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Strawberry-guava phenological monitoring in Paraná Southeast Region

Acompanhamento fenológico de araçazeiros na Região Sudoeste do Paraná

Monitoreo fenológico de araçazeiros en la Región Suroccidental de Paraná

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Abstract

Brazil has a considerable variety of species with edible fruits, such as strawberry-guava (Psidium cattleianum), which has significant environmental plasticity and great use potential.

Studies related to reproductive biology, involving the knowledge of phenology are efficient tools to contribute to the improvement of species management and conservation strategies. Thus, this study aimed to monitor and record the phenological development of yellow and red Strawberry-guava, contrasting the differences between both. The study was developed in Dois Vizinhos, with red and yellow strawberry-guava, cultivar *Ya-Cy*, with random tagged branches, proceeding photographic record and annotations of the peculiarities. The data were presented through images and a detailed description of each phase. The vegetative growth of the red strawberry-guava occurs between July and November, flowering between October and November with fruit ripening from late December to March. The vegetative growth of the yellow strawberry-guava occurs between July and October and between January and April, flowering from September to November and, January to March with fruit maturation between December and February and, from April to September. Red strawberry-guava produced only once a year, while the yellow strawberry-guava shows three outbreaks of production in the same period.

Keywords: *Psidium cattleianum*; Phenology; Phenological phases.

Resumo

O Brasil possui considerável variedade de espécies de frutos comestíveis, a exemplo do araçazeiro (Psidium cattleianum), que apresenta significativa plasticidade ambiental e grande potencial para utilização. Estudos relacionados a biologia reprodutiva, envolvendo o conhecimento da fenologia são eficientes ferramentas para contribuir no aprimoramento de estratégias de manejo e de conservação das espécies. Com isso o objetivo deste trabalho foi acompanhar e registrar o desenvolvimento fenológico de araçazeiros amarelo e vermelho, contrastando as diferenças entre ambos. O trabalho foi desenvolvido em Dois Vizinhos, com araçazeiros vermelho e amarelo cultivar *Ya-Cy*, com ramos marcados aleatoriamente, procedendo-se registro fotográfico e anotações das peculiaridades. Os dados foram apresentados através de imagens e descrição detalhada de cada fase. O crescimento vegetativo do araçazeiro vermelho ocorre entre julho e novembro, floração entre outubro e novembro com maturação dos frutos no final de dezembro até março. O crescimento vegetativo do araçazeiro amarelo ocorre entre julho e outubro e entre janeiro e abril, floração de setembro a novembro e, janeiro a março com maturação dos frutos entre dezembro e fevereiro e, de abril a setembro. O araçazeiro vermelho produziu uma única vez ao ano, enquanto o araçazeiro amarelo apresenta três surtos de produção neste mesmo período.

Palavras-chave: *Psidium cattleianum*; Fenologia; Fases fenológicas.

Resumen

Brasil tiene variedad considerable de especies de frutas comestibles, como los arazás (Psidium cattleianum), que tiene plasticidad ambiental significativa y gran potencial de uso. Los estudios relacionados con la biología reproductiva, que involucran el conocimiento de la fenología, son herramientas eficientes para contribuir al mejoramiento de las estrategias de manejo y conservación de especies. Así, este estudio tuvo como objetivo monitorear y registrar el desarrollo fenológico de arazás de piel amarilla y roja, contrastando las diferencias entre ambas. El estudio se desarrolló en Dois Vizinhos, con ramas marcadas al azar, procediendo con registro fotográfico y anotaciones de las peculiaridades. Los datos se presentaron mediante imágenes y una descripción detallada de cada fase. El crecimiento vegetativo de arazá roja se produce entre julio y noviembre, la floración entre octubre y noviembre, con la maduración del fruto desde finales de diciembre a marzo. El crecimiento vegetativo de arazá amarilla ocurre entre julio y octubre y entre enero y abril, floreciendo de septiembre a noviembre y, de enero a marzo con maduración de frutos entre diciembre y febrero y, de abril a septiembre. El arazá roja se produce solo una vez al año, mientras que el arazá amarilla presenta tres brotes de producción en el mismo período.

Palabras clave: *Psidium cattleianum*; Fenología; Fases fenológicas.

1. Introduction

Brazil has a considerable area of native forest with a variety of species that produce edible, attractive, and tasty fruits (Kohama et al., 2006; Danner et al., 2010a). However, what was seen in the late 19th and early 20th centuries in the states of Paraná, Santa Catarina, and Rio Grande do Sul loses diversity of native fruit trees as a consequence of deforestation, burning and monocultures (Citadin et al., 2005; Santos, 2013), and urgent efforts were need to minimize such impacts, before extinction or decrease to the critical levels of the genotypes that remain. Foreign companies and institutions eagerly search for plant resources as happened with the *Acca sellowiana* (feijoa), which was neglected in the country, introduced and acclimated in countries outside its natural area of occurrence, such as France, Italy, Russia, United States, Israel, Colombia, and New Zealand. In the latter, several cultivars have already been launched (Moretto et al., 2014).

