

Structure, spatial distribution and phenology of two Vochysiaceae species in Cerrado fragment in the Caatinga, Southern Ceará, Brazil

Estrutura, distribuição espacial e fenologia de duas Vochysiaceae em fragmento de Cerrado em meio à Caatinga, Sul do Ceará, Brasil

Estructura, distribución espacial y fenología de dos Vochysiaceae en un fragmento de Cerrado en la Caatinga, em Sur del Ceará, Brasil

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Abstract

The family Vochysiaceae, representative for Brazilian Cerrado, does not stand out in Caatinga environments. Due to the lack of studies that address the behavior of species of this family in disjunct Cerrado environments, this study aimed to investigate structural, ecological and phenological aspects of *Qualea parviflora* and *Callisthene fasciculata* populations. The phytosociological and phenological surveys were carried out in a Cerrado enclave at Serra do Boqueirão, Lavras da Mangabeira municipality, Southern Ceará, Brazil. Twelve sampling units of 12.0 x 30 m (0.432 ha) were plotted randomly, including all living individuals with a ground level diameter ≥ 3 cm, also measuring total heights. For the evaluation of phenophases, the Fournier percentage was used, allowing the estimation of intensity of the phenophase in each individual through a semi-quantitative interval scale of five categories (0 to 4), 0 being equivalent to 0%; (1) 1 to 25%; (2) 26 to 50%; (3) 51 to 75% and (4) 76 to 100%. Each sample was composed of 103 and 78 individuals respectively in 66.6% and 91.6% of the plots, of *Q. parviflora* and *C. fasciculata*, respectively. The spatial distribution, measured by the Dispersion (ID) and Morisita (IM) indexes reached the values of 17.14 and 18.26 (ID) and 1.08 and 1.16 (IM), respectively, indicating that the species have an aggregate distribution. The phenophases

generally correlated with all the climatic variables studied in the region such as rain and precipitation. All data and results presented here collaborate for future projects in the area.

Keywords: *Qualea parviflora*; *Callisthene fasciculata*; Cerrado fragmente.

Resumo

A família Vochysiaceae, representativa do Cerrado brasileiro não se destaca em ambientes de Caatinga. Pela carência de trabalhos que abordem o comportamento de espécies desta família em ambientes disjuntos de Cerrado, este estudo objetivou investigar aspectos estruturais, ecológicos e fenológicos de populações de *Qualea parviflora* e *Callisthene fasciculata*. Os levantamentos fitossociológico e fenológico foram realizados em enclave de Cerrado na Serra do Boqueirão, Lavras da Mangabeira, Sul do Ceará. Foram plotadas 12 unidades amostrais de 12,0 x 30 m (0,432 ha), de forma aleatória, incluídos todos os indivíduos vivos com diâmetro ao nível do solo ≥ 3 cm, também aferidas as alturas totais. Para a avaliação das fenofases foi utilizado o percentual de Fournier, que permite estimar a intensidade da fenofase em cada indivíduo por meio de uma escala intervalar sem quantitativa de cinco categorias (0 a 4), sendo 0 equivalente a 0%; (1) 1 a 25%; (2) 26 a 50%; (3) 51 a 75% e (4) 76 a 100%. Foram amostrados 103 e 78 indivíduos em 66,6% e 91,6% das parcelas, de *Q. parviflora* e *C. fasciculata*, respectivamente. A distribuição espacial, medida pelos índices de Dispersão (ID) e de Morisita (IM) atingiu os valores de 17,14 e 18,26 (ID) e 1,08 e 1,16 (IM), respectivamente, indicando que as espécies apresentam distribuição agregada. Em geral, as fenofases correlacionaram-se com todas as variáveis climáticas estudadas da região, tais como chuvas e precipitações. Os dados e resultados aqui apresentados colaboram para futuros projetos na área.

Palavras-chave: *Qualea parviflora*; *Callisthene fasciculata*; Fragmento de Cerrado.

Resumen

La familia Vochysiaceae, representativa del Cerrado brasileño, no destaca en ambientes de Caatinga. Este estudio tuvo como objetivo investigar aspectos estructurales, ecológicos y fenológicos de las poblaciones de *Qualea parviflora* y *Callisthene fasciculata*. Se realizaron estudios fitosociológicos y fenológicos en un enclave del Cerrado en la Serra do Boqueirão, Lavras da Mangabeira, Sur de Ceará. Se trazaron al azar 12 unidades de muestreo de 12,0 x 30 m (0,432 ha), incluyendo todos los individuos vivos con diámetro a nivel del suelo ≥ 3 cm, también se midieron las alturas totales. Para la evaluación de las fenofases se utilizó el percentil de Fournier, que permite estimar la intensidad de la fenofase en cada individuo a través de una escala de intervalo no cuantitativa de cinco categorías (0 a 4), siendo 0 equivalente a 0%; (1) 1 a 25%; (2) 26 a 50%; (3) 51 a 75% y (4) 76 a 100%. Se muestrearon 103 y 78 individuos en el 66,6% y 91,6% de las parcelas, de *Q. parviflora* y *C. fasciculata*, respectivamente. La distribución espacial, medida por el Índice de Dispersión (ID) y el Índice de Morisita (IM), alcanzó valores de 17,14 y 18,26 (ID) y 1,08 y 1,16 (IM), respectivamente, indicando que la especie presenta una distribución agregada. En general, las fenofases se correlacionaron con todas las variables climáticas estudiadas en la región. Los datos y resultados presentados aquí contribuyen a futuros proyectos en la zona.

Palabras clave: *Qualea parviflora*; *Callisthene fasciculata*; Fragmento de Cerrado.

1. Introduction

Studies referring to the phenology of native plants from the Cerrado (Brazilian Savana) are scarce and can be promising for a rational and sustainable use of their potential (Almeida et al. 2014). Phenology refers to the definition of phenophases on a time scale (Biondi et al. 2007), generating data on the sprouting, flowering, fruiting and seed dispersal and proposing hypotheses on the vegetative and reproductive patterns of the species.

Vochysiaceae A.St.-Hil. is a small Angiosperm family in the order Myrtales, comprising eight genera and about 240 species, being represented in Brazil by six genera and about 160 species (Shimizu, 2016). Currently the species are classified into two tribes: Erismae Dumort. and Vochysieae Dumort. (Azevedo et al. 2015). It is a predominantly tropical family, with 90% of its species located in South and Central America (Negrelle et al. 2007). According to Souza and Lorenzi (2008), it occurs in Brazil as one of the main families of the Cerrado biome, being also found in other biomes such as Atlantic Forest and Amazon.

Qualea parviflora Mart., also known as “pau-terra-da-flor-miúda” or “pau-terra-mirim”, is a plant considered semi deciduous or deciduous. Its flowers have purplish color, dehiscent dry fruit and its seeds are dispersed by the wind (Paula & Alves, 1997). It is found in high density in Cerrado and Cerrado fields in the following Brazilian states: Bahia, Minas Gerais, Mato Grosso do Sul, Goias, Federal District and São Paulo (Lorenzi, 2008). Its adaptation to Cerrado soils is related to the

ability to accumulate aluminum in its tissues (Haridasan, 1982; Ferreira et al. 2017). The wood is light, soft and not much durable and is used for production of charcoal, boxes, toys and canoes; the bark is rich in tannin, hence its antiseptic property; leaf tea is indicated against heartburn and its fruits can be used in craftsmanship (Pott & Pott, 1994).

