REPRODUCTIVE PHENOLOGY OF DOMINANT 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,*
J.N.U. New Delhi[+]

Abstract: Flowering and fruiting phenology of 20 selected dominant tree species in tropical deciduous forest of Hastinapur region in western U.P. was observed through fortnightly visit during November 2009 to December 2011 revealed that there exists a strong seasonality for flowering and fruiting phenophases. Reproductive interphenophases duration between phenological events varied for different selected dominant tree species. The fruiting phenology follows closely the flowering phenology. Correlation analysis shows that, there was a positive correlation between the interphenophase duration of production of young fruits (YFr) - maturation of fruits (MFr) and production of young flowers (YF1) - maturation of flowers (MF1) but no correlation was found between the interphenophase duration of maturation of fruits (MFr)- ripening of fruits (RFr) and maturation of flowers (MF1) - abscission of flowers (AF1). Phenological behaviour displayed by the trees are the result of interaction of surrounding biotic and abiotic environment.

Keywords: Correlation, Flowering, Fruiting, Hastinapur, Phenology

INTRODUCTION

Seasonal duration of leafing, flowering and fruiting mainly determine phenological behaviour in tropical trees. These phenological events are not mutually independent in woody species, and flowering may be partly or wholly dependent on leafing activity (van Schaik et al., 1993). Nevertheless, tree species with similar leaf phenology often differ in the timing of their flowering and fruiting (Seghieri et al., 1995). Many deciduous tree species show flowering and fruiting during the leafless period, exhibiting wide separation between leafing and flowering phenophases. In many evergreen and in some deciduous species leaf flush and flowering occur close in time on the same new shoot. An analysis of the proximate controls of flowering in tropical deciduous forest species indicates that the timing of vegetative phenology strongly determines the flowering periods, and thus flowering at least depends indirectly on environmental periodicity (Rivera et al., 2002). Variation in flowering time relative to vegetative phenology, induced by a variety of factors (significant rain in winter/summer, decreasing or increasing photoperiod, or drought-induced leaf fall), results in a number of flowering patterns in tropical trees (Borchert et al., 2004). 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 flowers, maturation of flowers (Anthesis), abscission of flowers, production of young fruits, maturation of fruits, ripening of fruits.

MATERIAL AND METHODS

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.

Three sites were selected for phenological study. Tree vegetation analysis was conducted during June-November, 2009 for selected sites of the forest. The quantitative information was carried out in the study forest site mainly for density, frequency, basal area and IVI (Importance value index) of tree layer vegetation. Importance Value Index (IVI) is a measure of dominance and ecological success of a species. Only the species with IVI over 10 were selected as dominant tree species for phenological study. The tree species were identified with flora guides. The tree vegetation analysis was conducted by using quadrat method. The size and number of the quadrats were determined by species area curve method (Mishra, 1968). Total 10 quadrats of 10×10 m^2 size were placed randomly in each forest site. The phytosociology characters such as density, frequency, basal area and IVI of individual species were quantified for different selected study sites using standard quantitative technique (Curtis and McIntosh, 1950; Mishra, 1968; Muller- Dombois and Ellenberg, 1974).

All the individual of 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 6 phenological events namely 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 six 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.

Study of soil properties

From each site the composite soil samples were collected from 0–10cm, 10-20cm and 20-30cm depth, packed in polythene bags and brought to the laboratory for analysis of physical and chemical properties. Moisture content was determined on dry wet basis, soil texture was determined using the sieve of different sizes. Soil Ph was measured using 1.5 proportions of soil and water by glass electrodes (Jackson, 1968).

Table-2.1: Composition of Tree Species in different study sites.

Site-1

S.No.	Species	D	F	TBA	R.D.	R.F.	R.Dom.	I.V.I.
1	*Acacia nilotica*	2.3	100	1075.20	21.10	15.87	19.76	56.73
2	*Acacia farnesiana*	1.8	90	828.21	16.51	14.28	15.22	46.01
3	*Prosopis juliflora*	1.9	90	676.05	17.43	14.28	12.42	44.13
4	*Acacia catechu*	1.8	80	670.25	16.51	12.69	12.32	41.52
5	*Dalbergia sissoo*	0.9	90	591.21	8.25	14.28	10.86	33.39
6	*Tectona grandis*	0.7	80	498.01	6.42	12.69	9.15	28.26
7	*Zizyphus xylopyra*	0.9	70	436.34	8.25	11.11	8.02	27.38
8	*Azadirachta indica*	0.2	10	238.26	1.83	1.58	4.37	7.78
9	*Albizia procera*	0.2	10	218.24	1.83	1.58	4.01	7.42
10	*Aegle marmelos*	0.2	10	208.37	1.83	1.58	3.83	7.24
	Total	10.9	630	5440.14	99.96	99.94	99.96	299.86

