



Foliar and flowering phenology of three rubber (*Hevea brasiliensis*) clones in the eastern plains of Colombia

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Abstract

Annual defoliation and refoliation cycles that occur in rubber trees after 5 years of age have a strong interaction with foliar diseases attacks. The rubber phenology was studied in the eastern plains of Colombia, in the municipality of Puerto López, department of Meta, where variables such as foliar density, percentage of leaves in stages A, B, C and D and flowering density were evaluated in clones IAN 873, FX 3864 and RRIM 600, between August 2016 and September 2018. All three clones showed a foliar density higher than 80% with leaves in stage D, between March and December (weeks 12–50 of the year). The defoliation started in the last weeks of the year, with the beginning of the dry season. The refoliation extended until mid-March (week 11) in 2017, and until February (week 6) in 2018. The presence of leaves in stages A, B and C during 8–13 weeks was observed at the plantation level, according to the clone and the evaluation year. The duration of the refoliation per tree was on average 6.73 ± 0.22 weeks in 2017 and 4.42 ± 0.39 weeks in 2018. Flowering coincided with refoliation, during a period of negative water balance and high solar radiation. Expansion of inflorescences was observed in the first weeks of the year between January and March, with the absence of reproductive development when the crop was dominated by leaves in stage D.

Keywords Defoliation · Insolation · Refoliation

1 Introduction

The rubber tree (*Hevea brasiliensis* [Willd. ex A. Juss.] Müll. Arg.) is a perennial plant native to the equatorial basin of the Amazon River (Schultes 1970; Zhai et al. 2017). Of the 11.27 million tons of rubber produced annually worldwide, 92% is produced in southeastern Asia, 6% in Africa and 2% in Latin America (Priyadarshan 2017). Colombia, with low participation in the world market, recorded a total of 52,222 hectares established with rubber tree for 2015, of which only 3178 ha have reached the productive stage, with an average yield of $920 \text{ kg ha}^{-1} \text{ year}^{-1}$. Eastern plains of Colombia, conformed by Meta (18,498 ha) and Vichada (9850 ha), account for 54.2% of established area with rubber tree and 28% of total area in productive stage (Confederación Cauchera Colombiana 2016).

Borchert et al. (2015) defined phenology as the study of the seasonality in the development of trees. Further, Lieth (1974) defines it as “the study of the time of recurrent biological events, the causes of their synchronization with respect to biotic and abiotic forces and the interrelation

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between phases of the same species or different species.” Primary productivity depends on a wide range of factors that operate through changes in plant phenology and physiological processes (Xia et al. 2015). Gasparotto et al. (2012) indicate the importance of knowing the phenological behavior of rubber trees for different clones, since this allows deciding the appropriate time to perform a certain management practice. In the case of rubber, phenological studies could have important applications in the management of foliar diseases (Rivano et al. 2016; Zhai et al. 2017; Guyot and Le Guen 2018), the planning of cultural tasks (Righi et al. 2001), the identification of flowering patterns for artificial hybridization programs (Liyanage et al. 2018) and the prediction of yield under different climate scenarios (Zhai et al. 2017). Fitchet et al. (2015) mentioned that phenology clearly reflects the effects of climate variability and change in plants. On the other hand, Corredor and García (2011) report that phenological studies can be related to the identification of floral visitors.

