

Original Article

Seasonal mite population distribution on *Caryocar brasiliense* trees in the Cerrado domain

Distribuição sazonal da população de ácaros em árvores de *Caryocar brasiliense* no domínio do Cerrado

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Abstract

Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) trees have a wide distribution in the Cerrado, and it is protected by federal laws. The need to monitor and understand pest damage to crops and forests is a major motivation for the study of population distribution. The mites (Acari) population distributions on *C. brasiliense* are unknown. We studied seasonal mite population distribution and their ecological indices on *C. brasiliense* trees in Cerrado areas during three years. Greatest number of *Agistemus* sp. (Stigmaeidae), *Histiostoma* sp. (Histiostomidae), *Proctolaelaps* sp. (Ascidae), and diversity and species richness on leaves of *C. brasiliense* occurred in the autumn; *Tetranychus* sp.1 (Tetranychidae) on leaves in the autumn and winter; *Histiostoma* sp., and *Proctolaelaps* sp. in fruits in the summer. No significant effect of season was observed in the abundance of *Eutetranychus* sp., *Tetranychus* sp.2 (Tetranychidae) and Acaridae. The populations of Acaridae, *Eutetranychus* sp., *Proctolaelaps* sp. and *Tetranychus* sp.1 negatively correlated with temperature. *Proctolaelaps* sp. and *Tetranychus* sp.1 correlated negatively with rainfall and *Eutetranychus* sp. and *Proctolaelaps* sp. positively with sunlight. The period with low rainfall and relative humidity increases the phytophagous mites and their predators, especially *Agistemus* sp.. The *Tetranychus* sp. and *Histiostoma* sp. species may become pests in *C. brasiliense* in the Cerrado domain.

Keywords: Acari, pequi, rainfall, sunlight, temperature.

Resumo

As árvores *Caryocar brasiliense* Camb. (Malpighiales: Caryocaraceae) têm ampla distribuição no Cerrado e são protegidas por leis federais. A necessidade de monitorar e entender os danos causados pelas pragas às culturas e florestas é uma das motivações para o estudo da distribuição populacional que para ácaros (Acari) em *C. brasiliense* é desconhecida. A distribuição sazonal de populações de ácaros e seus índices ecológicos em *C. brasiliense* em áreas de Cerrado foram estudados durante três anos. Maior número de *Agistemus* sp. (Stigmaeidae), *Histiostoma* sp. (Histiostomidae), *Proctolaelaps* sp. (Ascidae) e diversidade e riqueza de espécies nas folhas de *C. brasiliense* ocorreram no outono; *Tetranychus* sp.1 (Tetranychidae) no outono e inverno; *Histiostoma* sp. e *Proctolaelaps* sp. em frutos ocorreram no verão. Não foram observados efeitos das estações na abundância de *Eutetranychus* sp., *Tetranychus* sp.2 (Tetranychidae) e Acaridae. As populações de Acaridae, *Eutetranychus* sp., *Proctolaelaps* sp. e *Tetranychus* sp.1 correlacionaram-se negativamente com a temperatura. Correlações negativas foram observadas entre chuva e *Proctolaelaps* sp. e *Tetranychus* sp.1 e positivas entre luz solar e *Eutetranychus* sp. e *Proctolaelaps* sp.. Baixa pluviosidade e umidade relativa do ar aumentaram os ácaros fitófagos e seus predadores, principalmente *Agistemus* sp.. As espécies *Tetranychus* sp. e *Histiostoma* sp. podem se tornar pragas em *C. brasiliense* no domínio do Cerrado.

Palavras-chave: Acari, pequi, chuva, luz solar, temperatura.

1. Introduction

The Cerrado occupies approximately 23% of the Brazilian territory and *Caryocar brasiliense* Camb. (Malpighiales: Caryocaraceae) trees are widely distributed in this region (Pinheiro and Monteiro, 2010). Their fruits are used as

food, lubricants, in the pharmaceutical industry, for the production of cosmetics and represent the main source of income of many agricultural-extractive communities (Leite et al., 2006; Moura et al., 2013). Fruits and leaves of

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C. brasiliense are also used in the folk medicine to treat many diseases (Vieira and Martins, 2000).