Some native fruit trees are consecrated and already commercially cultivated in the national scene, as *Psidium guajava* (guava), *Passiflora edulis* f. flavicarpa (passion fruit), *Paullinia cupana* (guarana), *Euterpe oleracea* (açaí), *Anacardium occidentale* (cashew)

(Bruckner & Picanço, 2001; Alves & Freitas, 2007; Moretto et al., 2014). *P. edulis* f flavicarpa had a harvested area of 1,200 hectares and a production volume of 18,600 tons in 2016 (SEAB, 2017). *P. guajava*, the most important species of the genus *Psidium*, nationally appreciated, consumed in natura or industrialized (Franzon et al., 2009; Costa et al., 2015), with harvested area of 703 hectares and production estimate of 17.7 tons in 2016 (SEAB, 2017).

However other species, which, although little explored, stand out as a potential source for several uses, especially food, as, like *P. guajava*, produce edible fruits (Franzon et al., 2009). These fruit trees may be commercially exploited, aiming at diversifying fruit production and consumption (Danner et al., 2010b).

In this scenario, the strawberry-guava (*Psidium cattleianum*), a native plant originating in southern Brazil, with wide geographical distribution, found from Rio Grande do Sul to Bahia, with significant environmental plasticity in both tropical and subtropical climates, in the most varied edaphoclimatic conditions (Raseira et al., 2004; Franzon et al., 2009; Lisboa et al., 2011) has great potential for exploration, but for this, several basic studies are needed to understand the behavior, limitations, and ways of managing the plant.

Studies related to reproductive biology, involving knowledge of its phenology are efficient tools to contribute to the improvement of management strategies in cultivation and conservation (Perleberg, 2017). Phenology is the study of the flowering and fruiting patterns of a species, that is, the study of the biological cycle of plants that includes the monitoring of phases such as flowering, fruiting, and leaf change (Pereira et al., 2009). Such monitoring is necessary if the objective is their commercial exploitation, allowing the producer to estimate the time of harvest, care for fungal diseases and serve as a parameter for possible management practices.

Thus, the objective of this work was to monitor and record the phenological development of yellow and red Strawberry-guava, contrasting the main differences between both.

2. Material and Methods

The study was developed in the Collection of Native Fruit Trees of the Experimental Station of the UTFPR – Campus Dois Vizinhos. Two red Strawberry-guava plants, over 15 years old and 30 yellow Strawberry-guava plants cultivar *Ya-Cy*, aged approximately seven years, were used, all materials of seminiferous origin. Taxonomic confirmation of the species

was carried out following the key of Tuler et al. (2017). The botanical material was collected and preceded with the identification of the details of leaves and flowers following the methodologies of Vidal & Vidal (2000) and Gonçalves (2011).

To monitor phenology, the chosen individuals were observed weekly until the beginning of the reproductive phase, characterized by the appearance of the first floral structures. The period between evaluations was reduced for each second day, following the development of the flower and gathering information on details of anthesis to senescence of the floral organs. Photographic records were taken during all evaluations, as reported by Bezerra & Machado (2003).

Specificities of the vegetative phases were observed, such as the visual changes that occur in the leaves during the maturation of their tissues, as well as in the reproductive phase, through the monitoring and recording of the evolution of the floral parts and fruiting until the maturation of the fruits, relating the events phenological data with precipitation and temperature data, just as Maués & Couturier (2002) did.