In most plant species, phenological studies point to the flowering and fruiting processes; however, in rubber exploitation, phenological studies are focused on the seasonality of the foliage, since the product of commercial value (latex) depends on the supply of photoassimilates by these organs (Silva et al. 2012). The annual defoliation and refoliation cycles occur in rubber trees around 5 years of age and have a strong interaction with phytosanitary problems (Priyadarshan 2017). Regions of low phytosanitary risk related to South American Leaf Disease (*Pseudocercospora ulei* [Henn.] Hora Junior & Mizubuti), called escape zones, have been identified in Brazil (Camargo et al. 2003; Pilau et al. 2007), Ecuador (Rivano et al. 2015) and Colombia (Castañeda 1997; Jaimes et al. 2016). Such regions have a dry period that can last up to 5 months, being detrimental to the fungus development during the defoliation–refoliation period and allowing the use of high yielding susceptible clones, selected mainly in Asia (Rivano et al. 2016). In *P. ulei* non-escape zones, susceptible clones have low levels of retained leaves during the defoliation and refoliation period and the level of foliar damage is probably associated with the duration and intensity of each clone’s phenological cycle (Sterling et al. 2019). This study evaluates the foliar and flowering phenology of *P. ulei* susceptible rubber clones like FX 3864 (Cevallos et al. 2017), IAN 873 (Sterling et al. 2019) and RRIM 600 (Rivano et al. 2016) under non-escape conditions (Castañeda 1997) in Meta (Colombia).

Several authors have mentioned the relationship of the defoliation–refoliation cycles of the rubber tree with the presence of water-deficit periods (Carr 2012; Rivano et al. 2016), the number of sunshine hours (Liyanage et al. 2018), the annual radiation cycle (photoperiod) (Yeang 2007) and cold stress (Zhai et al. 2017; Lin et al. 2018). However, it is not clear what the foliar and flowering phenology triggers

in this crop are. The hypothesis of this study is that phenological patterns in rubber clones are modulated by their responses to rainfall regime as the main trigger for defoliation, refoliation and flowering in the eastern plains of Colombia.

According to the above mentioned and taking into account a large number of hectares that will start using and producing latex in the coming years in Colombia, it is important to carry out phenological studies in commercial rubber plantations that allow planning the application of cultural practices and forecast seasons of low yield and severe attacks of diseases, so the aim of this study was to characterize the foliar and flowering phenology in adult plantations of clones IAN 873, RRIM 600 and FX 3864, in the eastern plains of Colombia.

2 Materials and methods

Study area – This work was developed in the municipality of Puerto López (4.19°N; 72.53°W), Meta (Colombia). The study area is located at 222 m above the sea level and is characterized by having a monomodal rainfall regime where a dry season occurs from December to March and a rainy season from April to November (Fig. 1), with mean rainfall of 1870 mm year⁻¹, solar radiation of 6620 MJ m⁻² year⁻¹ (Fig. 2), minimum temperature of 22 °C and maximum temperature of 33 °C and average relative humidity of 80%, according to data processed by the authors from IDEAM (2018), corresponding to a tropical rainy climate with moderately humid forest (Botero 1999).

Study area is on a flat relief, having a slope of less than 3%. Soils are classified as Typic Hapludox (Latosolos) and are dominated by sandstones as quartz, feldspar and muscovite (Rodríguez et al. 2010), characterized by a very

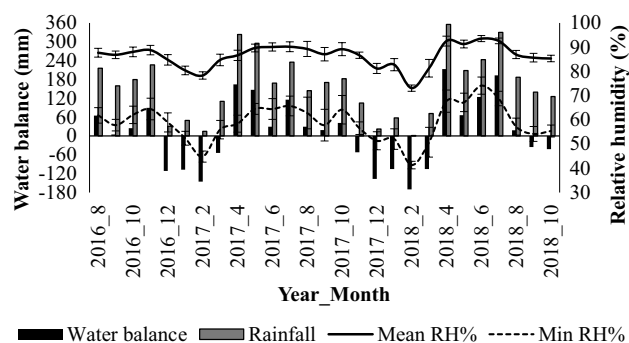


Fig. 1 Monthly rainfall, water balance, average minimum relative humidity (min %RH) and average relative humidity (mean %RH) data of the eastern plains of Colombia (Puerto López, Meta) from August 2016 to October 2018. The error bars correspond to 95% confidence intervals

