PHENOLOGICAL BEHAVIOUR OF SELECTED TREE SPECIES IN TROPICAL DECIDUOUS FOREST OF HASTINAPUR REGION IN WESTERN U.P.

Narendra Pal Singh*, R.C. Arya, Narendra Pratap Singh and Vinay Pratap Singh

**Department of Botany, Meerut College, Meerut (U.P.)*

Abstract : Vegetative and reproductive phenology of 20 selected tree species in tropical deciduous forest of Hastinapur region in western U.P. was monitored through fortnightly visit during November 2009 to December 2011 revealed that there exists a strong seasonality for leaf flush, leaf fall, flowering and fruiting phenophases. A considerable variation was found in leaf flushing, leaf fall, flowering and fruiting behaviour that could be partly attributed to biotic and abiotic factors. Peak activity of leaf fall and leaf emergence that occurred in the early dry period, could be to take full advantage of the first rainy season for vegetative growth and reproduction. Interphenophases duration between phenological events varied for different selected dominant tree species. The fruiting phenology follows closely the flowering phenology. The duration of maturation of leaves was the shortest, while that of fruit ripening was the longest.

Keywords: Hastinapur, phenology, tree species, tropical deciduous forest, etc.

INTRODUCTION

Phenology is the study of the timing of recurring biological events, among phases of the plant species, which provide a background for collecting and synthesizing detailed quantitative information on rhythms of plant communities. Tropical plants with their high level of species diversity display phenological events such as leaf drop, leaf flush, flowering and fruiting, etc. in relation to time and space. (Singh and Singh, 1992). Phenology patterns are most diverse and least understood. Studies from different parts of world have shown that climatic factors are mainly responsible for vegetative and reproductive phenology at both community and species level. Phenology of the tropical forest tree species is not well understood, although water stress is most frequently cited as a primary factor responsible for the timing of phenological events (Singh and Singh, 1992). However, various phenological events are triggered by rainfall, water availability, temperature, photoperiod, duration of dry spell and change in day length. The composition of tree species, their periodic straightification, and life span are some important analytic aspects of a plant community. Plant phenology has great significance because it not only provides knowledge of plant growth pattern and development as well as the effects of environment and selective pressure on flowering and fruiting behaviour (Zhang *et al*., 2006). Plant phenology are the result of interaction of biotic and abiotic factors over evolutionary time and through natural selection, the biotic and abiotic factors have entrained rhythemicity in plant life that results in appropriate of flowering, fruiting and leaf flushing and efficient growth and reproduction (Van Schaik *et al*.,1993).

The forests of Hastinapur, Meerut district of Uttar Pradesh west are facing various biotic, abiotic and anthropogenic pressures. Considering all the associated problems, it was found necessary to study the forest resources of Hastinapur, which not only protect the environment but also provide the basic needs of community residing in nearby areas, but the recent growing demand of growing population and tourism activities in this area has created various disturbances in the existing forest resulting in loss of phytodiversity and other natural resources thereby affecting the phenology of plants.

Objectives: The study describes the phenological patterns of the dominant tree species in tropical deciduous forest of Hastinapur region. Parameters considered for analysis of phenology are production of young leaves, maturation of leaves, abscission of leaves, production of young flowers, maturation of flowers (Anthesis), abscission of flowers, production of young fruits, maturation of fruits, ripening of fruits.

MATERIAL AND METHOD

Study Area: The study site is located at 36.4 km north east to Meerut (Western Uttar Pradesh). It lies at 29.17 °N, 78.02 °E longitudes. Hastinapur forest region is of dry thorn type. The species forming the scrub vegetation are *Zizyphus xylopyra, Zizyphus mauritiana, Butea monosperma*, *Prosopis juliflora* etc. as far as the structure and function of these forest are concerned. The elevation of Hastinapur is roughly 205 meters above the sea level. The temperature ranges from 35° C to 43° C in summers while remain between 20° C and 30° during winters. There are three different major seasons in Hastinapur, Meerut: summer season (April to mid June), winter season (November to February) and monsoon season (June to September). October-March constitute the transition month, between the monsoon and winter season and between the winters and summer seasons. Annual average rainfall is 145mm. About 85% of the total rainfall is observed during the rainy seasons (south- west monsoon). The soil of the forest contains sand, silt and clay in different proportions. The soils of the forest were alkaline in nature. The vegetation is at its zenith during the monsoon season because of high humidity and moderate temperature. The forest of study site is suffering from various disturbances such as grazing, burning and cutting etc.