Caryocar brasiliense are protected under federal law in Brazil and these trees remain isolated in deforested areas, increasing vulnerability to attack by mites, such as *Tetranychus* sp. and *Eutetranychus* sp. (Tetranychidae) on leaves and *Histiostoma* sp. (Histiostomidae) on fruits (Leite et al., 2020). The need to monitor and understand pest damage to crops and forests is a major motivation for the study of population distributions. For this reasons the field of Arthropod population distributions has played a prominent role in the development of basic ecology and in the understanding and management of serious pests over the landscape (Price et al., 2011).

Predators play an essential role in the *C. brasiliense* trees habitat, occurring naturally and controlling phytophagous peaks in favorable periods. Important mite's predators have been observed in *C. brasiliense* trees, such as *Agistemus* sp. (Stigmaeidae) and *Proctolaelaps* sp. (Ascidae) (Leite et al., 2020). However, mites' population distributions on these trees are unknown.

The diversity and abundance of mites can vary among seasons, hot and dry seasons may increase their attacks (Silva et al., 2009; Lemtur and Choudhary, 2016). The hypotheses tested in this study are: 1) Phytophagous and predatory mites and their ecological indices are affected by the seasons, with peaks of occurrence depending on climatic conditions; 2) Phytophagous and predators could be influenced differently by seasons which could favor or hinder natural biological control. We investigated the effect of seasons in relation to the seasonal mite population distribution and their ecological indices on *C. brasiliense* trees.

2. Material and Methods

The study was conducted in the municipality of Montes Claros, Minas Gerais state, Brazil, from June 2016 to June 2019. The region has dry winters and rainy summers with an Aw climate: tropical savanna according to Köppen (Alvares et al., 2013). Three areas were evaluated: Cerrado *stricto sensu*, pasture (formerly Cerrado area), and urban area in the campus of the "Instituto de Ciências Agrárias da Universidade Federal de Minas Gerais (ICA/UFMG)". The more detailed description of these sites, their soils, the height and crown widths of *C. brasiliense* trees are available in Leite et al. (2006).

The design was completely randomized with 10 replicates (10 trees) per area and four treatments (seasons of the year) to check possible effects of weather conditions in the distribution of the mites populations. A border area of 100 m has been defined, and then, we walked (~600 m) in a straight line, in northeast direction, per area. One adult of *C. brasiliense* tree (producing fruits) was randomly sampled, every 50 m, except at the urban area where the straight line walk was not used. Northeast direction is the predominant wind direction in this region's axis (Leite et al., 2006), favoring the transport of mites to the canopy trees (Tixier et al., 2000). Four expanded leaves, four flowers (Aug-Sep), and four fruits (Oct-Jan) from each stratum of

the canopy (bottom, medium, and apical part) and from each cardinal orientation of branches of 30 trees (average height 3 m) were monthly collected (in the morning) during those three years.

These plant materials were put in white plastic bags, which were sealed and transported to the laboratory where the number of immature and adults (sum) of mites (phytophagous and predators) were counted. The mites were counted within 2 h after collection, using a binocular microscope with 12.5 × magnification for leaves and flowers, and direct counting on the fruits (no lens) (Castro et al., 2019). The mites were counted in three visual fields in the central part, the fields were equidistant between the principal vein and the margin, from each leaf (adaxial and abaxial surface) and randomly distributed in three fields on the flowers (Leite et al., 2020). Whole fruits were evaluated. All counted mites were collected with brushes and preserved in vials with 70% alcohol for identification by Dr. A.L. Matioli and Dr. Eddie A. Ueckermann (only genus *Agistemus*).

