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Canopy trees leaf phenology in tropical dry deciduous and evergreen forests of Bhadra Wildlife Sanctuary Karnataka, India

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Leaf phenology tree species of dry deciduous and evergreen forests of Bhadra Wildlife Sanctuary (13°25' and 13°50' N, 75°15' and 75°50' E) was studied during June 2004 to May 2006. Leaf fall starts in September and with a peak in December and January. Leaf initiation starts in February and with a peak in April before monsoon, while leaf expansion starts in February with a peak in May and July during monsoon in dry deciduous forest. In evergreen forest, leaf falling and leaf initiation was observed in one or the other species with a peak in January to February, leaf expansion too observed throughout the year with a peak in January and April before monsoon. Varying leaf phenology of these forest types is dependent on a regional rainfall pattern.

Key words: Bhadra Wildlife Sanctuary, dry deciduous forest, evergreen forest, leaf phenology, seasonality.

INTRODUCTION

Phenology is derived from the Greek word *Phiano* meaning to show or to appear. Hence, phenology is defined as the study of the seasonal timing of life cycle events, and can be quantitatively defined as a statistical distribution characterized by such parameters as time of occurrence (onset, mean, and mode), duration (range) synchrony (variance), and skew ness (Rathcke and Lacey, 1985). Phenological information is important in monitoring all aspects of ecosystems (Lechowicz, 2001) and is essential to understand the dynamics of plant communities, which of course impact animal populations as well. Different forest types are considered to be indicators of the amount and annual distribution of rainfall because seasonal variation in tree water status constitutes a major determinant of tropical tree phenology (Borchert, 1994a).

The phenology of leaf is controlled by a number of factors such as rainfall, temperature, light and relative humidity (Singh and Singh, 1992; Borchert, 1994b; van Schaik et al., 1993; Wright and van Schaik, 1994), not discounting the effect of biotic factors such as herbivory (Aide, 1988; Murali and Sukumar, 1993). Although, it is now widely acknowledged that biological interactions and phylogenetic relations can shape phenological patterns (van Schaik et al., 1993; Wright and Calderon, 1995). The vegetative phenology of mature trees varies with topography from evergreen to deciduous forest (Singh and Kushwaha, 2005). To understand tree leaf phenology and seasonality in tropical dry deciduous and evergreen forests with available meteorological data, the following

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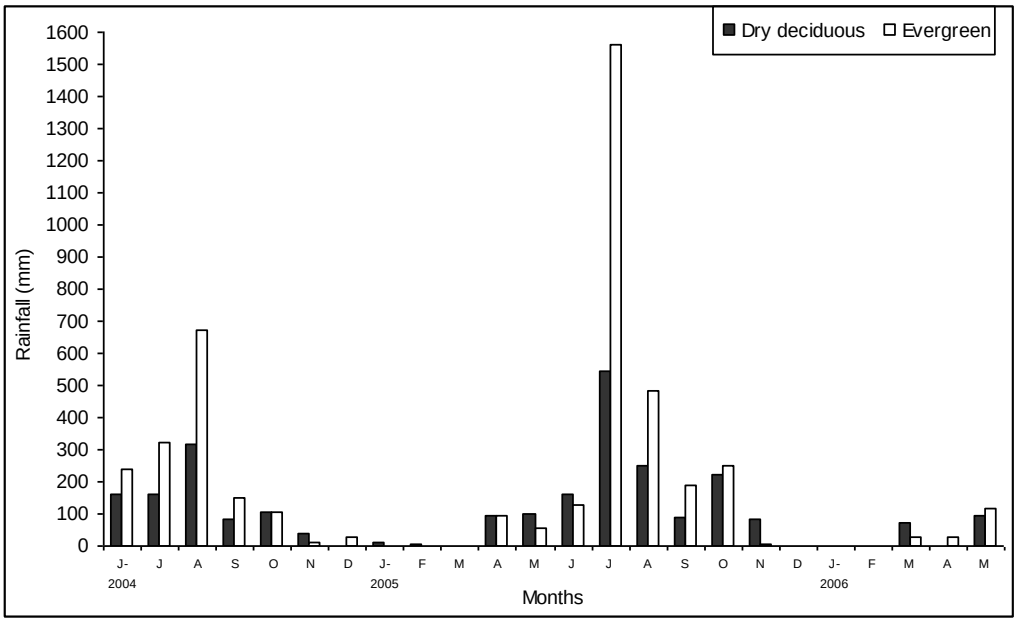

Figure 1. Total rainfall (mm) in dry deciduous and evergreen forests of the Bhadra wildlife sanctuary.

questions were addressed: (1) whether rainfall in the given period plays a determinant role in the development of leaf phenological patterns? (2) leaf phenology has what kind of influence on the strength of seasonality in two forest types?

