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Leafing Patterns and Seasonality at Community Level in a Tropical Dry Deciduous Forests of Bhadra Wildlife Sanctuary, Karnataka, Southern India

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ABSTRACT

This study describes the role of mean temperature and total rainfall patterns on the distribution and duration of various leafing phenophases of individual trees recorded at the community level in a tropical dry deciduous forest of Bhadra Wildlife Sanctuary, southern India. Plant stress to surrounding environment was assessed by individual trees' phenological response. Regression analysis was performed to examine how variations in rainfall and temperature influenced leafing phenology. We also investigated seasonality of various phenophases to know the cyclicity and strength of seasonality: Leaf initiation and leaf expansion in the beginning and late April, leaf senescence in the middle of January and leaflessness in March. Seasonality study indicates how tropical dry deciduous forest trees respond to their surrounding environment: a strong seasonality in leafless event followed by leaf senescence, leaf initiation and expansion were observed. Overall our study suggests that the response/ sensitivity of tropical dry deciduous forest foliar phenophases is an indication of regional environmental changes.

Keywords: foliar phenophases, mean rainfall, mean temperature, seasonality, tropical dry forests

INTRODUCTION

Different forest types are considered to be indicators of the amount and annual distribution of rainfall (Walter 1971) because seasonal variation in tree water status constitutes a major determinant of tropical tree phenology (Borchert 1994b; Borchert *et al*. 2002). Generally, the term 'deciduous' is applied indiscriminately to tropical tree species being leafless for just a few weeks or as long as 4–6 months. Tropical dry forests form the largest component of the world forest cover. Yet they are relatively less studied and understood tropical forest communities (Murphy and Lugo 1986). In seasonal forests of the tropics, phenology is usually strongly correlated with the dry season (Reich and Borchert 1984; Wright and van Schaik 1994a). Information on phenological patterns is essential to understand biological process of trees and organisms that depend on trees. Phenological events are useful indicators to assess the impact of environmental perturbations on trees (Kushwaha and Singh 2005). Chain *et al*. (1996) have considered leaf phenology an important variable in distinguishing plant functional types. Even though tropical dry deciduous forests account for 40% of the forested land in India (Singh and Singh 1988). As vegetative phenology of tropical trees is not well understood (Borchert *et al*. 2002). Documentation of time and duration on foliar phenological diversity, in these forests are scarce. Most tropical phenology studies have been conducted at the community level for both vegetative and reproductive phenophases. Hence, here we made an attempt to on every phenophses of leaf. The objectives of the present study were to know: (1) How rainfall and temperature influencing the foliar phenology at community level? (2) To quantify the foliar phenophases seasonality? (3). To assess the plant stress via phenological response? This is a pilot study from Bhadra wildlife sanctuary to understand sensitivity of foliar phenophases in the global climatic change scenario at regional level (Nanda 2009).

MATERIALS AND METHODS

Study area

The study was conducted in Umblebailu (13° 46′ to 13° 52′ N, 75° 36′ to 75° 42′ E) region of Bhadra wildlife sanctuary located in Chikmagalur and Shimoga districts (13° 25′ and 13° 50′ N, 75° 15′ and 75° 50′ E) of Karnataka, Central Western Ghats. The terrain is gently undulating with valleys and steep hillocks. Detailed geological account of the sanctuary is given by (Parameshwar 2001). The altitude varies from 750 to 2100 m above mean sea level rainfall and temperature data for the study area was collected from meteorological station, Bhadra River Project rainfall is mainly from the southwest monsoon during June – September (**Fig. 1**).

Vegetation

Vegetation of the sanctuary varies from dry deciduous to evergreen forests through moist deciduous type depending on the precipitation pattern. According to Champion and Seth (1968) the dry deciduous forests are classified as 'southern dry mixed deciduous forests'. The most common tree species of dry deciduous are *Terminalia paniculata*, Roth. *Anogeissus latifolia* Wall., *Ziziphus xylopyrus* Willd. *Cassia fistula* L., *Albizia lebbek* Benth., *Tectona grandis* L.f., *Diospyros montana* Roxb., *Mitragyna parviflora* Korth and *Pterocarpus marsupium* Roxb..

