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Research article

Phenology, growth and survival of *Vatica lanceaefolia* Bl.: A critically endangered tree species in a moist tropical forest of Northeast, India

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Abstract: An attempt has been made to unravel the major phenophases, seedling survival and growth of *Vatica lanceaefolia*, a critically endangered tree species in two different micro sites of Hollongapar Gibbon Wildlife Sanctuary, Assam. The study was carried out for a period of 24 months to investigate various phenophases with respect to seasonal variations of the year and, to understand the growth and survival of the seedlings in two micro sites (gap and understory) in relation with the prevailing meteorological parameters of the study area. Leaf flushing was observed twice in a year in the month of December and May, while flowering and fruiting occurs during pre-monsoon season (April and May). The seedlings showed better survival in gap (66.6%) compared to the understory (46.6%) and relative growth rates of the seedlings in terms of height and collar diameter varied significantly across the months and also between the micro environmental conditions of the two micro sites ($P<0.05$). Wet monsoon season favoured the survival and growth of seedlings. Relative humidity ($P<0.05$), average temperature ($P<0.05$) and rainfall ($P<0.05$) of the study area exhibited positive correlation with the growth of *V. lanceaefolia* seedlings in both the micro sites. This is the pioneer study on this species which will be helpful for developing proper conservation strategies and will serve as a baseline for further research on this species to improve the status, distribution and multiplication of the species.
Keywords: Phenology - Seedling growth - Micro sites - Temperature - Rainfall - Relative humidity.

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INTRODUCTION

Forest ecology and management gives the scientific knowledge of the interrelated patterns, ecosystems processes, flora and fauna of the forests. General community patterns in leafing, flowering and fruiting for many species, of which particular forest types are composed, determines the status of the forest (Frankie *et al.* 1974, Opler *et al.* 1980). Vegetative and generative phases of plants show species-specific dependences on geographical location, weather and environmental conditions. Therefore in today's world species-specific ecological studies have become crucial to understand the status of a particular species in its habitat with the changing global climate.

Vatica lanceaefolia is an evergreen tree species which is distributed in moist tropical forests of Bangladesh, Myanmar and in three states of India namely Arunachal Pradesh, Nagaland and Assam (Shiva & Jantan 1998). The species is listed in IUCN Red list category as critically endangered (CR) under criteria A1cd, C2a, version 2.3 (IUCN 2014). The plant is an important source of non-timber forest product (NTFP) and is used for firewood and charcoal making and, the bark yields a clean, white aromatic oleoresin which is used as incense in Bangladesh, Myanmar and India (Shiva & Jantan 1998).

Plant phenological study has a great significance because it provides knowledge about the plant growth pattern as well as provides knowledge on the effects of environment and selective pressure on flowering and fruiting behaviour (Zhang *et al.* 2006). The reproductive success of an individual plant is dependent on its ability to pass through several phenological events that occur during its life cycle: germination, establishment, growth to adulthood, and finally the production and dispersal of viable seed (Harper 1977).

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Phenology of vegetative phases is important, as cycles of leaf flush and leaf fall are intimately related to processes such as growth, plant water status and gas exchanges (Reich 1995). Phenological study is also essential for seed procurement of plant species. The knowledge on phenology of plants has helped to understand the influence of phenological events on feeding, movement patterns, and sociality of insects, birds and mammals (Foster 1982a, Prasad 1983, Coates-Estrada & Estrada 1986). The timing of flowering in plants can serve as an isolating mechanism in plant speciation (Newstrom *et al.* 1994). The timing of flowering and fruiting in tropical trees has been attributed to edaphic, climatic and biotic factors and photoperiod, temperature and soil moisture have been recognized as the main environmental cues for leafing and flowering (Rathcke & Lacey 1985). In most tropical forests, variation in rainfall is suggested to be the most significant climatic factor that influences the phenology of flowering and fruiting (Foster 1974, Hilty 1980, Borchert 1983).

