Tropical Ecology **56**(3): 393-399, 2015 ISSN 0564-3295

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Phenology and population structure of six tree species in tropical forest of Assam, northeast India

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Abstract: The present paper deals with phenology, population structure and regeneration status of six important tropical tree species namely, *Bauhinia variegata, Careya arborea*, *Dillenia pentagyna*, *Sterculia colorata*, *Sterculia villosa* and *Terminalia belerica*. The study was carried out in two forests of Assam, India, namely Lumding Reserve Forest and Doboka Reserve Forest. Phenophases like- leaf fall, leaf initiation, flowering and fruiting were recorded monthly for one year. Phenophases depend on environmental/meteorological conditions of the study area and were species specific. Cool and dry winter period is largely associated with leaf fall of all the selected species, however, *Bauhinia variegata* and *Terminalia belerica* showed fruiting during this period. *Bauhinia variegata*, *Careya arborea, Terminalia belerica* and *Sterculia villosa* showed expanding population. All the six species indicated either 'good regeneration' or 'fair regeneration'.

Resumen: El presente artículo trata sobre la fenología, la estructura poblacional y el estado de regeneración de seis especies importantes de árboles tropicales: *Bauhinia variegata, Careya arborea, Dillenia pentagyna, Sterculia colorata, Sterculia villosa* y *Terminalia belerica.* El estudio se llevó a cabo en dos bosques de Assam, India: la Reserva Forestal Lumding y la Reserva Forestal Doboka. Las fenofases como la caída de las hojas, la iniciación de las hojas, la floración y la fructificación se registraron mensualmente durante un año. Las fenofases dependieron de las condiciones ambientales/meteorológicas de la zona de estudio y fueron específicas de la especie. El período invernal fresco y seco se asocia en gran medida con la caída de las hojas de todas las especies seleccionadas; sin embargo, *Bauhinia variegata* y *Terminali abelerica* fructificaron durante dicho período. *Bauhinia variegata*, *Careya arborea*, *Terminali abelerica* y *Sterculia villosa* mostraron poblaciones en expansión. Las seis especies mostraron 'regeneración buena' o 'regeneración regular'.

Resumo: O presente artigo trata da fenologia, estrutura populacional e estado de regeneração de seis importantes espécies arbóreas tropicais: a *Bauhinia variegata*, a *Careya arborea*, a *Dillenia pentagyna*, a *Sterculia colorata*, a *Sterculia villosa* e a *Terminalia belerica.* O estudo foi realizado em duas florestas de Assam, na Índia, ou seja, a Reserva Florestal de Lumding e a Reserva Florestal de Doboka. As fenofases como queda de folhas, iniciação foliar, floração e frutificação foram registadas mensalmente durante um ano. As fenofases dependem das condições ambientais/meteorológicas da área de estudo e foram específicas para cada espécie. O período frio e seco de inverno é amplamente associado com a queda das folhas de todas as espécies selecionadas, no entanto, a *Bauhinia variegata* e a *Terminalia belericaa* presentaram frutificação durante este período. A *Bauhinia variegata*, a *Careya arborea*, a *Terminalia belerica* e a *Sterculia villosa* mostraram uma população em expansão. Todas as seis espécies revelaram ou 'boa regeneração"ou "regeneração razoável ".

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Key words: Leaf fall, leaf initiation, flowering, fruiting, population structure.

Phenology is the study of periodicity or timing of recurring biological events, and explains the relationship between climatic factors and periodic phenomena in organisms (Moza & Bhatnagar 2005; Sakai 2001; Yadav & Yadav 2008). Phenological patterns are basic for understanding biological processes and functioning of tropical trees and ecosystems (Tesfaye *et al.* 2011). Seasonal duration of leafing, flowering and fruiting mainly determines the phenological behaviour of tropical trees, and directly or indirectly their population dynamics.