Methods

Woody stems above 20 cm diameter at breast height (dbh) with clearly visible canopies were marked with a unique tag number on either side of the transect about 2 Km. A total of 277 individuals of 45 species these marked individuals were monitored for foliar phenophases once in a month from June 2004 to May 2006. Foliar phenophases includes five different phenophases such as 1. Leaf less/absence of leaf (LF1), 2. Initiating leaves/ leaf buds (LF2), 3. expanding/immature leaves (LF3), 4. mature leaves (LF4) and 5.

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Research Note

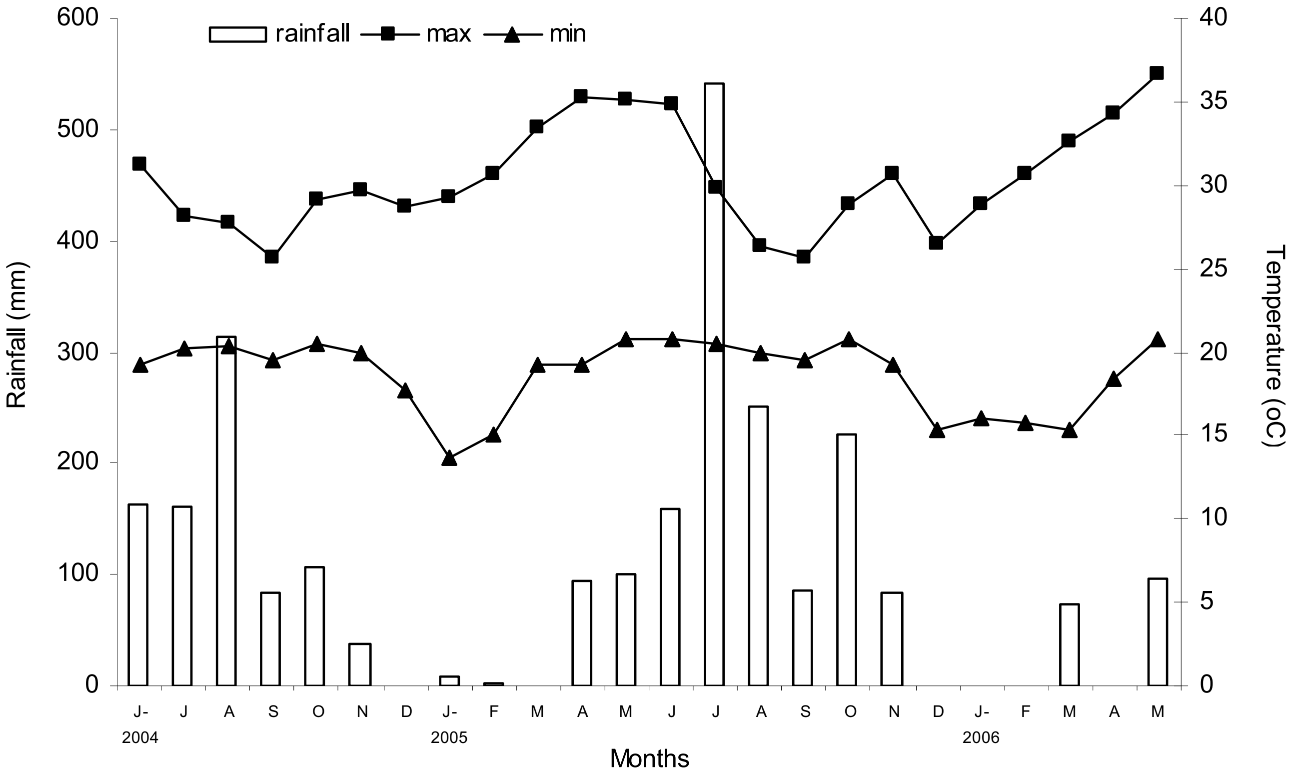

Fig. 1 Total monthly rainfall (mm), mean monthly maximum, and mean monthly minimum temperature (°C) at dry deciduous forest in Bhadra wildlife sanctuary during the study period.

