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Phenology of Trees Species in Tropical Montane Evergreen Forest, the Nilgiris, Southern Western Ghats, India

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Abstract Tree phenology and seasonality observations were made on 38 tree species in a tropical montane evergreen forest in Nilgiris, comprising of 190 individuals. The phenophases of flowering, fruiting, leaf fall and vegetative phase were made at monthly intervals from October 2014 to September 2016 in relation to seasonal rainfall and temperature at community level. Leaf fall peaked during dry season in December and April. Flower bud initiation begins in October, peaked in November and flower maturation continues with a high peak in March to April. Fruit formation initiated during November in wet season and fruit maturity peaked in March in the dry season and later achieved in second wet season of October. The significant of both vegetative and reproductive phenophases are influenced by seasonal rainfall peak from April to July and highest peak in May. There was no peaking of leafless and leaf flush phase during the study period.

Keywords Nilgiris, Shola, Leaf fall, Flowering, Fruiting.

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Introduction

Phenology of flowering and fruiting is the study in relation to seasons with climatic factors. The tropical ecosystems have distinct biological communities and high levels of endemism (Gentry 1992). The characteristic of phenology of tropical forests are vary greatly according to their location, topography and climate (Gentry 1974, Janzen 1978, Sakai 2001). Tropical tree species known to have general phenological aspects of leafing, flowering and fruiting (Daubenmire 1972, Frankie et al. 1974, Opler et al.1980, Borchert 1983, Suresh and Sukumar 2011, Sun et al. 1996, Kikim and Yadav 2001) and triggered by rainfall, temperature, photoperiods and day light (Bhat and Murali 2001, Hamann 2004). Tropical wet evergreen forest species exhibit annual flowering patterns due to regular reproductive cycles, and responses of species community to environment (Krishnan 2002, Singh and Kushwala 2006). In seasonal tropical forest , phenology usually has a strong correlation with wet and dry seasons

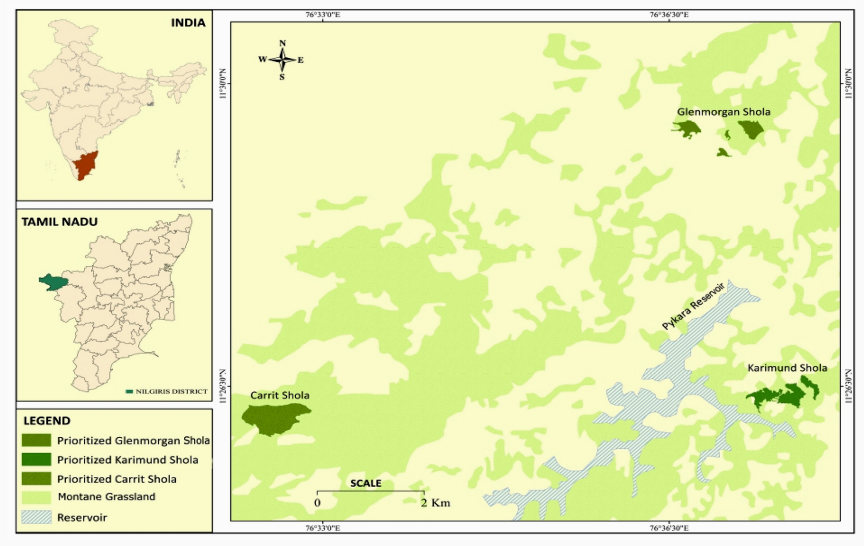

Fig. 1. Map of the selected study sites in Nilgiris.

(Reich and Borchert 1984, Wright and Van Schaik 1994, Gunter et al. 2008) and phenology is mainly determined by the duration and intensity of seasonal drought (Mooney et al. 1995, Kushwala and Singh 2005). The reproductive period generally occurs in low photosynthetic activity and accumulation (Fenner 1998, Singh and Kushwala 2006). Several studies in this ecosystem showed significant variation in onset of flowering and fruiting (Fitter and Fitter 2002, Chapman et al. 2005) and got little scientific attention at least in neotropics. However, variation indicates the seasonal changes in reproductive phenology determinants interactions to typical pollinators of bees and butterflies (Koptur et al. 1988) and dispersal patterns (Thompson and Willson 1979, Rathcke and Lacey 1985, Wright and Van Schaik 1994). Therefore the present study describes the phenological pattern of tree species in tropical montane evergreen forest with response to climatic factors and seasonality.