India with a wide range of variation in climate, altitude and physiography exhibits enormous variation in the life cycle of plants of different regions (Koul & Bhatnagar 2005). Several studies on phenology (Boojh & Ramakrishnan 1982, Shukla & Ramakrishnan 1982, Ralhan *et al.* 1985, Bhat 1992, Bajpai *et al.* 2012, Kaur *et al.* 2013) were made in different forest types of India. In recent years phenological studies on some forests of Assam have been reported by few workers (Nath 2012, Devi & Garkoti 2013, Barman *et al.* 2014, Devi *et al*. 2014). However, studies on phenology of tropical moist semi evergreen forest and species specific in particular of North East India, particularly in Assam have been little worked out.

An understanding of the population status and regeneration behaviour is a pre-requisite for developing conservation strategies for the threatened species (Upadhaya *et al.* 2009). Successful regeneration of a species in nature depends on its ability to withstand disturbance stress that plays a key role in seedling survival and establishment (Rao *et al.* 1990). Seedling survivorship relies on many factors, both abiotic and biotic (Karst *et al.* 2011). The process of seedling growth and development of forest trees largely depends on gaps/canopy openings in the forest created due to natural disturbance or seedling establishment barriers such as topography (Koide *et al.* 2011), thus influences the regeneration and species composition of the forest (Khumbongmayum *et al.* 2005). A canopy gap is defined as an area opened by the removal of canopy trees, in which most of the living plants were < 5 m tall and < 50 % of the height of surrounding canopy trees (Runkle 1982). Gap dynamics has been described by many researchers in tropical (Brokaw 1985, Lawton & Putz 1988, Khumbongmayum *et al.* 2005, Sapkota *et al.* 2009, Arihafa & Mack 2012) and sub-tropical forests (Barik *et al.* 1992, Arunachalam & Arunachalam 2000, Griffiths *et al.* 2007), and are being considered as a process capable of influencing the structure of plant communities, enhanced diversity of forest systems, as it expands environmental heterogeneity, and chances for the growth of tree species (Yamamoto 2000). Many workers reported better growth and survival of tree seedlings in tropical (Augspurger 1984) and subtropical (Khan & Tripathi 1991, Rao *et al.* 1997) forest in areas with more sunlight and there are evidences of fast growth and better survival of dipterocarp seedlings in gap compared to understory (Tuomela *et al.* 1996, Kuusipalo *et al.* 1997, d'Oliveira & Ribas 2011). These studies have suggested gap dynamics as an alternative management technique for the degraded and over- logged Dipterocarp forests. Studies on species-specific seedling growth and survival in northeast India is sparse with only a few documentations (Bharali *et al.* 2012, Saikia & Khan 2012a, Saikia & Khan 2012b).

The present study was carried out to understand the major phenological changes and, seedling growth and survival of *V. lanceaefolia* in the study area. The study examines the spatial and temporal changes of phenophases of the plant species and seasonal variation of seedling growth and survival in different micro-sites.

MATERIAL AND METHODS

Study area

The study was conducted for two years (2010-2012) in Hollongapar Gibbon Wildlife Sanctuary (HGWLS), which is situated in Mariani, Jorhat District of Assam, India. It covers an area of 20.98 km^2 and situated at 26°40" to 26°45" N and 94°20" to 94°25" E and is located in the south bank of the Great Brahmaputra river system at an altitudinal gradient of 100–120m above msl. The forest type of the sanctuary is 'Eastern Alluvial Secondary Semi Evergreen Forest (1/2/2B/2S2)' (Champion & Seth 1968) under moist tropical forest of India, dominated by plants namely, *Dipterocarpus macrocarpus*, *Vatica lanceaefolia* and *Mesua ferrea*. The sanctuary is divided into five compartments by the forest department. Continuous pressure by the people of fringe area mainly in the form of cattle grazing, fishing, illegal felling of trees and fuel wood collection have threatened the flora and fauna of this sanctuary.

Climate and soil type

The climate of HGWLS is seasonal with monsoonic pattern of rainfall having four seasons winter (December to February), pre-monsoon (March to May), monsoon (June to September) and post-monsoon (October to November). Rainfall data were collected from India Meteorological Department while relative humidity and temperatures were recorded with the help of a pocket weather station (Kestrel 4000 NV). Winter is cool and temperature goes down up to 7 °C and maximum temperature was recorded 32.4 °C in the monsoon season. Relative humidity ranged from 40–95 % during the study period (Fig. 1).

