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Reproductive phenology of Uspí tree *Couepia polyandra* (Kunth) Rose (Chrysobalanaceae) in Campeche, Mexico

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ABSTRACT

Objective. To describe reproductive phenological stages, since the formation of flower buds, flowering, fruiting, up to the formation of the ripe fruit and foliation of 21 *Couepia polyandra* trees; and correlation of allometric data of tree height, diameter at breast height (DBH) and crown diameter, as well as the correlation of precipitation with reproductive phenology data.

Methodology. The description of the reproductive phenology (foliage, formation of flower buds, flowers, fruits) was done by direct monthly observation with a digital camera (Canon SX60HS, 65). The correlation among precipitation, allometry, and types of soils where the trees grow was calculated by recording data from each tree by measuring height, diameter at breast height (DBH) and foliage.

Results. The highest tree was 21.0 m; the widest DBH measured 68 cm; and the greater crown diameter was 34.45 m; the overall averages were 10.38 m, 33.17 cm and 9.37 m, respectively. A significant correlation was found between height and DBH ($r=0.91$, $p<0.05$); the correlations for the variables Height-Crown and DBH-Crown were not significant ($p>0.05$).

Conclusions. Water as a factor is responsible for the formation of inflorescence and fruit; determining that these phenological events are dependent variables with precipitation, highlighting a mean positive relation with the growth of flowers.

Keywords: Uspí, southeast, backyard orchards, flowering, fruiting, precipitation.

INTRODUCTION

Despite the importance of phenological knowledge of tree species, to date in Mexico only those species with the highest commercial value have been studied in detail (Salinas-Peba & Parra-Tabla, 2007) and dry forests are not the exception (Porter-Bolland, 2003) from the Yucatán Peninsula in southeastern Mexico. Authors such as Valdez et al. (2010) point out differences in the phenology of tree species between subsequent years, and suggest that rains occurrence, as well as the duration of periods without rain, may play a more important role in phenology than the total annual precipitation. Differences among sites suggest a strong effect on the phenology of trees, and finally Rozendal and Zuidema (2011) confirm that these specific responses of

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tree growth to climate variability for each species could be a projection of the differences in growth strategies among species. The species *Couepia polyandra* (Kunth) Rose (Chrysobalanaceae) is a tree known by the name of Uspí (Pennington & Sarukhán, 2005) in the Yucatán Peninsula, Mexico; and it is the only identified species of the genus growing in Mexico (Ojasti, 2001). It is native to the country and has a neo-tropical distribution extending from Mexico to Costa Rica (Durán-Espinosa and Lorea, 2010). *C. polyandra* inhabits jungles, from medium sub-evergreen to low deciduous, preferably along river banks (Pennington & Sarukhán, 2005; Vázquez *et al*., 2010), and at altitudes 0 to 600 m (Durán-Espinosa & Lorea, 2010; Lascurain *et al*., 2010). It is a tree that can reach heights from 6 to 30 m (Figure 1) with a diameter at breast height (DBH) up to 40 cm (Pennington & Sarukhán, 2005; Durán-Espinosa & Lorea-Hernández, 2010). It has axillary, terminal and paniculate inflorescences with white flowers. The fruit is an ellipsoid drupe (up to 45 × 25 mm), green when immature and orange when ripe. It is important to highlight the fresh consumption of ripe fruits in the states of Veracruz, Tabasco and Yucatan (Martinez *et al*., 2007; Lascurain *et al*., 2010; Magaña, 2010; Vázquez *et al*., 2010; Román *et al*., 2016). It is worth mentioning that Ruenes-Morales *et al*., (2016) report Uspí as a floristic element of the Yucatan jungles, cultivated in an isolated or tolerated manner in domestic plots or backyard orchards, in addition to being considered underused because its market is just local. Given this, studies evaluating natural history data of *C. polyandra* are scarce. However, there are researches with other species of the Chrysobalanaceae family, among which there is the one by Knowles and Parrotta (1997) who studied the characteristics of the flowering of 160 species in the heart of the Amazon in Brazil, among them *Couepia longipendula*, *Couepia* sp., *Licania heteromorpha*, and *L. micrantha*, pointing out that tree species show an inverse relationship with rainwater, and flowering peaks occur during the first months of the dry season (July-October). Fruiting trends closely follow annual rainfall patterns, with a peak in the number of fruiting species occurring during the wet season (December-May).

