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Reproductive phenology of a tropical dry forest in Mudumalai, southern India

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Summary

1 Flowering and fruiting phenologies of a tropical dry forest in Mudumalai, southern India, were studied between April 1988 and August 1990. Two sites, a wetter site I receiving 1100 mm and a drier site II receiving 600 mm of rainfall annually, are compared. A total of 286 trees from 38 species at site I and 167 trees from 27 species at site II was marked for phenological observations. There were 11 species common to the two sites. Several hypotheses relating to the evolution of reproductive phenology are tested.

2 Frequency of species flowering attained a peak at site I during the dry season but at site II, where soil moisture may be limiting during the dry months, the peak was during the wet season. At both sites a majority of species flushed leaves and flowered simultaneously. Among various guilds, the bird-pollinated guild showed distinct dry season flowering, which may be related to better advertisement of large flowers to pollinators during the leafless dry phase. The wind-pollinated guild flowered mainly during the wet season, when wind speeds are highest and favourable for pollen transport. The insect-pollinated guild showed no seasonality in flowering in site I but a wet season flowering in site II.

3 Fruiting frequency attained a peak in site I during the late wet season extending into the early dry season; a time-lag correlation showed that fruiting followed rainfall with a lag of about two months. Site II showed a similar fruiting pattern but this was not statistically significant. The dispersal guilds (animal, wind, and explosive passively-dispersed) did not show any clear seasonality in fruiting, except for the animal-dispersed guild which showed wet season fruiting in site I.

4 Hurlbert's overlap index was also calculated in order to look at synchrony in flowering and fruiting irrespective of climatic (dry and wet month) seasonality. In general, overlap in flowering and fruiting guilds was high because of seasonal aggregation. Among the exceptions, at site II the wind-pollinated flowering guild did not show significant overlap between species although flowering aggregated in the wet season. This could be due to the need to avoid heterospecific pollen transfer.

5 Rarer species tended to flower earlier in the dry season and this again could be an adaptation to avoid the risk of heterospecific pollen transfer or competition for pollinators. The more abundant species flowered mainly during the wet season. Species which flower earlier have larger flowers and, having invested more energy in flowers, also have shorter flower to fruit durations.

Keywords: flowering phenology, fruiting phenology, pollination and dispersal guilds, community organization, Mudumalai sanctuary, southern India.

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Introduction

There are several explanations for the evolution of the timing of life cycle events in trees. Resource allocation to different physiologically active sites which are competing for resources may be optimized (Alvim 1964); thus selection may act for flowering to occur when resource availability is not a constraint. Plants also compete for resources, such as pollinators or dispersers, and hence may have evolved staggered flowering and fruiting phenologies (Levin & And-

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erson 1970; Mosquin 1971; Stiles 1977; Waser 1979). However, others have argued that phenologies may simply be random (Poole & Rathcke 1979; Stiles 1979; Cole 1981).

Biotic factors are more likely to play a major role in moulding phenological events in tropical as compared to temperate environments, especially in the aseasonal tropics such as equatorial rain forests. It is not clear, however, if this also holds good for tropical dry forests with distinct wet and dry seasons.

This study on flowering and fruiting phenology of a tropical seasonal dry deciduous forest in southern India was conducted with the following objectives:

1 To compare the flowering and fruiting phenology of tree communities at two sites, one wetter than the other, and relate these to abiotic and biotic factors.

2 To understand any differences in phenology that might exist among species belonging to different pollination and dispersal guilds.

Methods

STUDY SITES

The study was conducted in the Mudumalai Wildlife Sanctuary (321 km^2), Tamilnadu State, southern India (11°32′–11°43′N, 76°22′–76°43′E). Elevation generally varies from 800 to 1300 m above a.s.l. and the average annual rainfall from about 600 mm in the north-east to 1800 mm in the south-west. The vegetation similarly varies from tropical dry thorn forest in the north and east, through tropical dry deciduous forest, to tropical moist deciduous forest in the south and the west. More details of floristics and vegetation are available elsewhere (Sharma *et al.* 1978; Sukumar *et al.* 1992). The area is prone to man-made dry season fires which are usually confined to the undergrowth.

