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# Phenology of Leaf Flushing, Flower Initiation and Fruit Maturation in Dry Deciduous and Evergreen Forests of Bhadra Wildlife Sanctuary, Karnataka, Southern India

**A. Nanda[1]*, H.M. Prakasha[1], Y.L. Krishna Murthy[1] and H.S. Suresh[2]**

[1]*Department of PG studies and Research in Applied Botany, Bioscience Complex, Jnana Sahyadri Kuvempu University, Shankaraghatta, Shimoga- 577 451, Karnataka, India*
[2]*Center for Ecological Sciences, Indian Institute of Science, Bangalore- 560 012, Karnataka, India*
[*]*E-mail*: *nandabotany@gmail.com*

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**Abstract**
Varying with altitude and rainfall of two forest types of tropical forest were studied. Community wide pattern in both vegetative and reproductive phenophases among various tree species of Bhadra wildlife sanctuary, Karnataka is reported here. Leaf initiation peaks in the month of April in dry forest, after leaf less period of 1-2 months, in evergreen forest leaf initiation peaks in the month of January simultaneously with leaf senescence. Flower initiation begins from January till June with a peak in April in dry forest. Evergreen forest starts from November to march with a peak in January and February. Fruit maturation in dry forest starts from March to December with a peak in August and November, in evergreen forest from January to July with a peak in April.

***Key words*:** Community-wide, tree phenophases, tropical forests, Western Ghats

## Introduction

Tropical forest plant communities display various phenological patterns. 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 *et al.*, 2002). A variety of factors have been proposed to drive the phenology. These include abiotic factors such as rainfall, day length, irradiance, temperature and relative humidity (Wright and Van Schaik, 1994). Biotic factors are pollinators or seed dispersers (Rathke and Lacey, 1985), herbivory (Williams-Linera, 1999). Seasonal changes in abiotic and biotic factors can be expected to have consistent effects on phenology of tropical forests (Wright, 1996). There are several community wide studies on phenology (Murali and Sukumar, 1994; Justiniano and Fredericksen, 2000; McLaren and McDonald, 2003; Borchert *et al*., 2004; Singh and Kushwaha, 2005; Sundarapandian *et al*., 2005). Yet our understanding of phenophases in different forest types is scanty. Understanding of community wide patterns in phenophase is essential for understanding the functioning of ecosystem and scientific management of natural resources. This type of study will help to understand various phenophases in the global climatic change scenario at local level.

***Study area***

The study was conducted in Bhadra Wildlife Sanctuary located in Chikmagalur and Shimoga districts (13°25' and 13°50'N, 75º15' and 75º50'E) of Karnataka. The dry deciduous forest (Umblebailu, 13°46' to 13°52'N, 75°36' to 75°42'E). The altitude 690 to 750 m asl. The evergreen forest (Kemmangundi, 13º32' to 13º40'N, 75º44' to 75º45'E). These forests area common around the hills and valleys of where the altitude ranges from 1400 to 2000 m msl. These forests are on the windward side of the Western Ghats. The rainfall of the Sanctuary ranges from 500 to 2000 mm. The terrain is gently undulating with valleys and steep hillocks. Detailed geological account of the sanctuary is given by Parameswar (1996). Rainfall data for the dry forest was collected from meteorological station, Bhadra River Project. Whereas for evergreen forest rainfall data from the coffee estate. Annual rainfall in two forest types varies in evergreen forest 1561.1 mm and in dry forest 542 mm during the study period is shown in (Fig. 1).

***Vegetation***

Vegetation of the sanctuary varies from dry deciduous to evergreen forest. According to (Champion and Seth, 1968) the dry deciduous forests of Umblebailu are classified as 'southern dry mixed deciduous forests'. The characteristic tree species of this type are *Terminalia paniculata*, *Anogeissus latifolia*, *Xylia xylocarpa*, *Cassia fistula*, *Albizzia lebbeck, Terminalia crenulata, Tectona grandis, Diospyros montana, Mitragyna parviflora* and *Pterocarpus marsupium*.

Kemmangundi forests are classified as 'Tropical wet evergreen forests'. The characteristic tree species of this forest are *Artocarpus integrifolia, Cinnamomum* spp., *Myristica malabarica, Litsea spp. Neolitsea zeylanica. Syzygium* spp., *Macaranga peltata, Trema orientalis*, *Actinodaphne hookeri,* and *Isonandra perrottetiana.*

Detailed description of the study area can be found elsewhere (Raju and Hegde, 1995; Parameswar, 1996; Krishna murthy *et al*., 2010). The present study describes the certain phenological patterns of tropical tree communities in dry deciduous forest and evergreen forest at Bhadra Wildlife Sanctuary for 2 years during June, 2004 to May, 2006.