Figure 1. Uspí (*Couepia polyandra*) from solar del Cuyo, Palizada, Campeche, Mexico (Photo: SolMejenes 2017).

Ruíz and Alencar (1999) who documented the foliation, flowering and fruiting of five species (*Couepia longipendula*, *C. robusta*, *Licania heteromorpha*, *L. longistyla* and *L. octandra*) in the middle of the Brazilian Amazon rainforest, thus establishing that some climatic factors are involved with the interaction factors of the biotope environment and physiological factors causing long periods of intervals in flowering and fruiting. Ortiz *et al*. (2016) relate eleven species by their responses to environmental-abiotic variables in two ways: with a stronger correlation to water variables and the second, where thermic variables showed greater influence on growth. *Licania intrapetiolaris* was the species exhibiting the second response. Ríos-García *et al*. (2017) provide data on the durability of flowering and fruiting events, related to temperature and precipitation of *Licania arborea* in Chiapas, Mexico. They stated that flower production in the tree is influenced by a positive mean relationship with temperature, highlighting that both variables are dependent. The present study describes the different reproductive phenological stages since flower buds production, through flowering and fruiting to the formation of mature fruits and foliation of 21 *Couepia polyandra* trees grown in domestic plots and orchards, and associated with mango trees (*Mangifera indica*) in Palizada, Campeche, Mexico, during April 2016 to October 2017, correlating allometric data of tree height diameter at breast height (in Spanish, DAP) crown diameter, and reproductive phenology to precipitation data.

MATERIALS AND METHODS

Description of the study area

Field study was conducted in Palizada municipality, southwest of Campeche state (Figure 2). Elevations range from 0 to 40 m above sea level (Mendoza-Vega & Kú-Quej, 2010). Original vegetation according to Miranda and Hernández X. (1963) is medium sub-evergreen forest. The predominant climate is warm humid with abundant rains in summer A (m), and average annual temperature of 26.7 to 28 °C (INEGI, 2015). Average annual precipitation is 1200-2000 mm with a rainy period from May to October; the highest precipitation occurs in the months of July, August and September (García, 1981; INEGI, 2011). Dry season is relatively more pronounced; it begins in January and ends in April, and the driest month is March (García, 1981).

A mid-summer drought occurs during July to August (Gío-Argáez, 1996; Mendoza-Vega & Kú-Quej, 2010). The Palizada river and its tributaries, the Viejo river and the Limonar river, run across this municipality. The hydrological potential of this municipality is constituted by the Palizada River. According to the FAO / UNESCO classification, the soil types are Vertisols, Gleysol, Luvisols; and Leptosols in a minimal proportion (Bautista-Zuñiga *et al*. 2010).

Tree structure

Records were made monthly and were carried out during April to December, and from January to October, of 21 individuals of *C. polyandra* marked for identification in each of the visits that were made to plots and orchards with associated mango trees (*Mangifera indica*). Each tree had a descriptive card (passport data) which included name of the tree, tree number, location defined by GPS, initial date, diameter at breast height (DBH) measured at 1.30 m height using a caliper, tree height recorded with a SUUNTO clinometer, and crown width of each individual (Table 1); also, the subsequent data collection on reproductive phenology and foliage description. Leaves were cut into branches and flowers collected to be deposited in herbaria (CEDESU-UAC and UADY) and fruits were recollected for further germination study (Mejenes-Lopez *et al*., 2019).

