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Phenological Patterns of Selected Tree Species in Amrabad Tiger Reserve, Telangana, India

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Abstract: The present paper deals with phenology of selected tree species like *Phyllanthus emblica, Dalbergia paniculata, Hardwickia binata, Anogeissus latifolia, Albizia thompsonii, Chloroxylon swietenia, Diospyros melanoxylon, Givotia moluccana, Buchanania axillaris, Terminalia alata, Sterculia urens, Strychnos nux-vomica, Bombox ceiba, Butea monosperma, Madhuca indica, Eriolaena lushingtonii, Albizia odoratissima, Terminalia bellirica, Pterocarpus marsupium, Firmiana colorata, Careya arborea* in Amrabad Tiger Reserve, Telangana, India. The phenological observations include leaf flush, leaf mature, leaf fall, leaf less periods, flowering, fruiting, fruit fall, among the selected tree species. A total of ten individuals (≥50 cm gbh), for each of the selected 21 tree species were observed at fifteen days interval during 2018-2020 . It was observed that there were species specific phenophases relationship with deciduous period and initiation of seasonal rainfall and warm periods. In addition, intra species asynchrony in phenological activities was also recorded. Leaf flush activity was initiated in March and reached peak in the month of April and completed before the initiation of South-West monsoon. Leaf maturity started in the month of May and peak was recorded in June and completed in September. Leaf fall activity was initiated in the month of November and reached peak in January before the arrival of intense dry period. Deciduous period was recorded in December to April and the peak period was recorded in February. The reproductive phenophases like Flowering, Fruiting and Fruit fall have significantly varied across the different seasons among the observed tree species. Majority of tree species (43%) revealed synchronous flowering with Leaf flush activity. The results indicate that Leafing (48%) and flowering phenophases (70%) occur during the dry period before the onset of first rains and fruiting, fruit fall timing was in consequence to utilize the growing season. Thus, species specificity was recorded with respect to Phenophases were found to be in relation with the seasonal rainfall distribution and in turn soil moisture availability in the study area.

Keywords: Phenophases, Amrabad Tiger Reserve, Synchronous flowering

Among the plants, the variations in phenological activities such as leaf flesh, leaf fall, and flowering were directly related to deciduous period, seasonal distribution of rainfall, soil moisture and temperature (Moza and Bhatnagar 2005). Tropical dry deciduous forest consists of tree communities which grow in climates with marked pronounced dry and wet conditions in an annual period (Singh and Kushwaha 2006). Nanda et al (2014) observed that these forests constitute high variations in vegetative and reproductive phonological patterns at both large scale and small scales. The phenophases of tree species were mainly found to be based on the seasonal changing events such as availability of soil moisture, stem water status, photoperiod, changes in temperature and irradiance (Singh and Sahoo 2019) and biotic factors like pollinators attraction, competition for seed dispersers and avoidance of herbivore have been proposed to influence different phenological patterns in tropical dry forests (Singh and Kushwaha 2005). Thus pheonological events should be assessed by both abiotic factors and plant functional traits to achieve integrative understanding of tree community (Saha 2007). In seasonal tropical forests, plant phenological patterns were controlled by various interactions between biotic and climatic factors; especially seasonal variation in rainfall, dry periods which influence soil moisture, tree water status are considered as the principal factors influencing the timings of the periodic phenophases of growth and reproduction (Sakai 2001). In dry forests of southern Eastern Ghats the peak leaf flushing activity and flowering events occur during the dry period before the onset of first rains and fruit maturation period is high and fruit fall timing is in consequence to utilize the rains for germination. Thus, seasonal rains (soil moisture availability) and extent of deciduous period (photoperiod) influence the leafing and reproductive phenological events in dry deciduous forest (Mastan et al 2020). Few communities wide phenological studies in dry forests were carried out in dry forests of India, (Singh and Kushwaha, 2005, Nanda et al 2014, Mastan et al 2020). But no phenological studies were carried out in the dry

deciduous forests of Telangana. Hence the present study was undertaken with an objective to examine the various phenophases for the selected tree species in relation to the prevailing climatic and to test the hypothesis that different phenophases among the tree species do not show seasonality and seasonal rainfall has no role in the sequence of phenophases in Amrabad Tiger Reserve, Telangana.

