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Phenology of tree species in subtropical forests of Manipur in north eastern India

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Abstract: Phenological characteristics of 32 dominant tree species have been studied in forest ecosystems at Kangchup hills, Manipur (24o45′ to 24o51′ N latitude and 93o48′ to 93o55′ E longitude). The leaf drop, leaf flushing, flower and fruit development in understorey and overstorey tree species were studied during January 1993 to December 1994. The number of evergreen tree species were greater than that of deciduous tree species in all the forest sites. Majority of the species exhibited peak of leaf drop in cool dry period (January-February) and leaf flushing in the beginning of warm dry period (March-April) and another in rainy season (August) of the year. Both over and understorey species showed a sharp flowering peak in April. The peak period of fruit maturation occurred during September-October. Leaf flush and flowering were simultaneous in both over and understorey tree species whereas the fruiting of understorey tree species is one month earlier than that of overstorey tree species.

Resumen: Las características fenológicas de 32 especies arbóreas dominantes fueron estudiadas en ecosistemas forestales de las colinas Kangchup, Manipur (24o45' a 24o51' latitud N y 93o48' a 93o55' longitud E). La caída de hojas, la foliación y el desarrollo de flores y frutos en especies arbóreas del sotobosque y del dosel fueron estudiados de enero de 1993 a diciembre de 1994. El número de especies perennifolias fue mayor que el de especies arbóreas deciduas en todos los sitios de bosque. La mayoría de las especies mostraron un pico en la caída de hojas en el periodo seco fresco (enero - febrero) y la foliación al principio del periodo seco caliente (marzo - abril) y otro en la estación lluviosa (agosto) del año. Tanto las especies del dosel como las del sotobosque mostraron un agudo pico de floración en abril. El periodo pico de maduración de frutos tuvo lugar durante septiembre - octubre. La foliación y la floración fueron simultáneas tanto en las especies arbóreas del dosel como del sotobosque, mientras que la actividad de fructificación de las especies arbóreas del sotobosque ocurrió un mes más temprano que la de las especies arbóreas del dosel.

Resumo: As características fenológicas de 32 espécies arbóreas dominantes foram estudadas em ecossistemas florestais nas colinas de Kangchup, Manipur (entre as latitudes de 24º 45' e 24º 51' N e as longitudes de 93º 48' e 93º 55' E). A queda de folha, a rebentação, o desenvolvimento da floração e da frutificação foram estudadas entre Janeiro de 1993 e Dezembro de 1994. O número de espécies sempreverdes era maior do que as árvores de folha caduca em todas as estações florestais. A maioria das espécies exibiu um pico de queda de folhagem no período frio e seco (Janeiro-Fevereiro) e a rebentação da folhagem ocorreu no início do período quente e seco (Março-Abril) e no período chuvoso (Agosto). Quer as espécies do nível superior, quer as de sub-coberto, apresentaram um pico de floração intenso em Abril. O período dominante da maturação dos frutos verificou-se entre Setembro-Outubro. A rebentação das folhas e a floração ocorreram, simultaneamente, nas espécies dos níveis superiores e nas do sub-coberto, enquanto a frutificação das espécies de sub-coberto ocorre um mês mais cedo em relação às dos níveis dos andares superiores.

Key words: Biotic factor, deciduous, dominant, evergreen, phenological activity.

Introduction

Phenology is the study of growth of buds, leaf flushing, anthesis, fruiting and leaf fall in relation to seasons or years with climatic factors. The phenological studies are important from the point of view of the conservation of tree genetic resources and forestry management as well as for a better understanding of the ecological adaptations of plant species and community level interactions. The plant-animal interactions in the community is based on the knowledge of seasonal production of plant parts. The general phenological aspects of leafing, flowering and fruiting in tropical tree species are fairly known (Borchert 1983; Daubenmire 1972; Frankie *et al.* 1974; Opler *et al.* 1980; Putz 1979; Singh & Singh 1992; Sun *et al.* 1996). However, few reports are available on phenological studies in forest ecosystems of Central Himalaya (Ralhan *et al.* 1985a,b; Sundriyal 1990) and north eastern India (Boojh & Ramakrishnan 1981; Shukla & Ramakrishnan 1982). The phenological pattern of tree species in the forests of Manipur, north eastern India have been little worked out. Therefore, the present study aims to analyse the phenological pattern in tree species in the sub-tropical forests along disturbance gradient to understand the response of tree species to climatic factors and the periodicity of seasons.