**Materials and methods**

One transects each in evergreen forest (10 km) long and in dry deciduous forest (2 km) long was laid along the periphery of sanctuary for clear visibility of the tree canopy. A total of 177 individuals comprising of 47 tree species in site- I and 277 individuals comprising of 45 tree species in site-II all above 20 cm d.b.h (diameter at breast height) were identified using various regional floras (Yoganarasimhan *et al*., 1982; Saldhana, 1984-1996; Gamble and Fischer, 1998; Ramaswamy *et al.*, 2001; Neginhal, 2004). The representative plant specimens were collected, deposited in the Herbarium of the department of Applied Botany, Kuvempu University. Identified individuals were marked with a unique tag numbers with clear visibility to facilitate re-location. These marked individuals were monitored for both vegetative (foliar) and reproductive phenological events such has for leaf

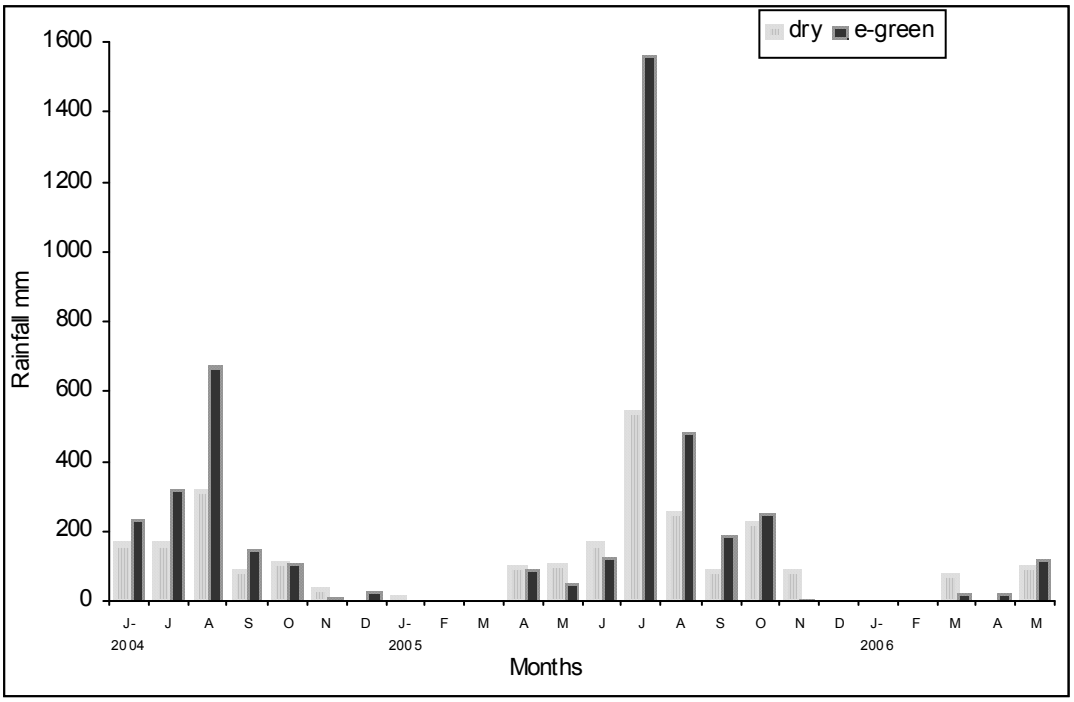


**Figure 1. .** Annual rainfall in dry and evergreen forest during the study period of Bhadra Wildlife Sanctuary.

flushing (LF2), flower budding (FL2) and fruit maturation (FR4) phenologies. Each stage in different categories of phenology was scored qualitatively with respect to both spread and intensity on canopy on a 0 to 100 scale.

***Data analysis***

Correlations analysis relating to rainfall parameter was computed. Differences in the patterns of frequency of leaf flushing, flower initiation and fruit maturation in a month between two forest types were analysed using the Kolmogorov-Smirnov test (KS test) and Chi-Square test (Zar, 2007).

## Results

***Leaf initiation phenology***

Leaf initiation peaks in the month of April in dry forest, after leaf less period of 1-2 months. Whereas leaf initiation peaks in the month of January simultaneously along with leaf senescence in evergreen forest (Fig. 2).

***Factors influencing leaf flushing phenology***

In dry deciduous forest, Rainfall had significant negative influence on leaf flush during two month lag period ($r = -0.62$, $p<0.001$) along with number of rainy days ($r = -0.61$, $p<0.002$) It is clear from the (Fig. 3) that peak leaf flush happens two months before the peak in rainfall. However in evergreen forest, Rainfall had significantly negative influence on leaf flush during the corresponding months ($r = -0.41$, $p<0.04$). Time lag correlations with rainfall were not significant either during one-month lag period or two-month lag period. Leaf flush peaks five months before the rainfall (Fig. 4).

