

Phenology and fruit biometrics in different positions of reproductive branches of *Campomanesia adamantium* (Cambess.) O. Berg.

Fenologia e biometria de frutos em diferentes posições de ramos reprodutivos de *Campomanesia adamantium* (Cambess.) O. Berg.

Marília Assis dos Santos¹, Alan Carlos Costa², Clarice Aparecida Megguer³,
Júliên da Silva Lima⁴, Paula Andrea Nascimento dos Reis Magalhães⁵,
Michellia Perreira Soares⁶, Priscila Ferreira Batista² & Sueisla Lopes Rezende-Silva^{7,*}

¹Federal Institute of Education, Science and Technology of Rondônia – Jaru Campus, – Avenue Otaviano Pereira Neto, number 874, Sector 2, Jaru, Rondônia, Brasil. CEP: 76890-000

²Federal Institute of Education, Science and Technology-Câmpus Rio Verde – Rodovia BR-153, Km 633, Zona Rural, Morrinhos, Goiás, Brasil. CEP: 75650-000. Laboratory of Ecophysiology and Plant Productivity

³Federal Institute of Education, Science and Technology-Câmpus Morrinhos – Rodovia Sul Goiana, Km 01, Zona Rural, Rio Verde, Goiás, Brazil. CEP: 75901-970

⁴Federal University of Viçosa, Avenida Peter Henry Rolfs, s/n – Campus Universitário, Viçosa, Minas Gerais, Brasil. CEP:365709000

⁵University of Rio Verde-Câmpus Rio Verde, Avenida Universitária, s/n – Setor Universitário, Rio Verde, Goiás, Brasil. CEP:75901-970. Monitoring Laboratory Environmental

⁶Federal Institute of Education, Science and Technology – Campus Salinas, Fazenda Varginha, Km 02 Rod.Salinas/Taiobeiras – Salinas, Minas Gerais, Brasil. CEP:39560-000

⁷Federal University of Goiás, Campus university city, Department of Biological Sciences, BR 364, Km 195, nº 3800, CEP: 75801-615, Jataí, Goiás, Brazil

(*E-mail: sueislalopes@gmail.com)

<https://doi.org/10.19084/rca.18153>

Received/recebido: 2019.06.27

Accepted/aceite: 2019.10.16

ABSTRACT

Phenology is very important to the understanding of plant cycles, the repetition of biological events, and the causes of these cycles in relation abiotic and biotic factors. The aim of this to evaluate the time of occurrence and intensity of the vegetative and reproductive phenological phases, their correlations with external factors, and the influence of photosynthetically active radiation in the fruit *Campomanesia adamantium* (Cambess.) O. Berg. The study was conducted on a farm in the municipality of Rio Verde, Brazil. The phenological characterisation was performed using ten adult plants. Phenological observations of vegetative and reproductive phenological phases were made monthly and weekly, respectively. The total number and the transverse and longitudinal diameters of the fruit of two branches per plant, with higher and lower incidence of radiation, were also evaluated. The young and adult leaves in *Campomanesia adamantium* were active for almost the entire study period, except the young leaves were inactive in the months of May and August. The presence of sprouts was also very high during the study period. There was a phenophase cycle of rapid and intense play between October and January for *C. adamantium*. The incidence of radiation interfered with the size and production of the fruit. Fruits that developed in the shadow of branches were fewer and their biometric values lower than those who developed in sunlight.

Keywords: *Gabiroba*, Plant adaptation, Myrtaceae, Cerrado, Irradiance.

RESUMO

A fenologia é muito importante para o entendimento dos ciclos das plantas, a repetição de eventos biológicos e as causas desses ciclos em relação a fatores abióticos e bióticos. Diante disto, objetivou-se com este trabalho avaliar a época de ocorrência e intensidade das fases fenológicas vegetativas e reprodutivas e suas correlações com fatores externos e a influência da radiação fotossinteticamente ativa na biometria de frutos de *Campomanesia adamantium* (Cambess.) O. Berg. O estudo foi conduzido em fazenda localizada no município de Rio Verde-GO, Brasil. A caracterização da fenologia foi feita em dez indivíduos adultos. As observações fenologia das fases fenológicas vegetativas foram feitas mensalmente e os eventos fenológicos, reprodutivos, semanalmente. Foram utilizados dois métodos para o registro dos eventos fenológicos: o percentual de intensidade de Fournier e o índice de atividade. Foram feitas também avaliações do número total e diâmetros transversal e longitudinal dos frutos de dois ramos por planta com maior e menor incidência de radiação.

Verificou-se atividade de folhas jovens e adultas em *Campomanesia adamantium* em quase todo o período de estudo, exceto nos meses de maio e agosto, para folhas jovens. A presença de brotos também foi bastante intensa durante o período. Observou-se um ciclo de fenofases de reprodução rápido e intenso entre os meses de outubro e janeiro para *C. adamantium*. A incidência da radiação interferiu na dimensão e produção dos frutos. Frutos desenvolvidos em ramos de sombra tiveram número reduzido e valores biométricos inferiores em relação àqueles que cresceram em ramos de sol.

Palavras-chave: *Gabiroba*, Adaptação da planta, Myrtaceae, Cerrado, Irradiância.

INTRODUCTION

Brazil has great biodiversity, but many species still require study, such as the fruit species of the Cerrado, including *Campomanesia adamantium* (Cambess.) O. Berg. (Arantes and Monteiro, 2002), popularly known as *gabiroba*. *Campomanesia adamantium* belongs to the Myrtaceae family, and Brazil has 24 genera and 975 species of this fruit (Sobral *et al.*, 2013). This family has been the focus of studies in the Atlantic Forest, the Araucaria forests, and even in the recovery of mining areas (Garcia *et al.*, 2009; Danner *et al.*, 2010; Lourenço and Barbosa, 2012), as well as histochemical studies (Kuster and Vale, 2016).

The *gabirobeira* is described as a 0.3- to 2-m tall shrub with fruiting between the months of September to November, producing globular fruit 2 to 2.5 cm in diameter, with yellow flesh when ripe (Porto and Gulias, 2010), and has antimicrobial activity, with high antibacterial and antifungal potential (Sá *et al.*, 2018). It is necessary to study of Cerrado plants, as well as phenology, due to the loss of natural vegetation, but in recent years more than 50% of its area has been converted to grain crops and pastures (Guilherme *et al.*, 2011; Franco *et al.*, 2014; Rezende-Silva *et al.*, 2019).

Phenology is dedicated to the observation of plant cycles (Staggemeier *et al.*, 2010), the repetition of biological events, and the causes of these cycles in relation to abiotic selective factors, such as temperature, precipitation, and photoperiod, and also in relation to biotic factors, such as seed dispersal syndromes, which help us to understand the spatial dispersion of the plants. Phenology is also dedicated to the understanding of the interrelationship between the phenological phases characterised by these repetitive events within one or multiple species (Lieth, 1974; Cortés-Flores *et al.*, 2013).

