

Flowering and Fruiting Phenology of Some Forest Plant Species in the Remnants of *Combretum - Terminalia* Woodlands of Western Ethiopia

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Abstract

Phenological background information for *Combretum-Terminalia* wood land species is limited in particular from lower altitudes. Flowering and fruiting phenology was monitored for 24 plant species ranging between 610-1580 m.a.s.l. of the Benishangul Gumuz Regional State North West Ethiopia. The dates of first flowering, peak flowering, end of flowering, first fruiting, peak fruiting and flowering period were recorded. There was a wide variation in onset of flowering, long flowering duration, a relative synchrony between the onset of flowering and fruiting. These results suggest that the species have evolved various phenological strategies as adaptations to the short growing season with limited resources and pollinators in this harsh environment at extremely lower elevations. With a background of climate change, local plant species will represent an advancing trend in onset of flowering and fruiting.

Keywords: Adaptation; *Combretum-Terminalia*; Climate Change; Phenology; Pollinators

Introduction

Studies of tropical rain forests suggest that phenological patterns of trees are driven by a variety of factors including: abiotic characters such as rainfall, irradiance, and temperature; mode of seed dispersal; activity of pollinators or seed dispersers; variation in germination conditions; canopy position and relative abundance of the trees themselves [50]. The timing of various phenological activities such as germination, bud break, flowering, fruit dehiscence, and leaf drop is important for survival and reproductive success of many plant species. Abiotic environmental conditions such as rain change in temperature, presence/absence of pollinators, competitors, and herbivores have been shown to play a significant role in timing of various phenological events [1-6]. Natural selection has also been considered to play some role in determining the phenological patterns of plant species [7]. Phenological studies are also important in understanding species interrelations and their interaction with the environment. Variations in phenophases among individuals of the same species or different species have been linked to environmental perturbations [8].

An understanding of the phenological patterns in different geographical regions and of factors underlying these patterns is important for a number of reasons. First, frugivores are the dominant group of vertebrates in most tropical forests and regional differences in their abundance may be caused by differences in food availability. Second, an understanding of phenological patterns and factors underlying these patterns will assist conservation scientists in predicting consequences of perturbations such as atypi-

cal climatic events or global warming. Third, phenological patterns are linked to many processes governing forest function and structure including: population biology of pollinators, dispersers, seed predators, and herbivores, interspecific competition among trees, and processes of primary production. Thus, an understanding of what governs phenological process is valuable in understanding forest function and structure and in providing the basis for developing management options [51].

Considerable amount of phenological data is available on different plant species from different parts of the world including tropical savanna and semi-deciduous forest of Venezuelan llanos (South America) [9], dry tropical forest in Ghana [10], NE Spain [11-13], Panama [14], Mexico [15], tropical rain forest in Malaya [16], semi-arid grassland in the Rock mountain, USA [17], and tibetan plateau [18].

A number of studies on phenology of different plant species from different parts of the world have also been undertaken which include those from a subtropical humid forest in North-Eastern India [19,20], Kumaun Himalayan forests [21, 22], deciduous forest of Bandipur in peninsular India [23], Shervaroy, Southern India [24], tropical moist forest of Western Ghats in Karnataka [25], Hathinala Forest in Uttar Pradesh [26], alpine expanse of North-West Himalaya [27], Orissa coast [28], tropical montane forests in the Nilgiris [8], Kolhapur region (Maharashtra) [29], and Katarniaghat wildlife sanctuary situated in the Himalayan Terai region in Uttar Pradesh [30], Northeastern India [31]. However, studies on phenology of

broad and deciduous leaf plants of *Combretum-Terminalia* woodland was minimal. Therefore, the present paper deals with phenological observations of twenty four leguminous plants growing at eight different sites in Benishangul Gumuz Regional State over a period of two years from 2017 till 2018/19 as these sites represent most of the plant diversity of this region.

