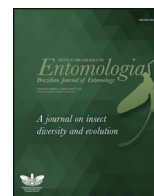









SOCIEDADE BRASILEIRA
DE ENTOMOLOGIA
FUNDADA EM 1937

REVISTA BRASILEIRA DE
Entomologia
A Journal on Insect Diversity and Evolution



Potential interactions between herbivorous arthropods and of their natural enemies on *Caryocar brasiliense* (Caryocaraceae) trees

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ARTICLE INFO

Article history:

Received 09 February 2021

Accepted 14 May 2021

Available online 09 June 2021

Associate Editor: Gustavo Gracioli

Keywords:

Aphids

Eurytoma sp.

Pequi

Sycophila sp.

Zelus armillatus

ABSTRACT

The study of arthropod communities foraging on monocultures of native plants (e.g. *Caryocar brasiliense*) in biodiversity hotspots (e.g. Brazilian Cerrado) is important to understand the processes driving their performance. This study evaluated the possible interactions between galling herbivores, free-feeding arthropods, and of their natural enemies on *C. brasiliense* trees, in an orchard (monoculture). The possible competition observed were: i) between galling insects with defoliators and phytophagous mites, ii) between sucking insects, iii) between phytophagous mites and, iv) between *Aphis gossypii* (Hemiptera: Aphididae) with *Histiostoma* sp. (Acari: Histiostomidae) on *C. brasiliense* trees. Numbers of predators and prey, parasitoids and hosts, and predators and parasitoids were directly related among them. The competitive interactions between herbivorous predator and parasitoid may reduce *Eurytoma* sp. (Hymenoptera: Eurytomidae) populations, a potential pest of *C. brasiliense*. The predator *Zelus armillatus* (Hemiptera: Reduviidae) and the parasitoids *Sycophila* sp. (Hymenoptera: Eurytomidae) and *Ablerus magistretti* (Hymenoptera: Aphelinidae) are important to determine the numbers of *Eurytoma* sp. and of its galls. These natural enemies may be important to control this galling insect on *C. brasiliense* trees. The arthropod competition affected their guild associated to *C. brasiliense* trees.

Introduction

The high diversity and endemism of insects and plants characterize the Cerrado region as an important biodiversity hotspot (Bridgewater et al., 2004; Laste et al., 2019). The Cerrado biome occupies approximately 23% of the Brazilian territory with the second largest area after the Amazonian rainforest (Da Silva and Bates, 2002; Roitman et al., 2018). The phytogeography of the Cerrado is structurally complex with a floristic composition from grasslands to forests areas with trees between 10–15 m high (Oliveira and Marquis, 2002). Planted forests, crops, and beef cattle occupy large areas of the Brazilian Cerrado (Sano et al., 2010).

Biodiversity reduction, deforestation and agricultural land use are major threats to Cerrado biodiversity (Symes et al., 2018). Extractivism, based on non-timber products, has low impact on this ecosystem (Schumann et al., 2010; Zardo and Henriques, 2011), but overharvesting products such as fruits and monocultures in large areas reduce plant regeneration and, consequently, the biodiversity (Leite et al., 2006a;

Giroldo and Scariot, 2015; Sanders et al., 2018). The environmental and economic relevance of the Cerrado is well known but its biodiversity functioning is not fully understood. The frequency with which new species are described indicates that many others remain undiscovered (Coelho et al., 2014; Souza and de-Paula Souza, 2016; São-Mateus et al., 2019; Colli et al., 2020). This increases the necessity of studies on inter and intra-specific relationships between organisms in the Cerrado biome.

Caryocar brasiliense Camb. (Caryocaraceae), an endemic tree widely distributed in the Brazilian Cerrado biome, particularly, in the Cerrado *sensu stricto* (Santos et al., 2015; Vieira Junior et al., 2020) presents high genetic diversity (Santos et al., 2018). The economic and social importance of this plant is high because many communities use its fruits for food and commercialization (Leite et al., 2006a, Zardo and Henriques, 2011). Legal protection aims to maintain *C. brasiliense* trees in the Cerrado biome (Leite et al., 2006a; Gonçalves et al., 2016), but individuals of this plant are left isolated in large extensions of monocultures, mainly in pastures. This isolation impacts the interspecific relationships between *C. brasiliense* and arthropod communities and the

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conversion of native forests into plantations affects the energy and mass flow between arthropods and plants (Barnes et al., 2014). Reduction of plant diversity due to agricultural monocultures can reduce inter- and intra-specific relationships, increasing the risks of biodiversity losses (Crutsinger et al., 2008; Koricheva and Hayes, 2018). The isolation of *C. brasiliense* in deforested areas of the Cerrado can negatively impact trophic interactions on this plant.

