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Phenological Changes Reflect the Microclimate of the Ecotone Area of Jagdalpur Division (CG)

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Abstract

Changing pattern of vegetation and ecological and climatic parameters are important for study of the ecotone and pure forest of both the species. The occurrence of changes in behavior, distribution, phenology of associate species in this junction as compared to pure the indicator species for forecasting about the change of climate in that particular area and also on change of biodiversity. The phenological changes take place one or two months earlier in ecotone area as compared to normal forest sites. This microclimatic changes may have the serious implications on decreasing the moist tropical trees (sal) and further reproductive success of dry tropical trees (teak). The presence of new species also reflects some microclimatic changes occurring in the ecotone zone.

Key words : Phenological changes, Microclimate, Ecotone, Biodiversity, Ecotone zone.

Phenology is the study of the cycling of the biological events throughout the year. Phenology is the timing of seasonal activities and life cycle events. Warming temperature are exposed to impact phenological events such as flowering and fruiting in plants. Physiological and phenological response to climate change in combination with altered interactions between species will influence the relative abundance and geographic distributions of most species. The teak forests and the sal forests as a rule, do not overlap each other except in ecotone. The environmental changes are due to change of microclimate of the ecotone forest and by also the timing of flowering and fruiting and other phenological parameters of some tree species in ecotone zone.

Methods

Study Sites. One ecotone site of Jagdalpur (CG) was selected and identified for the study. Another two sites dominated by sal and teak area near ecotone zone were also selected for comparison. Site is located 55 km SE direction from Jagdalpur town. This ecotone site is close to Machkot village and falls in Triya beat of Machlot range. The following comptt. viz. 50, 51, 52, 53, 56, 57 and 118 having 1985.15 ha area covered and falls under this ecotone zone have been surveyed. Another two sites one dominated by sal is also close to the Machkot village and the following comptt. viz. 32, 43, 44, 45 and 49 having 1,579.54 ha area covered and surveyed. Another one teak dominated site comptt. No. 123(N) / 1793(O) having 320.3 ha area falls in Nangoor beat of Jagdalpur Range was also been surveyed and studied (Table 1).

Phenology is the timing of seasonal activities and life cycle of plants. Warming temperatures are expected to impact phenological events, such as flowering and fruiting in plants. Phenological response to climate change in combination with altered interactions between species will influence the relative abundance and geographic distributions of most species.

The phenological changes and months wise comparative studies are enumerated in three zones (ecotone, sal and teak) are presented based on formation of new leaf, leaf flushing, leaf less, flowering, fruiting and fruits fall in relation to their vegetative growth and development with their climatic change.

The study was carried out with 10 different forest tree species namely *S. robusta, T. grandis, D. melanoxylon, T. tomentosa, A. latifolia, L. parviflora, M. indica, A. cardiofolia, E. officinalis and C. fistula* commonly found in ecotone, teak and sal area of study site viz. Jagdalpur (CG).

Results

The microclimatic study was carried out in eco-

Table 1. Microclimatic data inside of forest, Jagdalpur Forest Division (CG) (2006 to March 2009) observation recorded between (12-31 pm).

Location/ elevation	Species	Comptt. No	Season	Months	Temperature (C) Maxi	Temperature (C) Mini	Humidity (%) Maxi	Humidity (%) Mini	Light intensity Lux × 100
225120 N 180 50′ 13.7′′ E 820 7′ 22.1′′ Elevation- 518 m	Ecotone area	50, 51, 52, 53, 56, 57 & 118	Summer	M, A, M, J	40	37	56	23	113—120
			Rain	J, A, S, O	35	34	70	48	85—110
			Winter	N, D,	29	27	80	64	021—024
	Open		Summer	M, A, M, J	41	39	67	37	460—465
			Rain	J, A, S, O	37	35	72	55	160—225
			Winter	N, D, J, F	30	28	65	43	313—327
N 180 50′ 10.2′′ E820 7′ 53′′ Elevation- 540 m	Teak dominated natural forest	123	Summer	M, A, M, J	39	34	34	28	110—120
			Rain	J, A S, O	36	33	70	67	50–52
			Winter	N, D, J, F	30	23	68	48	41—69
	Open		Summer	M, A, M, J	40	37	67	40	260–264
			Rain	J, A, S, O	37	35	73	56	142—232
			Winter	N, D, J, F	29	25	85	62	224—245
N180 50′ 15.7′′ E820 7′ 19.6′′ Elevation- 487 m	Sal dominated natural forest	32, 43, 44, 45, & 49	Summer	M, A, M, J	36	35	67	51	46—92
			Rain	J, A, S, O	33	28	90	50	112—118
			Winter	N, D, J, F	27	23	76	73	28—41
	Open		Summer	M, A, M, J	37	35	70	52	381—465
			Rain	J, A, S, O	34	30	92	55	140—230
			Winter	N, D, J, F	28	24	78	46	220—368