Senescence/falling leaves (LF5). Each stage in different categories of phenology was scored qualitatively with respect to both spread and intensity on a 0 to 100 scale. The marked individual species were identified using various regional floras (Gamble and Fischer 1998; Saldhana 1996; Yoganarasimhan *et al.* 1990; Ramaswamy *et al.* 2001; Neginhal 2004). The representative plant specimens were collected, deposited in the Herbarium of the Department of Applied Botany, Kuvempu University.

Statistical analyses

We performed Spearman's rank correlations as well as multiple regressions during corresponding months and time lag periods to test the influence of rainfall and temperature on various foliar phenophases using procedures given by Zar (2007). Seasonality is defined as repeated occurrence of a given event in a cyclic fashion. The questions answered in this section includes a) are the different phenophases are cyclic? b) How strong is cyclicity in a given event? We calculated the Rayleigh's Z 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), indicates the strength of the seasonality (Morellato *et al.* 2000) Interpretation of Z statistic follows Zar (2007).

RESULTS

Factors influencing foliar phenology

1. Leaf flushing

Rainfall had significant negative influence on leaf flush during two month lag period (r_s = -0.62, p<0.001) along with number of rainy days (r_s = -0.61, p<0.002) and minimum temperature (r_s = -0.76, p<0.0001). It is clear from the (**Fig. 2**) that peak leaf flush happens two months before the peak in rainfall. Maximum temperature (r_s = 0.47, p<0.01) had positive influence during the corresponding months. Multiple regressions during the corresponding months were significant (r_s = 0.63, F = 3.28, p<0.03) with number of rainy days and maximum temperature influencing positively (**Fig. 3**). Time lag regressions for two months were significant with minimum temperature influencing negatively suggesting that reduction in minimum temperature (advent of warm period) triggers species to flush.

2. Leaf expansion

When different factors looked into independently maximum temperature had significant positive influence on expansion of leaves during corresponding (r_s = 0.44, p<0.02) as well as during one month lag period (r_s = 0.58, p<0.003) (**Fig. 4**). Minimum temperature had a negative influence during two month lag period (r_s = -0.54, p<0.009). Multiple regression during the corresponding months was significant (r_s = 0.72, F = 5.25, p<0.005) with maximum temperature and number of rainy days as influencing factors. Stepwise regression yielded maximum temperature coupled with number of rainy days significantly influenced the expansion of leaves (**Fig. 5**). Both time lag regressions were significant (r_s = 0.82, F = 9.78, p<0.0002 one month lag), (r_s = 0.74, F= 5.37, p<0.005 two month lag). During one month lag period all factors were significantly influencing expansion but relative influence of number of rainy days was not significant. During the two month lag period, it was temperature influenced event.

3. Leaf senescence

Rainfall (r_s = -0.70, p<0.0001), number of rainy days (r_s = -0.65, p<0.0004) and minimum temperature (r_s = -0.74, p<0.00002) had significant negative influence during corresponding months when tested independently. Maximum temperature had significant negative influence during lag periods. Multiple regression during the corresponding months was significant (r_s = 0.86, F = 14.10, p<0.00002)