Methodology: Three sites were selected for phenological study. All the individual of selected tree species with a girth of 31cm and above were marked with a metal tag. Each site was visited once a fortnight from November, 2009 to December, 2011 to record the change for the 9 phenological events namely production of young leaves (YL), maturation of leaves (ML), abscission of leaves (AL), production of young flowers (YF1), maturation (anthesis) of flowers (MF1), abscission of flowers (AF1), production of young fruits (YFr), maturation of fruits (MFr) and ripening of fruits (RFr).

During the fortnightly visits, marked individual were qualitatively characterized for these 9 phenological events (Prasad and Hegde, 1986) and phenostage of each species was determined by considering the status of majority of individuals. In the case of species represented by only a few individuals, those present in nearby areas were observed to confirm the phenological status of that species. For each selected dominant tree species, majority of individuals observed phenophages event on a sampling date was recorded. The duration of phenological events in a species was computed by obtaining the number of days required for the completion of an event from the date of the fortnightly visit when the event was first observed. For each species, interphenophase duration, i.e. period between successive phenological events, were then obtained.

Table-2.5: Tree species, vegetation type (VT) and interphenophase duration (days).

S.N.	Tree Species	VT	Interphenophase duration (days)					
			YL-ML	ML-AL	YF1-MF1	MF1-AF1	YFr-MFr	MFr-RFr
1	*Acacia nilotica*	D	29	278	29	28	58	153
2	*Acacia farnesiana*	D	30	283	31	27	49	151
3	*Acacia catechu*	D	34	267	34	30	47	161
4	*Ailanthus excelsa*	D	33	279	35	30	30	43
5	*Albizia lebbeck*	D	29	278	27	22	179	61
6	*Bauhinia purpurea*	SE	31	301	20	22	59	89
7	*Butea monosperma*	D	30	285	23	25	30	80
8	*Bauhinia racemosa*	D	32	287	27	29	37	67
9	*Bauhinia variegata*	D	29	285	28	27	41	69
10	*Cassia fistula*	D	25	268	29	26	136	125
11	*Dalbergia sissoo*	D	30	289	19	21	38	48
12	*Diospyros cordifolia*	D	20	296	23	24	61	38
13	*Eucalyptus globulus*	E	-	-	29	28	36	41
14	*Prosopis juliflora*	D	24	298	29	26	36	79
15	*Pongamia pinnata*	E	-	-	20	26	72	68
16	*Phoenix sylvestris*	E	-	-	18	46	129	117
17	*Pithecelobium dulce*	D	25	283	22	29	75	51
18	*Tectona grandis*	D	29	281	29	34	62	65
19	*Heterophragma adenophyllum*	D	34	302	35	75	31	73
20	*Zizyphus xylopyra*	D	38	282	25	23	125	116