Study site (NL 15°.21'- 16° 30' NE 78° 30'-80°10'): The Amrabad Tiger Reserve (ATR) is a part of the Nallamalais of Southern Eastern Ghats and it harbors rich floral and faunal diversity. ATR is one of the largest Tiger Reserves of India in terms of geographical area (2611.4 km^2) and it is home for largest number of Tigers in Telangana State. It spreads in Nagarkurnool and Nalgonda districts of Telangana State with 3 forest divisions namely Achampet, Amrabad (Nagar Kurnool District) and Nagarjunasagar (Nalgonda District). The hilly terrain of this Tiger Reserve with deep valleys and gorges forms the catchment of the Krishna River. The reserve was notified as Amarabad Tiger Reserve in 2014. Amrabad plateau stands as extension of Eastern Ghats and is cut into many slopes and valleys running south-southeast directions. The elevation in ATR ranges from 120 to 900m MSL. The climate of ATR is warm from January to March with an average temperature varies from 24° to 30°C and in April and May the climate be too hot with an average temperature of 35°C-45°C. During the succeeding four months of rainy season, the wind blows from western side and the average rainfall for ATR is about 900-1000mm and is mostly due to south-west monsoon. At the end of September, the onset of north-east monsoon occurs and rainfall is scarce in November and December. From November to February the temperature falls as low as 8°C. The average minimum temperature 18°C and maximum temperature of 40°C. The ATR comprising geologically ancient rocks and two principal geological formations the Kurnool and Cuddapah. The major portion of the ATR consists of the oldest geological formation known as the Archeans and mainly three types of soils red, black and mixed varieties were observed in ATR.

MATERIAL AND METHODS

The total of 21 tree species with 10 individuals of each species having girth at breast highest (GBH) ≥50cm were selected in the study site for the phenological observations. Two branches (A & B) of 21 reproductively matured individuals of each species were marked and monitored for every 15 days intervals over a period of 3 years from January 2018 to December 2020. The phenophases like leaf flush, leaf mature, leaf fall, leaf less, flowering, fruiting and fruit fall were recorded. If at least five individuals in the species feature a phenophase it was considered as the initiation of that particular activity and the extension of that activity was noticed till at least eight individuals have promulgated the phenophase activity. The average of the three years data was taken into consideration for the study (Table 1). Spearman rank correlations were carried to obtain coefficients for the number of tree species in each phenophase in a month by the current and one to three month lag period rainfall data.

RESULTS AND DISCUSSION

The leaf initiation was first recorded during March in two species *Phllanthus emblica* and *Strychnos nux-vomica* (9.5%) and reached peak during the months of April and May (38%) followed by June (14%). In all the 21 tree species, leaf flushing activity has conspicuously started on the total leafless twigs. Further, majority of tree species (85.7%) have promulgated their first leaves in summer period before the onset of rains, while three species *Terminalia bellirica, Firmonia colorata* and *Eriolaena lushingtonii* have produced new leaves after the first rains concurring with the onset of monsoon period. Leaf flushing activity revealed non-significant negative correlation with current month rainfall and a significant negative relation with three-month lag rainfall amounts (Fig. 1, Table 2). The leaf initiation period was in the range of 31 to 77 days with a minimum period in *Chloroxylon swietenia* and *Albizia thompsonii* and maximum period was among *Firmonia colorata* and *Eriolanea lushingtonii* individuals. Leaf expansion period has started in May among four species (19%) with a peak in June (52%) and extended during July (14%), August (9.5%) and up to September by *Eriolaena lushingtonii*. High duration of leaf maturation (>200 days) was among species *Phyllanthus emblica*, *Caraya arborea*, *Buchananaia axillaris* and *Strychnos nux-vomica* and at least four months of growing season was recorded in the rest of 17 species. Leaf fall was recorded just after the end of monsoon period and well before the onset of dry period in November among six species (28.5%) followed by four species (19%) in December and reached peak condition in January (9; 43%) and two species namely *Careya arborea* and *Diospyros melanoxylon* have shed their leaves in February. Species under leaf fall activity and rainfall had significant negative relationship with current rainfall and the negative relationship was highly correlated with one month lag rainfall (Fig. 2, Table 2). Distinct leaf less period (Deciduous period) was as low as 14, 16 and 17 days in *Strychnos nux-vomica, Pterocarpus marsupium, Caraya arborea* respectively and as high as 106 days in *Sterculia urens* and 105 days in *Anogeissus latifolia.*