Callisthene fasciculata Mart., is a tree that varies in height between 7-18 m, and is popularly known as “carvão-branco”, “carvoeiro”, “itapicuru” and “capitão-do-campo” (Oliveira et al. 2015). It is widely distributed in most states of Brazil abundant in the Cerrado biome and in the transition between Cerrado and broad-leaved semi-deciduous forest in formation areas. The species has ornamental potential for urban arborization, especially when it is in bloom. Its wood has economic value and is used for external structures, such as fence posts, bridge beams and light poles; moreover, it is used for firewood and energy generation (coal) (Lorenzi, 2008). According to Guarim-Neto (2006), the decoction of stem bark of this species is traditionally used by the inhabitants of the Pantanal as a medicine, being indicated for symptoms related to hepatitis, jaundice and anemia.

Enclaves are landscapes that show different configurations in comparison to their surroundings, resulting from their own dynamics, arising from natural factors, especially biogeographic, over geological time (Freire, 2007). In the Brazilian Northeast, the existence of Cerrado patches is attributed, mainly, to altitude, forming fragments resulting from the association with edaphic factors (Santos et al. 2014; Bezerra et al. 2020).

Cerrado spots occurring in Ceará state are associated with coastal plateaus, in the municipalities of Granja, Fortaleza, Cascavel, Caucaia and Horizonte, the Ibiapaba Plateau, small sedimentary reliefs located in the southern area of the state, in the municipalities of Lavras de Mangabeira, Aurora, Granjeiro, Várzea Alegre, Farias Brito, Cedro, Jucás and on the Chapada do Araripe (Moro et al. 2015). The Cerrado is Brazil's second largest biome, and is also considered a "hotspot" for the conservation of global biodiversity due to the high concentration of endemic species. (Serpa et al. 2020)

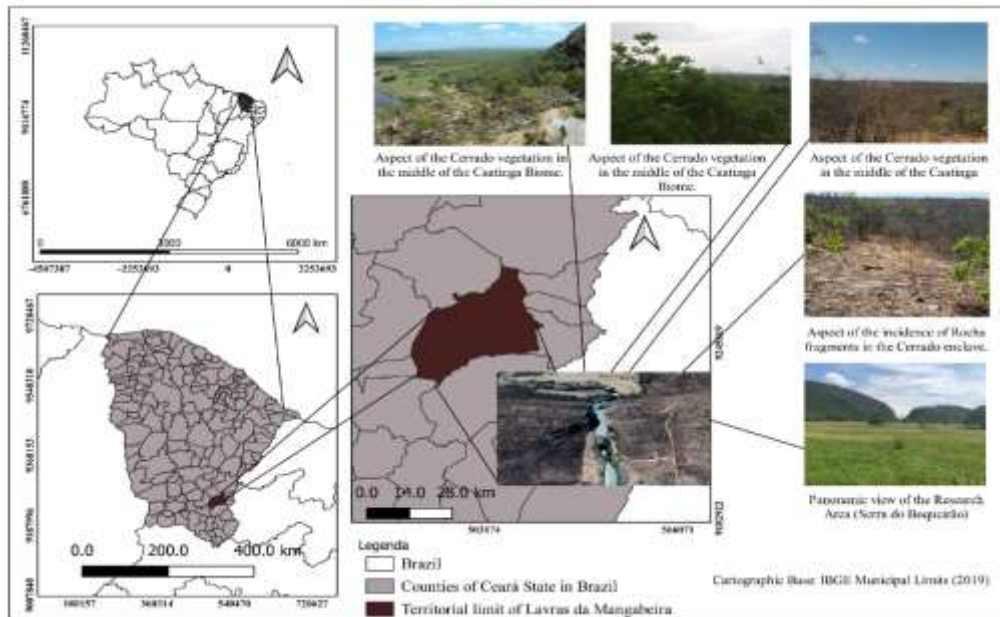
In this sense, this study aimed to analyze the spatial distribution and to identify the diametric and height structures of individuals from populations of *Q. parviflora* and *C. fasciculata* and also to know, evaluate and describe the phenological cycle of the two species occurring in a Cerrado fragment in middle of crystalline Caatinga, municipality of Lavras da Mangabeira, southern Ceará state, being the first study involving typical species of Cerrado in Caatinga core area. It is then expected to afford management actions and improve the understanding of the ecological behavior of these species in disjoint environments.

2. Methodology

2.1 Area of Study

Serra do Boqueirão is located in the municipality of Lavras da Mangabeira, (6°72'24" S and 38°97'73" W) (Figure 1), with elevations ranging from 252 to 401m. This municipality is located in the semiarid region of Northeastern Brazil, in the homonymous microregion and in the mesoregion of the Mid-Southern Ceará (Ibge, 2010). The area of study is located near the Lavras da Mangabeira sedimentary basin, a set of three small basins with an area of circa 60.27 km², and is inserted in private property, being remarkably preserved (without the use of agriculture). The climate is warm semi-arid tropical, with two well-defined seasons dry winter and wet summer, (Aw) according to Köppen classification, despite the transitory character with the semi-arid climate of Northeastern Brazil (BSh). The average rainfall in the municipality is 930.0mm (Funceme, 2019), with precipitation concentrated from January to April, with an average annual temperature of 26.8° C (Inpe, 2019).

Figure 1. Location of the Cerrado fragment in the middle of the Caatinga do Cristalino, Serra do Boqueirão, Lavras da Mangabeira, Ceará State.



Source: Moura et al. (2020).

The region is severely faulted, lines going in West-East direction, converging to the line of municipalities of Patos in Paraíba state, Brazil. The area under study is located between municipalities of Várzea Alegre, Granjeiro and Cuncas faults. The relief consists of surfaces dissected into structural crystals with elongated dales and interfluvia. The interfluvia already in an advanced process of dissection keep narrow horizontal surfaces, presenting in their slopes, parallel grooves that usually accompany the fractures (Figueiredo & Fernandes, 1987).

2.2 Phytosociology evaluation

The phytosociological survey was performed using the plot method, developed by Mueller-Dumbois and Ellenberg (1974). Twelve sampling units of 12.0 x 30 m (0.432 ha) were established, randomly distributed in the area. In each plot, all living individuals of *Qualea parviflora* and *Callisthene fasciculata* were counted, with a diameter at ground level (DNS) equal to or greater than 3 cm, using a gap dendrometer, in addition to measuring the total height with a graduated telescopic pole.

Therefore, each unit of the population is equally likely to form part of the sample, resulting in a highly representative sampling (Matteucci; Colma, 1982). The sample intensity was calculated considering an error limit of up to 20%, at a probability level of 10% for the variable AD (absolute density). The standard error, in percentage, was used to infer about the sampling precision, as suggested by Felfili and Rezende (2003).

The phytosociological analysis was performed using Fitopac 2.1.2 software (Shepherd, 2010), which allowed the analysis of the usual parameters (Density, frequency, dominance and importance value). Histograms of individuals distribution by height classes with an interval of 3 m, and by diameter classes, with an interval of 5 cm, were calculated by Liocourt quotient “q” by dividing the number of individuals in a diametric class by number of individuals in the previous class.

To analyze the individuals spatial distribution in the populations, two indices were used: I- variance/average ratio or dispersion index (*DI*) (Perry & Mead, 1979), calculated according to equation 1:

$$ID = \frac{s^2}{m} \quad (1)$$

Where: s^2 : sample variance and m : sample mean. This index is based on the sample variance/average ratio through the hypotheses of the Poisson model (Martins, 2008). II- Morisita Index (MI) (Morisita, 1959), calculated by equation 2:

$$IM = q \frac{\sum_{i=1}^q x_i(x_i - 1)}{T(T - 1)} \quad (2)$$

Where: q = number of plots; x = number of individuals in the i -th parcel; T = total number of individuals sampled.