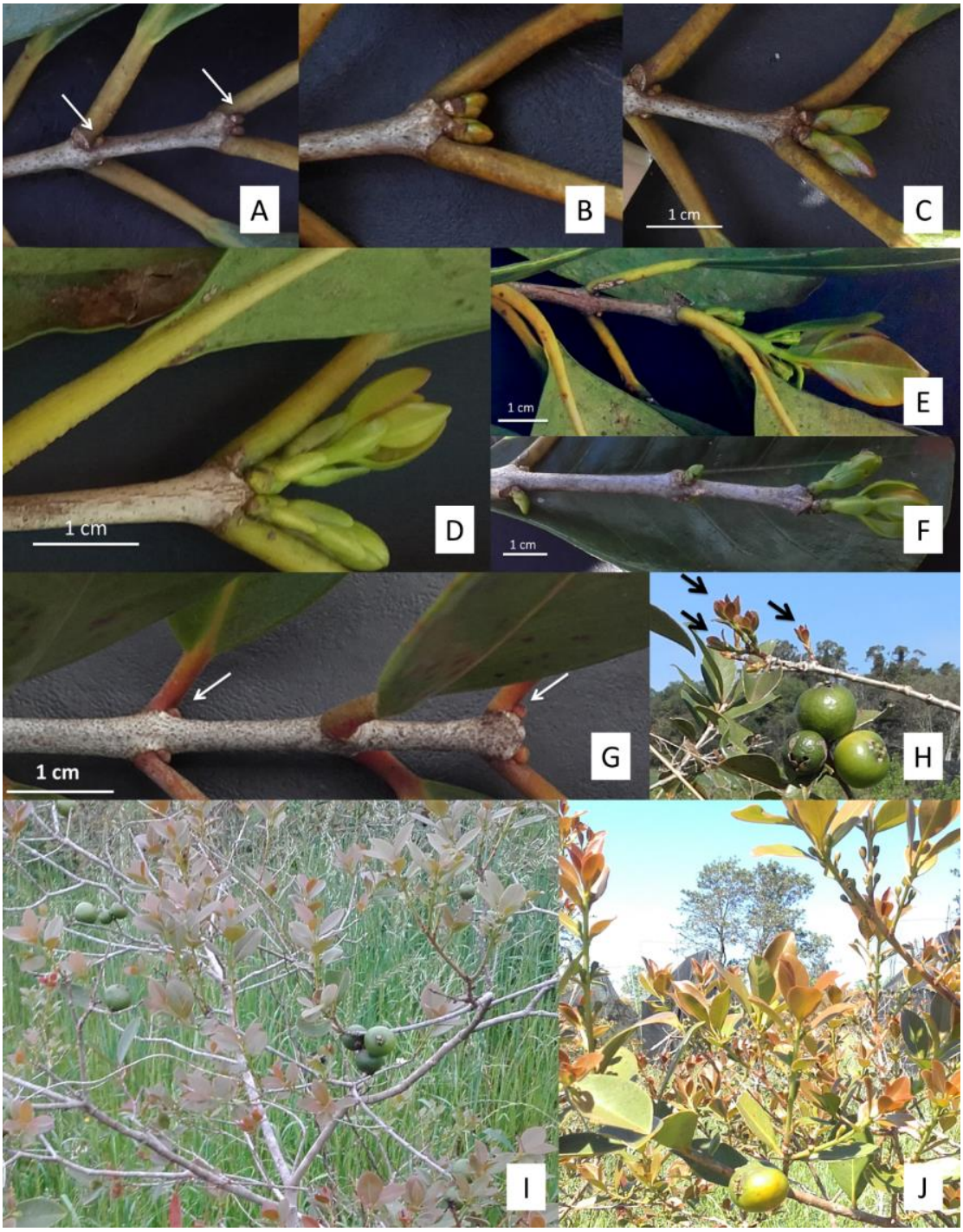
For the red strawberry-guava, the two focal individuals had 10 branches randomly marked, resulting in 20 branches, followed between June 2016 and February 2017, a period that covered the latency phases of the buds, vegetative, reproductive and fruit maturation phases. For the yellow strawberry-guava, 30 individuals were randomly selected, of which one branch per individual was marked for follow-up, between June 2016 and October 2017.

The data were presented through images and detailed description of each phase.

3. Result and Discussions

During June, Strawberry-guava's showed only well-expanded leaves, from the previous growing season and paralyzed vegetative buds, brown with approximately 2.5 mm in length, for the red Strawberry-guava (Figure 1A) and reddish-brown with size of approximately 1.5 mm, in the yellow strawberry-guava (Figure 1G), arranged in the leaf axils and apex of the branches. This month, the yellow strawberry-guava showed several stages of fruit ripening, from the previous growth spurt.

Figure 1. Vegetative growth of red Strawberry-guava with paralyzed buds (indicated by arrows) (A), overcoming paralysis (B), beginning of growth (C), elongation of internodes and opening of leaves (D) appearance of flower buds (E) and lateral sprouting (F). Vegetative growth of yellow strawberry-guava cv. *Ya-Cy* with paralyzed buds (indicated by the arrows) (G), fruits at various stages of ripeness and small buds (indicated by the arrows) (H), few fruits and bigger buds with flower buds (I) and big buds and flower buds well developed (J).



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At the end of July, red strawberry-guava branches had enlarged buds (Figure 1B), showing overcoming of paralysis, however, only in apical buds, with an average size of approximately 5 mm, but most of the branches had still paralyzed buds. The yellow strawberry-guava had several buds in this period, apical and lateral, different from the other structures due to the reddish color, with fruits still present, in different maturation stages (Figure 1H).

