



Phenology of *Cariniana pyriformis* in the Magdalena Medio region of Santander, northeastern Colombia

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Abstract - During one year the phenology of the Colombian mahogany (*Cariniana pyriformis* Miers), a native forest species, was registered in a rural area of the municipality of El Carmen de Chucuri, department of Santander, northeastern Colombia. Flowering showed a peak at the end of the rainy season (October and November). Subsequently, trees defoliated more intensely during the driest months (December to February). The mature fruit phenophase was more intense at the beginning of the next rainy season (April to June). Results showed the tendency that evaluated *C. pyriformis* phenophases register annual cycles and are related to rainfall in this region.

Fenologia de *Cariniana pyriformis* na região do Magdalena Médio de Santander, nordeste da Colômbia

Resumo - Durante um ano a fenologia de mogno colombiano (*Cariniana pyriformis* Miers), uma espécie nativa florestal, foi registrada em uma área rural do município de El Carmen de Chucuri, nordeste da Colômbia. A floração teve pico ao final do período das chuvas (outubro e novembro). Posteriormente, as árvores desfolharam mais intensamente durante os meses mais secos (dezembro a fevereiro). A fenofase de frutos maduros foi mais intensa ao iniciar o período de chuvas seguinte (abril a junho). Os resultados indicaram tendência das fenofases avaliadas de *C. pyriformis* nesta região registrarem ciclos anuais e estarem relacionadas com as precipitações.

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The botanical family Lecythidaceae is comprised by pantropical tree species, as *Bertholletta excelsa* Humb. & Bonpl. the Brazilian nut. The subfamily Lecythidoideae is restricted to 11 genera with around 210 species described and distributed in the western hemisphere (Mori et al., 2007; Huang et al., 2015). The Colombian mahogany or abarco (*Cariniana pyriformis* Miers) belongs to Lecythidoideae subfamily, and it is a native forest species from northern Colombia and Venezuela, with natural occurrence in humid and very humid tropical forests up to Panama. The species is highly valued for the quality of its wood and to be used

as a component in agroforestry systems (Cárdenas et al., 2015; Huang et al., 2015). In Colombia, the species is categorized as critically endangered according to the International Union for Conservation of Nature (IUCN) Red List and therefore, in some municipalities this species has a continuous ban on forest harvesting (Cárdenas & Salinas, 2007; Cárdenas et al., 2015). However, these measures continue to be insufficient for the conservation of the species in its natural habitat.

Phenological studies of plants include responses to biotic and abiotic factors, and rain seasonality is one of the most important for tropical forests (Stevenson

et al., 2008, Tonini, 2011, Machado et al., 2013). The understanding of these dynamics is basic in native and threatened species because it facilitates their conservation, restoration of degraded areas and economic use (Pavlik & Emberg, 2001; Machado et al., 2013). The aim of this study was to evaluate the phenology of *Cariniana pyriformis* in a rural area of the Magdalena Medio region of Colombia, contributing to the conservation and propagation of this species.

The study was carried out in a rural area of the municipality of El Carmen de Chucuri, department of Santander, northeast Colombia (6°41'56"N, 73°30'41"W, altitude of 771 m). We selected the first five adult trees of *C. pyriformis* with no apparent presence of diseases and that presented visible crown within an area of 60 km². These trees were observed approximately every three weeks, from August 2015 to August 2016, totaling 15 phenological visits. It was not possible to increase the number of trees due to the difficulty of physical access in the area and the low abundance of the species

as a consequence of the high deforestation. The climate of the region is tropical (Af) according to Köppen's classification, with an average temperature of 24 °C and rainfall of 2,560 mm distributed mainly from April to May and from October to November.

Five phenological events were evaluated: foliar sprouting, flowering (floral bud and open flower), leaf fall (presence of yellow leaves in the crown or broad areas with no leaves in the branches), and fruiting subdivided in the presence of immature fruits (green color and in formation) and mature fruits (dark brown color and close to the natural dispersion of the seeds). Data was recorded using two methods: (a) Fournier intensity percentage (Fournier, 1974), where the individuals were analyzed on a semi-quantitative scale of five categories (0 to 4), using the interval of 25%. Zero was adopted when there was no presence of the event; b) description of the phenological patterns from phenograms for each tree. In addition, the synchrony of the population sampled (equations 1 and 2) was calculated according to Augspurger (1983):

$$X_i = \sum_{j=1}^n e_j (N - 1) f_i \quad (1)$$

$$Z = \sum \frac{X_i}{N} \quad (2)$$

Where: X_i is the synchrony of the individual "i" with its co-specific; N is the total number of individuals in the sample; e_j is the number of records in which individuals "i" and "j" were in the same phenophase, $i \neq j$; f_i is the record number in which the individual "i" was in the considered phenophase; Z = synchrony of the population sampled. When $Z = 1$, this indicates a perfect synchrony, i.e. all sampled individuals occurred at the same time in a certain phenophase. When $Z = 0$, this means that there is absence of synchrony between individuals.