Population structure of a species is characterized by the proportion of seedlings, saplings and young trees (Saxena & Singh 1984). Knowledge of population structure and regeneration status of forest communities is important for formulating strategy for the maintenance of forests (Saikia & Khan 2013; Khumbongmayum *et al.* 2006).

We investigated the population structure, regeneration status and phenology of the six selected species namely, *Bauhinia variegata* L. (Caesalpinaceae), *Careya arborea* Roxb. (Lacythidaceae), *Dillenia pentagyna* Roxb. (Dilleniaceae), *Sterculia colorata* Roxb. (Sterculiaceae), *Sterculia villosa* Roxb. (Sterculiaceae) and *Terminalia belerica* Roxb. (Combretaceae). The study was carried out for a period of one year during January 2010 to December 2010 in two reserve forests of Assam, namely, Lumding Reserve Forest (93°0′0″- 93°15′0″ E longitude, 25°45′0″- 25°52′0″ N latitude) and Doboka Reserve Forest (longitudes 92°46′0″- 92°57′0″ E, latitudes 26°6′0″ - 26°13′0″ N) (Fig. 1). The Lumding and Doboka Reserve Forest cover an area of 26,004.13 ha and 12,251.23 ha, respectively and are situated at an altitude of 128 m and 106 m above msl, respectively. Variations in monthly rainfall and temperature during the study period were recorded from Lumding station (Fig. 2). Climatic condition of the study areas is broadly characterized in three seasons: cool-dry winter (November to February), dry-summer period (March to April) and hot-rainy summer which extends from May to October.

For phenological observations 60 individuals were tagged having ten adult individuals of each selected tree species. Individuals of tagged tree species were > 5 to 7 m in height and > 30 to 40 cm GBH (girth at breast height). For each tagged individual, personal visual/morphological observations were carried out monthly for leaf drop, leaf initiation, flowering and fruiting following Opler *et al.* (1980).

Population structure and regeneration status of the selected six tree species was studied with the help of GBH size class-density distribution curve. For this purpose, 100 quadrats, each of 10 × 10 m size, and equally distributed among the two sites, were laid following stratified random sampling method. Individuals of the selected species encountered within the quadrats having girth 0-10 cm at the base were considered as seedlings, >10-30 cm as saplings and >30 cm GBH as adult trees. Based on population size of seedlings, saplings and adults, the regeneration status of species was also determined as good, poor, fair, not regenerating and new. "Good regeneration" refer if seedlings > saplings > adults; 'fair regeneration' if seedlings > or ≤ saplings ≤ adults; 'poor regeneration' if the species survives only in sapling stage, but no seedling (sapling may be <, > or = adults). If a species is present, only in adult form it is considered as 'not regenerating'. Species is considered as 'new' or 'newly colonized' if the species is found only either in seedling or sapling stage without any adults (Bhuyan *et al.* 2003; Khan *et al.* 1987; Khumbongmayum *et al.* 2006; Shankar 2001).

It was observed that leaf fall of *B. variegata* and *D. pentagyna* begins from January/February and continued until April. *T. belerica* and *S. colorata* also shed their leaves from January and continued doing so until March. For *S. villosa* events of leaf shed were recorded from December to April while for *C. arborea* leaf fall started in November and continued until March (Table 1). Complete leaf less period of the selected species was one to two months (during February and March). All the six species shed their leaves during the cool and dry period of the year. Leaf fall during the dry-cold period is largely due to the effect of water stress on the morpho-physiological activities of the plants. Water stress can induce leaf fall by decreasing the water potential of leaf during the dry season and leaf fall is an adaptation to reduce the effect of water shortage (Borchert *et al.* 2002; Reich & Borchert 1982; Tesfaye *et al.* 2011).

