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Original Article

Distribution of galling insects and their parasitoids on *Caryocar brasiliense* tree crowns

Distribuição de insetos galhadores e seus parasitoides em copas de pequizeiros (*Caryocar brasiliense*)

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Abstract

Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) is widely distributed in the Brazilian savanna and its fruits are used by humans for food, production of cosmetics, lubricants, and in the pharmaceutical industry. This plant is damaged by galling insects. Number of these galling insects and their parasitoids was recorded, in the field (galls) and in the laboratory (adults emerged from the galls), from three *C. brasiliense* crown heights, during three years. Numbers of adults of *Eurytoma* sp. (Hymenoptera: Eurytomidae), galling insect (younger attack) and *Sycophila* sp. (Hymenoptera: Eurytomidae) (a parasitoid of *Eurytoma* sp.), were greater on the apical parts of *C. brasiliense* tree crowns. Numbers and groups of *Eurytoma* sp. globoid galls (older attack) were higher in the median and basal crown parts. The numbers of *Eurytoma* sp. galls were higher on apical part of *C. brasiliense* tree crown and also of their parasitoids.

Keywords: Cerrado, Eulophidae, *Eurytoma* sp., *Sycophila* sp.

Resumo

Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) é, amplamente, distribuída no cerrado brasileiro e seus frutos são utilizados para alimentação humana, produção de cosméticos, lubrificantes e na indústria farmacêutica, no entanto, é danificada por insetos galhadores. O número de insetos galhadores e seus parasitoides foram avaliados, em campo (galhas) e em laboratório (emergência de adultos das galhas), em três alturas do dossel de *C. brasiliense*, durante três anos. Os números de adultos *Eurytoma* sp. (Hymenoptera: Eurytomidae), inseto galhador (galhas novas) e de *Sycophila* sp. (Hymenoptera: Eurytomidae), parasitoide de *Eurytoma* sp., foram maiores na parte apical do dossel da copa de árvores de *C. brasiliense.* A quantidade de galhas globoides de *Eurytoma* sp., isoladas ou em grupo (galhas velhas), foi maior na parte mediana e basal da copa. Os números de adultos do galhador *Eurytoma* sp. e de seus parasitoides, que os seguem, foram maiores na parte apical da copa de árvores de *C. brasiliense*.

Palavras-chave: Cerrado, Eulophidae, *Eurytoma* sp., *Sycophila* sp.

1. Introduction

Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) trees are important to traditional people as food and production of cosmetics, lubricants, and in the pharmaceutical industry (Santos et al., 2018). Isolated *C. brasiliense* trees (i.e. pasture or gardening) are subjected to higher incidence of galling insects than in forest formations (i.e. cerrado) (Leite et al., 2017). *Caryocar brasiliense* leaves have four main galling insects (Hymenoptera) with distinct shape and morphology: i) *Eurytoma* sp. (Hymenoptera: Eurytomidae) with globoid galls; ii) *Bruchophagus* sp. (Hymenoptera: Eurytomidae) with vein galls; iii) Eulophidae (Hymenoptera) with spherical galls; and iv) hymenopteran discoid galls (Leite, 2014). *Eurytoma* sp., the main *C. brasiliense* leaf galler, has the parasitoids *Sycophila* sp. (Hymenoptera: Eurytomidae) and *Ablerus magistretti* Blanchard, 1942 (Hymenoptera: Aphelinidae) and an inquiline (Alycaulini (Diptera). *Quadrastichus* sp. (Hymenoptera: Eulophidae), is a hyperparasitoid of *Sycophila* sp. (Leite, 2014). Information and photos of the galling insects, their distribution within leaf and branch, the community of gall parasitoids, hyperparasitoids, and predator insects may be consulted on Leite (2014).