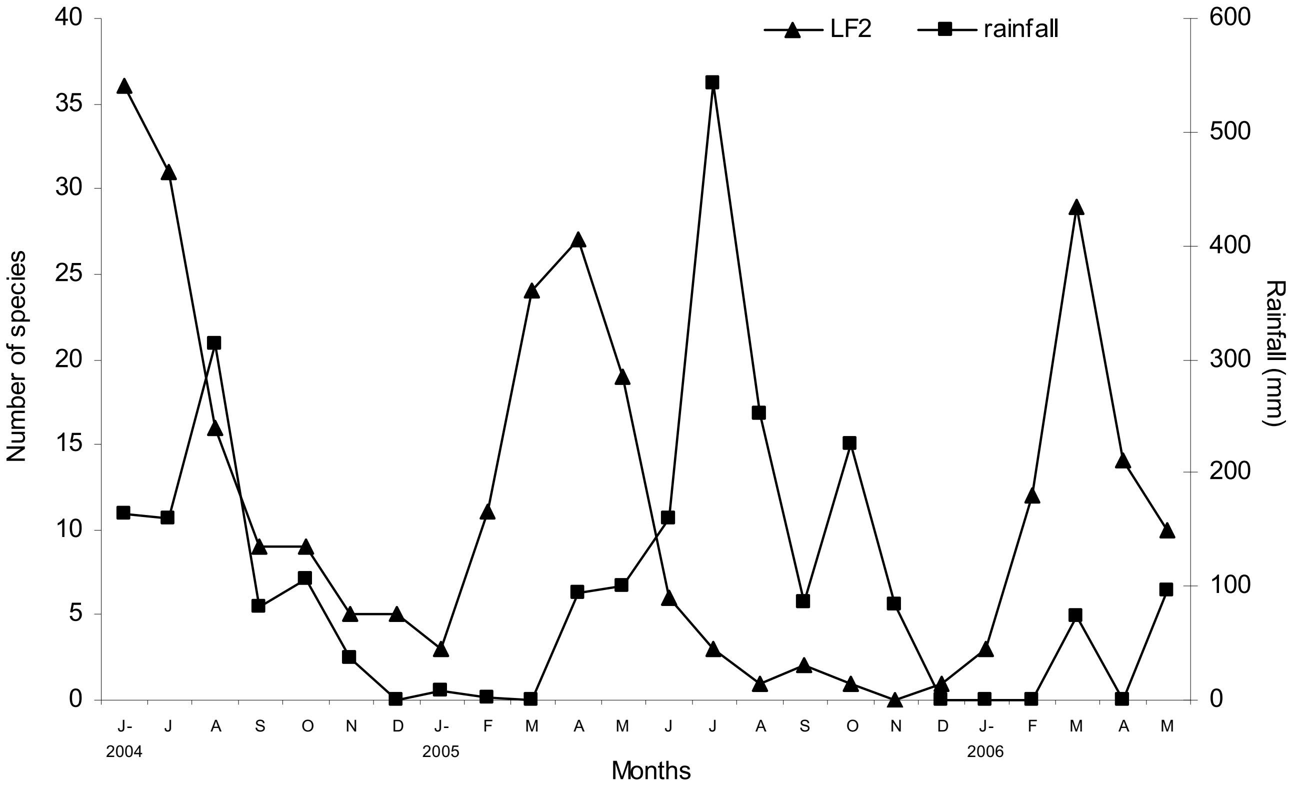

Fig. 2 Pattern of leaf initiation in relation to rainfall in dry deciduous forest of Bhadra Wildlife Sanctuary, Karnataka.