Materials and Methods

Study area

The present study was carried in forest patches at Glenmorgan (11°29.520' N 76°32.726' E) 2057m msl, Kariamund (11°26.651' N,76°37.248' E) 2195 m msl, Carrit shola (11°25.563' N 76°32.248' E) 2,105m msl, of south forest division, the Nilgiris district, Tamil Nadu (Fig. 1). The study was conducted in chain linked shola, well developed non-chain linked shola and degraded shola. The major part of the rainfall receive from southwest monsoon (June to August) and rest from northeast monsoon (October to November), temperature ranging from 2°C to 23°C , with layer of mist and fog covered in southern east slopes. Climate plays an important role in phenology of plants and influenced by southwest monsoon and northeast monsoon, the winter season is short (December to February) and the rest is dry season (March-May) (Fig. 2). The boundary of these sholas were marked by GPS coordination topographical maps were prepared

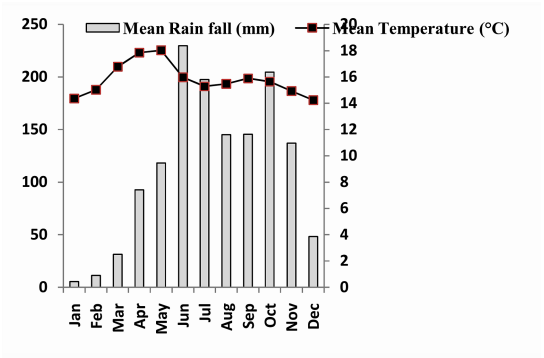

Fig. 2. Monthly rainfall and temperature pattern of the study area for the period from (1993 to 2013). (Source : Glenmorgan tea estate management authority and metrological station (CSWCRTI), Udhagamandalam.

using ArcGIS.

Methodology

Five reproductive individuals of 38 tree species (>30-gbh) were selected from shola patches such as Glenmorgan, Carritshola and Kariamund. The selected trees of each species were tagged with unique tags and phenology events were recorded once in a fortnight over a period of two years from October 2014 to September 2016. All the selected species were identified using floras (Gamble and Fischer 1915-1936, Fyson 1932, Henry et al. 1987, 1989) and voucher specimen of the species were prepared and deposited in Fischer Herbarium (Acronyme-FRC),IFGTB, Coimbatore. Individuals were observed for both vegetative and reproductive phenology.The observations were done by determining phenological events such as leaf fall, flushing, flowering and fruiting (bud initiation and maturation). During this period pollinators, avian guild and frugivore were also recorded by direct field observation.

Vegetation

The shola forest is classified as Southern tropical montane wet evergreen forest by (Champion and Seth 1968). Frankie et al.(1974) described the trees which are specific to different environmental conditions to their position in the canopy are divided into two categories : Overstorey and understorey species. The characteristic tree species in the upper storey of thisforest are *Prunus ceylanica, Schefflera stellata, Rhododendron arboreum* subsp. *nilagiricum, Mahonia leschenaultii, Elaeocarpus recurvatus, Ilex wightiana, Magnolia nilagirica, Syzygium calophyllifolium* and *Litsea wightiana.* Tree species in the middle storey are *Gordonia obtusa, Meliosma simplicifolia, Celtis tetrandra, Scolopia crenata, Xantolis tomentosa, Isonandra perrottetiana, Elaeocarpus munronii, Turpinia cochinchinensis* and *Melicope lunu-ankenda.* The tree species found in the margin and fringes are *Symplocos cochinchinensis, Cinnamomum wightii, Vaccinium leschenaultii, Vernonia arborea, Photinia integrifolia* and *Viburnum erubescens* (Nayar 1997, Rao 1997, Nair and Daniel 1986).

Results and Discussion

A total of 190 individuals under 38 species, 31 genera and 25 families were observed for their phenology. Among them, family Elaeocarpaceae were dominant with 4 species, followed by Lauraceae and Theaceae with 3 species each, Celastraceae, Daphniphyllaceae, Myrtaceae, Rosaceae, Sabiaceae and Sapotaceae with 2 each species, and all other 18 families represented one species each (Table 1).

Table 1. Flowering and fruiting months with fruit type and dispersal mode of tree species in the study site.

