Phenology of deciduous tree species in traditional Meitei homegardens of Barak valley, Assam, northeast India

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Abstract: Phenological characteristics of dominant deciduous tree species were investigated in the traditional Meitei homegardens at Bantarapur village, Barak valley, Assam, northeast India. A considerable variation was recorded in leaf flush, leaf fall, flowering and fruiting pattern of the tree species that could be attributed to climatic factors. The peak periods of leaffall occur in the months of November-January, leaf flush and flowering peaks in the months of February - March, and the peak fruiting occurs in the months of May-June. The leaf flushing and leaf fall periods were delayed during second year of observation for all the deciduous tree species. The leaf flush period of all the tree species showed a positive correlation with rainfall and temperature, while a negative correlation was observed between leaf fall and rainfall. Synchrony indices for leaf flush phenophase of the entire deciduous tree species ranged from 0.68–0.95. The leaf strategy index increased as a function of deciduousness duration and ranged from 0.61–1.00 for all the deciduous tree species. Present findings significantly enhanced in understanding the phenology of selected deciduous tree species growing homegarden in relation to varying climatic parameters. The outcomes of the present study could well be utilized significantly for further study in broader levels to understand the adaptive response of trees growing in the homegarden to changing climatic factors and their better management for sustainable use.

Keywords: Climatic factors - Deciduous - Homegarden - Meitei - Phenology.

INTRODUCTION

Plant phenology is considered to be one of the strongest indicators of global warming (IPCC 2014). Variations in plant phenology can have robust consequences on ecosystem processes, greenhouse gas emissions, and species interactions (Cleland et al. 2007, Post & Forchhammer 2008, Richardson et al. 2013, Ernakovich et al. 2014, Chaturvedi & Raghubanshi 2016). Globally, climate change has significantly altered the timing of seasonal events, or phenology (Parmesan & Yohe 2003, Bajpai et al. 2015a).

Homegarden is an important land use component of the Meitei community (an ethnic group settled over the states of Manipur, Assam and Tripura in northeast India) which fulfills the sociocultural and economic need of a family and thus helps in conserving plant diversity through utilization (Devi & Das 2010). Diverse tree species with multiseason and varied phenological behavior were recorded in home gardens. The selection of species with varied phenology, leaf area and density, fruit, flower, and branch production to nurture in homegarden let a family have products which can assure many of their needs throughout the year (Benjamin et al. 2001). Plant phenology is poorly known for the homegarden although this ecosystem has the greatest diversity of phenological patterns (Devi 2011). Phenology of tree in any ecosystem and community strongly determines the flowering periods which is indirectly dependent on the environmental variations (Zhang et al. 2006).

The study of plant phenology provides facts about the pattern of plant growth and development as well as the effects of environment and selective pressures on flowering and fruiting behavior (Zhang et al. 2006). Phenological studies are also important to understand ecosystem processes such as plant growth pattern, biomass production, plant water stress (Kikuzawa & Lechowicz 2011). Phenological events of plant species...
responds to a variety of environmental factors, comprising temperature, day length, insolation, precipitation, and soil nutrients (Bajpai et al. 2012, Fu et al. 2015, Piao et al. 2015, Shen et al. 2016, Bajpai et al. 2017). The effects of global warming on plant phenological traits have been found to be species-specific (Fu et al. 2015). Study also suggested that climate change enforced variation in the length of growing period, and competition among species may alter the resource use patterns in different species (Singh & Kushwaha 2005). The occurrence of various phenological events reflects the biotic and abiotic environmental conditions and helps to understand the impact of changing global climate. The management and conservation of natural systems can be significantly enhanced with a greater understanding of the phenology of species (Morellato et al. 2016, Sudip et al. 2017).

The present study is an attempt to explore the phenology of important deciduous trees in the traditional homegardens. The objectives of the present study were (1) to describe the vegetative and reproductive phenology of important deciduous tree species in the traditional homegardens of Meitei community, (2) to assess the impact of climatic factors on phenophases of the tree species.