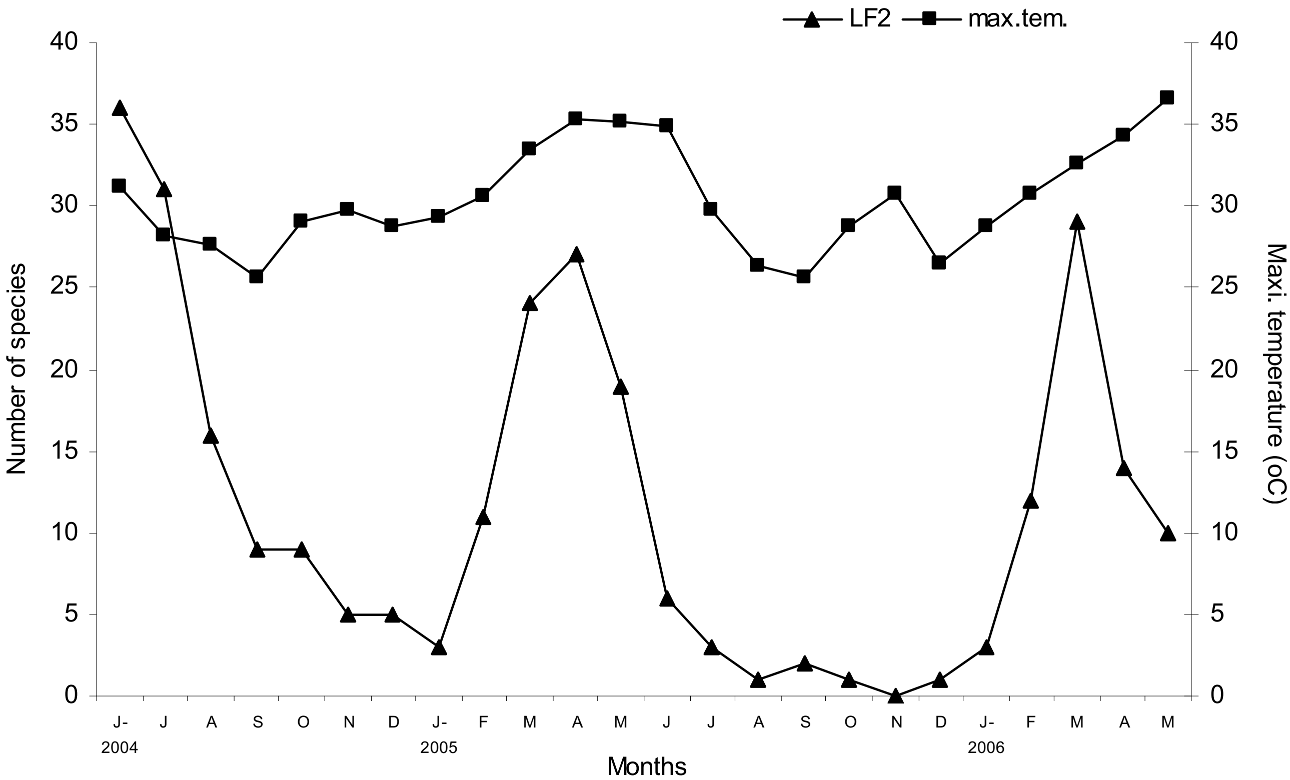

Fig. 3 Pattern of leaf initiation in relation to maximum temperature in dry deciduous forest of Bhadra Wildlife Sanctuary, Karnataka.

with minimum temperature having significant negative influence. Stepwise regression was also significant with minimum temperature having significant influence on the senescence of leaves. Both one month lag (r_s = 0.77, F = 6.79, p<0.001) and two month lag (r_s = 0.67, F = 3.61, p<0.02) regressions were significant with minimum temperature having positive influence while maximum temperature and number of rainy days having negative influence (**Fig. 6**).

Seasonality

Various foliar phenophases are strongly seasonal. Rayleigh's Z is highly significant. Most of the trees remain leafless during early March as indicated by the mean angle. Leaf initiation happens during April followed by leaf expansion during May. Leaf senescence happens during early January. The strength of seasonality denoted by the vector "r" indicates that leafless (0.63) event has strong seasonality followed by leaf senescence (0.58), leaf initiation (0.43),

