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Investigation on the phenological behavior of *Nothopegia aureo-fulva* Beed. in Agasthiyamalai Biosphere Reserve, Western Ghats, India.

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Abstract

Studies on the periodic behavior of a species are called phenology. Life cycle event of species may be greatly influenced by environmental factors. This is mostly regulated by external indication from environment. Vegetative phenological events such as leaf sprouting, leaf maturation, flushing, leaf fall and flowering, fruiting phenology of *Nothopegia aureo-fulva* have been regulated with climatic factors such as temperature, rainfall, humidity and CO_2. To examine the relationship between phenological pattern of the species and climatic variables such as temperature and rainfall, which is Spearman's rank correlation coefficients (rho) was used. Leaf initiation of *N. aureo-fulva* activity had significantly negative correlation (rho = - 0. 477; P < 0. 01) with rainfall. . Leaf abscission of *N. aureo-fulva* was having significantly positive correlation (rho = 0. 361; 0. 325; P < 0. 05) with the maximum and minimum temperatures. Significant negative correlations (rho = - 0. 424; - 0. 689; P < 0. 01) was observed for flower initiation with both maximum and minimum temperatures. All the fruit phases like initiation, maturation and ripening was not correlated with all the climatic factors such as rainfall, maximum and minimum temperatures. Hence, the data will be highly useful for conservation implementing the conservation strategies.

Keywords: Biological rhythms, endangered species, phenology, and *Nothopegia aureo-fulva*

Introduction

Plant phenological studies give a fundamental to understanding the forests as a resource base for other dependent populations or communities. Studies on the phenological behavior are basic to understanding the biological processes of tropical trees and organismal interaction with them is achieved by studying the phenological behavior (Justiniano and Fredericksen, 2000). Knowledge of the phenological patterns and how these are influenced by environmental factor is important for the prediction of potential effects of climate change on vegetation (Broadhead *et al.,* 2003). An understanding of what governs phenological process is valuable in understanding forest function and structure and in providing the basis for developing management options (Chapman *et al.,* 1999). Vegetative phenology is important to understand the ecology and instinct history of a plant species and may help to develop the conservation strategies of endangered species. Thus plant phenological study has great significance because it not only provides knowledge about the plant growth pattern but it also provides the idea on the effect of environment and selective pressure on flowering and fruiting behavior. *N. aureo-fulva* is a critically endangered tree species of moist deciduous forests of Aryankavu, Kerala (IUCN, 2013). It is also categorized as critically endangered or possibly extinct by Red Data Book (Nair and Sastry, 1987). Precise phenological information with respect to flowering and fruiting of *N. aureo-fulva* is evaluated against leafing and leafless periods is not explored in tropical forests in India. Hence, studies on the information on onset dates of different phenological events, duration of events and asynchrony in tropical forest trees is the essential need of the hour. Therefore, the present study aims to monitor and describe the vegetative phenological events such as leaf sprouting, leaf maturation, flushing and leaf fall of *N. aureo-fulva*. Flowering and fruiting phonologies of these vulnerable and critical endangered species also correlates with climatic factors.

Methodology

Leafing, flowering and fruiting phonologies were recorded monthly from March 2009 to March 2012 in Kulirkadu (KK) forests, Ariyankavu, Kerala. Twenty five full-grown individuals of *N. aureo-fulva* were selected. For phenological observations, the age (girth class) of the tree was selected in ± 5 cm DBH. All the individuals were marked with sequentially numbered metal tags to facilitate relocation. On each marked individual, four major branches (one in each direction) were selected, and on each branch four twigs (currently growing shoots of last-order branches) were marked with metal tags. Each individual was observed every fortnight for three years for phenological phases such as (i). Production of Young Leaves (YL), (ii) Maturation of Leaves (ML), (iii) Abscission of Leaves (AL), (iv) Production of Young Flowers (YF), (v) Maturation of Flowers (MF), (vi) Production of Young Fruits (YFR), (vii) Maturation of Fruits (MFR) and (viii) Ripening of Fruits (RFR). The presence of flowers and fruits were noted with the help of binoculars. During the visits, all marked individuals were qualitatively characterized and the phenostage of a species was determined by considering their status (Prasad and Hegde, 1986). All the species sampled, were considered large to be sexually mature, without vine infestations and deformities of obvious diseases. The species was considered to be flowering and fruiting that month if it is found with flowers or fruits. Voucher samples of specimens were deposited in the herbarium of Centre for Biodiversity and Forest Studies, Madurai Kamaraj University, Madurai.