tone zone, teak forest and sal forest of Jagdalpur Forest Division (CG). The study was conducted by taking observation for temperature, humidity and solar radiation. The tabulated data of three successive years (2006-2009) has been presented in Table 1.

In ecotone zone maximum temperature 40 C reaches in summer season and in rainy (35) C and winter (29) C season inside the forest. However in open forest maximum temperature increases from 40 to 41 C in summer and 29 to 30 C in winter season and 35 to 37 C recorded in rainy season. In ecotone zone maximum humidity 80% was observed in winter season, where as minimum (56%) in summer season. Intensity of light measured with the help of Lux meter. By using this instrument intensity of light which falls directly on the surface of the forest can easily measured and found that in ecotone zone light intensity was found to be more (113—120) in summer season while as in rainy season this shows less (85—110) and in winter season the same is found to be in between (021—024). Intensity of light also measure in open forest where there is no tree and found the intensity of light is comparatively higher in all three seasons.

In teak forest site of Jagdalpur maximum temperature reaches to 39 C in summer months where as in

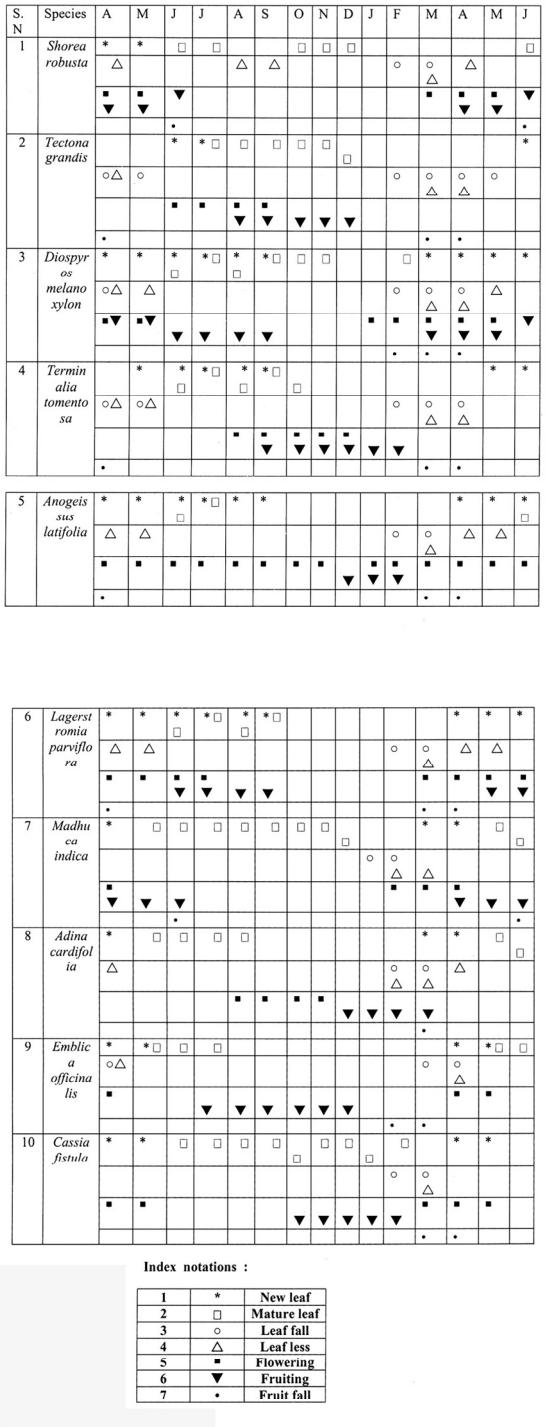


Figure 1. Flowering, fruiting and leafing phenology of 10 tree species.