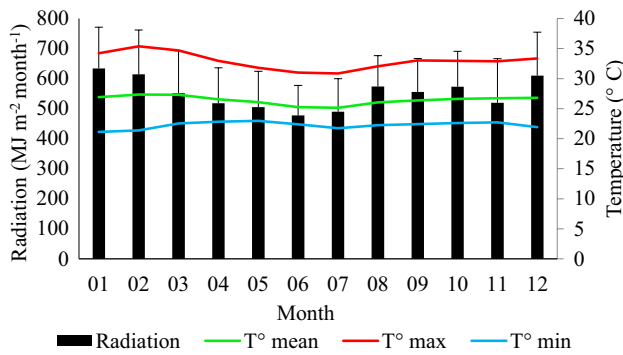


Fig. 2 Average global radiation (black bars), and minimum ($^{\circ}\text{T min}$, blue line), maximum ($^{\circ}\text{T max}$, red line) and mean temperature ($^{\circ}\text{T mean}$, green line), for the months of January to December in the eastern plains of Colombia (Puerto López, Meta) from 2006 to 2018. The error bars correspond to 95% confidence intervals for radiation

low fertility with acid pH (5.0), high saturation with aluminum (49.8%) and low content in organic matter (2.09%), phosphorus (4.14 mg kg^{-1}), calcium ($0.68 \text{ cmol}_+ \text{ kg}^{-1}$), magnesium ($0.27 \text{ cmol}_+ \text{ kg}^{-1}$), potassium ($0.09 \text{ cmol}_+ \text{ kg}^{-1}$) and low effective cation exchange capacity ($2.92 \text{ cmol}_+ \text{ kg}^{-1}$).

Plant material – Monoclonal plots of rubber tree clones FX 3864 (FX: Ford Cross) and IAN 873 (IAN: Instituto Agrônômico do Norte) of South American origin (Brazil) and from the rubber tree clone of Asian origin RRIM 600 (RRIM: Rubber Research Institute of Malaysia) were employed. These were established in 2008 and have been under harvest since 2015, sown at a distance of 3.0 m between plants and 6.0 m between rows. In the study area, trees are tapped in half spiral cut without rain-guard, at fourth daily frequency, six days in tapping followed by one day of tapping rest, stimulated with ethephon (2.5%), nine applications (mid-March to mid-December) per year at monthly intervals (S/2 d4 6d/7. ET 2.5%. 9 m/12). No repeated defoliation associated with foliar diseases is commonly observed in the study area, although symptoms of foliar diseases like those caused by *P. ulei* and *Colletotrichum* spp. have been observed in more than 80% of rubber tree individuals and affecting around 21% of the plantation's canopy from July to December, falling to undetectable levels from defoliation to complete refoliation.

For each clone, eight randomly distributed sampling sites conformed by four neighboring trees were identified and marked, with a total of 32 trees per clone as experimental units. Measurements were carried out between August 2016 and September 2018, with a weekly frequency during the months of December to March (defoliation–refoliation) and with a monthly frequency (from April to November);

meanwhile, trees were in foliar phenological stage D, according to Lieberei (2007).

Climatic characterization – Meteorological information analysis used minimum, average and maximum temperature ($^{\circ}\text{C}$), rainfall (mm), global radiation ($\text{MJ m}^{-2} \text{ s}^{-1}$) and relative humidity (%) data, obtained from the meteorological station La Palomera of the network of stations of Instituto de Hidrología, Meteorología y Estudios Ambientales de Colombia, located at $04^{\circ} 15' 37.4'' \text{ N}$ and $72^{\circ} 33' 51.9'' \text{ W}$, 8.2 km from the study site (IDEAM 2018), between August 2016 and October 2018. The average diurnal global radiation for each month was calculated based on the records from years 2006 to 2018. Crop evapotranspiration (ETc) was estimated using the Hargreaves equation, with a coefficient (K_c) for the rubber tree of 1.0 (Allen et al. 2006), and the monthly water balance was calculated as the difference between rainfall and ETc.