For DI and MI , values equal to 1 point to random spatial distribution. Values less than 1 indicate uniform disposition and values greater than 1 indicate an aggregate arrangement. To analyze the randomness pattern of the samples, the chi-square test (χ^2) was used according to equation 3:

$$\chi^2_{calc} = \frac{n \sum x^2}{T} - T \quad (3)$$

Where: the variables are the same as those defined for the MI equation.

If the DI and MI values differ statistically from 1, the chi-square value should be less than the critical values of the distribution at the 5% probability level (Brower & Zar, 1984).

2.3 Phenology evaluation

To collect the phenological data, 10 adult individuals of each species were used, randomly marked, with aluminum plates numbered sequentially and georeferenced using GPS. Observations were determined monthly from February 2018 to February 2020, in order to obtain two years of observation. The following reproductive phenophases were recorded: bud, open flower, immature and ripe fruit and the vegetative phenophases were: budding, young, adult and senescent leaf, according to proposed by Morellato et al. (1989).

The climatic data of the study area were obtained by Instituto de Nacional Meteorologia or Fundação Cearense de Meteorologia e Recursos Hídricos - FUNCEME.

For the evaluation of phenophases, the Fournier percentage was used, which allows estimating the intensity of phenophase in each individual according to a semi-quantitative interval scale of five categories, being: 0 – equivalent to 0%; 1 – 1 to 25%; 2 – 26 to 50%; 3 – 51 to 75% and 4 – 76 to 100%. Each month, the intensity values obtained for all individuals of each species were added and divided by the maximum possible value (number of individuals times four). The value obtained, which corresponds to a proportion, was then multiplied by 100, to transform it into a percentage value. The synchrony between individuals in the population was assessed using the presence/absence method, which indicates the percentage of individuals in the population that is manifesting a certain phenological event. An asynchronous phenological event was considered when < 20% of individuals in the population were presenting the phenophase; little synchronic with 20-60% of individuals and very synchronic with > 60% individuals, according to Bencke and Morellato (2002).

3. Results and Discussion

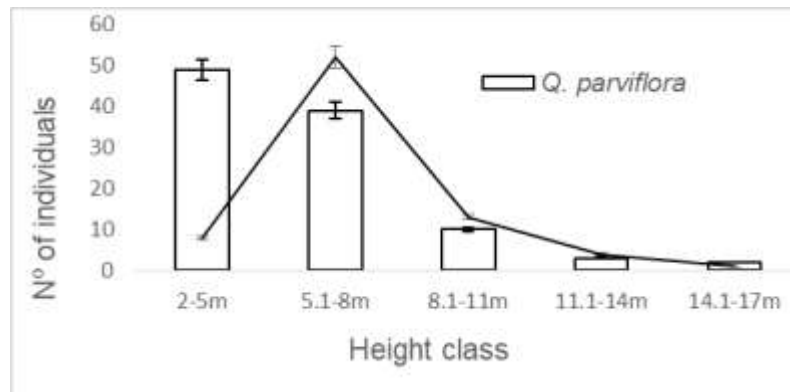
The inventory generated an absolute density estimate of 2,097.22 ind. ha⁻¹ (CI=± 202.67 ind.ha⁻¹) at 95% probability, with a standard error of 6.16% and basal area value (dominance) of 5.17 m² ha⁻¹ (CI=± 6.93 m² ha⁻¹) at 95% probability, with a standard error of 8.09%.

The sample consisted of 103 individuals of *Qualea parviflora* and 78 of *Callisthene fasciculata*, present in 66.6% and 91.6% of the parcels plotted in the area, with absolute density (AD) of 238.4 ind.ha⁻¹ and 180.6 ind.ha⁻¹, importance value index (IVI) of 38.29 and 19.42, and absolute dominance (ADo) of 1.04 m²/ha⁻¹ and 0.66 m²/ha⁻¹, respectively.

The minimum heights found in the populations were, respectively, 2.5 and 3.0 m, for *Q. parviflora* and *C. fasciculata*, and the maximum of 15 m for both species. The average height was 5.73 m for *Q. parviflora* and 7.43 m for *C. fasciculata*. In the population of *Q. parviflora*, the greatest number of individuals is found in the 1st and 2nd height classes (2.0 - 5.0 m and 5.1 - 8.0 m), which corresponds to 85.43% of all specimens sampled, highlighting the average vertical stratification of this population component.

In the population of *C. fasciculata* a greater number of representatives is found in the 2nd and 3rd height classes (5.1 - 8.0 and 8.1 - 11 m) (83.3%), inferring a greater proportional number of taller trees in comparison to the population of *Q. parviflora*. The large number of individuals in the lower height classes, as well as diameter classes, showing imbalance in the distribution of individuals, indicating constant potential for regeneration, that is, that the community shows fast regeneration (Figure 2).

Figure 2. Number of individuals of two Vochysiaceae species by height classes in the Cerrado fragment in the middle of the Caatinga, Serra do Boqueirão, municipality of Lavras da Mangabeira, Ceará State, Brazil.



Source: The authors.

The population of *Q. parviflora* showed Liocourt quotient values “q” ranging from q₅ = 1 to q₁ = 0.173, with an average of 0.49, showing a pattern of irregularity in the diametric distribution of individuals in this population. For *C. fasciculata*, a similar imbalance is observed, with a peak ratio q₃ = 0.33 and variation up to q₁ = 0.21 with an average of 0.257 in the population. This indicates the existence of imbalance or destabilization, since as there is no gradual decrease in the sequential classes, despite the existence of a large number of stock individuals (Table 1), indicating gain in the competitiveness of both species with over the of time in the community, as the number of young individuals has not decreased.

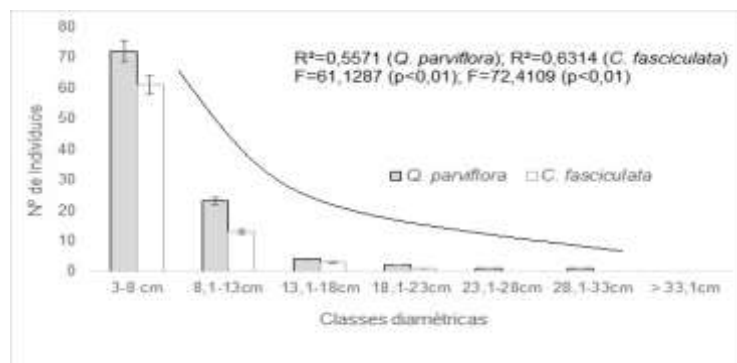
Table 1. Diametric distribution of two Vochysiaceae species and respective values of Liocourt's "q" coefficient on a fragment of Cerrado in the middle of Caatinga, Serra do Boqueirão, municipality of Lavras da Mangabeira, Ceará state, Brazil.

Diameter classes	Number of Individuals		"q" value	
	<i>Q. parviflora</i>	<i>C. fasciculata</i>	<i>Q. parviflora</i>	<i>C. fasciculata</i>
3-8 cm	72	61		
8.1-13cm	23	13	0.319	0.213
13.1-18cm	4	3	0.173	0.23
18.1-23cm	2	1	0.5	0.333
23.1-28cm	1	0	0.5	-
28.1-33cm	1	0	1	-
> 33.1cm	0	0	-	-

Source: The authors.