Two study sites in the dry forest, one distinctly wetter than the other, were selected; they are described by Murali and Sukumar (1993). Site I, to the north-west of Kargudi, has an annual rainfall of 1100 mm, and is a tropical dry deciduous forest dominated by *Tectona grandis*, *Anogeissus latifolia*, *Lagerstroemia microcarpa* and *Terminalia crenulata* trees (our nomenclature follows Gamble (1935) as modified by Saldanha & Nicholson (1976) where appropriate). Site II, a drier site about 10 km to the east of the first site, receives about 600 mm rainfall, and is a tropical dry thorn forest with the most common trees being *Ziziphus mauritiana*, *Anogeissus latifolia*, *Acacia chundra*, *Erythroxylon monogynum* and *Premna tomentosa*.

SAMPLING PROCEDURE

A total of 286 trees from 38 species in site I and 167 trees from 27 species in site II (all d.b.h. > 10 cm) was tagged and vegetative and reproductive phenologies recorded at 15-day intervals from April 1988 to August 1990. The species selected for the study represent a cross-section of the vegetation and include all the commoner species. However, the sample number per species varied from a minimum of 3 to a maximum of 10 depending on their relative abundances. Appendix 1 lists the species observed, their occurrence in the two study sites and their modes of pollination and dispersal.

In addition to vegetative phenology (Murali & Sukumar 1993), two flowering (bud and open flower) and three fruiting (bud, developing fruit and mature fruit) stages were recorded for all the marked trees. Data were also gathered on open flower sizes (lengths) and mature fruit sizes (dry weight). For classifying the species into different pollination and dispersal modes we tried to make first-hand observations on pollinating and dispersal agents for as many species as possible. Thus, when a species was in flower it was observed for visitation by pollinators such as bees (*Apis dorsata*, *A. cerena*, *A. florea*), butterflies and birds (*Acridotheres tristis*, *Sturnus pagadorum*, *Nectarinia asiatica*, *N. zeylonica*, *Zosterops palpebrosa*, *Psittacula cyanocephala*, *P. krameri*). Similarly, for determining the mode of dispersion, trees in fruit were observed for dispersal activity in birds (such as *Megalaima haemacephala*, *M. viridis*, *Eudynamys scolopacea*, *Psittacula krameri*, *Tockus birostris*), or for seed presence in the faeces of mammals such as elephant (*Elephas maximus*), gaur (*Bos gaurus*), spotted deer (*Axis axis*), sambar (*Cervus unicolor*) and sloth bear (*Melursus ursinus*). Only qualitative observations were possible on the pollinating and dispersal agents.

Where direct observations were not made, the modes of pollination and dispersal were inferred from floral and fruit morphologies. Species which had an attractive corolla or rewards such as nectar were considered insect-pollinated, while those which did not possess any apparent attractants were considered to be wind-pollinated (Rabinowitz *et al.* 1981). Species with fleshy and succulent fruits were considered animal dispersed even if we could not detect their seeds in animal droppings. Those with winged seeds or fruits were considered wind-dispersed while those which did not possess any of these characters were classified as explosively- or passively-dispersed (this was also obvious for several species from direct observations). Appendix I gives details of species for which modes of pollination and dispersal were determined through direct observation or indirectly from floral or fruit morphologies.

Rainfall data were collected at fortnightly intervals from rain gauges maintained by Tamilnadu Electricity Board near the study sites. Data on wind speed were obtained from the weather station maintained by the Centre for Ecological Sciences at Kargudi.

STATISTICAL ANALYSES

Frequencies of flowering or fruiting species during each month were plotted and Spearman's rank correlation coefficients (r_s) between rainfall and the frequency of flowering or fruiting were calculated. In addition, the proportion of individuals (p_f) in the community in flower during a given month was also computed as follows and regressed with rainfall:

$$p_f = \Sigma p_i p_s$$

where p_i is the proportion of individuals of the *i*th species in the community, and p_s is the proportion of individuals of the *i*th species in flower.

Correlation coefficients were computed between rainfall and the number of species in each dispersal or pollination guild which were flowering or fruiting to determine the relation between season and phenology. Pairwise Pearson's product moment correlation coefficients (r) between flowering date, fruiting date, flower-fruit duration, flower size, fruit size and species abundances were computed.