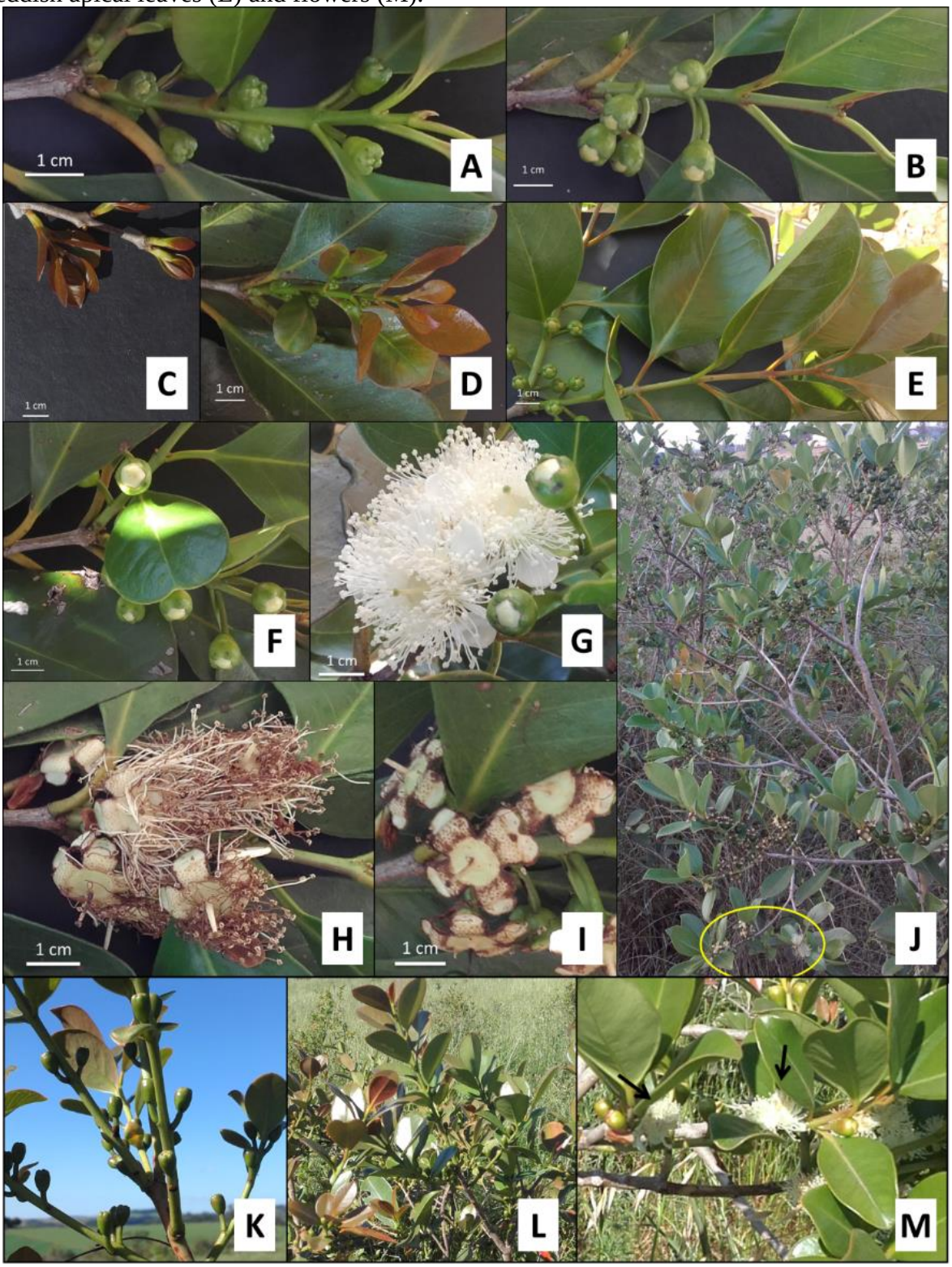
In early August, few branches of red strawberry-guava (<10%) had buds, which were approximately 7 mm in size (Figure 1C). In the yellow strawberry-guava, the crown is reddish, with the highest emission of buds (Figure 1I), and most of these, with visible flower buds, in addition to the presence of fruits at various stages of maturation.

At the end of August, the first emissions of flower buds in red strawberry-guava (Figure 1E) were observed, as well as lateral sprouting in some branches (5%) (Figure 1F), reaching average size of 2.5 cm and reddish color. During the same period, the yellow strawberry-guava had many buds with flower buds and fruits in the final stages of maturation (Figure 1J).

Sprouts of red strawberry-guava, at the beginning of September, had an average of 6 cm, with red leaves and flower buds with larger peduncles (Figure 2A). Almost all branches overcame the apical buds (> 85%). Of these, only a few (15%), with lateral budding, some even with reproductive structures. In the same period, most of the yellow strawberry-guava flower buds were well developed (Figure 2K), but with many reddish leaves (Figure 2L), that is, new ones.

In mid-September, red strawberry-guava showed few branches with paralyzed buds (15%), or lateral sprouting (20%). Larger shoots showed up to 16 cm, with reddish leaves and well-developed flower buds, making it easy to distinguish between corolla and calyx on the buds (Figure 2B, Figure 2F and Figure 2G). The yellow strawberry-guava also had reddish leaves, which were restricted to a few pairs in the apical portion of the branches (Figure 2L), observing the appearance of the first flowers (Figure 2J and Figure 2M), remaining with these characteristics until the end of the month.

Figure 2. Red strawberry-guava: buds with small flower buds (A), well-developed flower buds (B), side buds (C), bud with flower buds and reddish-colored leaves (D), buds with more developed structures with apical leaves reddish in color and flower buds only in the first pairs of basal buds (E) well-developed flower buds (F), anthesis flowers (G), senescent flowers (H) and flowers without androceu or petals (I). Yellow strawberry-guava cv. *Ya-Cy*: with fruits in development and flowers in the basal region (indicated by the circle) (J). Floral buds (K), reddish apical leaves (L) and flowers (M).



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In the last week of September, the red strawberry-guava had several stages of development of vegetative and reproductive structures (Figure 2). The shoots reached 18 cm; approximately 25% of the branches overcame the paralysis of the lateral buds, which gave rise to shoots with reddish leaves (Figure 2C). The main difference observed was the presence of reproductive structures in some lateral shoots. With the growth of shoots, this red coloration was restricted to the apical leaves (Figure 2D). Some branches had a longer internode length and completely green leaves, with total expansion, however, with a very malleable consistency (Figure 2E). When all flower buds on the new branch had lighter-colored petals and the diameter of the corolla reaching 7 mm (Figure 2F), the leaves were fully expanded and leatherier in appearance.