Phenological evaluation – In each marked tree of clones RRIM 600, FX 3864 and IAN 873, foliar density was evaluated with a scale from 0 to 10, where 10 corresponds to 100% of leaves in the crown and 0 to the absence of leaves (Cevallos et al. 2012; Rivano et al. 2016), the percentage of leaves in stages A, B, C and D (Lieberei 2007), indicating that the D1 stage corresponds to mature leaves of the previous year, and D2 and D3 as the leaves formed in the refoliation cycles of the following years (Rivano et al. 2016). Moreover, the flowering density was measured on a scale from 0 to 10, where 0 corresponds to the absence of flowering and 10 to the presence of inflorescences in 100% of the branches of the last floor of the trees, and finally, the percentage of expanding inflorescences, open flowers and wilted flowers.

Information analysis – From the values of foliar and flowering density, the percentage of the crown that did not show leaves or inflorescences was calculated for each tree, as follows:

$$\%Y = 100 - (10 \times d)$$

where % Y corresponds to the percentage of the crown that does not have leaves and/or inflorescences, and d is the observed value of foliar or flowering density.

The percentages of leaves in stages A, B, C, D1, D2 and D3, or expanding inflorescences, with open and wilted flowers, were transformed to an absolute percentage of the crown, as follows:

$$\%X = ((100 - \%Y)/100) \times n$$

where % X corresponds to the percentage of the crown that shows a certain foliar or inflorescence state development, and n is the percentage of leaves or inflorescences observed in a certain stage of development.

The estimated variables data per clone and the meteorological information were summarized in weekly or monthly averages, to analyze in a descriptive way, the duration, intensity and time of occurrence of the different phenological events in the rubber tree. Temporal co-occurrence of phenological and meteorological processes was discussed with published literature on rubber tree phenology, from similar and different latitudes and meteorological conditions around the world.

Confidence intervals (95%) were estimated using the Student's t test, for the duration of refoliation and flowering, expressed as the number of weeks on which individual trees of each clone have leaves in stages A, B or C, or open flowers, respectively. Analysis of variance (ANOVA) was carried out for assessing statistical significance of the difference between mean duration of refoliation or flowering of clones FX 3864, IAN 873 and RRIM 600. When significant differences were detected by the ANOVA, Tukey's test for multiple comparisons was applied, using R Project (R Core Team 2019). The duration of refoliation and flowering at plantation level (weeks clone⁻¹) was calculated as the number of weeks with almost one tree of each clone having leaves in stages A, B or C, or open flowers, respectively.

3 Results

Climatic characterization – Between October 2016 and September 2017, a total rainfall of 1947 mm and an ETc of 1747 mm were registered, where a marked dry period occurred extending between December and March, with an accumulated water deficit of 419 mm. Between October of 2017 and September of 2018, total rainfall was 1901 mm and the ETc was 1850 mm, where the dry period showed an accumulated water deficit of 570 mm between November and March. The rainfall regime observed was unimodal. The average relative humidity remained above 80% even in the dry months (except in February); meanwhile, the minimum relative humidity fluctuated around 58% (Fig. 1). Based on the records from years 2006 to 2018, the highest average global radiation is found in the months of December to February with values higher than 610 MJ m⁻² month⁻¹, and in the months of August to October with values higher than 550 MJ m⁻² month⁻¹ (Fig. 2). The highest mean temperature is found during the months of February and March with values of 27.3 °C, and the lowest mean temperatures occur in June (25.3 °C) and July (25.2 °C), showing a low variability of mean temperature of less than 2 °C, indicating that the study area presents a stable average temperature throughout

the year. Mean thermal amplitude is 10.8 °C, with mean maximum temperature of 32.8 °C and mean minimum temperature of 22.0 °C.

Phenological evaluation – Foliar density and percentage of leaves in stages A, B, C and D for clones IAN 873, FX 3864 and RRIM 600 are presented in Fig. 3. In all three clones, a foliar density higher than 80% with leaves in stage D was observed, between weeks 12 and 50 of the year (March and December, respectively), with the exception of clone RRIM 600, which showed an average foliar density of 77% in 2018. The defoliation process was evident from week 50, and the highest diversity of leaf stages (refoliation) occurred between the first weeks of the year, extending until week 11 (March) in 2017 and until week 6 (February) in 2018. The mean duration of the refoliation period for individual trees expressed as the number of weeks with presence of leaves in stages A, B and C (Lieberei 2007) was 6.73 ± 0.22 weeks for the period 2016–2017 and of 4.42 ± 0.39 weeks for the period 2017–2018, without evident differences between the clones. However, since there is no complete synchronicity in time between all the trees of the same clone, it was found