Materials and Methods

Site description

The assessment area that is the Northwestern Ethiopia speciality of Benishangul-Gumuz Region, which is situated within 11° 00' 0.00" N Latitude and 35° 44' 59.99" E Longitude (Figure 1). The region is well described by *Combretum-Terminalia* vegetation which is also center of endemism to some important trees and lilies. *Combretum-Terminalia* woodland or wooded grassland is a vegetation type with an open over storey that is dominated by *Combretum molle* (10 - 13 m) and *Terminalia mollis* (15 -17 m). This vegetation type is a fire climax community that has replaced dry evergreen forest on ridges and upper slopes in the western and northwestern part of Ethiopia [48]. *Combretum molle* woodland is probably a fire induced vegetation type that has replaced evergreen bush land (Be) or scrub forest on wetter upland areas. "Ethiopian undifferentiated woodland" is virtually equivalent to *Combretum-Terminalia* woodland and wooded grassland described in the atlas of potential natural vegetation types of Ethiopia [48,49].

Different sampling sites, that is, Mandura, Dangur, Guba, Sherkole, Homosha, Kurmuk, Assosa and Bambasi woredas' were selected for data collection. These sites were chosen as they represent most of the plant diversity of Benishangul Gumuz Regional State (BGRS). Figure 1 shows the location of eight sites on the map of BGRS.

Figure 1: Map of the assessment area.

Climate

The area is known in its uni-modal rain fall pattern with a long rainy season from May to October. The period from November to April is relatively dry. The mean annual temperature is 24°C (Figure 2, Figure 3). The soils are young and of volcanic origin, characterized by sandy or sandy loam, and it is shallow at steep convex slopes and at lower altitudes [47].

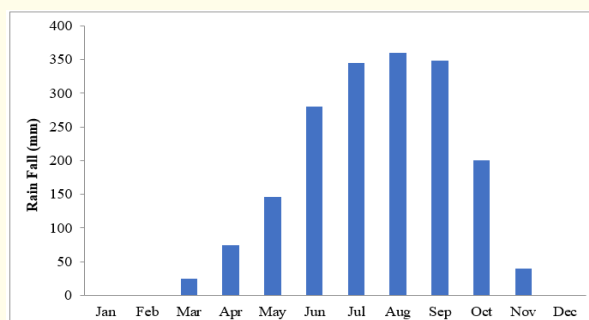


Figure 2: Mean monthly rainfall in mm for Benishangul Gumuz Regional State.

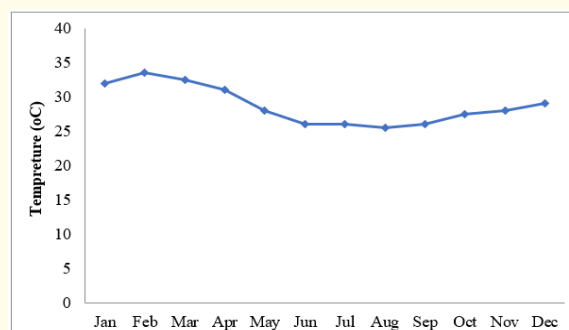


Figure 3: Mean maximum and minimum temperatures in °C for Benishangul Gumuz Regional State.

Phenological data

The data for each species was collected from a minimum of two sampling sites. At each site, one mature and healthy plant from the population of that species was fixed as reference for the study. The observations were made on the marked plant and 10-15 of its closest neighbours (minimum 6 plants if more plants were not available for a particular plant species at a particular site) for a period of 2 years starting from September 2017 up to December, 2018/19.

The areas with the plants under study were visited quarterly to record presence/absence of different phenological events or phenophases: flowering (FL), and fruit setting (FR). The information for the initial date and the last date when these various phenophases were observed was recorded.

A phenophase was considered to be active in the population just when it was observed in at least 5% of the crown in a minimum of 20% of the studied plants [12]. Phenophase calendars for each species were prepared and were studied for the interpretation of the overall results.

Results

A total of 24 plant species classified under 11 families were identified and documented in the study area. Families Fabaceae and Combretaceae ranked first and second with their total species number 13 and 2 in the same order (Table 1, Figure 4).