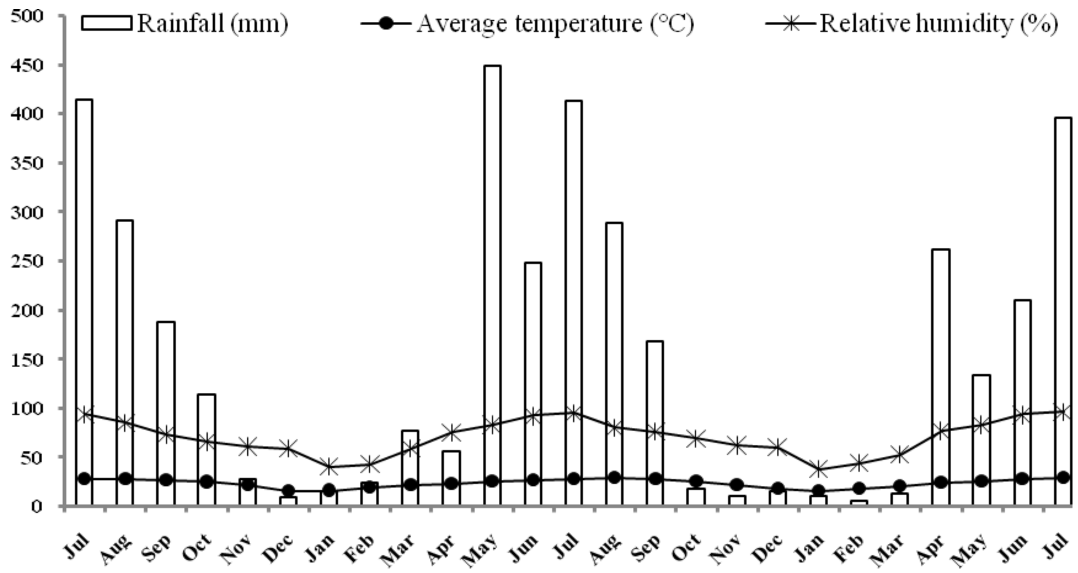


Figure 1. Meteorological parameters of the study area during the study period (July 2010–July 2012).

Different micro-environmental variables such as light intensity and edaphic characteristics of the two micro sites i.e. gap and understory were determined during the study period 2010–2012. Light intensity was measured using digital light meter (Extech EasyView™30). A total of 20 soil samples, 10 each from gaps and understory were collected from the depth of 10 to 15 cm after removing litter accumulation and physicochemical characteristics of the soil was analysed in the laboratory of Department of Environmental Science, Tezpur University, Assam. Soil type of the sanctuary is sandy clay loam and the surface soil is largely covered by litter fall. Light intensity and physicochemical parameters of soil of two micro sites of the study site are given in Table 1.

Table 1. Physico-chemical parameters of soil and environmental variables recorded in the understory and gap of HGWLS.

Variables	**Gap**	**Understory**
Light intensity (µmol m^{-2} s^{-1})	1235.4-2993.03	52.29-122.60
Soil texture	Sandy Clay Loam	Sandy Clay Loam
Sand (%)	67.47	68.83
Silt (%)	10.04	9.58
Clay (%)	22.49	21.59
Bulk density (g/cm^3)	1.1	1.23
Water holding capacity (%)	49.07	47.22
Soil pH	4.9	5.2
Conductivity (mS/cm)	0.2744	0.296
Available N (%)	0.0109	0.031
Available P (ppm)	6.06	6.01
Available K(ppm)	45.88	46.12
Organic Carbon (%)	1.548	2.12
Organic matter (%)	2.6438	3.82

Study species

Vatica lanceaefolia is a middle canopy evergreen tree species under the family Dipterocarpaceae (Fig. 2A). The species is distributed randomly in all the five compartments of the sanctuary. The density of the species inside the sanctuary is 227 individuals per hectare (Sarkar & Devi 2014). *V. lanceaefolia* is largely collected by villager inhabitant in the fringe of the wildlife sanctuary due to its good quality firewood. Large individuals (girth > 40 cm) of the species are also illegally cut down by the people of surrounding villages for commercial purpose. During the study period, cut stumps of the species were found to be highest in compartment no. 1 and 5 having 4 and 3 individual's ha^{-1}, respectively.