The average diameter value for *Q. parviflora* was 6.5 cm and for *C. fasciculata* it was 6.53 cm. The maximum and minimum values of diameter were 28.1 cm and 3 cm, for *Q. parviflora* and 18.1 cm and 3.5 cm for *C. fasciculata*. There were no representatives in all diametric classes in both populations. The large number of individuals in the first diameter classes in both populations (Figure 3), although the pattern of occurrence in the diametric structure indicates a trend of unbalanced distribution, may be explained by the existence of interventions in the natural succession process. The pattern of diametric distribution in the shaped as a "reverse-J" shown in this study is indicative of a positive balance between recruitment and mortality of individuals, which is characteristic of self-regenerating populations, as this pattern occurs when there is replacement of smaller individuals by adults in the population. However, considering the seven diameter classes established, the unbalanced distribution in both populations indicates that such species do not have a good balance between mortality and growth.

Figure 3. Diametric distribution of two Vochysiaceae species with respective R² coefficients of determination and F values for the populations of the Cerrado fragment in the middle of the Caatinga in Serra do Boqueirão, municipality of Lavras da Mangabeira, South Ceará state, Brazil.

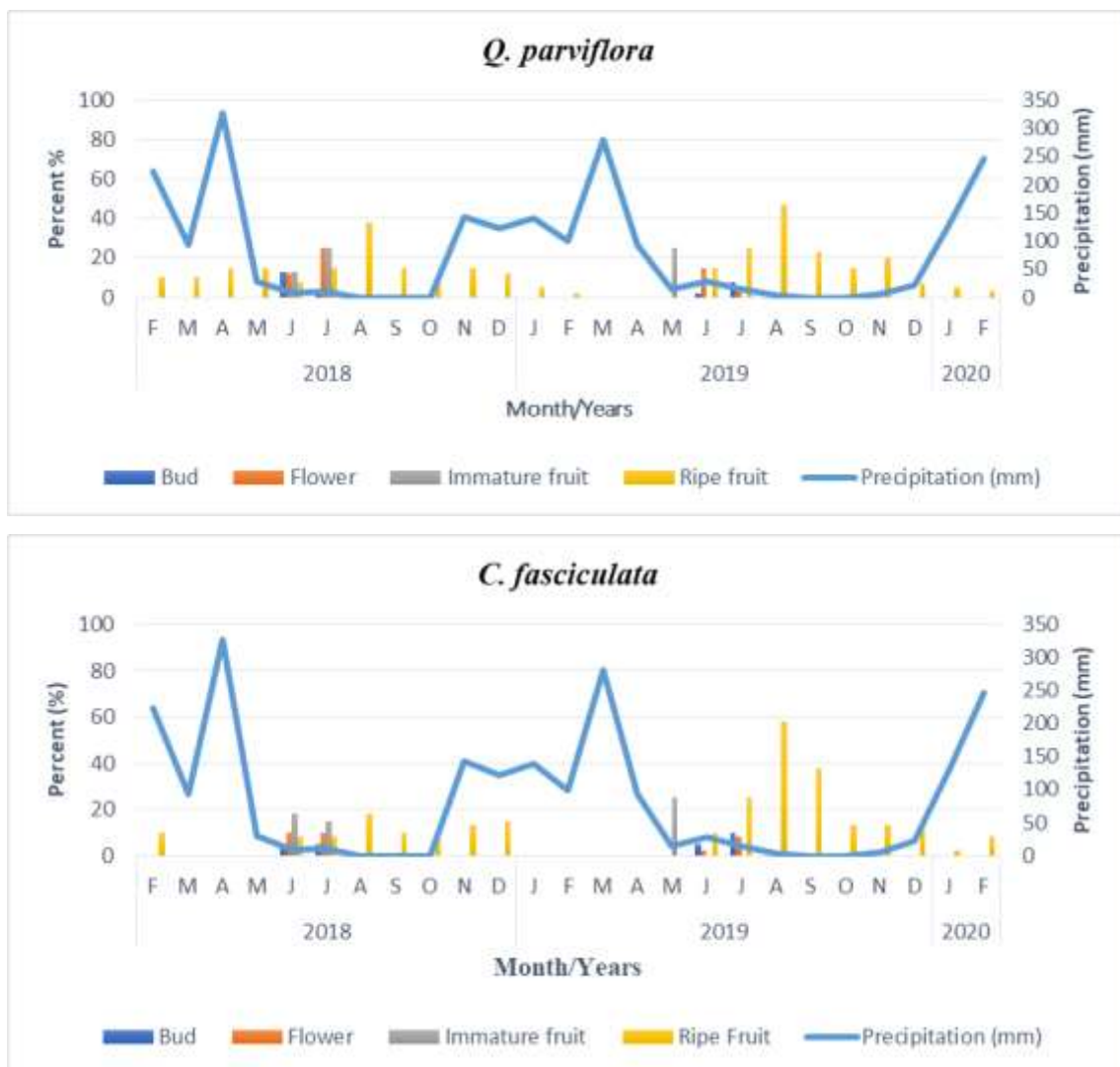


Source: The authors.

Using the Morisita index (**IM**) we found that the pattern of spatial distribution of both populations in the area was aggregate type, with respective values of 1.08 and 1.16 for *Q. parviflora* and *C. fasciculata* respectively.

In phenology (Figure 4), the “bud” and “open flower” phases had low percentage rates in the two species over the time, however, during the two-year period (in the months of June and July) obtained the highest index peaks. In *Q. parviflora*, the “bud” phenophase peaked 13% and 3% in the first year observed, and 2% and 8% in the second year observed, all referring to the months of June and July and in *C. fasciculata*, from 5% and 5% in the first year, and 5% and 10% in the second year. The appearance of open flowers in *Q. parviflora*, peaked at 12% and 25% in the first year, and 15% and 5% in the second year of observation, also in the period of June and July. For *C. fasciculata*, 18% and 10% were observed in the first year and 2% and 8% in the second year.

Figure 4. Percentage index of reproductive phenophase of *Q. parviflora* and *C. fasciculata* in the period observed in the fragment of Cerrado in the middle of the Caatinga in Serra do Boqueirão, municipality of Lavras de Mangabeira, South Ceará state, Brazil.