Environmental conditions and evolutionary parameters affect interactions between arthropod communities associated with tree species, such as *C. brasiliense* and, consequently, the identification of interactions and predicting anthropic actions in the ecosystem are often difficult. Inter-specific interaction studies are important for ecology research (Birkhofer et al., 2015; Tredennick et al., 2017) and, for this reason, a system composed of *C. brasiliense* and arthropods associated with this plant is a good study model due to this plant has a high richness and diversity of arthropods species (Leite, 2014). Herbivore damage to plants depends on their characteristics but that of gall insects and free-living sap-feeders may be similar (Zvereva et al., 2010). Gall-forming insects are extremely abundant in all major ecosystems with many species damaging plant of economic importance (Espírito-Santo et al., 2007). The omnivorous and specialist predators negatively can affect herbivorous insects and their complementary functional traits contributes to pest control (Chailleux et al., 2017). Competition between predatory mites (Acari: Phytoseiidae) [e.g., *Neoseiulus cucumeris* (Oudemans) x *Iphiseius degenerans* (Berlese)], *Tetranychus urticae* (Koch) (Acari: Tetranychidae) females, hymenopteran gall-forming insects [e.g., *Eurytoma* sp. (Eurytomidae) x other three gall-forming insects], proto-cooperating ants (Hymenoptera: Formicidae) [e.g., *Tapinoma melanocephalum* (Fabr.) x *Paratrechina longicornis* (Latreille)], and proto-cooperating ants [e.g., *Oecophylla smaragdina* (Fabr.)] with song birds (Phylum Chordata, Class Aves, Subfamily Oscines) have been reported (Hammen et al., 2012; Macke et al., 2012; Leite et al., 2017; Liu et al., 2020; Supriya et al., 2020). The density of leaf chewer insects and mines was positively related to leaf damage, and arthropod groups responded to beech dominance and harvest intensity (Leite et al., 2012a).

The ecology of the arthropods interacting with *C. brasiliense* needs to be studied to protect this plant in nature and in plantations (monoculture). Predation, interference and competition are inter-specific interactions affecting arthropod distribution (Ulyshen, 2011). Potential interactions (relative frequency, parasitism, predation and competition) were evaluated on *C. brasiliense* trees to test the hypothesis that interactions (cause and effect across of simple regression analysis) between defoliation herbivores (Coleoptera and Lepidoptera), sucking insects (Hemiptera), phytophagous mites (Acari) and gall-forming insects (Hymenoptera) and of their natural enemies (parasitoids and predators, biological control) can affect negatively their populations (e.g., food competition or predation).

Materials and methods

Study site

The study was carried out in a 10-year-old *C. brasiliense* monoculture (orchard) with 6,800 m² and 272 plants, spaced 5x5 m in the municipality of Montes Claros, Minas Gerais State, Brazil from June 2016 to June 2019. This area is located in the campus of the “Instituto de Ciências Agrárias da Universidade Federal de Minas Gerais (ICA/UFMG)” (16°40'54.5"S, 43°50'26.8"W with an altitude of 633 m elevation and dystrophic red oxisol with medium texture) with dry winters and rainy summers with Aw climate: tropical savanna according to Köppen (Alvares et al., 2013). 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 are controlled by monthly manual weeding.

Study host plants

Caryocar brasiliense Camb. (Caryocaraceae), with wide distribution in the Brazilian savanna (Cerrado) (Pinheiro and Monteiro, 2010; Santos et al., 2018), can reach over 10 m high and a 6 m wide canopy (Leite et al., 2006a). Its fruits are rich in oil, vitamins, proteins and compounds with medicinal importance, used for food, cosmetics, production of lubricants, in the pharmaceutical industry, and as the main source of income for many communities (Segall et al., 2005; Leite et al., 2006a; Khouri et al., 2007). Strategies for *C. brasiliense* conservation include protection by Brazilian laws (n°12.651/2012 and n°1.970/2019). However, isolated individuals of this plant, left in deforested areas of the agro-landscape, are subjected to higher leaf, flower, and fruit damage by insects, representing a significant threat to *C. brasiliense* conservation (Leite et al., 2012a, 2012b, 2012c).

Study design

Fifteen plants, around 50 m apart from each other, were selected and marked among 272 *C. brasiliense* trees that made up the plantation. The characteristics of the plants selected were: i) healthy branches and trunks without damage by the fungus *Phomopsis* sp. and the wood borers Cossidae (Lepidoptera), respectively, since they cause high mortality of this plant (Leite et al., 2012d); ii) larger plants may host a greater number of arthropods (Leite et al., 2011; 2012a, 2016, 2017); and iii) evaluation of branches in the north, south, east and west sides of the apical, middle and basal parts of their canopies.

Arthropods were collected over three consecutive years (e.g., including rare ones), once a month, in the morning (7:00-11:00 A.M). The distribution of gall-forming insects and of their galls, predators and parasitoids, insect defoliators, leaves with galls, sap-sucking Hemiptera and mites (Acari) was recorded on 12 fully expanded leaves (each leaf with three leaflets, all evaluated) from 15 *C. brasiliense* trees: four leaves from each stratum of the canopy (bottom, medium, and apical parts) and from each cardinal orientation of the branches (North, South, West, and East), totaling 6,480 leaves over 3 yr. were evaluated. Insect defoliation was evaluated visually by the leaf area losses on a 0–100% scale with 5% increments for the area removed (Silva et al., 2020) on the 15 trees (12 leaves/tree) per evaluation. Arthropods were observed during sampling and collected with tweezers, brushes, or aspirators and preserved in vials with 70% alcohol for identification by taxonomists.

Leaf samples were collected from *C. brasiliense* on multiple branches and transported to the laboratory, where the nymphs and adults (sum) of insects and mites (phytophagous and predators) were counted starting within 2 h after the material was collected by examining the leaves under a binocular microscope with 12.5 X magnification (Leite et al., 2003). Three random areas were selected in the central part of each leaf blade (between the principal vein and the margin, adaxial and abaxial surface). Each area (0.60 mm²) was distributed per leaf part (distal, median, and proximal, near the petiole) (Leite et al., 2003). Mites on *C. brasiliense* were collected with a brush and preserved in vials with 70% alcohol. The leaves were put in white plastic pots (temperature of 25°C) and evaluated every two days to obtain the total number of gall-forming insects, parasitoids, hyperparasitoids, and inquiline, during a 30 day data collection period. The insects were preserved as described and sent to taxonomists for identification.