Figure 2. *Vatica lanceaefolia* Bl.: **A,** Adult Tree; **B,** Seedling; **C,** Flowers; **D,** Germinated seeds on the forest floor.

Phenological investigations

Preliminary investigations on major phenological events of *V. lanceaefolia* were carried out for a period of two consecutive years (April 2010-March 2012) in Hollongapar Gibbon wildlife sanctuary. A total of twenty five adult plants (having gbh > 40 cm) with uniform canopy coverage were tagged using Aluminium sheets and plastic thread in five different compartments of the study site having five individuals in each compartment for phenological investigation. Monthly observations for phenological changes were made for six major phenological phases viz., leaf abscission or senescence of leaves, leaf flushing, flowering, fruiting, and dropping of fruit and vegetative growth. The phenological characteristics are reported as per Newstrom *et al.* (1993 & 1994) and phenophases were represented with the help of a phenogram.

Survival and growth of seedlings

Two micro sites namely understory and gap were selected for the study of seedling survival and growth of *V. lanceaefolia* in HGWLS. The area of gap was measured using the equation for the area of an ellipse, after measuring the longest axis and its perpendicular shorter axis by laying down long meter tapes (Sapkota *et al.* 2009). A gap of 942.48 m^2 in size inside the forest area located at 26°40′40.2″N and 94°20′53.4″E were selected for the purpose of the study. Thirty seedlings of uniform size and shape within height range of 9 to10.5 cm without any physical damage or herbivory attack were selected in each of the understory and gap (Fig. 2B). To analyse the temporal variation of growth of seedlings, plant height (cm) and collar diameter (cm) of each tagged seedling were measured and recorded at monthly intervals for a period of two years (July 2010-June 2012). The Relative Growth Rate (RGR) in terms of height (RGRH) and collar diameter (RGRD) was calculated as per the formula (Hunt 1982).

$$RGR\ (t_{n-1}-t_n) = l_nS(t_n)-l_nS(t_{n-1})/\ t_n-t_{n-1}$$

Where, S is the plant size, i.e. height (cm) or collar diameter (cm) and t is the time (months).

Seasonal variation for RGRH and RGRD in gaps and understory seedlings of the study site was analysed by one-way ANOVA and significance in variation of the RGRH and RGRD between the seedlings in gap and understory was tested using t-test. The correlation between few meteorological parameters viz. relative humidity, rainfall and average temperature with the relative growth rates of seedlings in both understory and gaps were analysed. All of these analyses were performed in SPSS software version 16.0.

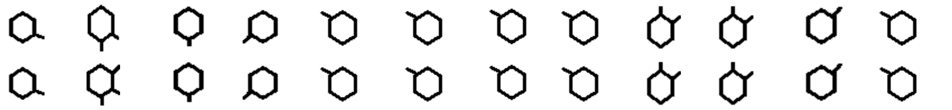
RESULTS

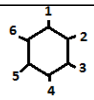
Phenological observations

Vatica lanceaefolia did not show any significant difference among the phenological events from year to year during the two years of consecutive study. It was also observed that the meteorological parameters recorded were more or less same during the two years observation (Fig. 1). The two years study depicts that, leaf abscission accompanied by large scale leaf flushing of *V. lanceaefolia* takes place in the month of December. Flowering takes place once in a year in the month of April, fruit initiation takes place in May with fruit maturation in late June and dropping of fruit takes place in the month of July. From August to November the plant species did not show any major event of phenology and it was considered as vegetative growth (Table 2). In late July, germination of *V. lanceaefolia* takes place in the forest floor.

Table 2. Monthly phenophases of *Vatica lanceaefolia* recorded during the study period.

Study years	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
2010-2011												
2011–2012												





Abbreviations: 1=Leaf abscission, 2=Leaf flushing, 3=Flowering, 4=Fruiting, 5=Dropping of fruit and 6=Vegetative growth.