Name of Plant	Phenophase	Months											
		Sept	Oct	Nov	Dec	Jan	Fab	Mar	Apr	May	Jun	Jul	Aug
<i>Acacia polyacantha</i>	Flowering	Yellow									Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red								
<i>Acacia senegal</i>	Flowering		Yellow	Yellow	Yellow								
	Fruiting			Red	Red	Red	Red	Red					
<i>Acacia seyal</i>	Flowering	Yellow	Yellow	Yellow									
	Fruiting		Red	Red	Red	Red							
<i>Annona senegalensis</i>	Flowering							Yellow	Yellow	Yellow	Yellow		
	Fruiting	Red									Red	Red	Red
<i>Anogeissus leiocarpa</i>	Flowering									Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red									Red
<i>Balanitesaegyptiaca</i>	Flowering						Yellow	Yellow	Yellow	Yellow	Yellow		
	Fruiting	Red	Red	Red	Red						Red	Red	Red
<i>Boswelliapapyrifera</i>	Flowering	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow						
	Fruiting			Red	Red	Red	Red	Red	Red				
<i>Cassia arereh</i>	Flowering									Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red	Red							Red
<i>Cordia africana</i>	Flowering	Yellow	Yellow	Yellow	Yellow								
	Fruiting				Red	Red	Red	Red	Red	Red			
<i>Dalbergia melanoxyylon</i>	Flowering									Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red								Red
<i>Dichrostachys cinerea</i>	Flowering	Yellow	Yellow	Yellow							Yellow	Yellow	Yellow
	Fruiting		Red	Red	Red	Red	Red	Red					
<i>Entadaafricana</i>	Flowering	Yellow	Yellow	Yellow								Yellow	Yellow
	Fruiting	Red	Red	Red	Red								Red
<i>Erythrina abyssinica</i>	Flowering		Yellow	Yellow	Yellow	Yellow							
	Fruiting				Red	Red	Red	Red	Red				
<i>Gardenia ternifolia</i>	Flowering	Yellow	Yellow	Yellow	Yellow						Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red	Red							
<i>Securidaca longepedunculata</i>	Flowering								Yellow	Yellow	Yellow	Yellow	
	Fruiting	Red	Red	Red	Red							Red	
<i>Senna obtusifolia</i>	Flowering	Yellow	Yellow										
	Fruiting		Red	Red	Red								
<i>Senna occidentalis</i>	Flowering	Yellow	Yellow							Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red									
<i>Sterculia africana</i>	Flowering	Yellow								Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red	Red	Red	Red					
<i>Strychnos innocua</i>	Flowering	Yellow								Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red	Red							
<i>Tamarindes indica</i>	Flowering								Yellow	Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red	Red	Red	Red					Red
<i>Terminalia laxiflora</i>	Flowering									Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red	Red	Red						
<i>Vitex doniana</i>	Flowering	Yellow								Yellow	Yellow	Yellow	Yellow
	Fruiting	Red	Red	Red	Red								
<i>Ziziphus abyssinica</i>	Flowering	Yellow	Yellow	Yellow									Yellow
	Fruiting	Red	Red	Red	Red								
<i>Ziziphus mucronata</i>	Flowering	Yellow	Yellow										Yellow
	Fruiting	Red	Red	Red									

Table 1. Phenological diagrams of twenty four plant species belonging to eleven families. The yellow and redish colored bars indicate the whole period of appearance of different phenophases including flowering and fruiting.

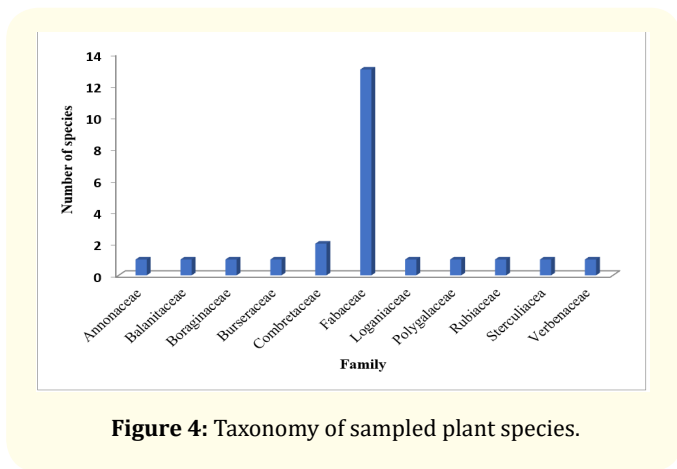


Figure 4: Taxonomy of sampled plant species.