The influence between precipitation, temperature and relative humidity (independent variables) was correlated with the intensity index in each phenophase (dependent variable) of the same month, including the previous one, as stated by Bianchini et al. (2015). Spearman's correlation index (r_s) was performed on the data using the statistical program R 3.3.1 (R Core Team, 2014). Climatic data were obtained from the meteorological station of El Carmen de Chucuri that belongs to Instituto de Hidrología, Meteorología y Estudios Ambientales IDEAM (06°41'N, 73°30'W, altitude of 815 m). The distance from this station to the study area ranges between 5 to 10 km. During the study period the accumulated precipitation, means of temperature and

relative humidity were 2,405 mm, 25 ± 2.4 °C and $77.0 \pm 2.9\%$, respectively (Figure 1a).

The occurrence of the phenophases evaluated in *C. pyriformis* had a sequential pattern (Table 1). The end of the rainy period of the second semester of 2015 coincided with the flowering peak (45%), which occurred in November (Figures 1b, 2b and 2c) and there was a median synchronicity for this event in the population ($Z = 0.58$). No flowering and fructification were observed in the smaller individual (DBH = 41.5 cm and height = 23.5 m). Then, between the driest period and the beginning of the rains the following year, the fall of leaves occurred showing a peak in January (60%) and high synchrony ($Z = 0.70$) in the population (Figures 1c, 2d, 2e and 2f).

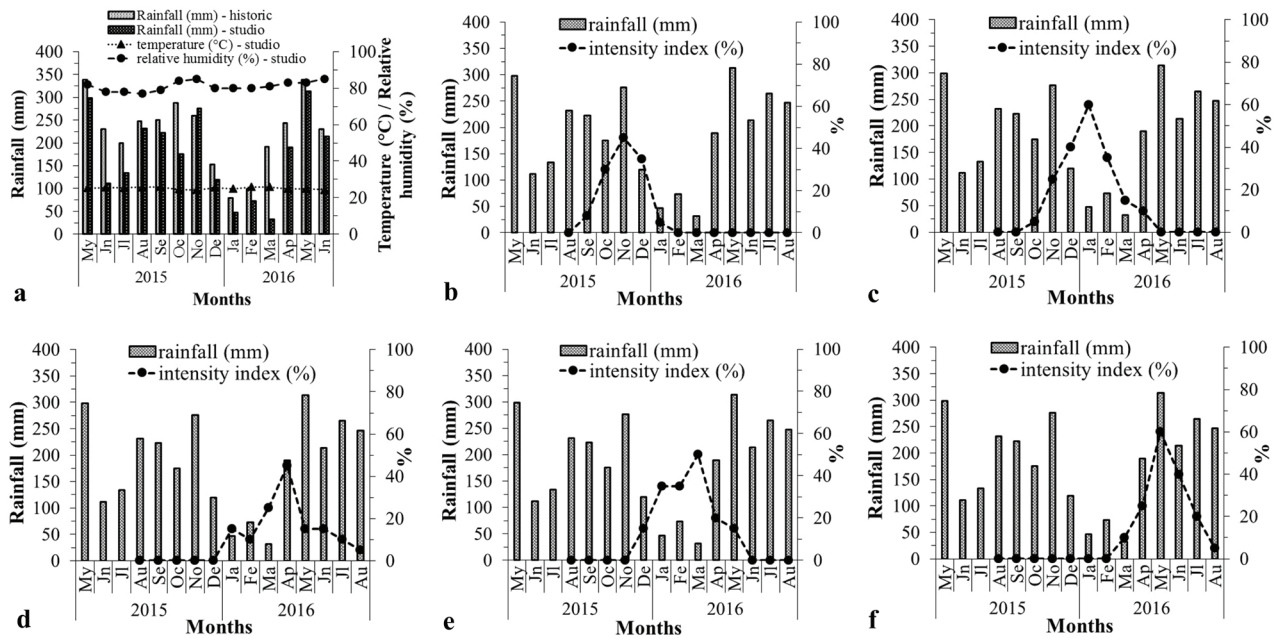


Figure 1. a) Monthly climatic data of the study period and historical rainfall (2000 to 2014); percentage of the phenophases intensity of *Cariniana pyriformis* for: b) flowering, c) leaf fall, d) leaf sprouting, e) immature fruits, and f) mature fruits. Solid gray bars = precipitation from May 2015 to August 2016.