The climatic data from June 2016 to June 2019, (temperature, rainfall, relative humidity of the air, sunshine, direction and wind speed) were obtained from the main climate station of Montes Claros of the "Estação Climatológica Principal do 5º DISME-INMET" (16° 84' 10" S, 43° 85' 00" W at an elevation of 646.29 masl).

Ecological indices (diversity and species richness) were calculated per identified mite species and treatment (seasons) using the BioDiversity Professional software, Version 2 (©1997, The Natural History Museum) (Krebs, 1989). Diversity was calculated using Hill's formula (Hill, 1973; Jost, 2006), and species richness was calculated using Simpson's indices (Begon et al., 2007; Lazo et al., 2007). Correlations of numbers of individuals of mites (phytophagous and predators) with climatic data and phytophagous vs. predators were subjected to Spearman's correlation ($P < 0.05$) using the statistical program System for Analysis Statistics and Genetics (SAEG), version 9.1 (SAEG, 2007) (Supplier: "Universidade Federal de Viçosa"). Number of mites (phytophagous and predators) data were transformed to $\sqrt{x} + 0.5$ and submitted to Lilliefors' normality test. The climatic, mite data and ecological indices were submitted to ANOVA ($P < 0.05$), and subsequently with Tukey's test ($P < 0.05$) using the SAEG.

3. Results

The herbivorous mites Acaridae, *Eutetranychus* sp., *Tetranychus* sp.1 and *Tetranychus* sp.2 were observed on the leaves of *C. brasiliense*. The *Histiostoma* sp. on fruits. Predatory mites *Agistemus* sp. and *Proctolaelaps* sp. were observed, respectively, in leaves and fruits. Climate data (2016-2019) shows the highest temperature and rainfall in the spring, the relative humidity in the summer, sunlight in the autumn and winter and the lowest wind speed in the autumn.

Greatest number of *Agistemus* sp. ($F = 6.592$, $P < 0.001$), *Histiostoma* sp. ($F = 7.051$, $P < 0.001$), *Proctolaelaps* sp. ($F = 5.502$, $P < 0.001$), and diversity ($F = 3.303$, $P < 0.04$) and species richness ($F = 3.941$, $P < 0.02$) on leaves of

C. brasiliense occurred in the autumn; *Tetranychus* sp.1 ($F = 5.500, P < 0.001$) on leaves in the autumn and winter; *Histiostoma* sp. ($F = 9.294, P < 0.001$) and *Proctolaelaps* sp. ($F = 8.182, P < 0.001$) in fruits in the summer. No significant effect of season was observed in the abundance of *Eutetranychus* sp., *Tetranychus* sp.2, and Acaridae. The largest individual mite peaks (three-year average \pm SE), per leaf, were observed in January (summer) to *Agistemus* sp. (10.11 ± 10.11), March (end of summer) to *Tetranychus* sp.1

(9.67 ± 4.73), April (autumn) to *Tetranychus* sp.2 (4.24 ± 2.64), May (autumn) to Acaridae (3.57 ± 3.56) and *Eutetranychus* sp. (1.33 ± 1.33), and June (end of autumn) to *Histiostoma* sp. (158.63 ± 108.07) and *Proctolaelaps* sp. (11.33 ± 7.72) and, per fruit, February (summer) to *Histiostoma* sp. (234.55 ± 181.27) and *Proctolaelaps* sp. (10.93 ± 10.10) on *C. brasiliense* trees (Figure 1).

The highest temperature ($F = 25.709, P < 0.001$) and rainfall ($F = 7.176, P < 0.001$) were observed in spring,