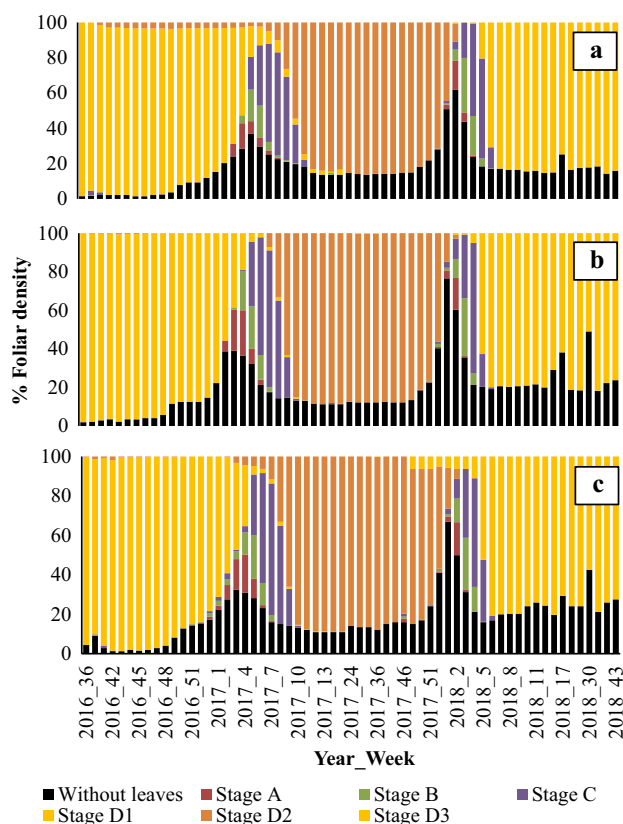


Fig. 3 Foliar density and percentage of leaves by stages (A, B, C, D) in the rubber tree clones **a.** IAN 873, **b.** FX 3864 and **c.** RRIM 600, in the eastern plains of Colombia (Puerto López, Meta) from August 2016 to October 2018

that the refoliation process at the plantation level (weeks clone⁻¹) extended up to 9 weeks for clones IAN 873 and FX 3864, and 13 weeks in clone RRIM 600 between 2016 and 2017. Meanwhile, in the period 2017–2018 the duration of the refoliation was 8 weeks for the three clones at the plantation level (Table 1, Fig. 3).

The flowering process coincided with the refoliation process. The expansion of inflorescences was observed in the first weeks of the year, between January and March, with the absence of reproductive development when the crop was dominated by leaves in stage D (Fig. 4). During the flowering periods, inflorescences were produced in about 50% of the crown in clone IAN 873; meanwhile, in clones FX 3864 and RRIM 600, this value was around 40%. The presence of open flowers was observed during 3.88 ± 0.35 weeks in the period 2016–2017 and during 4.61 ± 0.20 weeks in the period 2017–2018 on average per tree; although, in spite of not having complete synchrony between all the trees of the same clone, the presence of open flowers was observed during 9 and 12 weeks for the periods 2016–2017 and 2017–2018, respectively, at the plantation level in clone RRIM 600, meanwhile, this duration was shorter, i.e., 7 weeks for clones IAN 873 and FX 3864 in both periods (Table 2).