Knowledge of the distribution of the types of vegetation and their phenological variations are indispensable in programs aimed at developing and understanding the coexistence of different ecosystems, whether natural, agricultural, or industrial (Canavesi *et al.*, 2005). It is also essential to better understand the ecology and evolution of species and communities (Newstrom *et al.*, 1994).

Phenology is very important also to the botanical and ecological points of view, contributing directly or indirectly to the development and understanding of projects and research in forestry. Phenology is also a fundamental tool in the management and restoration of degraded and riparian areas (Santos and Ferreira, 2013).

Campomanesia adamantium is one species with high economic potential due to the varied potential uses of fruits and other plant parts. However like most native Cerrado species, there is a lack of agronomic information that will enable the start of commercial crops, in this regard the information on growth and development of plants of this species should be prioritized (Araújo and Souza, 2018).

Several researchers have given great importance to external factors, such as seasonality, periodicity and timing, which act as triggers for endogenous factors that trigger the vegetative and reproductive phenological phases (Janzen, 1967).

Another external factor studied in fruit is the photosynthetically active radiation received by olives (Cherbiy-Hoffmann *et al.*, 2013), apples (González-Talice *et al.*, 2013), blueberries (Lobos *et al.*, 2013), strawberries (Costa *et al.*, 2011) and melons (Pereira *et al.*, 2010). The shading of a plant may cause changes in the microclimate in which it is located and, according to the time and intensity, there may be physiological, anatomical, and

reproductive changes that negatively affect fruit production (Mitchell, 2003).

The yield of a crop, crop genetics, and other conditions are directly linked to the efficiency of photosynthetic radiation (Morais *et al.*, 2009). Thus, the production of a culture depends on effective interception of the incident solar radiation on the photosynthetic plant organs, its conversion into energy, and translocation of assimilates in the different plant organs (Ferreira, 1995).

In view of this, the aim of this study was to evaluate the time of occurrence, intensity of reproductive and vegetative phenological phases, and their correlations with climate variables, such as temperature, humidity, and precipitation, and the influence of photosynthetically active radiation in the fruit *Campomanesia adamantium* (Cambess.) O. Berg.

MATERIALS AND METHODS

Study site

The phenological study and growth of *Campomanesia adamantium* was conducted in Rio Verde, Goiás, Brazil, located at the coordinates of latitude 17° 56' 46" S and longitude 51° 11' 50" W, at an elevation of 694 m.

The location studied is in the phytogeographical area of Cerrado, or cerrado *sensu lato*, and the cerrado is the predominant vegetation type on site (Veloso *et al.*, 1991).

According to Köppen, the region falls within the Aw climate type, characteristic of tropical humid climates, with two distinct seasons: dry in winter and humid in the summer. The average annual rainfall is between 1200 and 1800 mm. The rainy season extends from November to March, with the wettest quarter corresponding to the months of January, February, and March. The dry period is represented by the months of June, July, and August, with May and September as the months of transition between the dry and wet seasons, respectively. The average maximum temperatures are around 18 °C, and the annual temperature range is less than 4 °C (SEPLAN-GO, 2005; EPE, 2006).

Phenological data collection

The phenological characterisation was made in ten *Campomanesia adamantium* adults, which were numbered, labelled, and evaluated in terms of age. The inclusion criteria for the plants were that the diameter at breast height (30 cm ground) was ≥ 3 cm and the plants were in the reproductive stage.

The collected botanical material was deposited in the Green River Herbarium (IFRV) of the Federal Institute Goiano – Campus Rio Verde. The species identification was based on the scientific literature and consultation with experts.

Phenological observations of vegetative phenological phases (shoot, young leaf, adult leaf, and senescent leaf) were made monthly and reproductive phenological phases (button, anthesis, immature fruit, and ripe fruit) weekly. The observations of vegetative and reproductive phenological phases occurred between October 2012 and September 2013, always by the same observer.

The phenological events were recorded by the intensity ratios and activity phenological phases. The intensity index of phenophase in each individual was verified by the Fournier method using a semiquantitative scale interval of five categories (0-4), with an interval of 25% in each category, as follows: 0 = absence of phenology; 1 = presence of phenophase of magnitude of 1-25%; 2 = presence of phenophase of magnitude 26-50%; 3 = presence of phenophase with magnitude 51 to 75%; and 4 = presence of phenophase of magnitude 76-100%. The activity index revealed the presence or absence of phenophase in each individual (Bencke and Morellato, 2002).

To calculate the intensity index, the intensity values for all individuals of each species were summed and divided by the maximum possible value (number of individuals multiplied by four) each month. The obtained value was then multiplied by 100 to turn it into a percentage value (Fournier, 1974; Bencke and Morellato, 2002). The activity index method indicates the percentage of individuals in the population that is manifesting certain phenological events. This method can also be used to calculate the timing of individuals in a population (Morellato *et al.*, 1990), taking into

account that the greater the number of individuals simultaneously expressing phenophase, the greater the timing of this population.

The environmental variables for the study period were obtained from the Meteorological UniRV- University of Rio Verde Station and correlated to the studied phenological phases based on the Spearman correlation coefficient (rs).

Biometric data collection

The photosynthetically active radiation (PAR) levied on each individual was measured weekly by radiation sensors (Decagon Devices, Pullan, USA) in the middle region of the crown and apex of the region (Figure 1). From these data, two branches were marked in each individual: a branch with a higher incidence of light on the plant apex and a branch with a lower incidence in the middle region of the plant, called the sun and shade branches, respectively.

Prior to biometric evaluation monitoring, the total number of fruits per branch (sun and shade) were counted. Five fruits were selected at random in the middle portion of each branch for further monitoring of the longitudinal diameter and transverse diameter of the fruit to full maturity. Measurements were made with a hand calliper with an accuracy of 0.02 mm.

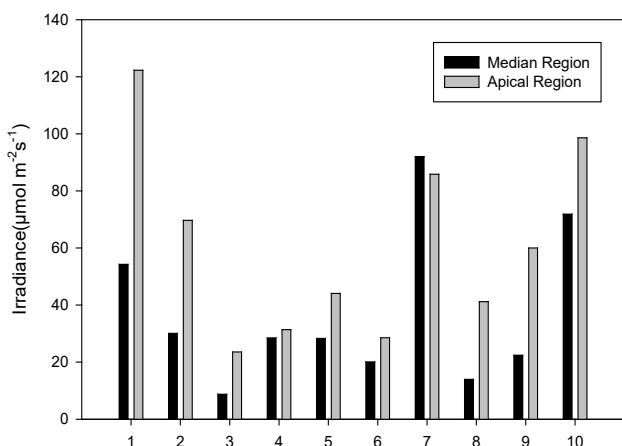


Figure 1 - Mean values of photosynthetically active radiation (PAR) incident in the median and apical regions in each individual *Campomanesia adamantium*. Rio Verde, GO, 2012/2013.

