Biotemas, 32 (3): 1-9, setembro de 2019
ISSNe 2175-7925

http://dx.doi.org/10.5007/2175-7925.2019v32n3p1

Reproductive phenology of shrubs and trees in a Cerrado area of Mogi Guaçu, SP, Brazil

Adriana de Oliveira Fidalgo

Núcleo de Pesquisa em Sementes, Instituto de Botânica, SMA/SP
Avenida Miguel Stefano, 3687, CEP 04.310-902, São Paulo – SP, Brazil
aofidalgo@hotmail.com

Submetido em 13/11/2018
Aceito para publicação em 10/07/2019

Resumo

Fenologia reprodutiva do estrato arbustivo arbóreo em área de Cerrado da Reserva Biológica de Mogi Guaçu, SP, Brasil. A fenologia reprodutiva de arbustos e árvores de uma área de Cerrado da Reserva Biológica Mogi Guaçu (22°10'S; 47°11'W) foi estudada de setembro de 2009 a maio de 2013. Em um transecto de 900 m^2, os indivíduos foram marcados e o número total de flores e frutos estimado mensalmente. Os dados foram analisados usando estatística circular para determinar os períodos de maior intensidade de floração e frutificação na comunidade, de acordo com seus modos de dispersão. A floração na comunidade ocorreu entre outubro e novembro. A frutificação foi distribuída continuamente ao longo do ano, com valores de r até 0,3. No último período de observação, a frutificação foi mais intensa no mês de dezembro, provavelmente devido às espécies zoocóricas. Considerando as três famílias principais, Myrtaceae floresceu e frutificou entre agosto e setembro, Malpighiaceae floresceu em novembro e frutificou entre dezembro e janeiro, e as Vochysiaceae floresceram em janeiro e frutificaram em março. Em geral, a comunidade teve como principal característica a fraca sazonalidade de sua fenologia reprodutiva. No entanto, os eventos reprodutivos tenderam a se concentrar nos meses mais quentes do ano.

Palavras-chave: Cerrado; Floração; Frutificação; Sazonalidade

Abstract

The reproductive phenology of shrubs and trees in an area of Cerrado (Brazilian savanna) in the Mogi Guaçu Biological Reserve (22°10'S; 47°11'W) was studied from September 2009 to May 2013. In a 900 m^2 transect, individuals were marked, and the total number of flowers and fruits was estimated monthly. The data were analyzed using circular statistics to determine the periods of most intense flowering and fruiting in the community, according to their dispersal modes. Flowering occurred between October and November. Fruiting was distributed continuously throughout the year, with *r* values up to 0.3. In the last period of observation, fruiting was more intense in December, probably due to zoochorous species. For the three main families, Myrtaceae flowering and fruiting occurred between August and September, Malpighiaceae flowering occurred in November and fruiting was between December and January, and Vochysiaceae flowering was in January and fruiting was in March. In general, a main characteristic of the community was the weak seasonality of its reproductive phenology. However, reproductive events tended to take place in the hottest months of the year.

Key words: Brazilian savanna; Flowering; Fruiting; Seasonality

Introduction

The Brazilian savanna (Cerrado) occupies about 24% of Brazil, mainly in the central region of the country. It is the second largest biome in Brazil, one of the most diverse regions of the planet, and includes a mosaic of vegetation, such as savannas, fields, forests, and wetlands. It is adjacent to the Caatinga, Atlantic Forest and Pantanal, and has transition zones or ecotones along these borders (MMA, 2009).

The predominant climate is seasonal, with a well-defined dry season from May to September, and dry spells (periods without rain) during the rainy season, from October to April (ASSAD, 1994).

Studies of woody species in the Cerrado show weak seasonality of reproductive events in communities; flowering and fruiting appear to be distributed throughout the year and it is possible to observe species in a particular phenophase during any season (BATALHA; MARTINS, 2004; LENZA; KLINK, 2006; TANNUS et al., 2006; OLIVEIRA, 2008; PIRANI et al., 2009).

On the other hand, peaks of flowering and fruiting can be observed around the wettest periods of the year, which guarantees the maintenance of populations, synchronizing germination with the beginning of the rainy season (OLIVEIRA, 2008).