4 Discussion

Climatic characterization – Rivano et al. (2015) defined the escape zones to the South American leaf disease (*P. ulei*) based on five criteria: 4 to 5 months with rainfall less than 50 mm, 2 to 5 months with rainfall less than 30 mm, average annual rainfall higher than 1250 mm, water deficit of 100 to 400 mm and relative humidity of 70% in the driest month. On the other hand, Castañeda (1997) defines the escape zones for rubber tree cultivation as those where they occur for at least 2 months with relative humidity values less than 65%, water deficit of 100 to 300 mm year⁻¹ and a dry period of at least 4 months. The study area meets all these criteria, except those that refer to the relative humidity, based on the

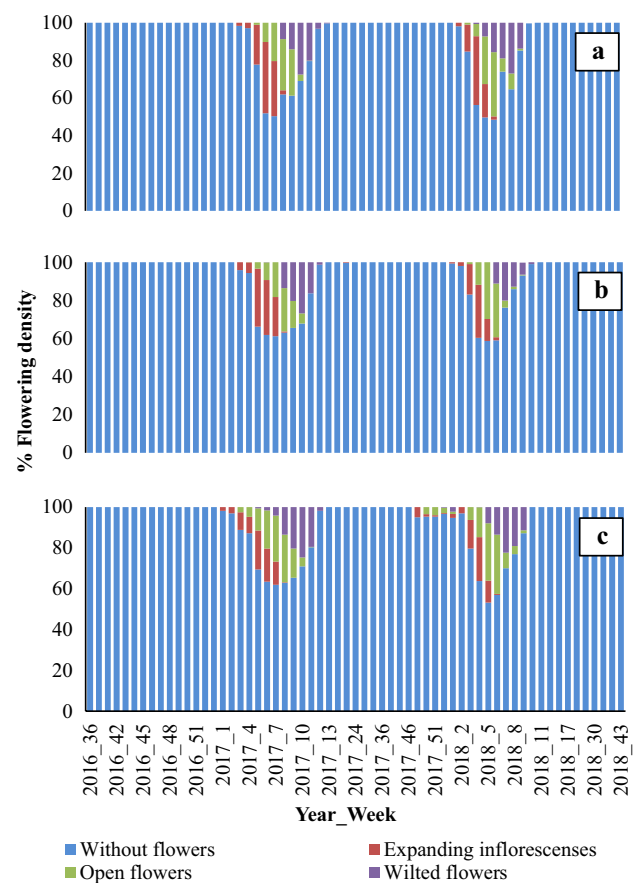


Fig. 4 Flowering density and percentage of inflorescences by stages (expanding, open and wilted) in the rubber tree clones **a.** IAN 873, **b.** FX 3864 and **c.** RRIM 600, in the eastern plains of Colombia (Puerto López, Meta) from August 2016 to October 2018

meteorological information recorded between August 2016 and October 2018.

In Ecuador, under escape conditions to *P. ulei*, the susceptible clone RRIM 600 reached the opening threshold for tapping panel, of 50 cm at 1 m above the ground, at 7.5-years-old trees and the foliar density was around 80% during 8 months of the year (Rivano et al. 2016). In Bahía (Brazil), under non-escape condition to *P. ulei*, the susceptible clone

Table 1 Refoliation duration in rubber trees: presence of leaves in stages A, B and C, defined by Lieberei (2007), in the eastern plains of Colombia (Puerto López, Meta)

Clone	2016–2017		2017–2018			
	Weeks tree ⁻¹	Weeks clone ⁻¹	Weeks tree ⁻¹	Weeks clone ⁻¹		
IAN 873	$6.91 \pm 0.29^*$	a**	9	$4.78 \pm 0.27^*$	a**	8
FX 3864	6.69 ± 0.42	a	9	4.31 ± 0.28	a	8
RRIM 600	6.59 ± 0.46	a	13	4.16 ± 0.53	a	8

*Confidence interval 95%

**Different letters indicate significant differences between clones ($p < 0.05$)

Table 2 Flowering duration in rubber trees in the eastern plains of Colombia (Puerto López, Meta)

Clone	2016–2017			2017–2018		
	Weeks tree ⁻¹		Weeks clone ⁻¹	Weeks tree ⁻¹		Weeks clone ⁻¹
IAN 873	3.25 ± 0.65*	b**	7	4.19 ± 0.28*	b**	7
FX 3864	3.78 ± 0.55	ab	7	4.59 ± 0.34	ab	7
RRIM 600	4.59 ± 0.56	a	9	5.06 ± 0.39	a	12

