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Studies on the phenological behaviour of *Elaeocarpus venustus* Beed. in Agasthiyamalai Biosphere Reserve, Western Ghats, India

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Abstract

Phenology is study of the timing of recurring biological events, among phases of the plant species, which provides background for collecting and synthesizing detailed quantitative information on the rhythms of plant communities. During the visits, all marked individuals were qualitatively characterized and the phenostage of a species was determined by considering their status. 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 Upper Kodayar of Western Ghats climate is characterized by three seasons. . In the present study, all the individuals of *E. venustus* were observed to have their leaf initiation, leaf fall, flowering and fruiting occurring seasonally i.e once in a year. The fruit initiation (YFR) episode was in the months from September to November. The activity of leaf initiation of *E. venustus* negatively correlated with rainfall, maximum temperature and minimum temperature. The highest flowering peak of *E. venustus* was recorded during monsoon episodes. 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 post monsoon seasons in *E. venustus*.
Key words: phenological behaviour, *E. venustus*, *conservation.*

Introduction

Phenology is study of the timing of recurring biological events, among phases of the plant species, which provides background for collecting and synthesizing detailed quantitative information on the rhythms of plant communities. 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).

Elaeocarpus venustus Bedd. is an endemic, vulnerable large tree species of the southern Western Ghats peninsular India (IUCN, 2013). Due to its narrow geographical distribution and low population size, it is considered as endangered by Red Data Book (Nayar and Sastry 1988) and vulnerable by IUCN (World Conservation Monitoring Centre 1998). But recent assessment considered this species as critically endangered (Venkatesh *et al.*, 2012). The population of *E. venustus* in KMTR is heavily destructed by construction of hydroelectric dams for power generation, construction of roads, buildings and extension of plantations like eucalyptus and tea (Saravanan and Muthuchelian 2013). Habitat degradation caused by these anthropogenic pressures along with natural factors such as poor regeneration ability of the species and small population size with unique microhabitat adaptation have threatened the *Elaeocarpus* species survival in Arunachal Pradesh (Bhuyan *et al.*, 2002). 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. Learning about the phenology of endemic and endangered species is very much essential for recovery and reintroduction program. Precise phenological information with respect to flowering and fruiting of *E. venustus* 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

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maturation, flushing and leaf fall of *E. venustus*. Flowering and fruiting phonologies of the vulnerable tree species also correlates with climatic factors.

Methodology

Leafing, flowering and fruiting phonologies were recorded monthly from March 2009 to March 2012 in Upper Kodayar (UP) Agasthiyamalai Biosphere Reserves, Western Ghats. Twenty five individuals of mature *E. venustus* were selected. For phenological observations, the age (girth class) of the tree was ± 25 cm DBH in *E. venustus* was selected. 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 Upper Kodayar of Western Ghats climate is characterized by three seasons. The climate consists of wet rainy season (July to September), cool dry winter (November to February) and hot dry summer (April to June). March and October represent the transitional months between the seasons, the major part of both being closer to the season following them. The maximum average temperature varies from 26 °C in December to 35 °C in March during the study period. The minimum average temperatures differ from 20 °C in December to 24 °C in April during the study period. The month of November (313 mm) was recorded to have the highest rainfall and the lowest rainfall was recorded in February (1.5 mm) (Fig. 1).

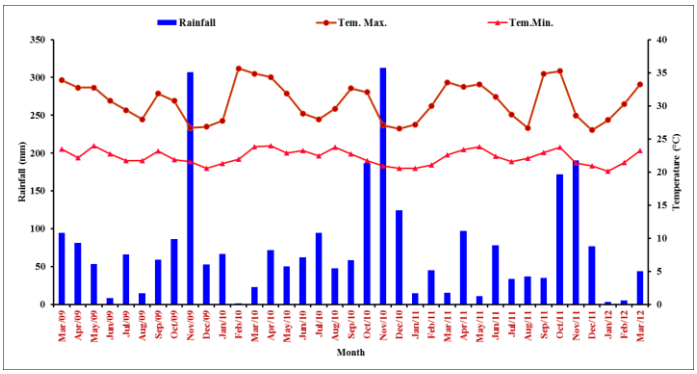

Fig. 1. Ombrothermic diagram for Upper Kodayar, mean monthly maximum and minimum temperature (°C) and rainfall (mm).

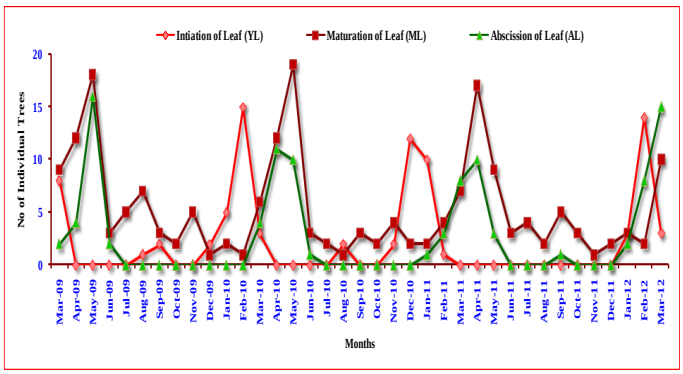

Fig. 2. Leaf phenology of *E. venustus* in Agasthiyamalai Biosphere Reserve, Western Ghats.

YL - Initiation of Leaf, ML - Maturation of Leaf, AL - Abscission of Leaf

Seasonal peaks for leaf initiation and leaf flush are quite common in tropical forest species. In the present study, all the individuals of *E. venustus* were observed to have their leaf initiation, leaf fall, flowering and fruiting occurring seasonally i.e once in a year. The production of young leaves (YL) occurred in the months from December to March during the study period. The peak activity for the production of young leaves was recorded in February. Leaf fall (AL) occurred during the dry period (March to May). The initiation

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of leaf and leaf fall was occurring synchronized during dry season.