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The number of galling insects in the *C. brasiliense* tree crowns varies with branch position and wind direction (Leite, 2014). The numbers of *Eurytoma* sp. and hymenopteran galls on *C. brasiliense* leaves were highest on the eastern slope, and those of *Bruchophagus* sp. and Eulophidae galls on the northern slope (Leite, 2014). These leaves, on these slope orientations, received more wind and sunlight in the north of Minas Gerais State, with low relative humidity and high temperature (Leite, 2014). These harsher ecophysiological conditions favor galling insects (Price et al., 1998). The vertical distribution of galling insects in the crown of *C. brasiliense* needs further studies due to the increase in the commercial monocultures of *C. brasiliense*. *Eurytoma* sp., as an example, can heavily damage the leaves of *C. brasiliense* seedlings and trees, having potential to become a pest of this plant (Leite et al., 2006, 2007). Studies on the vertical distribution of herbivorous insects and their natural enemies are important for sampling plans and pest management on forest and agricultural systems (Lamien et al., 2008).

The hypothesis tested is that galling insects, and their parasitoids, would be more abundant on the apical part of *C. brasiliense* tree crowns (i.e. harsher ecophysiological conditions).

2. Material and Methods

The study was developed in the campus of the "Instituto de Ciências Agrárias" of the "Universidade Federal de Minas Gerais" (16°40'54,5"S, 43°50'26,8"W, 633m altitude) in the municipality of Montes Claros, Minas Gerais State, Brazil from Jun 2009 to Jun 2012. This region has dry winters and rainy summers with Aw climate: tropical savanna according to Köppen (Alvares et al., 2013). An area of 6,800 m^2 and 272 *C. brasiliense* trees with 10-years old (monoculture), spaced 5 × 5 m with gardens in the surrounding ~300 m was used. These trees were 3.85 ± 0.18 m high with 1.81 ± 0.15 m crown width (average ± standard error). The weeds between plant rows were cut by manual weeding.

A completely randomized design, with 15 replications (one tree/replication) and crown heights represented the treatments considered for the statistical analysis. Fifteen trees were selected and marked. Galling insects and their parasitoids (i.e., including rare ones) were collected during three consecutive years. Average number of individuals per crown part/tree were analyzed. The distribution of galling insects and their galls, leaves with galls, and parasitoids were recorded on four fully expanded leaves per *C. brasiliense* crown part [basal (0 to 33% of total plant height), medium (33 to 66% of total plant height) and apical (66 to 100% of total plant height)] on 15 *C. brasiliense* trees per month (36 months).

Evaluations in the three crown parts accounted for a total of 6,480 leaves (each leaf had three leaflets, all evaluated) during the 3 year or 12 leaves/tree/month. *Caryocar brasiliense* leaves were collected and transported to the laboratory. Gall size was measured with a digital caliper (accurate to the nearest 0.1 mm). The leaves were scanned and the total leaf area and that per galling species calculated using SigmaScan Pro software (Sigma Scan Pro). Subsequently, these leaves were placed inside a white plastic pot (temperature of 25 °C), and the emergence of galling insects, parasitoids, hyperparasitoids, and inquilines were evaluated, per sample, every two days, during a 30-day period. The insects that emerged were collected and preserved in vials with 70% alcohol for identification by taxonomists. Alycaulini was identified by Dr. V.C. Maia and *Eurytoma* sp. and *Quadrastichus* sp. by Dr. M.A.P. Azevedo (Museu de História Natural, Universidade Federal do Rio de Janeiro, Rio de Janeiro State, Brazil); and *A. magistretti*, *Bruchophagus* sp., Eulophidae, Hymenoptera, and *Sycophila* sp. by Dr. O.H.H. Mielke (CDZOO, Universidade Federal do Paraná, Paraná state, Brazil) (voucher number: 1595/02).