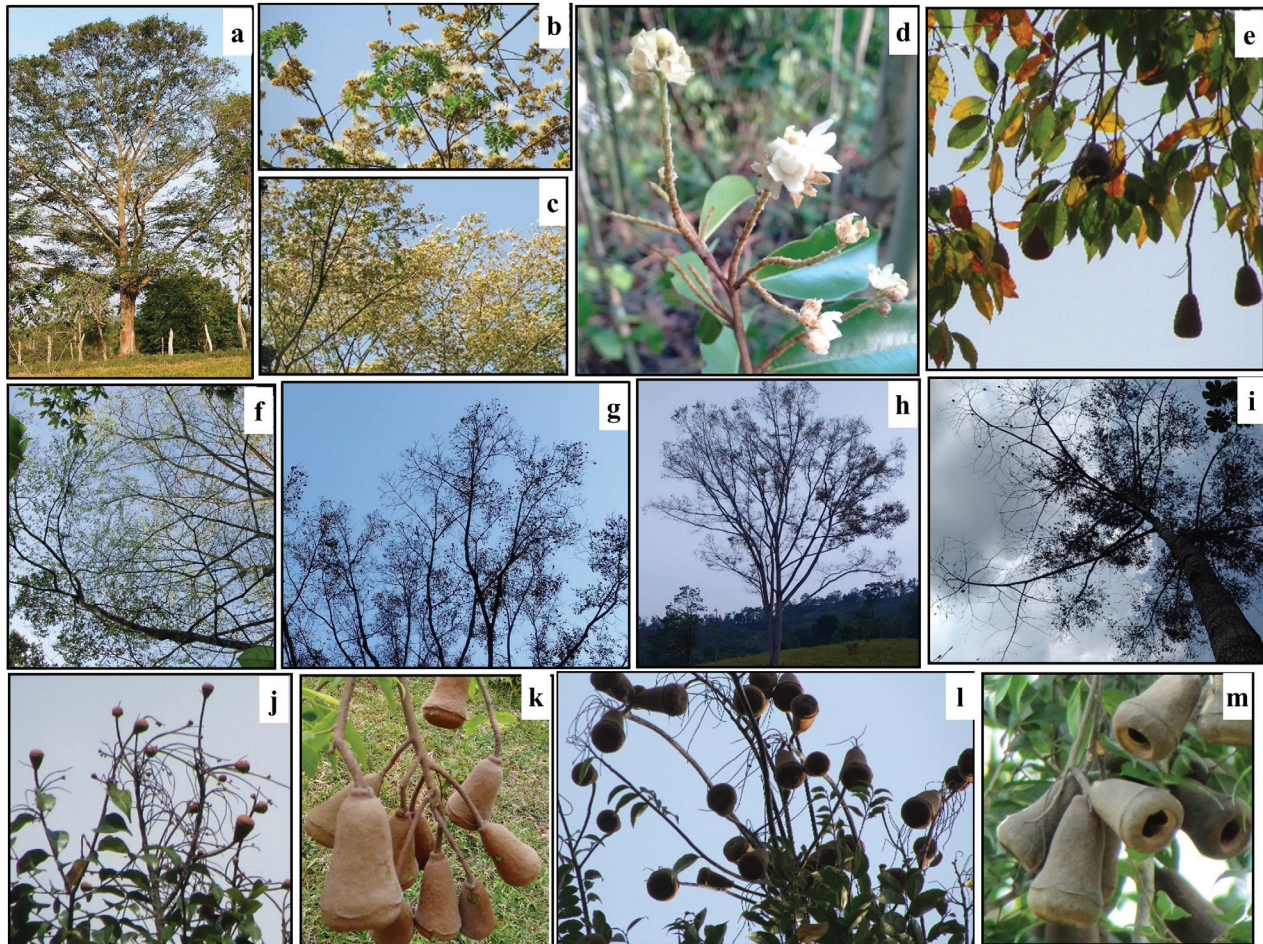
Table 1. Phenological events of each individual of *Cariniana pyriformis* population studied in the rural area of El Carmen de Chucuri municipality (Santander, Colombia) from August 2015 to August 2016.