The actual fruit set was checked weekly by the total number of fruits counted in the sun and shade branches.

For fruit biometrics, the experiment was conducted in an experimental design that consisted of randomised blocks and the means and the standard error of the mean were obtained. The correlation between the number of fruits and the diameters was tested by Pearson correlation, using Bioestat software.

RESULTS

Vegetative Phenological phases

Shoots were observed in almost all of the evaluation period, except for the months of March, May, and August. The largest shoot activity peaks were observed in October, November, and January 2012 and September 2013 (Figure 2), and the highest percentage of individuals presenting shoots occurred in September, along with most of the canopy coverage ratio (Figure 2B).

The young leaf activity was recorded between the months of October and April and the months of June, July, and September; this activity decreased as time went on (Figure 2A). The maximum activity was recorded in October, together with greater intensity; however, after this period, intensity values declined (Figure 2B).

The adult leaves were less active during the first three weeks of evaluation and only after the month of November did the adult leaves reach maximum activity; the period of maximum activity extended until the month of August and decreased thereafter (Figure 2A). The intensity of mature leaves was inversely proportional to the intensity of young leaves. For mature leaf intensity, lower values were observed in October, followed by an increase in the percentage with maximum values in December, with a slow decrease afterward (Figure 2B).

The senescent leaf was observed from December 2012 and the maximum values of fall activity occurred between February and September (Figure 2A). The leaves' intensity decrease was zero in October and November 2012; intensity increases

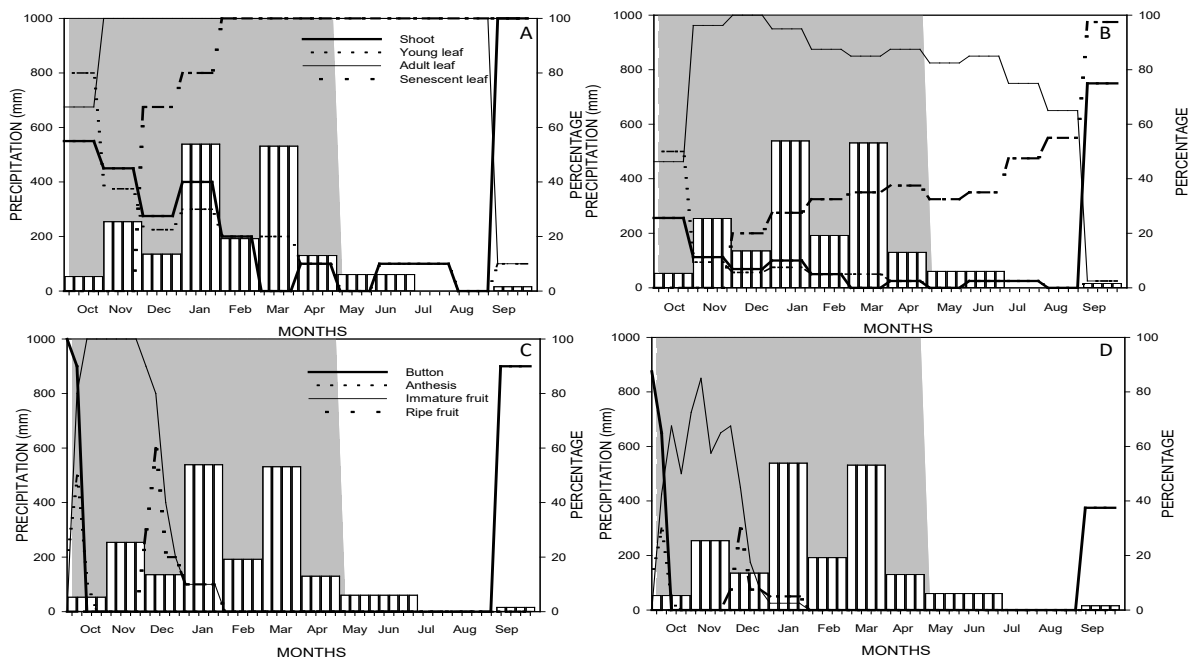


Figure 2 - Distribution of precipitation and phenophases studied in *Campomanesia adamantium* (Cambess.) O. Berg. According to the activity index of the vegetative (A) and reproductive (C) phenological phases and with the intensity index of vegetative (B) and reproductive (D) phenophases. Shoot and button phenophases (continuous thick line); young leaf and anthesis (lower dashed line); adult leaf and immature fruit (continuous thin line); and senescent leaf and ripe fruit (larger dashed line). The gray area corresponds to the wet season.

from December 2012 to almost 100% in September 2013 (Figure 2B).

Reproductive Phenological phases

The button activity, Figure 2C, and the intensity, Figure 2D, were only observed in October 2012 and September 2013 (Figure 2C). At the beginning of October these features were more prominent in relation to the end of the month, making it outstanding at the beginning of September.

Anthesis activity was observed only in October 2012 and the peak of this activity was reached in the second week of the month (Figure 2C). The intensity of anthesis did not cover more than 40% of the cup (Figure 2D).

Fruiting occurred from the third week of October 2012 to January 2013, evidenced by the presence of immature fruit. The maximum activity of immature fruits was observed between the

third and the last weeks of October and November, respectively (Figure 2C). The higher intensities of immature fruits were observed in the months of October, November, and December, with values of 67.5%, 72.5%, and 67.5%, respectively (Figure 2D). The intensity of 2.5% immature fruit was checked in January 2013 (Figure 2D).

The activity of ripe fruits was observed only in the months of December and January, with a peak in December (Figure 2C). The intensity of ripe fruit in the month of December was approximately 40%, which is the maximum value reached during the evaluation period (Figure 2D).

Correlation between phenology and climatic factors

During the study period, the average temperature in the months ranged from 21.3 °C to 32.7 °C. The highest average temperatures, recorded in July, August, and September, were 32, 26, and 25 °C,

respectively. The relative humidity ranged between 41.5% and 83.6%. The highest relative humidity was found in January (83.6%), followed by February (76.9%) and March (75.7%). Precipitation changed by 0.0 mm to 538.8 mm over the study period. The highest rainfall was recorded in January, followed by March, whereas precipitation was zero in August.

Table 1 shows the correlation values of phenology (activity and intensity of vegetative and reproductive phenological phases) with the climatic factors (temperature, humidity, and precipitation).