Materials and methods

The study site is a sub-tropical mixed forests located in the hills of Kangchup in Senapati district of Manipur, India (24o45′ to 24o51′ N latitude and 93o48′ to 93o55′ E longitude). The elevation above mean sea level ranges between 865 m to 1785 m. The climate of the area is monsoonic and divisible into three seasons: summer (March to May), rainy (June to October) and winter (November to February). The climatic description is based on temperature and rainfall data during 1985-1995 by the Meteorological Department of Airport, Imphal. The annual rainfall averages 1511.5 mm and about 81.7% of the rainfall occurs in the wet period from April to October. During the study period (January 1993 to December 1994) the rainfall was 1390.35 mm, the mean maximum temperature varied from 22.3oC (January) to 30.1oC (September) and mean minimum temperature from 4.9oC (January) to 22.9oC (August) (Fig. 1). The soil of all the forest sites is blackish brown in colour and clay loam texture. The soil is alluvial and acidic in nature.

Tree vegetation

The vegetation is dominated by *Lithocarpus fenestrata, Castanopsis tribuloides* and *Lithocarpus dealbata.* These forests have been categorised as 8B/C1 Eastern Himalayan sub-tropical wet hill forests (Champion & Seth 1968).

Phenological observations were made on 32 tree species from five forest sites along a biotic disturbance gradient determined on the basis of protection afforded to each forest site which is reflected through the tree density of forest sites. Out of these 19 were overstorey and 13 were understorey tree species. Five individuals of each of the 32 tree species were marked and tagged. Detailed observations were carried out at monthly intervals over a period of two years from January 1993 to December 1994. For each tagged tree records were made of leaf drop, leaf flushing, flowering and fruiting. The phenological activity for each forest tree was evaluated as the sum of species with different phenological stages every month. The duration of activity and phenological behaviour of tree species were determined following the method given by Opler *et al.* (1980).

The phytosociological characters such as density, basal cover and importance value index (IVI) of individual species were quantified for different forest sites using standard quantitative techniques (Curtis & McIntosh 1950; Mueller-Dombois & Ellenberg 1974) (Table 1). In protected, least dis-

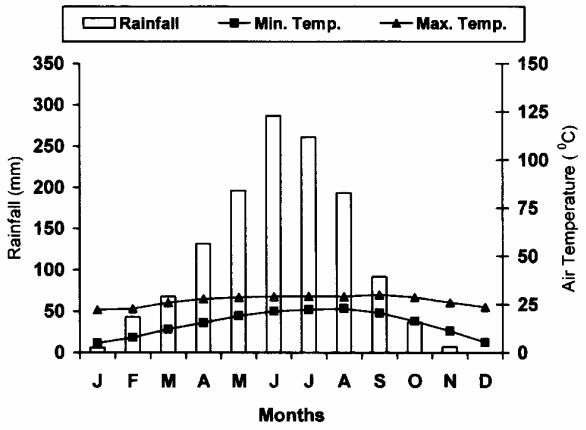

Fig. 1. Ombrothermic diagram for the study period (1993-1994).

Table 1. Certain phytosociological values of important tree species in over and understories. Only the species with IVI over 10 are included (OS = overstorey; US = understorey).