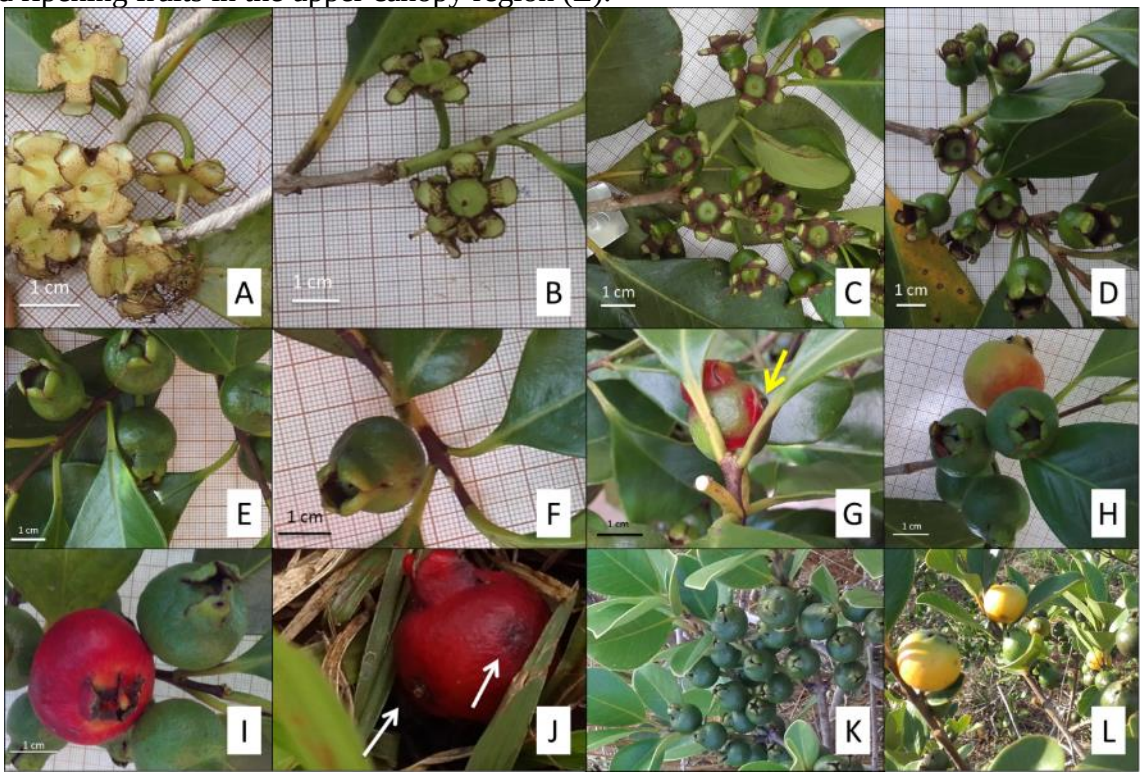
In the first week of October, the red strawberry-guava branches almost entirely, had an average length of 22 cm, with flowers and/or flower buds. Most of the leaves were fully expanded, but some buds still had reddish leaves, which is characteristic of young material. Flower buds of different sizes and stages of development were observed, small opening diameter from the upper part of the chalice (Figure 2E) to well-developed balloons, with greater exposure of the corolla (Figure 2B and Figure 2F). Flowers in anthesis (Figure 2G), senescent (Figure 2H) and without petals and androceu (Figure 2I) were recorded. In mid-October, there were still branches with new reddish leaves and most of the branches had fruits in formation. At the end of the month, no young or reddish leaves were observed.

In October, the reddish color in the leaves of the yellow strawberry-guava was not noticed and in practically all the branches there were fruits at the beginning of development. At the end of this month, the fruits were more present in the upper region of the crown and the lower region there were flower buds and flowers (Figure 2J).

In early November, in red strawberry-guava, only 30% of the branches had flower buds or flowers and 45%, with fruits in the formation and little variation in color and shape. After the dehiscence of the floral pieces, the chalice showed a light color and curved sepals towards the peduncle (Figure 3A), turning the color more greenish and forming an angle of 90° concerning the carpel (Figure 3B). With the development of the ovary, the sepals began to take the vertical position, with an angle of less than 90°, about the pistil, which was no longer present (Figure 3C) crowning the fruit and taking a more vertical position. The branches begin the lignification process, taking on a yellowish color, with darkened spaces (Figure 3D). In November, most yellow strawberry-guava had well-developed immature fruits (Figure 3K), but still with anthesis flowers in the basal region of the crown (Figure 2J), only in the first half of the month.

At the beginning of December, no flowers or flower buds were observed in the red strawberry-guava. The vegetative growth was stopped, and the fruits were in full growth, reaching an average of 2 cm in diameter and dark green color, crowned by the set of sepals that touched laterally, parallel in a vertical position. The leaves were fully expanded and leathery. The dark-colored and woody branches (Figure 3E), but some with light spots (Figure 3F). In mid-December, parts of the fruit showed a reddish crown color, not due to spontaneous ripening, but due to pest attacks (Figure 3G), as it had dark spots and the fruit was expanding. In the first half of December, in yellow strawberry-guava, only immature and well-developed fruits were found (Figure 3K), with no flowers or flower buds.