The rainfall and temperature data was collected from Indian Meteorological Department (IMD), Ministry of Earth Sciences, Government of India (http://www.imd.gov.in/). To examine the relationship between phenological pattern of the species and climatic variables such as temperature and rainfall, which is Spearman's rank correlation coefficients (rho) was used. All the variables were correlated with three phenological phases (leafing, flowering and fruiting) (Kushwaha and Singh, 2005).

Results

The Aryankavu of Western Ghats climate is characterized by four seasons. It consists of south west monsoon (July to September), north east monsoon (October to December), cool early dry period (January to March) and hot summer dry period (April to June). The maximum average temperature ranges from 25 °C in August to 35 °C in February during the study period. The minimum average temperatures differ from 18 °C in July to 23 °C in March. The highest rainfall was recorded in the month of November (312 mm) and lowest was at February (1.5 mm) (Fig. 1).

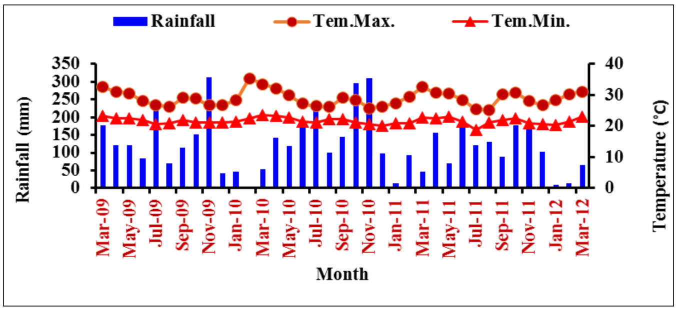

Fig. 1. Ombrothermic diagram for Aryankavu, mean monthly maximum and minimum temperature (°C) and rainfall (mm).

Phenology of *N. aureo-fulva* observed indicated the occurrence of leaf initiation, leaf flush, leaf fall, flowering and fruiting annually. The young leaves (YL) initiation showed two peaks: a larger one from the month of January to March and a smaller peak in August and September. The peak activity for the production of young leaves was recorded in February (Fig. 2). Leaf abscission (AL) of the species was observed in the dry period (March to May). Maturation of the leaves (ML) was also reported in the month of early dry and dry seasons (February to April). Almost all the vegetative phenostage of the species occurred during early dry and dry periods. The flower bud initiation (YF) of *N. aureo-fulva* was noticed in November and December. Maturation of the flower (MF) was occurred from December to March (Fig. 3). The peak activity of the flower initiation was observed during the month of December every year. The fruit initiation (YFR) was recorded during the early dry period (January to March). Peak activity of the fruit initiation was seen at February (Fig. 4). Fruit maturation (MFR) was noticed during the months from February to April. The ripening (RFR) of the fruits was recorded in March and April.

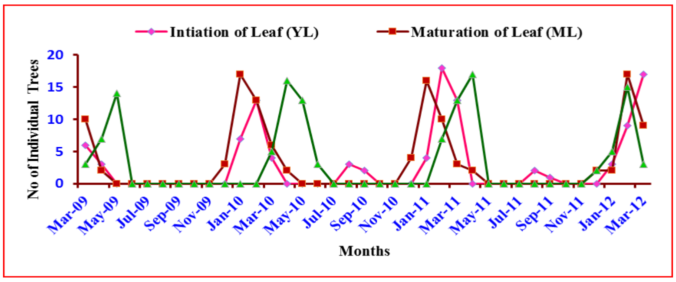

Fig. 2. Leaf phenology of *N. aureo-fulva* in Agasthiyamalai Biosphere Reserve, Western Ghats.
YL - Initiation of Leaf, ML - Maturation of Leaf, AL - Abscission of Leaf