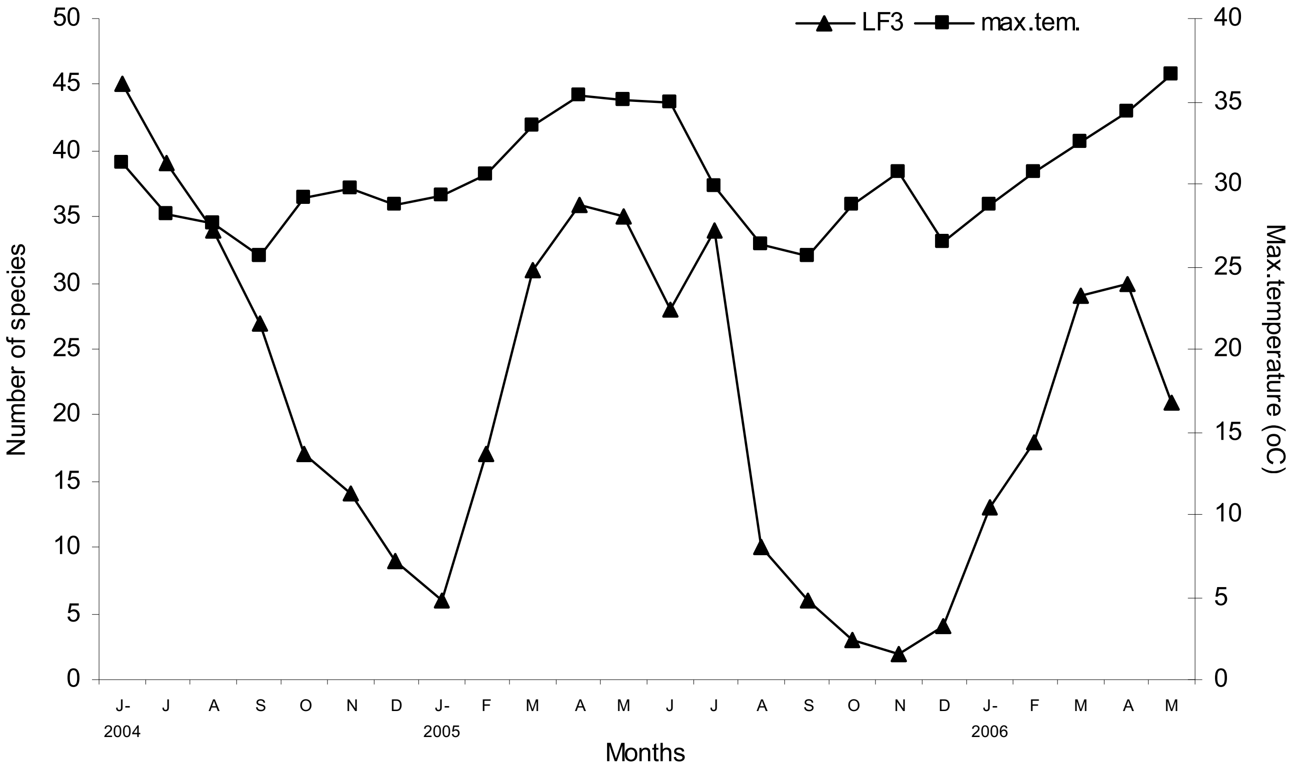

Fig. 4 Pattern of leaf expansion in relation to maximum temperature in dry deciduous forest of Bhadra Wildlife Sanctuary, Karnataka.