**MATERIALS AND METHODS**

**Study area**

The study was conducted in the village Bantarapur (24° 38′35" N, 92° 54′65" E) of Cachar district, southern Assam; inhabited by the Meitei community on bank of the River Sonai. Agriculture is the main occupation of the villagers. The mean annual rainfall recorded in the study area was 2193.9 mm and the average monthly maximum and minimum temperature was 30.8°C and 20°C respectively. Climatic diagram of the study site from 2011 to 2012 is shown in figure 1.

![Climatic data of the study site from January 2011 to December 2012.](image)

**Figure 1.** Climatic data of the study site from January 2011 to December 2012.

**Phenological data collection**

For the present study fifty homegardens with the average size of 0.35 ha were selected. For the phenomenological study, 10 dominant deciduous tree species having multipurpose uses for the villagers were selected. The tree species were Albizia lebbeck (L.) Benth., Bombax ceiba L., Cordia grandis Roxb., Erythrina stricta Roxb., Gmelina arborea Roxb., Lagerstroemia speciosa (L.) Pers., Parkia timoriana (DC.) Merr., Premna bengalensis C.B.Clarke, Spondias pinnata (L.f.) Kurz and Toona ciliata M.Roem. Twenty individuals each with CBH≥15cm for every species were selected for phenological monitoring. Phenological changes were recorded at 15 days interval of every month in the selected individuals on leaf initiation, leaf fall, flowering and fruiting. Vegetative and reproductive phenology was observed on the basis of phenological score. Leaf cover was scored using a four-point scale denoting the proportion of the canopy bearing leaves as follows- 0 (absent), 1 (low), 2 (intermediate), 3 (high) (Broadhead et al. 2003). Detailed observation was recorded for a period of two years from January 2011 – December 2012. The phenological activity for each tree species was evaluated as the sum of species with different phenological stages every month. The phenophases of a species was determined by considering the status of the majority of individuals. The duration of a phenological event in a species was computed by obtaining the number of days required for the completion of an event from the date of the
fortnightly visit when the event was first observed. A synchrony index for leaf flush and leaf fall phenophases of each tree species was calculated as the ratio between the individuals mean period of a phenological phase and the overall periods of the phase in all conspecific trees (Devineau 1999). The higher the ratio, the greater the coincidence between different individuals of a species (i.e. at ratio 1.0 perfect synchrony will occur and as the ratio decrease from 1.0 asynchrony will increase) (Kushwaha & Singh 2005).

**Data analysis**

Statistical analysis was done using SPSS 16.0. Relationships between duration of deciduousness, leaf strategy index, of different species were examined by computing correlation coefficients using species mean values. Regression and Pearson correlations were performed to investigate correlation between monthly phenophase activity and environmental variables such as temperature and rainfall. Aridity index was estimated by the following formula (Ewer & Hall 1978):

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

Where, \(P\) = mean monthly rainfall (mm) and \(T\) = mean monthly temperature (°C)

**RESULTS**

**Phenological observation**

| Name of species                | Leaf fall | Leaf flushing | Flowering | Fruiting |
|--------------------------------|-----------|---------------|-----------|----------|
| Albizia lebbeck (L.) Benth.    | PD        | Pe            | PeA       | PeL      |
| Bombax ceiba L.               | PD        | Pb            | PbS       | Pbr      |
| Cordia grandis Roxb.          | PD        | Pb            | PbS       | Pbr      |
| Erythrina stricta Roxb.       | PD        | Pb            | PbS       | Pbr      |
| Gmelina arborea Roxb.         | PD        | Pb            | PbS       | Pbr      |
| Lagerstroemia speciosa (L.) Pers| PD       | Pb            | PbA       | PeL      |
| Parkia timoriana (DC.) Merr.  | PD        | Pe            | PbS       | PbL      |
| Premna bengalensis C.B.Clarke | PD        | Pb            | PbS       | Pbr      |
| Spondias pinnata (L.f.) Kurz  | PD        | Pb            | PbA       | PeL      |
| Toona ciliata M.Roem           | PD        | Pb            | PbA       | PeL      |