Table 1 - Values of Spearman correlations between vegetative and reproductive phenophases with the weather conditions, temperature, humidity, and precipitation

	Phenophases	Temperature	Humidity	Precipitation
Activity	Shoot	0.4978**	-0.4868**	-0.3454*
	Anthesis	0.1489	-0.2975*	-0.1872
	Immature F.	-0.0209	0.2582	0.3948**
	Ripe F.	-0.2161	0.4828**	0.4305**
	Button	0.2217	0.0073	0.1244
	Young Leaf	-0.0052	0.4356**	0.5973**
	Adult Leaf	-0.5061**	0.4852**	0.3484*
	Senescent Leaf	-0.0194	-0.1598	-0.3468*
Intensity	Shoot	0.4930**	-0.4854**	-0.3436*
	Anthesis	0.1489	-0.2975*	-0.1872
	Immature F.	-0.0291	0.2585	0.4027**
	Ripe F.	-0.2155	0.4826**	0.4306**
	Button	0.2237	0.0032	0.1217
	Young Leaf	-0.0036	0.4337**	0.5973**
	Adult Leaf	-0.5019**	0.7822**	0.7645**
	Senescent Leaf	0.3862**	-0.4550**	-0.5738**

A significant variation between the correlated factors is indicated (* $p = 0.05$ and ** $p \leq 0.01$).

The activity and the button of intensity showed significant correlations with temperature, relative humidity, and precipitation: positive when correlated with temperature and negative for relative humidity and precipitation.

The activity and intensity of anthesis were negatively correlated with the relative humidity.

The activity and intensity of immature fruits was significantly positively correlated with precipitation.

Significant positive correlations were observed for both the activity and intensity of ripe fruit with humidity and precipitation.

The activity and intensity of shoots were not correlated with any of the variables.

Young leaf activity and intensity were significantly positively correlated with relative humidity and precipitation.

The activity and intensity of adult leaves were significantly positively correlated with moisture and precipitation, but negatively correlated to activity in relation to temperature.

A significant negative correlation was found between senescence and precipitation, as well as the fall in intensity with relative humidity and precipitation; the decrease in intensity correlated positively with temperature.

Biommetry of fruits

A higher number of fruits were observed in sun branches than in shadow branches. On average, in the first assessment, each sun branch had 55 fruits, while the shadow branches had 28 fruits on average (Figure 3A).

In both branches, sun and shade, the number of fruits decreased as they developed.

The longitudinal diameter, Figure 3B, and the transverse diameter of the fruit, Figure 3C, increased with increased development.

No differences were observed in the longitudinal diameter values between fruit from the sun and shade branches up to the 7th day; afterward, fruit from sun branches showed higher values.

For the transverse diameter, differences were also identified only on days 7, 14, 35, and 49 after fruiting; the other days, the sun fruits showed higher values. On the last day of evaluation, we observed

Table 2 - Values of the Pearson correlations between the number of fruits of sun and shade and longitudinal and transverse diameters

	D. Longitudinal	D. Transverse
Number of sun fruits	-0.9196**	-0.8403*
Number of shade fruit	-0.9410**	-0.9188**

A significant variation between the correlated factors is indicated (* $p = 0.05$ and ** $p \leq 0.001$)

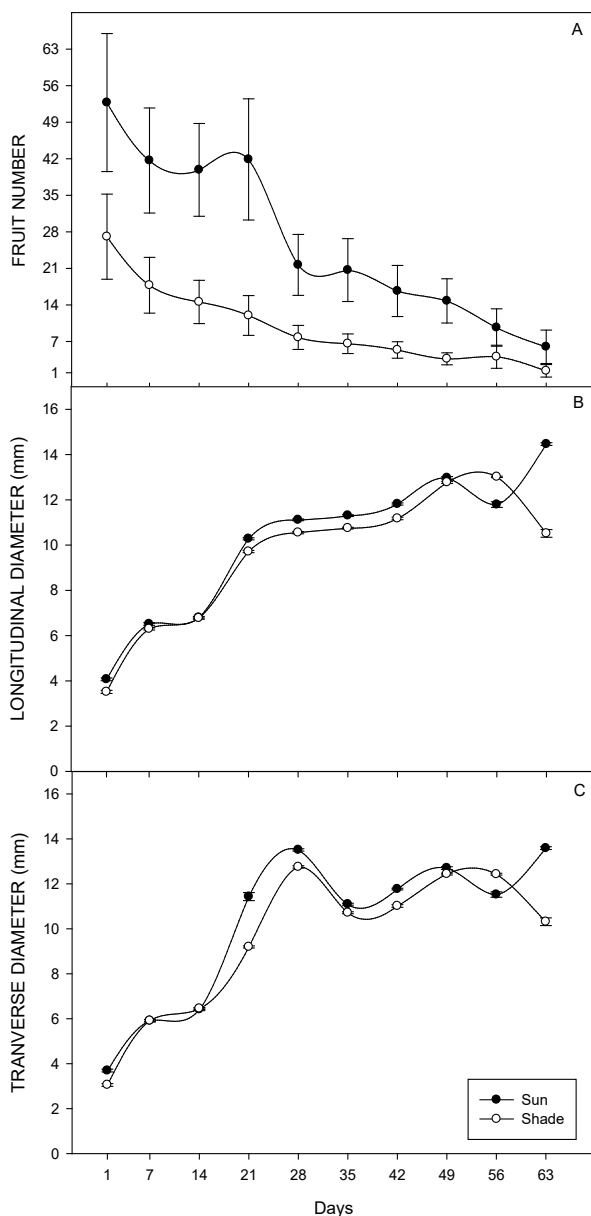


Figure 3 - Values corresponding to the number (A), longitudinal diameter (mm) (B), and transverse diameter (mm) (C) of fruits developed in branches of sun and shade. Rio Verde, GO, 2012/2013.

a reduction in the diameter of the fruits grown under shade.

The initial longitudinal diameter of the sun fruits was 4.1 mm and that of the shadow fruits was 3.5 mm; the maximum values were 14.5 and 13.0 mm, respectively. The initial transverse diameters were 3.7 mm and 3.0 mm for the fruits of the sun and the shadow, respectively; their maximums were 13.6 and 12.4 mm, respectively.

Significant negative correlations were found between the number of sun and shade fruits and their longitudinal and transverse diameters (Table 2).

DISCUSSION

The peak occurrence or shoot activity, along with higher intensity during the month of September, took place during a period of lower rainfall. Similar results were found by Braga *et al.* (2010), who studied four native Cerrado species, two of which belonged to the Myrtaceae family, which presented leaf drop and sprouting during the dry season.

The lack of a significant correlation of shoot activity and intensity with the studied variables indicates that the temperature, relative humidity, and precipitation are not the main factors that boost budding. Different results were found by Amorim *et al.* (2010), who found higher shoot values in months of higher temperatures in species belonging to the Myrtaceae family.

The non-occurrence of a positive correlation between shoots and precipitation is probably related to the ability of Cerrado plants to develop deep roots with exclusive access to the denser layers of the soil and thus have moisture throughout the year; this would be a way for species present in seasonal environments to survive (Canadell *et al.*, 1996).