Leaf initiation in *T. bellirica*, *S. colorata* and *C. arborea* started in April and in *B. variegata*, *S. villosa* and *D. pentagyna* during May (Table 1). Leafing is initiated during dry-summer period and

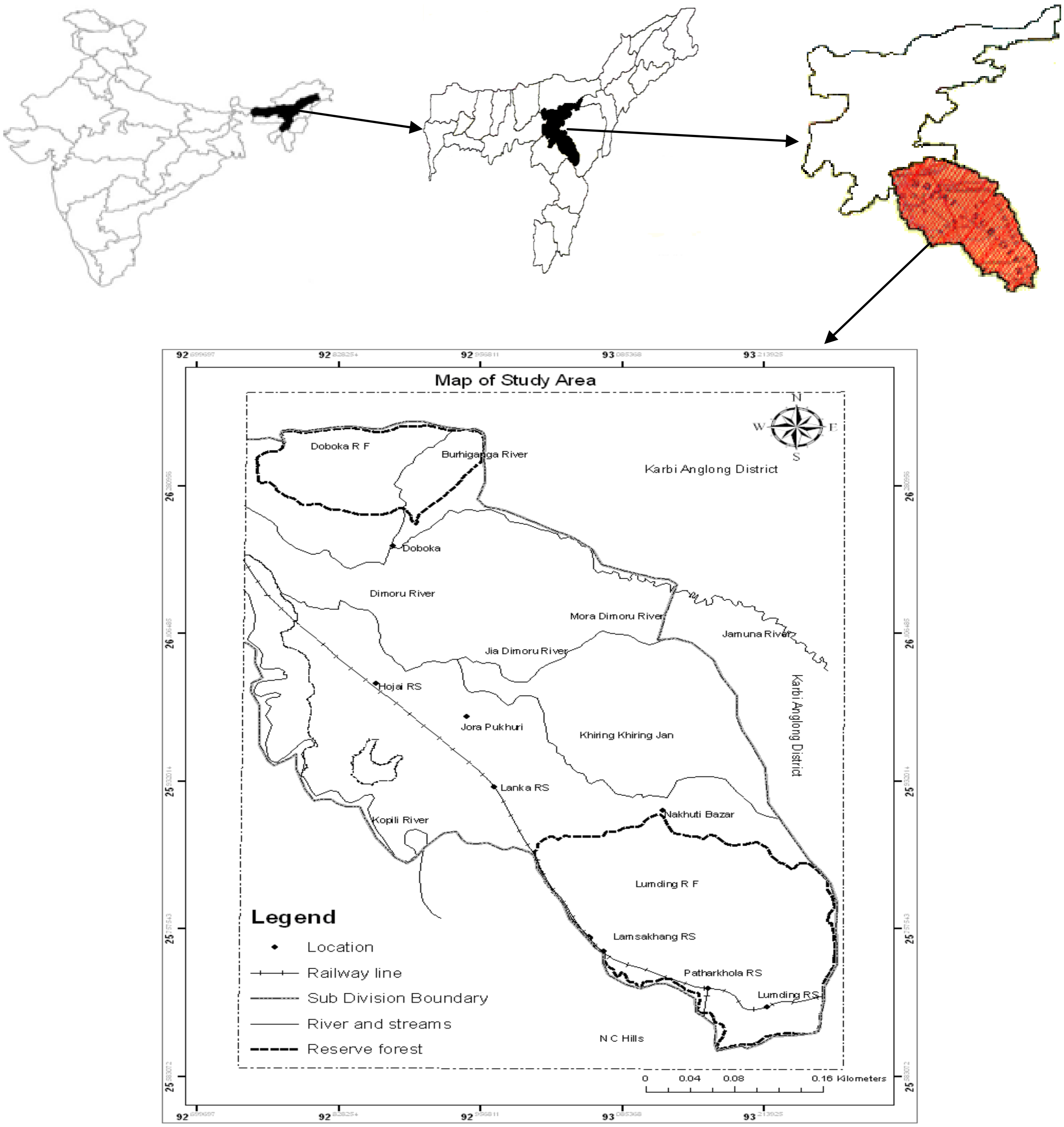

Fig. 1. Map of Nagaon South forest division showing the study sites, Lumding and Doboka Reserve Forest.