Forest type with dominant species	Storey	Density (100 m^{-2})	Basal cover (cm^2 100 m^{-2})	IVI
Protected				
Lithocarpus fenestrata (Roxb.) Rehder	OS	7.70	866	63
Lithocarpus dealbata (Miq.) Rehder	OS	6.45	795	56
Schima wallichii Choisy	OS	4.55	545	42
Quercus serrata Thunb.	OS	2.15	370	26
Machilus bombycina King. ex Hook f.	OS	1.00	202	15
Rhus succedanea Linn.	US	1.20	259	18
Wendlendia grandis Cowan	US	0.75	108	11
Litsaea citrata Blume	OS	0.60	125	10
Least disturbed				
Lithocarpus fenestrata	OS	4.80	834	58
Lithocarpus dealbata	OS	4.55	733	54
Quercus serrata	OS	4.10	749	51
Schima wallichii	OS	3.15	513	41
Callicarpa psilocalyx Clarke	OS	0.90	188	13
Emblica officinalis Gaertner	US	0.55	79	11
Litsaea polyantha Juss.	US	0.50	36	10
Mildly disturbed at lower elevation				
Lithocarpus fenestrata	OS	5.30	929	73
Schima wallichii	OS	2.90	817	55
Lithocarpus dealbata	OS	3.60	323	44
Wendlandia grandis	US	1.75	295	31
Quercus serrata	OS	1.20	254	18
Rhus succedanea	US	0.55	182	15
Machilus bombycina	OS	0.55	110	12
Litsaea thomsonii Meissn.	US	0.50	140	10
Mildly disturbed at higher elevation				
Castanopsis tribuloides A.DC.	OS	3.40	906	58
Engelhardtia spicata Blume	OS	3.00	729	50
Alnus nepalensis D. Don.	OS	1.40	672	36
Litsaea thomsonii	US	1.25	184	24
Schima wallichii	OS	0.95	359	22
Machilus bombycina	OS	0.90	143	18
Drimycarpus racemosus Hook.f.	US	1.10	125	15
Elaeocarpus serratus Blume	OS	0.70	93	13
Highly disturbed				
Castanopsis tribuloides	OS	3.60	1388	69
Engelhardtia spicata	OS	2.55	1051	54
Albizia chinensis (Osb.) Merr.	OS	1.05	617	27
Machilus bombycina	OS	1.30	320	19
Schima wallichii	OS	0.45	283	14
Litsaea thomsonii	US	0.90	66	12
Wendlandia grandis	US	0.45	119	11

turbed and mildly disturbed sites at lower elevation *L. fenestrata* was dominant and exhibited maximum density, basal cover and IVI and followed by *L. dealbata. Schima wallichii* was found to be dominant in mildly disturbed sites at lower elevation. In mildly disturbed sites at higher elevation *C. tribuloides* was dominant. *Engelhardtia spicata* was dominant in highly disturbed sites.

All tree species were divided into two categories: (a) overstorey species consists of canopy and sub-canopy trees with a height of >10 m and (b) understorey species with <10 m tall. Evergreen species continually produce at least small amount of new leaves throughout the year and do not show heavy leaf fall at any time whereas deciduous species has a marked leaf drop and leaf flushing of the year.

Duration of activity

Brief and extended activity indicate the periodicity of leaf flushing, flowering and fruiting activity by individuals of a species population. Brief activity extends for 2 weeks or less while extended activity refers to periods more than 2 weeks. A more or less continuous flowering and fruiting activity throughout the year is referred to as continuous activity.

Pattern of activity

The term "seasonal" and "extended" activity refers to flowering/fruiting occurs during a given period and extending into more than one period respectively. "Marginal" activity refers to species that have their activity occurring during transition period of seasonal changes. When some individuals of a tree species are in flowering/fruiting simultaneously is referred to as "synchronous" activity (S). The species population showing flower/fruit development during a distinct period is known as "asynchronous" (A).

Fruit maturation activity

There are two categories of fruiting activity i.e. rapid and lengthy. "Rapid" (r) can be character-

Table 2. Phenological patterns of overstorey tree species.

Name of species	Behavioural patterns			
	Leaf drop	Leaf flushing	Flowering	Fruiting
Albizia chinensis	PD	PeM	PeA	PeL
Alnus nepalensis	CE	CS	PeA	Per
Betula alnoides	PD	PeM	PeA	Pbr
Callicarpa psilocalyx	PD	PeM	PeA	Pbr
Castanopsis tribuloides	PE	PeM	PeA	PeL
Celtis australis	PD	PeM	PeA	Per
Elaeocarpus serratus	PE	PeM	PeA	PeL
Engelhardtia spicata	PD	PeM	PeA	Pbr
Glochidion assamicum	PD	PeM	PeA	PeL
Litsaea citrata	PD	PeM	PeA	PeL
Macaranga denticulata	PE	PeM	PeA	Pbr
Machilus bombycina	PE	PeM	PeA	PeL
Myrica esculenta	PE	PeM	PeA	PeL
Lithocarpus dealbata	PE	PeM	PeA	Per
Lithocarpus fenestrata	PE	PeM	PeA	Per
Quercus griffithii	PD	PeM	PeA	PeL
Quercus serrata	PD	PeM	PeA	PeL
Quercus spicata	PE	PeM	PeA	PeL
Schima wallichii	PE	PeM	PeA	PeL

*P = Periodic, C = Continuous, b = Brief periods ≤2 weeks per episode, e = Extended periods ≥2 weeks per episode, M = Multiple events per year, S = Synchronous, A = Asynchronous, D = Deciduous, E = Evergreen, r = Rapid fruit maturation ≥ 4 months, L = Lengthy fruit maturation > 4 months.

ised as fruit maturation periods of 4 months or less following fertilization and those more than 4 months are termed as "lengthy" (L).