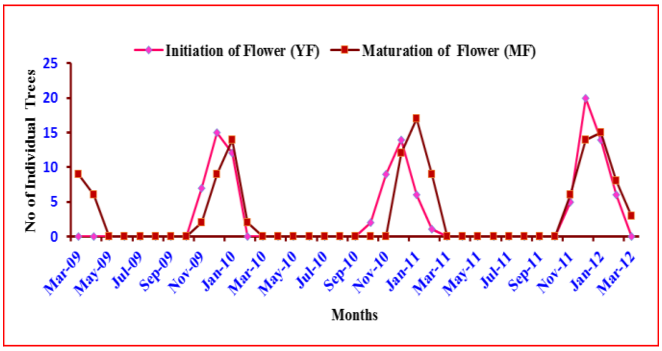

Fig. 3. Flowering phenology of *N. aureo-fulva* in Agasthiyamalai Biosphere Reserve, Western Ghats.
YF - Initiation of Flower, MF - Maturation of Flower

Leaf initiation of *N. aureo-fulva* activity had significantly negative correlation (rho = - 0. 477; P < 0. 01) with rainfall (Table 1). Maturation of the leaves was did not correlate with rainfall and maximum and minimum temperatures. Leaf abscission of *N. aureo-fulva* was having significantly positive correlation (rho = 0. 361; 0. 325; P < 0. 05) with the maximum and minimum temperatures. Significant negative correlations (rho = - 0. 424; - 0. 689; P < 0. 01) was observed

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for flower initiation with both maximum and minimum temperatures. Similarly, significant negative correlation (rho = - 0. 344; *P* < 0. 05; rho = - 0. 676; *P* < 0. 01) was observed in flower maturation with maximum and minimum temperatures. All the fruit phases like initiation, maturation and ripening was not correlated with all the climatic factors such as rainfall, maximum and minimum temperatures.

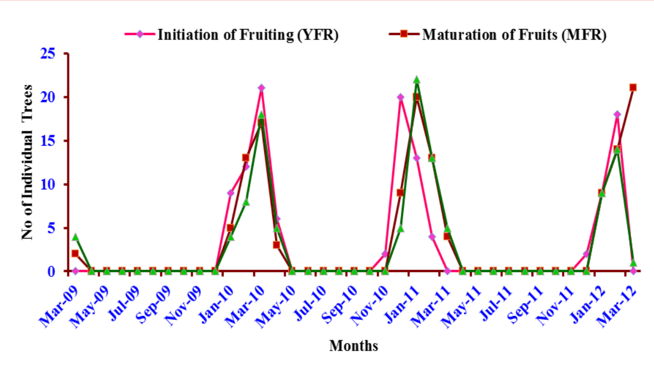

Fig. 4. Fruiting phenology of *N. aureo-fulva* in Agasthiyamalai Biosphere Reserve, Western Ghats.
YFR - Initiation of Fruiting, MFR - Maturation of Fruits, RFR - Ripening of Fruits

Table 1: Phenological patterns of *Nothopegia aureo-fulva* in relation to rainfall, maximum and minimum temperatures in Aryankavu of Western Ghats, Kerala

Phenophase	Environmental factor		
	Rainfall	Maximum temperature	Minimum temperature
	Spearman's rank correlation coefficients (rho)		
Leaf Initiation (YL)	- 0.477**	0.250	- 0.050
Leaf Maturation (ML)	- 0.259	0.000	- 0.158
Leaf Abscission (AL)	- 0.285	0.361*	0.325*
Flower Initiation (YF)	0.074	- 0.424**	- 0.689**
Flower Maturation (MF)	0.018	- 0.344*	- 0.676**
Fruit Initiation (YFR)	- 0.134	- 0.146	- 0.303
Fruit Maturation (MFR)	- 0.234	- 0.051	- 0.203
Fruit Ripening (RFR)	- 0.266	0.067	- 0.262