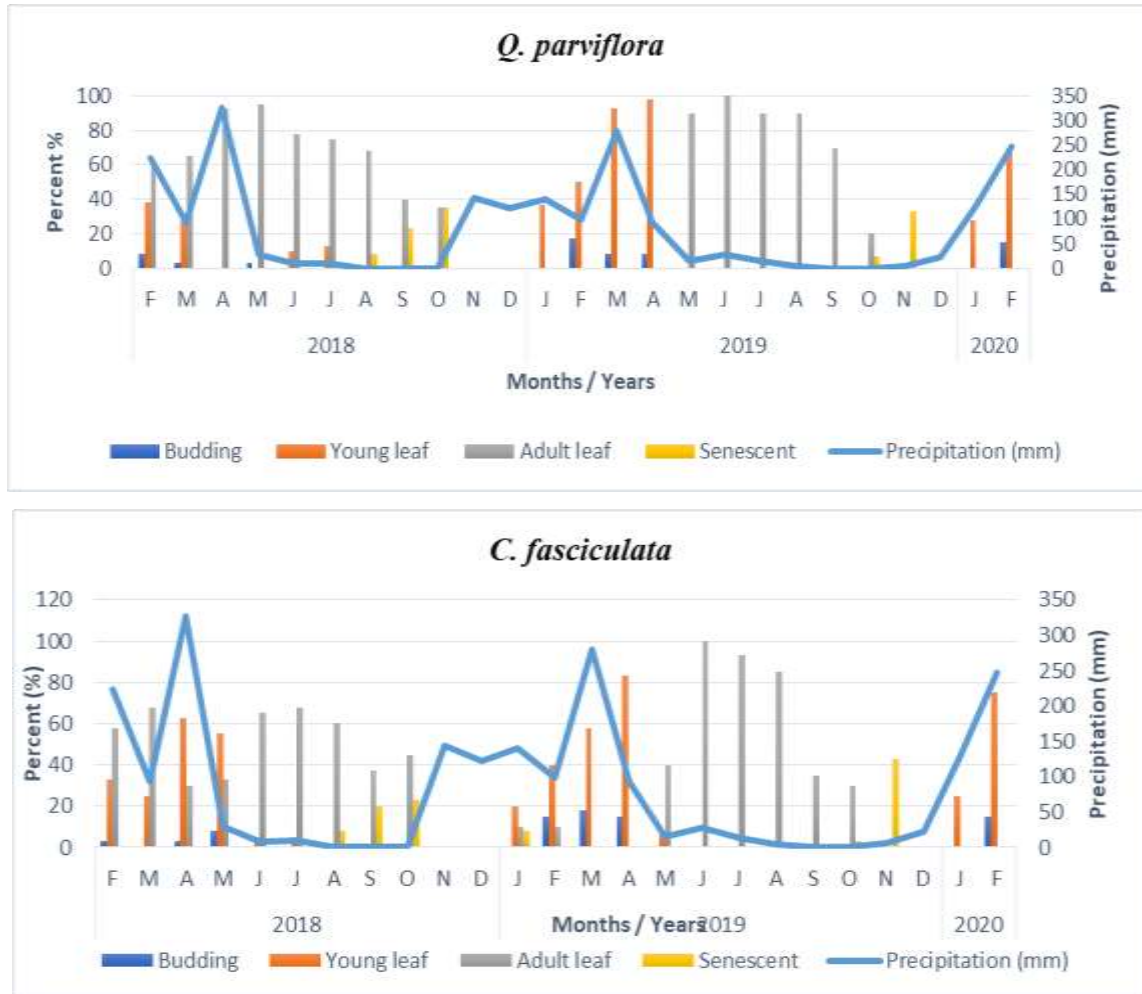


Source: The authors.

In the “ripe fruit” phase, the rates are higher. In the first year, the phenophase was present in all months in *Q. parviflora*, with peak of 38% in August, and in *C. fasciculata*, between June and December, with peak of 18% also in August. In the second year, the peak also occurred in August, with 47% and 58% respectively in *Q. parviflora* and *C. fasciculata*.

Regarding vegetative phenophases (Figure 5), the “budding” proved to be unsuccessful, even though it was observed in three months (from January to March) in both years. In *Q. parviflora* the percentage was relatively low, with a peak of 17% in February 2019 and a low rate of 3% in March 2018. In *C. fasciculata*, February 2018 had a peak of 10% and in 2019 the month of March had the highest index, with 18%.

Figure 5. Percentage index of vegetative phenophase of *Q. parviflora* and *C. fasciculata* in the period observed in the Cerrado fragment in the middle of the Caatinga in Serra do Boqueirão, municipality of Lavras de Mangabeira, South Ceará state, Brazil.



Source: The authors.

Young leaves were abundant in the periods observed in both species, in *Q. parviflora*, between the months of February and July 2018, in low and medium index, reaching 38% in February, in 2019 they occurred from February until April, with high levels of intensity, reaching 98% in April. In *C. fasciculata*, they occurred from February to June in 2018, with a peak of 63% in April, and from February to May 2019, with a peak of 83% in April.

The "adult leaf" phenophase was the one that showed the best results in percentage in both species. In *Q. parviflora* and *C. fasciculata* it was obtained from February to October in the first year and from May to October in the second year, with both species having a 100% peak in June in the second year of the research. The months of March, April and May stood out in the second year, as they all had a peak of over 90% in *Q. parviflora*. In *C. fasciculata*, only May, with 40%, stands out in the first year of research.

The "senescent leaf" phenophase, observed in the dry season (absence of rain) in both species, was from August to October in 2018, and October and November in 2019, with a peak of 35% in the first year for *Q. parviflora* and 43% in November of the second for *C. fasciculata*.

These values of density, as highlighted by Felfilli and Rezende (2003), corroborate for the sampling precision to be considered adequate and comprehensive for the estimation of quantitative variables.

Similar results for diametric distribution and respective values of Liocourt's "q" coefficient were found by Santana (2009) when studying the distribution and diametric structure of *Croton sonderianus* in a Caatinga area at Seridó Potiguar, Rio Grande do Norte state. Calixto Júnior et al. (2011) also observed a pattern of irregularity in the diametric distribution of individuals for a population of *Mimosa tenuiflora* in Petrolina, Pernambuco state, as well as Fabricante and Andrade (2007), who found an unbalanced diametric distribution when studying the population of *Cnidocolus phyllacanthus* in Juazeiro, Bahia state, inferring that the distribution in height classes of species may also demonstrate the conservation status of the landscapes in which they occur. When the quotient "q" is not constant, as verified in this study, there is a discrepancy between recruitment and mortality rates, which may lead to changes in the community structure.

According to Felfili and Silva Júnior (1988), the interpretation of diameter measurements in class frequency histograms may indicate possible past, natural or anthropogenic disturbances, such as logging, selective logging, fires, deforestation and herbivory. These events appear as interruptions in the histograms, indicating that the species' life cycle could not be completing (Felfili & Silva Júnior 1988; Bernasol & Lima-Ribeiro, 2010). The fluctuations in the frequency of the diametric classes of these two populations suggest an increase in seedling mortality in the past, evidenced by the low frequency of individuals in the second, third and fourth classes in relation to the immediate upper class. Such irregularity indicates interruption in the proportional flow of individuals that would occupy these intermediate classes today, due to the growth of individuals, which suggests that the populations of the two species of Vochysiaceae are susceptible to variations and environmental disturbances, such as those caused by the visible penetration of the Caatinga flora, combined with climatic changes, and the acceleration of deforestation by anthropism, which tends to diminish the Cerrado enclave, being restricted to the area much less extensive than that covered the region in the past, considered now as a vegetation relic. On the other hand, the high proportion of individuals in the first size class may be an indication that possible disturbances do not influence the structure of the population and that the populations are in the process of being restored in the Cerrado fragment, or that, if they still exist, influence negatively individuals only at the intermediate stage of development.

Fidelis and Godoy (2003) highlighted that higher concentration of individuals in the first size classes, according to the "reverse-J" pattern, may also be explained by genetic potential of most species in the Cerrado, which have small individuals, even as adults. For Harper (1990), this pattern is observed for most species of large tropical forests with well-developed individuals.

Similar evidence is also suggested by the relationship between stem circumference and plant height, in both populations, regarding susceptibility to variations and environmental disturbances. The higher proportion of individuals with high height, but with relatively thin stems, also suggests that the two species have a high capacity for regeneration in relation to disturbing factors, positively influencing the recruitment rate in the population.

The presence of individuals in these same conditions was evidenced for two species of the *Qualea* genus (*Q. grandiflora* and *Q. multiflora*) by Bernasol and Lima-Ribeiro (2010), studied in the municipality of Jataí, southwestern Goiás state, in the area of Cerrado. The authors suggested a certain balance between the capacity for regeneration, recruitment and susceptibility to disturbing pressures. According to Lorenzi (2008), species of the *Qualea* genus regrow easily after being burned, for example.