Different phenological patterns can be observed in the Cerrado tree community, when considering the dispersal modes of the species and/or investigating the behavior within each family (BATALHA; MANTOVANI, 2000; PILON et al., 2015). Synchronizing the flowering and fruiting of individuals can be a strategy to increase the reproductive success of species since it affects the availability of resources for pollinators and dispersers (NEWSTROM et al., 1994; SILVA et al., 2011).

The aim of this study was to investigate the phenological behavior of shrub and tree species in a Cerrado area, at the community level. The influence of climatic factors, the dispersal syndromes of each species, as well as the main families to which they belong, on the observed phenological patterns, was evaluated.

Material and Methods

The study was conducted in a transition area between Cerrado and seasonal forest in the Mogi Guaçu Biological Reserve (Reserva Biológica Mogi Guaçu – RBMG), which is part of Campininha Farm (22°10'S; 47°11'W; 600 m elevation; Aw/Cwa – Köppen) (Figure 1). RBMG is 470 ha, is bordered in the south by the Mogi-Guaçu River, and varies from 585 m to 660 m elevation. The soil is a red-yellow latosol with a medium texture. The reserve is bordered by the Ecological and Experimental Station of Mogi Guaçu, which is administered by the Instituto Florestal (SMA, 2011).

Phenology was studied from September 2009 to May 2013. A transect three meters wide and 300 meters long was defined along one of the trails in the study area (Figure 1). Throughout this transect, all shrubby and arboreal individuals were tagged and identified. The total number of flowers was estimated by extrapolation of the number of flowers and fruits present in a quadrant (1/4 of canopy) of each individual under observation.

The species were classified according to their frequency of flowering and fruiting events, annual (one event each year) and biannual (events at two-year intervals), following Newstrom et al. (1994). The dispersal syndromes, anemochorous (dispersed by wind) and zoochorous (dispersed by animals), were established according to the classification of van der Pijl (1982).

Data were sorted by period, transformed in proportion, plotted as phenograms and analyzed using circular statistics (BATSCHELET, 1981), in order to determine the period of most intense flowering and fruiting in the community for the main families present in the area and the species according to their dispersal modes. Circular statistics is based on an analysis of points around a circle; the acrophase or middle angle is the phase in which there is the highest probability of finding the activity under observation. The reference point used here was 0º and the acrophase is represented by angular units (degrees). The mean length of the *r* vector is a measure of concentration (min = 0, maximum = 1) (BATSCHELET, 1981; BENEDITO-SILVA, 1997; ZAR, 1999). The Rayleigh test (ZAR, 1999) and was used to obtain the significance of

FIGURE 1: Location of the Mogi Guaçu Biological Reserve (22° 10’S, 47° 11’W) in the state of São Paulo, Brazil, showing the transect used for marking individuals and collecting phenological data.

acrophases. Bimodal data were discarded from the analyses.

The Spearman correlation test was used to evaluate the existence of a correlation between monthly accumulated temperature and precipitation and the percentage of flowering and fruiting species in the community as a whole, within the main families observed and for the species grouped according to dispersal mode (ZAR, 1999). The data of monthly average temperature and monthly accumulated precipitation for the region of Mogi Guaçu, during the study period, were obtained from the Horto Mogi Guaçu climatological station, which belongs to International Paper – Brazil.

Results

For the 21 species monitored, flowering and fruiting varied in relation to duration and time of occurrence. In every month, flowering or fruiting individuals were observed. Flowering occurred for short periods (one to two months) for 18 species and for long periods (four or more months) for three species. Fruiting lasted from one to three months for four species and for five or more months for 14 species. Three species did not bear fruit (Table 1). There was a predominance of species with annual flowering and fruiting events (85 and 80%, respectively) (Table 1).