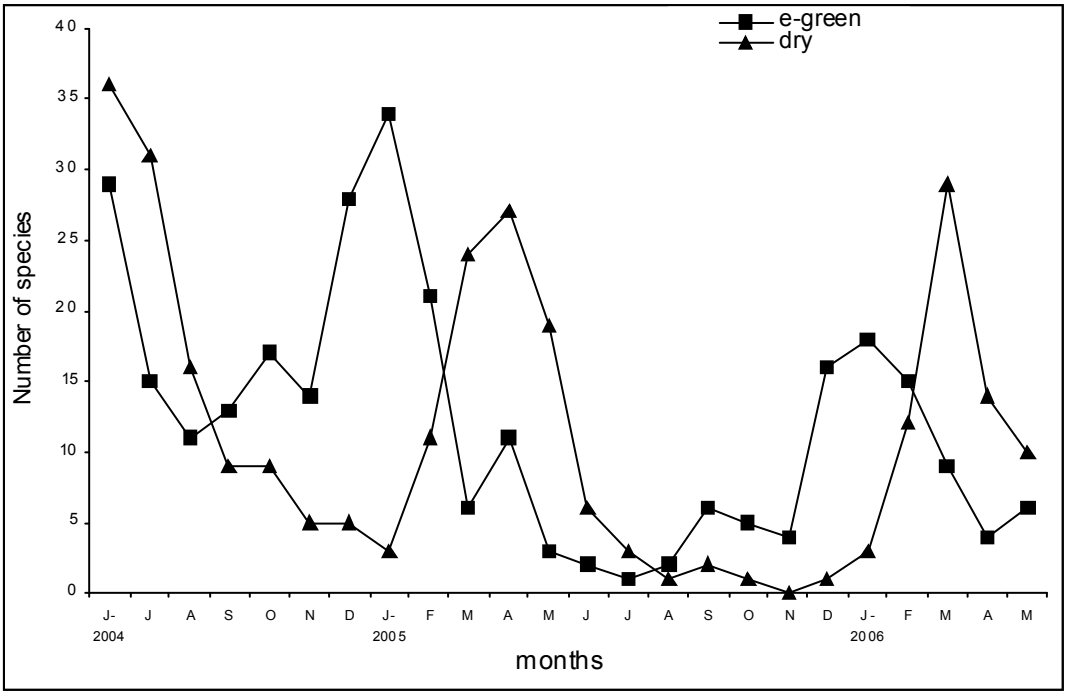


**Figure 2**. Leaf flushing in dry and evergreen forest of Bhadra Wildlife Sanctuary.

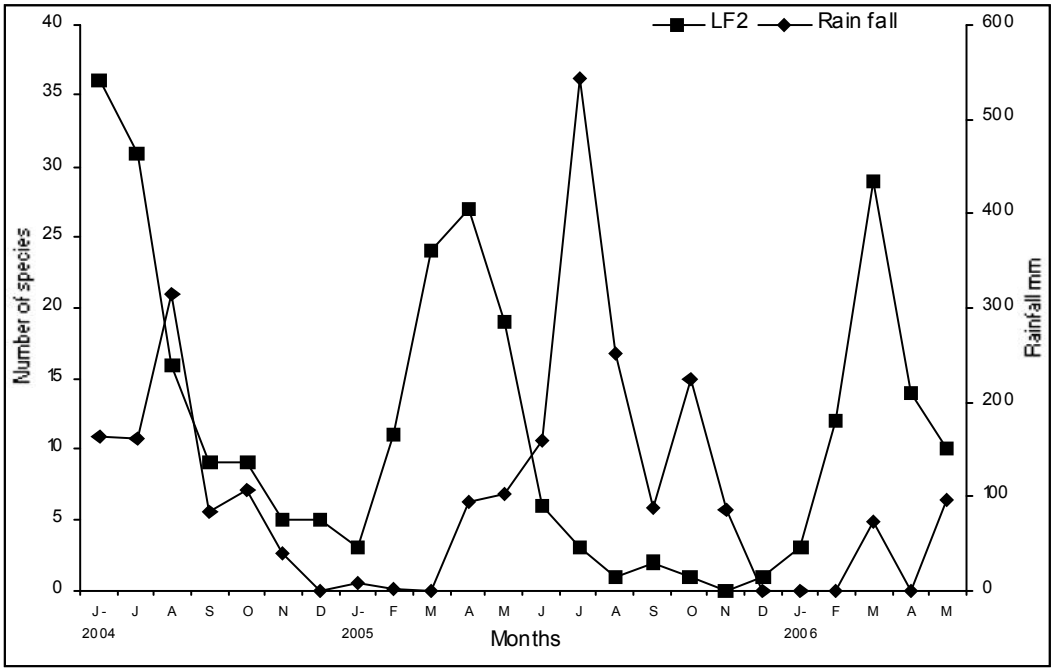


Figure 3. Leaf flushing and rainfall in dry forest of Bhadra Wildlife Sanctuary.