Sl. No.	Species	Family	FL & FR months	Fruit type	Dispersal mode
1	*Celtis tetrandra* Roxb.	Ulmaceae	Nov - May	Fleshy	Zoochory
2	*Cinnamomum wightii* Meisner in DC.	Lauraceae	Dec - May	Dry	Autochory
3	*Daphniphyllum neilgherrense* (Wight) K. Rosenth	Daphniphyllaceae	Nov - Jun	Fleshy	Zoochory
4	*Elaeocarpus munronii* (Wight) Mast.	Elaeocarpaceae	Nov - May	Fleshy	Zoochory
5	*Elaeocarpus recurvatus* Corner	Elaeocarpaceae	Jan - May	Fleshy	Zoochory
6	*Elaeocarpus serratus* L.	Elaeocarpaceae	Jun - Nov	Fleshy	Zoochory
7	*Elaeocarpus variabilis* Zmarzty	Elaeocarpaceae	Jan - Jul	Fleshy	Zoochory
8	*Euonymus crenulatus* Wall.ex Wight & Arn.	Celastraceae	Jul - Nov	Fleshy / later dry	Zoochory
9	*Eurya nitida* Korth.	Theaceae	Sep - Feb	Fleshy / later dry	Zoochory
10	*Gordonia obtusa* Wall. ex Wight & Arn.	Theaceae	Dec - Jul	Dry	Zoochory/autochory
11	*Glochidion ellipticum* Wight	Euphorbiaceae	Dec - Apr	Fleshy / later dry	Zoochory

Table 1. Continued.

Sl. No.	Species	Family	FL & FR months	Fruit type	Dispersal mode
12	*Gnidia glauca* (Fresen.) Gilg in Engl.	Thymeleaceae	Oct - May	Fleshy	Autochory
13	*Ilex wightiana* Wall. ex Wight	Aqufoliaceae	–	Fleshy	Zoochory
14	*Isonandra perrottetiana* A. DC.	Sapotaceae	Jun - Dec	Fleshy	Zoochory
15	*Litsea wightiana* (Nees) Hook.f.	Lauraceae	Nov - Aug	Fleshy	Zoochory
16	*Mahonia leschenaultii* (Wall.ex.Wight & Arn.)	Berberidaceae	Oct - Apr May - Aug	Fleshy / Berry	Zoochory
17	*Mangnolia nilagirica* (Zenker) Figlar	Magnoliaceae	Oct - Apr Jun - Aug	Fleshy	Zoochory
18	*Melicope lunu-ankenda* (Gaertn.) T. G. Hartley	Rutaceae	Aug - Dec	Fleshy	Zoochory
19	*Meliosma pinnata* (Roxb.) Maxim	Sabiaceae	Jan - May	Fleshy/later dry	Zoochory/autochory
20	*Meliosma simplicifolia* (Roxb.) Walp.	Sabiaceae	Nov - Jun Aug-Sep	Fleshy / later dry	Zoochory/autochory
21	*Microtropis densiflora* Wight	Celastraceae	Jan - Jun	Fleshy	Zoochory
22	*Neolitsea scrobiculata* (Meisn.) Gamble	Lauraceae	_	Fleshy	Zoochory
23	*Nothopodytes nimmoniana*	lcacinaceae	Jan - Jul Oct - Dec	Fleshy	Zoochory
24	*Photinia integrifolia* Lindl. var *sublanceolata* Miq.	Rosaceae	Oct - Jan Apr - Jul	Fleshy/later dry	Zoochory
25	*Prunus ceylanica* (Wight) Miq.	Rosaceae	Aug - Feb Apr - May	Fleshy	Zoochory
26	*Rhododendron arboreum* subsp. *nilagiricum* (Zenker) Tagg	Ericaceae	Oct - Mar Aug - Sep	Dry	Autochory
27	*Scohefflera stellata* (Gaertn.) Baill.	Araliaceae		Fleshy	Zoochory/autochory
28	*Sclopia crenata* Clos	Flacourtiaceae	Nov - Jul	Fleshy	Zoochory
29	*Symplocos obtusa* Wall. ex G. Don	Symplocaceae	Jan - May	Fleshy	Zoochory
30	*Symplocos cochinchinensis* (Lour.) S. Moore	Symplocaceae	Jan - May	Fleshy	Zoochory
31	*Syzygium calophylli folium* (Wight) Walp.	Myrtaceae	Dec - May	Fleshy	Zoochory
32	*Syzygium densiflorum* Wall.ex Wight & Arn.	Myrtaceae	Nov - May	Fleshy	Zoochory
33	*Ternstomeia gymnenthera* (Wight & Arn.) Sprague	Theaceae	Dec - Mar Apr - May	Fleshy / later dry	Zoochory/autochory
34	*Turpinia cochinchinensis* (Lour.) Merr.	Staphyleaceae	Feb - Jul	Fleshy / later dry	Zoochory
35	*Vaccinium leschenaultii* Wight	Vacciniaceae	Nov - May	Fleshy	Zoochory
36	*Vernonia arborea* Buch. - Ham.	Asteraceae	Nov - May	Fleshy/later dry	Autochory
37	*Viburnum erubescens* Wall.	Caprifoliaceae	Dec - Apr	Fleshy	Zoochory
38	*Xantolis tomenstosa* (Roxb.) Raf.	Sapotaceae	Jul - Sep Dec - Mar	Fleshy	Zoochory