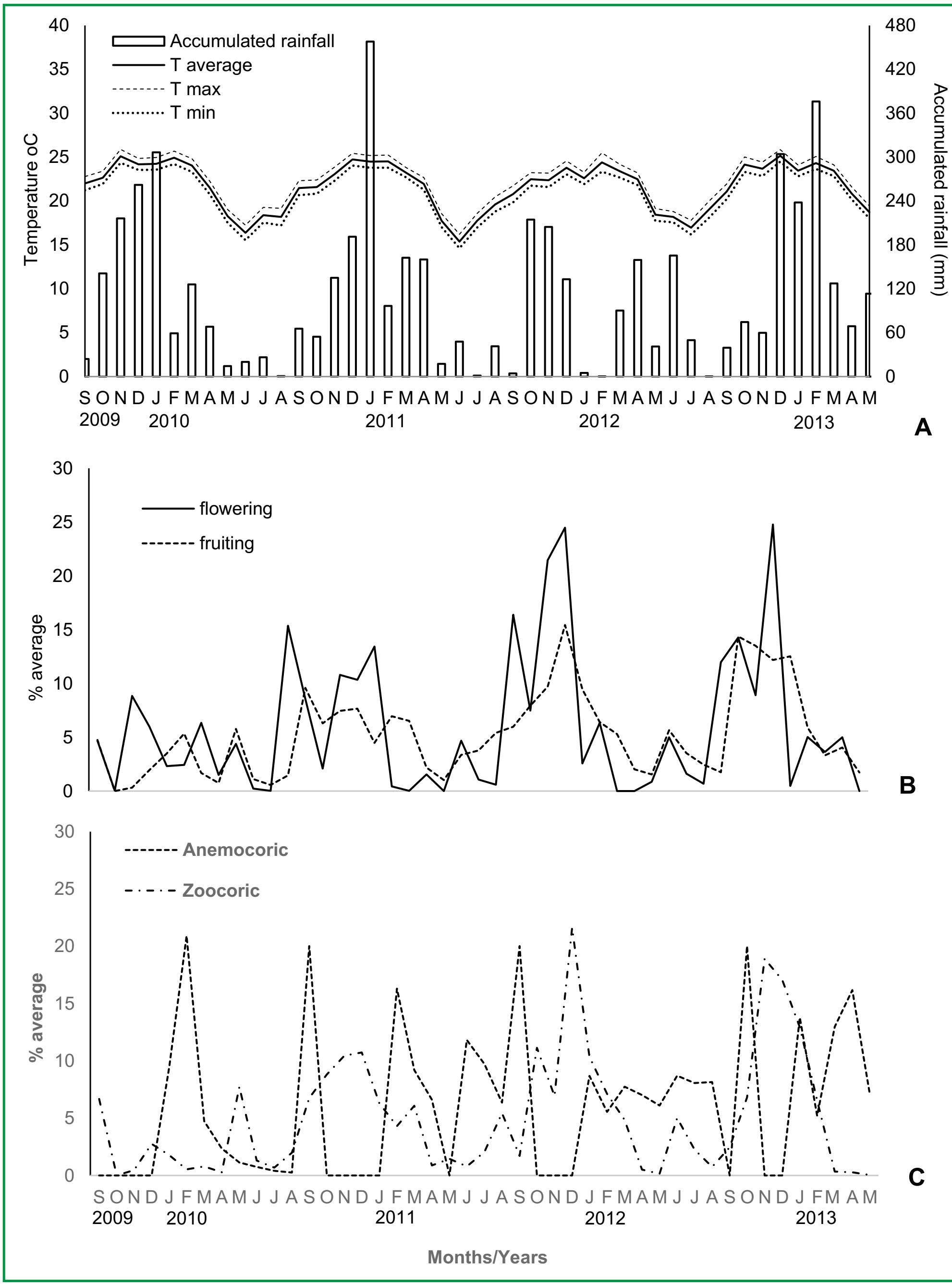
The species *Vochysia tucanorum, Byrsonima intermedia, Campomanesia pubescens, Ouratea spectabilis* and *Prunus myrtifolia* contributed to fruit occurrence throughout the year due to their abundance (Table 1). The three families with the highest number of species and individuals in the study area were Myrtaceae, Malpighiaceae and Vochysiaceae.