Flower buds, flowering and fruiting

Observations were made directly on a monthly basis, with a photographic camera (Canon SX60HS 65, using Zoom); recording in the individual formats, observation date and changes according to reproductive phenological stage of flower buds setting, flowering and fruiting, recorded in percentage with the method described by Fournier (1974), modified by Newstrom *et al*. (1994) and Pineda-Herrera *et al*. (2012), where a scale is used according to the percentage of presence, in events that range from 0 to 4, as follows: total absence of the event = 0, 1–25% = 1, 26–50% = 2, 51 - 75% = 3 and 76 - 100% = 4.

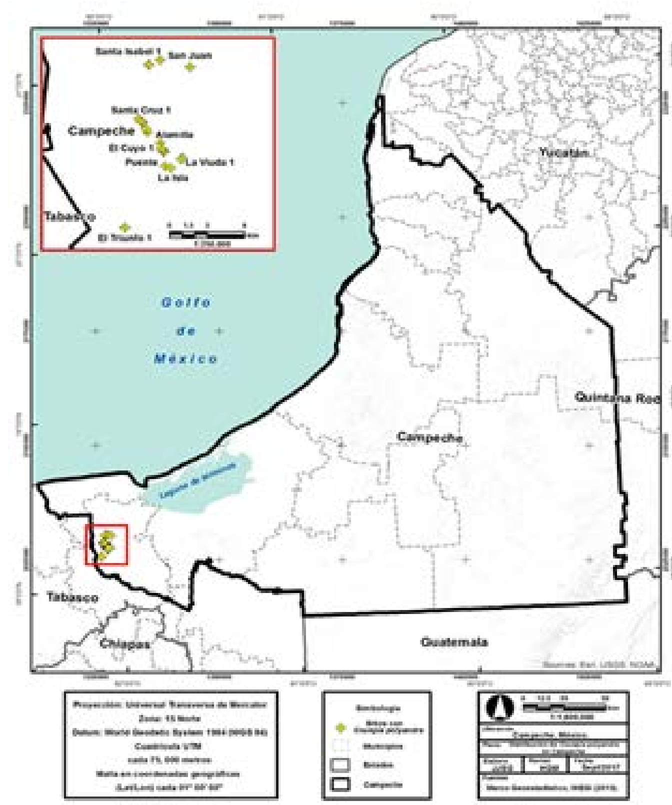

Figure 2. Location of individuals of *Couepia polyandra* (Kunth) Rose in the municipality of Palizada, Campeche, Mexico.

Foliage

For this variable, presence of leaves was observed in each tree crown and the percentage was evaluated using the method described for reproductive phenology (Op. Cit).

Statistical analysis/Correlation

Data matrices were constructed for the correlation analysis among the variables height, DBH and crown diameter (statistical software STATISTICA V.7.1, Stat Soft, 2005); as well as for the correlation between reproductive phenological stages and monthly total precipitation (mm) (INEGI 2016, 2017). They were evaluated with comparison of Tukey means $p>0.05$ (Spearman) (Gotelli & Ellison, 2004).

RESULTS AND DISCUSSION

Tree structure and correlation of allometric data

The highest tree was 21.0 m and the shortest, 5.75 m with an average height of 10.38 m. The highest recorded DBH was 68 cm while the lowest was 15 cm, with a general average of 33.17 cm. Regarding crown diameter, the smallest was 4.6 m and the largest was 34.45 m, average width was 9.37 m. A significant correlation was found between tree height and DAP ($r=0.91$, $p<0.05$);

Table 1. Locality, UTM coordinates and morphometric data of the Individuals of *C. polyandra*. The records are presented in the order that they appeared during sampling.

