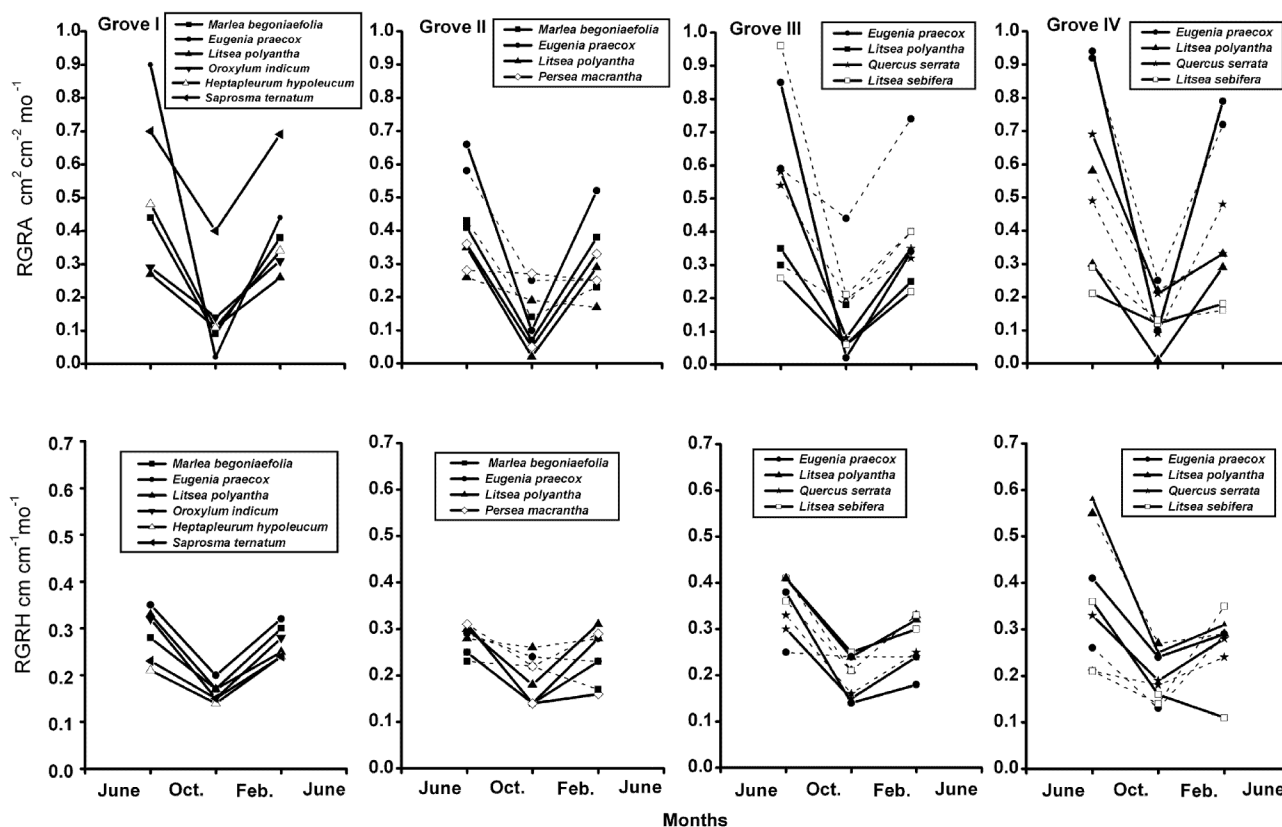
Relative growth rate for stem height ( $F = 35.83$ ,  $P < 0.0001$ ) and for total leaf area ( $F = 19.56$ ,  $P < 0.0001$ ) was significant among the selected species between understorey and gaps of the three groves (Mahabali, Langol Thongak Lairembi and Heingang Marjing) throughout the study period and showed substantial variation on each observation date. Temporal changes in relative growth rates for height differed significantly between  $RGRH_1$  and  $RGRH_2$  ( $F = 60.65$ ,  $P < 0.0001$ ) and  $RGRH_2$  and  $RGRH_3$  ( $F = 28.47$ ,  $P < 0.0001$ ). Differences in RGRAs also varied significantly between  $RGRA_1$  and  $RGRA_2$  ( $F = 26.67$ ,  $P < 0.0001$ ) and  $RGRA_2$  and  $RGRA_3$  ( $F = 50.64$ ,  $P < 0.0001$ ). Generally, growth of the selected seedlings in terms of RGRH and RGRA was characterized by seasonality showing marked decline during the period  $t_1$  and  $t_2$ , which corresponds to the winter season (Figure 3). In general, majority of the selected seedlings recorded higher RGRH and RGRA in gaps than in the understorey, particularly during the rainy season ( $t_0$  and  $t_1$ ) and summer season ( $t_2$  and  $t_3$ ). Exceptionally,  $RGRA_1$  and  $RGRA_3$  in Grove (II) show better growth in understorey, which may possibly be determined by the physiology of the species interacting with the microclimate of the grove and may be due to larger canopy open-