Statistical analyses

Mean number of each arthropod species per 12 leaves/tree/year were obtained, totaling 45 samples. The relative frequency, general (among all the arthropods) and specific (per group - e.g. sucking insects) means were calculated as $F = (n/N) \times 100$, where n = number of individuals for a taxon collected and N = total number of individuals collected. The relationship between the number of individuals (means, $n = 45$) of each herbivorous arthropod and natural enemy species were subjected to simple regression analysis ($P < 0.05$) using the statistical program System for Analysis Statistics and Genetics (SAEG), version 9.1 (SAEG, 2007) (Supplier: "Universidade Federal de Viçosa"). Simple equations were selected by observing the criteria: i) distribution of data in the figures (linear or quadratic response), ii) the parameters used in these regressions were the most significant ones ($P < 0.05$), iii) $P < 0.05$ and F of the Analysis of Variance of these regressions, and iv) the coefficient of determination of these equations (R^2).

Results

Relative frequency

The general relative frequency (80.5%) of the galling wasp *Eurytoma* sp. (Hymenoptera: Eurytomidae) ($n = 15625$) was the highest on *C. brasiliense* leaves (total arthropods = 19420) (Table 1). The *Tetranychus* sp.1 (Tetranychidae) (phytophagous mites) (69.6%, $n = 102$), *Aphis gossypii* (Glover) (Hemiptera: Aphididae) (phytophagous Hemiptera) (77.7%, $n = 382$), *Eurytoma* sp., a unique galling insect observed, *Histiostoma* sp. (Histiostomidae) ($n = 486$), a unique detritivore arthropod observed, *Sycophila* sp. (Hymenoptera: Eurytomidae) (98.2%, $n = 2085$), which is an *Eurytoma* sp. parasitoid, *Quadrastichus* sp. (Hymenoptera: Eulophidae) ($n = 121$), a unique *Sycophila* sp. parasitoid observed, *Zelus armillatus* (Lepelletier and Serville) (Hemiptera: Reduviidae) (predators) (41.5%, $n = 176$), galling insect (phytophagous arthropods) (96.1%), and parasitoids (natural enemies) (84.1%, $n = 2245$) were the arthropods with highest specific relative frequency inside their groups (Table 1).

Table 1

Total number of arthropods species (n) and of their groups (N), their specific (inside of each group -SRF) and general (among all the arthropods) relative frequency (%) (GRF) on *Caryocar brasiliense* tree in three years. Montes Claros, Minas Gerais State, Brazil.

Arthropods		SRF	GRF
Phytophagous mites	Acaridae ($n = 25$)	16.89	0.13
	<i>Eutetranychus</i> sp. ($n = 7$)	4.66	0.04
	<i>Tetranychus</i> sp.1 ($n = 102$)	69.60	0.53
	<i>Tetranychus</i> sp.2 ($n = 13$)	8.84	0.07
Phytophagous Hemiptera	<i>Aphis gossypii</i> ($n = 382$)	77.67	1.96
	<i>Pseudococcus</i> sp. ($n = 110$)	22.33	0.56
Galling insects	<i>Eurytoma</i> sp. ($n = 15625$)	100	80.47
	Detritivores	<i>Histiostoma</i> sp. ($n = 486$)	100
<i>Eurytoma</i> sp. parasitoids	<i>Ablerus magistretti</i> ($n = 39$)	1.82	0.20
	<i>Sycophila</i> sp. ($n = 2085$)	98.18	10.74
<i>Sycophila</i> sp. parasitoid	<i>Quadrastichus</i> sp. ($n = 121$)	100	0.62
	Predators	<i>Agistemus</i> sp. ($n = 31$)	7.10
<i>Chrysoperla</i> sp. ($n = 140$)		32.95	0.72
<i>Holopothrips</i> sp. ($n = 24$)		5.68	0.12
Spiders ($n = 54$)		12.77	0.28
Phytophagous	<i>Zelus armillatus</i> ($n = 176$)	41.50	0.91
	Mites ($N = 147$)	0.90	---
	Hemiptera ($N = 492$)	3.03	---
	Galling insects ($N = 15625$)	96.07	---
Natural enemies	Parasitoids ($N = 2245$)	84.08	---
	Predators ($N = 425$)	15.92	---

Competition between herbivores

The higher number of *Eurytoma* sp. adults, on *C. brasiliense* leaves, was negatively correlated with reduced defoliation ($R^2 = 0.22$, $P < 0.01$) (Fig. 1 A) and numbers of *Eutetranychus* sp. (Tetranychidae) ($R^2 = 0.25$, $P < 0.00$) (Fig. 1 B). The number of groups of *Eurytoma* sp. globose galls ($R^2 = 0.17$, $P < 0.02$) (Fig. 1 C) and the percentage of defoliation ($R^2 = 0.20$, $P < 0.00$) (Fig. 1 D) were negatively correlated with that of Acaridae, and that of *A. gossypii* that of *Pseudococcus* sp. (Pseudococcidae) ($R^2 = 0.18$, $P < 0.02$) (Fig. 1 E) and *Histiostoma* sp. (Histiostomidae) ($R^2 = 0.12$, $P < 0.03$) (Fig. 1 F). The numbers of *Histiostoma* sp. were negatively correlated with that of *Eutetranychus* sp. ($R^2 = 0.20$, $P < 0.01$) (Fig. 2 A), *Eurytoma* sp. ($R^2 = 0.14$, $P < 0.04$) (Fig. 2 B) and *A. gossypii* ($R^2 = 0.12$, $P < 0.03$) (Fig. 2 C). Similarly, the numbers of *Tetranychus* sp.2 (Tetranychidae) ($R^2 = 0.17$, $P < 0.03$) (Fig. 2 D) and *Eurytoma* sp. ($R^2 = 0.31$, $P < 0.00$) (Fig. 2 E) were negatively correlated with that of *Eutetranychus* sp.. The higher number of *Tetranychus* sp.1 reduced the number of *Eurytoma* sp. globose galls ($R^2 = 0.20$, $P < 0.01$) (Fig. 2 F). A similar relationship was observed between the numbers of *Tetranychus* sp.2 and *Tetranychus* sp.1 ($R^2 = 0.29$, $P < 0.00$) (Fig. 2 G). The increase in the number of Acaridae reduced that of *Histiostoma* sp. ($R^2 = 0.16$, $P < 0.04$) (Fig. 2 H).