Results and discussion

A total of 32 trees species were selected for this study out of which 20 were evergreen (10 species each of over and understorey) and 12 were deciduous species (9 over and 3 understorey). The forest maintains its green appearance throughout the year as majority of the species are evergreen in this forest. However, in the drier and cool months of November to February evergreen aspect of the forest is not so conspicuous due to marked leaf fall.

The general phenological stages of all species have been presented on the basis of number of species (Tables 2 & 3). The seasonal phenological behaviours in some important tree species have been discussed under leaf drop, leaf flushing, flowering and fruiting activities.

Leaf drop

Majority of the species start leaf shedding in cool and dry winter months i.e. from November and extending upto April being low in other months. The peak of leaf fall was recorded in January-February in both overstorey and understorey species (Fig. 2a). Among the overstorey species *Betula alnoides* exhibited maximum leaf fall during August-September whereas *Callicarpa psilocalyx* and *Litsaea citrata* shed their leaves from September and continued upto February. However, in *Quercus griffithii* leaf drop initiated in November and the trees remained leafless during January to March. The understorey species shed their leaves during November-March excepting in *Schoepfia fragrans* which showed maximum leaf fall in August-September. Asynchronous behaviour in leaf fall among individuals of most of the species were observed (Tables 2 & 3). This difference in leaf fall may be due to microenvironmental factors as also has been reported by Boojh & Ramakrishnan (1981) for sub-tropical forest of Meghalaya and Sundriyal (1990) for temperate forest of Garhwal Himalaya in both over and understorey tree species. Thus the replacement strategy during March-April appears to minimize water loss by leaf fall during dry periods and maximize photosynthetic activity during the wet warm season of the year. The rate of leaf fall during the dry season was strongly correlated with the decline in soil moisture and increasing water stress of the tree (Reich & Borchert 1982). Reich (1995) suggested that the timing of leaf fall and bud break were generally determined by tree water status, which in turn was a function of the in-

Table 3. Phenological patterns of understorey tree species.

Name of species	Behavioural patterns			
	Leaf drop	Leaf flushing	Flowering	Fruiting
Cinnamomum zeylanicum	PE	PeM	PeA	PbL
Drimycarpus racemosus	PE	PeM	PeA	PeL
Emblica officinalis	PD	PeM	PeA	PeL
Eurya japonica	CE	CS	CS	CL
Bauhinia purpurea	PD	PeM	PeA	PeL
Lindera pulcherrima	PE	PeM	PbA	PbL
Litsaea polyantha	PE	PeM	PbA	Pbr
Litsaea thomsonii	PE	PeM	PbA	PeL
Rhus semialata	PD	PeM	PeA	PeL
Rhus succedanea	PD	PeM	PeA	PeL
Saurauja pundauana	CE	CS	CS	CL
Shoepfia fragrans	PE	PeM	PeA	Pbr
Wendlandia grandis	PE	PeM	PeA	PbL

*P = Periodic, C = Continuous, b = Brief periods ≤ weeks per episode, e = Extended periods >2 weeks per episode, M = Multiple events per year, S = Synchronous, A = Asynchronous, D = Deciduous, E = Evergreen, r = Rapid fruit maturation ≤4 months, L = Lengthy fruit maturation > 4 months.

teraction between the water status of the environment and the structural and functional state of the tree.