The plants have organs called sources and drains. The source body, from photosynthesis, produces assimilates that can be used as a source of energy in breathing or be transported and stored in organs reserves, better known as drains. The main source organs are the adult leaves and the drains are the young leaves, roots, meristems and fruits,

which, with development, became a source organ (Duarte and Peil, 2010). The shoots' and young leaves' activity decreased across the study period, indicating development into adult leaves. The leaves begin to develop as drain organs, assimilate importers, and transitions into a drain source; increasing shoot sprouts in September indicates a new cycle of the plant.

The activity and the intensity of young leaves was inversely proportional to the activity and the intensity of mature leaves due to leaf development, which, in time, moved from mature leaves to young leaves. The activity and the intensity of young leaves had a significant positive correlation with moisture and precipitation, indicating that increased precipitation increased the number of young leaves. Correlations between precipitation and young leaves have been found in other vegetative species, such as *Anadenanthebra macrocarpa* (Benth.) Brenan (Silva *et al.*, 2012).

A significant positive correlation of adult leaves with moisture and precipitation and a negative correlation for the temperature indicates that with increased humidity and precipitation and reduced temperature, there was a higher incidence of adult leaves. A high humidity environment favours leaf expansion and stomatal aperture, allowing greater CO₂ assimilation with consequent production of assimilates, thus aiding in the transition of young leaves to mature leaves.

The senescent leaf activity was negatively correlated with precipitation, revealing that decreasing precipitation increased leaf drop. The decline in intensity was positively correlated with temperature and negatively correlated with humidity and rainfall, indicating that more falling leaves were found with higher temperatures and lower humidity and rainfall. The negative correlation between precipitation and leaf fall was also found in other species, as reported by Silva *et al.* (2012).

Leaf abscission is directly related to the production of ethylene, which is the primary signal that drives this process, while auxin reduces the sensitivity of cells to ethylene action (Taiz and Zeiger, 2013). Thus, probably as the temperature increased, the plant suffered from heat stress, triggering an autocatalytic formation of ethylene, leading to leaf

abscission. However, the gradual leaf fall during the year may also be the result of a natural senescence or a species adaptation to prevent the loss of water, acting as a defence mechanism (Lenza and Klink, 2006).

In the growing season, the plant initially mobilises stored reserves in its cotyledons or endosperm and builds its rudimentary form by the activity of the apical meristems of the root and the stem, followed by the formation of floral organs (sepals, petals, stamens, and carpel). After this period, there will be a transition to the reproductive period, with consequent formation of the buttons, which will result in flowering (Taiz and Zeiger, 2013).

It was fast and intense button activity for *Campomanesia adamantium* with increased temperatures and reduced humidity and rainfall, a fact confirmed by Vogado *et al.* (2009) in Myrtaceae species. The anthesis period was also fast, only in October, though not as intense as the button period. Both the activity and the intensity of anthesis increased with decreasing moisture.

The presence of flowers was observed for the months from August to November in *Campomanesia pubescens* Martius in cerrado fragments located in the Ecological Park Falls Rio Bonito, in Minas Gerais (Borém, 2009), differing from the data obtained in this study, in which flowering occurred only in October 2012. It has also been reported that *Campomanesia adamantium* (Cambess.) O. Berg present in the south of Mato Grosso do Sul, shows a peak of flowering from September to October (Nucci and Alves-Júnior, 2017). The identification of flowering periods is important in breeding programs because it allows planning to collect pollen and direct crosses for the species (Danner *et al.*, 2010).

The reproduction of a plant is dependent on the time of occurrence of the phenology of anthesis, because any variation that occurs in this phase will influence the successful pollination and seed production rate (Stephenson, 1981). Some authors point out that anthesis would be triggered by increasing the photoperiod, temperature, and humidity in the transition from the dry season to the wet; flowering in the hottest and rainy season is advantageous due to increased availability of light, nutrients, and pollinating insect activity

(Morellato *et al.*, 1989; Morellato, 1991; Morellato and Leitão Filho, 1992).

Although they belong to the same genus, some species may have different behaviour in relation to flowering. In a study on the reproductive phenology of the species *Campomanesia xanthocarpa* O. Berg and *Campomanesia guaviroba* (DC.) Kiaersk, the researchers detected the presence of buds or flowers during the period of a year of study for *C. xanthocarpa*. As for *C. guaviroba*, the presence of flowers was observed only in February (Staggemeier *et al.*, 2007), revealing behaviours in both species that are different from those of *C. adamantium* in this study, and although they belong to the same genus, these three species have different behaviours.

In the period of flowering and fruiting, humidity and temperature are the key factors for fruit set. High humidity can adversely affect the retention of the pollen grain by reducing the viscosity of the stigmatic fluid, while the high temperature dries the stigma and, as a result, there is premature fall of flowers and fruits fruit set in phase.

The fruiting of *C. adamantium* at the beginning of the wet weather event was also observed in *Myrcia guianensis*, which also belongs to the family Myrtaceae (Vogado *et al.*, 2009). However, the peak of immature and mature fruits occurred in November, the beginning of the rainy season, in *Myrcia guianensis* (Vogado *et al.* 2009) and *C. adamantium* in this study. Only the unripe fruit peaked in November, with the peak of the ripe fruits in December, also in the rainy season.

Divergent results of the fruiting period were found in a study with *C. pubescens* in Cerrado fragments in Minas Gerais, whose fruiting began in September (Borém, 2009). In species of the same genus but different domains, fruiting occurred in May in *C. xanthocarpa* and *C. guaviroba* present in the Atlantic Forest (Staggemeier *et al.*, 2007).

However, in general, the pattern of fruiting of *C. adamantium* was similar to that of the species of the cerrado fleshy fruits studied by Camargo (2008), who also studied these fruits in the rainy season, as the weather conditions are favourable for fruit development (Batalha and Martins, 2004). According to Santos *et al.* (2015) the fruiting period

of *Campomanesia adamantium* (Cambess.) O. Berg lasts 63 days, between the months of another and December.

The months with the presence of immature fruits corresponded to the period when the adult leaf activity was higher; thus the adult leaves acted as source organs of assimilates to the fruits and young leaves. The activity and intensity of immature fruits were triggered by increased precipitation, while the ripening of fruits was triggered by the increases in humidity with precipitation. This was unlike *Myrcia guianensis*, also belonging to the Myrtaceae family, which increases production of immature fruit with increasing temperature (Vogado *et al.*, 2009).

Fruit maturation of *C. adamantium* was a little later than that of *C. xanthocarpa*, studied in Araucaria Forest, whose fruit ripened at the end of November to the end of December (Danner *et al.*, 2010), while in the present study, there was ripened fruit from December to January for *C. adamantium*. Knowledge of the fruit maturation period is of great importance because it allows the timing of the harvest in commercial fruit planting (Danner *et al.*, 2010).

Most fruit production in the branches with the highest radiation is according to published studies, which found that artificial lighting promoted an increase in the number of fruits and fruit area of yellow passion fruit (Cavichioli *et al.*, 2006) and Royal Gala apple, and it has been observed that the shading promoted decreases in fruit set and yield (Amarante *et al.*, 2007).