According to Figure 2A, the study area had a dry period (rainfall below 60 mm) from May to August and a wet period from September to April, between 2009 and 2010 and between 2010 and 2011. Between 2011 and

TABLE 1: Time of occurrence and frequency of the shrub and tree species in the Cerrado/Forest transition in the Mogi Guaçu Biological Reserve, SP, Brazil. N = number of individuals; months of occurrence of the phenophases (1-12 correspond to the months of January to December); DS = dispersal syndromes (ane = anemochorous, zoo = zoochorous); frequency of flowering and fruiting cycles (- = unclassified species because they presented the event once or twice during the observation period). The months in parentheses refer to the most likely period of the event according to the Rayleigh test ($P < 0.05$). A hyphen (-) represents continuity between the months or absence of the event, while a comma (,) means interruption.

Family / Species	**N**	**Months of occurrence**		**DS**	**Frequency**	
		Flowering	**Fruiting**		**Flowering**	**Fruiting**
Anacardiaceae						
Tapirira guianensis Aubl.	2	8-9	-	Zoo	Biannual	-
Bignoniaceae						
Tabebuia ochracea (Cham.) Standl.	2	8-9	9-10	Ane	Annual	Annual
Clusiaceae						
Kielmeyera variabilis Mart. &Zucc.	1	11-12	7-8, 1-3	Ane	Annual	Annual
Erythroxylacea						
Erythroxylum suberosum A. St.-Hil.	2	9-11	11-12	Zoo	Annual	Annual
Fabacea						
Acosmium dasycarpum (Vogel) Yakovlev	4	12-1 (12)	1-5 (2/3)	Ane	Annual	Annual
Lauraceae						
Ocotea pulchella (Nees & Mart.) Mez	2	12, 2-4	5	Zoo	Annual	Annual
Malpighiaceae						
Byrsonima intermedia A. Juss.	10	11-3 (11)	11-5 (1)	Zoo	Annual	Annual
Byrsonima coccolobifolia Kunth	3	11-12 (11)	12-3 (1)	Zoo	Annual	Annual
Byrsonima crassifólia (L.) Kunth	1	10-12	11-2	Zoo	Annual	Annual
Melastomataceae						
Miconia langsdorffii Cogn.	3	3, 11 (11)	12-4 (1)	Zoo	Annual	Annual
Myrtaceae						
Campomanesia pubescens (DC.) O. Berg	7	9-10 (9)	9-12 (10/11)	Zoo	Annual	Annual
Eugenia uniflora L.	2	8-10	9-11	Zoo	Annual	Annual
Eugenia sp1 L.	1	10	11	Zoo	Biannual	Biannual
Eugenia hiemalis Cambess.	2	6, 10	6-11	Zoo	Annual	Annual
Myrcia bela Cambess.	1	9-10	10-11	Zoo	Annual	Annual
Ochnaceae						
Ouratea spectabilis (Mart. ex Engl.) Engl.	7	7-10 (8/9)	9-12 (9/10)	Zoo	Annual	Annual
Rosaceae						
Prunus myrtifolia (L.) Urb.	5	2, 4-9 (4/5)	4-12 (8/9)	Zoo	Annual	Annual
Solanaceae						
Solanum palinacanthum Dunal	1	5, 11-12	-	Zoo	Annual	-
Styracaceae						
Styrax camporum Pohl	2	12-1	1-5	Zoo	Annual	Annual
Vochysiaceae						
Vochysia tucanorum Mart.	14	12-3 (1/2)	1-8 (3/4)	Ane	Annual	Annual
Qualea grandiflora Mart.	1	12	-	Ane	Biannual	-

FIGURE 2: Reproductive phenology of the shrubby/arboreal stratum in the Cerrado in the Mogi Guaçu Biological Reserve (22°10'S, 47°11'W), São Paulo. A. Average, maximum and minimum temperature and monthly cumulative precipitation. B. Average percentage of flowers and fruits. C. Average percentage of fruits of zoochorous and anemochorous species.



2012, rainfall was irregular, with a low period in January and February and precipitation above the average between May and July. From September 2012 to May 2013, the volume of rainfall had a pattern closer to that described for the region. More species tended to flower and fruit during the hotter and wettest period between September and February (Figure 2B). Nevertheless, there were species flowering or fruiting in the dry periods, such as *K. variabilis*, *O. pulchella, E. hiemalis*, and *P. myrtifolia* (Table 1).