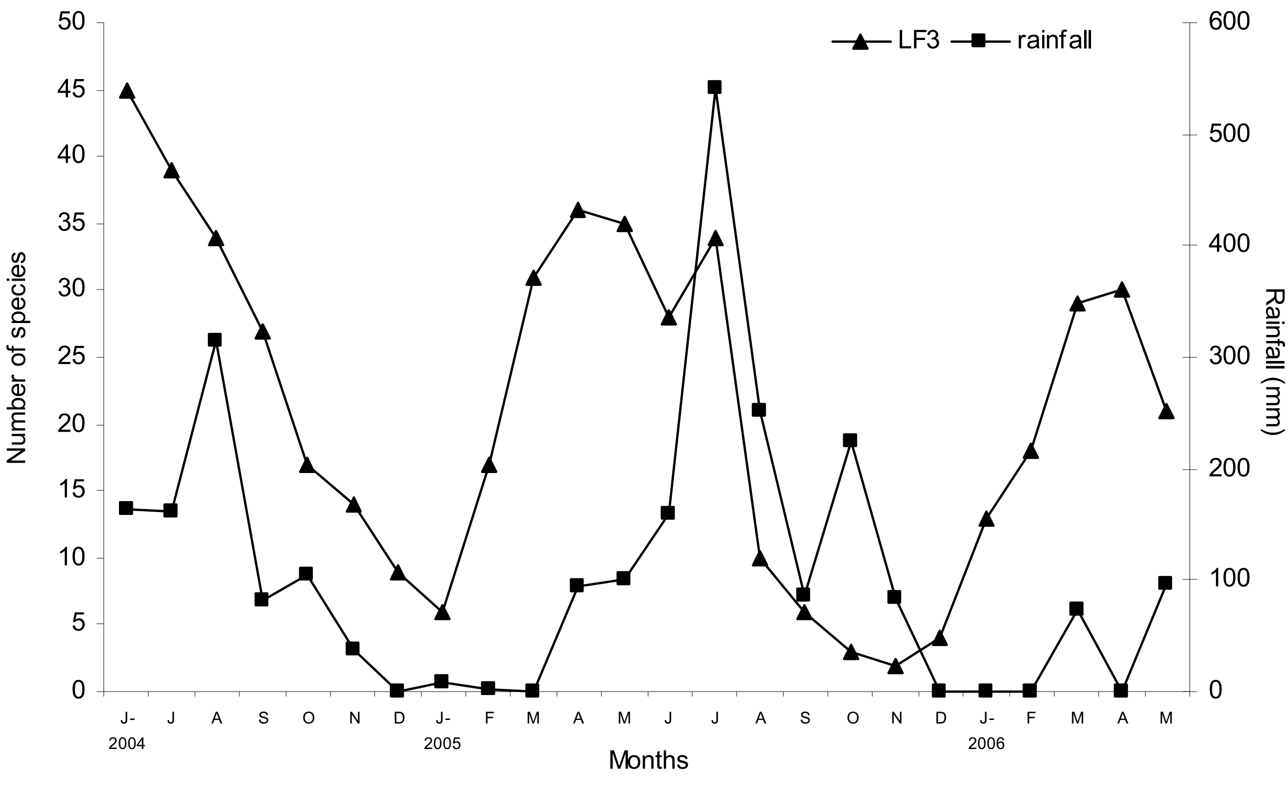

Fig. 5 Pattern of leaf expansion in relation rainfall in dry deciduous forest of Bhadra Wildlife Sanctuary, Karnataka.

and expansion (0.35). Seasonality parameters are given in the (**Table 1**).

DISCUSSION

This study shows that trees in dry deciduous forests of Bhadra Wildlife Sanctuary in southern India peak leaf flushing before the onset of rains in dry season may be to maximize them photosynthetically (Nanda 2009). Dry periods in tropical dry forests are characterized by intense physiological activities as most of leafing phenological activities occurred during dry season. However, even the short dry periods that occur in aseasonal tropical forests are an important influence on phenology (van Schaik 1986). Vegetative phenology in tropical dry forests is a moisture regulated event (Borchert 1994a). There are several studies which have highlighted the influence of rainfall on the vegetative phenology. Leaf flush with the onset of rain after a spell of dry period, as in Barro Colorado Island (Leigh and Windsor 1982). Whereas in Bandipur, Southern India, leaf flush soon after the onset of rains is the signaling of the end of unfavourable physiological period and beginning of