Figure 3. Beginning of formation of the red Strawberry-guava fruit with clear sepals facing the peduncle (A), oxidized greenish sepals and an approximate angle of 90 degrees concerning the peduncle (B), expansion of the ovary and sepals facing the apex of the fruit (C), more developed ovary with sepals more upward forming crown (D), immature fruits with lignified and dark branches (E), branches in the process of lignification (F), beginning of maturation due to insect attack (indicated by the arrow) (G), in natural maturation process (H), completely ripe (I) and fruits on the ground with spikes caused by pest attack (pointed by the arrows) (J). Strawberry-guava yellow cv. *Ya-Cy* with well-developed immature fruits (K) and ripening fruits in the upper canopy region (L).



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At the end of December, the red strawberry-guava fruit's started to ripen, which showed partial closure of the crown (formed by persistent sepals) and the epidermis became

lighter, with color varying from yellow, orange or red tones (Figure 3H). When mature, the color of the epidermis was intense red (Figure 3I). However, it was present in a reduced quantity in the plants during this period. Some fruits were observed on the ground, below the canopy projection area, with lesions caused by pests (Figure 3J). In the second half of December, ripe yellow strawberry-guava fruits were found (Figure 3L), first in the upper canopy region and then in the lower region.

At the beginning of January, there was a greater amount of ripe fruits (Figure 3I) of red Strawberry-guava, easily observed in the canopy of the plants due to the distinction of colors between the fruits and leaves, in addition to a greater quantity on the soil. In yellow strawberry-guava, many of the fruits were ripe and the reddish color more present in some branches, from the second growth spurt of the season, was observed again.

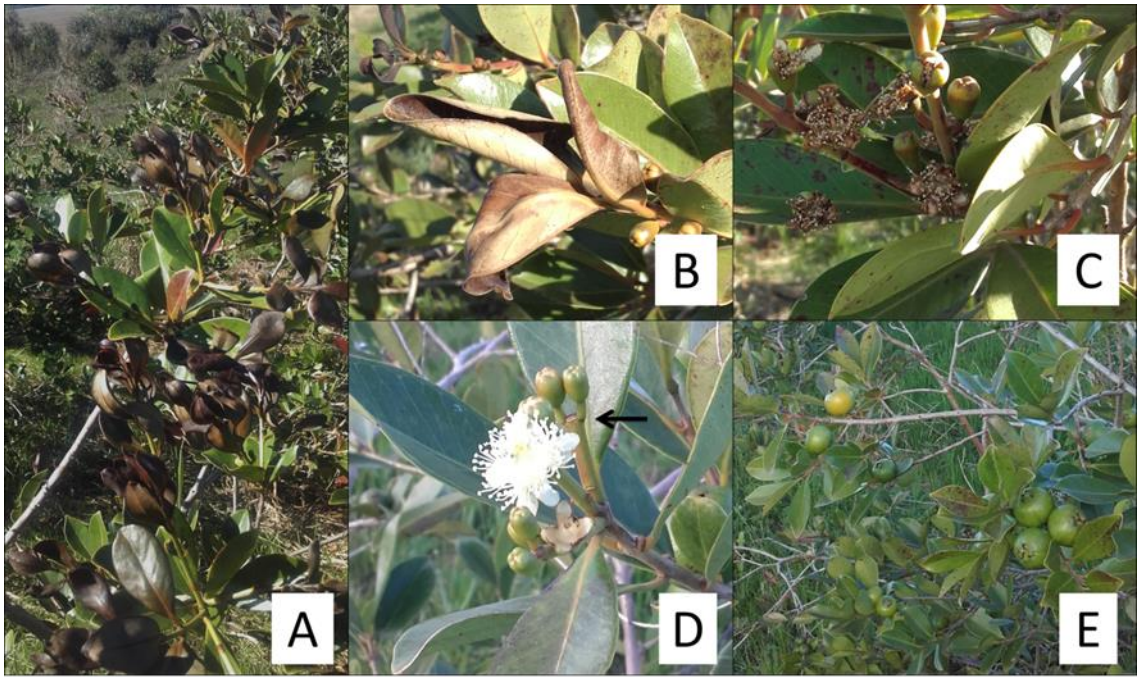
At the end of January, most of the evaluated branches no longer had fruit, only dry, blackened peduncles. In the canopy of the plant, there were many ripe fruits, as well as, on the soil. This condition was maintained until the first week of February when all the branches evaluated no longer showed fruit, however, the plants showed fruit maturing until the beginning of March. After this period, no outbreaks of vegetative growth or new flowering were observed.

At the end of January, few yellow strawberry-guava fruits were still present on the plants, most of them in the final ripening process, accompanied by the emission of shoots in part of the branches, which gave the plants canopy a reddish color. The presence of other structures was observed, such as flower buds, which could be easily found in several plants, as well as flowers in anthesis.

During the months from February to April, the behavior of the yellow strawberry-guava was very similar to that reported in September, with the presence of flower buds and flowers but different from September, the period in which these structures appeared extended for three months, with less production of fruits. In May, the plants showed fruits at different stages of development, from the beginning to maturation, as well as new buds in some plants. In June it was possible to observe some sporadic buds, some flowers, and flower buds, as well as immature and ripening fruits.