Figure 2C shows the fruiting patterns of the species according to the dispersal mode. Zoochorous species showed peaks of fruiting in the hotter and humid periods, while the anemochorous species tended to bear fruit throughout most of the year.

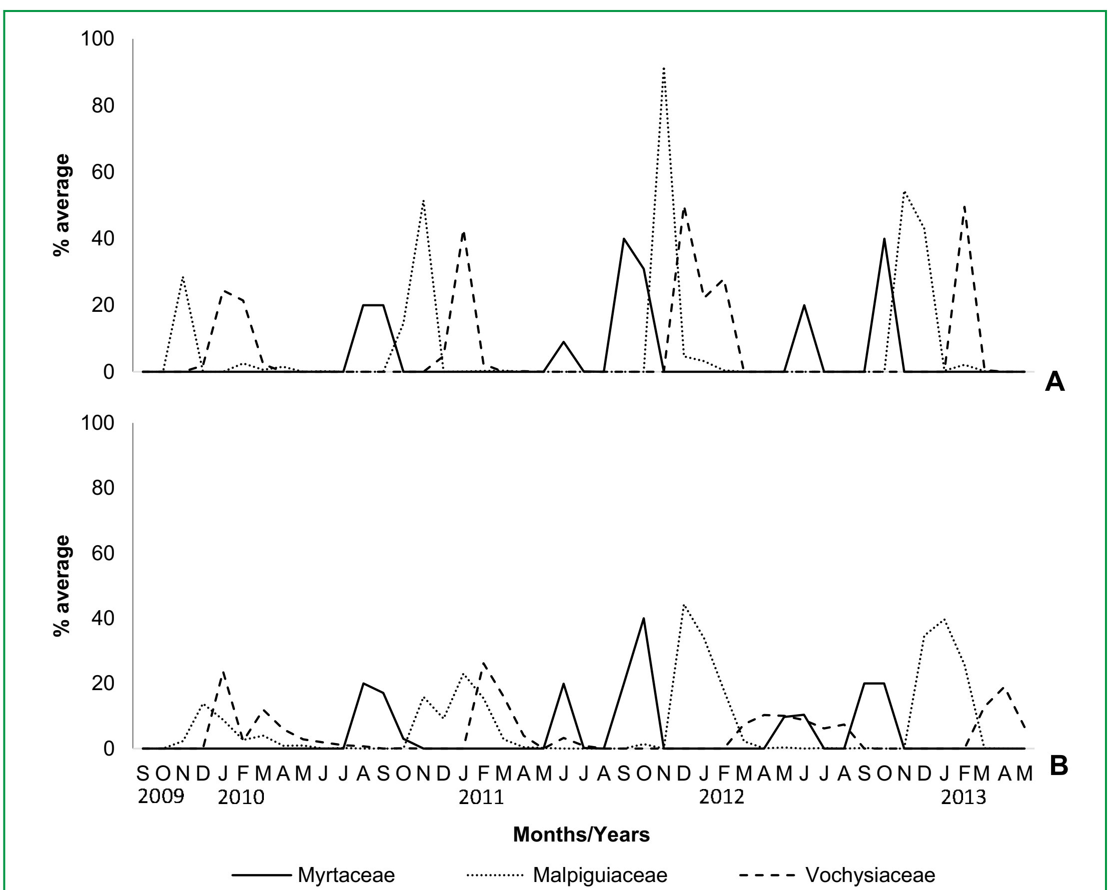
The frequency of flowering species showed a correlation with the mean temperature ($rs = 0.386$, $p < 0.01$). In addition, frequency of fruiting of the zoochorous species had a significant positive correlation with the average monthly temperature ($rs = 0.311$, $p < 0.05$).

Figure 3 describes the patterns of flowering and fruiting of the three most common families in the study area. It is possible to see two peaks of flowering and fruiting for the family Myrtaceae, one near the period of lower temperatures for the region and another when temperatures began to rise. The family Malpighiaceae showed peaks during periods of higher temperature. Vochysiaceae flowered in the warmer periods and fruited during periods when the temperatures fell.