winter it goes down to 30 and 36 C was recorded in rainy season . In open forest temperature rises to 39 to 40 C in summer and in winter 30 to 29 C. Humidity was maximum 70% in rainy season where as it is minimum in summer season (34%). But in open forest/ area winter season shows maximum (85%) humidity. The teak forest which do not have more number of shrub/saplings/regeneration the intensity of light directly falls on the surface and variation is noticed in summer, rainy and winter season viz. 110—120, 50—52 and 41—69 respectively. Similar changes were also noticed in open forest/area.

In sal forest maximum (36 C) temperature was recorded in summer season and minimum (27 C) was found in winter season. But in open forest area temperature rises to 36—37 C in summer and in winter season temperature increases from 27 to 28 C and in rainy season temperature varies from 33 to 34 C. Humidity per cent was observed and found maximum (90%) in rainy season (inside the forest). However, humidity was maximum (92%) in rainy season and minimum (70%) in summer season (out side the forest). Inside the sal forest where microclimatic change in temperature and humidity were found to have significant difference, viz., Temperature : From maximum temperature of ecotone, the difference is 4 C and (2) from maximum temperature of teak the difference is 3C. Humidity : From maximum humidity of ecotone, the difference is 10% and from maximum humidity of teak, the difference is 20%. Intensity of light inside the forest was varied in different seasons however the difference between the two type of forest is not much significant. But out side the sal forest intensity of light have been found comparatively higher viz., summer (318—465), rainy (140—230) and winter (220—368).

Phenological Studies

Phenology is the timing of seasonal activities and life cycle events. Warming temperatures are exposed to impact phenological events such as flowering and fruiting in plants. Physiological and phenological response to climate change in combination with altered interactions between species will influence the relative abundance and geographic distributions of most species. The teak forest and the sal forests as a rule, do not overlap each other except in ecotone.

Phenological Diagram

Diversity of flowering and fruiting phenology Ecotone area. Jagdalpur Forest Division (CG) is presented in Figures 1 and 2.

Flowering/Fruiting and Leaf Phenological State (Duration)

Different species flowering in different seasons exhibited variaus fruiting duration. Formation of fruits continued through 2—3 months, following the peaks flowering time in different species. However, the time required for fruit maturation varied considerably with species (Fig. 2).

Shorea robusta. Spring flushing, semi-evergreen *shorea-robusta* began flowering with the onset of leaf fall in winter. Its flowering (March—June) coincided with the leaf transitional state (leaf fall, leaf initiation) and fruit formation and leaf flushing both were supported at the same time (Fig. 1).

Tectone grandis. It is a deciduous tree flowered in the month of rainy season and leaf flushing ocurred in February—May. In the winter season matured leaf and fruiting continued through 4—5 month (August—January).

Diospyrous melanoxylon. Flowered is in the hot dry period no new shoots (summer flowering) showing virtual synchronization of leaf flushing, leaf initiation with flowering. Fruiting starts from March and