$^*P < 0.05$, $^{**}P < 0.01$

Discussion

Seasonal occurring of leaf emergence, leaf flush, flowering and fruiting primarily determine the phenological behavior of tropical tree species. Phenostage of the plants having their seasonal peaks are the usual event in tropical forests. Synchronization of flowering and fruiting with a particular season of the annual cycle by many species appears to be under the control of prevailing climatic conditions of that season. The detection of several flowering types in Indian tropical trees revealed that a variety of strategies have evolved to ensure survival and reproduction under a monsoonic bioclimate.

The peak activity of the leaf emergence was noticed in the dry period. Leaf initiation coincided with dry period (summer) and was seasonal in both the candidate species. Maturation of the leaves occurred during the February to April. Leaf flush and leaf fall happened during the dry period and sometimes it occurred during later summer. Highest activity of the leaf emergence in the dry season observed in selected tropical tree species is in agreement with other earlier observations (Frankie *et al.,* 1974; Shukla and Ramakrishnan, 1982; Murali and Sukumar, 1993; Bhat, 1992; Bhat and Murali, 2001). According to Borchert (2000), the re-hydration of the trunk after leaf fall may be possible due to root penetration to deep soil levels, which would allow leaf budding even during the dry period. *Tibouchina fissinervia* produced leaves even in the dry period, indicating a reduction in transpiration flux (Miranda *et al.,* 2011).

Peak activity of leaf flush and leaf fall are seasonal, quite common in tropical forests, especially during dry periods. Sundarapandian *et al.* (2005) showed that most of the tropical tree species observed had their leaf fall during the early dry seasons (December and January) and some of the species during dry period. Leaves initiation and maturation happens during the period with minimal rainfall, high temperature and increasing day length. Temperature begins to decrease with day length may short which is essential characters for leaf fall occurs. Similar results were reported by Shukla and Ramakrishnan (1982), Bhat and Murali (2001) and Sundarapandian *et al.* (2005) in tropical forests of India and in Costa Rica by Daubenmire (1972) and in Ghana by Lieberman (1982). Leaf abscission is attributed during the dry season to avoid the water stress and it may also be a mechanism of maintaining shoot turgidity (Borchert, 1980; Singh and Singh, 1992). The leafless period is an adaptation to avoid water stress, where water stress affects flowering time in tropical forest trees (Bullock, 1995). Leaf flushing and senescence of the tropical deciduous forests was episodic and represents the interaction between the environmental water status and the structural and functional state of the tree.

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Quantitative and eco-physiological studies demonstrated that increasing day length or temperature during the late dry season influences the phenophase of the semi-evergreen species (Borchert, 2000; Rivera *et al.,* 2002; Elliott *et al.,* 2006; Miranda *et al.,* 2011). This may not be applicable to the results obtained from tropical forests of Costa Rica and Malaysia (Kunkel-Westphal and Kunkel, 1979; Bhat, 1990). Nevertheless, the dry season leaf flushing permits renovation of the canopy before the monsoon rain arrives, such that the plants are able to take full advantage of the short rainy season for their growth and production (Sundarapandian *et al.,* 2005).