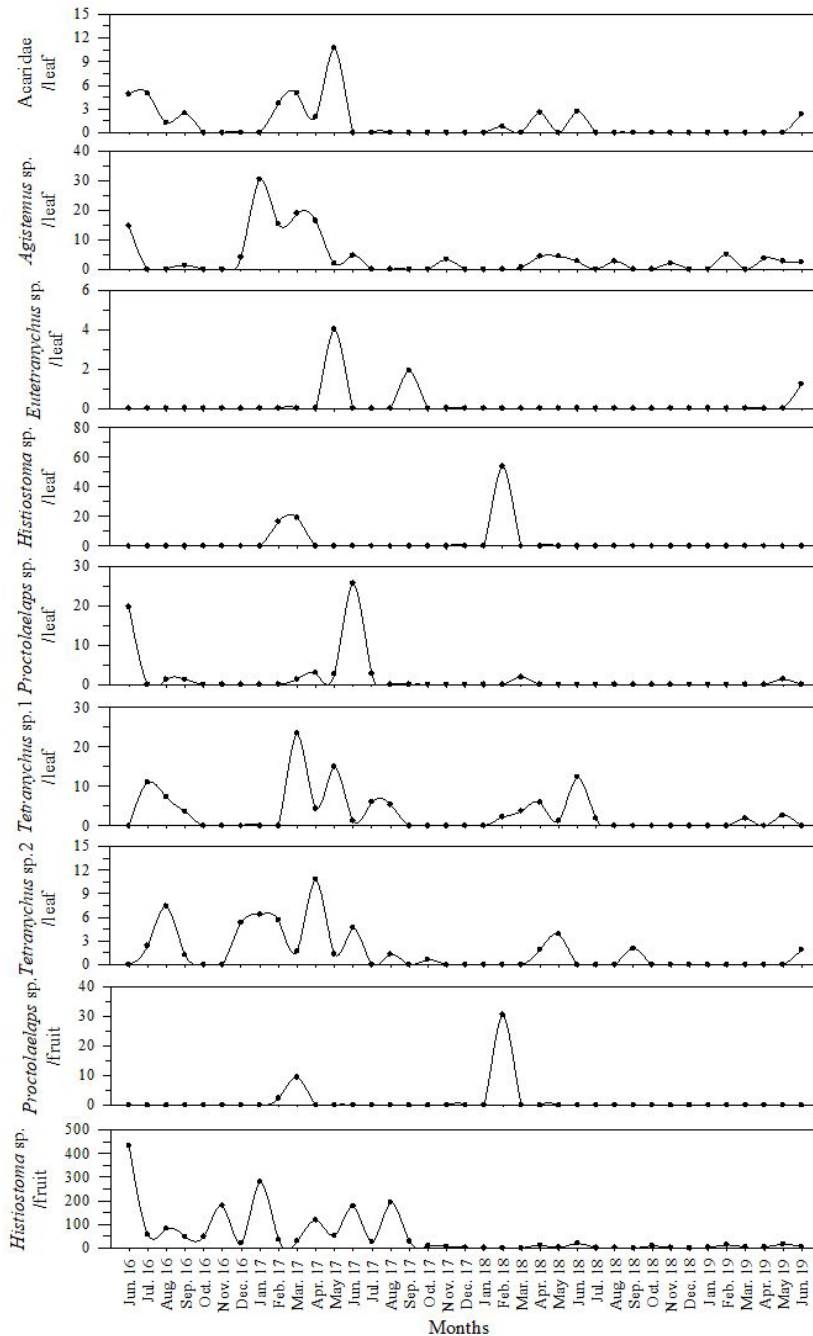


Figure 1. Number of Acaridae, *Agistemus* sp., *Eutetranychus* sp., *Histiostoma* sp., *Proctolaelaps* sp., and *Tetranychus* sp.1 and 2 on leaf (per cm²), and number of *Proctolaelaps* sp. and *Histiostoma* sp. per fruit on *Caryocar brasiliense*. Montes Claros, Minas Gerais State, Brazil.