The influence of the climatic parameters on the phenological events of the three families showed that Myrtaceae presented a negative correlation with temperature for both flowering and fruiting ($rs = -0.304$, $p < 0.05$ and $rs = -0.370$, $p < 0.05$, respectively), while Vochysiaceae showed a positive correlation between flowering and temperature ($rs = 0.611$, $p < 0.0001$). Malpighiaceae had a positive correlation with cumulative precipitation and average monthly temperature for flowering ($rs = 0.293$, $p < 0.05$, $rs = 0.547$, $p < 0.0001$) and fruiting ($rs = 0.452$, $p < 0.01$, $rs = 0.654$, $p < 0.0001$).

In the first two study periods, flowering had a more continuous temporal distribution pattern, reflected by the low concentration indices (*r*) found, especially in

FIGURE 3: Reproductive phenology of the main families of the shrubby/arboreal stratum in the Cerrado in the Mogi Guaçu Biological Reserve (22°10'S, 47°11'W), São Paulo. A. Average percentage of flowers. B. Average percentage of fruits.



the first period. In the third and fourth periods, more intense peaks and higher concentration indices were observed. The flowering months, indicated by the calculated average angle, were October or November (Table 2), which correspond to the beginning of the warmer and rainy period in the study area (Figure 2A). In general, Myrtaceae species flowered between August and September ($r = 0.812$, $p < 0.05$), Malpighiaceae in November ($r = 0.938$, $p < 0.05$), and Vochysiaceae in January ($r = 0.913$, $p < 0.05$).

From September 2009 to August 2010, fruiting was distributed continuously throughout the year, as demonstrated by the low r value. When the zoochorous and anemochorous species are considered separately, the same pattern is repeated for the zoochorous species, whereas for the anemochorous species fruiting is concentrated between January and February ($r = 0.805$, $p < 0.05$) (Table 2). In the two following periods, from September 2010 to August 2012, the concentration index remains low for fruiting, in general, and for anemochorous species. Zoochorous species have a slightly higher concentration. In the last observation period, fruiting appeared more intense in December ($r = 0.607$, $p < 0.05$), probably due to zoochorous species ($r = 0.799$, $p < 0.05$). In general, Myrtaceae fruited between August and September ($r = 0.695$, $p < 0.05$), Malpighiaceae between December and January ($r = 0.875$, $p < 0.05$), and Vochysiaceae in March ($r = 0.636$, $p < 0.05$).

Discussion

The community of shrub and tree species studied in the Cerrado/Forest transition in the RBMG had, as main feature, low seasonality for its reproductive phenology. Nevertheless, reproductive events tended to be more concentrated in the hottest and wettest months of the year.

Most of the studied species exhibit an annual flowering and fruiting pattern that is frequently described

TABLE 2: Values of the circular distributions of reproductive phenophases in the RBMG Cerrado/Forest transition area, Mogi Guaçu, SP, between Sept/2009 and May/2013 (N = 21 species). r = concentration of the event around the mean month; S = significant according to the Rayleigh test (P < 0.05); N/S = not significant.

Period	2009/2010	2010/2011	2011/2012	2012/2013
	Flowering			
Month	10	11	10	11
Acrofase (º)	303.8	341.4	328.6	337.7
r	0.188	0.495	0.604	0.621
Conclusion	N/S	S	S	S
	Fruiting			
Month	03	11	12	12
Acrofase (º)	96.9	325.8	359.4	2.1
r	0.172	0.244	0.304	0.607
Conclusion	N/S	S	S	S
	Fruiting – Anemocorics			
Month	1/2	6/7	6/7	2
Acrofase (º)	80.8	208.2	193.2	66.6
r	0.805	0.306	0.226	0.354
Conclusion	S	S	S	S
	Fruiting – Zoocorics			
Month	6/7	11	12	11/12
Acrofase (º)	207.4	335.5	0.1	354.5
r	0.198	0.432	0.520	0.799
Conclusion	N/S	S	S	S

for woody Cerrado species (LENZA; KLINK, 2006; PIRANI et al., 2009). However, although many tropical species do not show an annual flowering pattern, even annual flowering species may exhibit variation in the number of flowers they produce (and hence fruits) between years, which can reduce the availability of resources in a community (NEWSTROM et al., 1994; PIRANI et al., 2009). *Ouratea spectabilis*, *Styrax caporum* and *Ocotea pulchella*, for example, flowered every year of the present study; however, they did not produce fruits in 2012, showing a supra-annual fruiting pattern.