In order to know the extent to which flowering and fruiting phenologies of species within a guild overlap, Hurlbert's general overlap measure (Hurlbert 1978) as given by Ludwig & Reynolds (1988) was computed. General overlap index (HO) is given by:

$$\mathrm{HO} = p_{1j} p_{2j} / c_j$$

where p_{1j} is the proportion of species 1 flowering at the *j*th time, p_{2j} is the proportion of species 2 flowering at the *j*th time and c_j is the proportion of individuals flowering at the *j*th time of the total. Computed Hurlbert's overlap values were compared with a χ^2 table at appropriate degrees of freedom as suggested by Ludwig & Reynolds (1988) to test for statistical significance of aggregation or randomness in phenologies.

Results

GENERAL FLOWERING PHENOLOGY

Most species flowered during the late dry and early wet seasons. There were four basic patterns of flowering in relation to leaf flushing phenology.

1 Flowering before leaf flushing: shown by the three bird pollinated species *Bombax ceiba*, *Erythrina indica* and *Butea monosperma*, and also by *Radermachera xylocarpa*

2 Flowering and flushing leaf simultaneously: the majority of the species, including *Emblica officinalis*, *Schleichera oleosa*, *Stereospermum colias* and *Lagerstroemia parviflora*.

3 Flowering soon after leaf flushing: e.g. *Cassia fistula*, *Tectona grandis*, *Lagerstroemia microcarpa*, *Eriolaena quinquelocularis* and *Cordia obliqua*.

4 Flowering later than leaf flushing: e. g., *Anogeissus latifolia*, *Cassine glauca* and *Kydia calycina*.

Thirty-one species out of 38 in site I and 20 species out of 27 in site II flushed leaf and flowered simultaneously at least for a short period. A χ^2 analysis shows that leaf flushing and flowering times are not random, i.e. flowering and leaf flushing for species in the community occurs simultaneously at a much higher frequency than expected by chance ($\chi^2_1 = 15.15$, $P < 0.005$ for site I and $\chi^2_1 = 6.26$, $P < 0.025$ for site II).

In site I the peak in species flowering is attained before the peak in rainfall; this pattern was more striking during 1989 (peak flowering in March and peak rainfall in July) than during other years (Fig. 1a). Time-lag correlations of flowering and rainfall showed the highest correlation for a 2-month lag period (flowering preceding rainfall; $r_s = 0.68$, $n = 26$, $P < 0.01$). In site II, however, the frequency of flowering (Fig. 1b) was positively correlated with rainfall during the corresponding month ($r_s = 0.66$, $n = 28$, $P < 0.01$).

There is a positive relationship between the proportion of individuals in the community (irrespective of species) in flower and rainfall ($y = 0.61x + 0.06$, $r = 0.55$, $P < 0.01$ for site I; $y = 0.34x + 0.03$, $r = 0.43$, $P < 0.05$ for site II: Fig. 2). This pattern may arise due to the fact that the more abundant species generally tend to flower during the wet season.

FLOWERING PHENOLOGY BASED ON POLLINATION GUILDS

There were seasonal differences among species of different pollination guilds at both sites (Fig. 3). Bird-pollinated species ($n = 3$) showed peak flowering during the dry months of January–March; the correlation coefficient of flowering with rainfall was negative and

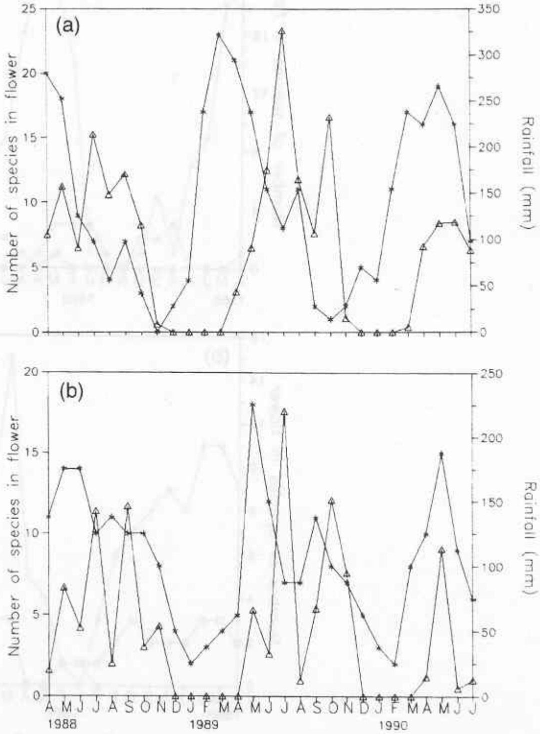

Fig. 1 Number of species in flower (*) and monthly rainfall (△) in (a) study site I and (b) study site II.