relative humidity of air ($F = 33.807$, $P < 0.001$) in summer, and sunlight ($F = 11.085$, $P < 0.001$) in autumn and winter, but the lowest velocity of wind ($F = 3.498$, $P = 0.01976$) was noted in autumn (Table 1, Figure 2). Populations of Acaridae ($r = -0.52$, $P = 0.0411$), *Eutetranychus* sp., ($r = -0.29$, $P = 0.0421$), *Proctolaelaps* sp. ($r = -0.61$, $P = 0.0213$), and *Tetranychus* sp.1 ($r = -0.54$, $P = 0.0376$) were negatively correlated with temperature. *Proctolaelaps* sp. ($r = -0.35$, $P = 0.0177$) and *Tetranychus* sp.1 ($r = -0.38$, $P = 0.0111$) correlated negatively with rainfall and *Eutetranychus* sp. ($r = 0.43$, $P = 0.0821$) and *Proctolaelaps* sp. ($r = 0.35$, $P = 0.0192$) positively with sunlight. *Agistemus* sp. and *Proctolaelaps* sp. correlated positively with Acaridae ($r = 0.39$, $P = 0.0242$ and $r = 0.34$, $P = 0.0207$, respectively) and *Tetranychus* sp.2 ($r = 0.55$, $P = 0.0002$ and $r = 0.51$, $P = 0.0011$, respectively). The two largest peaks of rainfall were observed in December 2016 (404.4 mm) and January 2019 (288.70 mm) and virtually no mites were found on *C. brasiliense* trees during this period.

4. Discussion

The higher abundance of phytophagous mites and their predators per leaf and their ecological indices in autumn and winter and in fruits in summer confirm our first

hypothesis that these mites and their ecological indices are affected by the seasons, with peaks of occurrence depending on climatic conditions. On the other hand, our second hypothesis with phytophagous and predators being influenced differently by the seasons has not been confirmed. This is, probably, because predators depend on their prey and follow them (Castro et al., 2014).

The higher abundance of phytophagous mites (e.g. *Tetranychus* sp.1) and their predators (e.g. *Agistemus* sp.), and their ecological indices (e.g. diversity) per leaf in the autumn and winter is, probably, due to the dry climate and low rainfall (~1.04 mm per day) and air humidity (~58.34%), moderate temperature (~22.47 °C), and high sunlight (~8.20 h) on these seasons, that favors the development of these mites (Lemtur and Choudhary, 2016). On the other hand, the numbers of predators may also increase due to the increase in their prey density (Castro et al., 2014), being indirectly affected by the seasons. High population of phytophagous could be a threat to trees, because *Tetranychus* sp.1 and sp.2 and *Eutetranychus* sp., when in high populations, produce chlorotic spots on the leaves, reducing their photosynthetic capacity (Leite et al., 2020). In *Citrus sinensis* (L.) Osbeck (Rutaceae) orchard localized in São Paulo State, Brazil, the highest population size of predator mite *Euseius concordis* (Chant) (Phytoseiidae) was observed in hottest and rainiest period of the year,

Table 1. Number of mites (cm² of leaf) or per fruit, diversity and species richness (cm² of leaf/tree), temperature (°C), rainfall (mm), relative humidity of air (%), sunlight (h), and velocity of wind (m/sec) (average ± SE) according to the season of the year on *Caryocar brasiliense*. Montes Claros, Minas Gerais State, Brazil.