Note: P= Periodic, bs= Brief periods, less than 2 weeks per episode, e= Extended periods, equal or more than 2 weeks per episode, S= Synchronous, A= Asynchronous, D= Deciduous, r= Rapid fruit maturation, l= Lengthy fruit maturation.

| Species                        | Synchrony index of leaf flush | Leaf strategy index | Leafless duration (days) |
|--------------------------------|-------------------------------|---------------------|--------------------------|
| Albizia lebbeck (L.) Benth.    | 0.76                          | 0.67                | 68.92                    | 65-71                    |
| Bombax ceiba L.               | 0.94                          | 0.85                | 96.07                    | 76-114                   |
| Cordia grandis Roxb.          | 0.82                          | 0.70                | 53.02                    | 50-58                    |
| Erythrina stricta Roxb.       | 0.68                          | 0.71                | 62.39                    | 61-64                    |
| Gmelina arborea Roxb.         | 0.88                          | 0.61                | 56.02                    | 54-58                    |
| Lagerstroemia speciosa (L.) Pers| 0.95                         | 0.79                | 76.42                    | 74-79                    |
| Parkia timoriana (DC.) Merr.  | 0.84                          | 0.61                | 45.88                    | 43-49                    |
| Premna bengalensis C.B.Clarke | 0.78                          | 0.88                | 112.60                   | 105-121                  |
| Spondias pinnata (L.f.) Kurz  | 0.79                          | 0.99                | 102.65                   | 96-108                   |
| Toona ciliata M.Roem           | 0.80                          | 0.67                | 54.27                    | 46-59                    |

The selected tree species with respect to the timing of leaf flushing and leaf fall, showing widely varying timing and duration of deciduousness. The general phenological stages of all species have been presented in table 1. In this study, tree species exhibited maximum leaf production in the warmer dry season just before the onset of monsoon. The tree species exhibited varied (10–30 days) leaf flush initiation between the first year and second year of observation (Fig. 2). Phenological periodicity, scores ascribed for selected tree species is shown in figure 3. A single leaf flushing peak was observed during the months of March to June (Fig. 4A). Toona ciliata M.Roem is the only tree species in which the leaf initiation starts in the dry month of December and maintained full leaf cover in the early stages of rainfall. Parkia timoriana (DC.) Merr. initiated leaf flush during pre monsoon period and maximum leaf flushing occurred during the rainy season (April–June) which continued throughout the favorable season. The leaf initiation of tree species was strongly influenced by temperature and
precipitation. The leaf flush of the tree species showed positive correlation with rainfall and temperature during the 1st and 2nd year of study (Table 2). The Aridity index indicated strong correlations with leaf flush (Table 3). Regression analysis showed significant impact of minimum temperature during first \( (r=0.864, F=29.52, P<0.0001) \) and second year \( (r=0.907, F=46.144, P<0.0001) \) of the study on leaf flush. The regression analysis of leaf flush and temperature also proves the positive influences of temperature in triggering the species to flush.

\[ \text{Figure 2. Vegetative phenological characters (leaf flush, leaf mature, leaf fall and leafless) of deciduous trees in Meitei homegardens of Barak valley, Assam, Northeast India} \]

The peak leaf fall for the majority of the species was observed during the months of November–January (Fig. 4B). The selected tree species exhibited variation in the initiation of leaf fall from the first year to the second year of observation. In certain species such as *Bombax ceiba* L., *Spondias pinnata* (L.f.) Kurz, *Erythrina stricta* Roxb. and *Parkia timoriana* (DC.) Merr. variation (10–20 days) was seen in the initiation of leaf fall from the first year to the second year of observation.
Figure 3. Leaf cover, leaf flushing, leaf fall, flowering and fruiting periods of ten selected species in Meitei homegardens of Barak Valley, Assam, Northeast India. Scores ascribed for all variables were: (0) absent, (1) low, (2) intermediate, (3) high.
Figure 4. Phenological periodicity of selected tree species in Meitei homegardens of Barak Valley, Assam, Northeast India: A, Number of species in leaf flushing; B, in leaf fall; C, in flowering; D, in fruiting.