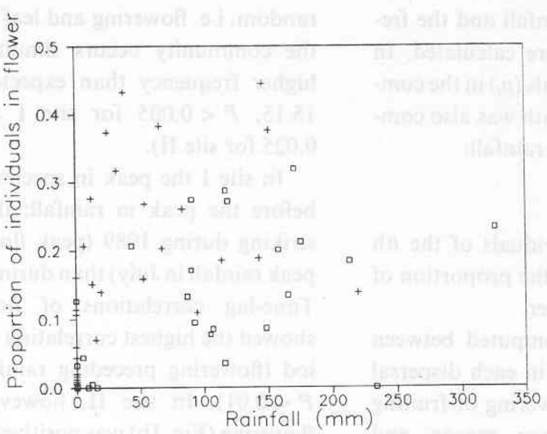

Fig. 2 Proportion of individuals in the community in flower and monthly rainfall in study site I (□) and study site II (+).

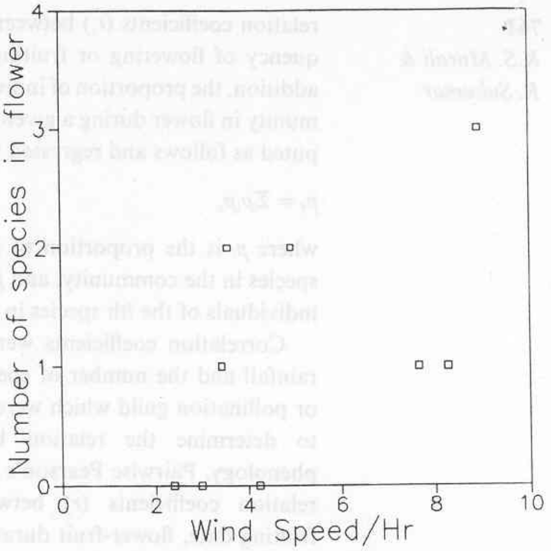

Fig. 4 Relationship between wind speed (in km h^{-1}) and the number of wind-pollinated species in flower.

significant (site I: $r_s = -0.48$, $n = 28$, $P < 0.05$; at site II only one species was sampled). In contrast, wind-pollinated species flowered mainly during the wet months (site I, 4 species; $r_s = 0.51$, $n = 28$, $P < 0.05$; site II, 5 species; $r_s = 0.78$, $n = 28$, $P < 0.01$). This is significantly correlated ($r_s = 0.62$, $n = 9$, $P < 0.05$; Fig. 4) with mean monthly wind speeds (between December 1989 and August 1990, Fig. 4). Insect-pollinated species in site I (31 species) showed the highest correlation with seasonality for a two-month lag period between flowering and rainfall (flowering preceding rainfall, $r_s = 0.66$, $n = 26$, $P < 0.001$), while in site II (21 species) they showed a distinct tendency to flower during the wet season ($r_s = 0.57$, $n = 28$, $P < 0.01$).

GENERAL FRUITING PHENOLOGIES

In site I there was some fruiting activity throughout the year, with a minimum of five species bearing mature fruit in any given month. The frequency of fruiting, however, reached a peak (Fig. 5a) during the