This figure 4 reveals that percentage of plant species exhibiting each phenophase, that is, flowers, and fruits, showed almost a similar trend for years within each phenophase. Flower formation showed a peak in the beginning of summer (60%) and another small peak during mid of winter and was almost evenly distributed through the rest of the year. Opposite trend was observed for fruiting which also showed a peak (66.67%) at the end of summer and another small peak (53.33%) during mid of summer period for all the years. Maximum percentage of plant species showing fruiting was observed in the months of October, December, and January (60%) (Figure 5, Figure 6) which resulted in maximum seed set following these months. Comparison of results on observations of flowering in different plant species during the years recorded, reveals that maximum percentage of plant species (66.67%) showing flowering was observed in the month of October, June and July during 2018/19.

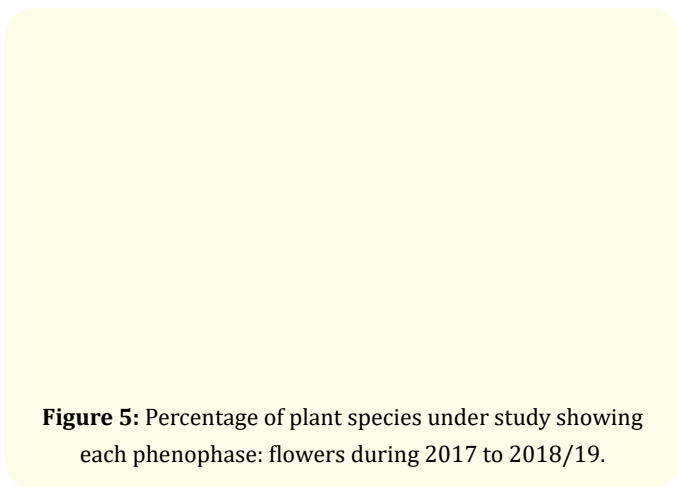


Figure 5: Percentage of plant species under study showing each phenophase: flowers during 2017 to 2018/19.

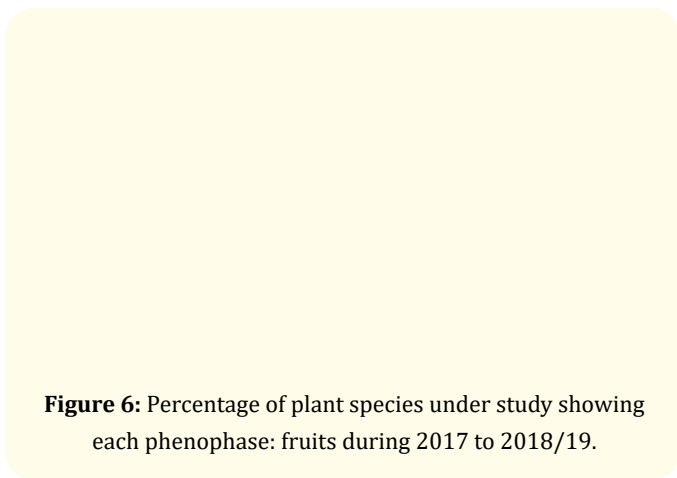


Figure 6: Percentage of plant species under study showing each phenophase: fruits during 2017 to 2018/19.

Figure 7 also shows phenological patterns of individual plant species studied. For each plant species, the whole period of appearance of different phenophases-like flowering, and fruiting, has been indicated for two consecutive years. The study reveals high phenological diversity for different phenophases studied among twenty four plant species. Moreover, for individuals of the same species, there was a significant difference in the appearance of different phenophases across different geographic ranges.