Parasitism and predation

The numbers of *Eurytoma* sp. ($R^2 = 0.48$, $P < 0.00$) (Fig. 3 A) and their groups of globose galls ($R^2 = 0.15$, $P < 0.01$) (Fig. 3 B) correlated negatively with that of *Sycophila* sp. on *C. brasiliense* leaves. Higher *Z. armillatus* and *Ablerus magistretti* Blanchard (Hymenoptera: Aphelinidae) numbers reduced those of groups of *Eurytoma* sp. globose galls ($R^2 = 0.21$, $P < 0.01$) (Fig. 3 C) and their lengths ($R^2 = 0.18$, $P < 0.01$) (Fig. 3 D), respectively. The number of *Histiostoma* sp. was negatively correlated with that of *Agistemus* sp. (Stigmaeidae) ($R^2 = 0.63$, $P < 0.00$) (Fig. 3 E). On the other hand, the higher percentage of leaflets with *Eurytoma* sp. globose galls increased the number of *Sycophila* sp. ($R^2 = 0.14$, $P < 0.01$) (Fig. 3 F). High numbers of *Sycophila* sp. ($R^2 = 0.16$, $P < 0.01$) (Fig. 3 G) and *Quadrastichus* sp. ($R^2 = 0.11$, $P < 0.03$) (Fig. 3 H) increased that of *Holopothrips* sp. (Thysanoptera: Phlaeothripidae). The numbers of *Eurytoma* sp. adults ($R^2 = 0.11$, $P < 0.03$) (Fig. 4 A) and of their globose galls ($R^2 = 0.18$, $P < 0.02$) (Fig. 4 B), and *Sycophila* sp. ($R^2 = 0.17$, $P < 0.01$) (Fig. 4 C), on *C. brasiliense* leaves, were negatively correlated with those of spiders. The greater number of the latter organism was positively correlated with those of *Eurytoma* sp. groups of globose galls ($R^2 = 0.15$, $P < 0.01$) (Fig. 4 D), *Chrysoperla* sp. (Neuroptera: Chrysopidae) ($R^2 = 0.33$, $P < 0.00$) (Fig. 4 E), and *A. gossypii* ($R^2 = 0.31$, $P < 0.00$) (Fig. 4 F). The numbers of *Chrysoperla* sp. were positively correlated with those of *A. gossypii* ($R^2 = 0.82$, $P < 0.00$) (Fig. 4 G).

Discussion

Relative frequency

The high relative frequency of *Eurytoma* sp., a unique galling insect, on *C. brasiliense* leaves indicates the great potential of this insect to become a pest in commercial *C. brasiliense* plantations causing premature abscission of leaves from this plant (Leite et al., 2020). The specific relative frequency of *Tetranychus* sp.1 (phytophagous mite) and *A. gossypii* (phytophagous Hemiptera) was also the highest of their groups and both are pests of *C. brasiliense* (Leite et al., 2006b, 2021). The number of individuals of *Sycophila* sp. (*Eurytoma* sp. parasitoid) and the predator *Z. armillatus* were the highest in their groups and, for this reason, may be important natural enemies of this galling insect (Leite et al., 2017).