Leaf flushing

The first peak period of leaf flushing was observed in the beginning of warm dry season (March-April) whereas the second peak occurred during the mid wet season (August-September) in both overstorey and understorey species (Fig. 2b). The species are divided into four distinct categories according to their flushing behaviour i.e. single, double, multiple (M) and continuous determinate (C) flushing. The overstorey species such as *B. alnoides, C. tribuloides, Lithocarpus* and *Quercus* species produced double determinate leaf flushes. The understorey trees *viz. Emblica officinalis, Lindera pulcherrima* and *S. fragrans* etc. exhibited more number of species with a single determinate leaf flush. A few evergreen species e.g. *Alnus nepalensis, Eurya japonica* and *Saurauja punduana* showed continuous leaf fall and continuous flushing. At the community level, certain species have evolved completely different approaches to leaf flushing and leaf fall which may be due to intrinsic factors (Boojh & Ramakrishnan 1981). This explains strong seasonal periodic leaf flushing observed in this study.

In the present investigation large number of overstorey and understorey species exhibited maximum leaf production in the warmer months of the year before rains. Flushing and leaf production towards the end of dry season and just before the rains has also reported by several worker (Frankie *et al.* 1974; Shukla & Ramakrishnan 1982; Sundriyal 1990). This may be attributed to the triggering effect of the rising temperature. The phenology of sub-tropical forest in the present study differs from the phenology of tropical deciduous tree species as leaf flushing initiated towards the end of winter season and beginning of warm season whereas it occurred only after the first rains of the wet season in later forests. The results are in conformity to those reported by Bullock & Solis-Magallenus (1990).

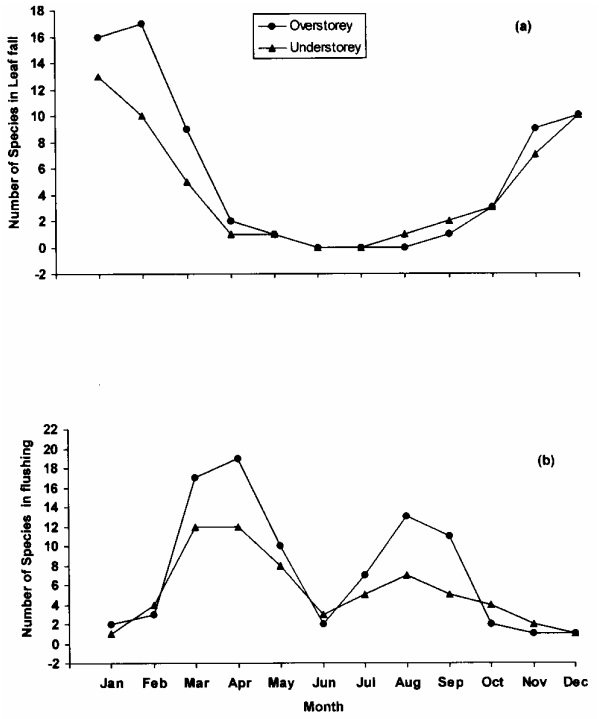

Fig. 2. Phenological periodicity of overstorey and understorey tree species (a) Number of species in leaf fall (b) Number of species in flushing.

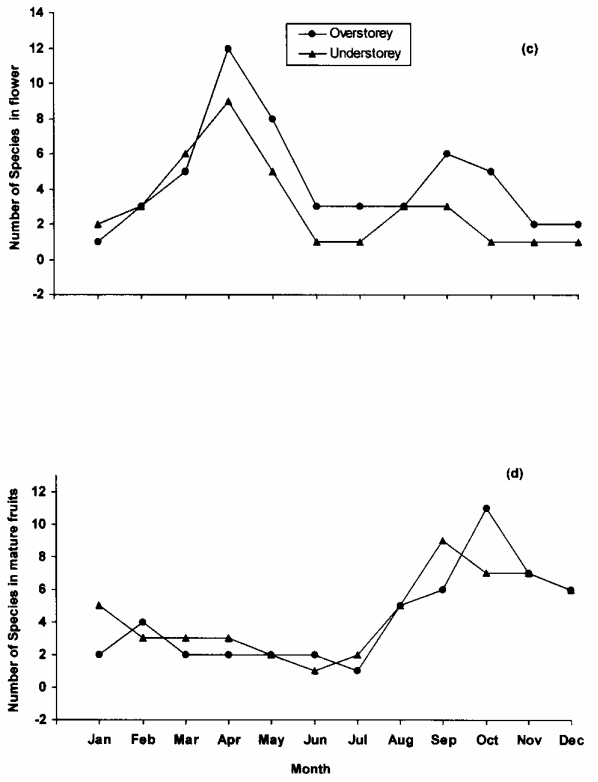

Fig. 2. Phenological periodicity of overstorey and understorey tree species (c) Number of species in flower (d) Number of species in mature fruits.