Table 3. Phenological patterns of tree species in relation to Aridity Index in Meitei homegardens of Barak valley, Assam, Northeast India.

| Phenophases      | 2011  | 2012  |
|------------------|-------|-------|
| Leaf flush       | 0.80**| 0.94**|
| Leaf fall        | -0.61*| -0.69*|
| Flower           | 0.58NS| 0.49 NS|
| Fruit            | 0.86**| 0.65* |

Note: Pearson correlation**p<0.01, *p<0.05, NS-not significant

Varied duration of the leafless period in tree species growing in the homegarden was observed between the first and second year of observation (Fig. 2). A negative correlation was observed between leaf fall and rainfall in the first year of study while in the second year, no significant relation was recorded. Leaf fall was significantly (–ve) correlated with maximum temperature during second year but insignificant in the first year (Table 2). The relation of leaf fall and the aridity index was observed to be negatively significant (Table 3). Regression analysis showed significant influence of rainfall in the first year (r=0.601, F=5.563, P<0.039) and maximum temperature during the second year (r=0.98, F=1.496, P<0.002) on the leaf fall.

The seasonal patterns of flowering in the present study exhibit two peaks - one major peak during March-April and another minor one in October-November (Fig. 3C). *Albizia lebbeck* (L.) Benth. flowers twice in a year (Fig. 4C). The flowering did not show any significant relation with rainfall and temperature in the first year of study, but positively significant relation with maximum temperature was recorded during the second year (Table 2). The flowering in the tree species showed no significant relation with the aridity index during the study period (Table 3). Regression study showed no significant influence of rainfall and temperature in the second year, but in the second year positive influence was recorded (r=0.649, F=7.280, P<0.022) on flowering. The selected tree species in the present study exhibited four basic patterns of flowering in relation to leaf flushing as described by Kikim & Yadava (2001): a) Flowering before leaf flush and during leafless period, e.g. *Spondias pinnata* (L.f.) Kurz, *Erythrina stricta* Roxb. and *Gmelina arborea* Roxb. b) Flowering long before leaf flush and during leafless period e.g. *Bombax ceiba* L., *Albizia lebbeck* (L.) Benth and *Toona ciliata* M.Roem d) Flowering later, after leaf flushes e.g. *Lagerstroemia speciosa* (L.) Pers. and *Parkia timoriana* (DC.) Merr.

In this study, two peak periods of fruit maturation were observed, a major peak during the month of June-July and a minor one in October-November (Fig. 4D). The major peak period of fruit maturation included
**Bombax ceiba** (L.), *Gmelina arborea* Roxb and *Toona ciliata* M.Roem while species included in the minor peak were *Parkia timoriana* (DC.) Merr. and *Spondias pinnata* (L.f.) Kurz. Majority of the species started fruit maturation during the month of May. During the 1st year of study fruiting is significantly related with rainfall, maximum and minimum temperature but during 2nd year the relation is significant only for rainfall and minimum temperature (Table 2). Aridity index also showed positive correlation with fruiting (Table 3). Regression analysis showed positive influence of rainfall and temperature during the first and second year ($r=0.860$, $F=29.29$, $P<0.0001$) on fruiting.

![Figure 4](image)

**Figure 4.** Phenological periodicity of selected tree species in Meitei homegardens of Barak Valley, Assam, Northeast India: A, Number of species in leaf flushing; B, in leaf fall; C, in flowering; D, in fruiting.