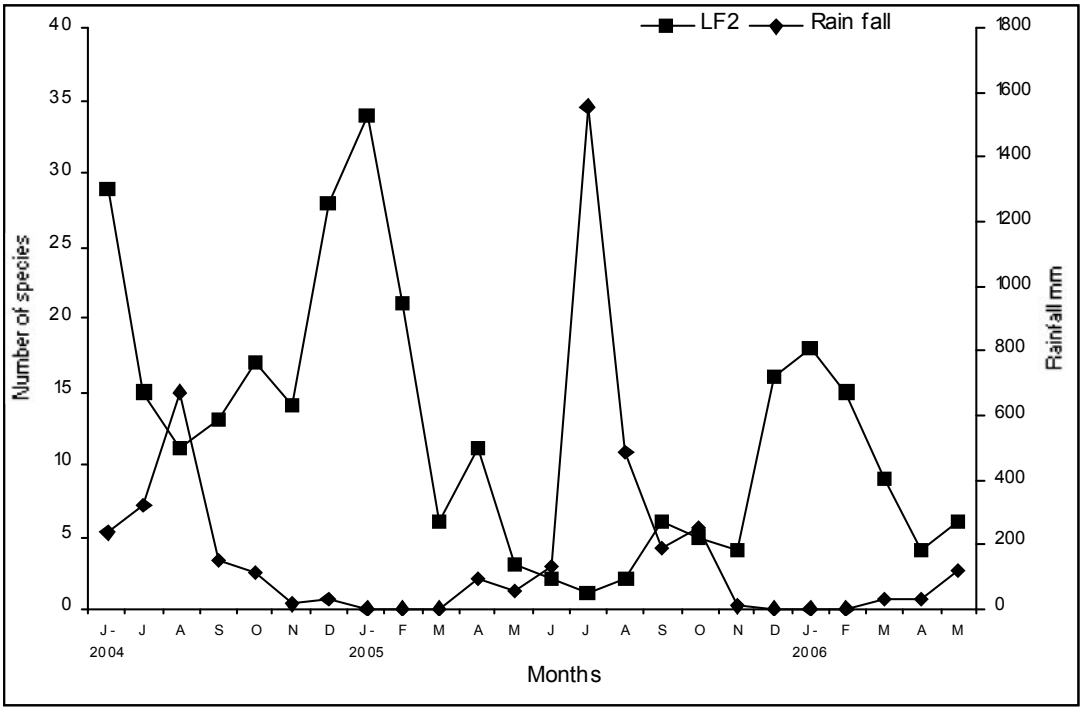


**Figure 4**. Leaf flushing and rainfall in evergreen forest of Bhadra Wildlife Sanctuary.

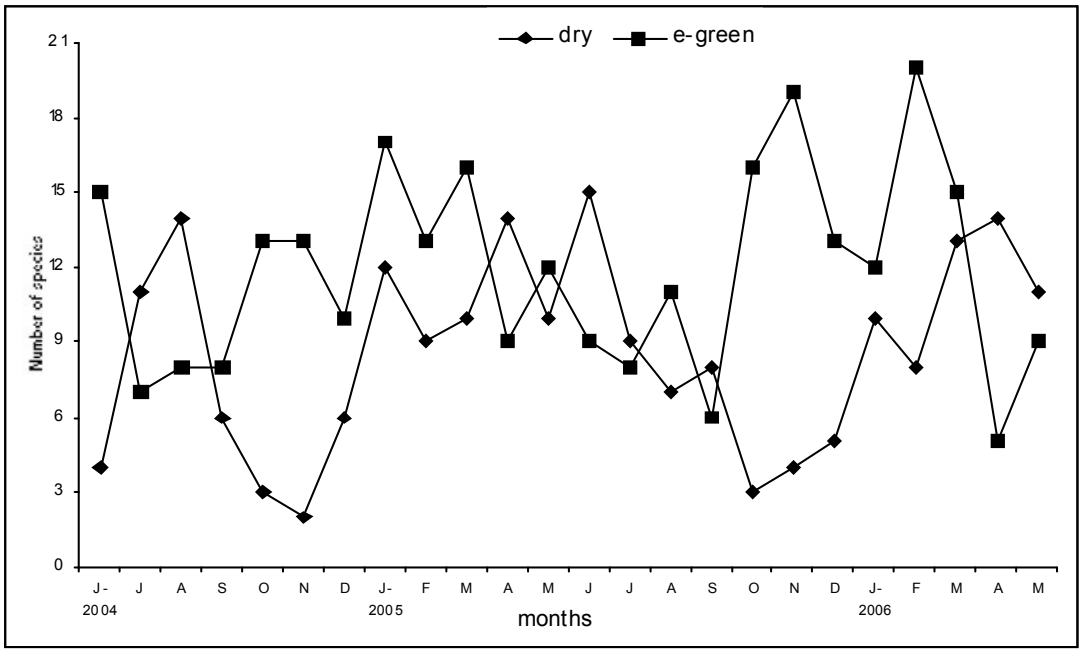


**Figure 5**. Flower budding in dry and evergreen forest of Bhadra Wildlife Sanctuary.

***Flower phenology***

Flower initiation begins from January till June with a peak in April, i.e., most species initiate flowering in leafless period and few species simultaneously leafing and flowering in summer period. But the pattern in evergreen forest starts from November to march with a peak in January and February in post-winter to pre-summer (Fig. 5).

***Factors influencing flower initiation phenology***

In dry deciduous forest flowers initiation during two month lag period. Rainfall ($r = -0.49$, $p<0.02$), and number of rainy days ($r = -0.57$, $p<0.005$) during corresponding month had a significant negative influence.

Most of the species initiate flower during dry season in dry deciduous forest. It is also clear from the figure that the initiation begins in January and continues till June with peaks during April to June. Leaf initiation and flower initiation coincide (Fig. 6). But some of the species do initiate flower while having senescent leaves or during the leafless period. In dry deciduous forest some trees had leaf initiation and flower initiation coincide with each other (KS test $D = 0.2916$, $P>0.10$). In dry deciduous forest leafing and flowering events had taken place simultaneously. Chi-Square ($\chi^2=83.74$, $df = 23$, $p<0.0001$) is highly significant.