Flowering activity

The seasonal pattern of flowering in the present forest has two peaks, a major peak was recorded in April (beginning of the warm and dry season) and a minor one in September for both overstorey and understorey species (Fig. 2c). Most of the species flowered before rainy season and a few species flowered during the wet period. Certain species such as *A. nepalensis, C. tribuloides* and *S. wallichii* showed extended of flowering upto 16 weeks among the overstorey species while *Wendlandia grandis, E. japonica* and *S. punduana* showed extended flowering activity upto 20, 28 and 48 weeks respectively in understorey species. A majority of the discontinuous flowering individuals had extended flowering activity. Asynchrony type of flowering was quite pronounced for both the category of species (Tables 2 & 3).

However, in the evergreen species flowering is mostly after leaf flushing but deciduous species exhibited four basic pattern of flowering in relation to leaf flushing : (i) flowering before leaf flushing e.g. *Bauhinia purpurea, E. spicata* and *L. citrata* (ii) flowering and leaf flushing simultaneously e.g. *E. officinalis* and *Rhus succedanea* (iii) flowering soon after the flushing showed majority of the species e.g. *Albizia chinensis, C. psilocalyx, Celtis australis, Glochidion assamicum* and *Q. serrata* (iv) flowering later after the leaf flushing is shown in *Betula alnoides, Q. griffithii* and *R. semialata.*

The synchronization of flowering with leaf flushing seems to be related to moisture, temperature and photoperiod as found in similar other studies (Boojh & Ramakrishnan 1981; Murali & Sukumar 1994). Thus cool and dry winter period is responsible for maximum leaf drop whereas increase in temperature during warm and dry periods induces the leaf flushing and flowering in most of the species.

Fruiting activity

In the present study, the overstorey species attained a major peak in October and a minor one in February whereas the understorey species showed a first peak in September and second peak in January (Fig. 2d). The peak period of mature fruits in the present forest species corresponds with the onset of dry and cool season after October. The fruit development period for different species varied from 4 to 20 weeks. Similar pattern of fruit development was observed for both stories. A majority of species showed discontinuous and extended fruiting activity. Besides a larger proportion of the species recorded lengthy fruit development behaviour but few species had brief period of time in both storeys (Tables 2 & 3). Ripening of fruits initiates in the later part of rainy season and continued upto end of cool and dry winter period. The peak for retention of mature fruits occurred after about five months of flowering. This was due to the difference in time taken for fruit maturation.

13 out of 19 overstorey species showed extended activity and lengthy fruit maturation with the exception of four species *viz., A. nepalensis* and *C. australis, L. dealbata* and *L. fenestrata* which had extended fruit retention but rapid maturation while *B. alnoides. C. psilocalyx, E. spicata* and *Macaranga denticulata* Muell having brief activity and rapid fruit maturation. Out of 13 understorey species, 6 species had extended and lengthy fruit maturation and two species namely *L. polyantha* and *S. fragrans* had brief and rapid maturation, 3 species exhibited brief activity with lengthy maturation i.e. *Cinnamomum zeylanicum, L. pulcherrima* and *W. grandis*. However, *E. japonica* and *S. punduana* showed continuous fruiting activity.

Therefore most of the species have seeds with winter dormancy which is broken only after the warm rainy season. Similar observation have also been reported for tropical forests (Bullock & Solis Margallenus 1990; Frankie *et al.* 1974) and subtropical evergreen forest of Himalaya (Boojh & Ramakrishnan 1981; Ralhan *et al.* 1985a).

Conclusion

The results of this study suggest that there is a strong seasonality in phenological pattern of tree species in the sub-tropical forest ecosystems. Leaf flushing and flowering are simultaneous in most of the species exhibiting major peak in March-April and minor during August-September, whereas fruiting occurs in cool and dry winter. The phenological timing of most of the species seems to be set during the transition of winter and spring seasons so that summer rainfall facilitates recruitment of plants through germination. Seasonal variations in environmental factors and the dissemination of the propagules by birds and animals have a vital role to regulate the phenological pattern of tree species in the sub-tropical forest ecosystems. The spatial and temporal variations

in the phenology of the tree species maintain a highly dynamic and productive forest ecosystem.

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