According to Mantovani and Martins (1988), several shrub-tree species studied in the Mogi Guaçu Biological Reserve flower within a period of two years. Among the few biannual species in the studied area is *Eugenia* sp1, and *Eugenia* is frequently described in the literature as presenting this pattern (FIDALGO; KEINERT, 2009).

The weak seasonal pattern of reproductive phenophases described in this paper has also been observed in several woody Cerrado communities and seems to indicate a lower dependence on the constraints imposed by the climate (BATALHA, MARTINS, 2004, LENZA, KLINK, 2006, TANNUS et al. 2006; OLIVEIRA, 2008; PIRANI et al., 2009). According to Newstrom et al. (1994), more asynchronous populations tend to generate a pattern closer to the continuum. This was observed in the present study for the flowering patterns of common species in the community, such as *Prunus myrtifolia*, *Ouratea spectabilis* and *Vochysia tucanorum*, and for the fruiting patterns of the same three species, as well as *Acosmium dasycarpum* and *Byrsonima intermedia*.

In general, species flowered and produced fruits when the temperatures were higher in the study area. However, several species flower and fruit during colder and dryer periods. According to Batalha and Mantovani (2000), Azevedo et al. (2014) and Silva (2016), the reproductive phenology of Cerrado species does not seem to be limited by the availability of water in the soil, which would explain the flowering and/or fruiting observed in dry periods and near the beginning of the rainy season.

Overall, flowers were available throughout the year, with peaks between October and November, which is the beginning of the rainy season. Fruiting peaks tended to occur in the warmer, wetter months of the year. Considering the dispersal modes, anemochorous species exhibited peak fruiting during the driest periods or at the end of the rainy season, when environmental conditions favor the dispersal of their propagules (PIRANI et al., 2009). Zoochorous species tended to fruit in the wetter months, which may be related to dispersal efficiency and synchronization with seed germination (MANTOVANI; MARTINS, 1988; OLIVEIRA, 2008).

Studies have shown that the combination of different phenological strategies in communities can hide the phylogenetic constraints present in certain ecological and/or taxonomic groups (SILVA et al., 2011; AZEVEDO et al., 2014). The sequence in which phenological events occur in each family in this study generated a tendency towards weak seasonality in the community, especially for fruiting. However, the weak seasonal pattern in reproductive phenology changed to clear seasonality when families and/or species were considered separately, as evidenced by circular statistics.

Acknowledgments

We thank the directors of the Mogi Guaçu Biological Reserve and the Botanical Institute for the institutional support, the public workers Edson Pires, Adão Martinho Barbosa and Elisamara Augusto da Silva Guilherme for the logistical and fieldwork support, and J. Rodolfo Lima for reviewing the English in the manuscript.

References

ASSAD, E. D. **Chuva nos cerrados.** Análise e espacialização. Brasília: EMBRAPA/SPI, 1994. 423 p.

AZEVEDO, I. F. P.; NUNES, Y. R. F.; ÁVILA, M. A.; SILVA, D. L.; FERNANDES, G. W.; VELOSO. R. B. Phenology of riparian tree species in a transitional region in southeastern Brazil. **Brazilian Journal of Botany**, São Paulo, v. 37, n. 1, p. 47-59, 2014.

BATALHA, M. A.; MANTOVANI, W. Reproductive phenological patterns of cerrado plant species at the Pé-de-Gigante Reserve (Santa Rita do Passa Quatro, SP, Brazil): a comparison between the herbaceous and woody floras. **Revista Brasileira de Biologia**, São Carlos, v. 60, n. 1, p. 129-145, 2000.