Whereas in evergreen forest rainfall during the corresponding months has a significant negative influence on the initiation of flowers among the species ($r = -0.57$, $p<0.003$). Time lag correlations are not significant. Flower initiation and leaf flush happens simultaneously among the species (KS test, $D = 0.333$, $p>0.10$), though in some months there are more number of species initiating flowers than having young leaves Chi-Square ($\chi^2 =71.87$, $p<0.0001$, $N = 23$) is highly significant (Fig. 7).

***Fruiting phenology***

Fruit maturation in dry forest starts from March to December with a peak in August and November. From summer periods to end of rainy season. Whereas in evergreen forest from January to July with a peak in April i.e., fruit maturation in evergreen forest starts from onset of winter to a peak rainfall (Fig. 8).

***Factors influencing fruit maturation phenology***

In dry forest number of rainy days had a significant negative influence on maturity of fruits during corresponding months. Multiple regression during one month lag period was significant ($r = 0.65$, $F = 3.43$, $p<0.02$) with number of rainy days and rainfall influencing the event. Step wise regression was also significant ($r = 0.65$, $F = 4.82$, $p<0.01$) with number of rainy days and rainfall influencing the event. Though rainfall influences maturity of fruits, it did not have significant impact on the maturity of fruits (Fig. 9).

Similar pattern was observed with maturity of fruits in evergreen forest also. Correlation during corresponding month was not significant with respect to fruit maturity (Fig. 10). Time lag correlations were negatively significant ($r = -0.66$, $p<0.004$, one-month lag) ($r = -0.64$, $p<0.001$, two-month lag).

**Discussion**

Dry periods in tropical dry forests are characterized by intense physiological activities. Most of the phenological