The low yield of fruit can be a consequence of the reduction in the light supply, which reduces the accumulation of reserves and may compromise the differentiation of reproductive buds and fruit set. However, responses to shading can vary by species. This fact was proven in a study with tomato in the north of Minas Gerais, where shaded environments conditioned better responses to the cultivation of the species and did not influence the quality of tomato fruits (Otoni *et al.*, 2012).

The longitudinal and transversal diameter values of shaded fruits are not within the range of values found for *C. adamantium* (Oliveira *et al.*, 2008). Fruits with lower incidence of radiation had lower

biometric values than the fruits with the highest incidence, showing that even within values reported in the literature, fruit on shadowed branches were affected by the low radiation.

Shading also decreased the growth rate of apples, which was attributed by the authors to the simultaneous reduction in the daily amount of sap received by the fruit in shade conditions (Morandi *et al.*, 2011).

When the penetration of solar radiation inside the canopy is affected, there is a reduction of source power and, consequently, the availability of assimilates decreases, thereby reducing the amount intended for fruit and increasing the rate of abortions. This device is for the benefit of the vegetative organs, as there is a stimulating leaf growth to improve the capture of light by canopy (Duarte and Peil, 2010).

The negative correlation between the number of fruits with longitudinal and transverse diameters in both the sun and shade fruits indicates that, insofar as reducing the number of fruit per branch, the fruits present in the branch had increased their longitudinal and transversal diameters. Such a correlation may be connected directly with the distribution of photoassimilates by the relative source and drain, since the photoassimilates are produced to be used as an energy source or as reserves for

drain organs, such as fruits (Duarte and Peil, 2010). Thus, to the extent that the number of drain organs decreased, assimilate accumulation was greater, increasing the diameters of the fruits.

CONCLUSION

In the region of Rio Verde, there was young and adult leaf activity in *Campomanesia adamantium* throughout the study period, except young leaves were inactive in May and August. The presence of sprouts was also quite significant over the period. There was a phenophase cycle of rapid and intense play between October and January for *C. adamantium*. Shading affected the number of fruits per plant and the longitudinal and transverse diameters of the fruits.

ACKNOWLEDGMENTS

We thank the agencies that funded the study and the equipment used in the research, the CNPq [National Council for Scientific and Technological Development], CAPES [Brazilian Federal Agency for Support and Evaluation of Graduate Education], FAPEG [Goiás Research Foundation], Federal Institute of Rondônia, Jaru Campus (IFRO - Campus Rio Jaru) and the Federal Institute of Goiás, Rio Verde Campus (IFGoiano - Campus Rio Verde).

REFERENCES

- Amarante, C.V.T.; Steffens, C.A.; Mota, C.S. & Santos, H.P. (2007) – Radiação, fotossíntese, rendimento e qualidade de frutos em macieiras ‘Royal Gala’ cobertas com telas antigranizo. *Pesquisa Agropecuária Brasileira*, vol. 42, n. 7, p. 925-931. <http://dx.doi.org/10.1590/S0100-204X2007000700003>
- Amorim, J.S.; Amorim, J.S.; Cerqueira-Silva, C.B.M. & Romagnolo, M.B. (2010) – Fenologia das espécies *Campomanesia xanthocarpa* O.Berg e *Eugenia uniflora* L. (Myrtaceae) no bosque municipal de Paranavaí. *Revista Eletrônica de Biologia*, vol. 3, n. 1, p. 84-98.
- Arantes, A.A. & Monteiro, R.A. (2002) – A família Myrtaceae na Estação Ecológica do Panga. *Lundiana*, vol. 3, n. 2, p. 111-127.
- Araújo, E.F.L. & Souza, E.R.B. (2018) – Fenologia e reprodução de *Campomanesia adamantium* (Cambess.) O. Berg (Myrtaceae). *Scientific Electronic Archives*, vol. 11, p. 166-175.
- Batalha, M.A. & Martins, F.R. (2004) – Reproductive phenology of the cerrado plant community in Emas National Park (Central Brazil). *Australian Journal of Botany*, vol. 52, n. 2, p. 149-161. <https://doi.org/10.1071/BT03098>
- Bencke, C.S.C. & Morellato, P.C. (2002) – Comparação de dois métodos de avaliação da fenologia de plantas, sua interpretação e representação. *Revista Brasileira de Botânica*, vol. 25, n. 3, p. 269-275. <https://doi.org/10.1590/S0100-84042002000300003>