In July, with the occurrence of lower temperatures and frosts, shoots that showed a reddish color suffered irreversible tissue damage (Figure 4A). The red Strawberry-guava did not suffer injuries with low temperatures since it did not present young tissues in this period.

Figure 4. Yellow strawberry-guava cv. *Ya-Cy* with herbaceous shoots damaged by the cold two days after the frost occurrence (A). Damage caused to leaves, flower buds (B) and flowers with impaired anthesis (C) ten days after the occurrence of frost. Flowers, flower buds and abscission (indicated by the arrow) (A). Immature fruits at various stages of ripeness (B).



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At 10 days after frost, the leaves that suffered necrotic damage, initially appearing blackish and then drying (Figure 4B), being aborted with the evolution of necrosis. The most affected flower buds showed a yellowish color (Figure 4B) with subsequent abscission. The more developed ones, close to the time of the anthesis, did not get to complete it, because the anthers inside had a dark color, as well as their petals. What most affected the process was the incomplete division of the sepals, to the point of not exposing the other floral pieces, damaging the anthesis (Figure 4C).

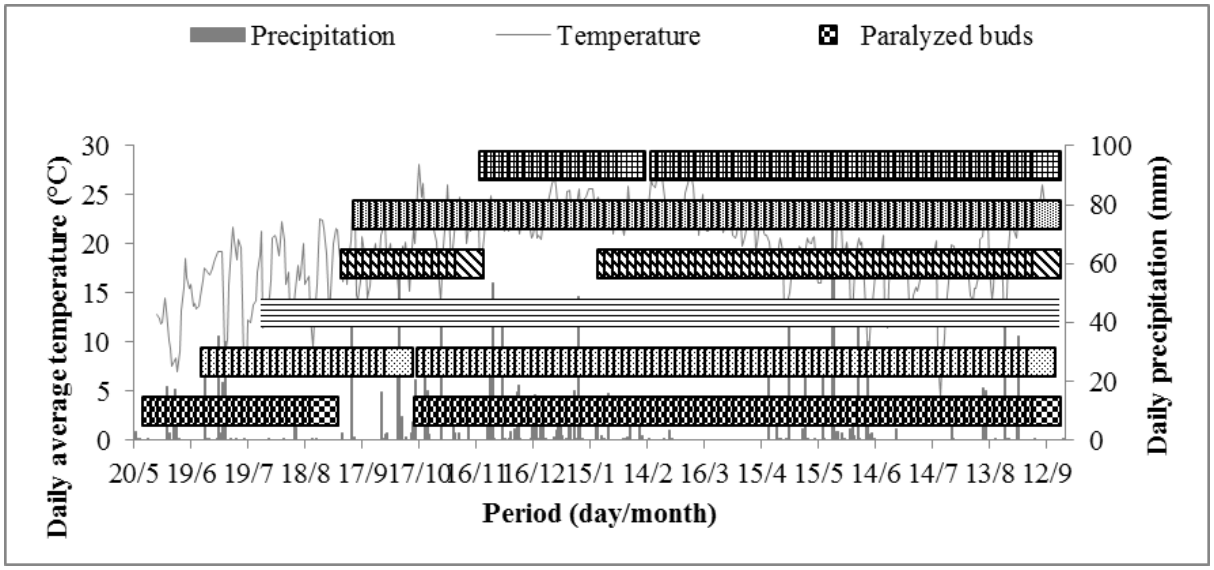
In August, after senescence and abscission of the tissues damaged by the cold (Figure 4D indicated by the arrow), the flower buds that persisted in the plants, completed anthesis (Figure 4D). In addition to the flowers at this time, fruits were found at different stages of maturation (Figure 4E) and new shoots responsible for the beginning of the new reproductive cycle.

With the phenological monitoring of the red strawberry-guava, only one production cycle was observed. In the yellow strawberry-guava, it was noticed the presence of fruits during practically the whole year, as reported by Lorenzi (1992), but in the growth spurt just after winter, there was a greater amount of fruit produced. It was observed that there was no

synchronization of flowering in the same branch, as there were simultaneous and sequential flower launches, as well as irregular flowering and no defined season. This behavior is typical of wild plant (Brandão et al.; 2015).

The phenology of the red strawberry-guava responded directly to the oscillation of temperature and precipitation. After a short period of drought and a gradual increase in temperature, in late July, shoots began, followed by their growth until November. Between August and November, there was the presence of flower buds, coinciding with the period of higher temperatures and an increase in the regularity of precipitation (Figure 5), as well as for Campomanesia adamantium, species Myrtaceae, which emits flowers according to temperature variations and precipitation (Nucci & Alves-Júnior, 2017). After approximately 60 days of drought, there was precipitation of approximately 40 mm, which seems to have triggered the beginning of flowering in October and continued until the end of November, a result similar to that reported by Lisboa et al. (2011) and Speroni et al. (2012) for this species.

Figure 5. Phases of development of red strawberry-guava, during a productive cycle, with elapsed time in which the structure can be found in the plant. Daily rainfall and average daily temperature data during the 2016/2017 production period.