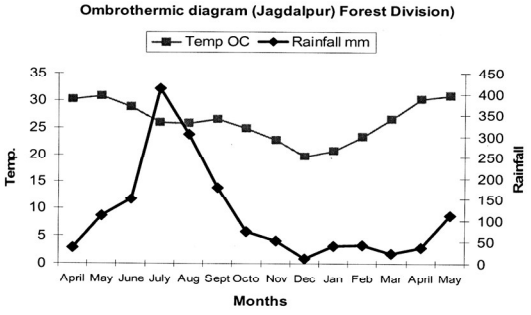
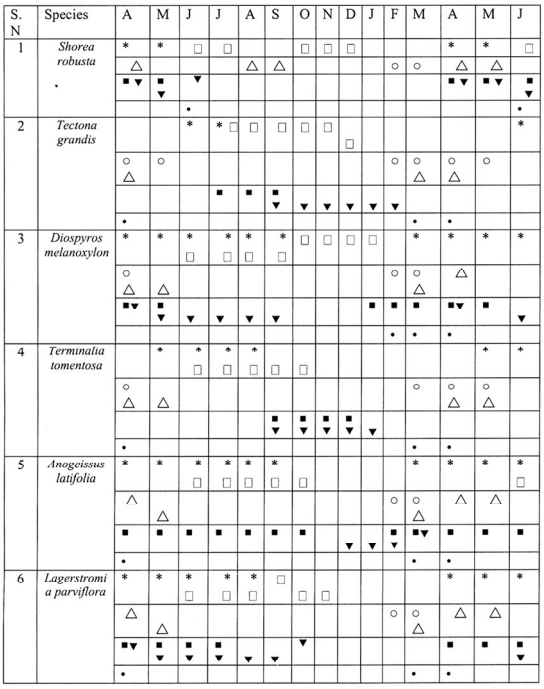


Figure 2. Climatic conditions as observed during two consecutive annual cycles in tropical moist deciduous forest at Jagdalpur (CG). Values of April, May and half of June are shown twice to clearly depict the leafless period.



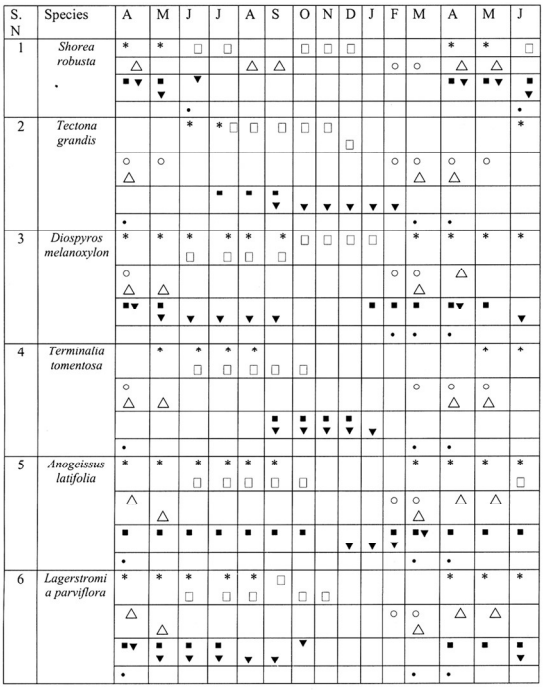


Figure 3. Flowering, fruiting and leafing phenology of 10 tree species as observed during two econsecutive annual cycles in tropical moist deciduous forests at Jagdalpur (CG). Values of April, May and half of June are shown twice to depict the leafless period.

it will continues upto September.

Terminalia tomentosa. The deciduous *terminalia tomentosa* species occurred at the end of leaf flushing (on growing shoots). Leaf flushing, leaf fall synchronizing from February to April (summer season). However flowering and fruiting is in winter season (August—December). Leaf intiation may take place in summer season and this will continues up to rainy season.

Anogeissus latifolia. Autumn flowering in deciduous *anogeissus latifolia* species occurred at the end of leaf flushing (ongoing shoots). Flowering starts from Jan to September, however fruiting may take place from Novemver to February.

Lagerstromia parviflora. The deciduous *lagerstromia parviflora* species coincided with their leaf flushing phenophase. Flowering starts from March to June, however fruiting may take place from May to September. Matured leaf remains in the tree from June to October.

Madhuca indica. The deciduous species *Madhuca indica* flowered in the hot day period on new starts (summer flowering) showing virtual synchronization of leaf flowering, fruiting with leaf flushing. Mature leaf remains in the tree from July to December.

Adina cardiofolia. It is a tropical forest tree species exhibits leaf fall, leaf less, leaf initiation, fruiting synchronizing in the dry season. Mature leaf remains in the tree from May to September. However, flowering starts in winter season (August to November) and fruiting continues from December to March.

Emblica officinalis. It is a middle storied deciduous tree flowering and leaf initiation takes place in summer and mature leaf present in the May to July. Fruiting takes place in July to December.

