Vegetative and reproductive phenology of a floodplain tree species
Barringtonia acutangula from North East India

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Abstract

Vegetative and reproductive phenology of Barringtonia acutangula, a floodplain tree species was studied at Chatla floodplain, Assam North East India with the aim to investigate vegetative and reproductive phenology under stressful environment of seasonal submergence and to assess the impact of environmental variables (temperature and precipitation) on tree phenophases. Quantitative assessment was made at 15 day interval for all the phenophases (leaf initiation, leaf-fall, flowering and fruiting) by tagging 40 (forty) trees over a period of two years (2012-14). To test seasonal influence on the phenology of Barringtonia acutangula different phenophases were correlated with environmental variables and statistical spearman’s rank correlation coefficient was employed. Aridity index was computed that delineate influence of rainfall and temperature together on any phenophases. Leaf initiation showed positively significant correlation with temperature ($r = 0.601$, $p < .05$) during the year 2012-2013 whereas it was significantly correlated with rainfall ($r = 0.583$, $p < .05$) and aridity index ($r = 0.583$, $p < .05$) during the year 2013-2014. Leaf-fall was significantly negatively correlated with temperature ($r = -0.623$, $p < .05$), rainfall ($r = -0.730$, $p < .01$) and aridity index ($r = -0.730$, $p < .01$) for both the studied years. Flowering was significantly influenced by temperature ($r = 0.639$, $p < .05$), rainfall ($r = 0.890$, $p < .01$) and aridity index ($r = 0.890$, $p < .01$) while in one month lag flowering was significantly correlated with rainfall ($r = 0.678$, $p < .01$) in 2012-13. Fruiting was also positively significant with temperature ($r = 0.795$, $p < .05$), rainfall ($r = 0.835$, $p < .01$) and aridity index ($r = 0.835$, $p < .01$) for both the years. During one month lag period fruiting was positively correlated with temperature, rainfall and aridity index in both the years. Temperature, rainfall and aridity index were major determinants of the various vegetative and reproductive phenology of B. acutangula and any changes in these variables in future due to climate change, might have profound effect on phenophases of this tree species.

Key words

Adaptive strategy, Climatic factors, Deciduousness, Phenophases

Introduction

Floodplains are highly diverse and productive systems of great social, ecological and economical values. The river floodplain interaction is mainly governed by seasonal pulsing of flood water from the river onto the floodplain, and its subsequent recession into the river. Floodplains are well known for their important role in sustaining regional biodiversity and water quality, and for their capacity to produce trees and fishes (Tockner et al., 2008). In physiographic configuration of Barak Valley, North East India floodplains cover a distinctive quantity of land coverage with promising potentiality to conserve socio-economic, livelihood security and environmental services. Barringtonia acutangula (L.) Gaertn. locally known as Hijol is naturally growing tree, that grows on the bank of fresh water reservoirs like rivers, swamps, lagoons and low laying flood plains (Chakraborty, 2001). Chatla floodplain of Barak...
Valley originally had rich vegetation of *B. acutangula* as the dominant tree species. The species is highly significant, not only because it is adapted to seasonal inundation, but also due to important role it plays in the benefits of rural livelihood (Nath *et al.*, 2010).

Plant phenology is the study of recurring life-cycle events including leaf formation and fall, flowering, fruiting and seed dispersal (Morissette *et al.*, 2009). The study of plant phenology provides knowledge about the pattern of plant growth and development as well as the effects of environment and selective pressure on flowering and fruiting behavior (Marques *et al.*, 2004, Zhang *et al.*, 2006). Phenological studies are also important to understand ecosystem processes such as plant growth pattern, biomass production, plant water stress (Kikuzawa and Lechowicz, 2011). In recent years, there have seen an increased interest in plant phenological study because it may be an important mechanism behind ecosystem response to future global climate change (Morissette *et al.*, 2009; Korner and Basler, 2010). The climatic change related to precipitation and temperature has generated the need for mechanistic understanding of interactions between environment and tree phenology. Environmental factors (e.g. seasonal variations in rainfall, day length, temperature and soil water storage) are mainly responsible for variety of species-specific phenological patterns in tropical trees (Singh and Kushwaha, 2005). In subtropical and tropical climates, precipitation and temperature are likely to be the primary driver of plant seasonality (Nord and Lynch, 2009). Global climate change may force variation in timing, duration and synchronization of phenological events (e.g. dates of initiation and completion of leaf-flush and leaf-fall and leafless period) in tropical forests (Marques *et al.*, 2004). Trends of erratic precipitation and increasing temperature are likely to reduce the length of the growing season by affecting the timing of leaf-flush and leaf-fall and increasing the leafless period (Singh and Kushwaha, 2005). Drought during rainy season or rain spell during dry season may cause shift in flushing and/or flowering (Borchert *et al.*, 2002). Floodplain species have received little attention in terms of phenological study. As floodplain species possess specialized physiological characteristics, stressful growth and development under submerged and high moisture environment, it is vital to understand how different plant phenophases responses to climatic variables. Therefore, the present study was carried out with the aim to study the vegetative and reproductive phenology of *Barringtonia acutangula* tree and to assess the impact of environmental variables on different tree phenophases.