Flowering and fruiting phenophases : Flower bud break was first recorded in *Butea monosperma* during January,

followed by *Phyllanthus emblica* in February and got pronounced in March (47%) extended during April (10.5%), May (15.8%) and *Dalbergia paniculata* and *Buchanania axillaris* have produced flowers in July. There was no flowering activity for *Hardwickia binata* and *Eriolaena lushingtonii* in the study period and all the tree species have revealed unimodal type (annual) of flowering except *Strychnos nux-vomica* in which bi-modal flowering in the months of March and July. Flower bud break and rainfall indicated negative relationship with current rainfall; but showed significant positive relationship with three-month lag rainfall (Fig. 3, Table 2). Flowering was recorded on completely leaf less twigs in 10 species in the summer season, four species have registered synchronous leaf initiation and flower initiation and another four species have produced flowers after the leaf initiation period was

Table 1. Vegetative and reproductive phenology data with initiating, ending days and duration period of the selected tree species

	Deciduous period	Leaf Initiation	Leaf maturation	Leaf Fall	Flowering	Fruiting	Fruit dispersal
Phyllanthus emblica	Jan16-Feb 15 (30)	Feb 01-Mar 30 (58)	Apr 01-Dec 30 (274)	Jan 01-15 (15)	Feb 16-Mar 30 (45)	Aug 01-Nov 15 (46)	Nov16-Dec 30 (45)
Dalbergia paniculata	Feb 01-Apr 30 (89)	Apr 15-June30 (76)	June 16-Oct 30 (138)	Oct16-Jan 30 (106)	May 01-July 30 (92)	Aug 01 -Oct 30 (62)	Nov 01-Dec 30 (60)
Hardwickia binata	May 01-30 (30)	Apr 15-June 15 (61)	June 16-Jan 30 (229)	Feb 01-Apr 30 (89)	ABSENT	ABSENT	ABSENT
Anogeissus latifolia	Jan01-Apr 15 (105)	Apr 16-June 15 (61)	June 16-Oct 30 (138)	Nov01-Dec 30 (60)	Sep 01 -Oct 15 (45)	Oct 16-Dec 15 (75)	Dec 16-Jan 15 (30)
Albizia thompsonii	Feb 01-Mar 15 (43)	Apr 15-May 15 (31)	May 16-Nov 15 (184)	Nov 16-Jan 30 (76)	Mar 16- Apr 30 (46)	May 01-Nov 30 (214)	Dec 01-Jan 01 (31)
Chloroxylon swietenia	Feb01-Mar30 (59)	Apr 01-May 15 (45)	May 16-Oct 31 (169)	Nov 01-Jan 30 (91)	March 01-31 (31)	April 01- 30 (30)	May 01-30 (30)
Diospyros melanoxylon	March 16 - Apr 30 (46)	May01-June 30 (61)	July 01-Jan 30 (214)	Feb 01-Mar 15 (43)	Apr 01-May 30 (61)	June 01-July 30 (61)	July 16-Aug 15 (30)
Givotia moluccana	Feb 16-Apr 30 (74)	May 01-July 15 (76)	July 16-Dec 30 (169)	Jan 01-Feb 15 (45)	May 01- 30 (30)	July 01-Oct 30 (122)	Nov 01-30 (30)
Buchanania axillaris	April 01-30 (30)	Apr 01-June 15 (76)	June 16-Jan 15 (215)	Jan 16 –Ma r30 (45)	June 01-July 30 (61)	Aug 01-Dec 30 (152)	Jan 01-Feb 28 (58)
Terminalia alata	Mar 01-Apr 30 (60)	Ap r01-May 30 (61)	June 01-Oct 30 (152)	Nov 01-Feb 28 (119)	May 01-June 30 (61)	July 01-Oct 30 (122)	Nov 01-Jan 31 (91)
Sterculia urens	Dec30-Apr15 (106)	Apr 30-May 30 (31)	June 15-Oct 30 (138)	Nov 15-Dec 15 (30)	Mar 30-Apr 30 (30)	May 15-Aug 15 (92)	Aug 30-Oct 15 (46)
Strychnos nux-vomica	Feb15-Feb28 (14)	Mar 15-Apr 15 (31)	Apr 30-Dec 30 (245)	Jan 15-Jan 30 (15)	Mar 15-Mar 30 & July 30-Aug 15 (32)	Apr 15-June 15 & Aug 30-Oct 30, (62) &(60)	June 30-July 15 & Nov 15-Feb 28 (16) & (73)
Bombox ceiba	Feb 28-Apr 30 (62)	May 15-June 15 (32)	June 30-Dec 30 (184)	Jan 15-Feb 15 (31)	Mar 30-Apr 15 (16)	Apr 30-May 30 (30)	June15-July15 (30)
Butea monosperma	Jan15-Mar 30 (74)	Apr 15-May 30 (45)	Jun 15-Oct 30 (137)	Nov 15-Dec 30 (45)	Jan 15-Feb 15 (31)	Feb 28-Mar 30 (31)	Apr 15-May 15 (30)
Madhuca indica	Feb 15-Apr 15 (59)	Ap r30-May 30 (31)	Jun 15-Dec 15 (184)	Dec 30-Jan 30 (31)	Mar 30 -Apr 30 (30)	May 15-Aug 30 (107)	Sep 15-Oct 30 (45)
Eriolaena lushingtonii	Mar 15-June 15 (92)	June 30 -Aug 30 (62)	Sep15-Dec 30 (106)	Jan 15-Feb 28 (44)	ABSENT	ABSENT	ABSENT
Albizia odoratissima	Feb 15-Ma r30 (43)	Apr 15-May 15 (30)	May 30-Nov 15 (169)	Nov 30-Jan 30 (91)	Mar 15 -Apr 15 (30)	Apr 30-Aug 15 (107)	Aug 30-Sep 30 (31)
Terminalia bellirica	Mar 30-May 30 (60)	June15-July 30 (46)	Aug 15-Nov 15 (91)	Nov 30-Mar 15 (134)	May 15- June 15 (30)	June 30-Oct 15 (122)	Oct 30-Nov 30 (30)
Pterocarpus marsupium	Feb 28-Mar 15 (16)	Mar 30-Apr 30 (31)	May 15-Dec 15 (211)	Dec 30-Feb 15 (46)	Apr 15 - June 15 (62)	June 30-Oct 15 (122)	Oct 30-Dec 15 (46)
Firmiana colorata	Feb 28-May 15 (89)	May 30-July 30 (62)	Aug 15-Oct 30 (76)	Nov 15-Feb 15 (92)	Mar 15 -Apr 15 (30)	Apr 30-Sep 15 (139)	Sep 30-Oct 30 (31)
Careya arborea	Mar 30-Apr 15 (17)	Apr 30-May 30 (31)	June 15-Jan 30 (230)	Feb 15-Mar 15 (31)	Mar 30-Apr 15 (16)	Apr 30-Oct 15 (169)	Oct 30-Nov 30 (30)