Cassia fistula. It is a middle storied tropical forest tree species found leaf initiation and flowering in February to April and leaf fall in March—April. Fruiting continues from October to February.

Diversity of flowering and fruiting phenology teak area, Jagdalpur Forest Division is presented in Figures 4 and 5.

Phenological Changes Observed in Teak Forest, Jagdalpur Forest Division (CG)

Shorea robusta. Spring flushing semievergreen *Shorea robusta* began flowering with the onset of leaf fall in winter. Its flowering and fruiting coincided with the leaf transitional state (leaf fall, leaf initiation) in the month of April to June (Figs. 4 and 5).

Tectona grandis. It is a deciduous tree flowered in the month of rainy season (July to September) and leaf flushing occurred in the months of February to May. In the winter season matured leaf and fruiting continued through 4—5 months (September to February).

Diospyros melanoxylon. It is a deciduous species flowered in the hot dry period on new shoots (summer flowering) showing virtual synchronization of leaf flushing with leaf initiation (Jan to April). Fruiting starts from April and it will continues up to sept. Mature leaf remains in the tree for long duration (July to January).

Terminalia tomentosa. The deciduous *terminalia tomentosa* species occurred at the end of leaf flushing (ongoing shoots). Leaf flushing, leaf fall synchronizing from march to May. However flowering and fruiting may taken place in winter season (September to January) and (September to March) respectively. Leaf initiation may takes place in summer season (May—June) and it will continues up to rainy season (August).

Anogessus latifolia. Summer flowering in deciduous *Anogeissus latifolia* species occurred at the end of leaf flushing (ongoing shoots). Flowering starts from February to October, however fruiting is in winter months (December to March). Mature leaf remain in the from June to October.

Lagerstromia parviflora. The deciduous *lagerstromia parviflora* species coincided with their leaf flushing phenophase. Flowering starts from April—July, however fruiting may takes place long duration (June to October). Mature leaf remains in tree from June to December.

Madhuca indica. The deciduous species *Madhuca indica* flowered in the hot day period on new starts (summer flowering) showing virtual synchronization of leaf initiation, flowering, fruiting and leaf flushing. Mature leaf remains in the tree from June to November.

Adina cordifolia. It is a tropical forest tree species, leaf initiation, leaf fall, leafless, synchronizing in the dry season (February to June). Mature leaf present in June to September. However flowering starts in August and it continues up to October (winter sea-

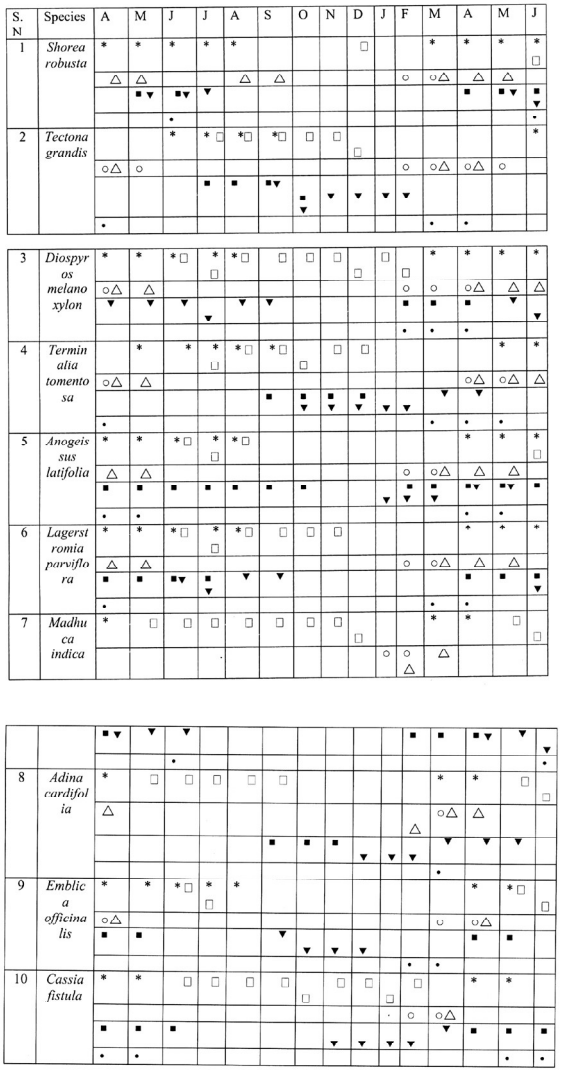


Figure 4. Flowering, fruiting and leafing phenology of 10 tree species as observed during two consecutive annual cycles in tropical moist deciduous forests at Jagdalpur (CG). Values of April, May and half of June are shown twice to clearly depict the leafless period.

son) and fruiting continues from December to March.