is continued up to hot rainy summer season in all the selected species. The leaf initiation during dry season and after the dry season for few tropical tree species is also reported from Western Ghats, India (Sundarapandian *et al.* 2005). Many researchers (Frankie *et al.* 1974; Shukla & Ramakrishnan 1982; Singh & Kushwaha 2006; Singh & Singh 1992) have reported leaf initiation during dry season before rains. But a few cases of leaf initiation during wet season have also been observed in many studies (Bullock & Solis-Magallenus 1990; Lieberman & Lieberman 1984). Elliot *et al.* (2006) and Yadav & Yadav (2008) also supported that few species strongly relate with rainfall for their leaf developmental activity. Water is an essential component for leaf initiation

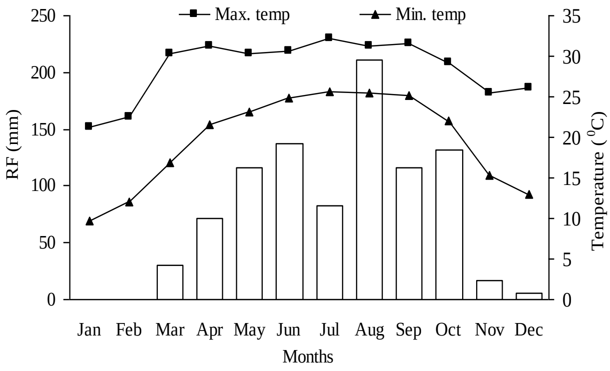

Fig. 2. Total monthly rainfall (RF), mean monthly maximum temperature (Max. temp) and minimum temperature (Min. temp) of the study sites recorded during study period.

and those species, which can produce new leaves during the dry season, depend on water stored in the tree stem or water remaining in the subsoil (Sayer & Newbery 2003). Moreover, deep rooting canopy trees do not experience a water deficit condition during dry season and can continue leaf-flushing activity (Steinberg *et al.* 1989).

Most of the selected species flowered during the late dry and early wet season. Flowering of *B. variegata* was observed in October and November, for *T. belerica* in April that prevailed up to June, for both *C. arborea* and *D. pentagyna* flowering occurred in March/April (Table 1). Both *S. villosa* and *S. colorata* produced flowers during leafless phase (February and March). In both species of *Sterculia*, flower initiation occurred during dry season, this is in conformity with the report of Yadav & Yadav (2008) for dry deciduous forest trees. Flowering during the dry season reflects the availability of water by different sources, for example, through sporadic winter rains, absorption from soil and water stored in stem (Singh & Kushwaha 2006). Some other workers also reported peak flowering period before rainy season (Boojh & Ramakrishnan 1981; Kikim & Yadava 2001; Singh & Singh 1992), and it has been argued that moisture, temperature and photoperiod seem to be responsible for flowering (Frankie *et al.* 1974; Lawton & Akpan 1968; Murali & Sukumar 1993; Pandey *et al.* 2002; Wright & van Schaik 1994; Yadav & Yadav 2008).

B. variegata, C. arborea, S. colorata and *S. villosa* show 'rapid' fruit maturation. 'Rapid' fruiting period for *B. variegata* and *C. arborea* was recorded during December to January and May to June, respectively. But for *S. villosa* and *S. colorata* it was recorded from March to May/June (Table 1). *T. belerica* and *D. pentagyna* show 'lengthy' fruit maturation period extending up to five months from October to February and March to July, respectively. In *S. villosa*, *S. colorata* and *D. pentagyna* initiation of fruiting was recorded along with flowering and in *B. variegata*, *C. arborea* and *T. belerica* fruiting was recorded after completion of flowering phase. Initiation of fruiting mostly depends upon the timing and period of flowering rather than climatic parameters like rainfall and temperature. But fruit ripening and the length of fruiting period are dependent on temperature and photo-period (Pandey *et al.* 2002). In dry tropical trees the duration of fruiting phenophase depends at least to some extent on the time of flowering and the leafless period during the annual cycle (Singh & Kushwaha 2006). *T. belerica* and *B. variegata* prefer dry season while *S. villosa*, *D. pentagyna* and *C. arborea* prefer hot-rainy summer season for fruiting/fruit maturation. Therefore, most of the species have seeds with winter dormancy which germinate when favourable warm rainy season starts (Boojh & Ramakrishnan 1981; Bullock & Solis-Magallenus 1990; Kikim & Yadava 2001; Ralhan *et al.* 1982).