Number	Locality	Coordinates (UTM)	Height (m)	Diameter at breast height DBH (cm)	Cup diameter (m^2)
1	San Isidro, puente de palizada	2018752.275-596421.464	5.75	54	10.22
2	Rivera Santa Isabel, Km.13. Highway Palizada Santa Isabel, S/N.	2027940.549-596610.364	10.92	21	5.1
3	Rivera Santa Cruz, Highway Palizada-Santa Isabel	2023030.86-594556.25	10.80	68	10.79
4	Rivera Alamilla, Highway Santa Isabel	2020773.432-596152.973	7.90	60	9.62
5	Rivera Santa Isabel	2027603.843-595660.992	1.05	16	7.6
6	Rivera Santa Isabel	2027607.034-595684.459	11.79	30	7.4
7	Rivera El Cuyo. Domicilio Conocido, Km. 1.3	2019984.784-596412.378	13.45	28	34.45
8	Rivera El Cuyo. Domicilio Conocido	2020021.316-596341.719	9.58	27.5	7.8
9	Rivera El Cuyo, Km. 2	2020251.296-596231.922	11.69	27.8	8.89
10	Rivera El Cuyo, Km. 2.1	2020306.665-596240.455	6.00	16	3.25
11	Rivera Santa Cruz	2021767.603-595187.864	8.00	21.1	6.56
12	Rivera Santa Cruz	2022099.105-595095.206	8.77	22.2	7.5
13	Highway La Viuda	2019355.894-597877.965	2.10	53.5	8.07
14	La Isla, San Isidro	2018572.986-596833.504	9.94	23.1	10.71
15	Rivera San Juan, Highway Palizada-Santa Isabel	2027196.272-598944.853	9.12	15	4.6
16	Rivera Santa Cruz Highway Palizada-Santa Isabel	2022642.129-594825.343	14.13	35	9.58
17	Rivera Santa Cruz, Highway Palizada-Santa Isabel	2022738.875-594747.354	12.53	34	11.25
18	Rancho El Triunfo, Km 9, Highway Palizada-Jonuta	2013650.323-592846.398	10.58	56	7.75
19	Rancho El Triunfo, Km 9, Highway Palizada-Jonuta	2013650.014-592846.106	7.92	23	7.63
20	Rancho El Triunfo, Km 9, Highway Palizada-Jonuta	2013649.705-592845.814	7.45	24	9.95
21	Highway La Viuda a 1.6 km de la Parroquia San Joaquín	2019260.914-597755.987	10.25	41.5	8.12

correlations for the variables Height-Crown and DAP-Crown were not significant ($p>0.05$).

Reproductive Phenology and phenological calendar

The development of phenological events of *C. polyandra* in the study area during 18 months (2016-2017) presented the same pattern (Table 2). Flower buds appear from April to July, while flowering also begins in April, but its maximum representation occurs in May and June, and decreases in July and August. Fruiting develops between May and June, with the highest value in August. The vegetative phenological stage of foliation was the most notable event, since individuals maintain their foliage throughout the year. This fact qualifies this species as an evergreen tree (Pennington & Sarukhán, 2005) despite it is a cultivated species.

Phenology related to precipitation

According to precipitation data during the study period, variations were registered each month of the sampling period, in June 2016 (223 mm) and 2017 (210 mm). As well as in November 2016, the highest (289.5 mm) precipitation occurred; and the lowest (345.4 mm) was in September 2017. This may indicate that phenological stages of the *C. polyandra* species are related to precipitation. Since flower bud production, flowering and fruiting occur on these precipitation events, we suggest that those stages are favored by the season (Figure 3). While with high rainfall no presence of any phenological stage. Precipitation of 34.14 ± 6.78 mm was recorded during the dry period, while during the rainy season, the recorded value was 204.49 ± 23.76 mm.

All individuals were reproductive from the minimum height of 5.75 m. DBH has a correlation with height which define this tree species as sexually mature for producing fruits, *C. polyandra* resulted a species of annual reproduction.

Table 2. Summary of the phenology pattern of *C. polyandra* individuals during the years 2016 and 2017.