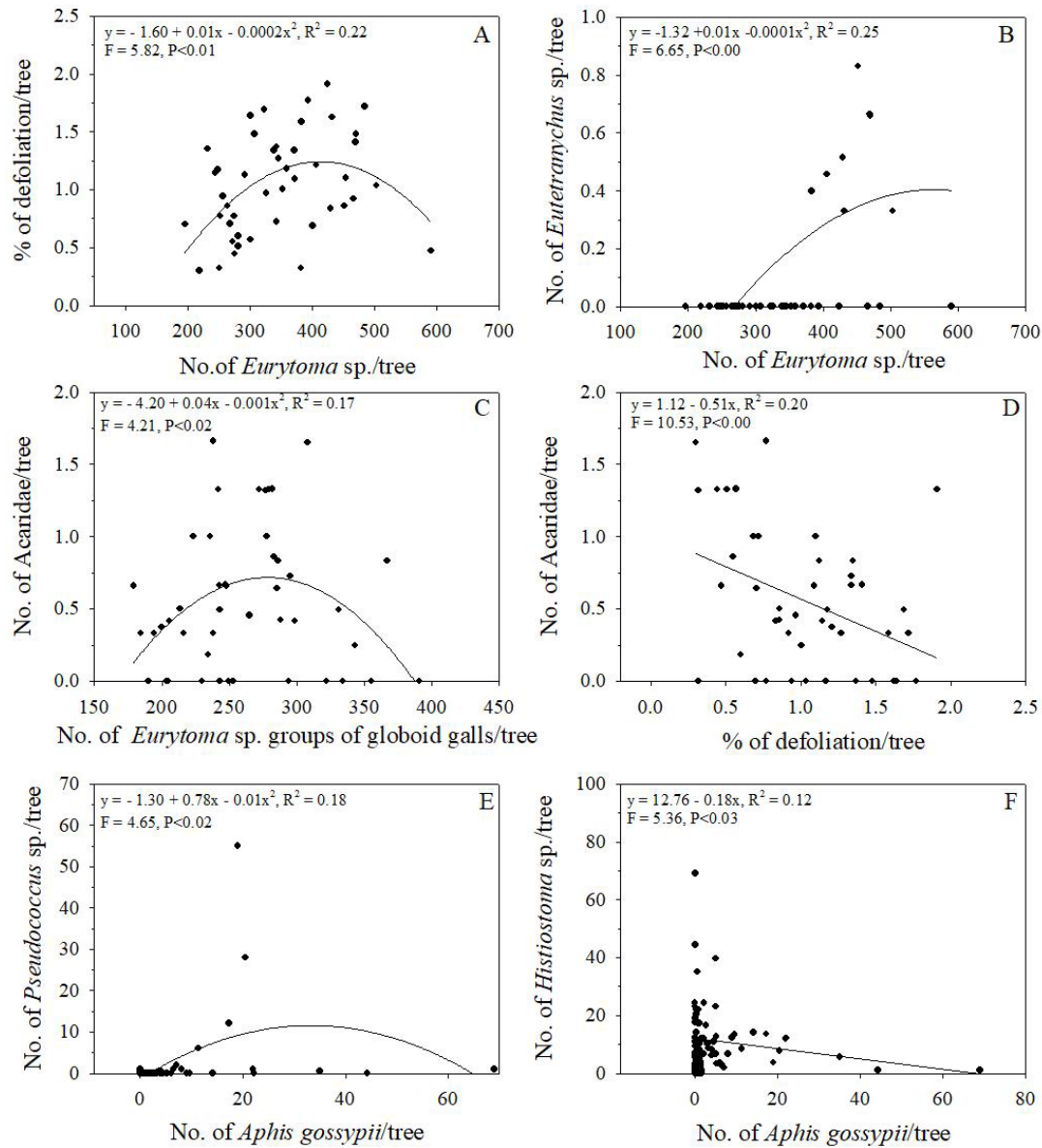


Figure 1 Relationship between the number of *Eurytoma* sp. adults with the percentage of defoliation (A) and numbers of *Eutetranychus* sp. (B); that of *Eurytoma* sp. groups of globose galls (C) and percentage of defoliation (D) with number of Acaridae; and that of *Aphis gossypii* with those of *Pseudococcus* sp. (E) and *Histiostoma* sp. (F) per 12 leaves on *Caryocar brasiliense* trees in three years. Montes Claros, Minas Gerais State, Brazil. The symbols represent the averages. N = 45.

Competition between herbivores

The inverse correlation between the defoliation and the number of galling insects and defoliators (e.g., *Eurytoma* sp. x defoliation) and phytophagous mites (e.g., *Eurytoma* sp. x *Eutetranychus* sp.) was similar to that observed between sucking insects (e.g., *A. gossypii* x *Pseudococcus* sp.), phytophagous mites (e.g., *Tetranychus* sp.1 x *Tetranychus* sp.2), and of *A. gossypii* with *Histiostoma* sp. on *C. brasiliense* trees. The relationship between galling insects and of other free-feeding herbivores may be a consequence of competition for food and space on *C. brasiliense* trees as observed with the high abundance of *A. gossypii*, *Pseudococcus* sp. and *Eurytoma* sp. on leaves of seedlings and adult trees of *C. brasiliense* (Leite et al., 2006b, 2007). In addition, galling insect populations adapt locally to individual trees, that is, those that are of better quality (Egan and Ott, 2007). The lower number of coleopteran and lepidopteran defoliators on *C. brasiliense* leaves in the university campus than in the cerrado and pasture environments, probably, resulted from competition for food and space with galling insects and aphids,

similarly for *Eurytoma* sp. with three other galling hymenopterans (Leite et al., 2012c, 2017). Moreover, ecosystem engineering, realized by organisms that modify the physical environment, can initiate cascades of trophic interactions that shape the structure of the community in no expected ways, and may have negative indirect effects on abundance and diversity in community components that do not interact directly with habitat modifications (Wetzel et al., 2016). The galling insects, that have limited mobility, can be attractive food sources for other herbivores. In this case, it is important for galling insects to develop efficient defense techniques (Yamazaki, 2016). One possibility, in the course of evolution, was to visually resemble caterpillars (Lepidoptera), reducing the herbivory of plant tissues by herbivores, including galls in these tissues (Yamazaki, 2016). This is due to other herbivores can avoid colonizing or consuming parts of the plant that appear to be occupied by other herbivores. In addition, galls that resemble caterpillars can attract natural enemies that will reduce the populations of real caterpillars, favoring galls (Yamazaki, 2016). Competition among predator mites for free space (Hammen et al., 2012; Strodl and Schausberger,