Survival and growth of seedlings

Seedling survival in two micro sites

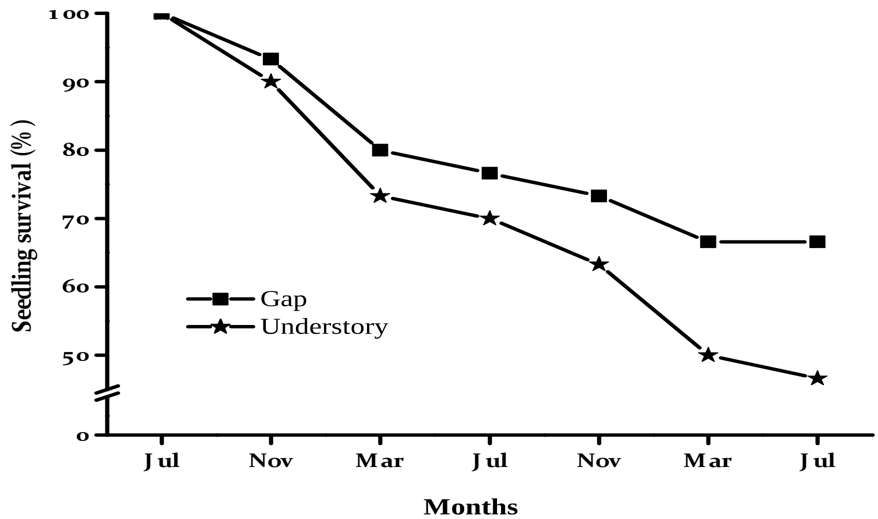


Figure 3. Survival of seedlings (%) of *Vatica lanceaefolia* in understory and gap during the study period.

At the end of the study period, the seedling survival percentage of *V. lanceaefolia* in the two micro sites viz. understory and gaps was recorded 46.6 % (N=14) and 66.6 % (N=20), respectively. The seedling survival was comparatively high in gap compared to the understory (Fig. 3). In the first year observation, the mortality rate of seedlings in gap was 23.33 % while in the following second year observation mortality rate was reduced with 13.04 %. Similarly, seedlings of understory also showed higher mortality rate of 30 % in the first year of observation compared to 26.32 % in the second year of observation. Seedling mortality was high in the month of January and February, which experience the cool and dry winter season in both the study years.

Variation in relative growth rates of seedlings between two micro sites

Relative growth rates in terms of height (RGRH) and collar diameter (RGRD) of the seedlings recorded in both the micro sites during the study period shows higher increment during the month of May and August which corresponds to pre-monsoon and monsoon season and less during February (winter season) and November (post-monsoon season). However, RGRH and RGRD of seedlings exhibit different increment between the gaps and understory with response to seasonal changes. RGRH of understory seedlings shows slightly higher growth rate during winter and post-monsoon compared to the seedlings in gap (Fig. 4).