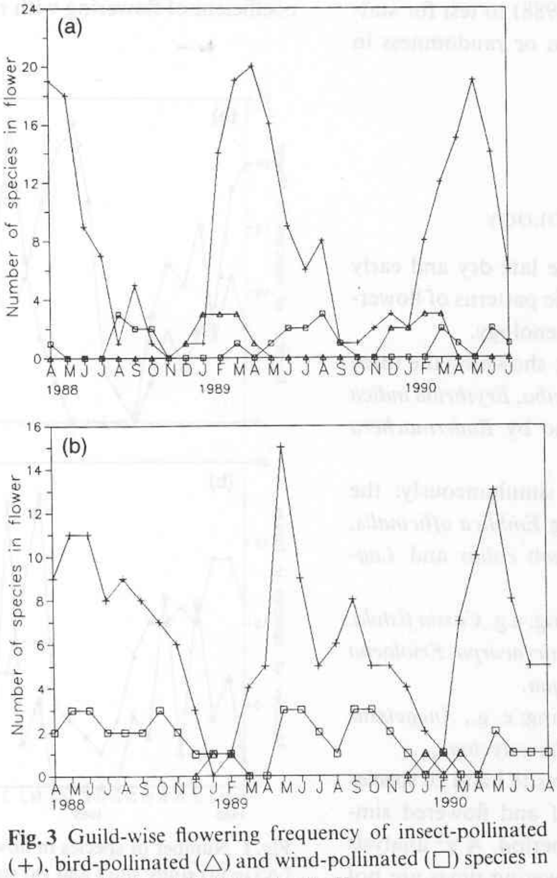

Fig. 3 Guild-wise flowering frequency of insect-pollinated (+), bird-pollinated (△) and wind-pollinated (□) species in (a) study site I and △ (b) study site II.

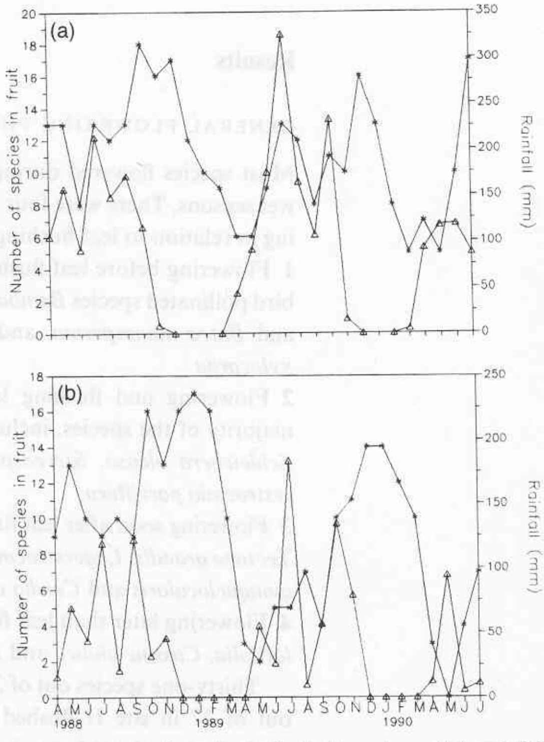

Fig. 5 Number of species in fruit (*) and monthly rainfall (△) in (a) study site I and (b) study site II.

late wet season extending into the early dry season. This is supported by time-lag correlations, which showed the highest correlation ($r_s = 0.63$, $n = 28$, $P < 0.01$) for a two month lag between rainfall and fruiting. In site II, although a peak in fruiting was observed during January and February, there was no statistically significant correlation between rainfall and frequency of species fruiting (Fig. 5b) ($r_s = 0.28$, $n = 28$, $P > 0.05$).

FRUITING PATTERN OF DISPERSAL GUILDS

Dispersal guilds showed no clear seasonality in fruiting (Fig. 6), except that in site I the animal-dispersed species ($n = 15$) tended to fruit during the wet seasons as indicated by the correlation between fruiting frequency and rainfall ($r_s = 0.63$, $n = 28$, $P < 0.01$). Species whose fruits are dispersed by wind ($n = 14$) or passively or by explosion ($n = 8$) did not show any seasonality in fruiting either during dry or wet months. In site II, none of the fruit-dispersal guilds showed any seasonality in fruiting.

PHENOLOGICAL OVERLAP MEASURES

As opposed to looking at presence or absence of seasonality in flowering and fruiting phenology with respect to rainfall (i.e. wet or dry months), the general overlap index provides a measure of the degree of synchrony in phenology within a guild, irrespective of whether or not this is related to rainfall.

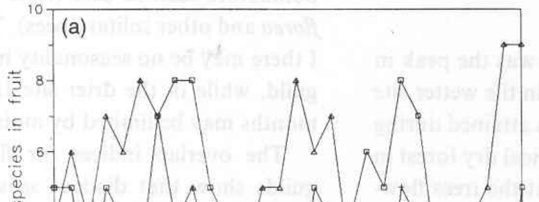

Fig. 6 Guildwise fruiting frequency of animal-dispersed (□), wind dispersed (+) and explosive- or passive-dispersed (△) species in (a) study site I and (b) study site II.