All the species, except for *S. colorata* and *D. pentagyna*, showed higher population size in lower girth classes (Table 2). *B. variegata* recorded highest adult population size (38 individuals ha^{-1}) while saplings of *S. colorata* were absent in study sites. Population structure depending on size-class distribution of the six species is given in Fig. 3. Number of seedlings of *B. variegata*, *C arborea*, *S. villosa* and *T. belerica* were higher than those of saplings and adults, indicate an evolving or expanding population structure (Sahu *et al.* 2012). *D. pentagyna* reveals a critical situation of seedling to sapling conversion in the prevailing environmental conditions representing more or less equal number of seedling (21 individuals ha^{-1}) and adult populations (25 individuals ha^{-1}). *S. colorata* having a lower number of seedlings and absence of saplings might reflect adverse influence of disturbance inhibiting the survival and growth of young individuals. For adult population, the highest basal area was recorded for *D. pentagyna* (4.77 m^2 ha^{-1}) followed by *C. arborea* (3.41 m^2 ha^{-1}) and lowest in *S. villosa* (0.63 m^2 ha^{-1}).

T. belerica and *C. arborea* exhibited 'good regeneration' showing a population size of seedlings > saplings > adults while *D. pentagyna*, *B. variegata*, *S. colorata*, and *S. villosa* showed 'fair regeneration' exhibiting density of seedlings >