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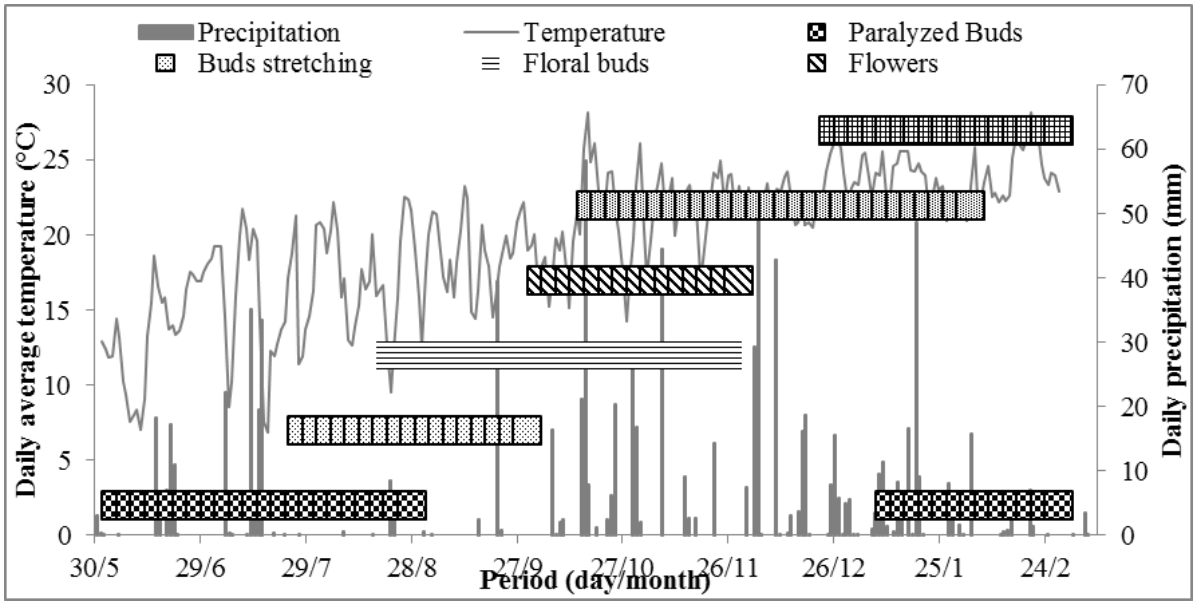
Fruits were present between October and January, a period with reduced thermal amplitude. Fruit maturation occurred between December and February, a period of more regular precipitation and higher temperatures, with less thermal amplitude. The development stages of the plant may undergo changes related to climatic variations, with a strong influence of the rain cycle (Nucci & Alves-Júnior, 2017).

For yellow strawberry-guava, growth spurts were observed in the marked branches, which comprises the winter until the following winter. The presence of fruits in the plant did not inhibit a new growth spurt. The vegetative growth was paralyzed by the reallocation of the reserves involved with the partition that exists for the drain that has fruits as preference.

The yellow strawberry-guava plants had vegetative buds paralyzed until August, with vegetative growth beginning between the end of June and September, when it presented a small interval until October, resuming growth through new sprouts. In the evaluated branches, from the end of July until September of the following year, flower buds were always present. Flowers were observed between September and November, with an interval of 70 days and the reappearance of these structures occurred in mid-January, extending until the end of the evaluations. In September, the growth of the fruits started, structures present until the evaluations end. From November, ripe fruits were found until the end of evaluations, but in February there was a short interval, of approximately 15 days, without their presence (Figure 6).

Figure 6. Development phases of yellow strawberry-guava, during three productive cycles in the same growing season, with elapsed time when the structure can be found in the plant. Daily rainfall and average daily temperature data during the 2016/2017 production period.



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The ecological strategy for flowering strawberry-guava is the cornucopia, as it presents flower production over a few weeks (Rech et al., 2014). On a population scale, greater flowering time decreases the chances of exposure to periods of low pollinator activity

(Perleberg, 2017).

The flowering observed in the present study, in both types of strawberry-guava, presented a period much longer than that reported in the literature for species, which, according to Speroni et al. (2012) varies between five and 16 days between different genotypes of yellow and red strawberry-guava trees. Such discrepancy may be due to the location of the experiment, climatic conditions, and genetic factors. Besides, the authors did not observe other growth spurts as reported in the present study.

In yellow strawberry-guava 100% of the branches used produced fruits in the first production cycle with an average of 10 ± 0.5 fruits per branch, of these, only 50% also produced in the second productive cycle, with 4 ± 1 fruit per branch and 20% of branches in the third cycle with 3 ± 1 fruit per branch. The fruiting of both types of strawberry-guava takes place in the branches of the year, up to the fifth pair of basal buds.

4. Conclusions

1. The yellow strawberry-guava was tolerant to frost and low temperatures, but only well-developed tissues, because when herbaceous they showed irreversible damage.

2. The vegetative growth of the red strawberry-guava begins in July, extending until November. Flowering starts in October and lasts until November. Fruit ripening starts in late December and ends in early March.

3. The vegetative growth of the yellow strawberry-guava occurs between July and October and between January and April. Flowering occurs between September and November and, January to March, with fruit ripening between December and February and April to September.

4. The red strawberry-guava produced only once a year, while the yellow strawberry-guava produced three times a year.

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