*Confidence interval 95%

**Different letters indicate significant differences between clones ($p < 0.05$)

FX 3864 did not reach the opening threshold 10 years after planting and showed a foliar density near 0% after the re-fo- liation period, due to severe damage caused by the fungus (Cardoso et al. 2014). Similarly, in Caquetá (Colombia), under non-escape conditions, Sterling et al. (2019) reported a circumference of less than 40 cm at 1 m above the ground and a foliar retention smaller than 60%, 8 years after planting, in clone IAN 873, due to its high susceptibility to *P. ulei*. In the eastern plains of Colombia, the clones FX 3864, IAN 873 and RRIM 600 reached the opening threshold for tapping panel 7 years after planting and showed a foliar density higher than 77% from March to December, resembling the results for an escape zone (Rivano et al. 2016), and the results obtained with resistant clones to *P. ulei* under non-escape conditions (Cardoso et al. 2014; Sterling et al. 2019). The water deficit of 419 mm from December of 2016 to March of 2017, and the water deficit of 570 mm from November of 2017 to March of 2018, allowed the rubber trees to recover their foliage under suitable phytosanitary conditions keeping a high foliar density until the next year.

Phenological evaluation – According to Gasparotto and Pereira (2012), the duration of stages A, B and C is 9, 10 and 8 days, respectively, for total refo- liation duration of 27 days (3.85 weeks). The duration of refo- liation in the eastern plains of Colombia ranked from 4.03 to 6.95 weeks. This duration is important because it corresponds to the period in which the trees are more exposed to the attack of the fungi *P. ulei*. Authors such as Guyot and Le Guen (2018), Da Hora Júnior et al. (2014) and Chee (1976) mention that only young leaves (stages A, B and C) are susceptible to being infected by *P. ulei*.

Rivano et al. (2016) evaluated foliar density and phenol- ogy in 10 rubber clones of Asian and South American ori- gin in Ecuador (1° Sur), finding a very similar phenological behavior in all of the clones assessed, with a foliar den- sity higher than or equal to 80% in at least 8 months of the year. The defoliation–refo- liation processes occurred at the same time for 3 years (August to October) lasting between 11 and 20 weeks depending on the year, and coinciding with dry seasons. Carr (2012) mentions that the defoliation

in rubber trees is induced by dry periods, decreasing the duration of defoliation when the drought intensifies. Subse- quently, the refo- liation begins before the beginning of the rains. Duangngam et al. (2020) mentioned that defoliation and refo- liation occur from January to March in Thailand (13.5°N), coinciding with the dry season (December to April). Various authors have mentioned the relationship of vegetative and reproductive flows with the transition from dry to rainy seasons in various crops, such as Orduz and Garzón (2012) in “Valencia” orange and Borchert (1983) in some forest species.

Authors such as Zhai et al. (2017) and Lin et al. (2018) found that cold stress was the triggering factor for rubber defoliation, without a clear relationship with water stress in southwestern China (> 21° N). Furthermore, Lin et al. (2018) argue that water column cavitation in the xylem that occurs during water stress can also occur because of cold stress, since water viscosity at 10°C is 32% higher than at 30°C, and this could be enough to generate water stress in leaves. Liyanage et al. (2018) mention that apart from the minimum temperature, high number of sunshine hours had an accelerating effect on defoliation and refo- liation. How- ever, cold stress does not explain the behavior of foliar phe- nology in tropical conditions, nor why phenological events occur at the same times in all latitudes of the northern hemi- sphere (January to March) and also in all the latitudes of the southern hemisphere (August to October), as reported by Yeang (2007).

Priyadarshan (2017) mentions that flowering in rubber trees occurs at the end of the defoliation–refo- liation pro- cess, coinciding with dry seasons, i.e., in March–April in the northern hemisphere and in September–October in the southern hemisphere, although in some areas near the equa- tor, flowerings may occur in both seasons. Yeang (2007) reports that the flowering of rubber trees in tropical areas occurs around the spring equinox (March in the northern hemisphere, and September in the southern hemisphere), at the end of the refo- liation, and that in some areas, a period of secondary flowering occurs around the autumn equinox without defoliation–refo- liation. The same author mentions that these periods coincide in all the rubber tree producing regions of the world, even in localities that do not have a

marked dry period (e.g., Bahia in Brazil, some producing areas of Malaysia, among others).