Site-2

S.No.	Species	D	F	TBA	R.D.	R.F.	R.Dom.	I.V.I.
1	*Acacia nilotica*	2.1	100	546.21	17.21	11.90	8.72	37.84
2	*Eucalyptus globulus*	1.7	100	532.56	13.93	11.90	8.50	34.34
3	*Butea monosperma*	0.9	80	960.55	7.37	9.52	15.34	32.24
4	*Bauhinia purpurea*	1.0	90	538.32	8.19	10.71	8.60	27.51
5	*H. adenophyllum*	0.9	80	477.43	7.37	9.52	7.62	24.52
6	*Pongamia pinnata*	1.0	70	401.78	8.19	8.33	6.41	22.94
7	*Tectona grandis*	0.9	60	331.34	7.37	7.14	5.29	19.81
8	*Albizia lebbeck*	0.7	50	481.75	5.73	5.95	7.69	19.38
9	*Cassia fistula*	0.8	60	371.64	6.55	7.14	5.93	19.63
10	*Bauhinia racemosa*	0.7	50	432.12	5.73	5.95	6.90	18.59
11	*A. odoratissima*	0.4	20	218.72	3.27	2.38	3.49	9.15

12	*Mangifera indica*	0.3	20	282.36	2.45	2.38	4.51	9.35
13	*Acacia leucophloea*	0.4	20	213.04	3.27	2.38	3.40	9.06
14	*D. melanoxylon*	0.2	20	241.12	1.63	2.38	3.85	7.87
15	*E. officinalis*	0.2	20	230.23	1.63	2.38	3.67	7.69
	Total	12.2	840	6259.17	99.89	99.96	99.92	299.92

Site- 3.

No.	**Species**	**D**	**F**	**TBA**	**R.D.**	**R.F.**	**R.Dom.**	**I.V.I.**
1	*Acacia catechu*	0.9	70	732.67	8.57	8.75	11.37	28.69
2	*Butea monosperma*	0.9	60	491.43	8.57	7.50	7.62	23.69
3	*Ailanthus excelsa*	0.9	60	461.46	8.57	7.50	7.16	23.23
4	*Cassia fistula*	0.8	60	521.32	7.61	7.50	8.09	23.20
5	*Phoenix sylvestris*	0.8	60	329.26	7.61	7.50	5.10	20.22
6	*Tectona grandis*	0.7	50	431.64	6.66	6.25	6.69	19.61
7	*Dalbergia sissoo*	0.8	50	356.29	7.61	6.25	5.52	19.39
8	*Bauhinia purpurea*	0.7	50	341.78	6.66	6.25	5.30	18.22
9	*Acacia nilotica*	0.5	50	421.91	4.76	6.25	6.54	17.55
10	*Bauhinia veriegata*	0.7	40	379.64	6.66	5.00	5.89	17.55
11	*Pongamia pinnata*	0.5	50	331.05	4.76	6.25	5.13	16.14
12	*Pithecelobium dulce*	0.5	40	374.34	4.76	5.00	5.80	15.57
13	*Bauhinia racemosa*	0.5	40	342.31	4.76	5.00	5.31	15.07
14	*Albizia lebbeck*	0.4	40	276.15	3.80	5.00	4.28	13.09
15	*Eucalyptus globulus*	0.4	40	231.67	3.80	5.00	3.59	12.40
16	*Diospyros cordifolia*	0.3	30	219.87	2.85	3.75	3.41	10.01
17	*Zizyphus jujuba*	0.2	10	201.08	1.90	1.25	3.12	6.27
	Total	10.5	800	6443.87	99.91	100	99.92	299.90

D-Density(individual/100m^2); F-Frequency(%); TBA-Total Basal Area(cm^2/100m^2): R.D.-Relative Density(%); R.F.-Relative Frequency(%); R.Dom.-Relative Dominance(%); I.V.I.-Importance Value Index.

Table-2.2. Physico-Chemical Properties of Soil.