Mites/cm ² of leaf	Season of the year			
	Summer	Autumn	Winter	Spring
Acari ^{n.s.}	0.0019 ± 0.0007A	0.0066 ± 0.0018A	0.0019 ± 0.0009A	0.0000 ± 0.0000A
<i>Agistemus</i> sp.*	0.0086 ± 0.0021AB	0.0139 ± 0.0032A	0.0019 ± 0.0011B	0.0026 ± 0.0014B
<i>Eutetranychus</i> sp. ^{n.s.}	0.0000 ± 0.0000A	0.0013 ± 0.0007A	0.0008 ± 0.0008A	0.0000 ± 0.0000A
<i>Histiostoma</i> sp.**	0.0376 ± 0.0094C	0.0834 ± 0.0094A	0.0675 ± 0.0093B	0.0598 ± 0.0157B
<i>Proctolaelaps</i> sp.**	0.0010 ± 0.0007B	0.0156 ± 0.0061A	0.0022 ± 0.0012B	0.0000 ± 0.0000B
<i>Tetranychus</i> sp.1**	0.0059 ± 0.0018AB	0.0150 ± 0.0034A	0.0124 ± 0.0041A	0.0000 ± 0.0000B
<i>Tetranychus</i> sp.2 ^{n.s.}	0.0017 ± 0.0010A	0.0060 ± 0.0018A	0.0038 ± 0.0016A	0.0011 ± 0.0008A
Mites/fruit				
<i>Histiostoma</i> sp.*	76.76 ± 18.67A	0.00 ± 0.00B	0.00 ± 0.00B	0.00 ± 0.00B
<i>Proctolaelaps</i> sp.*	2.80 ± 0.79A	0.00 ± 0.00B	0.00 ± 0.00B	0.00 ± 0.00B
Ecological indices				
Diversity**	3.82 ± 1.02AB	5.19 ± 1.36A	3.54 ± 0.87AB	1.96 ± 0.32B
Species richness*	2.70 ± 0.65AB	3.60 ± 0.71A	2.70 ± 0.73AB	1.60 ± 0.26B
Variables				
Temperature**	24.10 ± 0.11B	22.16 ± 0.30C	22.78 ± 0.23C	25.05 ± 0.27A
Rainfall**	5.15 ± 0.73B	1.04 ± 0.35B	1.03 ± 0.40B	22.48 ± 7.59A
Humidity*	75.80 ± 1.21A	64.31 ± 1.51B	52.36 ± 0.98C	63.97 ± 2.80B
Sunlight**	5.98 ± 0.32B	8.33 ± 0.16A	8.06 ± 0.20A	6.84 ± 0.56B
Wind**	2.48 ± 0.29A	1.80 ± 0.02B	2.30 ± 0.06A	2.12 ± 0.03AB

Means followed by the same letter (average ± SE) in each row are not different by the test of Tukey (* = $P < 0.01$ and ** = $P < 0.05$). Freedom degree: mites/leaf = 5281, mites/fruit = 2184, ecological indices = 27, and climatic data = 72, "n.s." = non-significant data.