Figure in parentheses indicate number of days

completed. The total of nine tree species (47%) have registered lesser flowering period (≤ 30 days) and the rest ten species have > 30 days flowering period with a maximum period of 61 days among *Dalbergia paniculata, Terminalia bellirica* and *Buchanania axillaris*. The fruit bud break was observed distinctly among *Butea monosperma* in February and *Anogeissus latifolia* has produced flowers lately in the whole forest during October. The peak fruiting activity was registered in April (31.5%), extended during May (15.8%), June (15.8%) and another lower peak was recorded in August (26.3%). Fruit maturation period was in the range of 30 – 214 days with a remarkably high period for *Albizia thompsonii* and species such as *Careya arborea* (183 days) and *Buchanania axillaris* (153 days) have registered high fruit maturation periods. In the same order of first tree to show flowering, fruiting buds break up, *Butea monosperma* has scored the first position for the fruit/seed dispersal also in April (Fig. 4). The peak condition for fruit/seed dispersal was registered in November and the range was 30-90 days with a minimum period shown by *Anogeissus latifolia* and higher period for *Terminalia bellirica* and *Buchanania axillaris* in which dispersal occurred during January of the next calendar year. Fruiting phenophase activity among the species and rainfall had positive relationship and with one-month lag rainfall the relationship was significant (Fig. 5, Table 2).