Site/Horizon	**Texture**			**Moisture**	**Bulk density**	**Organic Carbon (Mean ±S.D)**	**pH**
Hillock	**Sand**	**Slit**	**Clay**				
Horizon A	87	9	8	95.00	1.49	0.51±0.014	7.67
B	79	8	11	96.58	1.44	0.48±0.014	8.05
C	78	8	15	91.79	1.47	0.47±0.014	8.13
Block- 1							
Horizon A	88	2	10	74.62	1.69	1.20±0.84	7.29
B	86	2	12	75.38	1.58	0.64±0.58	7.16
C	89	3	9	72.32	1.68	0.94±0.077	7.39
Block- 2							
Horizon A	84	8	9	71.16	1.71	0.42±0.021	8.34
B	91	2	10	73.54	1.67	0.46±0.027	8.41
	89	2	8	74.18	1.62	0.38±0.027	8.32

Table-2.3. Trees species, Vegetation Type (VT) and Interphenophase duration

S.N.	**Tree Species**	**VT**	**Interphenophase duration (days)**			
			YF1- MF1	**MF1- AF1**	**YFr- MFr**	**MFr- RFr**
1	*Acacia nilotica*	D	29	28	58	153
2	*Acacia farnesiana*	D	31	27	49	151
3	*Acacia catechu*	D	34	30	47	161
4	*Ailanthus excelsa*	D	35	30	30	43
5	*Albizia lebbeck*	D	27	22	179	61
6	*Bauhinia purpurea*	SE	20	22	59	89
7	*Butea monosperma*	D	23	25	30	80
8	*Bauhinia racemosa*	D	27	29	37	67
9	*Bauhinia variegata*	D	28	27	41	69

10	*Cassia fistula*	D	29	26	136	125
11	*Dalbergia sissoo*	D	19	21	38	48
12	*Diospyros cordifolia*	D	23	24	61	38
13	*Eucalyptus globulus*	E	29	28	36	41
14	*Prosopis juliflora*	D	29	26	36	79
15	*Pongamia pinnata*	E	20	26	72	68
16	*Phoenix sylvestris*	E	18	46	129	117
17	*Pithecelobium dulce*	D	22	29	75	51
18	*Tectona grandis*	D	29	34	62	65
19	*Heterophragma adenophyllum*	D	35	75	31	73
20	*Zizyphus xylopyra*	D	25	23	125	116

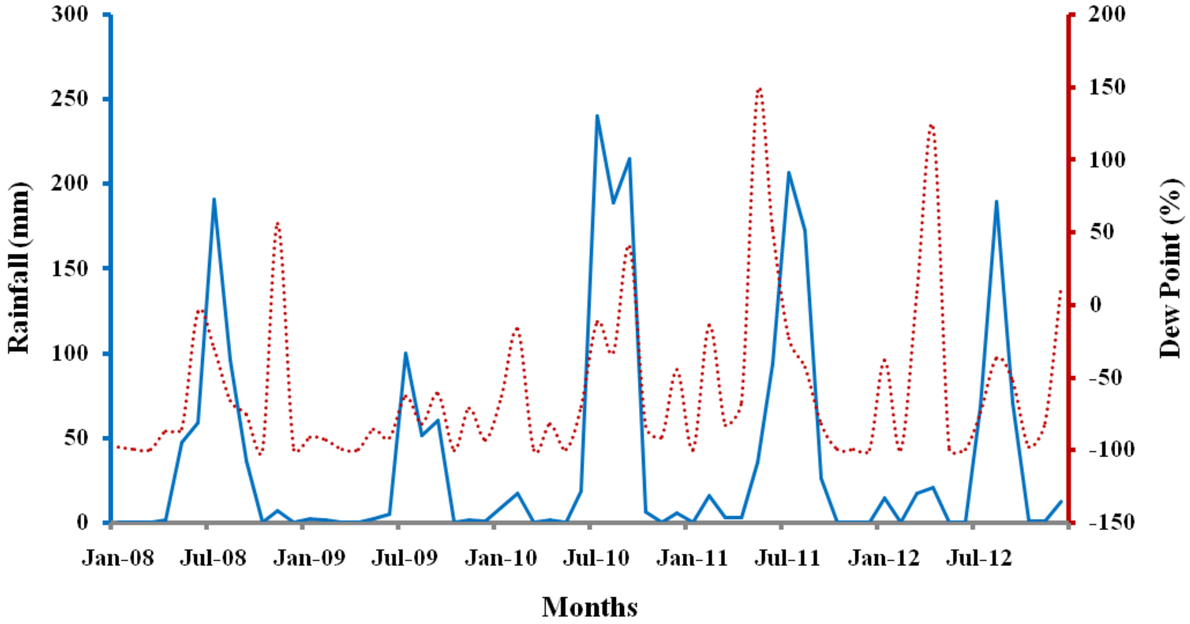

Figure-1: Monthly Average Rainfall and Dew Point Time Series of Meerut.