According to Lorenzi (2008), the two species analyzed have dispersion of seeds by anemocory. For a species whose diaspores are dispersed by the wind, should be common for seed distribution to occur on the substrate occasionally, since there is no purposeful deposition of diaspores in specific microenvironments and, therefore, individuals have a random distribution. However, the data obtained in this study point to an aggregate spatial distribution pattern, which implies that there are other factors that influence the establishment of seedlings and the recruitment of specimens in certain microenvironments in this Cerrado fragment. Such factors can originate from natural (biotic and abiotic) and/or anthropic processes (Mueller-dombois & Ellenberg, 1974; Barbour et al. 1987; Bernasol & Lima-Ribeiro, 2010).

The analyzed populations are probably being spatially structured under the influence of anthropic factors, since this area is fragmented and history indicates recurrence of fires (of anthropic origin, with a three-year frequency), extraction and use for pasture. Adult individuals often have burnt trunks with lateral regrowth.

Among the environmental factors, the substrate (abiotic factor) is one of the most important in determining the spatial structure of plant populations (Kershaw, 1973; Mueller-Dombois & Ellenberg, 1974; Barbour et al. 1987). According to Haridasan (2005), the geographic distribution of some species in the Cerrado is directly influenced by the heterogeneity of soil edaphic conditions, such as: age, texture, depth, fertility and water availability. On the other hand, local heterogeneity influences the spatial distribution of individuals on smaller scales (populations, for example), since the establishment of plants occurs according to the characteristics of the substrate conducive to their development (Bernasol & Lima-Ribeiro, 2010). Thus, if the soil of a region presents local spots with different physical and chemical characteristics, plant populations are structured in the same way, thus presenting individuals aggregated in space (Barbour et al., 1987). Lemos et al. (2013) observed that *Q. parviflora* is common to environments other than Cerrado. one elevated and the other rocky in Tocantins state.

The aggregate distribution in populations of *Q. parviflora* was also observed by Meireles and Luiz (1995) in the Cerrado s.s. in Brasília, Distrito Federal, as well as by Souza and Coimbra (2005) in the Cerrado s.s. in Caldas Novas, Goiás state, Bruzinga et al. (2014), observing *Caryocar brasiliensis* in Cerrado s.s. in Rio Preto, Minas Gerais state and Sousa e Cunha (2018), studying *Anacardium humile* in Cerrado s.s. Similar results were observed in the spatial distribution of species in the Caatinga: Fabricante et al. (2009) for *Cenostigma pyramidale* (Tul.) E.Gagn. & G.P.Lewis [*Caesalpinia pyramidalis* Tul.] in Acari, Rio Grande do Norte state and Santa Luzia, Paraíba state and Santana (2009) for *Croton. sonderianus* in Serra Negra do Norte, Rio Grande do Norte state, both in well-preserved Caatinga environments.

The results of this study also corroborate those obtained by Calixto Júnior et al. (2011), for *M. tenuiflora* in Caatinga areas after 30 and 20 years of logging in Petrolina and Floresta, respectively, in Caatinga areas in Pernambuco state. Alves Junior et al. (2006), when studying a fragment of dense ombrophilous forest in Recife, Pernambuco state, identified that the species with the highest VI in the community tend to occur together or in small patches and corroborate the results described by Martins et al. (2003), who claimed that the occurrence of this fact is common in tropical forests, where more abundant species appear grouped or with a tendency to grouping, corroborating with Ricklefs (1996), when affirming that the grouped distributions may result from the social predisposition to form groups or grouped resource distributions. The aggregate spatial structure of these two populations corroborates the general pattern found in other works and proves to be dominant among plant species in the Caatinga and Cerrado, at different scales and phytophysiognomies.

Lenza and Klink (2006) observed that several species of the cerrado have an annual and unimodal flowering pattern with fast and synchronous peaks. This strategy is also common among species pollinated by insects, favoring the attraction of pollinators and facilitating the flow of pollen and cross-pollination (Marquis, 1988).

According to Neves (2012) the Cerrado species have their initial maturation period in March, however, their peaks are concentrated in the month of August. The dry season favors the drying of the pericarp in dehiscent fruits, caused mainly by the low humidity of the air and the increase in the speed of the winds (Batalha & Mantovani, 2000).

In regions with seasonal climate, as occurs in the Cerrado biome, leaf sprouting occurring in the period preceding the first rains may suggest as a strategy to avoid the emission of new leaves during unfavorable seasons (Van Schaik et al. 1993).

This shows that the species remained leafless during the driest period of the year, a behavior identical to that found for the same species by Franco et al. (2005) in the Federal District (central Cerrado of Brazil) and by Silvério and Lenza (2010) in a typical Cerrado in the state of Mato Grosso, Central-Western Brazil.

4. Conclusion

The results pointed to the aggregate distribution of the two species of Vochysiaceae in the Cerrado *sensu stricto* fragment located in the middle of the crystalline Caatinga, in the semiarid region of Northeastern Brazil, being this the first study to focus on the occurrence and ecological behaviors of plant populations in that area.

The grouping may be the result of the way the natural resources were distributed in the area and the structure pointed to a process of progressive natural regeneration.

In phenology, *Qualea parviflora* and *Callisthene fasciculata* phenophases can be influenced by climatic variables: precipitation, average temperature and relative moisture. The species are abundant in the cerrado spot and have similar characteristics to those of the central Cerrado of Brazil.

The aggregate spatial structure corroborates the general pattern found in other studies in Caatinga and Cerrado in different phytogeographies.

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References

- Almeida, J., Santos, J.A., Alberton, B., Torres, R.S. & Morellato, L.P.C. (2014). Applying machine learning based on multiscale classifiers to detect remote phenology patterns in Cerrado savanna trees. *Ecological Informatics*, 23 (1), 49-61. doi.org/10.1016/j.ecoinf.2013.06.011
- Alves Júnior, F. T., Brandão, C. F. L. S., Rocha, K. D., Marangon, L. C. & Ferreira, R. L. C. (2006). Efeito de borda na estrutura de espécies arbóreas em um fragmento de Floresta Ombrófila Densa, Recife, PE. *Revista Brasileira de Ciências Agrárias*, 1 (1), 49-56. Retrieved from <https://www.redalyc.org/pdf/1190/119018241008.pdf>
- Azevedo, F. P., França, F. & Junqueira, M. E. R. (2015). Estudos taxonômicos da família Vochysiaceae A.St.-Hil. no Município de Caetitê, Bahia, Brasil. *Iheringia, Série Botânica*, 70 (1), 25-38. Retrieved from <https://isb.emnuvens.com.br/iheringia/article/view/296>
- Barbour, M. G., Burk, J. H., & Pitts, W. D. (1987). *Terrestrial Plant Ecology*. Menlo Park: Benjamin Cummings.
- Batalha, M. A. & Mantovani, W. (2000). 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*, 60 (1), 129-145. doi.org/10.1590/S0034-71082000000100016
- Bernasol, W. P. & Lima-Ribeiro, M. S. (2010). Estrutura espacial e diamétrica de espécies arbóreas e seus condicionantes em um fragmento de cerrado sentido restrito no sudoeste goiano. *Hoehnea*, 37 (2), 181-198. doi.org/10.1590/S2236-89062010000200001
- Bencke, C. S. C. & Morellato, L. P. C. (2002). Comparação de dois métodos de avaliação da fenologia de plantas, sua interpretação e representação. *Brazilian Journal of Botany*, 25 (3), 269-275. doi.org/10.1590/S0100-84042002000300003
- Bezerra, J. S. Linhares, K. V. Calixto Júnior, J. T. Duarte, A. L. Mendonça, A. C. A. M. Pereira, A. E. P. Batista, M. E. P. Bezerra, J. W. A. Campos, N. B. Pereira, K. S. Sousa, J. D. & Silva, M. A. P. (2020) Floristic and dispersion syndromes of Cerrado species in the Chapada do Araripe. *Research, Society and Development*, v.9, n.9, e864997934. DOI:10.33448/rsdv9i9.7934. Disponível em: <https://rsdjournal.org/index.php/rsd/article/view/7934>. Acesso em: 14 apr. 2021.
- Biondi, D., Leal, L. & Batista, A. (2007). Fenologia do florescimento e frutificação de espécies nativas dos Campos. *Acta Scientiarum: Biological Sciences*, 29 (3), 269-276. doi.org/10.4025/actascibiolsci.v29i3.478