	H ^a (m)	DBH ^b (cm)	Year / Month															
			2015						2016									
			Aug	Sep	Out	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug			
Individuals	1	29.5		+	+	+	+					▲	▲	▲				
							●	●	●	●		×	×	×	■	■	■	■
	2	26.9			+	+	+						▲	▲	▲			
								●	●	●	●	×	×	×	■	■	■	■
	3	28.8		+	+	+												
									▲	▲	▲	▲	▲					
4	23.5																	
						●	●	●	●	●	●	▲	▲	▲	▲			
5	30.3			+	+	+												
									●	●	●	●	●	×	×	×	■	■

^aH = Estimated height measured with a clinometer (Pm-5/360 P, Suunto ®); ^bDBH = Diameter at 1.30 m above ground level. ▲ Foliar sprouting; + Flowering; ● Leaf fall; × Immature fruits; ■ Mature fruits. Trees were locate at an altitude of 347.2 ± 55.5 m.

Trees recovered their foliage quickly one to two months after the defoliation peak (Figures 1d and 2a). However, foliar sprouting had little synchrony in the population ($Z = 0.51$). Leaf fall showed negative correlation with precipitation during the month of the event ($p < 0.05$, $r_s = -0.66$). Moreover, the same correlation was found between both the phenophase of immature fruits and the precipitation in the month of

the event ($p < 0.01$; $r_s = -0.68$), and the previous one ($p < 0.05$; $r_s = -0.66$). The intensity peak occurred in March (50%) (Figures 1d and 2g). The phenophase of ripe fruits had a peak in May (60%) at the beginning of the following rainy season (Figures 1e and 2h). Higher synchrony of this event was evidenced ($Z = 0.58$) in relation to immature fruits ($Z = 0.51$), however, it was considered low. Finally, in July, the fruits had their pixidia opened (Figure 2i).



Credits: Lina Zapata and Andrés Prato.

Figure 2. Phenological events of *Cariniana pyriformis* trees in: a) leaf sprouting; b, c, d) flowering; e, f) initiated leaf fall (yellow leaves); g, h, i) leaf fall peak; j, k) immature fruits, l) ripe fruits, and m) open fruits.

The phenology events of *C. pyriformis* in the current study was similar to the ones described for the department of Choco, Colombia, by Benítez & Mosquera (2004), where fruiting occurred throughout the season evaluated (October 2002 to March 2003), with a peak in February and March, as soon as leaf fall occurred in the driest months. Similarly, in the department of Antioquia, Colombia, Gómez (2010) reported the flowering of the

species from July to September, coinciding with the highest rainfall period, meanwhile the fruits matured mainly between March and April, i.e. at the end of the dry period and the beginning of the rainy season. Some trees even lost up to 100% of their leaves, but they started sprouting quickly with the onset of the rains. Fructification and flowering presented an annual phenological pattern.

Although the phenophase periods of *C. pyriformis* varies according to the locality, there seems to be a general pattern conditioned with precipitation, where flowering occurs at the end of the rainy period, meanwhile the fall of mature leaves and fruits occurs in the months with less precipitation. Several species of the subfamily Lecythidoideae exhibit this pattern in regions with defined dry periods (Mori, 1987). This was also observed in *B. excelsa*, Roraima State, Brazil (Tonini, 2011). The ripening or natural opening of fruits can be related to the wettest period, when the dispersion is optimized and the chances of emergence and establishment of the seedlings in the field increases.

The strong influence of precipitation, even in tropical regions without evident climatic seasonality, was also proven in the growth rings of *C. pyriformis* for a natural population (DBH = 0.82 to 1.92 m) located in the department of Choco, Colombia. It was concluded that reduced growth (narrow growth rings) was more frequent during the climatic phenomenon of El Niño, comparatively to the positive growth effect generated during La Niña, however there was no influence of temperature (Moreno & Valle, 2015). Likewise, for four tree species of the tropical dry forest, *Jacaranda caucanaa*, *Pithecellobium dulce*, *Samanea saman* and *Tabebuia rosea*, in the metropolitan area of the municipality of Cali, Valle del Cauca, Colombia, phenology was mainly related to precipitation, and there was almost no effect of temperature (Henao et al., 2015). Finally, the alternate rainy/dry periods seems to condition the phenophases of *C. pyriformis* for the Magdalena Medio region of Santander. Nevertheless, it is necessary to continue with studies in other phytogeographic zones, with a larger sample size of native population trees and longer assessment periods.

Conclusions

For the Magdalena Medio region of Santander, flowering, leaf fall, leaf sprouting and fruiting of *Cariniana pyriformis* in a natural population were recorded in an annual cycle. The most suitable period to harvest ripe fruits in the region is from April to June.

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