Leaf fall and vegetative phase

As in the case of deciduous forest, there was no synchronous leaf fall observed in any of the selected sholas. The highest peak of leaf fall was observed during December and August-September in both the years of observation. The vegetative phase in this study area has two peaks, major peak is on first wet season from (July-September), and the second phase starts from early October and peak in second wet season of

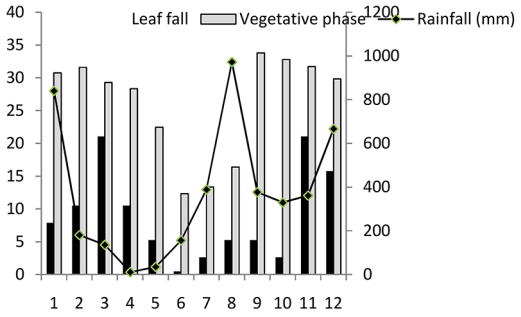

Fig. 3. Number of species in leaf fall and vegetative phase from October 2014 to September 2016 in relation to rainfall.

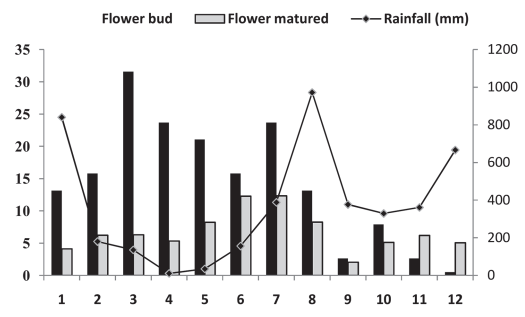

Fig. 4. Flower bud and flower maturation in relation to rainfall among different species during study from October 2014 to September 2016.

November and falls down to dry season March-April (Fig. 3). Leaf drop occurs during the peak of monsoon were in post wet season (September and December) both southwest monsoon and northeast monsoon. Tree species such as *Celtis tetrandra, Elaeocarpus recurvatus, Gordonia obtusa, Isonandra perrottetiana, Litsea wightiana, Rhododendron arboreum* subsp. *nilagiricum, Daphniphyllum neilgherrense* and *Syzygium densiflorum* had maximum leaf fall during (August-September), whereas *Elaeocarpus serratus* shed their leaves from December and continued up to mid of February.

A few species like *Ilex wightiana, Elaeocarpus variabilis, Cinnamomum wightii, Turpinia cochinchinensis, Neolitsea scorbiculata* and *Schefflera stellata* dropped their leaves continually during post wet season to dry season (November to February) extended up to 8, 10 and 12 weeks respectively. Species like *Gnidia glauca* and *Magnolia nilagirica* sheds leaves in first wet season of June as abnormal due to wind and rainfall. However, trees in lower canopy and fringes remain constant due to wellness of moisture. Species such are *Vernonia arborea, Vaccinium leschenaultii, Symplocos cochinchinensis, Glochidion ellipticum* and *Ternstroemia gymnanthera* leaf emergence was correlated with any season in the study areas, as compared to onset of rainy season in deciduous forest (Kunhikannan and Rao 2014).

Flowering activity

The flowering period is divided into two phases : (i) flower bud and initiation (ii) flower opening. The seasonal pattern of flowering in these selected shola forests has showed one peak starting from of February (late dry season) and high peak towards March-April and pre-wet season of May (Fig.4). In most of the species flower bud initiation started during the post- monsoon and pre-winter season. Species like *Rhododendron arboreum* subsp. *nilagiricum, mahonia leschenaultii, Syzygium densiflorum, Elaeocarpus variabilis, Litsea wightiana* and *Gnidia glauca* showed extended flowering upto 24 weeks. In this case, few middle storey trees e.g *Magnolia nilagirica* and *Symplocos obtusa,* the flowering occurred during the second wet season of northeast monsoon. The dominant annual species included *Cinnamomum wightii* and *Syzygium calophyllifolium* and *Photinia integrifolia.* The species *Nothapodytes nimmoniana* have two flowering phase. However, in the montane evergreen species in leaf fall exhibits lower than flowering phase and flowering before leaf fall e.g. *Elaeocarpus recurvatus, E. serratus* and *Turpinia cochinchinensis,* whereas flowering and leaf shedding simultaneously e.g. *Gordonia obtusa, Magnolia nilagirica* and *Cinnamomum wightii.*