- Borchert, R. (1980). Phenology and Ecophysiology of tropical trees: *Erythrina poeppigiana* O. F. Cook. *Ecology*, 61 (5), 1065-1074. doi.org/10.2307/1936825
- Brower, J. E., & Zar, J. H. (1984). *Field and laboratory methods for general ecology*. Dubuque: Wm. C. Brown.
- Bruzina, J. S., Oliveira, M. L. R., Nogueira, G. S., Pereira, I. M., Leite, H. G. & Machado, E. L. M. (2014). Métodos de amostragem para quantificar indivíduos adultos do pequi *Caryocar brasiliense* Cambess. *Ciência Rural*, 44 (8), 1341-1347. doi.org/10.1590/0103-8478cr20130239
- Calixto Júnior, J. T., Drumond, M. A. & Alves Júnior, F. T. (2011). Estrutura e distribuição espacial de *Mimosa tenuiflora* (Wild.) Poir. em dois fragmentos de Caatinga em Pernambuco. *Revista Caatinga*, Mossoró, 24 (2), 95-100. Retrieved from <https://ainfo.cnptia.embrapa.br/digital/bitstream/item/31889/1/Drumond-2011.pdf>
- Fabricante, J. R. & Andrade, L. A. (2007). Análise estrutural de um remanescente de caatinga no Seridó Paraibano. *Oecologia Brasiliensis*, 3 (11), 341-349. Retrieved from <https://dialnet.unirioja.es/servlet/articulo?codigo=2685119>
- Fabricante, J. R., Feitosa, S. S., Bezerra, F. T. C., Feitosa, R. C. & Xavier, K. R. F. (2009). Análise populacional de *Caesalpinia pyramidalis* Tul. (Fabaceae Lindl.) na caatinga da região do Seridó nordestino. *Revista Brasileira de Biociências*, 7 (3), 285-290. Retrieved from <http://www.ufrgs.br/seerbio/ojs/index.php/rbb/article/view/1188>
- Felfili, J. M. & Rezende R. P. (2003). *Conceitos e Métodos em Fitossociologia*. Brasília: Universidade de Brasília, Departamento de Engenharia Florestal.
- Felfili, J. M. & Silva Júnior, M. C. (1988). Distribuição dos diâmetros numa faixa de cerrado na Fazenda Água Limpa (FAL), em Brasília - DF. *Acta Botanica Brasiliensis*, 2 (1-2), 85-105. doi.org/10.1590/S0102-33061988000100005
- Ferreira, K. R., Fina, B. G., Rêgo, N. H., Rui, R. F. & Kusano, D. M. (2017). Fenologia de *Qualea parviflora* Mart. (Vochysiaceae) em um remanescente de Cerrado *sensu stricto*. *Revista de Agricultura Neotropical*, 4 (3), 15-22. Retrieved from <https://periodicosonline.uems.br/index.php/agriconeo/article/view/1534/1549>
- Fidelis, A. T. & Godoy, S. A. P. (2003). Estrutura de um cerrado stricto sensu na Gleba Cerrado Pé-de-Gigante, Santa Rita do Passa Quatro, SP. *Acta Botanica Brasiliensis*, 17 (4), 531-539. doi.org/10.1590/S0102-33062003000400006
- Figureiredo, M. A. & Fernandes, A. (1987). Encraves de Cerrado no interior do Ceará. *Ciência Agrônômica*, 18 (2), 103-106.
- Fournier, L. A. (1976). Observaciones fenológicas en el bosque humedo premontano de San Pedro de Montes Oca, Costa Rica. *Turrialba*, 26 (1), 54-59.
- Franco, A. C., Bustamante, M., Caldas, L. S., Goldstein, G., Meinzer, F. C., Kozovits, A. R., Rundel, P. & Coradin, V. T. R. (2005). Leaf functional traits of Neotropical savanna trees in relation to seasonal water deficit. *Trees*, 19 (3), 326-335. doi.org/10.1007/s00468-004-0394-z
- Freire, L. M. (2007). *Paisagens de exceção: problemas ambientais no Município de Mulungu*. Dissertação de mestrado, Universidade Estadual do Ceará, Serra de Baturité, Ceará, Brasil.
- Funceme – Fundação Cearense de Meteorologia e Recursos Hídricos. (2019). *Calendário de chuva*. Retrieved March 25, 2019, from <http://www.funceme.br/>
- Guarim Neto, G. (2006). Saber tradicional pantaneiro: as plantas medicinais e a educação ambiental. *Revista Eletrônica do Mestrado em Educação Ambiental*, 17 (1), 71-89. Retrieved from <https://periodicos.furg.br/remea/article/view/3025/1747>
- Haridasan, M. (2005). Competição por nutrientes em espécies arbóreas do cerrado. In: J. C. Souza-Silva & J. M. Felfili (orgs.). *Cerrado: Ecologia, biodiversidade e conservação*. Ministério do Meio Ambiente, Brasília, 73-92.
- Haridasan, M. (1982). Aluminum accumulation by some cerrado native species of central Brazil. *Plant and Soil*, 65 (2), 265-273. Retrieved from <https://www.jstor.org/stable/42933929>
- Harper, J. L. (1990). *Population Biology of Plants*. London: Academic Press.
- INPE - Instituto Nacional de Pesquisas Espaciais. (2019). Previsão de tempo: *Lavras da Mangabeira - CE*. Retrieved April 24, 2019, from <https://tempo.cptec.inpe.br/ce/lavras-da-mangabeira>
- Lemos, H. L., Pinto, J. R. R., Mews, H. A. & Lenza, E. (2013). Structure and floristic relationships between Cerrado *sensu stricto* sites on two types of substrate in northern Cerrado, Brazil. *Biota Neotropica*, 13 (4), 121-132. doi.org/10.1590/S1676-06032013000400013
- Lenza, E. & Klink, C. A. (2006). Comportamento fenológico de espécies lenhosas em um cerrado sentido restrito de Brasília, DF. *Brazilian Journal of Botany*, São Paulo-SP, 29 (4), 627-638. doi.org/10.1590/S0100-84042006000400013
- Lorenzi, H. (2008). *Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil*. Nova Odessa: Plantarum.
- Marquis, R. J. (1988). Phenological variation in the Neotropical understory shrub *Piper arieianum*: causes and consequences. *Ecology*, 69 (5), 1552-1565. doi.org/10.2307/1941653
- Martins, G. A. (2008). *Estatística geral e aplicada*. São Paulo: Atlas.
- Martins, S. S., Couto, L., Machado, C. C. & Souza, A. L. (2003). Efeito da exploração florestal seletiva em uma floresta estacional semidecidual. *Revista Árvore*, 27 (1), 65-70. doi.org/10.1590/S0100-67622003000100009
- Matteucci, S. D. & Colma, A. (1982). *Metodología para el estudio de la vegetación*. Washington: The General Secretariat of The Organization of American States.
- Meireles, M. L. & Luiz, A. J. B. (1995). Padrões espaciais de árvores de um cerrado em Brasília, DF. *Revista Brasileira de Botânica*, 18 (1), 185-189. Retrieved from <https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/12845/1/LuizPadroes.pdf>