Table 1 General overlap indices in different flowering and fruiting guilds at the two study sites

Pollination/Dispersal Mode	Overlap index	N	d.f.	χ^2
Site I				
Flowering				
Bird	0.95	3	22	1.47
Insect	0.44	30	319	528.38**
Wind	0.53	4	33	38.36
Fruiting				
Animal	0.67	15	143	114.50
Explosive	0.46	8	88	146.31
Wind	0.47	14	143	178.00**
Site II				
Flowering				
Insect	0.56	20	209	271.25
Wind	0.50	5	44	83.87**
Fruiting				
Animal	0.61	14	143	208.44**
Explosive/Passive	0.45	8	77	126.91**
Wind	0.52	5	44	48.71

**indicates that flowering or fruiting periods within the guild do not overlap significantly (at 1% level).

Table 1 gives the overlap indices for both flowering and fruiting guilds. With three exceptions, the guilds show a direct correspondence between seasonality and overlap in phenology. That is, species within a guild which show distinct seasonality in flowering or fruiting also show significant overlap in these phenologies. The exceptions are the wind-pollinated flowering guild in site II which does not show significant overlap (but generally flowers in the wet season), the explosive-dispersed fruiting guild in site I and wind-dispersed fruiting guild in site II which show significant overlap (but no seasonality in fruiting).

CORRELATION BETWEEN FLOWER AND FRUIT CHARACTERS

Table 2 gives the pairwise correlation values for flower and fruit characters. Here only relevant correlations will be highlighted; obvious correlations such as between flowering date and fruiting date are not considered. There were negative correlations between flower size and both flowering and fruiting dates, and a positive correlation between fruiting date and time to fruit maturity. These correlations indicate that early flowerers have larger flowers and species which fruit later have longer time to fruit maturity. The correlation between species abundance and fruiting and flowering dates were significant and positive ($r_{36} = 0.43$, for flowering date and $r_{36} = 0.44$ for fruiting date, $P < 0.01$) indicating that the more abundant species flower and fruit later in the season than do rarer species.

Table 2 Pairwise Pearson's correlation coefficients between flower and fruit characters at site I (d.f. = 36)

	Fruiting date	Flower-fruit	Flower size	Fruit size	Species density
Flowering date	0.670**	0.736**	0.339*	−0.189	0.429
Fruiting date		0.654**	−0.489*	−0.031	0.435**
Flower–fruit duration			−0.420*	−0.107	0.253
Flower size				0.370**	−0.193
Fruit size					−0.097

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

There was no association between pollination and dispersal modes. A χ^2 analysis shows that the frequency of species which are animal pollinated and animal dispersed are not different from the frequency of species which are animal pollinated and wind or explosive dispersed ($\chi^2{}_1 = 0.13$, $P > 0.05$).

Discussion

In seasonal tropical forests there can be pronounced aggregation in phenological events (Janzen 1967; Frankie *et al.* 1974; Opler *et al.* 1980; Prasad & Hegde 1986; Bullock & Solis-Megallenus 1990). In the tropical dry deciduous forests of Mudumalai too there was evidence for seasonality in flowering and fruiting phenologies. The two study sites, in drier and wetter locations, showed some important differences in this respect.

FLOWERING PHENOLOGY

A major difference between the sites was the peak in flowering during the late dry season in the wetter site I, while in the drier site II this peak is attained during the wet season. In a seasonal neotropical dry forest in Costa Rica, Janzen (1967) found that the trees flowered during the dry season. He attributed this to the necessity for avoiding competition for physiologically active sites within the individual and to the availability of pollinators. This is similar to the peak in dry season flowering seen in site I. It may not, however, always be true that trees have to avoid competition for physiologically active sites, because both leaf flushing and flowering occurred simultaneously in a majority of species. In site I the trees may be able to maintain the physiological activity necessary for flowering through stored water and food resources, and also with the help of deep tap roots. On the other hand, Opler *et al.* (1980) found that treelets and shrubs in a dry forest in Costa Rica, flowered mainly during the wet season. They explained this as due to moisture stress in shallow-rooted plants and we can draw a parallel with the flowering pattern in site II. Here, the moisture stress during the dry season is probably sufficiently high to inhibit flower initiation. Trees at this site are relatively stunted, probably with shallower roots, and hence may undergo a period of protective dormancy during the dry months.