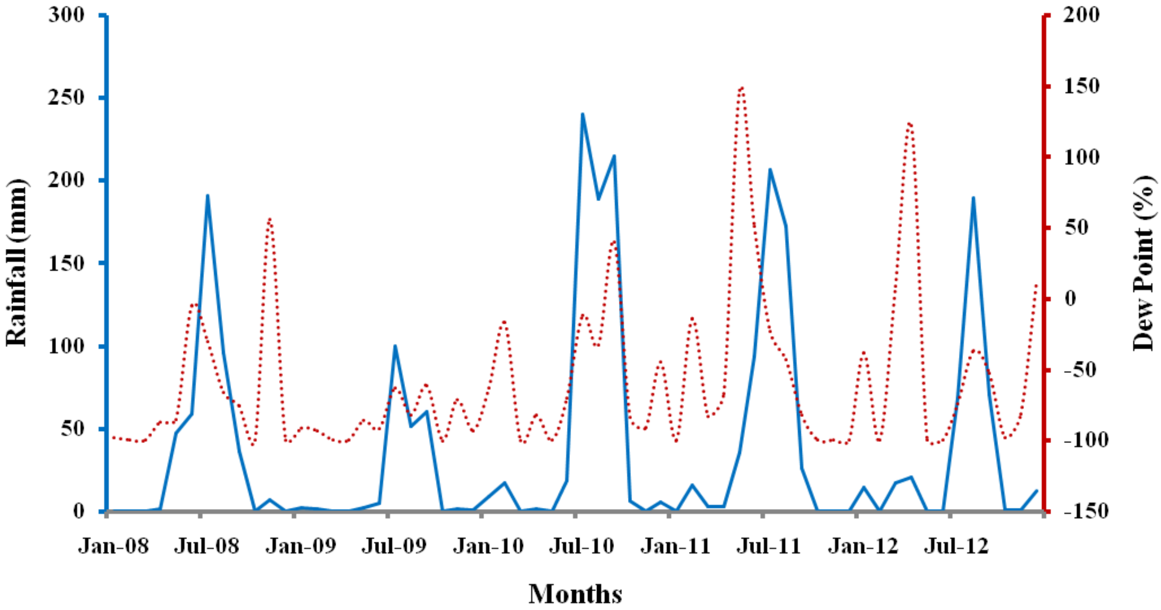


Figure-2.1: Monthly Average Rainfall and Dew Point Time Series of Meerut.

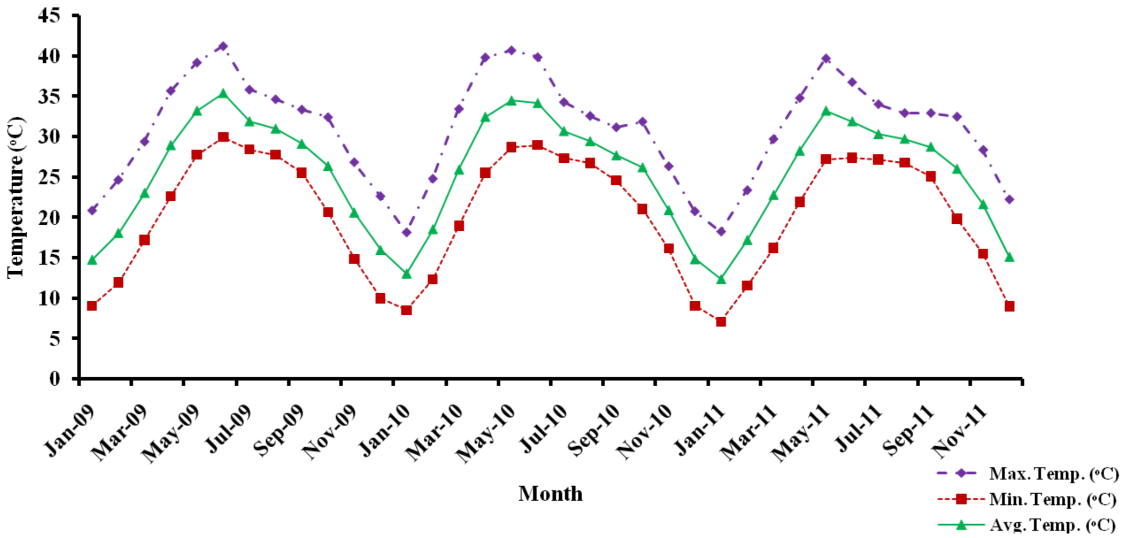
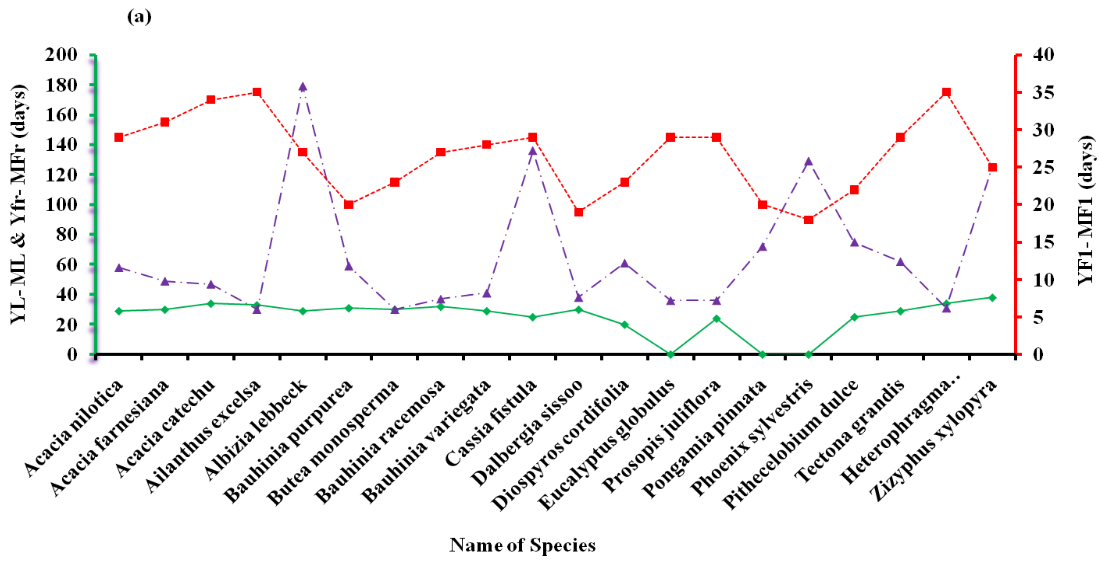