The insect number means per crown tree part were used. The effect of crown height in the number of galling insects and parasitoids was evaluated with the statistical model: $y_{ij} = m + a_i + b_j + e_{ij}$, where y_{ij} is the observed value of the i-th plant part (i= 1, 2, ..., 3) of the j-th plant (j= 1, 2, ..., 15), m is the general average analyzed; a_i the effect of the i-th plant part (i= 1, 2, ..., 3); e_{ij} the effect of the experimental error associated with i-th part of the j-th plant. R software was used for statistical analysis. The *aov* function was used in the analysis of variance. The normality and homogeneity of the residual variances were identified by the tests Kruskal-Wallis and Bartlet, respectively. The means were compared using Tukey test ($P \leq 0.05$) with the aid of the *glht* function of the *multcomp* package.

3. Results

Number of *Eurytoma* sp. adults and length and width of their globoid galls were higher on the apical part of *C. brasiliense* tree crowns. However, *Eurytoma* sp. globoid gall groups were higher in the median and basal parts of the crown. The percentage of leaflets galled by all galling insects, leaflet area with *Eurytoma* sp. globoid galls and height and diameter of their globoid galls, numbers of *Bruchophagus* sp. vein galls, Eulophidae spherical galls, and Hymenopteran discoid galls did no differ between tree crown parts (Table 1).

Number of *Sycophila* sp. adults (parasitoid of *Eurytoma* sp.) and Alycaulini adults (inquiline of *Eurytoma* galls) was higher on the apical tree parts. Number of *A. magistretti* adults, parasitoid of *Eurytoma* sp., and *Quadrastichus* sp. adults, hyperparasitoid of *Sycophila* sp., was similar ($P > 0.05$) between tree crown parts (Table 1).

4. Discussion

The higher number of adults of *Eurytoma* sp. globoid galls in the apical part (n = 6676) of the *C. brasiliense* trees, in the semiarid northern Minas Gerais State, agrees with the preference of galling insects by the upper crown, as observed for tropical rainforest trees (Ribeiro and Basset, 2007), probably because this crown part receives more solar radiation than the basal one (total emerged = 4952) (Ribeiro and Basset, 2007). That is, the apical part shadows the basal part of the *C. brasiliense* trees and, therefore, the leaves at this last part receive lower solar radiation. This would explain the thermal comfort provided by large trees used in parks,

Table 1. Percentage of leaflet galled by all galling insects (Leafgalls), numbers of total *Eurytoma* sp. globoid galls per leaflet (Leafgloboid), *Eurytoma* sp. globoid gall height (Ggheight), *Eurytoma* sp. globoid gall diameter (Gg. diam.), *Eurytoma* sp. groups of globoid gall area (Area (cm^2) of ggg.), *Eurytoma* sp. groups of globoid gall length (Len. ggg.), *Eurytoma* sp. groups of globoid gall width (mm) (Wid. ggg), *Eurytoma* sp. globoid gall number (Gg. num.), *Eurytoma* sp. groups of globoid gall number (Num. ggg), *Bruchophagus* sp. vein galls (Num. vg), Eulophidae spherical galls (Num. sg), hymenopteran discoid galls (Num. dg), adults of *Eurytoma* sp., *Sycophila* sp. (parasitoid of *Eurytoma* sp.), *Ablerus magistretti* (parasitoid of *Eurytoma* sp.), Alycaulini (inquiline of *Eurytoma* sp. galls), and *Quadrastichus* sp. (hyperparasitoid of *Sycophila* sp.) per 12 leaflets/crown part of *Caryocar brasiliense* tree.