ness compared to other gaps recorded in other groves. This clearly indicates that species differed in response to light environment and the growth of the seedlings was influenced by the canopy openness. Moreover, the warm and wet period during summer season encouraged the growth of seedlings.

#### *Absolute height and leaf area of the selected seedlings in the four sacred groves*

At the end of a one-year study, significant differences ( $F = 14.06$ ,  $P < 0.0001$  for height and  $F = 15.02$ ,  $P < 0.0001$  for leaf area) were observed in absolute height and leaf area of the seedlings of different selected tree species in the understorey of Konthoujam Lairembi sacred grove. *L. polyantha* recorded the highest absolute growth followed by *O. indicum*, *H. hypoleucum*, *M. begoniaefolia*, *E. praecox* and *S. ternatum*. (Figure 4). Maximum leaf area was exhibited for *L. polyantha* followed by *O. indicum*, *H. hypoleucum*, *S. ternatum* and *M. begoniaefolia*, while *E. praecox* recorded the minimum leaf area (Figure 4).

Differences in absolute height of the two common species, *E. praecox* and *L. polyantha* in the understorey and gaps of the three groves were significant ( $F = 12.52$ ,  $P < 0.0001$ ), whereas the differences were insignificant in the case of leaf area.



**Figure 3.** Relative growth rate for height (RGRH) and for total leaf area (RGRA) of seedlings of selected tree species in understorey and gaps of four groves. Grove I, Konthoujam Lairembi; Grove II, Mahabali; Grove III, Langol Thongak Lairembi and Grove IV, Heingang Marjing. Continuous lines represent understorey and broken lines represent gaps.

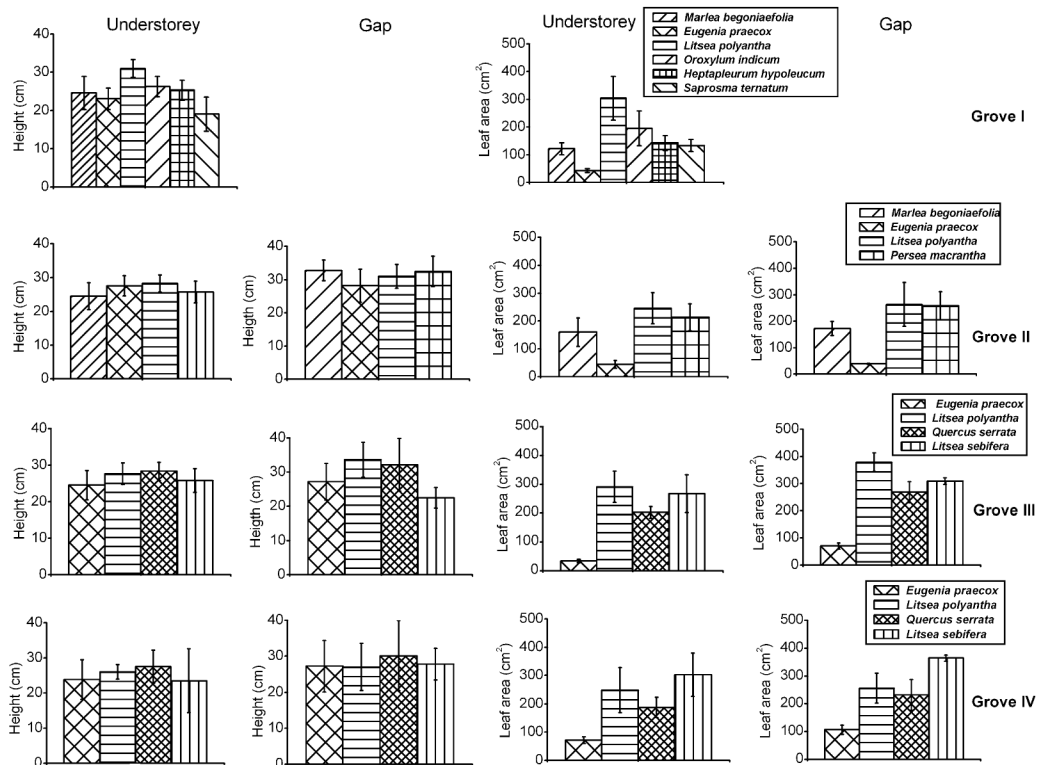
Absolute growth for height and leaf area varied significantly (height,  $F = 3.61$ ,  $P < 0.0001$ ; leaf area,  $F = 19.46$ ,  $P < 0.0001$ ) in the understorey and gaps of the three groves. Height and leaf area of the seedlings of different species were slightly greater in gaps than in the understorey (Figure 4); however differences were not significant.