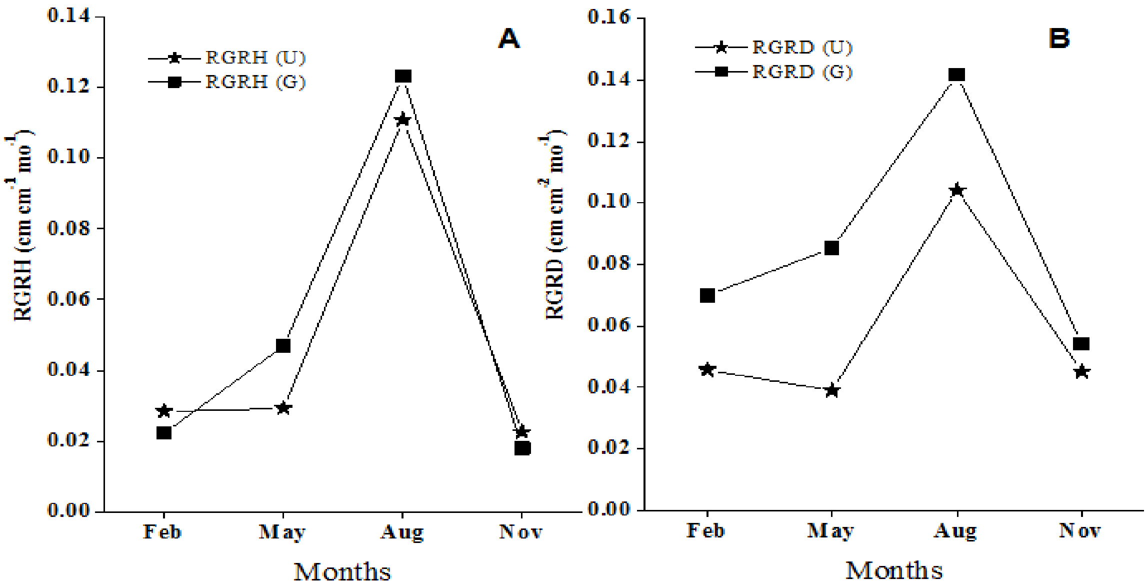


Figure 4. Relative Growth Rates of *Vatica lanceaefolia* seedlings recorded in understory (U) and gap (G): **A**, Height (RGRH); **B**, Collar Diameter (RGRD).

RGRH (t=4.362, df=11, P=0.001) and RGRD (t=5.575, df=11, P=0.000) of seedlings varied between gap and understory and the difference was highly significant. RGRH and RGRD of seedlings of *V. lanceaefolia* in both the micro sites also varied significantly (P=0.000) across the months {RGRH(U), t=5.41, df=23; RGRH(G), t=4.794, df=23; RGRD(U), t=4.450, df=23; RGRD(G), t=4.552, df=23}.

It was observed that relative growth rate in terms of height (RGRH) in both understory (U) and gap (G) exhibited positive correlation with rainfall, relative humidity and average temperature of the study area during the study period (July 2010–Jun 2012). Relative growth rates in terms of collar diameter (RGRD) in understory (U) and gap (G) also showed little correlations with these meteorological parameters (Table 3).

Table 3. Correlations of RGRH and RGRD of seedlings of understory and gaps with meteorological parameters.

	Data from July 2010–June 2011			Data from July 2011–June 2012		
	RF	RH	AVT	RF	RH	AVT
RGRH(U)	R=0.637*	R=0.602*	R=0.687**	R=0.786**	R=0.544*	R=0.609*
RGRH(G)	R=0.702**	R=0.665**	R=0.781**	R=0.686**	R=0.560*	R=0.675**
RGRD(U)	R=0.548*	R=0.548*	R=0.482^{ns}	R=0.452^{ns}	R=0.543*	R=0.416^{ns}
RGRD(G)	R=0.521*	R=0.349^{ns}	R=0.197^{ns}	R=0.673**	R=0.395^{ns}	R=0.521*

RF=Rainfall, RH=Relative humidity and AVT =Average temperature
*significant at the 0.05 level
**significant at the 0.01 level
^{ns}not significant

Absolute height and collar diameter of Vatica lanceaefolia seedlings in gap and understory

At the end of the 12 months observation, the absolute height of the tagged seedlings of *V. lanceaefolia* reached 20.7±0.303 cm and 23.9±0.259 cm in understory and gap, respectively whereas, collar diameter of the seedlings reached 1.3±0.055 cm and 1.6±0.089 cm, respectively for understory and gap. But the difference in absolute height of the seedlings in understory and gap was not significant (P>0.05). At the end of the two years study, the absolute height of the tagged seedlings reached 32.2±2.25 cm and 35.7±0.72 cm in understory and gap, respectively. Correspondingly, collar diameter of the seedlings reached 3±0.29 cm and 3.6±0.28 cm, respectively for understory and gap. Variations in absolute height (t=58.428, df=14, P=0.000) and collar diameter (t=39.884, df=14, P=0.000) of seedlings of *V. lanceaefolia* between the two micro sites was highly significant at the end of two years of observation.