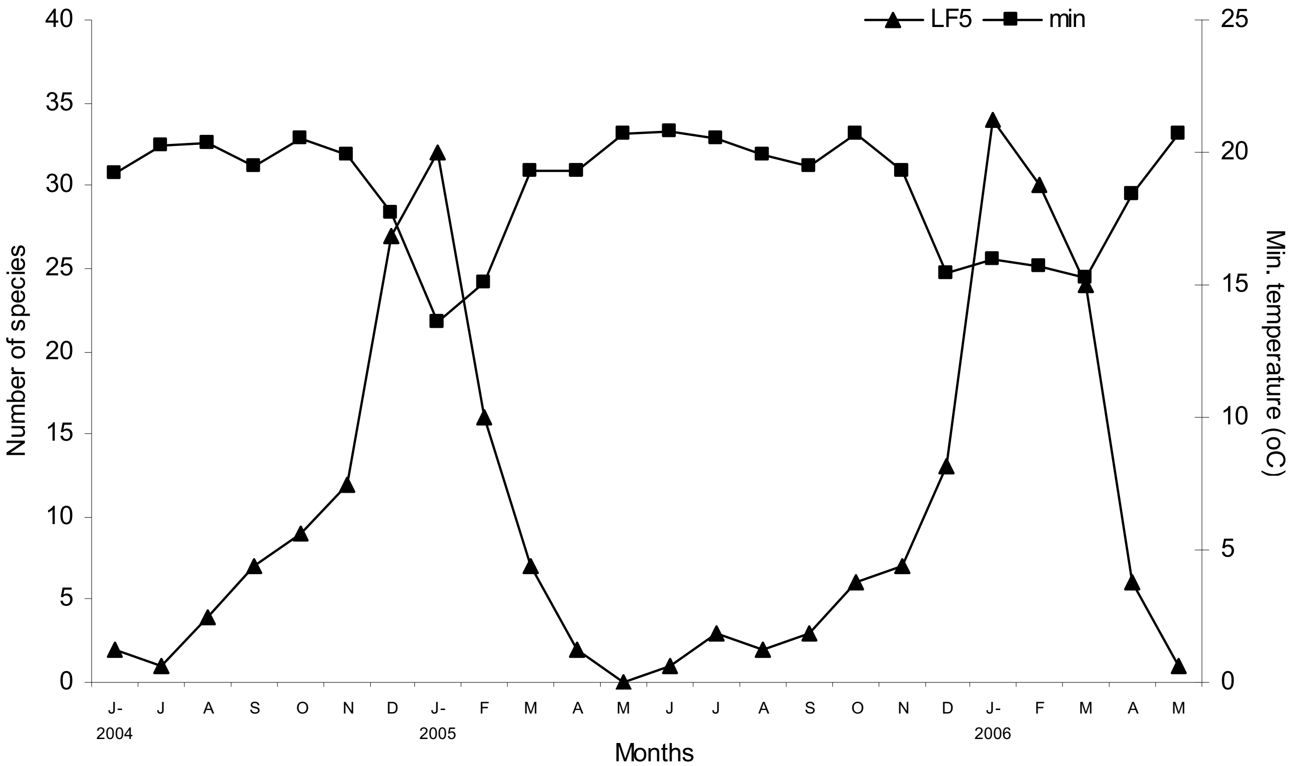

Fig. 6 Pattern of leaf senescence in relation to rainfall in dry deciduous forest of Bhadra Wildlife Sanctuary, Karnataka.

a favourable growth period (Prasad and Hegde 1986). Most of the studies on phenology have considered rainfall as most important environmental variable.

In this study, rainfall had a significant negative time lag influence on leaf flush, leaf expansion and leaf senescence. This pattern is reported in other studies also (Murali and Sukumar 1993; Singh and Khushwaha 2005; Elliott *et al.* 2006). Increasing day length, as has been described earlier for numerous tree species of Neotropical dry forests by (Rivera *et al.* 2002). On contrary to this leaf flushing in dry forests of Ghana is confined to wet season (Lieberman 1982). Similar trend was also reported for forest from Vindhya Mountains of India (Singh and Singh 1992). Advantage of dry season flushing in trees can have full canopy during the wet season which facilitates primary production and growth. This also results in continuous supply of photosynthetically active tissue. Leaflessness in trees is ill defined (Kushwaha and Singh 2005). Apart from rainfall and temperature Hinckley *et al.* (1991) suggests that the wide differences in duration of leaf flush and leaf fall may be caused by variation among the components of the soil plant and atmosphere. A number of authors have proposed that the leaf age might influence the timing of leaf abscission through a reduced ability of older leaves to control the water loss (Reich 1984), increasing their sensitivity to water stress (Borchert 1994a; Martin *et al.* 1994). Generally, in tropical regions, it is the amount of rainfall and especially the length of the dry season that predicts forest seasonality (Whitmore 1984; Reich 1995; Corlett and Lafrankie 1998). Duration and seasonality of foliar phenophases of the present study shows that leaf senescence in the middle of the January followed by leafless phase in the middle of March, leaf initiation in the beginning of April, and expansion in the end of May month of a monsoon seasonal forest of southern India. Despite the low climate seasonality and the absence of a dry season, phenological pattern were seasonal in Atlantic rain forest trees (Morellato *et al.* 2000). This study shows that foliar phenophases are adapted to cool dry season to onset of rainfall as indicating foliar pheophases is an adaptation to their local climate their response and change in species number year to year is an indication tree stress to surrounding external environment (Nanda 2009).

Table 1 Results of the circular statistic analysis testing for the occurrence of seasonality in different foliar phenophases among species in Bhadra wildlife sanctuary.

Parameters	Leafless	Leaf initiation	Leaf expansion	Leaf senescence
Mean angle	74.12	128.25	147.94	18.56
Mean vector r	0.63	0.43	0.35	0.58
Angular SD	48.88	61.16	65.23	52.03
Rayleigh's Z	75.65	51.26	62.90	85.96
P value	<0.000	<0.000	<0.000	<0.000

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