![Figure 5](image)

**Figure 5.** Relationship between leafless duration and leaf strategy index in Meitei homegardens of Barak valley, Assam, Northeast India

![Table 4](image)

**Table 4.** Phenological patterns of tree species in relation to rainfall and temperature of Meitei homegardens of Barak Valley, Assam, Northeast India.

| 2011 | 2012 |
|------|------|
| Phenophases | Rainfall (mm) | Max Temp ($^\circ$C) | Min Temp ($^\circ$C) | Rainfall (mm) | Max Temp ($^\circ$C) | Min Temp ($^\circ$C) |
| Leaf flush | 0.80** | 0.85** | 0.86** | 0.84** | 0.89** | 0.91** |
| Leaf fall | -0.60* | -0.47NS | -0.03NS | -0.59* | -0.79** | -0.59* |
| Flower | 0.55NS | 0.29NS | 0.20NS | 0.39NS | 0.65* | 0.38NS |
| Fruit | 0.86** | 0.69* | 0.75** | 0.84** | 0.50NS | 0.70* |

**Note:** Pearson correlation**$p<0.01$, *$p<0.05$, NS-not significant.
Deciduous and leaf Strategy index

Synchrony indices for leaf flush phenophase of different tree species ranged from 0.68–0.95. Maximum leaf flush Synchrony occurred in Lagerstroemia speciosa (L.) Pers. and minimum in Erythrina stricta Roxb. The selected tree species differed considerably in terms of leafless period. The leaf strategy index increased as a function of deciduousness duration and ranged from 0.61 to 0.99 for the tree species (Table 4). The leaf strategy index for <2 month deciduous tree ranged from 0.61 to 0.67 and 0.67 to 0.99 for 2–3 months deciduous. Relationships between leafless period and leaf strategy index were examined across different species (Fig. 5).

DISCUSSION

The flushing and leaf production towards the end of the dry season and just before the rains has also been reported from other parts of India (Singh & Kushwaha 2005, Nath et al. 2016, Bajpai et al. 2017). It is found that the leaf flush advanced by 2 to 13 days during 2nd year of study, whereas, Thakur et al. (2008) reported a leaf flush advancement of 5 to 40 days. Increased rainfall in March–April months during 2nd year compared to that of the 1st year might result in the advancement in leaf flush of tree species. The leaf initiation of tree species was strongly influenced by temperature and precipitation (moisture) (Bajpai et al. 2012, 2017, Chaturvedi & Raghubanshi 2016).

Leaf fall during the dry-cold period is largely due to the effect of water stress on the morpho-physiological activities of the plants. Water stress can induce leaf fall by decreasing the water potential of leaf during the dry season and leaf fall is an adaptation to reduce the effect of water shortage (Borchert et al. 2002, Tesfaye et al. 2011). As a defense mechanism to tolerate the dry conditions, the species shed leaves and recover during the rainy seasons, this leaf fall may be induced by microenvironment factors as reported by other studies (Kikuzawa & Lechowicz 2011, Chaturvedi & Raghubanshi 2016, Omondi et al. 2016). In the present study negative correlation was observed between temperature and leaf fall in tree species. The findings of the present study resembles the vegetative leaf phenology of trees from Northeast India (Nath et al. 2016). Negative correlations between leaf fall and environmental variables indicate that this phenophase is associated with a reduction in temperature and precipitation (Nunes et al. 2005).

In the present study area variation of flowering and fruiting was recorded that will facilitate in seed germination during favourable conditions. The tree species Gmelina arborea Roxb. and Toona ciliata M.Roem. flower during the monsoon, which reflects the importance of high water availability for reproductive success as also reported by other studies (Das & Das 2013, Bajpai et al. 2017).

The initiation of flowering by the end of winter, during high temperature and increasing day length has also been reported from other tropical areas (Yadav & Yadav 2008, Kushwaha et al. 2011, Gritto et al. 2015, Bajpai et al. 2017, Mohandass et al. 2018). The selected tree species in the present study exhibited four basic patterns of flowering in relation to leaf flushing as described by (Kikim & Yadava 2001), a) Flowering before leaf flush and during leafless period, e.g. Spindias pinnata (L.f.) Kurz, Erythrina stricta Roxb. and Gmelina arborea Roxb. b) Flowering long before leaf flush and during leafless period e.g. Bombax ceiba L. c) Flowering soon after leaf flushes e.g. Albizia lebbek (L.) Benth., Toona ciliata M.Roem. d) Flowering later, after leaf flushes e.g. Lagerstroemia speciosa (L.) Pers., Parkia timoriana (DC.) Merr. whereas five flowering types in 119 tropical tree species was recorded by Singh & Kushwaha (2006). The tree species produced flowers during leafless phase, favored wind pollination as well as a floral display to attract pollinators. Such tree species which flower in leafless conditions could act as ‘keystone species’ which provide food for birds when food availability is low during the dry season (Murali & Sukumar 1994, Das & Das 2013, Bajpai et al. 2015b).