The highest flowering peaks of *N. aureo-fulva* were obtained during the month of November and December (post monsoon and early dry period). Immense pre monsoon or monsoon flowering is prevalent for the tropical tree species which means continued availability of energy in the subsequent rainy seasons for developing fruits, when the foliage is actively photosynthesizing (Singh and Singh, 1992; Sundarapandian *et al.,* 2005). Very often synchronous flowering is correlated with rainfall and after the dry spell (Augspurger, 1982) and such flowering is believed to attract pollinators (Bullock and Bawa, 1981) as insect activity is probably greatest in the months with warm and dry days (Janzen,1967; Kaul *et al.,* 1986; Schaik, 1986, Bhat, 1992). Flowering in different seasons could help to avoid competition for pollinators. Unlike species that flower during the later part of the winter season, which do not experience heavy demands for energy for vegetative growth, species that bloom during the pre-monsoon dry period make large investment in reproduction while they are leafless or flushing and must depend on the reserve food (Bullock and Solis-Magallanes, 1990). Leaf flush precedes or coincides with flowering, as observed in endangered species (*Caesalpinia echinatai*) and has been reported in other species also (Bencke and Morellato, 2002; Borges *et al.,* 2009). In species flowering during the first heavy rainy season rain may act as a flowering cue. Autumn flowering occurs during the early dry season at a time when carbohydrate reserves are in plenty and climatic conditions are favorable for reproduction before soil water reserve depletion. Declining day length may induce synchronous development of flowers in autumn-flowering (September–November) species (*Anogeissus* and *Terminalia*). Flower development on foliated shoots after the autumn equinox indicates flower induction by declining day length (Rivera and Borchert, 2001; Singh and Kushwaha, 2006; Kushwaha *et al.,* 2011). The large fraction of species flowering in Indian tropical forests during the dry season (83 %, December–June) reflects the availability of water required for the growing organs (e.g. through sporadic winter rains, absorption from soil water reserves by leaf exchanging species, or using stored stem water in stem succulents) (Singh and Kushwaha, 2006).

Our study reveals that the activity of fruit initiation was observed in December and was followed by fruit maturation and ripening during February and March (dry period). In majority of species, fruit ripening was close to the onset of rainfall or at the onset of early rainy season, as also indicated by the correlation between fruiting phenology and rainfall (Wycherley, 1973; Murali and Sukumar, 1994). Ripening of fruits in the later part of pre monsoon dry period or close to rainfall is observed in the forest of Uttara Kannada district (Bhat, 1992). Similar features have been explained to gain post dispersal success (Rathcke and Lacey, 1985), escape predation (Janzen, 1983), enhanced dispersal (Foster, 1982; Prasad and Sharatchandra, 1984) and avoiding pathogen infection (Augspurger, 1983). As happens in *Diospyros* fleshy-fruited species bear fruit when the moisture levels are sufficient (mainly during the wet season) to allow fruit growth and maturation (Lieberman, 1982). In a few species such as *Lagerstroemia microcarpa*, *Chukrassia tabularis* and *Terminalia paniculata* fruits ripen at odd seasons (post rainy season) when the germination success is usually minimal and incidence of pest and pathogen attack is high. Ripening of fruits in pre-monsoon dry period, especially in species dispersed by wind, could be a consequence of selection to disperse propagules at a time when the wind velocity is maximum. Animal-dispersed species to fruit during the rainy season is to maintain moisture in the fruits and also to regenerate during the rainy months. Odd-season ripening of fruits in some of the hard seed coated species such as *Terminalia bellerica*, *T. chebula* and *Phyllanthus emblica* may help dispersal, since many of these were ingested by animals and dropped (Bhat, 1992). Fruit maturation and suitable dispersal conditions are closely synchronized in tropical dry forests because of the pronounced differences of biotic and abiotic conditions between dry and rainy seasons (Griz and Machado, 2001).

Conclusion

A strong seasonality exists with respect to vegetative and reproductive phenology in tree species of *N. aureo-fulva* in Agasthiyamalai Biosphere Reserve, Western Ghats. Increasing day length and rise in temperature during the pre-monsoon dry period are probably responsible for leaf flush and maturation, while shorter day length and decrease in temperature might have induced leaf drop during the post-monsoon period. The leaf initiation and leaf fall was found synchronized with dry season. The highest flowering peak of *N. aureo-fulva* was recorded during post monsoon seasons. Concurrent ripening of fruits by majority of species in pre-monsoon period may offer post dispersal advantage for seeds to germinate. Fruit initiation was occurring during the early dry or dry period in *N. aureo-fulva*.

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