The more interesting patterns in the timing of flowering relate to differences among pollination guilds. The bird-pollinated guild flowered only during the dry season, although birds such as common myna (*Acridothera tristis*), brahmini myna (*Sturnus pagadorum*), purple sunbird (*Nectarinia asiatica*), purple-rumped sunbird (*Nectarinia zeylonica*), white eye (*Zosterops palpebrosa*), blossom-headed parakeet (*Psittacula cyanocephala*) and rose-ringed parakeet (*Psittacula krameri*) are resident species. The species involved, which sport larger and brightly coloured flowers, may be able to advertise their presence to potential bird pollinators much better during the leafless phase in the dry season. These tree species could act as keystone species which provide food for birds when food availability is low during the dry season.

In insect-pollinated plants, the limiting factor may be moisture availability rather than availability of pollinators such as bees (*Apis dorsata*, *A. cerena*, *A. florea* and other solitary bees). Thus, in the wetter site I there may be no seasonality in flowering within this guild, while in the drier site II flowering in the dry months may be limited by moisture.

The overlap indices for flowering and fruiting guilds show that distinct seasonality in these phenologies also correspond to significant overlap among species in phenology. The wind-pollinated flowering guild in site II having wet season flowering, however, shows nonoverlap or staggering among the species flowering within the season. This could be related to avoidance of heterospecific pollen transfer, which is more likely for wind-pollinated species. In site II the insect-pollinated species did show overlap in flowering time during the wet season, but in site I the results are more difficult to interpret. Several factors such as lack of moisture stress, pollinator availability or prevalence of monsoon winds may all contribute to shaping flowering times among species within a guild.

FRUITING PHENOLOGY

As reported for other regions (Frankie *et al.* 1974; Prasad & Hegde 1986) this study also showed no specific seasonality for fruiting. Seasonal patterns were not clear even in guild-wise phenology. Only animal-dispersed species showed seasonal fruiting during the wet months in site I. These are fleshy fruits in which moisture may be necessary for maintaining turgor pressure (Smythe 1970). Site II however, differed by showing no seasonality for animal-dispersed fruits. The exact relationship between the movement of large herbivorous mammals (elephant and gaur) which are also dispersers and seasonality in fruiting in this guild is not clear. In any case, resident mammals (spotted deer, monkeys and sambar) and birds also disperse many of these fruits.

The wind-dispersed fruiting guild in site I and explosive-dispersed fruiting guild in site II show significant overlap but no seasonality because fruiting extends from late wet season into the early dry season in both cases. Wind-dispersed species did not show any correlation with wind-speed. Explosive-dispersed fruits are obviously adapted to dehiscing during the dry months when relative humidity is low. The time of seed germination was not noted in this study; it is therefore difficult to state whether the time of fruit maturity and dispersal are adaptive.

RELATION BETWEEN FLOWERING, FRUITING AND SPECIES ABUNDANCE

The observation that early flowerers bear larger flowers could be due to the bird-pollinated species flowering during early dry season. In addition, species which flower during the early dry period, such as *Cassia fistula*, *Gmelina arborea* and *Eriolaena quinquelocularis*, are insect-pollinated and the flowers may be more conspicuous at this time. Species which flower early would have invested more resources in flowers and hence have shorter flower to fruit duration. This is seen in the bird-pollinated species, in which the fruits mature within two months and are then dispersed by wind or by explosion.

It has been suggested that it may be beneficial for a species to have the same vector for pollination and dispersal (Uma Shaanker *et al.* 1990). Our results, however, indicate that many species had different pollinator and dispersal agents. This suggests that dependence on a single agent for both pollination and seed dispersion may increase constraints for pollen and fruit or seed dispersal.

The rarer species seem to flower earlier in the season as compared to the more abundant species. One reason could be that rarer species might not be able to attract pollinators shared with the abundant species if they were to flower at the same time. The risk of heterospecific pollen transfer would also be far greater for the rarer species and they therefore benefit from staggering their flowering in relation to the flowering time of common species.