MATERIALS AND METHODS

Site description

Bhadra Wildlife Sanctuary (BWS) is located in Chikmagalur and Shimoga districts (13°25' and 13°50' N, 75°15[1] and 75°50[1] E) of Karnataka, Central Western Ghats, southern India. The study was conducted in two different forest types of the sanctuary.

Site I (dry deciduous forest)

The study was conducted in Umblebailu, (13°46'to 13°52' N, 75°36'to 75°42'E) region is a dry deciduous forest between 690 to 750 amsl. The average rainfall is 100 to 540 mm. The terrain is gently undulating with valleys and steep hillocks, Parameshwar (2001). The characteristic canopy tree species are *Terminalia paniculata*, *Anogeissus latifolia*, *Acrocarpus fraxinifolius, Haldina cordifolia, Bombax malabaricum, Dalbergia latifolia, Lagerstroemia lanceolata. Mitragyna parviflora*, *Pterocarpus marsupium*,*Terminalia bellerica, Ficus benghalensis*, *Lannaea coromandelica* and *Melia dubia*.

Site II (evergreen forest)

The study was conducted in kemmanugundi (Lat.13°32' to13°40'N, long. 75°44' to 75°45'E), popularly known as poor man's Ooty, is chiefly dominated by evergreen forest in hills and valleys between 500 to 2000 amsl. The rainfall ranges from 2500 to 4500 mm. The characteristic canopy tree species of this site are *Artocarpus hirsuta, Elaeocarpus tuberculatus, Cedrela toona*, *Mallotus tetracoccus*, *Syzygium cumini*, Persea *macrantha*, *Myristica malabarica*. The detailed description of the study area is given by Raju and Hegde (1995) and in draft management plan for Bhadra Wildlife Sanctuary (1996 to 2001) (Parameshwar, 2001).

Methods

Woody stems above 20 cm diameter at breast height (dbh) with clearly visible trees were marked with a unique tag number on either side of the transect about 2 Km. A total of 157 individuals of 22 species in site I and 66 individuals comprising of 17 canopy tree species in site II were marked with a unique tag on either side of the 5 km transect. These marked individuals were monitored for leafing phenophases once in a month. Leafing phenophases includes different categories such as leaf initiation / leaf budding, leaf expansion and leaf senescence / leaf fall. Each stage in different categories of phenology was scored on a 0 to 100%, viz. 0, no leaves; 1, 1 to 25% of the canopy where leaves are present; 2, 26 to 50% of the canopy where leaves are present; 3, 51 to 75% of the canopy where leaves are present; 4, 76 to 100% of the canopy where leaves are present (Mclaren and Mcdonald, 2005).

The marked individual species were identified using various regional floras (Yoganarasimhan et al., 1990; Saldhana, 1996; Gamble and Fischer, 1998; Ramaswamy et al., 2001; Neginhal, 2004) and forest types by (Champion and Seth, 1968). Monthly average data on rainfall (mm) was collected from Bhadra River Project meteorological station for sites I and II from Baby Coffee Estate, which are 2 and 5 km away from the study area (Figure 1).

Data analyses

Spearman's rank correlation was performed to establish the relationship between frequency of species responding to leafing patterns during current and one to three months lag periods with