## Discussion

Seedling survival was greater in the gaps than in the understorey of the groves. Canopy openness influences the survival rate of seedlings of different species<sup>21</sup>. Seedling mortality was greater during February and lower during June, which is a wet month in Manipur. It has been reported that survival rate of the seedlings of tree species increased progressively during the wet season<sup>26</sup>. The seedlings are generally vulnerable to cool and dry climatic conditions prevailing during the winter season and a large number of seedlings died in both understorey and gaps. The detrimental effect of soil moisture stress on the survival of tree seedlings has been reported by several workers<sup>27–31</sup>. The microenvironmental conditions created due to the formation of natural gaps in the groves might be potentially favourable for the survival of tree seedlings<sup>32</sup>. The higher light intensity in gaps and difference in the microenvironmental conditions

recorded (Table 1) in gaps and understorey may influence the growth and survival of the species in the groves. This signifies the role of light and microenvironmental variables during seedling establishment and survival. The importance of light<sup>33,34</sup>, temperature<sup>35</sup> and litter depth<sup>36</sup> in regulating tree seedling survival in tropical forests has been emphasized. A large number of species show better survival in gaps than in the understorey<sup>37,38</sup>.

The overall RGRHs and RGRAs for the seedlings of different species varied seasonally. Seasonal variability in growth response to light environment is an important parameter to determine the growth of subtropical tree species. There were increases in RGRHs and RGRAs during the wet season, attaining a peak during June. Survival and growth of seedlings is directly related to the way in which species can adjust their morphological and physiological characteristics to the environment<sup>39</sup>. Seedlings of all the species showed low RGRHs and RGRAs during October and February, which may be due to cold and dry winter season with high soil moisture stress due to low rainfall. The role of soil moisture in influencing growth of seedlings has been studied<sup>40</sup>. The peak seedling growth during rainy season could be attributed to the increased availability of nutrients due to rapid decomposition of litter on the forest floor and also to the higher moisture content of the soil. Relative



**Figure 4.** Growth of tree seedlings in terms of height and leaf area after one year in understory and gaps of selected sacred groves. Grove I, Konthoujam Lairembi; Grove II, Mahabali; Grove III, Langol Thongak Lairembi and Grove IV, Heingang Marjing. Line bar indicates  $\pm$  SD.

growth rate for height and total leaf area was higher in the gaps than in the understory. It has been found that higher growth rates exist in gaps for pioneer species than the primary species<sup>14</sup>. An increase in canopy openness is not always beneficial for plant performance, as larger canopy openness may lead to reduce growth rates<sup>39</sup>. The better growth in understory for RGRA<sub>1</sub> and RGRA<sub>3</sub> in Grove (II) may be due to the narrow ecological amplitude of the species in response to light and differences in morphological characteristics that adjust to the prevailing environment conditions. Spatial variation in light among gaps and understory, and its effect on growth has been reported by many workers<sup>41–43</sup>. The absolute seedling height and leaf area were also greater in the gaps than the understory for all species in the four groves. Minimum leaf area exhibited in *Eugenia praecox* (Figure 4) may be due to proportionally small leaf size of the plant compared to other species.

Variation in height growth and leaf area of the seedlings of different species may be partly responsible for the difference in growth behaviour under a given set of environmental conditions. Variation in the nutrient supply, light intensity and microenvironmental conditions in the gaps and understory plays an important role in differential growth behaviour of seedlings of different tree species.

The results of the present study indicate that different species differed in their growth responses in the understory and gaps, which may be due to their specific attributes to

influence the physiological ability to utilize the environmental resources efficiently.

In conclusion it may be stated that gaps created due to natural disturbance in the sacred groves, where human interferences are strictly regulated due to the indigenous beliefs in socio-cultural and religious practices, and associated taboos significantly favour the growth and survival of tree seedlings. Therefore, natural gaps in the grove sustain the natural regeneration and maintain the species composition of the forest, thus helping in forest conservation and management.

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