Figure-2.2: Monthly Average Time Series of Temperature.



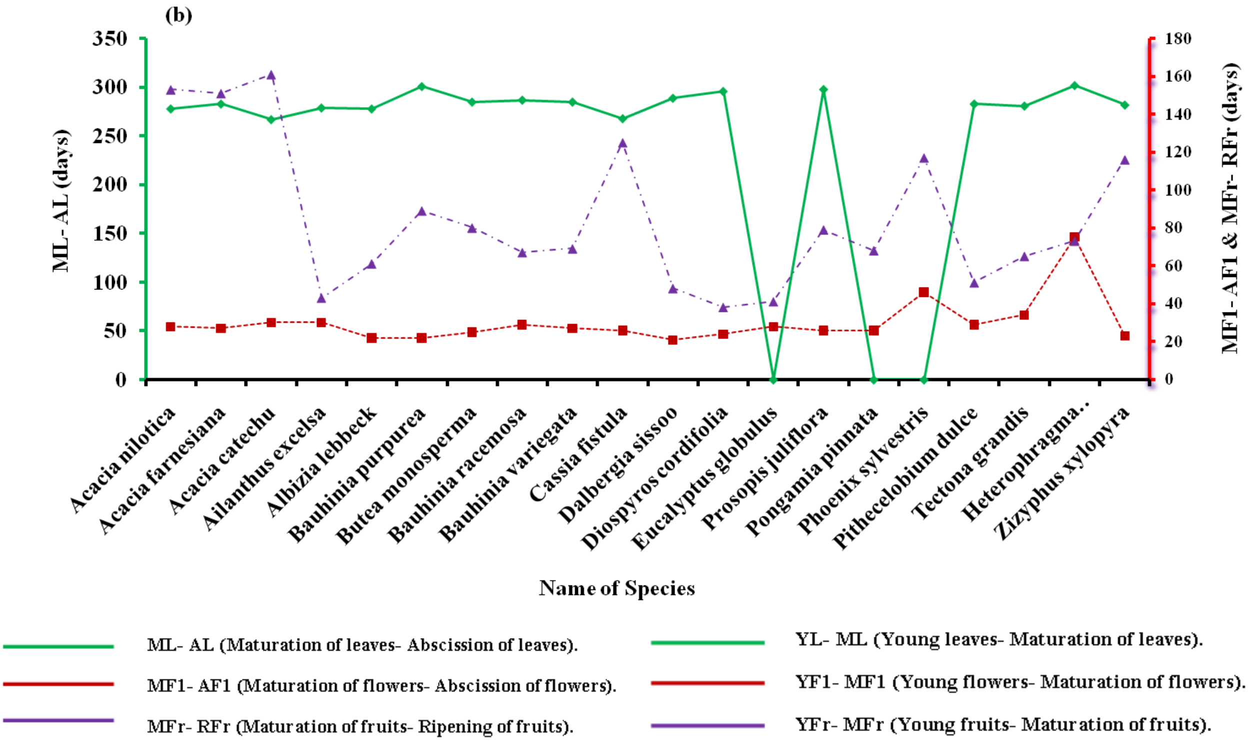


Figure-2.3 (a & b): Variation in different interphenophases of dominant tree species.

RESULT AND DISCUSSION

Leaflessness or leaf shading nature (deciduousness) in trees is ill defined; the precise quantification of leaflessness has been least attempted and no convenient categorisation is available (Kushwaha and Singh, 2005). Currently the terminology used to describe phenological functional types lacks uniformity. In most phenological studies, terminology varies with the investigator and the climatic conditions of the habitat studied (Singh and Kushwaha, 2005).