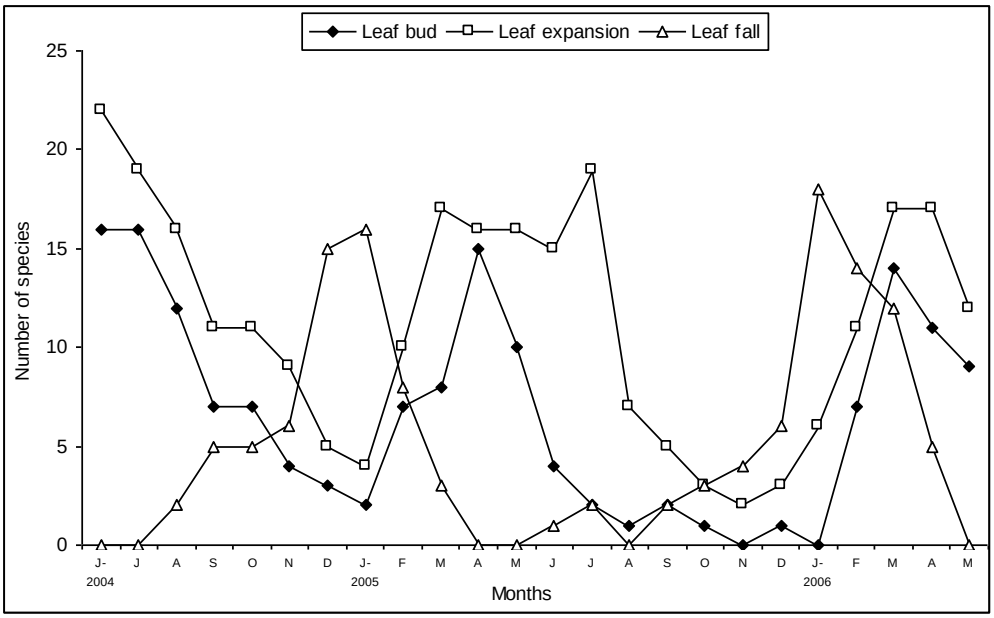

Figure 2. Leaf phenophases in dry deciduous forests of the Bhadra wildlife sanctuary.

amount of total rainfall received in a month which was computed using procedures given by Zar (2007).

Seasonality analysis

Seasonality is defined as repeated occurrence of a given event in a cyclic fashion. The question answered in this section includes: a) are the different phenophases cyclic and b) how strong is cyclicity in a given event? Rayleigh's Z was calculated which tests significance of cyclicity in a given phenophase.

Hypothesis tested is:
H_0 = the given phenophase is seasonal or cyclic,
H_A = the given phenophase is not seasonal

We used statistical software "*STASTIXL*," a package for spreadsheets to estimate seasonality in the data. We converted the day of observation in a given month to angles and used these angles and number of species in a given month in a given phenophase to estimate Rayleigh's Z. Mean vector r has no units and may vary from 0 (when phenological activity is distributed uniformly throughout the year) to 1 (when phenological activity is concentrated around one single date or time of year), which indicates the strength of the seasonality (Morellato et al., 2000; Zar, 2007).

RESULTS

Site I: Dry deciduous forest leafing phenology

Among the 22 species, leaf flush or leaf initiation became more pronounced from February, (7 species with10%) and peaks in April (15 species with 23%) in the dry season were *Acrocarpus fraxinifolius, Anogeissus latifolia, Tectona grandis,* and *Terminalia paniculata* (Figure 2). The leaf expansion begins in February (10 species with15%) and peaks in July (19 species with 29%) are *Dalbergia latifolia*, *Melia dubia* and *Lannaea coromandelica* (Figure 3), and leaf senescence begins from September (two species with 3%) and peaks in January (18 species with 28 %) are *Haldina cordifolia*, *Careya arborea* and *Tectona grandis* (Figure 2).

The leaf initiation is not significant to rainfall during current month and had a strong negative significant correlation during three month lag period (r_s = -0.70, p<0.0003). The leaf expansion and rainfall had strong negative significant correlation during three months lag period (r_s = -0.68, p<0.0005). The leaf senescence / leaf falling phenology, rainfall had strong negative influence during current months (r_s = -0.73, p<0.00005) and negative influence during one month lag period (r_s = -0.44, p<0.03).

Site II: Evergreen forest leafing phenology

Among 17 species leaf flush or leaf initiation with a peaks in October (6 species with 3.66%), January (10 species with 6.6%) and April (five species with 3.3%) are *Cedrela toona*, *Mallotus tetracoccus* and *Ficus nervosa* (Figure 2). The leaf expansion peaks in January (11 species with 7.26%) and March (10 species with 6.6%) are *Artocarpus integrifolia*, *Elaeocarpus tuberculatus*, *Gordonia obtusa*, *Persea macrantha* and *Syzygium cumini* (Figure 3). The leaf senescence peaks in January (four species with 2.64 %), July (two species with 1.32%) and November (six species with 3.96%) are Ficus *nervosa*, *Cedrela toona*, *Elaeocarpus tuberculatus* and *Gordonia obtusa* (Figure