Fruiting activity

The fruiting period is divided into two phases as : (i) fruit initiation and (ii) fruit maturation . The fruiting species extends over a few months on both for seasonal as well as extended to flowering species. The fruit initiation showed two peaks with highest activity in March and post-monsoon at November. The species attained a major peak period of mature fruits in March and minor one in first wet season of July. Out of 38

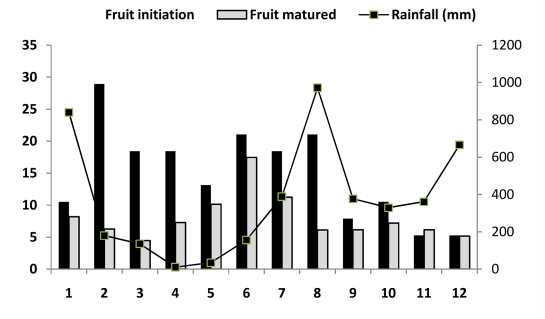

Fig. 5. Fruit initiation and fruit maturation in relation to rainfall among different species during the period from October 2014 to September 2016.

species, 17 tree species performed in the month of March (Fig. 5). Species like *Mahonia leschenaultii, Glochidion ellipticum, Magnolia nilagirica* and *Trenstromeia gymnanthera* exhibited an extended phase of fruit maturation till the end of dry season.

Species such as *Litsea wightiana, Isonandra perrottetiana, Nothapodytes nimmoniana* and *Magnolia nilagirica* fruit maturation period was long during wet season (June-September). However, species such as *Cinnamomum wightii, Ilex wightiana, Schefflera stellata* and *Neolitsea scorbiculata* showed negative response in fruiting phase during this period. Species like, *Vibrunum erubescens*, *Vernonia arborea, Microtropis densiflora, Melicope lunu-ankenda* and *Turpinia cochinchinensis* showed fruiting only for a month and fruit maturation during dry season.

Phenological events at tropical montane evergreen forest in Nilgiris are strongly correlated with the seasonality of rainfall. Similarly, with respect to other wet evergreen forests in Western Ghats, the species richness is relatively low (Somasundaram and Vijayan 2010). Predictable annual cycle in the bio tic and abiotic factors affects the growth and reproduction of tree species in relation to phenophase (Anderson et al. 2005). Variation in flowering and fruiting activity in these selected shola forest are also due to rainfall seasonality as reported in several other montane forest in Nilgiris (Mohandass et al. 2016, Mohandass and Davidar 2010). Species flowered in the dry season (February-March), which also continued to the pre-monsoon of first wet season (April-May), but compared to tropical forest the dry season activity is less in fruiting, reported by Murali and Sukumar (1994), Ganesh et al. (1996), Sundarapandian et al. (2005).

Therefore, species like *Mahonia leschenaultii* have been observed to have regular flowering pattern, with fruiting phase continued up to 10 months duration with a maturing phase from January to April. Species such as *Nothopodytes nimmoniana* had shown both the events equally in different seasons of Southwest and Northeast monsoon, where as *Neolitsea scrobiculata* had showed only vegetative phase in the study site. These events generally go under different selective pressures by pollinators and fruiting does not follow flowering events if pollination fails (Chapman et al. 2005). Similar observations have also been reported for tropical evergreen forests (Frankie et al. 1974, Sundarapandian et al. 2005, Bendix et al. 2006, Nanda et al. 2017), tropical deciduous forests (Singh and Kushwala 2006, Yadav and Yadav 2008, Kunhikannan and Rao 2014) and sub-tropical forests (Kikim and Yadav 2001, Shukla and Ramkrishna 1982). Thus, flowering phase of tropical montane evergreen forest are mostly synchronous, but fruiting phase are highly concentrated to wet season and have definite fruiting seasonality compared to other tropical forests.

Conclusion

The phenology of flowering and fruiting pattern varies in different species of tropical montane evergreen forest. The variation in phenophase among individuals in the population are also due to different biotic and abiotic factors of the environment. Thus, the leaf fall, flowering and fruiting period in tropical montane evergreen forest is strongly related with seasonal changes and correlated with rainfall and temperature. The major peak of flowering and fruiting occurs in wet season, March-April and later continued on September-October. This study indicates the temporal variation in selection of species between reproductive and vegetative phase are more robust with seasonal variations in phenophase. This small-scale selection exposure to species individual of flowering and fruiting period with different pollinators play an important

role in phenology in plant communities. Therefore phenology are long term stability as an indicator of tree species community with climate change in tropical montane ecosystem.

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