DISCUSSIONS

Phenological observations

From the present study it was revealed that, *V. lanceaefolia* is an annual flowering plant with brief flowering (< 1 month) duration (Newstrom *et al.* 1993 & 1994). Bud initiation in *V. lanceaefolia* takes place after the first shower of monsoon or in mid-April and flower fully opens in the month of May. White flowers of the plant species (Fig. 2C) bear a very mild, pleasant fragrance. Flowering takes place almost at the same time in all the inflorescences of the plant. Occurrence of peak flowering and fruiting records in the months of April to May corresponds with the increased temperature during the pre-monsoon season or the summer. Increasing day length, soil moisture and temperature may have induced flowering during warm pre-monsoon period (Foster 1974, Hilty 1980, Rathcke & Lacey 1985). Regular flowering in some tropical deciduous trees after the spring equinox during March–June has been reported by many workers (Felger *et al*. 2001, Singh & Kushwaha 2006). After 25 days of flowering fruit initiation takes place as the monsoon rain starts and earlier studies also suggested that the seasonal availability of water is the primary determinant of fruiting (Foster 1974, Borchert 1983, Bach 2002). Fruit maturation takes place in June during the monsoon period. The need of high moisture level for the proper development of fleshy fruits has been reported by Zahner (1968), and it was also showed experimentally that the shortage of soil moisture reduces the rate of enlargement and final size of fruits. Seeds of *V. lanceaefolia* germinates without any dormancy period within 6-10 days of dropping, in late July which was favoured by the sufficient availability of soil moisture content due to heavy precipitation and prevailing warm temperature (Fig.2D). This relationship of germination with availability of soil moisture has also been supported by several earlier studies (Foster 1982b, Shukla & Ramakrishnan 1982, White 1994, Bach 1998). In relation to temperature, genera *Vatica* are known to germinate at temperatures above 14°C (Yap 1981). In general seedlings of dipterocarps germinate quickly in warm and moist climate (Tompsett 1986).

Flushing and leaf production completes towards the end of the dry season, before the onset of rains. Leaf fall occurs when temperature declines and day length becomes short during winter which is also supported by earlier studies (Shukla & Ramakrishnan 1984, Bhat 2001). There are several reports of maximum leaf-fall during the driest period of the year in different tropical forest types (Richards 1952, Frankie *et al.* 1974, Opler *et al.* 1980, Liberman & Liberman 1984). During dry season leaf abscission may be attributed to avoid water stress. It was found that leaf flushing and leaf fall in *V. lanceaefolia* requires low temperature (20–25ºC) and low relative humidity (40–50 %). In February the plant bears completely new leaves in its branches. This has also been shown for other seasonal tropical forests (Boaler 1966, Frankie *et al.* 1974). After maturation of leaves, heavy insect infestation is observed during the study period (*personal observation*). Studies have shown that seasonal peaks and depressions for leaf flush and leaf fall are quite common in tropical rain forests with pronounced dry period (Kramer & Kozlowski 1960, Fogden 1972). In tropics emergence of leaves peaked either in dry season (Frankie *et al.* 1974, Whitmore 1984) or in the wet season (Fogden 1972, Proctor *et al.* 1983). Leaf flushing during dry season probably permit renovation of the canopy before the onset of monsoon, so that the plant becomes able to take full advantage of the rainy season to produce and store nutrients for their growth and development. A small scale of leaf flushing observed in the month of May during the second year of observation indicates minor difference in phenological events during the two year of study periods. However, such slight variation could not interpret any remarkable changes in phenological events of the species and it may be stated that the two year phenological observation of *V. lanceaefolia* reveals more or less similar pattern of phenophase which corresponds with the recorded meteorological parameters.

Survival and growth of seedlings

During the two years of seedling survival and growth study, seedling mortality was recorded highest both in understory and gap during the cold dry winter season (December to February) which resulted in sudden decline in the survival percentage of the seedlings in the month of March in both the study years (Fig. 3). Large number of mortality of seedlings during the winter season may be due to the detrimental effect of soil moisture stress on the seedlings which has been stated by many workers (Khan *et al.* 1986, Kikim 1999, Khumbongmayum *et al.* 2005). From June, with the onset of monsoon and increase in soil moisture content, survival rate of the seedlings was stabilized. Increase in survival rate of seedlings during the wet season is reported by various researchers (Tompsett 1986, Lieberman & Li 1992, Bharali *et al.* 2012). Lower mortality rate recorded in the second year observation than the first year observation may be attributed due the establishment of the seedling towards the preliminary stage of sapling.