Tree species of Amrabad Tiger Reserve showed concentration (85.7%) of leaf initiation activity during the dry season and negative relation with a time lag of three months rainfall was noticed as in dry deciduous forests of Bhadra wildlife sanctuary (Nanda et al 2014). The triggering events for new set of leaves may be influenced by the photoperiod (increasing day length) as the timings of high frequency leaf initiation events corresponds with the initiation of spring equinox period where the day length period starts increasing. The leaf initiation timings in the dry period suggests that trees make sure of better utilizing the short growing season by

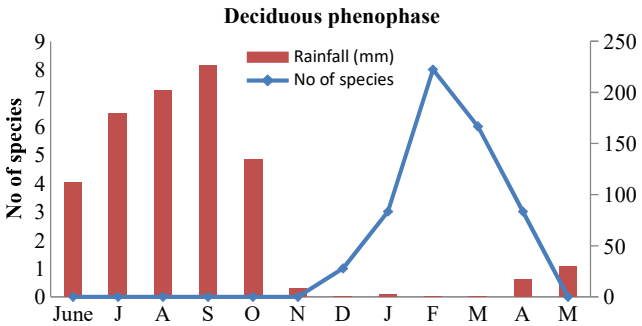

Fig. 2. Deciduous phenophase

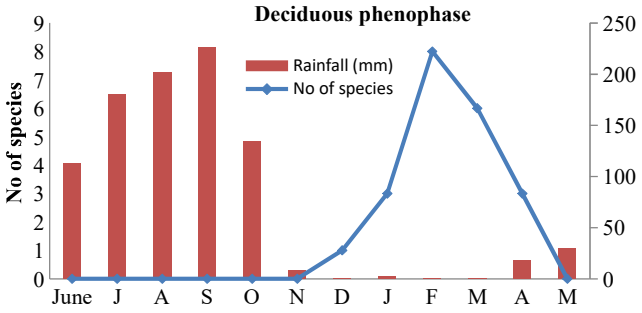

Fig. 3. Flowering phenophase

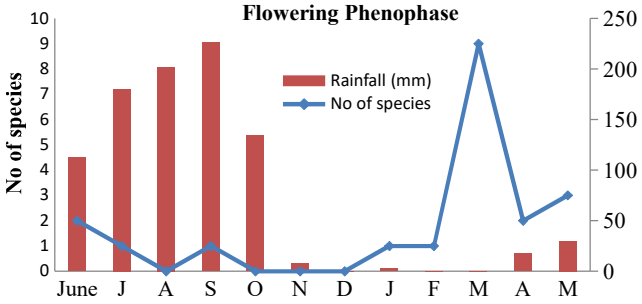

Fig. 4. Fruit bud break phenophase

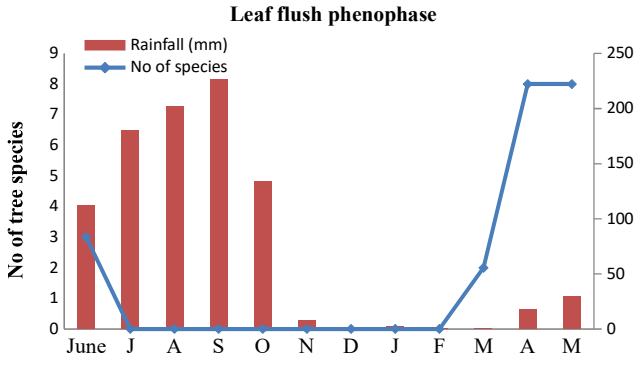

Fig. 1. Leaf flush phenophase

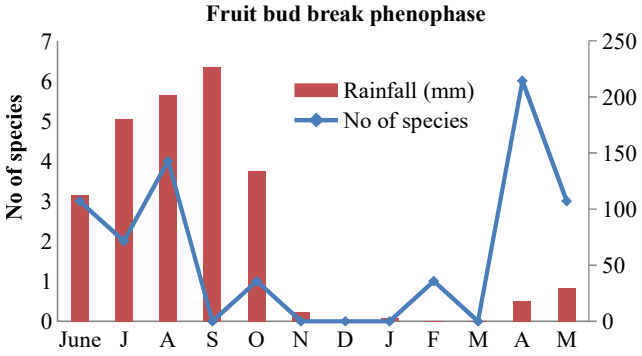

Fig. 5. Fruit/seed dispersal Phenophase

Table 2. Spearman rank correlation values between four different phenophase activities and current rainfall amounts and one to three months lag rainfall amounts