In present study, on the basis of leaf shading nature we categorized 16 tree species namely *Acacia nilotica*, *Acacia farnesiana*, *Acacia catechu*, *Ailanthus excelsa*, *Albizia lebbeck*, *Butea monosperma*, *Bauhinia racemosa*, *Bauhinia variegata*, *Cassia fistula*, *Dalbergia sissoo*, *Diospyros cordifolia*, *Prosopis juliflora*, *Pithecelobium dulce*, *Tectona grandis*, *Heterophragma adenophyllum and Zizyphus xylopyra* as deciduous species, three tree species namely *Eucalyptus globulus*, *Pongamia pinnata*, *Phoenix sylvestris* as evergreen and one namely *Bauhinia purpurea* as semi- evergreen species (Table-2.1).

Foliage phenology: In the present study, we observed that leaves emerge and mature during the period with minimal rainfall, high temperature and increasing day length in all three sites and leaves abscission occurs when the temperature begins to decrease and day length is short. The duration of leaf maturation varied from 20 days (*Diospyros cordifolia)* to 38 days (*Zizyphus xylopyra)*. The period between maturation and abscission of leaves ranged from 267 days (*Acacia catechu)* to 302 days (*Heterophragma adenophyllum)* (Table-2.1).

Leaf Initiation: Leaf flushing was also a periodic phenomenon in all the selected 20 dominant tree species with considerable variation. Among 20 species observed, 11 species namely *Acacia nilotica*, *Acacia farnesiana*, *Ailanthus excelsa*, *Albizia lebbeck*, *Butea monosperma*, *Bauhinia racemosa*, *Bauhinia variegata*, *Dalbergia sissoo*, *Prosopis juliflora*, *Pithecelobium dulce* and *Heterophragma adenophyllum* leaf initiation started in March, two species namely *Cassia fistula* and *Zizyphus xylopyra* leaf initiation started in June, two species namely *Diospyros cordifolia* and *Tectona grandis* leaf initiation started in February whereas in *Acacia catechu* in April and *Bauhinia purpurea* in January. There was a complete absence of leaf flushing in most of the selected tree species from September to January except *Bauhinia purpurea* (semi- evergreen) which showed leaf initiation in January.

Leaf Flush Duration: Single episodic of leaf flush and leaf fall occurred in all selected deciduous tree species during the annual cycle. Wide diversity existed among the species in terms of duration of leaf flush. 11 species (*Acacia nilotica*, *Acacia farnesiana*, *Ailanthus excelsa*, *Albizia lebbeck*, *Butea monosperma*, *Bauhinia racemosa*, *Bauhinia variegata*, *Dalbergia sissoo*, *Prosopis juliflora*, *Pithecelobium dulce* and *Heterophragma adenophyllum)* produced new leaves through March-April, two species (*Cassia fistula* and *Zizyphus *xylopyra*) produced new leaves through June- August and two species (*Diospyros cordifolia* and *Tectona grandis*) produced new leaves through February-April. *Bauhinia purpurea* (semi- evergreen) produced new leaves through January- February. It was also observed that a few individual of each species continued to leaf flush in later month also. The three evergreen tree species (*Eucalyptus globulus, Pongamia pinnata and Phoenix sylvestris*) showed leaves exchanging. These tree species exchanged leaves because leaf- flushing usually occurs shortly before or immediately after the completion of leaf shading during the early or mid dry season.

Leaf fall: Leaf fall initiation was a periodic activity in all selected dominant tree species; the onset of leaf fall initiation was different in all selected tree species. In mostly selected tree species leaf shading began in late October with peak in November and December. Many deciduous tree species were leafless in February, whereas a few of them were almost leafless in March for a short duration. However three evergreen tree species (*Eucalyptus globulus, Pongamia pinnata* and *Phoenix sylvestris*) showed no concentrated leaf fall during the study period.