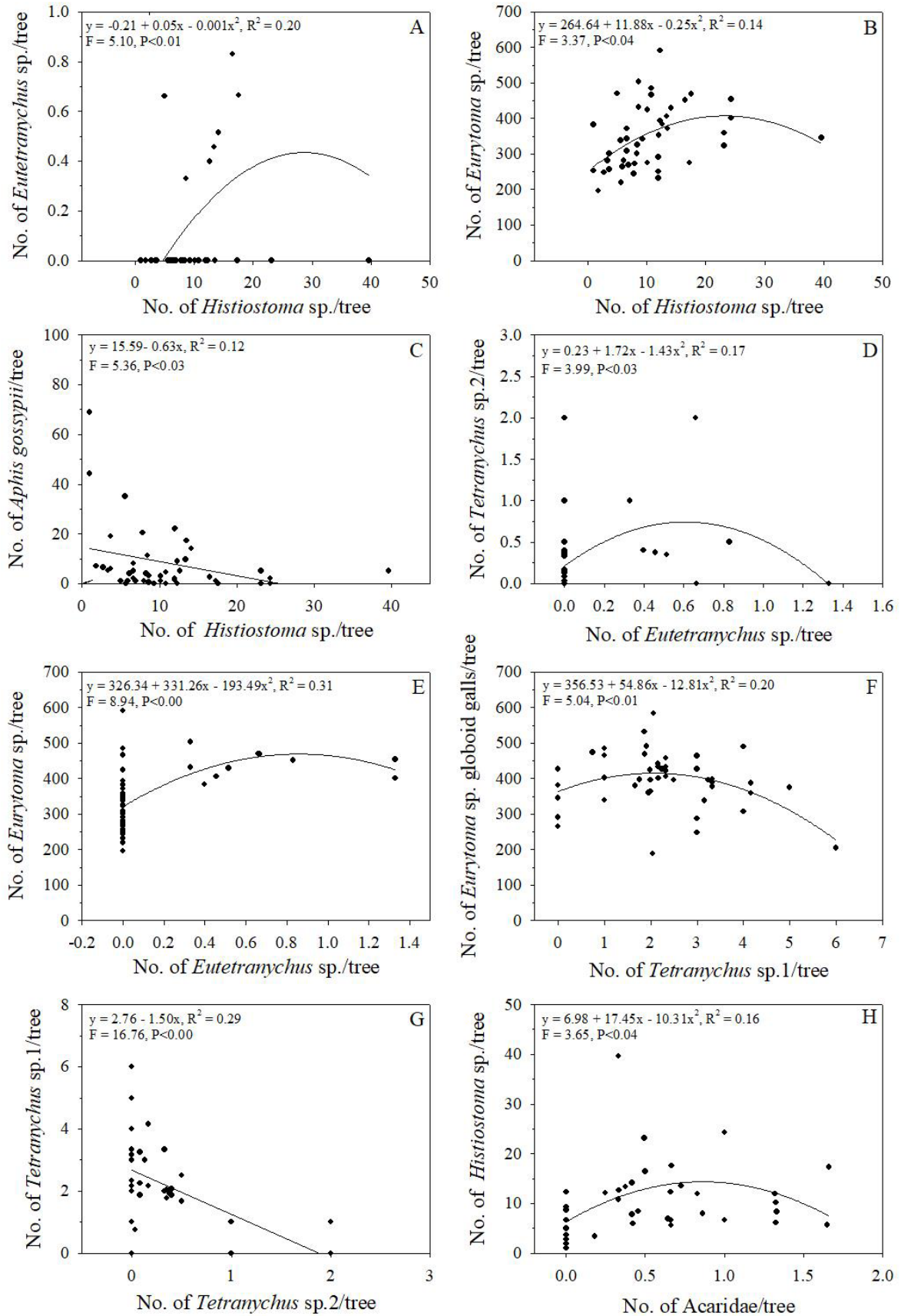


Figure 2 Relationship between the number of *Histiostoma* sp. with those of *Eutetranychus* sp. (A), *Eurytoma* sp. adult (B) and *Aphis gossypii* (C); that of *Eutetranychus* sp. with those of *Tetranychus* sp.2 (D) and *Eurytoma* sp. (E); that of *Tetranychus* sp.1 with that of *Eurytoma* sp. globoid galls (F); that of *Tetranychus* sp.2 with that of *Tetranychus* sp.1 (G); and that of Acaridae with that of *Histiostoma* sp. per 12 leaves on *Caryocar brasiliense* tree in three years. Montes Claros, Minas Gerais State, Brazil. The symbols represent the averages. N = 45.