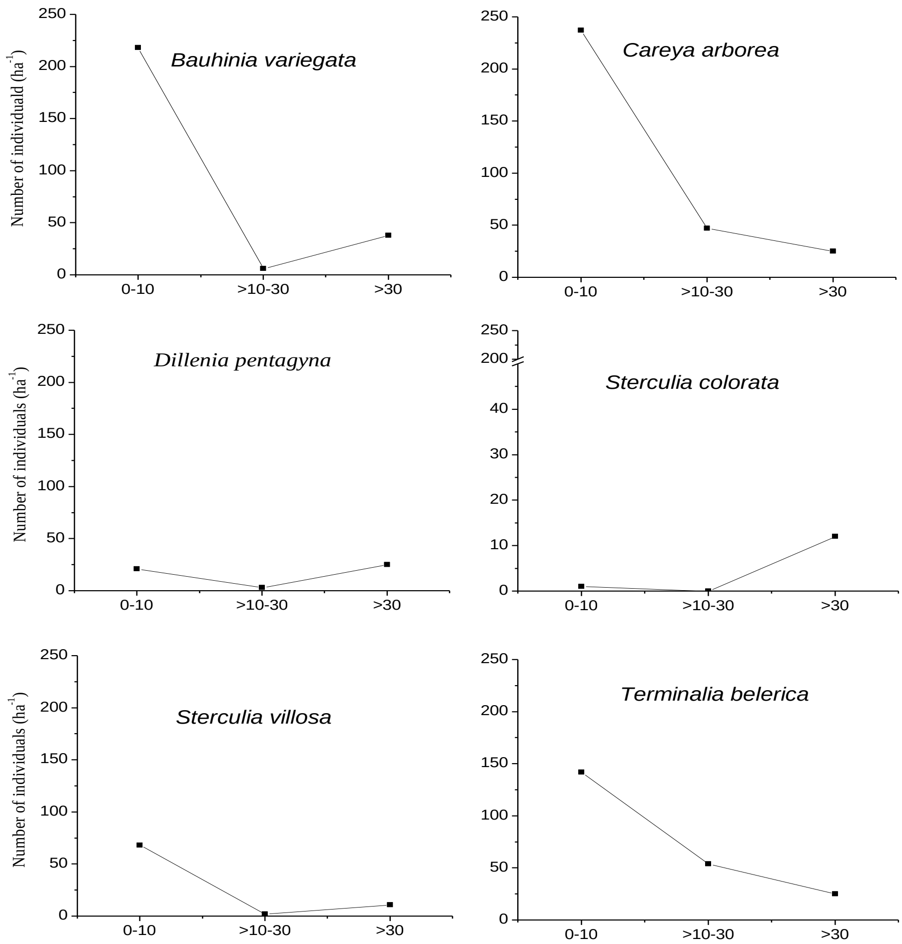

Fig. 3. Density-diameter curve of the selected tree species in both the study sites.

Table 1. Flowering, fruiting and leafing phenology of selected tree species recorded in both the study sites.

	Bauhinia variegata	*Careya arborea*	*Dillenia pentagyna*	*Sterculia colorata*	*Sterculia villosa*	*Terminalia belerica*
January	LF,FR	LF	LF	LF	LF	LF,FR
February	LF	LF	LF	LF,FL	LF,FL	LF,FR
March	LF	LF	LF,FL,FR	LF,FL,FR	LF,FL,FR	LF
April	LF	LI,FL	LF,FL,FR	LI,FR	LF,FR	LI,FL
May	LI	FR	LI,FR	FR	LI,FR	FL
June	-	FR	LI,FR	-	LI,FR	FL
July	-	-	FR	-	-	-
August	-	-	-	-	-	-
September	-	-	-	-	-	-
October	FL	-	-	-	-	FR
November	FL	LF	-	-	-	FR
December	FR	LF	-	-	LF	FR

Note: LF=Leaf fall, LI=Leaf initiation, FL=Flowering, FR=Fruiting.

Table 2. Density (ha^{-1}) and basal area ($m^2\ ha^{-1}$) of the selected tree species recorded in both the study sites.

Name of species	Seedling		Sapling		Adult	
	Density	Basal area (± SD)	Density	Basal area (± SD)	Density	Basal area (± SD)
Bauhinia variegata	218	0.016 (± 0.0001)	6	0.014 (± 0.002)	38	2.44 (± 0.067)
Careya arborea	237	0.03 (± 0.002)	47	0.128 (± 0.002)	25	3.41 (± 0.14)
Dillenia pentagyna	21	0.002 (0)	3	0.009 (± 0.002)	25	4.77 (± 0.13)
Sterculia colorata	1	0.00007 (0)	0	0	12	1.96 (± 0.13)
Sterculia villosa	68	0.009 (± 0.0001)	2	0.004 (± 0.001)	11	0.63 (± 0.08)
Terminalia belerica	142	0.013 (± 0.0002)	54	0.0137 (± 0.001)	25	1.26 (± 0.077)

saplings < adults. Absence of saplings of *S. colorata* may be due to site specific and failure of establishment and development of seedlings induced by disturbance.

Species having lower population size of higher girth classes require investigation of the underlying factors, and survival and growth of existing seedlings and saplings need proper protection and conservation for successful development upto adult stage.

Acknowledgements

We highly acknowledge Prof. N. P. Todaria for his valuable suggestions and comments to improve the quality of the manuscript. We sincerely acknowledge the D.F.O of Nagaon South Forest Division for his kind permission to work in Lumding and Doboka Reserve Forest. We are extremely grateful to Mr. Dilip Dutta for his constant support during field visit. Thanks are also due to the forest guards of Doboka and Udali beat office for accompanying us during field visits. The first author is a recipient of UGC fellowship and hence it is duly acknowledged.

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(Received on 25.09.2012 and accepted after revisions, on 11.11.2013)