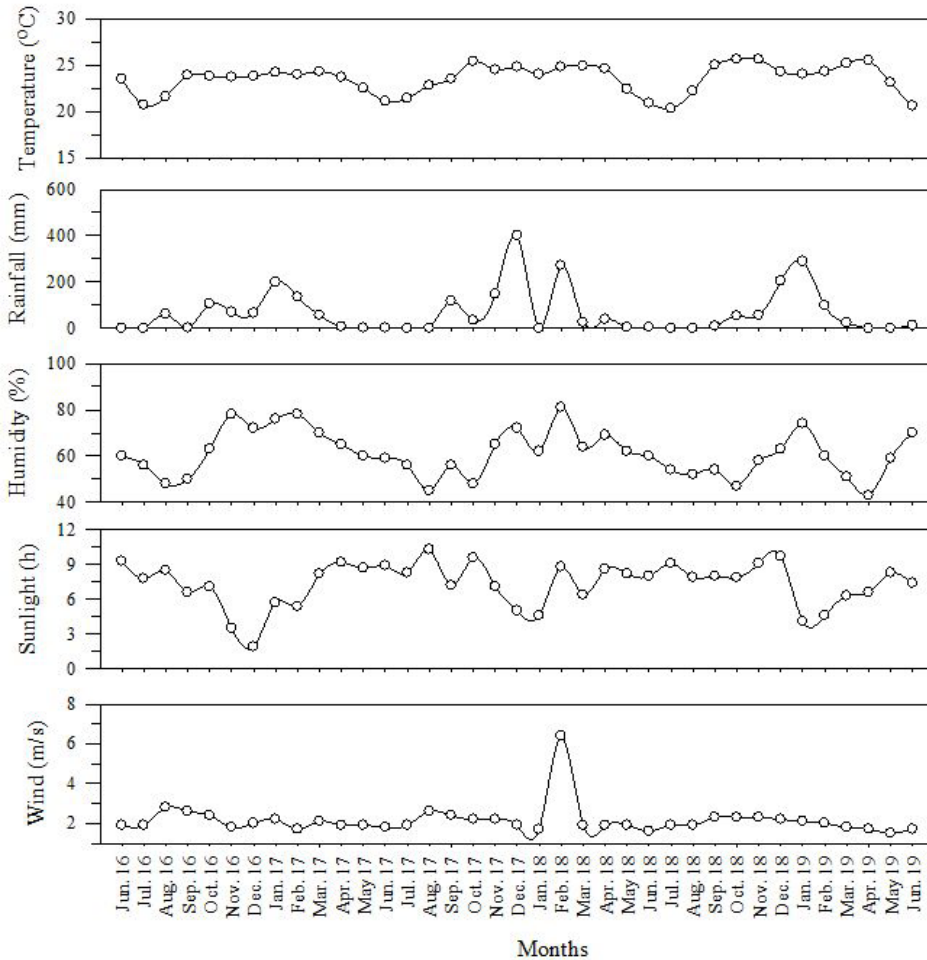


Figure 2. Temperature (°C), rainfall (mm), relative humidity of air (%), sunlight (h), and velocity of wind (m/sec). Montes Claros, Minas Gerais State, Brazil.

but for *Phyllocoptura oleivora* (Ashmed) (Eriophyidae) and *Brevipalpus phoenicis* (Geijskes) (Tenuipalpidae), both important pests for this plant, this period had smallest populations (Silva et al., 2012). *Tetranychus kanzawai* Kishida (Tetranychidae) feeding on *Malus domestica* (Borkh.) (Rosaceae) leaves increased its intrinsic rate of growth with the temperature raising from 0.043 day⁻¹ at 15 °C to 0.252 day⁻¹ at 30 °C, then decreased to 0.134 day⁻¹ at 37.5 °C (Hasanvand et al., 2019). *Tetranychus evansi* Baker and Pritchard (Tetranychidae), a pest of solanaceous crops, showed high adaptability to a wide range of summer temperatures, explaining their current distribution.

Climate changes may favor mites spread and expand its distribution (Ghazy et al., 2019) because many species increase their population and injuries to plants in warmer climates. On the other hand, *Tetranychus ludeni* Zacher (Tetranychidae) has best performance at 22–28 °C and the worst at 29–35 °C, suggesting that this mite could to invade regions with temperate weather (Ristyadi et al., 2019). This shows the importance of knowing the population distributions of pests and developing mechanisms to correlate their occurrence with the climate.

Another explanation for the greater abundance of phytophagous and predators mites on *C. brasiliense* leaves in the autumn and winter is probably determined by the reduction in the number of *C. brasiliense* leaves available due to their gradual loss during the dry period and by the end of last season (winter) (Leite et al., 2006), which can result in a concentration of mites per leaf in this plant, such as observed for other insect groups (e.g. coleopteran) in this same plant (Leite et al., 2012, 2013). The highest number of *Histiostoma* sp. (phytophagous mite) and *Proctolaelaps* sp. (predator mite) on fruits during the summer is due to the end of fruit production (Leite et al., 2006), also concentrating these mites.

The largest numbers of predator mite *Agistemus* sp. on leaves on autumn, and *Proctolaelaps* sp. on fruits on summer, probably, indicate that their populations responded to an increase in their prey density (Matioli et al., 1998; Castro et al., 2014). The correlation between *Agistemus* sp. and *Tetranychus* sp.1 on *C. brasiliense* leaves was positive in Cerrado, pasture and urban areas (Leite et al., 2020). This shows that this predator is the main biological controller of this phytophagous mite.

5. Conclusions

The period with low rainfall and relative humidity increases mites (phytophagous and predators) and their ecological indices. The *Tetranychus* sp. and *Histiostoma* sp. species may become pests in *C. brasiliense* in the Cerrado domain. *Agistemus* sp. could be used as an important predator of these mites.

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