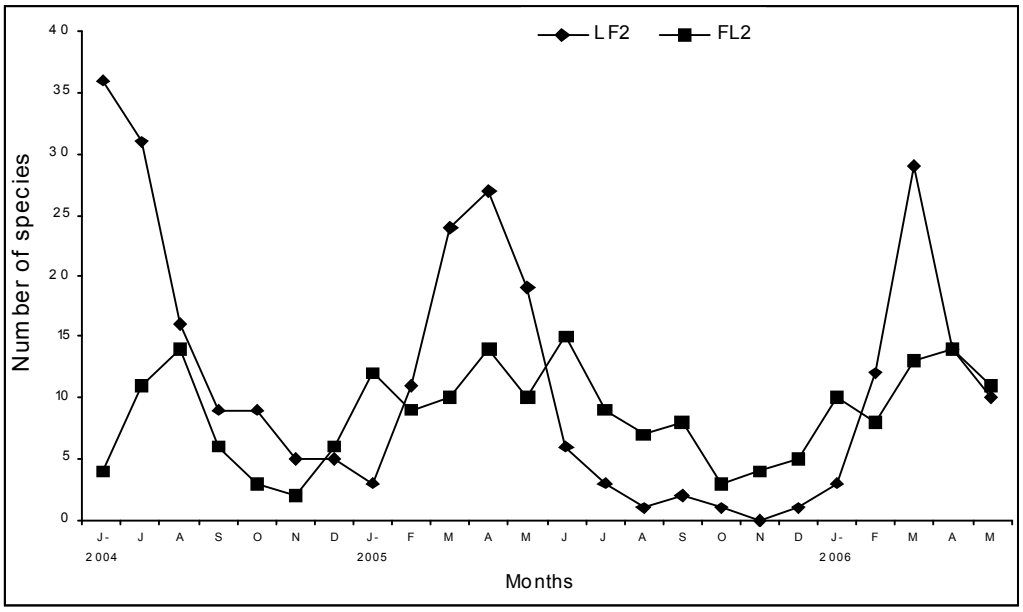


**Figure 6.** Leaf flushing and flower budding in dry forest of Bhadra Wildlife Sanctuary.

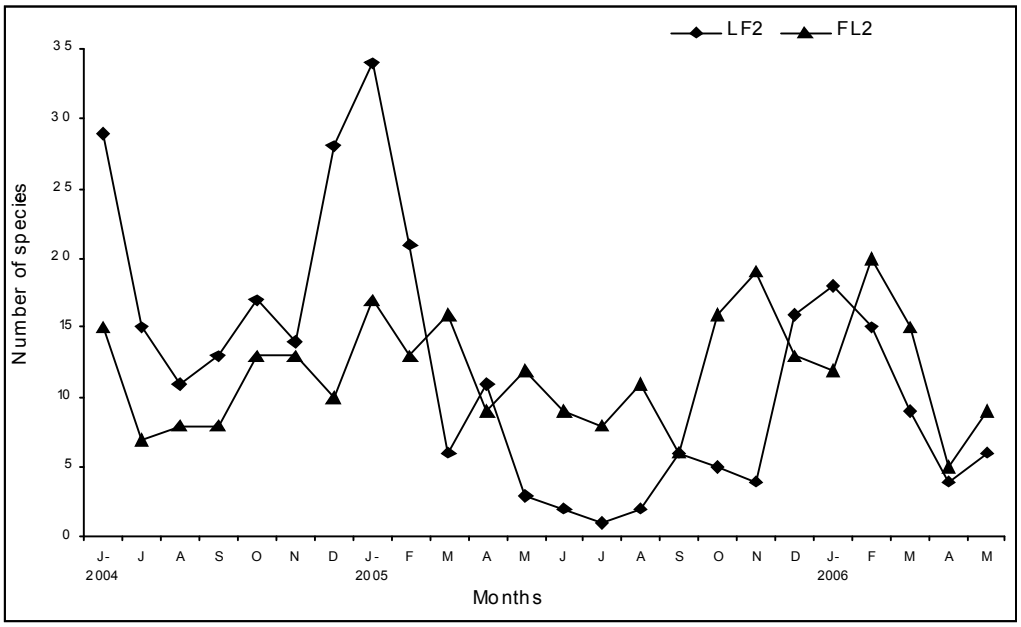


**Figure 7.** Leaf flushing and flower budding in evergreen forest of Bhadra Wildlife Sanctuary.

activities happen during the early of the dry season in evergreen forest and in dry season in dry forest. In this present study leaf flushing and leaf fall happens before the on set of rains in evergreen forest of Kemmangundi. This synchronization between senescence and flushing ensures that trees were never totally leafless. This