- Borém, R.A.T. (2009) – Biologia reprodutiva de *Campomanesia pubescens* Mart. (Myrtaceae), uma espécie arbustiva dos cerrados do Brasil, e sua ocorrência no Parque Ecológico Quedas do Rio Bonito. In: *III Congresso Latino-Americano de Ecologia*. p. 1-4.
- Braga, L.O.; Cunha, E.J.R. & Oliveira, M.C.P. (2010) – Estudos Fenológicos de Quatro Espécies de Plantas de Cerrado de Interesse Ecológico e Econômicos Ocorrentes no Eco Resort Nazareth, Município de José de Freitas. In: *XIX Seminário de Iniciação Científica da UFPI. Teresina. Anais do XIX Seminário de Iniciação Científica da UFPI*. Teresina, Piauí, Brasil.
- Camargo, M.G.G. (2008) – *Influência da borda na frutificação e nas síndromes de dispersão de sementes em uma área de cerrado stricto sensu*. Dissertação de Mestrado em Ciências Biológicas. Instituto de Biociências do Campus de Rio Claro da Universidade Estadual Paulista “Júlio de Mesquita Filho”. Rio Claro. Brasil. 132 p.
- Canadell, J.; Jackson, R.B.; Ehleringer, J.B.; Mooney, H.A.; Sala, O.E. & Schulze, E.-D. (1996) – Maximum rooting depth of vegetation types at the global scale. *Oecologia*, vol. 108, n. 4, p. 583-595. <https://doi.org/10.1007/BF00329030>
- Canavesi, V.; Coura, S.M.; Formaggio, A.R.; Shimabukuro, Y.E. & Quirino, V.F. (2005) – Dinâmica espectro-temporal MODIS em região de Cerrados e intenso uso Agropecuário. In: *Simpósio Brasileiro de Sensoriamento Remoto. Goiânia. Anais*. INPE. Goiânia, Goiás, Brasil. p. 1435-1442.
- Cavichioli, J.C.; Ruggiero, C.; Volpe, C.A.; Paulo, E.M.; Fagundes, J.L. & Kasai, F.S. (2006) – Florescimento e frutificação do maracujazeiro-amarelo submetido à iluminação artificial, irrigação e sombreamento. *Revista Brasileira de Fruticultura*, vol. 28, n. 1, p. 92-96. <https://doi.org/10.1590/S0100-29452006000100026>
- Cherbiy-Hoffmann, S.U.; Hall, A.J. & Rousseaux, M.C. (2013) – Fruit, yield, and vegetative growth responses to photosynthetically active radiation during oil synthesis in olive trees. *Scientia Horticulturae*, vol. 150, p. 110–116. <https://doi.org/10.1016/j.scienta.2012.10.027>
- Cortés-Flores, J.; Andresen, E.; Cornejo-Tenorio, G. & Ibarra-Manríquez, G. (2013) – Fruiting phenology of seed dispersal syndromes in a Mexican Neotropical temperate forest. *Forest Ecology and Management*, vol. 289, p. 445-454. <https://doi.org/10.1016/j.foreco.2012.10.038>
- Costa, R.C.; Calvete, E.O.; Reginatto, F.H.; Cecchetti, D.; Loss, J.T.; Rambo, A. & Tessaro, F. (2011) – Telas de sombreamento na produção de morangueiro em ambiente protegido. *Horticultura Brasileira*, vol. 29, n. 1, p. 98-102. <https://doi.org/10.1590/S0102-05362011000100016>
- Danner, M.A.; Citadin, I.; Sasso, S.A.Z.; Sachet, M.R. & Ambrósio, R. (2010) – Fenologia da floração e frutificação de mirtáceas nativas da floresta com araucária. *Revista Brasileira de Fruticultura*, vol. 32, n. 1, p. 291-295. <https://doi.org/10.1590/S0100-29452010005000008>
- Duarte, T.S. & Peil, R.M.N. (2010) – Relações fonte:dreno e crescimento vegetativo do meloeiro. *Horticultura Brasileira*, vol. 28, n. 3, p. 271-276. <https://doi.org/10.1590/S0102-05362010000300005>
- EPE (2006) – *Avaliação ambiental integrada dos aproveitamentos hidrelétricos da bacia do rio Paranaíba*. Empresa de Pesquisa Energética. Ministério de Minas e Energia, Brasília.
- Fereres, C.E. (1995) – Productividad de los sistemas de cultivo em invernadero. In: *Symposium Iberoamericano Sobre Aplicación de Los Plásticos em Las Tecnologías Agrárias*. Almeria. Actas... Almeria: FIAPA/CE-PLA. p.287-296.
- Fournier, L.A. (1974) – Un método cuantitativo para la medición de características fenológicas en árboles. *Turrialba*, vol. 24, p. 422-423.
- Franco, A.C.; Rossatto, D.R.; Silva, L.C.R. & Ferreira, C.S. (2014) – Cerrado vegetation and global change: the role of functional types, resource availability and disturbance in regulating plant community responses to rising CO₂ levels and climate warming. *Theoretical and Experimental Plant Physiology*, vol. 26, n. 1, p. 19–38. <https://doi.org/10.1007/s40626-014-0002-6>
- Garcia, L.C.; Barros, F.V. & Lemos-Filho, J.P. (2009) – Fructification phenology as an important tool in the recovery of iron mining areas in Minas Gerais, Brazil. *Brazilian Journal of Biology*, vol. 69, n. 3, p. 887-893. <https://doi.org/10.1590/S1519-69842009000400017>
- Gonzalez-Talice, J.; Yuri, J.A. & Pozo, A. (2013) – Relations among pigments, color and phenolic concentrations in the peel of two Gala apple strains according to canopy position and light environment. *Scientia Horticulturae*, vol. 151, p. 83-89. <https://doi.org/10.1016/j.scienta.2012.12.007>

- Guilherme, F.A.G.; Salgado, A. de A.; da Costa, E.A. & Zortéa, M. (2011) – Fenologia de *Cybistax antisiphyltica* (Mart.) Mart. ex DC. (Bignoniaceae) na região urbana de Jataí, Goiás. *Bioscience Journal*, vol. 27, n. 1, p. 138-147.
- Janzen, D.H. (1967) – Synchronization of sexual reproduction of trees within the Dry Season in Central America. *Evolution*, vol. 21, n. 3, p. 620-637. <https://doi.org/10.2307/2406621>
- Lenza, E. & Klink, C.A. (2006) – Comportamento fenológico de espécies lenhosas em um cerrado, sentido restrito, de Brasília, DF. *Revista Brasileira de Botânica*, vol. 29, n. 4, p. 627-638. <https://doi.org/10.1590/S0100-84042006000400013>
- Lieth, H. (1974) – Introduction to phenology and the modeling of seasonality. In: Phenology and seasonality modeling. Lieth, H. (Ed.) – *Ecological Studies*. Berlin: vol. 8, p. 3-19.
- Lobos, G.A.; Retamales, J.B.; Hancock, J.F.; Flore, J.Á.; Romero-Bravo, S. & Pozo, A. (2013) – Productivity and fruit quality of *Vaccinium corymbosum* cv. Elliott under photo-selective shading nets. *Scientia Horticulturae*, vol. 153, p. 143–149. <https://doi.org/10.1016/j.scienta.2013.02.012>
- Lourenço, A.R.L. & Barbosa, M.R.V. (2012) – Myrtaceae em restingas no limite norte de distribuição da Mata Atlântica, Brasil. *Rodriguesia*, vol. 63, n. 2, p. 373-393. <http://dx.doi.org/10.1590/S2175-78602012000200011>
- Morais, H.; Caramori, P.H.C.; Koguish, M.S. & Gomes, J.C. (2009) – Sombreamento de cafeeiros durante o desenvolvimento das gemas florais e seus efeitos sobre a frutificação e produção. *Ciência Rural*, vol. 39, n. 2, p. 400-406. <https://doi.org/10.1590/S0103-84782009000200013>
- Morandi, B.; Zibordi, M.; Losciale, P.; Manfrini, L.; Pierpaoli, E. & Rappadelli, R.C. (2011) – Shading decreases the growth rate of young apple fruit by reducing their phloem import. *Scientia Horticulturae*, vol. 127, n. 3, p. 347–352. <https://doi.org/10.1016/j.scienta.2010.11.002>
- Morellato, L.P.C. (1991) – *Estudo da fenologia de árvores, arbustos e lianas de uma floresta semidecídua no sudeste do Brasil*. Tese de Doutorado. Instituto de Biociências. Universidade Estadual de Campinas. Campinas, São Paulo, Brasil. 176 p.
- Morellato, L.P.C.; Leitão Filho, H.F.; Rodrigues, R.R. & Joly, C.A. (1990) – Estratégias fenológicas de espécies arbóreas em floresta de altitude na Serra do Japi, Jundiá São Paulo. *Revista Brasileira de Biologia*, vol. 50, n. 1, p. 149-162.
- Morellato, L.P.C. & Leitão Filho, H.F. (1992) – Padrões de frutificação e dispersão na Serra do Japi. In: Morellato, L.P.C. (Org.) – *História Natural da Serra do Japi: ecologia e preservação de uma área florestal no sudeste do Brasil*. Campinas: UNICAMP/FAPESP. p.112-140.
- Morellato, L.P.C.; Rodriguez, R.R.; Leitão-Filho, H.F. & Joly, C.A. (1989) – Estudo comparativo da fenologia de espécies arbóreas de floresta de altitude e floresta mesófila semidecídua na Serra do Japi, Jundiá. São Paulo. *Revista Brasileira de Botânica*, vol. 12, p. 85-98.
- Newstrom, L.E.; Franki, G.W. & Baker, H.G. (1994) – A new classification for plant phenology based on flowering patterns in Lowland tropical Rain Forest Tress at La Selva. *Biotropica*, vol. 26, n. 2, p. 141-159. <https://doi.org/10.2307/2388804>
- Nucci, M. & Alves-Junior, V.V. (2017) – Biologia floral e sistema reprodutivo de *Campomanesia adamantium* (Cambess.) O. Berg. – Myrtaceae em área de cerrado no sul do Mato Grosso do Sul, Brasil. *Interciência*, vol. 42, n. 2, p. 127-131.
- Oliveira, M.C.; Santana, P.G.; Borges, K.C.F.; Anastácio, M.R. & Lima, J.A. (2008) – Biometria de frutos e sementes de *Campomanesia adamantium* (Camb.) O. Berg. e *Campomanesia pubescens* (DC) O. Berg. In: IX Simpósio Nacional Cerrado e II Simpósio internacional Savanas Tropicais. Brasília, Distrito Federal, Brasil.
- Otoni, B.S.; Mota, W.F.; Belfort, G.R.; Silva, A.R.S.; Vieira, J.C.B. & Rocha, L.S. (2012) – Produção de híbridos de tomateiro cultivados sob diferentes porcentagens de sombreamento. *Revista Ceres*, vol. 59, n. 6, p. 816-825. <https://doi.org/10.1590/S0034-737X2012000600012>
- Pereira, F.H.F.; Puiatti, M.; Finger, F.L.F.; Cecon, P.R. & Aquino, L.A. (2010) – Produção e qualidade de frutos de melões amarelo e charentais cultivados em ambientes sombreados. *Revista Brasileira de Engenharia Agrícola Ambiental*, vol. 14, n. 9, p. 944–950. <http://dx.doi.org/10.1590/S1415-43662010000900006>
- Porto, A.C. & Gulias, A.P.S.M. (2010) – *Gabirola*. In: Vieira, R.F.; Agostini-Costa, T. da S.; Silva, D.B. da; Sano, S.M. & Ferreira, F.R. (Eds.) – *Frutas Nativas da Região Centro-Oeste do Brasil*. 1ª Ed. Embrapa Informações Tecnológica. Brasília, Distrito Federal, Brasil. p. 175-184.