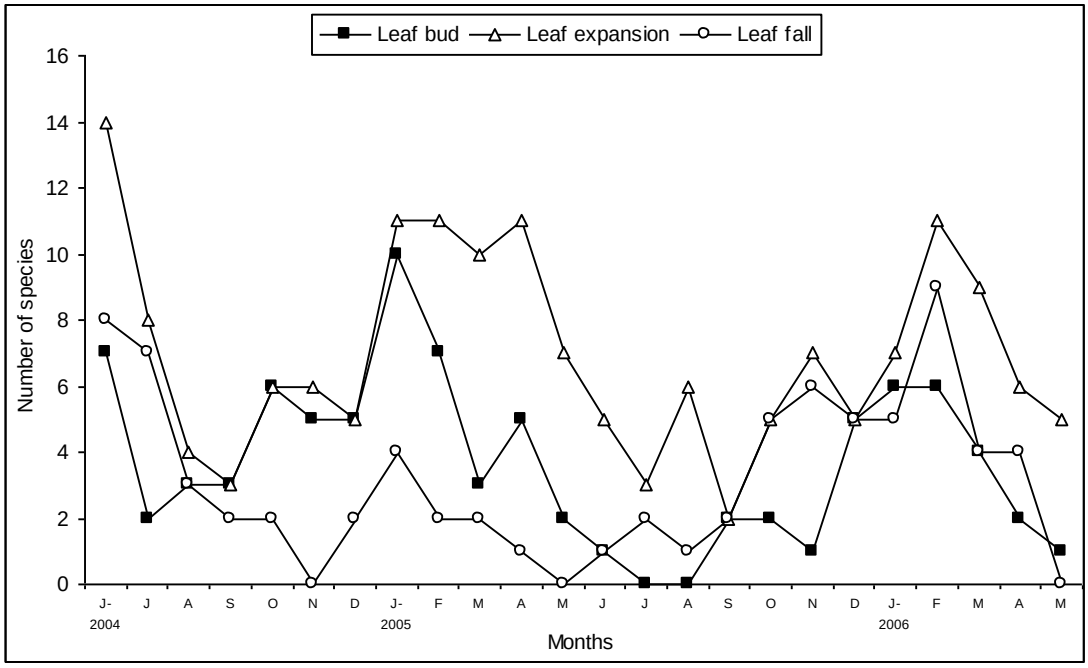

Figure 3. Leaf phenophases in evergreen forests of the Bhadra wildlife sanctuary.

3).

The leaf initiation and rainfall had a significant negative influence during the current month (r_s = -0.56, p<0.004) and one month lag period. The leaf expansion of canopy trees and rainfall had significant negative influence (r_s = -0.50, p<0.01) during current months as well as lag periods, One (r_s = -0.60, p<0.002) and two (r_s = -0.68, p<0.0004) months. Number of rainy days had significant negative influence on leaf expansion both during current months (r_s = -0.49, p<0.01) and lag periods, One (r_s = -0.63, p<0.001) and two (r_s = -0.67, p<0.0006) months.

The leaf senescence and rainfall had no significant influence during current months. The leaf senescence and number of rainy days had no significant influence during current and lag periods.

Seasonality studies

Seasonality of leafing phenology in dry deciduous forest

Seasonality of various leafing phenophases is strong as the Rayleigh's Z values are highly significant. Their leafing pattern is indicated by the mean angle. The leaf initiation starts in the middle of May month (136.0), leaf expansion in the end of May month (146.0) and senescence in mid January (15.95). The strength of seasonality measured by the vector **"**r" indicates that leaf senescence (0.58) event has strong seasonality followed by leaf initiation (0.37) and leaf expansion (0.31; Table 1).

Seasonality of leafing phenology in evergreen forest

Seasonality of various leafing phenophases is strong as the Rayleigh's Z values are highly significant. Their leafing pattern is indicated by the mean angle. The leaf initiation begins in the end of January (21.16), followed by leaf expansion in beginning of March (67.75) and leaf fall happens in the beginning of January month (8.86). The strength of seasonality measured by the vector "r" indicates that the leaf initiation (0.32) has a strong seasonality followed by leaf expansion (0.20) and leaf fall (0.14; Table 2).