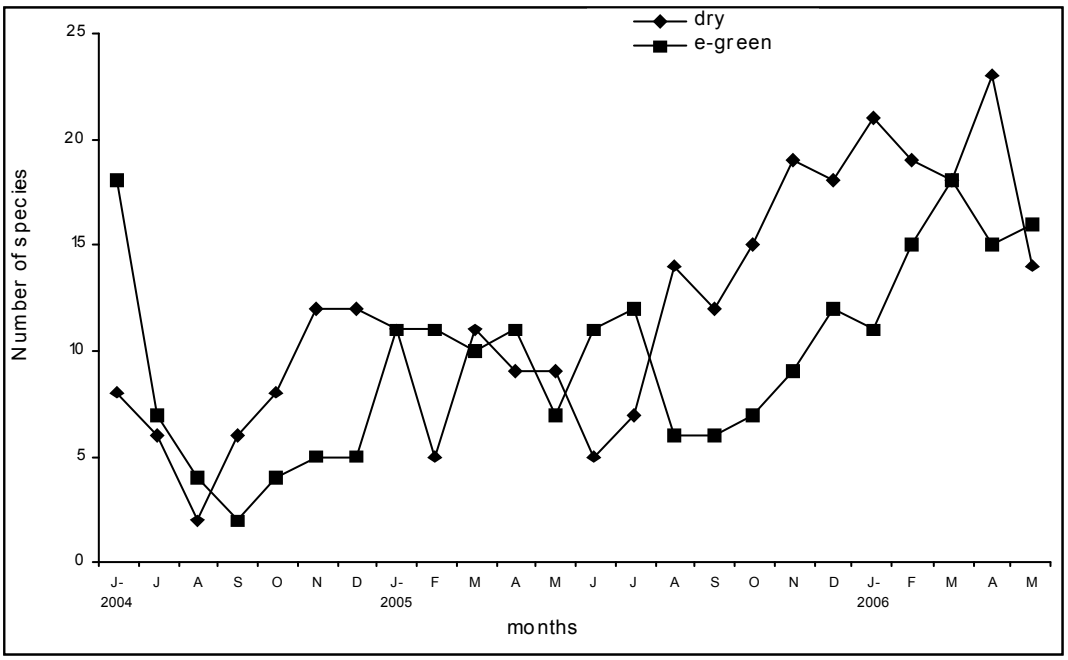


**Figure 8.** Fruit maturation in dry and evergreen forest of Bhadra Wildlife Sanctuary.

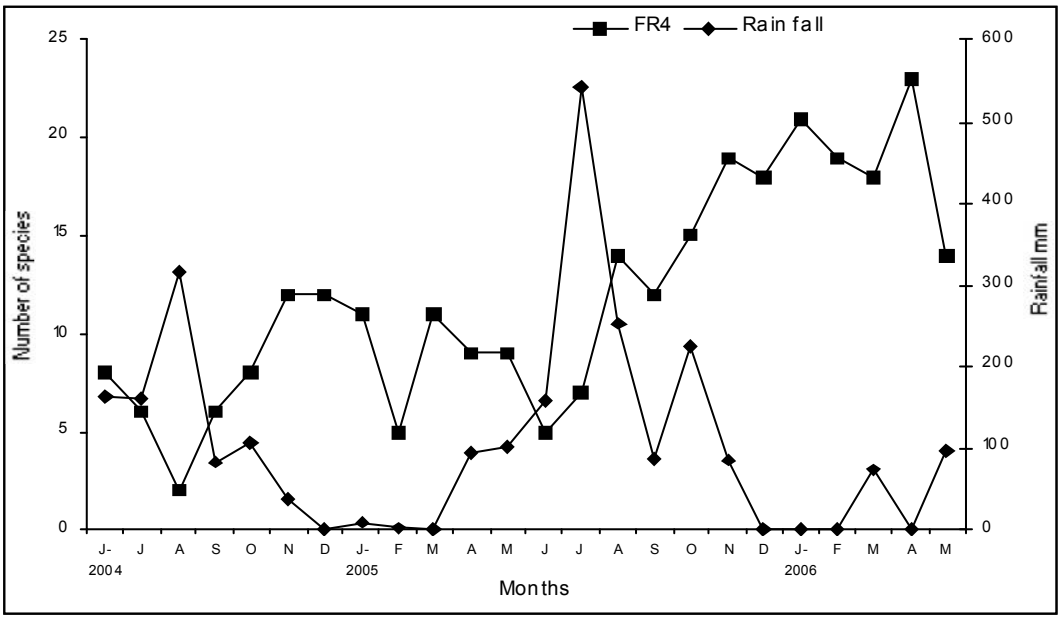


**Figure 9**. Fruit maturation and rainfall in dry forest of Bhadra Wildlife Sanctuary.

pattern is similar to other studies (Shukla and Ramakrishnan, 1982; Ralhan *et al*., 1985; Bhat, 1992; Saha, 2007).