	Leaves	Flower bud	Flowering	Fructification
jan^{2017}	4			
feb^{2017}	4			
mar^{2017}	4			
apr$^{2016-2017}$	4	2	2	
may$^{2016-2017}$	4	3	4	1
jun $^{2016-2017}$	4	3	4	2
jul$^{2016-2017}$	4	2	4	3
agu$^{2016-2017}$	4		2	4
sep$^{2016-2017}$	4			1
oct$^{2016-2017}$	4			
nov^{2016}	4			
dec^{2016}	4			

Escale: 0 (0%), 1 (1-25%), 2 (26-50%), 3 (51-75%), 4 (76-100%).

Through phenological analysis, it is recognized that the species has a suitable period for the collection of seasonal fruits in the months of June, July and August; when fruits show maturity and are recollected from the ground for self-consumption, that is the moment of peak maturity (Chi-Saénz, 2016; Ruenes Morales *et al*., 2016; Mejenes-López *et al*., 2019).

This study area has well-defined climatic seasons (dry and rainy); its influence was recording in the expression of flower buds, flowering itself, and fruiting of *C. polyandrous* that occurs in early June. This suggests that the water factor can be a strong trigger to the formation of inflorescence and fruit, as it was indicated by Rios-Garcia *et al*. (2017) for L. arborea, pointing out that flowering and fruiting events, as well as their relationship with temperature and precipitation, are dependent variables; and temperature registered a positive average relationship with the production of flowers in the tree.

CONCLUSIONS

C. polyandra species shows a pattern in reproductive phenological stages, showing a duration of flowering (April to August) and fruiting (May to September), five months for both events. Phenological traits are referred to the period and site of study; therefore, it is recommended to continue studying wild populations of the Pacific slope, in order to build the foundation needed to clarify the complex physiological processes and their relation to phenology.

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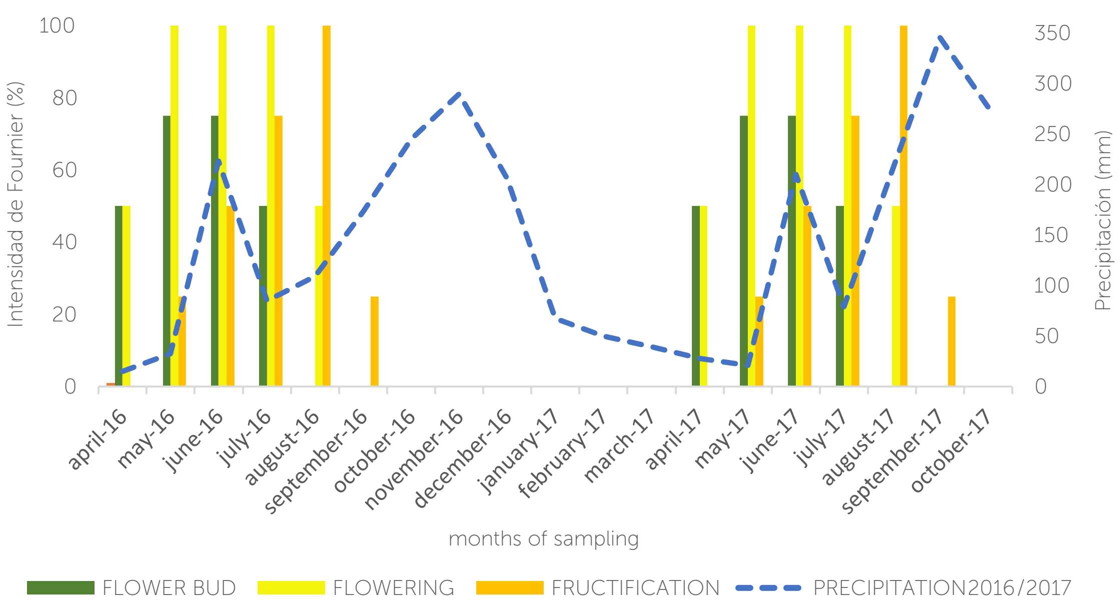

Figure 3. Phenology vs. precipitation of the year 2016 and 2017.

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