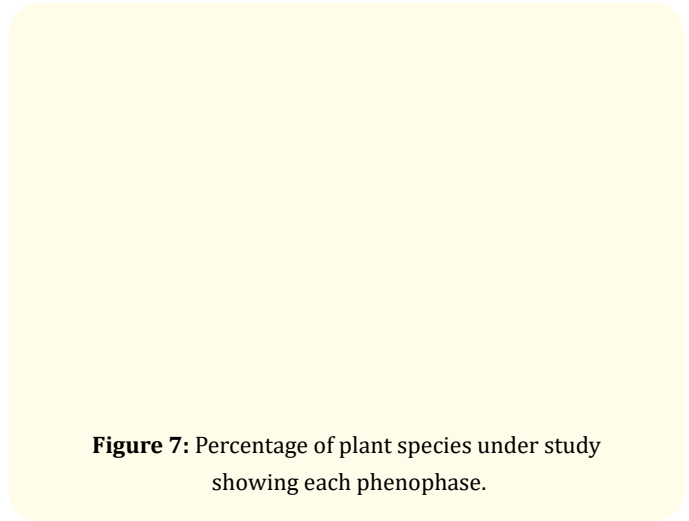


Figure 7: Percentage of plant species under study showing each phenophase.

Discussion

Our study reveals high phenological diversity for the two phenological patterns (flowers and fruits) among twenty four plant species growing in Western Ethiopia under similar environmental conditions for the two consecutive years, that is, 2017 and 2018/19. Changes in plant phenological patterns have been associated with the species specific plant structural architecture, availability and transfer of nutrients [33], plant growth rates [34], temperature [35], and water [36].

A comparison of observations on flowering time for the two years under study reveals an advancement of flowering time by about 2-4 weeks in the year 2018 for some species like *Acacia senegal*, *Acacia seyal*, *Dalbergia melanoxylon*, *Entada africana*., and *Ziziphus mucronata* as compared to that observed in 2017. This change in phenological shift can be attributed to increase in temperature in 2018 as compared to that reported for 2017. The total length of flowering period was extended by 2-4 weeks in 2018-19 as compared to 2017 for some species.

Some other studies have also demonstrated an association of advancement in flowering date with climate change. One study has reported an increase in the mean terrestrial surface temperature by more than 0.2oC per decade ever since 1970 [37]. A number of other studies have shown an advancement of phenological events as a result of increase in temperature [38-41]. With the increase in the temperature, most of the species showed earlier flowering time period [39] and even increase in their time period of flowering (e.g., *Bauhinia variegata* Linn., *Prosopis juliflora* DC.). Similarly early flowering was observed for 24 out of the 32 plant species studied in semiarid grassland by Lesica and Kittelson [17].

The period of maximum activity of the flowering period (started at the beginning of summer and extended to the beginning of autumn) coincided with the observations of Pilar and Gabriel [12, 32]. Flower development dates have been shown to be synchronous among individuals of the same plant species studied which seems to be important in increasing the chances of outcross pollinations as suggested by Ollerton and Lack [42].

These changes in the phenological patterns can result in adverse effects on insect pollinators as well as herbivores (if the plant species is present in barren or wild areas) that depend on those species for food [43, 44]. The changes in phenological patterns of plant's response to different temperature and rainfall availability have been shown to be species specific [45, 46]. Hence changes in vegetation community species composition might also be responsible for changes in the phenology of the studied plants. The present study reveals that different plants of the same family (Leguminosae) flower at different times during the same year growing at same location under similar environmental conditions which can be attributed to species-specific plant structural architecture.

Conclusion

The present study reveals high phenological diversity for two different phenophases among twenty four plant species growing in western Ethiopia with tropical dry deciduous type of vegetation. This study would be of great help in knowing the timing of different phenophases of the studied plants which can be of interest to Ethiopian Biodiversity Institute and people of this region (or where similar climatic conditions prevail) who wish to plan for conservation of the species and wish to have flowers in their gardens round the year. So, they can select plants which flower during different parts of the year. This type of study can provide important insights into the biology of the plants concerned and reveal phenological pattern of surveyed species. This study would also be of great help for comparison over long duration of time. For example, to see if there is any change in the phenological patterns of the same plant species in next 10 or so years. Such comparative study could not be possible at this time since no relevant literature is available for this region.

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