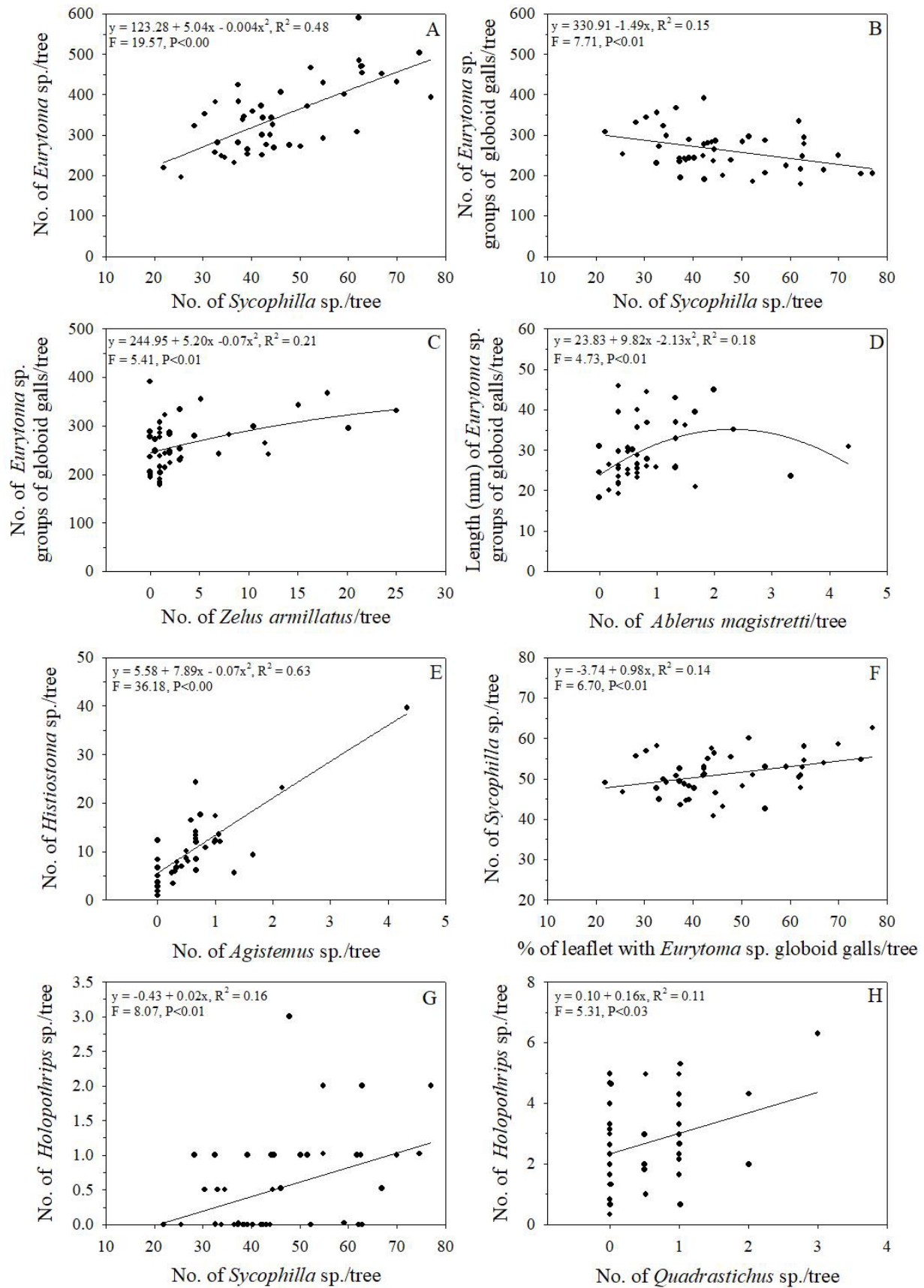


Figure 3 Relationship between the number of *Sycophilla* sp. with those of *Eurytoma* sp. (A) and its globose galls (B); that of *Zelus armillatus* with that of *Eurytoma* sp. groups of globose galls (C); that of *Ablerus magistretti* with the length of *Eurytoma* sp. groups of globose galls (D); number of *Agistemus* sp. with that of *Histiostoma* sp. (E); percentage of leaflets with *Eurytoma* sp. globose galls with the number of *Sycophilla* sp. (F); that of *Sycophilla* sp. with that of *Holopothrips* sp. (G); and that of *Quadrastichus* sp. with that of *Holopothrips* sp. (H) per 12 leaves on *Caryocar brasiliense* tree in three years. Montes Claros, Minas Gerais State, Brazil. The symbols represent the averages. N = 45.