DISCUSSION

Dry deciduous forest

Trees of tropical dry deciduous forest of BWS, responded to leafing during dry season (Nanda et al., 2010). Moisture appears to be a major determinant of the timing of leaf flush in dry tropical forest of Ghana (Lieberman, 1982). The patterns of leaf formation were strongly influenced by rainfall, as expected for tropical semi-arid vegetation (Rathcke and Lacey, 1985; Bullock and Solis-Magallanes, 1990). Most deciduous species of dry monsoon forests in Thailand and India form new leaves one to two months before the first monsoon rains, during the hottest and driest part of the year around the spring equinox (Elliot et al., 2006). Dry season flushing was more in the present study which is similar to earlier

Table 1. Canopy circular statistic seasonality in different leafing phenophases among tree species in dry deciduous forest (site I) of the Bhadra wildlife sanctuary.

Parameter	Leaf initiation	Leaf expansion	Leaf senescence
Mean angle	136.0	146.0	15.95
Mean vector **r**	0.37	0.31	0.58
Angular SD	80.45	87.67	59.04
Rayleigh's Z	22.13	26.25	43.91
P value	<0.000*	<0.000*	<0.000*

*Significant at < 0.05.

Table 2. Canopy circular statistic seasonality in different leafing phenophases among tree species in evergreen forest (site II) of the Bhadra wildlife sanctuary.

Parameter	Leaf initiation	Leaf expansion	Leaf senescence
Mean angle	21.16	67.75	8.86
Mean vector **r**	0.32	0.20	0.14
Angular SD	85.44	101.56	112.32
Rayleigh's Z	9.52	7.212	1.649
P value	<0.000*	<0.001*	<0.193

*Significant at < 0.05.

studies (Frankie et al., 1974; van Schaik, 1986; Bhat, 1992; Murali and Sukumar, 1993; Khushwaha and Singh, 2005; Whitmore, 1996). Bolivian dry forest canopy species lost their leaves during the dry season (Justiniano and Fredericksen, 2000). Several studies suggest low temperatures (e.g. daily mean temperature below a 8°C threshold; Estrella and Menzel, 2006) and short days (Koike, 1990, with a 13 h photoperiod threshold by 63°N latitude in Keskitalo et al., 2005) to be among the main factors involved in triggering leaf senescence in deciduous trees. Borchert (1994) suggested that the leaf-fall during the dry season was directly influenced by the decline in soil moisture and increasing water stress conditions. The present observation also show that leaf senescence or absence of leaf or no leaf phase begins from January in one or the other species with a peak in February and March. The results are also in conformity with Singh and Singh (1992) in which the initiation of leaf fall coincides with the onset of the post-monsoon low temperature dry period and can be a mechanism maintaining turgidity of shoots.

Evergreen forest

In evergreen forest of BWS, most of the leafing activities happen during pre summer to summer season as rainfall plays a significant negative influence. In the present study, canopy trees leaf initiation begins from November or December and with a peak in January or February. This kind of response is due to adaptive nature of species and similar observations from other studies (Bhat, 1992; Murali and Sukumar, 1993; Singh and Singh, 1992; Prasad and Hegde, 1986; Singh and Khushwaha, 2005; Kikim and Yadava, 2001) have been reported. At the community level, certain species have evolved completely different approaches to leaf flushing and leaf fall which may be due to intrinsic factors (Boojh and Ramakrishnan, 1981).

The leaf expansion begins from December and peaks till January to April. Other researchers have also observed that stomatal density and that stomatal size have a role in the expansion phase (Abrams and Kubiske, 1990; Abrams and Mostoller, 1995; Ashton and Berlyn, 1994). Leaf fall begins in December and peaks in January and July months. This difference in leaf fall may be due to micro-environmental factors as also has been reported by Boojh and Ramakrishnan (1981) for sub-tropical forest of Meghalaya and Sundriyal (1990) for temperate forest of Garhwal Himalaya in both over and understorey tree species. The rate of leaf fall during the dry season was strongly correlated with the decline in soil moisture and increasing water stress of the tree (Reich and Borchert, 1982).

Seasonality in phenological events from India (Singh and Singh, 1992; Murali and Sukumar, 1993; Bhat, 1992; Prasad and Hegde, 1986; Sundrapandian et al., 2005) merely mention about the seasons of leafing, flowering and fruiting in community. This study provides a quantitative measure for seasonality in these events in canopy tree species. Attempts have been made not only to quantify the seasonality but also to find out the

strength of seasonality. Various leaf phenophases in dry and evergreen forests of Bhadra Wildlife Sanctuary are significantly seasonal. The long term study with many more environmental factors is needed to understand their stability, while this short duration data helps to know the environmental perturbations during the study period.

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