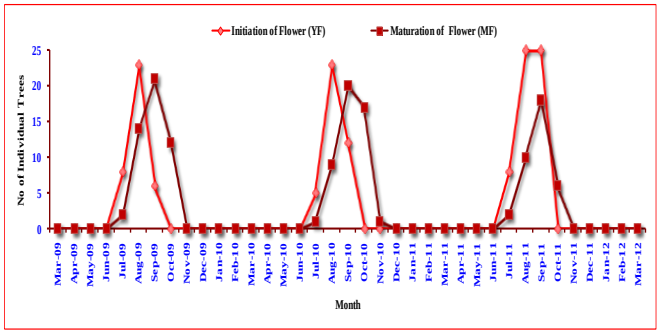

Fig. 3. Flowering phenology of E. venustus in Agasthiyamalai Biosphere Reserve, Western Ghats
YF - Initiation of Flower, MF - Maturation of Flower

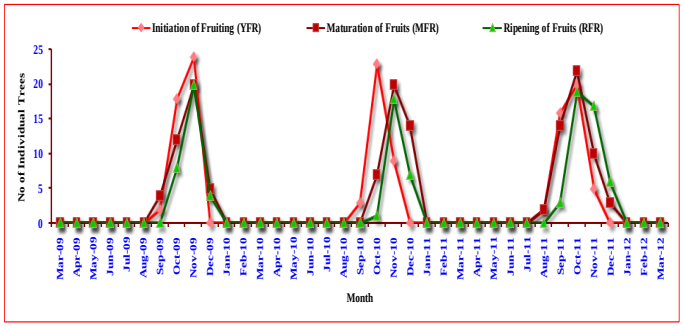

Fig. 4. Fruiting phenology of *E. venustus* in Agasthiyamalai Biosphere Reserve, Western Ghats.
YFR - Initiation of Fruiting, MFR - Maturation of Fruits, RFR - Ripening of Fruits

Leaf maturation (ML) was recorded in the early dry period in *E. venustus* (Fig. 2). The flower bud inception occurred in the month of June and flower initiation (YF) occurred from July to September. The peak activity of the flower initiation was observed in the month of August every year (Fig. 3). Maturation of *E. venustus* flower (MF) was recorded in the months September and October.

The fruit initiation (YFR) episode was in the months from September to November. The peak activity of fruit initiation was recorded from September to October and maturation (MFR) of the fruits occurred during October and November. The ripening (RFR) of the fruits was recorded in the months of November and December and peak ripening period was observed in November (Fig. 4).

The activity of leaf initiation of *E. venustus* negatively correlated with rainfall, maximum temperature and minimum temperature. Similarly leaf maturation negatively correlated (rho = - 0. 019; $P < 0.01$) with rainfall, whereas the maximum and minimum temperatures showed significant correlation positively (rho = 0. 473; 0. 520; $P < 0.01$ respectively) (Table 1). Abscission of leaves showed negatively significant correlation (rho = - 0. 336; $P < 0.01$) with rainfall. However, the maximum and minimum temperatures exhibited significantly positive correlations (rho = 0. 503; 0. 450; $P < 0.05$ respectively). Initiation and maturation of the flowers did not correlate with the climatic factors. Fruit initiation of *E. venustus* significantly positive correlated (rho = 0. 494; $P < 0.01$) with rainfall and had negatively significant correlation (rho = - 0. 353; $P < 0.05$) with minimum temperature. Maturation of the fruits significantly correlated with all the climatic variables, positively with rainfall (rho = 0. 357; $P < 0.05$) and negatively with (rho = - 0. 527; - 0. 633; $P < 0.01$) the maximum and the minimum temperatures respectively. Ripening of the fruits negatively significant correlated with (rho = - 0. 587; - 0. 698; $P < 0.01$) with both maximum and minimum temperatures.

Table 1: Phenological patterns of *E. venustus* in relation to rainfall, maximum and minimum temperatures in Upper Kodayar of Western Ghats, Tamil Nadu

Phenophase	Environmental Factor		
	Rainfall	Maximum temperature	Minimum temperature
	Spearman's rank correlation coefficients (rho)		
Leaf Initiation (YL)	- 0.304	- 0.109	- 0.313
Leaf Maturation (ML)	- 0.019	0.473**	0.520**
Leaf Abscission (AL)	- 0.336*	0.503**	0.450**
Flower Initiation (YF)	- 0.18	- 0.001	0.128
Flower Maturation (MF)	0.288	- 0.042	0.035
Fruit Initiation (YFR)	0.494**	- 0.293	- 0.353*
Fruit Maturation (MFR)	0.357*	- 0.527**	- 0.633**
Fruit Ripening (RFR)	0.299	- 0.587**	- 0.698**

*$P < 0.05$, **$P < 0.01$

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

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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 early dry period in *E. venustus*. Leaf initiation was occurred in dry period (summer). Maturation of the leaves occurred during the February to April in *E. venustus*. 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. 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).

In the present study, the crest flowering peaks of *E. venustus* occurred during the monsoon seasons. Highest peak flowering was observed in August (pre monsoon 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; Borgesa *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 during the post monsoon period in *E. venustus*. Fruit maturation and ripening was recorded during the November and December. 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).

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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 of *E. venustus* of 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 *E. venustus* was recorded during monsoon episodes. 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 post monsoon seasons in *E. venustus*.

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