Unlike temperate zones where maximum radiation occurs at the summer solstice, in the tropics there are two radiation peaks per year during the equinoxes when the rays of the sun are perpendicular to the surface of the earth. This is why Yeang (2007) states that the annual radiation cycle is strongly linked to the induction of flowering. Other authors such as Calle et al. (2010) and Borchert et al. (2015) have reported the alternation of periods of growth and dormancy of vegetative and reproductive buds, in addition to the control of the phenology of various tropical tree species by annual sunshine hours or insolation cycles (integrated solar intensity), where the peaks of growth coincide with the radiation peaks that occur around the equinoxes. Dornelas and Rodriguez (2005) studied the expression of the HbLFY gene in young plants (less than 2 months) and adults (more than 16 years) of the rubber tree clone RRIM 600 in Piracicaba, Brazil (southern hemisphere). They found that HbLFY is not expressed in vegetative tissues or meristems, but they detected its expression by hybridization in buds in the transition from the vegetative to the reproductive state, shortly after the winter solstice. However, they observed the first flowers open between September and October. It is possible to deduce that the flowering induction is related to low radiation (winter solstice), but the development of the inflorescences is stimulated by increases in radiation that occur before the equinoxes, indicating a proleptic behavior [discontinuous meristem development from induction to anthesis (Borchert 1983)] for rubber trees, as mentioned by Yeang (2007). Sakai and Kitajima (2019) reported that the time lag existing between the induction by the environmental signal and flower development masks the relation between the cue and the phenological event in several tropical tree species.

Defoliation and refoliation processes occurred in the dry season, coinciding with the months with highest average global radiation and the highest mean temperature, in an area with unimodal rainfall regime, in the eastern plains of Colombia. The shorter refoliation was observed in the period 2017—2018 (4.42 ± 0.39 weeks tree⁻¹), coinciding with a larger water deficit of 570 mm, compared to the refoliation period of 2016—2017 (6.73 ± 0.22 weeks tree⁻¹), associated with a water deficit of 419 mm. However, the decisive factors of the time of occurrence of phenological processes in rubber trees are far from being fully understood. Cold stress, water stress or the amount of radiation have not been able to explain the high synchronicity with which the phenological events occur in this species in different longitudes of the northern hemisphere (January to March) and in different longitudes of the southern hemisphere (August to October) worldwide. Seasonal variation in day length and insolation (even in tropical areas) are the only environmental signals

that are constant from year to year and whose behavior pattern depends on latitude. Multiple authors have found that these variables are responsible for floral synchrony in tropical trees, but their behavior could be masked by cloudiness.

The processes of defoliation, refoliation and flowering of the rubber tree clones IAN 873, FX 3864 and RRIM 600 in the eastern plains of Colombia were observed between the months of January and March. The amplitude of the refoliation period in clone RRIM 600 at the plantation level was up to 13 weeks; meanwhile, in FX 3864 and IAN 873, the maximum duration was 9 weeks. This implies that RRIM 600 is exposed to phytosanitary problems for a longer time window.

As a conclusion, the results of this study support the hypothesis of drought stress as one of the principal triggering factors for foliar and flowering phenology in rubber crops and suggest an important role for radiation on induction and development of refoliation and flowering, as have been reported by other authors. It is necessary to deepen into the study of the relationship between the phenological rubber tree events with the triggering climatic factors, to establish warning systems before the occurrence of conditions with high risk of an attack of foliar diseases or another situation that may alter the production of latex.

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Author's contribution DE Correa, FG López, JP Gil and JJ Guerra performed field data collection. AJ Gutiérrez and OJ Córdoba performed research design. All authors contributed to data analysis, writing of the paper and discussion.

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