**Materials and Methods**

**Study area:** The present study was carried out in Chatla floodplain (90°14'N and 24°45'E) in Cachar district of Barak Valley, Assam. Chatla is the catchment of river Ghagra, the tributaries of river Barak. Topography of the area is low lying with numerous small hillocks in between that are inhabited by the villagers. Chatla has an area of around 10 km² and has maximum water spread area of c. 1500 ha, when inundated (Gupta, 2003). The duration of water logged condition around 110-120 days and annual rainfall ranges from 1800 mm to 2500 mm. When it is covered by water during the monsoon, it is treated as “Common Property Regime” with community fishing rights. However after the water recedes the land reverts to a “Private Property Regime” with restoration of individual property rights. During the season the fishermen community used to capture and tread of fishes.

The flood plains originally had rich vegetation with *B. acutangula* as the dominant tree species. This tree can withstand prolonged water logging and is common swamp forest species of this region. Large scale removal of this species was initiated in the 1960-70s at the time of settlement of the fishermen community and now a few patches remain (Gupta, 2003).

**Methodology:** A total of 100 trees were randomly selected covering smallest to largest and measured for Circumference Breast Height (CBH) and classified into girth classes ranging from 10-120 cm. Forty individuals from 40-60 cm size girth class were selected. This is because 40-60 cm girth size was represented by highest number of individuals. The selected trees were marked with a metal tag for observation. Phenological observations were made on leaf initiation, leaf-fall, flowering and fruiting. Phenological observations were based on phenological score such as 0 for no phenophase, 1 for less, 2 for moderate and 3 for high (Broadhead *et al.*, 2003). Detailed observations were carried out at 15 day intervals over a period of two years from June 2012 to May 2014.

The meteorological data of the study area is presented in Fig. 1. Aridity Index was used to delineate dry and wet months. A dry month has an aridity index of less than 30 and wet month equal to or greater than 30. Aridity index was estimated by the following formula (Ewer and Hall, 1978):

\[
\text{Aridity index} = 12 \frac{P}{T} + 10
\]

where, P is mean monthly rainfall (mm) and T mean monthly temperature (°C)

**Data analysis:** Data analysis was performed using the statistical software M.S. Excel 2010. Spearman rank correlations were performed to investigate correlations between monthly phenophase activity and environmental variables such as temperature and rainfall (Zar, 1999). Aridity index was used to correlate the influence of temperature and precipitation together on the different phenophases.
Results and Discussion

Leafing practice in *B. acutangula* initiated during pre-monsoon period (March-April) and continued throughout the favorable season extending up to post monsoon period (October-November) (Fig. 2 A). Peak leaf initiation was observed during the period of March-April (Fig. 3). The findings of the present study resembles with the vegetative leaf phenology of different tree species (Devi and Garkoti, 2013; Das and Das, 2013) of identical geographical location. Peak leaf initiation during pre-monsoon period could possibly be explained by the fact to take the advantages of monsoon period by the fully developed foliage on trees. Temperature registered its influence on leaf initiation significantly during the year 2012-2013 whereas rainfall displayed its impact in 2013-2014 (Table 1). Combined effect of temperature and rainfall was analyzed using aridity index which indicated strong correlation with leaf initiation (Table 2). It seemed leaf initiation was strongly influenced by the combined effect of temperature and precipitation rather than their individual effect. Role of temperature and precipitation as a driving factor for leaf initiation has also been reported for tropical trees (Rivera *et al.*, 2002, Singh and Kushwaha, 2005). Leaf initiation in early rainy season is attributed end of the long dry season (Tesfaye, 2011) and also due to joint action of increasing day length and temperature (Kushwaha, 2010).

Successive leaf-fall was observed from mid monsoon period (June) to winter (January) with highest tendency in the month of December-January (Fig. 2 B). During the monsoon period, *Barringtonia* trees remain partially submerged under water. Flooding creates water deficit in crown as anaerobic root conditions lead to greatly reduced root activity (Worbes, 1985). This could have triggered leaf shedding of *Barringtonia* during the flooding period. This stands in contrast to studies, which found that leaf shedding is strongly correlated with seasonal changes in tree water status (Eamus and Prior, 2001). Leaf-fall presented negative slope in correlation with significance with temperature, rainfall (Table 1) and aridity index (Table 2). In the present study peak leaf-fall occurred when the temperature decrease and day length is short and trees remain leaf-less in February. Periodicity of deciduousness varied from 7-21 days. In 2012-13, half of the observed trees remained leaf-less for 7-14 days while rest half for 14-21 days. While in 2013-14, 60% of the observed trees were leaf-less for 14-21 days (Fig. 4). It was also observed comparatively trees growing on slightly sloped area exhibited longer deciduous period. Variation in periodicity of deciduousness within the same species and within the same locality reflects its different level of tolerance to stress under different soil moisture regimes. Temporal variation in leaflessness in floodplain trees may be important adaptation to dry conditions to optimize vegetative growth in next season, crucial for tree survival. Moreover, leaf-less