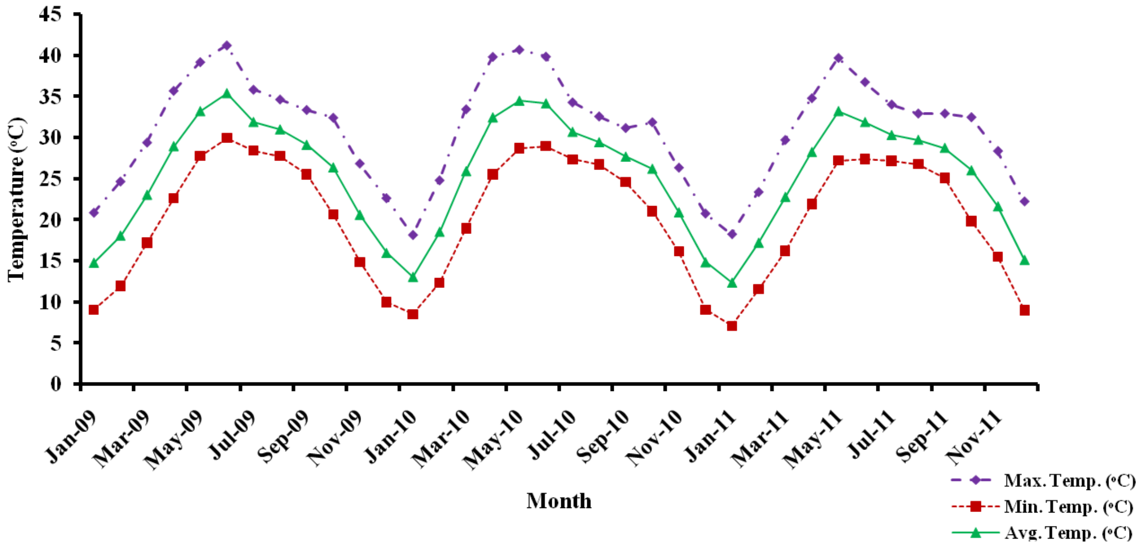

Figure-2: Monthly Average Time Series of Temperature.