BATALHA, M. A.; MARTINS, F. R. Reproductive phenology of the cerrado plant community in Emas National Park. **Australian Journal of Botany**, Collingwood, v. 52, n. 2, p. 149-161, 2004.

BATSCHELET, E. **Circular statistics in biology.** London: Academic Press, 1981. 371 p.

BENEDITO-SILVA, A. A. Aspectos metodológicos da cronobiologia. In: MARQUES, N.; MENNA-BARRETO, L. (Org.). **Cronobiologia:** princípios e aplicações. São Paulo: EDUSP, 1997. p. 215-238.

FIDALGO, A. O.; KLEINERT, A. M. P. Reproductive biology of six Brazilian Myrtaceae: is there a syndrome associated with buzz-pollination? **New Zealand Jounal of Botany**, Wellington, v. 47, n. 4, p. 355-365, 2009.

LENZA, E; KLINK, C. A. Comportamento fenológico de espécies lenhosas em um cerrado sentido restrito de Brasília, DF. **Revista Brasileira de Botânica**, São Paulo, v. 29, n. 4, p. 627-638, 2006.

MANTOVANI, W.; MARTINS, F. R. Variações fenológicas das espécies de cerrado da Reserva Biológica de Mogi Guaçu. Estado de São Paulo. **Revista Brasileira de Botânica**, São Paulo, v. 11, n. 1/2, p. 101-112, 1988.

MMA – MINISTÉRIO DO MEIO AMBIENTE. **Plano de ação para prevenção e controle do desmatamento e das queimadas no Cerrado – PPCerrado.** Brasília: MMA. 2009. 152 p.

NEWSTROM, L. E.; FRANKIE, G. W.; BAKER, H. G. A new classification for plant phenology based on flowering in lowland tropical rain forest trees at La Selva, Costa Rica. **Biotropica**, Malden, v. 26, n. 2, p. 141-159, 1994.

OLIVEIRA, P. E. Fenologia e biologia reprodutiva das espécies de cerrado. In: SANO, S. M.; ALMEIDA, S. P.; RIBEIRO, J. F. (Ed.). **Cerrado:** ecologia e flora. Brasília: EMBRAPA, 2008. p. 275-290.

PIJL, L. van der. **Principles of dispersal in higher plants.** Berlin: Springer-Verlag, 1982. 214 p.

PILON, N. A. L.; UDULUTSCH, R. G.; DURIGAN, G. Padrões fenológicos de 111 espécies de Cerrado em condições de cultivo. **Hoehnea**, São Paulo, v. 42, n. 3, p. 425-443, 2015.

PIRANI, F. R., SANCHEZ, M.; PEDRONI, F. Fenologia de uma comunidade arbórea em cerrado sentido restrito, Barra do Garças, MT, Brasil. **Acta Botanica Brasilica**, Feira de Santana, v. 23, n. 4, p. 1096-1109, 2009.

SMA – SECRETARIA ESTADUAL DO MEIO AMBIENTE. **Resumo executivo do plano de manejo da Reserva Biológica e Estação Ecológica de Mogi-Guaçu.** São Paulo: SMA, 2011. 96 p.

SILVA, I.; SILVA, D.; CARVALHO, G.; BATALHA M. Reproductive phenology of Brazil-in savannas and riparian forests: environmental and phylogenetic issues. **Annals of Forest Science**, Les Ulis Cedex, v. 68, n. 7, p. 1207-1215, 2011.

SILVA, P. O. Estratégias fenológicas reprodutivas de *Xylopia aromatica* (Lam.) Mart. (Annonaceae) em área de cerrado. **Cerne**, Lavras, v. 22, n. 1, p. 129-136, 2016.

TANNUS, J. L. S.; ASSIS, M. A.; MORELLATO, L. P. Fenologia reprodutiva em campo sujo e campo úmido numa área de cerrado no sudeste do Brasil, Itirapina-SP. **Biota Neotropica**, Campinas, v. 6, n. 3, p. 1-27, 2006.

ZAR, J.H. **Biostatistical analysis.** New Jersey: Prentice-Hall, 1999. 663 p.