Galls and insects	Crown part			ANOVA	
	Apical	Median	Basal	*F*	*P*
Leaf galls$^{n.s.}$	51.90 ± 1.49	48.70 ± 0.95	52.95 ± 1.18	3.23	0.05
Leaf. globoid$^{n.s.}$	57.07 ± 7.48	46.73 ± 5.20	44.94 ± 3.77	2.43	0.10
Gg. height (mm)$^{n.s.}$	2.22 ± 0.07	2.23 ± 0.04	2.36 ± 0.05	2.04	0.14
Gg.diam. (mm^2)$^{n.s.}$	1.83 ± 0.11	1.67 ± 0.04	1.79 ± 0.03	1.83	0.17
Area (cm^2) of ggg*	3.35 ± 0.39a	2.06 ± 0.20b	2.11 ± 0.19b	12.75	0.00
Len. ggg (mm)*	33.47 ± 2.21a	26.96 ± 1.60b	27.08 ± 1.52b	7.58	0.00
Wid. ggg (mm)*	9.54 ± 0.55a	7.43 ± 0.32b	7.62 ± 0.32b	13.01	0.00
Gg. num.*	333.96 ± 23.06b	431.10 ± 17.84a	415.80 ± 8.88a	14.29	0.00
Num. ggg*	218.91 ± 8.75b	292.80 ± 12.02a	274.58 ± 10.41a	13.97	0.00
Num. vg$^{n.s.}$	0.30 ± 0.08	0.60 ± 0.26	0.50 ± 0.15	0.69	0.51
Num. sg$^{n.s.}$	0.13 ± 0.05	0.07 ± 0.03	0.03 ± 0.02	3.30	0.05
Num. dg$^{n.s.}$	0.93 ± 0.17	0.61 ± 0.09	0.63 ± 0.13	1.79	0.18
Eurytoma sp.*	445.04 ± 15.25a	266.51 ± 9.50c	330.09 ± 12.96b	50.05	0.00
Sycophila sp.*	59.54 ± 2.91a	40.17 ± 2.78b	39.25 ± 1.51b	21.25	0.00
Ablerus magistretti$^{n.s.}$	0.79 ± 0.12	0.85 ± 0.28	0.93 ± 0.23	0.11	0.89
Alycaulini*	0.27 ± 0.09a	0.00 ± 0.00b	0.00 ± 0.00b	7.52	0.00
Quadrastichus sp.$^{n.s.}$	2.55 ± 0.38	3.24 ± 0.34	2.29 ± 0.36	1.84	0.17

Means ± standard error followed by the same letter per row do not differ by the Tukey test (*= $P< 0.01$ and **= $P< 0.05$). Values of *F* and *P* were obtained by ANOVA. $^{n.s.}$ = non-significant by ANOVA. df's of treatments, blocks, and errors were 2, 14, and 28, respectively.

gardens, and sidewalks in cities (Richards and Edwards, 2017). Higher sclerophylly with a suitable ecosystem for gall-forming insects on taller tree crown in wet tropical rainforests was attribute to nutrient stress in meristems of this part (Ribeiro and Basset, 2007). The Amazonian forest upper canopy has similar conditions as those of the Mediterranean vegetation habitats: hygrothermically stressed environments and the leaves with high levels of leaf sclerophylly and temperature at lethal limits (Juliao et al., 2014). Higher galling insect's survival in more sclerophilous leaves (i.e. tree tops) was found in the Panama wet rainforest (Neotropical) and Australia subtropical forest (Australian) (Ribeiro et al., 2014). The harsher environment favors oviposition, survivorship, distribution, diversity, and abundance of galling insects in sclerophyllous vegetation (Fernandes and Price, 1988, 1992; Ribeiro and Basset, 2007).

The higher number of *Sycophila* sp. adults, most important *Eurytoma* sp. parasitoid (Leite et al., 2013), in the apical part (total emerged = 894) than in the basal part (total emerged = 589) of the *C. brasiliense* tree crown, associated with galls of this insect, agrees with the natural enemy's pattern – parasitoids follow their hosts (Leite et al., 2017). For this reason, natural enemies in high populations may reduce the numbers of galling insects (Leite et al., 2013). The indole butyric acid (phytohormone) and numbers of *Eurytoma* sp. adults, and of their galls, and *Sycophila* sp. on *C. brasiliense* trees were ppositively correlated (Leite et al., 2007).

The numbers of *Eurytoma* sp. galling insect and of its parasitoid *Sycophila* sp. and inquiline Alycaulini were higher on the apical *C. brasiliense* crowns. with the latter following the first one.

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