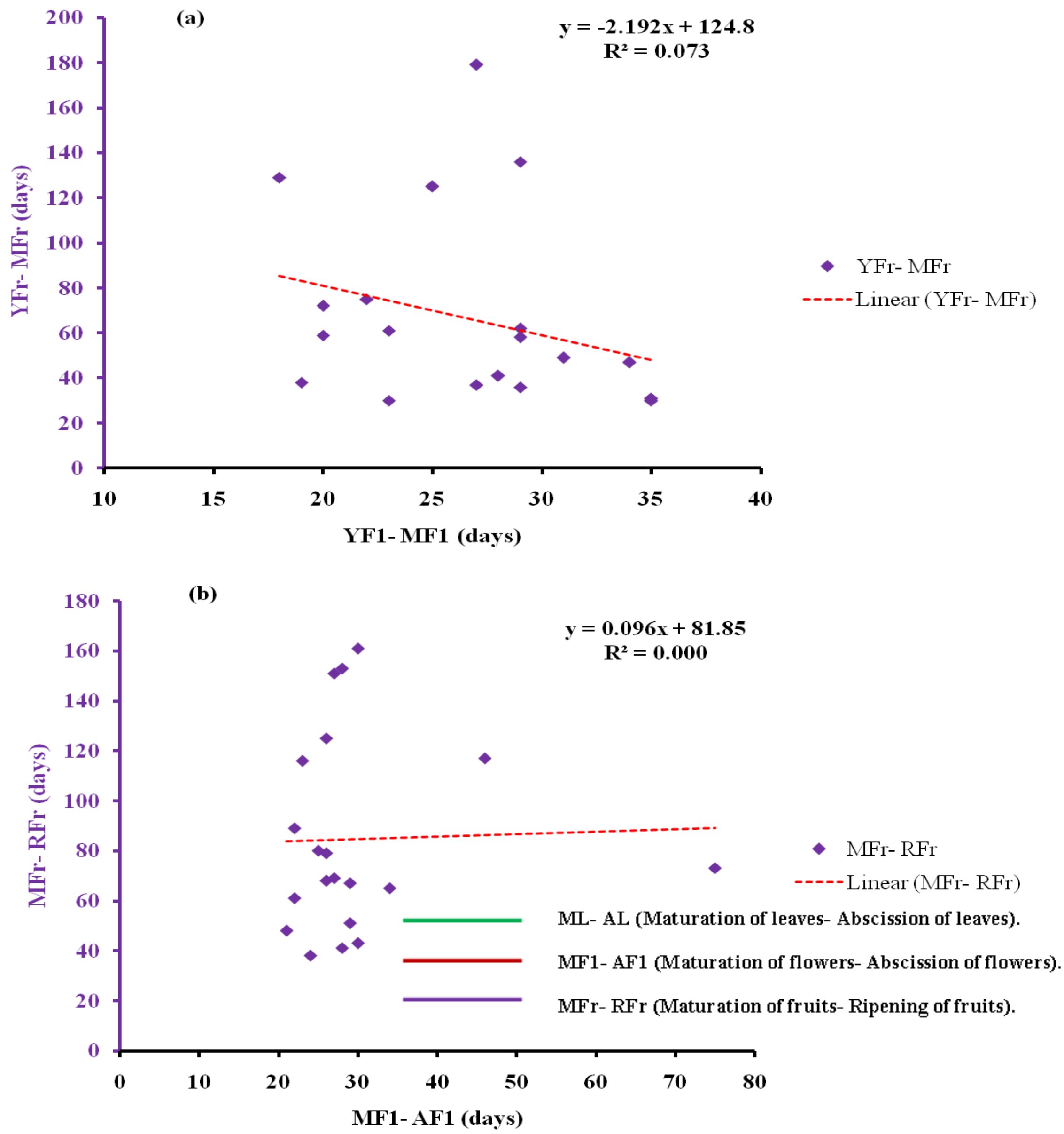

Figure-3:(a&b): Scatter plot of different interphenophases of dominant tree species.

RESULT AND DISCUSSION

Soil Characteristics: The nature of soil profile, soil pH, the nutrient cycling between the soil and trees are the important dimensions in determining the site quality. Soil analysis was done to observed that pH of the soil ranged from 7.16 on horizon B of site-2 to 8.41 on Horizon B of site-3, which indicated that soil was alkaline in nature. The soil is coarse in texture (i.e. sand predominating). The moisture percentage of soil has been found to be higher for site-1; it varies from 71.16% (horizon A of site-3) to 96.58% (horizon B of site-1). The availability of nutrient content was not enough due to low decomposition rate of organic matter and secondly the removal of litter by the villagers for their daily local needs. The range of organic carbon ranged from 0.38 (horizon C of site-3) to 1.20 (horizon A of site-2) (Table-2.2).

Quantitative Analysis of Tree Vegetation: The present study is based on the quantitative information of tree layer of forest in reference to density, frequency, basal area, Importance Value Index (IVI) and certain soil characteristics. Only the species with IVI over 10 were selected as dominant tree species in each site. A sum of twenty nine (29) tree species was reported in the study sites. On the basis of quantitative analysis, 20 dominant tree species were selected for phenological observations. Two species (*Acacia nilotica* and *Tectona grandis*) were present in each study sites. *Acacia nilotica* with highest value of IVI (56.73) showed its dominance in site-1 followed by *Acacia farnesiana* (46.01) and *Prosopis juliflora* (44.13). In site-2 *Acacia nilotica* was the dominant species with highest value of density (2.10), total basal area (546.21) and IVI (37.84). Study site-3 was dominated by *Acacia catechu* (IVI= 28.69) followed by co- dominant species *Butea monosperma* (IVI= 23.69) and *Ailanthus excelsa* (IVI= 23.23) (Tables 2.1).

Although 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-2.3).

Reproductive Phenology: We have selected and observed 20 dominant 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.. From the correlation analysis we found that there was a positive correlation between the interphenophase duration of production of young fruits (YFr) - maturation of fruits (MFr) and production of young flowers (YF1) - maturation of flowers (MF1) but no correlation was found between the interphenophase duration of maturation of fruits (MFr)- ripening of fruits (RFr) and maturation of flowers (MF1) - abscission of flowers (AF1)(Figure-2.3).

Flowering Activity: Flowering continued in different selected dominant 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*).

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. (Table-2.3).