- Ministerio do Meio Ambiente. Levantamento da cobertura vegetal e do uso do solo do Bioma Caatinga. Relatório final. 19p. Disponível at: <http://www.mma.gov.br/index.php?ido=conteudo.monta&idEstrutura=72&idMenu=3813&idConteudo=5976> Accessed in: Jan. 11th. 2008.
- Morellato, L. P. C., Rodrigues, R. R., Leitão-Filho, H. F., & Joly, C. A. (1989). Estudo comparativo de espécies arbóreas de floresta de altitude e floresta mesófila semidecídua na Serra do Japi, Jundiá, São Paulo. *Revista Brasileira de Botânica*, 12 (1), 85-98.
- Morisita, M. (1959). Measuring of the dispersion of individuals and analysis of the distributions patterns. *Memoirs of the Faculty of Science*, 2 (4), 215-235.
- Moro, M. F., Macedo, M. B., Moura-Fé, M. M., Castro, A. S. F., & Costa, R. C. (2015). Vegetação, unidades fitoecológicas e diversidade paisagística do estado do Ceará. *Rodriguésia*, 66 (3), 717-743. doi.org/10.1590/2175-7860201566305
- Moura, J. C., Lisboa, M. A. N., Gonçalves, B. L. M., Cruz, G. V., Barreto, E. S. S. T., Pinho, A. I., Santos, M. A. S., Cordeiro, L. D. S., Mendonça, A. C. A. M., Silva, M. A. P., Barros, L. M., Silva, T. I., Rocha, L. S. G., Drumond, M. A., & Júnior, J. T. C. (2020). Influence of Soil Type and Rocky Outcrops on the Species Distribution in a Woody Plant Community at Brazilian Semiarid. *Journal of Agricultural Science*, 12 (5), 155-166. doi.org/10.5539/jas.v12n5p155
- Mueller-Dombois, D. & Ellenberg, H. (1974). *Aims and methods of Vegetation Ecology*. Canada: Wiley & Sons, New York.
- Negrelle, R. R. B., Morokawa, R. & Riba, C. P. (2007). Vochysiaceae St. Hil. do Estado do Paraná, Brasil. *Acta Scientiarum Biological Sciences*, 29 (1), 29-38. /doi.org/10.4025/actascibiolsci.v29i1.124
- Neves, C. N., Silva, F. E., Haseloff, T. G., Lúcio, N. W., Souza, M. G. R. S., & Gomes, L. (2012). Comparação das alturas e diâmetros de *Qualea parviflora* Mart., *Qualea grandiflora* Mart. e *Qualea multiflora* Mart. em três fitofisionomias no Parque Municipal do Bacaba, Nova Xantina, Mato Grosso, Retrieved from <http://www.sbpnet.org.br/livro/63ra/resumos/resumos/3023.htm>
- Oliveira, A. K. M., Souza, S. A., Souza, J. S., & Carvalho, J. M. B. (2015). Influência da temperatura e substrato na germinação de sementes e no crescimento inicial de plântulas de *Callisthene fasciculata* (Vochysiaceae) em laboratório. *Revista Árvore*, 39 (3), 487-495. doi.org/10.1590/0100-67622015000300009.
- Oliveira, P. T. B., Trovão, D. M. B. M., Carvalho, E. C. D., Souza, B. C. & Ferreira, L. M. R. (2009). Florística e fitossociologia de quatro remanescentes vegetacionais em áreas de serra no Cariri Paraibano. *Revista Caatinga*, 22 (4), 169-178. Retrieved from <https://periodicos.ufersa.edu.br/index.php/caatinga/article/view/655/762>
- Paula, J. E., & Alves, J. L. H. (1997). *Madeiras Nativas: Anatomia, dendrologia, dendrometria, produção e uso*. Brasília: Gutenberg Ltda.
- Perry, J. N. & Mead, R. (1979). On the power of the index of dispersion test to detect spatial pattern. *Biometrics*, 35 (1), 613-622. doi.org/10.2307/2530252
- Pott, A., & Pott, V. (1994). *Plantas do Pantanal*. Corumbá-MT: Embrapa.
- Ricklefs, R. E. (1996). *A economia da natureza*. Rio de Janeiro: Guanabara Koogan S.A.
- Santana, J. A. S. (2009). Padrão de distribuição e estrutura diamétrica de *Croton sonderianus* Muell. Arg. (Marmeleiro) na caatinga da Estação Ecológica do Seridó. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, 4 (3), 85-90. Retrieved from <https://www.gvaa.com.br/revista/index.php/RVADS/article/view/201/201>
- Santos, L. S., Silva, H. P. B. & Pereira, E. C. G. (2014). Cerrado em Área Disjunta em Brejo de Altitude no Agreste Pernambucano, Brasil. *Boletim Goiano de Geografia*, 34, p.337-353. doi.org/10.14393/SN-v32-2020-45721
- Serpa, K. M., Monteiro, F. das N., Falcão, K. dos S., Menezes, R. da S., Ferreira, R. S. & Panachuki, E. (2020). Physical attributes and organic matter content in the Cerrado area under different cultivation systems. *Research, Society and Development*, 9 (3), e131932399. doi.org/10.33448/rsd-v9i3.2399
- Shepherd, GJ 2010. Fitopac 2.1.2: *Manual do usuário*. Campinas, UNICAMP.
- Shimizu, G. H. (2016). *Estudos filogenéticos, taxonômicos e nomenclaturais em Vochysiaceae e sinopse de Vochysia no Brasil*. Tese de Doutorado, Universidade Estadual de Campinas, Campinas, São Paulo.
- Silvério, D. V. & Lenza, E. (2010). Fenologia de espécies lenhosas em um cerrado típico no Parque Municipal do Bacaba, Nova Xavantina, Mato Grosso, Brasil. *Biota Neotropica*, 10 (3), 205-216. doi.org/10.1590/S1676-06032010000300024
- Sousa, D. G., & Cunha, H. F. (2018). Population structure, spatial distribution and phenology of *Anacardium humile* A. St.-Hil. (Anacardiaceae) in cerrado *stricto sensu*. *Hoehnea*, 45 (3), 450-467. doi.org/10.1590/2236-8906-81/2017
- Souza, J. P. & Coimbra, F. G. (2005). Estrutura populacional e distribuição espacial de *Qualea parviflora* Mart. em um cerrado *sensu stricto*. *Bioscience Journal*, 21 (2), 65-70. Retrieved from <http://www.seer.ufu.br/index.php/biosciencejournal/article/view/6590/4323>
- Souza, V. C. & Lorenzi, H. (2008). *Botânica Sistemática: Guia ilustrado para identificação das famílias de angiospermas da flora brasileira em APG II*. São Paulo: Instituto Plantarum.
- Van Schaik, C. P., Terborgh, J. W. & Wright, S. J. (1993). The phenology of tropical forests: adaptative significance and consequences for primary consumers. *Annual Review of Ecology and Systematics*, 24 (1), 353-377. doi.org/10.1146/annurev.es.24.110193.002033