From the present study it was found that, RGRH, RGRD and absolute height of seedlings of *V. lanceaefolia* is affected by different micro-environmental conditions and the seedling survival was favourable in gap (66.6 %) compared to the understory (46.6 %). Better growth and survival is recorded in a large number of plant species in gaps compared to understory by many workers (Brokaw 1985, 1987, Welden *et al.* 1991, Nagamastu *et al.* 2002). Higher light intensity and the prevailing micro-environmental conditions in gap may have influence in the better growth rates of seedlings of *V. lanceaefolia* compared to the understory (Table 1). The effect of light (Burton & Mueller-Dombois 1984, Connel *et al.* 1984) and temperature (Sorenson & Ferrel 1973) in regulating the growth of tree seedlings in tropical forests has been reported earlier by many workers. Seasonal variability in growth response to light environment is an important parameter to determine the growth of subtropical tree species (Khumbongmayum *et al.* 2005). Growth in terms of height and collar diameter of the seedlings increased in both understory and gap during pre-monsoon and monsoon period probably because of the rainfall, as it shows significant positive correlation with the rainfall of the study area during the study period, however, growth rate decreases during cold dry seasons from November to February (post-monsoon and winter) (Fig. 4). These may be attributed to the high moisture content in soil along with the high surface temperature. The peak seedling growth during rainy season may be because of the increased availability of nutrients in soil due to rapid decomposition of litter on the forest floor and because of the higher moisture content of the soil (Mueller-Dombois *et al*. 1980, Khumbongmayum *et al.* 2005). It was observed that, relative growth rates in terms of height and collar diameter of the seedlings in understory and gap also increases with the increase in relative humidity during the monsoon period. Growth performance was highest in the months of April to September with higher relative humidity and least in the months of November to February with lower relative humidity. Growth reduction in plants due to low relative humidity of the air is reported earlier (Grantz 1990).

Prevailing average temperature of the study area also exhibited positive correlation with the seedling growth performance. This reveals that, seedling growth of *V. lanceaefolia* is largely influenced by rainfall, relative humidity and average temperature of the study area. It can be concluded that, seedling growth of *V. lanceaefolia* shows better in gaps and growth rate increases with increase in soil moisture regime, ambient temperature and rainfall during the summer monsoon season.

CONCLUSIONS

The present study reports the timing of occurrence of different phenological phases of *Vatica lanceaefolia,* an annual flowering plant. Senescence of old leaves occurs with the onset of large scale leaf flushing as a simultaneous process in the cold dry winter months. Flowering and fruiting occurs once in a year in pre-monsoon season. Dropping of mature fruit takes place in late July and correspondingly germination of seeds starts on the forest floor. The study also reveals that, seedling growth of *V. lanceaefolia* is significantly affected by different micro-environmental conditions in terms of their survival and growth parameters. Significantly higher growth performance was observed in the seedlings growing in gap area compared to the understory during the study period in HGWLS. Thus, plantation of *V. lanceaefolia* seedlings in the gaps or in open areas will be a fruitful measure to multiply the number of this critically endangered plant species in their habitat. Germination showed dependency on water availability in the soil as it starts in the rainy season without any dormancy period. Monthly relative growth rate (RGR) in terms of height and collar diameter indicates dependency of the species on wet season as growth rates were found higher during the rainy hot months compared to the cool dry months. The long rainy season from April to September (pre-monsoon and monsoon) during the study period had a positive impact on the growth and development of seedlings in both the micro sites, which was associated with the major changes in the phenological events of the plant.

Presently the sanctuary harbours a good density of *V. lanceaefolia*, but continuous anthropogenic pressure exerted in terms of illegal cutting and felling for the purpose of firewood has emerged as a serious threat to the survival of this species. So, possible measures should be undertaken to control the illegal logging of this species by the fringe village people and proper strategies should be adopted to conserve the plant and multiply its number in the study area in particular and other similar habitats of the species in northeast India in general. This investigation on phenological characteristics and survival and growth of seedlings on this species is a pioneer study and data of the present study may be helpful not only in the formulation of conservation strategies but also in implementing further research aspects of this species *viz*. reproductive phenology, chemical analysis, genetic improvement, etc.

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