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. It is suggested that flowering time and time lag between the onset of leafing and flowering affect the degree of separation of resource use for vegetative and reproductive events within trees. Variation in flowering time in different species may be related to resource-use rate during vegetative growth (which depends on the duration of deciduousness) and the time required for fruit development (Singh and Kushwaha, 2006).In dry tropics water stress has frequently been cited as a primary trigger for leaf shading, but very little is known about its effect on reproductive phenology (Diaz and Granadillo, 2005). 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. 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. However, various phenological events are triggered by rainfall, water availability, temperature, photoperiod, duration of dry spell and change in day length. It is often difficult to identify the direct trigger from simple observation, because many meteorological factors, such as temperature, rainfall, humidity, and solar radiation, are closely related, and never change independently. Flowering and fruiting also depends on the internal conditions of trees. Therefore, the same climatic conditions do not always bring about the same tree responses. An experimental approach is needed to evaluate the possible triggers of phenophases events. The present study revealed that the vegetative and reproductive phenologies of the selected dominant tree species are the results of interaction of biotic and abiotic environment and gives an idea about the time span of different phenophases in the dominant tree species of Hastinapur region.

REFERENCES

Bullock, S. H. (1982). Population structure and reproduction in the neotropical dioecious tree *Compsoneura sprucei*. *Oecologia*, *55*(2), 238-242.

Borchert, R. (1983). Phenology and control of flowering in tropical trees. *Biotropica*, 81-89.

Borchert R, Meyer SA, Felger RS, Porter-Bolland L. (2004). Environmental control of flowering periodicity in Costa Rican and Mexican tropical dry forests. *Global Ecology and Biogeography* 13: 409–425.

Borchert, R., Renner, S. S., Calle, Z., Navarrete, D., Tye, A., Gautier, L., & von Hildebrand, P. (2005). Photoperiodic induction of synchronous flowering near the Equator. *Nature,433*(7026), 627-629.

Curtis, J. T., & McIntosh, R. P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology, 31*(3), 434-455.

Diaz, M., & Granadillo, E. (2005). The significance of episodic rains for reproductive phenology and productivity of trees in semiarid regions of northwestern Venezuela. *Trees*, *19*(3), 336-348.

Jackson, M.L. (1968). Soil chemical analysis .Prentice Hall. New Delhi 498 pp.

Kikim, A., & Yadava, P. S. (2001). Phenology of tree species in subtropical forests of Manipur in north eastern India. *Tropical Ecology*, *42*(2), 269-276.

Kushwaha, C. P., & Singh, K. P. (2005). Diversity of leaf phenology in a tropical deciduous forest in India. *Journal of Tropical Ecology, 21*(1), 47-56.

Lieberman, D. (1982). Seasonality and phenology in a dry tropical forest in Ghana. The *Journal of Ecology*, 70, 791-806.

Mishra, R. (1968). Ecology work book. *Oxford and IBH Publishing Co., Calcutta*.

Muller- Dombois, D. And Ellenberg, H. (1974). Aims and Methods of Vegetation Ecology. *John Wiley and Sons, New York*.

Prasad, S. N., & Hegde, M. (1986). Phenology and seasonality in the tropical deciduous forest of Bandipur, South India. *Proceedings: Plant Sciences*, *96*(2), 121-133.

Rivera, G., Elliott, S., Caldas, L. S., Nicolossi, G., Coradin, V. T., & Borchert, R. (2002). Increasing day-length induces spring flushing of tropical dry forest trees in the absence of rain. *Trees, 16*(7), 445-456.

Sarukhan, J., Martinez-Ramos, M., & Pinero, D. (1984). Analysis of demographic variability at the individual level and its population consequences. *Perspectives on plant population ecology/edited by Rodolfo Dirzo and Jose Sarukhan*.

Seghieri J, Floret Ch, Pontanier R. (1995). Plant phenology in relation to water availability: herbaceous and woody species in the savannas of northern Cameroon. *Journal of Tropical Ecology* 11: 237–254.

Singh, K. P., & Kushwaha, C. P. (2005). Paradox of leaf phenology: *Shorea robusta* is a semi evergreen species in tropical dry deciduous. *Current Science*, *88*(11).

Singh, K. P., & Kushwaha, C. P. (2006). Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Annals of Botany*, *97*(2), 265-276.

Van Schaik, C. P., Terborgh, J. W., & Wright, S. J. (1993). The phenology of tropical forests: adaptive significance and consequences for primary consumers. *Annual Review of Ecology and Systematics*, 353-377.

Zeevaart, J. A. (1976). Physiology of flower formation. *Annual Review of Plant Physiology*, *27*(1), 321-348.