The reason behind the emergence and maturation of leaves in dry season could be due to increased daylength, rise of temperature and change in photoperiod which favours to maximise the photosynthesis and vegetative growth (Kushwaha and Singh, 2005; Bajpai *et al*., 2012; Thakur *et al*., 2013). Seasonal changes in photoperiod and thermoperiod are generally coupled and their joint action may control growth rhythm of trees. The summer flushing enables tree species to activate canopy development before the monsoon rainfall begins and to make maximum use of short rainy season for productivity. Increasing photoperiod along with rising temperature may cause starch to sugar conversion in roots and stems and osmotic adjustment in bud tissues of the summer flushing tree; this may induce bud break through increased water absorption and availability of sugar (Borchert, 1994). Osmotic adjustment in fine roots may also have a role in increased water absorption from the soil during the dry season, helping rehydration of stem. The role of photoperiod has also been confirmed by Rivera *et al*., (2002) who reported that spring flushing in tropical semi deciduous trees is induced by an increase in photoperiod of 30 minutes or less. They further suggested that production of new foliage shortly before the rainy season is likely to optimise the synthetic gain in tropical forests with relatively short growing season. This was also supported by Elliot *et al*., (2006) and Kushwaha and Singh, (2005).

The leaf fall was concentrated in cool and dry winter months i.e. from October to February. Prasad and Hegde, (1986) observed a similar pattern of leaf fall in tropical deciduous forest in Bandipur Tiger Reserve, Southern Indian region. Raich and Borchert, (1982) suggested that leaf fall during the dry season was directly influenced by the decline in soil moisture and increase in water stress condition. The result was also in conformity with Singh and Singh, (1992) who reported that initiation of leaf fall coincides with the onset of the post monsoon low temperature dry period and can be a mechanism maintaining turgidity of shoots. In the present study, marked asynchrony occurred in selected tree species with respect to leaf flush completion, initiation and completion of leaf fall and the extent of leafless period. The wide difference in duration of leaf flush and timing of leaf fall observed amongst tree functional groups, exposed to same regime of climatic conditions, may be caused by the variation among the components of the soil- plant- atmosphere continuum that determine tree water status. The variation in the onset of monsoon, amount and distribution of rainfall during the annual cycle may affects the factors regulating the soil- plant- atmospheric water continuum, resulting in change in asynchrony/synchrony (Kushwaha and Singh, 2005). Borchert, (1994) hypothesized that in the dry forest, within species asynchrony in trees is guided by differences in water availability and hence tree water is likely to cause the observed variation in phenology. Global climate change may force variation in timing, duration and synchronisation of phenological events (e.g. date of initiation and completion of leaf flush, leaf fall and leafless period) in the tropical forests (Raich, 1995). Although progress has been made in understanding the drivers of leaf phenology at the molecular level (Yoshida, 2003), a picture of leaf onset and senescence mechanisms is only beginning to emerge.

Reproductive Phenology: We have selected and observed 20 selected tree species in 3 different sites of Hastinapur, Meerut during the study. All the tree individual of each selected species showed high variability in production of flowers and fruits in terms of quantity and frequency.

Flowering Activity: Flowering continued in different selected tree species throughout the year. However , two peak period of flowering were distinguished; the first peak in the month of March and April when *Acacia nilotica*, *Acacia farnesiana, Acacia catechu*, *Ailanthus excelsa, Albizia lebbeck, Butea monosperma, Bauhinia racemosa, Bauhinia veriegata, Cassia fistula, Dalbergia sissoo, Diospyros cordifolia, Prosopis juliflora, Pithecelobium dulce* and *Zizyphus xylopyra* exhibited initiation in response to increasing length of photoperiod. The second peak of flowering was observed in November when *Acacia farnesiana, Albizia lebbeck*, *Bauhinia purpurea* and *Heterophragma adenophyllum* produced flower. *Acacia nilotica* and *Acacia farnesiana* and *Albizia lebbeck* showed two peaks in flowering. They showed first in April but *Acacia farnesiana* and *Albizia lebbeck* showed second peak in November while *Acacia nilotica* in September. The duration of flower maturation and abscission varied in different selected species. The duration of flower maturation varied from 18 days (*Phoenix sylvestris*) to 35 days (*Ailanthus excelsa* and *Heterophragma adenophyllum*). The period between maturation and abscission of flower ranged from 21 days (*Dalbergia sissoo*) to 75 days (*Heterophragma adenophyllum*) (Table-2.1)

Fruiting Activity: In the present study of Hastinapur forest sites, most tree species (*Acacia nilotica, Acacia farnesiana, Acacia catechu, Ailanthus excelsa, Albizia lebbeck, Butea monosperma, Bauhinia racemosa, Bauhinia veriegata, Dalbergia sissoo, Diospyros cordifolia, Eucalyptus globulus, Prosopis juliflora, Pongamia pinnata, Pithecelobium dulce*) peak fruit ripening activity in monsoon period. But in some species (*Cassia fistula, Phoenix sylvestris, Tectona grandis, Heterophragma adenophyllum* and *Zizyphus xylopyra*) fruit ripening begins in post monsoon period and continues up to the end of cool and dry winter period, that may be due to the difference in fruit maturation activity of different species as reported for sub- tropical forests in North- Eastern India (Kikim and Yadav, 2001).