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Appendix I List of species studied, occurrence, pollination and dispersal modes

Species	Occurence in study sites	Pollination mode	Dispersal mode
Anacardiaceae			
Semecarpus anacardium L.f.*	I	B	A
Apocynaceae			
Wrightia tinctoria R.Br.	II	B	E
Bignoniaceae			
Stereospermum colias (Dillw) Mabberley	I	B	W
Radermachera xylocarpa (Roxb) K. Schum.	I,II	B	W
Bombacaceae			
Bombax ceiba L.	I	BI	W
Boraginaceae			
Cordia obliqua Willd.	I,II	B	A
Burseraceae			
Garuga pinnata Roxb.*	I	B	A
Combretaceae			
Anogeissus latifolia (DC) Wall Ex Bedd.,*	I,II	W	E
Terminalia bellirica (Gartener) Roxb.	I	B	A
Terminalia crenulata. Roth.	I	B	W
Terminalia chebula Retz.	I,II	B	A
Celastraceae			
Cassine glauca (Rottl) Kuntze.*	I,II	W	E
Mayetinus emarginata (Willd.) Ding Hou *	II	W	E
Ebenaceae			
Diospyros montana Roxb.	II	B	A
Erythroxylaceae			
Erythroxylon monogynum Roxb.	II	B	A
Euphorbiaceae			
Emblica officinalis Gaertner	I,II	B	A
Bridelia retusa (L.) Spreg.	I,II	W	A
Givotia rottleriformis Griff.	II	B	A
Fabaceae			
Acacia chundra (Rottler) Willd.	II	B	E
Acacia ferruginea DC	II	B	E
Acacia leucophloea (Roxb) Willd.*	II	B	E
Albizia amara (Roxb) Boivin.*	II	B	E
Albizia odoratissima (L.f.) Benthem	I	B	E
Bauhinia malabarica Roxb.	I	B	E
Bauhinia racemosa Lam	II	B	E
Butea monosperma (Lam) Taubert.	I,II	BI	W
Cassia fistula L.,	I,II	B	A
Dalbergia lanceolaria L.f.	II	BF	W
Dalbergia latifolia Roxb.,	I	BF	W
Ougenia oojeinensis (Roxb.) Hochr.*	I	B	E
Erythrina variegata L.	I	BI	E
Pterocarpus marsupium. Roxb.	I,II	B	W
Flacourtiaceae			
Casearia esculenta Roxb.*	I	B	A
Lacythidaceae			
Careya arborea Roxb.*	I	B	A
Loganiaceae			
Strychnos potatorum L.f.*	II	W	A
Lythraceae			
Lagerstroemia microcarpa Wight.	I	B	W
Lagerstroemia parviflora Roxb.	I	B	W

Appendix I *continued*

Species	Occurrence in study sites	Pollination mode	Dispersal mode
Malvaceae			
Kydia calycina Roxb.	I	B	W
Myrtaceae			
Syzygium cumini (L) Skeels.	I	B	A
Oleaceae			
Schrebera switenioides Roxb.	I	B	W
Rubiaceae			
*Hymenodictyon orixens**	I	W	W
Mitrogyna parvifolia (Roxb.) Kunth.*	I	B	E
Xeromphis spinosa (Retz) Pior.	I	B	A
Canthium parviflorum Lam	II	B	A
Rhamnaceae			
Ziziphus rugosa Lam.*	I	B	E
Ziziphus xylopyrus (Retz) Willd	I,II	B	A
Ziziphus mauritiana Lam.	II	B	A
Rutaceae			
Naringi crenulata (Roxb.) Nicolson	II	B	A
Sapindaceae			
Schleichera oleosa (Lour) Oken.*	I	B	A
Sterculiaceae			
Eriolaena quinquelocularis (Wight & Arn.) Cleghorn.	I	B	W
Tiliaceae			
Grewia tiliifolia Vahl.	I	B	A
Verbenaceae			
Gmelina arborea Roxb.	I	B	A
Gmelina asiatica Roxb.	II	B	A
Premna tomentosa Willd.*	II	B	A
Tectona grandis L.f.	I	BF	E

*Species for which the modes of pollination and dispersal were determined by flower and fruit morphology.
Pollination modes: B = bee, BI = bird, BF = butterfly, W = wind
Dispersal Modes: A = animal, E = explosive, W = wind
Unripe fruits of *Bauhinia* spp and *Acacia* spp. are also consumed by elephants.