In the majority of species fruit maturation started from the month of May. The fruiting peak and ripening of fruits in the latter part of pre-monsoon dry period or close to rainfall recorded in our study was similar to that in subtropical forests of Manipur (Kikim & Yadava 2001). Fruit ripening of majority of tree species close to the rainy season could help in fruit dispersal and also to regenerate during the rainy season. Fruiting during the rainy season may have evolved to ensure dispersal of seeds when soil moisture conditions are favorable for seed germination, seedling growth and survival (Singh & Kushwaha 2006, Bajpai et al. 2017). Selected species in the present study included explosive, dispersal by birds and wind. This was also observed in other parts of India (Murali & Sukumar 1994, Yadav & Yadav 2008, Borah & Devi 2014). The difference in the pattern of fruiting activity and the period of ripening of fruits maintains the availability of fruits throughout the year. Flowering and fruiting pattern of this study is similar to that found in other tropical seasonal environments. The findings also reveal that flowering and fruiting were significantly associated with rainfall and temperature and this pattern is similar to that described in many previous studies (Yadav & Yadav 2008, Mohandass et al. 2018).
The higher synchrony ratio (0.68 to 9.5) of leaf flush and leaf fall in the present study indicates that most of the total population of selected tree species shows both the phenophases in the similar time period and this is similar to that reported from tropical dry deciduous forest (Kushwaha & Singh 2005) as well as tropical moist deciduous forest (Bajpai et al. 2017). Tree species adjusted to variable micro climatic conditions often show diverse leaf strategies. Leaf strategy primarily denotes adaptation in leaf dynamics controlling the ability of a tree species to utilize resources in relation to its ability to conserve the resources (Kushwaha & Singh 2005). Selected tree species in the present study showing varied leafless period exhibits significant differences in their leafing pattern, as reflected by the leaf strategy index. The higher leaf strategy index (0.61–0.99) recorded in the present study is comparable to that of tropical deciduous forests from other parts of India (Kushwaha & Singh 2005). Greater the value of the leaf strategy index than 0.5, longer is the deciduousness duration (Kushwaha & Singh 2005) and the same pattern is also reflected in our observation.

Most of the studies on the vegetation phenological trends during last few decades commonly assumed the climate change as the key factor for the changes (Zhang et al. 2019). Singh & Kushwaha (2005) also suggested that changes in the length of the growing period, and competition among species for the resource use patterns resulted due to climate change. Present findings also indicating the influence of varied climatic parameters (between 1st and 2nd year of study) on the phenology of deciduous trees. Long term phenological study on the same species might clearly exhibit their phenological adaptation to varied climatic condition.

CONCLUSION

From this study, our understanding of the influence of varied climatic parameters e.g. temperature and rainfall on the phenophases of deciduous tree species is significantly improved. Selected deciduous tree species were observed to be sensitive to the variation in rainfall pattern, thereby to the moisture availability. Thus it can be concluded that any sudden change in climatic parameters would have a drastic effect on the plant phenology and so to the sustainability of homegarden resources. However, more detailed and long term observations on the impact of environmental parameters to the species–specific phenology for multipurpose deciduous trees are needed to understand a tree’s ability to capture environmental resources successfully in response to changing climatic conditions. This would facilitate the selection of suitable tree species to nurture in the traditional Meitei homegarden and also in managing the trees efficiently to fulfill the needs of the landowner.

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