- Rezende-Silva, S.L.; Costa, A.C.; Dyszy, F.H.; Batista, P.F.; Crispim-Filho, A.J.; Nascimento, K.J. & Silva, A.A. (2019) – *Pouteria torta* is a remarkable native plant for biomonitoring the glyphosate effects on Cerrado vegetation. *Ecological Indicators*, vol. 102, p. 497-506. <https://doi.org/10.1016/j.ecolind.2019.03.003>
- Sá, S.; Chaula, L.T.; Alves, V.F.; Fiuza, T.S.; Tresvenzola, L.M.F.; Vazd, B.G.; Ferri, P.H.; Borges, L.L.; José, R. & Paula, J.R.P. (2018) – Phytochemistry and antimicrobial activity of *Campomanesia adamantium*. *Revista Brasileira de Farmacognosia*, vol. 28, n. 3, p. 303–311. <http://dx.doi.org/10.1016/j.bjp.2018.02.008>
- Santos, P.L. & Ferreira, R.A. (2013) – Fenologia de *Tapirira guianensis* Aubl. (Anacardiaceae) no município de São Cristóvão, Sergipe. *Revista Árvore*, vol. 37, n. 1, p. 129-136. <https://doi.org/10.1590/S0100-67622013000100014>
- Santos, M.A.; Megguer, C.A.; Costa, A.C. & Lima, J.S. (2015) – Growth and development of *gabiroba* [*Campomanesia adamantium* (Cambess.) O. Berg] fruits. *African Journal of Agricultural Research*, vol. 10, n. 14, p. 1765-1772. <https://doi.org/10.5897/AJAR2014.8517>
- SEPLAN-GO (2005) – *Anuário estatístico do estado de Goiás*. Secretaria de Planejamento e Desenvolvimento do Estado de Goiás, Goiás, Brasil.
- Silva, A.G.; Barros, H.H.D.; Senna, D.S. & Carvalho, C.D.V. (2012) – Fenologia de *Anadenanthebra macrocarpa* (Benth.) Brenan em uma floresta estacional semidecidual no Sul do Espírito Santo. *Enciclopédia Biosfera*, vol. 8, p. 938-945.
- Sobral, M.; Proença, C.; Souza, M.; Mazine, F. & Lucas, E. (2013) – Myrtaceae In: *Lista de Espécies da Flora do Brasil*. Jardim Botânico do Rio de Janeiro. [cit. 2013.08]. <http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB171>
- Staggemeier, V.G.; Diniz-Filho, J.F. & Morellato, L.P.C. (2010) – The shared influence of phylogeny and ecology on the reproductive patterns of Myrteae (Myrtaceae). *Journal of Ecology*, vol. 98, n. 6, p. 1409-1421. <https://doi.org/10.1111/j.1365-2745.2010.01717.x>
- Staggemeier, V.G.; Morellato, L.P.C. & Galetti, M. (2007) – Fenologia reprodutiva de Myrtaceae em uma ilha continental de Floresta Atlântica. *Revista Brasileira de Biociências*, vol. 5, p. 423-425.
- Stephenson, A.G. (1981) – Flower and fruit abortion: proximate causes and ultimate functions. *Annual Review of Ecology and Systematics*, vol. 12, p. 253-279. <https://doi.org/10.1146/annurev.es.12.110181.001345>
- Taiz, L. & Zeiger, E. (2013) – *Fisiologia vegetal*. 5. ed. Editora Artmed. Porto Alegre, Rio Grande do Sul, Brasil.
- Veloso, H.P.; Rangel-Filho, A.L. & Lima, J.C.A. (1991) – *Classificação da vegetação Brasileira, adaptada a um sistema universal*. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística (IBGE). 124 p.
- Vogado, N.O.; Camargo, M.G.G.; Reys, P. & Morellato, L.P.C. (2009) – Fenologia reprodutiva de *Myrcia guianensis* em um fragmento de cerrado stricto sensu no interior de São Paulo. In: *VI Congresso de Meio Ambiente da AUGM. Anais de Eventos da UFSCAR*. São Carlos, São Paulo, Brasil.