Fruit maturation and abscission period varied in different selected tree species. In the case of fruit, the duration of maturation varied from 30 days (*Ailanthus excelsa and Butea monosperma)* to 179 days *(Albizia lebbeck).* The period between maturation and abscission of fruits ranged from 41 days (*Eucalyptus globulus*) to 161 days (*Acacia catechu*). During the study it is observed that the fruiting phenology follows closely the flowering phenology most of the tree species. Interphenophase duration between different phenological events varied for different species. It was shortest for maturation of leaves and longest for ripening of fruits (Table-2.1).

Trees are highly variable among the individual in the quantity of flowers and fruits produced, and even the frequency of reproduction (Bullock, 1982; Sarukhan *et al*., 1984). Vegetative and reproductive developments are strongly interrelated in all plants, but in trees these relationships are considerably more complex than in herbaceous plants because of the structural complexity of the shoot system. In contrast to herbaceous plants, flower development in many trees is not continuous from flower induction to anthesis, but may become temporarily arrested at some intermediate stage. Final development of flower buds and anthesis will occur many months after flower initiation. This functionally important distinction has not been adequately considered in many discussions of flowering in tree (Borchert, 1983). At present, available evidence suggests that carbohydrate levels as well as the balance between plant growth regulators in vegetative buds are involved in the control of flower induction (Zeevaart, 1976). The combination of all biotic and abiotic factors establishing conditions favorable for flower initiation and development varies with the species-specific position of the inflorescence within a tree's branch system and with the seasonal pattern of vegetative and reproductive growth. Like all other aspects of tree development, the phenology of flowering is determined partly by genetic, partly by environmental factor (Borchert, 1983). Various physiologically active sites or sinks (e.g. leaf buds and leaves, flower buds and flowers, and fruit) may compete for water, nutrients and metabolites (Lieberman, 1982), and such internal competition may lead to the partitioning in time of plant functions like leafing and flowering. Tropical dry region trees exhibit considerable diversity in seasonal water relation (Borchert *et al*., 2005). Interaction between water availability, tree structure and ecophysiological characteristics leads to varying phenological patterns.

Selected deciduous tree species (including *Bauhinia purpurea*, a semi- evergreen species) present in the study sites exhibited four basic patterns of flowering in relation to leaf flushing as described by Kikim and Yadav, (2001); (a) Flowering before leaf flushing in *Butea monosperma, Cassia fistula* and *Zizyphus xylopyra.* (b) Simultaneous flowering and leaf flushing in *Prosopis juliflora*, (c) Flowering soon after leaf flushing in *Bauhinia racemosa, Bauhinia veriegata, Dalbergia sissoo*, (d) Flowering long after leaf flushing in *Acacia nilotica*, *Acacia farnesiana, Acacia catechu, Ailanthus excelsa*, *Albizia lebbeck, Bauhinia purpurea, Diospyros cordifolia Tectona grandis and Heterophragma adenophyllum*. However, Singh and Kushwaha (2006) recognized five flowering types in 119 tropical tree species.

In several species initiation of fruit ripening begins in post-monsoon period and continues up to the end of cool and dry winter period that may be due to the difference in fruit maturation activity of different species as reported for sub-tropical forests in north-eastern India (Kikim and Yadava 2001). In our study, some tree species (*Cassia fistula, Tectona grandis, Heterophragma adenophyllum and Zizyphus xylopyra*) fruit ripening begins in post monsoon period and continues up to the end of cool and dry winter period. Thus fruit dehiscence of tree species coincides with the onset of monsoon to allow optimal germination (Singh and Singh, 1992; Singh and Kushwaha, 2006). The pattern of fruiting activity maintains the availability of fruits to herbivores throughout the year. In the present study the edible fruits of *Acacia nilotica, Acacia farnesiana, Acacia catechu, Ailanthus excelsa, Cassia fistula* and *Zizyphus xylopyra* are available in winter season whereas those of *Bauhinia purpurea*, *Butea monosperma, Dalbergia sissoo* and *Diospyros cordifolia* are available in summer season to the wild animals.

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