However in dry forest leaf flushing is in dry season after a 1 to 2 month of leafless period, i.e., before the onset of rains is in

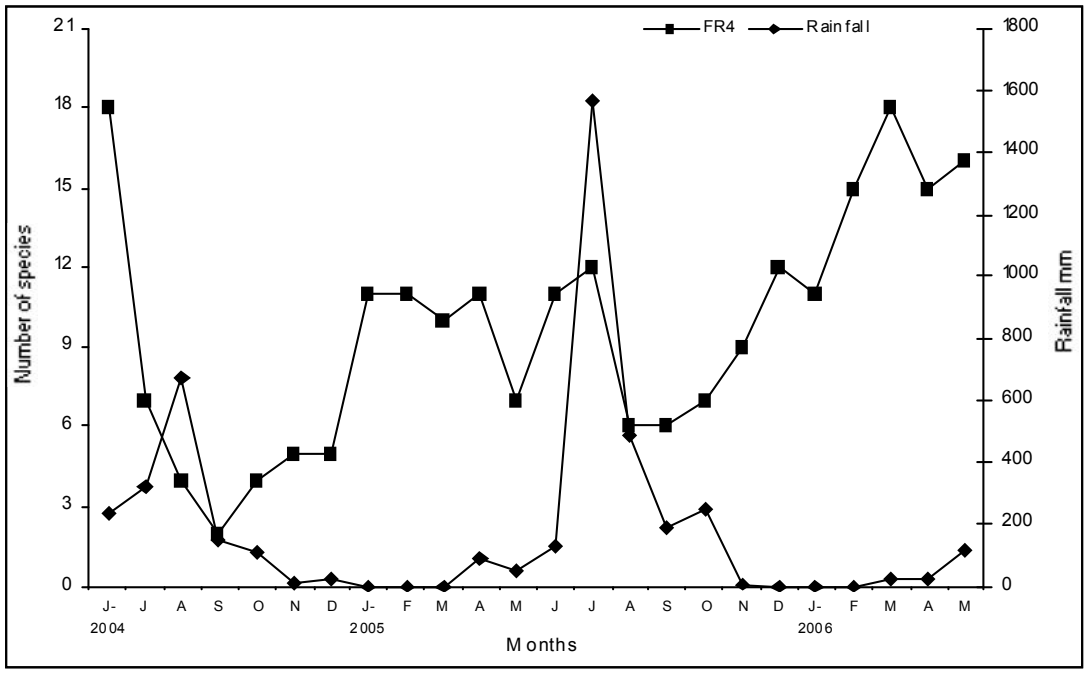


**Fig. 10**. Fruit maturation and rainfall in evergreen forest of Bhadra Wildlife Sanctuary.

agreement with other observation (Justiniano and Fredericksen, 2000; Kushwaha and Singh 2005).

Flower initiation also differs with respect to forest type in this study. As evergreen trees initiated flowering in the winter period is similar to other studies (Bhat, 1992; Sundarapandian *et al*., 2005; Saha, 2007). Whereas in dry forest trees initiated flowering during the beginning of the dry season at the time most of the trees were leafless or leaf flushing stage. As flower initiation can advertise to pollinators as they get pollinated as seen in other tropical forest (Murali and Sukumar, 1994; Sundarapandian *et al*., 2005). Whereas in Costa Rica rainfall (wet season) play a role in flower initiation (Opler *et al*., 1976).

Reproductive phenological studies in seasonal tropical forest ecosystems have indicated rainfall seasonality as being the major abiotic factor controlling the timing, intensity and duration of flowering and fruiting periodicities (De Lampe *et al.,* 1992; White, 1994; Sun *et al*., 1996; Justiniano and Fredericksen, 2000; Borchert *et al*., 2004; Nanda *et al*., 2010). Van Schaik *et al*., (1993) deduced that leaf flushing and flowering fell within 1 month before the onset of the rainiest period in strongly seasonal forests. In deciduous trees, anthesis can be induced by the temporal rehydration of the trees after leaf fall by isolated rainfall during the dry season or by the onset of the wet season (Reich and Borchert, 1984).

For these reasons, it has been assumed that water availability is both the proximate and the ultimate factor controlling phenology in tropical dry forest plants (Reich and Borchert, 1984). The timing of synchronous flowering in individual species of tropical trees and the resulting flowering

periodicity at the community level are widely thought to have evolved as a result of biotic interactions between trees and their pollinators (Borchert *et al*., 2004).

The duration of fruit maturation was longest in dry forest from August to April (monsoon to pre-monsoon period) with a peak in November to January (Nanda *et al*., 2009). This pattern is in agreement with other tropical studies (Murali and Sukumar, 1994; Sundarapandian *et al*., 2005). However in evergreen forest the Fruit maturation was from January to July with a peak in the month of April. Maturation was more in pre-monsoon and lessens after a monsoon.

However, tropical wet forests exhibit a wide range of fruiting patterns, including unimodal or bimodal fruiting peaks (Zhang and Wang, 1995; Hamann, 2004). Some tropical dry forest plant phenology studies describe a single fruiting peak related to the dry season or several peaks in the wet and dry seasons (Bullock and Solis-Magallanes, 1990).

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