Emblica officinnalis. It is a middle storied deciduous tree, flowering and leaf initiation takes place in summer and mature leaf present in May & August. Fruiting may takes place from August to December.

Cassia fistula. It is a middle storied tropical forest tree species shows leaf initiation, leaf fall and flowering in the month of March to May (summer season). Fruiting takes place from October to February. Mature leaf remains in the tree from June to September.

Diversity of flowering and fruiting phenology sal area, Jagdalpur Forest Division (CG) is presented in Figures 6 and 7.

Phenological Changes Observed in Sal Forest, Jagdalpur Forest Division (CG)

Shorea robusta. It is a spring flushing, semi-ev-

ergreen species flowering with the onset of leaf fall in winter. Its flowering (February to May) coincided with the leaf transitional state (leaf fall, leaf initiation) and fruit formation and leaf flushing both were supported at the same time (April—June).

Tectona grandis. It is a deciduous tree flowered in the months of rainy season (July to October) and leaf flushing occurred in March—April (Figs. 6 and 7). In the rainy season matured leaf and flowering seen simultaneously. Similarly fruiting is done in winter season (October—February) for a long duration.

Diospyrous melanoxylon. It is a deciduous species flowered in the hot dry period on new shoots (summer flowering) showing virtual synchronization of leaf flushing with leaf initiation (February to April). Fruiting starts from May and it continues up to September. Mature leaf remains in the tree for long duration (June to February).

Terminalia tomentosa. It is a deciduous tree species occurred at the end of leaf flushing (ongoing shoots). Flowering is in winter season (September to December) where as fruiting starts from October to April. Mature leaf remains in the tree from June to November (rainy to winter season).

Anogeissus latifolia. Summer flowering in deciduous *Anogeissus latifolia* species occurred at the end of leaf flowering (ongoing shoots). Flowering starts from February to October however fruiting may takes place from January to May.

Lagerstromia parviflora. The deciduous *lagerstromia parviflora* species coincided with their leaf flushing phenophase. Flowering starts from April tb and this will continues to July. However fruiting may takes place in june to September. Mature leaf remains in the tree from May to December.

Madhuca indica. The deciduous species *Madhuca indica* flowered in the hot day period on new starts (summer flowering) showing virtual synchronizing of flowering, fruiting and leaf flushing. Mature leaf remains in the tree from May to December.

Adina cardiofolia. It is a tropical forest tree species, leaf initiation, leaf fall, leafless, synchronizing in the dry season (February to June). Mature leaf present in May to September. However flowering starts in September and it continues up to November (winter season) and fruiting continues from December to May.

Emblica officinalis. It is a middle storied deciduous tree flowering, leafless, leaf fall and leaf initiation takes place in summer (April to May). Mature leaf remains in the tree (June to July). However fruiting may takes place in September to December.

Cassia fistula. It is a middle storied tropical forest tree species found leaf initiation, flowering coincided in April to June. Fruiting continues from November to March and mature leaf remains in the tree from June to February.

Discussion

Dry season flowering on leafless shoots during the early part of the dry period may have evolved in response to resource use rate during their short growing period. Water storage in their trunk may enable maintenance of a high stem water potential and flowering during the dry season (1). Predominant summer flowering in the majority of forest tree species (*S. robusta, D. melanoxylon, E. officinalis* and *C. fistula*) of the site reflects the leafless for 1 to 4 months in association with summer leaf flushing seasons to be an unique adaptation to survive under a strongly seasonal climate with a short wet period and a long dry period (2). The proportion of species flowering during the dry period of the year varies widely among tropical deciduous forests bearing differing intensity of drought.