Phenophase activity	Correlation type	Correlation with variable	Significance NS= Not Significant S*= Significant at 0.05 level
Leaf flush	Negative	With current monthly rainfall amount	r = -0.138 P>0.05 (NS)
	Negative	With three-month lag rainfall amount	r = -0.77 P<0.05 (S*)
Leaf fall	Negative	With current rainfall	r = -0.57 P<0.05 (S*)
	Negative	With one month lag rainfall amount	r = -0.78 P<0.05 (S*)
Flower bud break	Negative	With current monthly rainfall amount	r = -0.38 P>0.05 (NS)
Flower bud break	Negative	With three month lag rainfall amount	r = -0.86 P<0.05 (S*)
Fruit bud break	Positive	With current monthly rainfall amount	r = 0.41 P>0.05 (NS)
Fruit bud break	Positive	With one month lag rainfall amount	r = 0.58 P<0.05 (S*)

projecting well-formed leaves well before the advent of monsoon periods as also observed in Vindhyan dry forests (Singh and Kushwaha, 2005). Majority of tree species like *Chloroxylon swietenia, Strychnos nux-vomica, Albizia thompsonii* have initiated the leaf senescence 3-4 months before the initiation of dry season. Such high frequency of leaf senescence events at the advent of low temperature dry period helps the trees to maintain turgidity in the shoots which helps in leaf bud and flower bud break up in the dry period itself strengthening the water stress hypothesis (Elliot et al 2006). Species have showed varied deciduous period (30-136 days) which indicates that certain species can tolerate, and few species avoid the water stress conditions in the hot dry season. In the study, six species featured nearly 30 days leafless period showing their tendency towards high tolerance for water stress conditions; while another six species had 31-70 days deciduous period and nine species projected greater than 70 days deciduous period indicating ability to avoid water stress conditions. Majority of species produced flowers during the dry season as well as on leaf less twigs. These observations are in line with reports that water deficit conditions in branch tips will induce the flower bud development and break ups in dry forests and the presence of flowers on the leafless twigs provide better opportunities for pollinators visit (Singh and Kushwaha, 2005). More over synchrony between flower and leaf initiation was noticed during dry season in species like *Pterocarpus marsupium, Phyllanthus emblica, Givotia molluccana*as also recorded in Mudumalai dry forests and dry forests of Rajasthan (Yadav and Yadav, 2008) which seems to related to moisture and day length. It indicates that water storage ability in tree trunks make few species to maintain high stem water potential and as well produce flowers in the dry period (Schongart et al 2002). Except *Butea monosperma* all other tree species in the present study are insect pollinated. *Butea monosperma* pollinated by squirrels and sun birds.

Fruiting was recorded in both wet and dry seasons registering two peaks in these dry forests. This indicates that both advent of rains and concentrated of rainfall events trigger the fruit bud break ups and similar trend was observed in Lankamalleswara forests (Mastan et al 2020). Among 16 species fruit maturation was completed before the onset of pre monsoon period with relatively lengthy period of fruit retention and 12 species had rapid maturation period. Thus Fruit/ seed dispersal events coincide with the onset of monsoon period for better germination success rates. Fruit dispersal in *Phyllanthus emblica, Diospyros melanoxylon, Madhuca indica Terminalia bellirica, Careya arborea* are zoochory in wet season and the remaining species were dispersed by the wind in dry season.

CONCLUSIONS

Occurrence of leaf flush events before the advent of dry period, flowering activity in the peak dry period, synchrony between leaf initiation and flowering in the late dry period, leaf expansion in the wet monsoon period and fruit fall in the post monsoon period and before rains indicates that seasonality prevails in the occurrence phenophases. Photoperiod seems to majorly influence the phenological patterns of the majority of tree species. Phenophases relate with dry period and rainfall period either in the particular month or in the previous months of their occurrence making them prominent factors that influence the phenophases that occur in the dry forests.

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