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**Table 1.** Phenological patterns of *Barringtonia acutangula* in relation to corresponding month and one month lag period of rainfall and temperature in Barak Valley, North East India

<table>
<thead>
<tr>
<th>Environmental factors</th>
<th>Spearman’s rank correlation coefficients (r)</th>
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<tbody>
<tr>
<td></td>
<td>Temperature (°C)</td>
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<tr>
<td></td>
<td>2012-13</td>
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<tr>
<td>Leaf initiation</td>
<td>0.601*</td>
</tr>
<tr>
<td></td>
<td>(0.433 NS)</td>
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<tr>
<td>Leaf-fall</td>
<td>-0.623*</td>
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<td></td>
<td>(-0.217NS)</td>
</tr>
<tr>
<td>Flowering</td>
<td>0.639*</td>
</tr>
<tr>
<td></td>
<td>(0.467NS)</td>
</tr>
<tr>
<td>Fruiting</td>
<td>0.795*</td>
</tr>
<tr>
<td></td>
<td>(0.569NS)</td>
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</tbody>
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Values in parenthesis refer to one month lag period. **<.01,*<.05, NS: not significant
condition in trees helps in the rehydration of the stem, a prerequisite for leaf flushing and subsequent flowering (Borchert et al. 2002).

Flowering of *Barringtonia* is seasonal and it blooms once in a year. The species flowered profusely during the monsoon period (May-June) (Fig. 2C) soon after completion of peak leaf flushing. Peak flowering in monsoon season reflects importance of high water availability for reproductive success. The result of the present study resembles with the flowering phenology of some multipurpose tree species (*Vatica lanceaefolia*, *Psidium guajava*) in the homegardens of Barak Valley, northeast India (Das and Das, 2013). Synchronization of flowering during particular season of annual cycle appears to be under the control of prevailing climatic condition of that season (Kushwaha and Singh, 2005). Potential adaptive significance of peak flowering following peak leaf flushing, under stressful submergence period, might be due to invest accumulated photosynthate for reproductive phase acquired during peak flushing phase. Flowering was significantly influenced by temperature and rainfall while in one month lag period only rainfall was significantly correlated with flowering in 2012-13 (Table 1) and aridity index was also significantly, with flowering (Table 2). It seems rainfall of current and proceeding month is crucial determinant of flowering in floodplain trees. An analysis of the proximate control of flowering in tropical deciduous trees indicated that

Table 2: Phenological patterns of *Barringtonia acutangula* in relation to Aridity Index in Barak Valley, North East India

<table>
<thead>
<tr>
<th>Phenophases</th>
<th>Aridity index</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2012-13</td>
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<tr>
<td>Leaf initiation</td>
<td>0.290 NS</td>
</tr>
<tr>
<td>Leaf-fall</td>
<td>-0.730**</td>
</tr>
<tr>
<td>Flowering</td>
<td>0.890**</td>
</tr>
<tr>
<td>Fruiting</td>
<td>0.835**</td>
</tr>
</tbody>
</table>

**<.01, *<.05, NS: not significant
the timing of vegetative phenology strongly determines the flowering periods, and thus flowering at least depends indirectly on environmental periodicity (Rivera et al., 2002). Fruiting phase extended over monsoon period (June-September) with peak during July- August (Fig. 2 D). Fruiting presented the correlation distinctively with temperature and rainfall while in one month lag only rainfall was significantly related with fruiting (Table 1) and aridity index also showed positive correlation with fruiting (Table 2). A strong relationship between fruiting and one month lag rainfall suggests that seasonal availability of water and flood pulse have strong impact on fruiting (Schongart et al., 2002). Fruiting in high-water season is the only homogenous trait among floodplain forest trees (Parolin et al., 2002). Indeed, it was observed that *B. acutangula* fruited during the rainy season with a peak in inundation pulse (Haugasen and Peres, 2005). Fruiting during the rainy season in tropical forests may have evolved to ensure dispersal of seeds when soil moisture conditions are favorable for seed germination, seedling growth and survival (Singh and Kushwaha, 2006). Identical phenomenon was also reported in Central Amazonian and adjacent Amazonian floodplain forest (Ferrira et al., 2007). This is an adaptive strategy of floodplain trees for having adequate development time from flowering to fruit dispersal so that seeds are released during rainy periods (Stevenson et al., 2008) when germination is most likely to be induced and seedlings start growing with low probability of drought.

*B. acutangula* exhibited diverse adaptive strategies in vegetative and reproductive phenophases to grow under stressful environment of seasonal submergence. Temperature, rainfall and aridity index were major determinants of different vegetative and reproductive phenology and therefore, might respond vigorously to changes in climate. Shifts in rainfall pattern, as it is expected under global climate change scenario (IPCC 2007), will have pronounced effect on variation (advanced or delay) in onset dates of phenophases (Fitter and Fitter, 2002). Therefore it will be important to develop long term phenological study of floodplain trees to evaluate the trees response of floodplain to future climate change.

**Acknowledgments**

Authors are thankful to 'Tea Research Centre', Silcoorie, Assam for providing meteorological data. Financial assistance by University Grants Commission, New Delhi is gratefully acknowledged.
References