In general large fraction of species flowering during the dry season (85%, December—June) reflects the availability of water required for the growing organs (e.g. through sporadic winter rains, absorption from soil water reserves by leaf exchanging species or using stored stem water in stem succulents.

Deciduousness and Leafing-Flowering Time

Occurrence of leaf flushing (vegetative phase) and flowering (reproductive phase) requires the availability of substantial amounts of resources within the trees. 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 re-

source-use rate during vegetative growth (which depends on the duration of deciduousness) and the time required for fruit development. In the deciduous tree species in the present study, the longer the leafless duration, the more delayed is the initiation of flowering relative to leaf flushing. The leafless period is an adaptation to avoid water stress and water stress affects flowering time in tropical forest tress (3). Increase in leafless period in deciduous species results in reduction in the vegetative growth period and drought stress is not only reflected in terms of leafless period, but is also evident from the greater seasonal separations between the two phases.

The temporal separation of leafing and flowering in tropical deciduous tree species serves as an important adaptation to a strongly seasonal, dry climate, where optimization of vegetative growth during the short growing season may be crucial for tree survival.

Fruiting Durations and Flowering Time

Different flowering types are related to varying durations of fruiting phenophase (summer–flowering species), approx 11 months; rainy species, 7—9 months; autumn species 6—7 months; winter and dry season species 3—4 months. Thus all flowering types complete the fruiting phenophase during late dry season before the onset of the succeeding rainy season ensuring that some, if not all, seeds are available for germination when the soil is sufficiently moist. Fruit maturation and suitable condition for dispersal are closely synchronized in tropical dry forest because of the pronounced differences of biotic and abiotic conditions between dry and rainy seasons (4).

Different species flowering in different seasonal exhibited varying fruiting duration. Formation of fruits continued through 2—3 months following the peak flowering time in different species. However, the time required for fruit maturation varied considerably with species.

Winer Flowering. Ecotone, sal and teak site : *Tectona grandis* showed 3—4 month long fruiting phenophase. Among other deciduous species *Diospyrous melanoxylon* which flowers in summer before the onset of rains, showed the longest fruiting phenophase (in other deciduous species flowering in succeeding season fruiting duration was invariably shortened. *Terminalia tomentosa* (2—3 months and *Anogeissous latifolia* (2—3 months).

Rainy Season. Ecotone, sal and teak site : *Lagerstromia parviflora* and *Adina cordifolia* showed a 7—9 months long flowering and fruiting phenophase.

Autumn Flowering. Ecotone, sal and teak site : *Anogeissus latifoliaand terminalia tomentosa* showed 5—8 months of fruiting.

Dry season. Ecotone, sal and reak site : Dry season flowering of *Shorea robusta, Emblica officinalis* and *Cassia fistula* in sal and ecotone site takes place in April to May, however in teak site the same may starts from March onward. Fruiting extended through 3—4 months of the fruiting phenophase (excepting *Lagerstromea* 6 months). Generally fruit fall was completed in the April—June period.

Possible Climate Change Impact

The importance of understanding the determination of phenological patterns has been emphasized to predict responses of specific communities to global climatic change (5). Trends of erratic precipitation and increasing temperature are likely to alter the length of the growing season, by affecting the timing of leaf flush and leaf fall, to various extents in different functional types. The competition among species is likely to become modified, if their phenological behavior differs in sensitively to the environment conditions (6). The timing of flowering will vary greatly according to the onset of the rainy season (earlier or delayed) this will affect their reproductive success.

Introduction of New Species (Indicator Species)

In ecotone area of Jagdalpur few new species viz. *Litsea* sp. (Maida), *Dalbergia latifolia* (Shisam), *Terminalia chebula* (Harra), *Holarrhena antidysentrica* (Kirich) and *Sterculia urens* (Kulu) have been observed and identified. These species are not found in sal and teak forest of the studied sites. These species are identified as indicator species of this site because these species are uncommon for teak and sal forest and found in only ecotone

areas of sites. The presence of new species also reflects some microclimatic changes occurring in the ecotone zone.

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