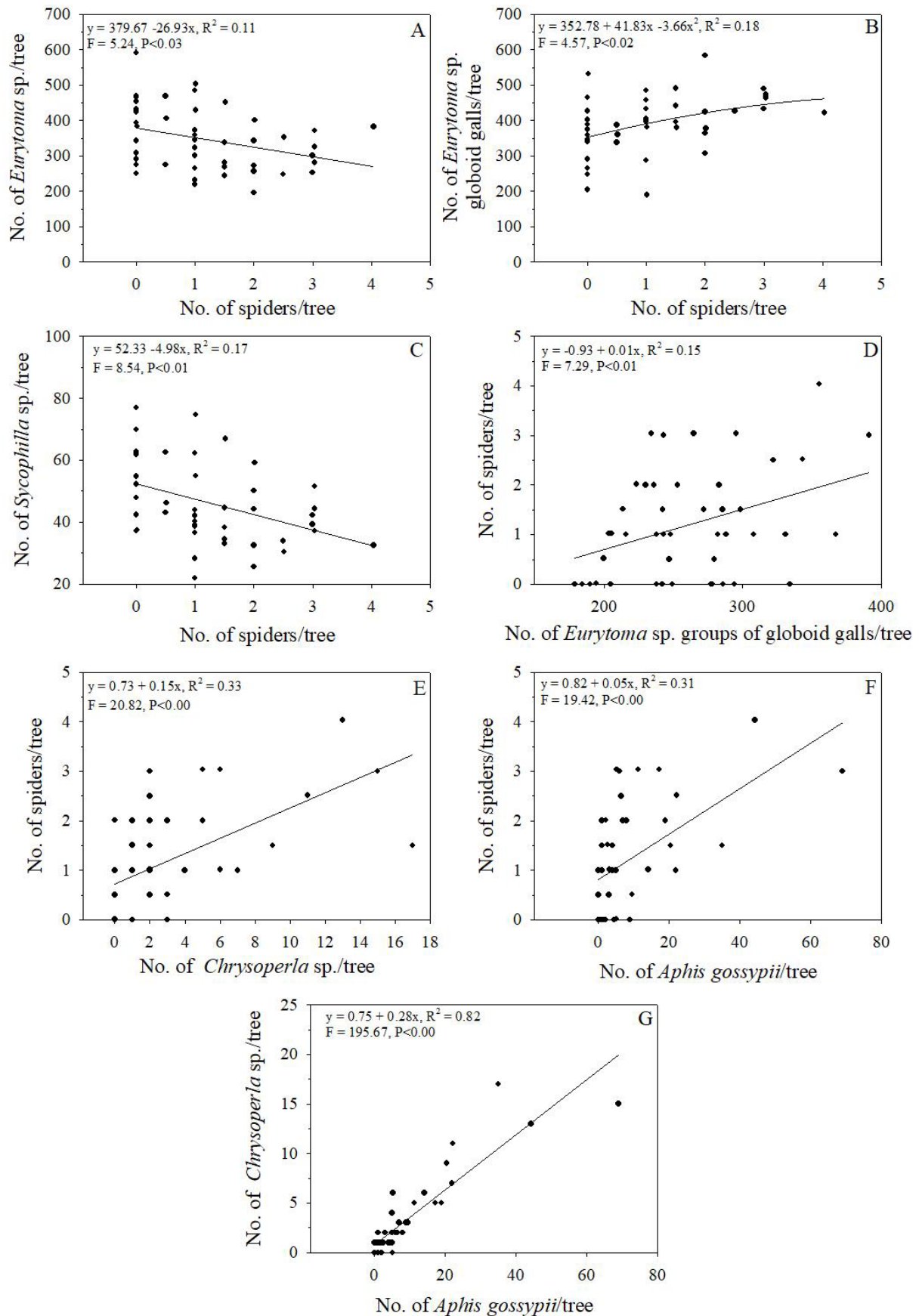


Figure 4 Relationship between the number of spiders with those of *Eurytoma* sp. (A) and its globoid galls (B) and *Sycophilla* sp. (C); those of *Eurytoma* sp. groups of globoid galls (D), *Chrysoperla* sp. (E), and *Aphis gossypii* (F) with that of spiders; and that of *Aphis gossypii* with that of *Chrysoperla* sp. (G) per 12 leaves on *Caryocar brasiliense* tree in three years. Montes Claros, Minas Gerais State, Brazil. The symbols represent the averages. N = 45.

2012) and *T. urticae* females (Macke et al., 2012) have been reported. The importance of this last group in the tropics was confirmed by the competition with defoliators and gall-formers, aphids, leafhoppers, miners and mites (Morris et al., 2004). Phylogenetic proximity tends to favor the formation and maintenance of groups of mixed species (eusocial or gregarious), possibly due to similar scales in size, life parameters and communication between members (Boulay et al., 2019), but this can increase competition between species sharing similar ecological niches (Boulay et al., 2019). The balance between resource sharing and competition is important to understand species clusters occupying the same ecological niche with low food availability or few reproductive partners (Boulay et al., 2019). Arthropods use mixtures of chemical compounds, such as hydrocarbons, for communication, but interspecific competition can benefit one species at the expense of another (Boulay et al., 2019). Food webs are complex due to interactions between host plants, phytophagous insects, predators, parasitoids, and soil and climatic conditions (Gratton and Denno, 2003), especially in the Cerrado (Marquis et al., 2001; Gratton and Denno, 2003; Morris et al., 2004). The competition affects arthropod distribution on *C. brasiliense* plants confirming our initial hypothesis.

Parasitism and predation

Possible effect of predation on galling insects (e.g., *Z. armillatus* x *Eurytoma* sp. galls), phytophagous mites (e.g., *Agistemus* sp. x *Histiostoma* sp.), sucking insects (e.g., *Chrysoperla* sp. x *A. gossypii*), predators (e.g., spiders x *Chrysoperla* sp.) and parasitoids (e.g., *Holopothrips* sp. x *Sycophila* sp.), and parasitism (e.g., *Sycophila* sp. x *Eurytoma* sp.) on *C. brasiliense* trees were observed. The high number of the predator *Z. armillatus* and the parasitoids *Sycophila* sp. and *A. magistretti* determined the number of *Eurytoma* sp. and its galls. This shows the importance of these natural enemies in controlling this galling insect on *C. brasiliense* trees (Leite et al., 2007, 2009, 2012c). The correlations between indole butyric acid (phytohormone) and globoid galls and numbers of adult *Eurytoma* sp. and, consequently, its major parasitoid *Sycophila* sp. - following its host, on the *C. brasiliense* plants were positive (Leite et al., 2007) and galling insects may select plants with higher concentrations of the hormone indole butyric acid, which may play a role in gall induction (Leite et al., 2007). These observations highlight the importance of studies regarding plant hormones in gall formation and its indirect effect on parasitoids (Leite et al., 2007). The higher numbers of the predator *Z. armillatus*, *Holopothrips* sp., and spiders on *C. brasiliense* trees at the university campus may be due to the higher numbers of *Eurytoma* sp. galls on leaves of this plant in this area compared to those in the pastureland and in the Cerrado (Leite et al., 2012c). *Zelus armillatus* preyed on *Eurytoma* galls colonizing up to 70% of *C. brasiliense* leaf area (Leite et al., 2006b, 2007, 2009) and these galls support a high diversity of natural enemies generating consequent mortality - top down effect - (Price et al., 2004; McGeoch and Price, 2005; Price, 2005). The higher number of green lacewings at the university campus may be due to the large number of *A. gossypii* individuals given the proximity of a legume production area (e.g., okra) (Leite et al., 2012c). The negative correlation between the predatory mite *Agistemus* sp. and the herbivore mite *Histiostoma* sp. on *C. brasiliense* leaves shows the importance of that natural enemy controlling phytophagous mites and the necessity of increasing floristic diversity to maintain or to increase its populations (Leite et al., 2008; Saber and Rasmy, 2010; Eichelberger et al., 2011).

The phytophagous arthropods *Eurytoma* sp. (galling insect), *Tetranychus* sp.1 (mite), and *A. gossypii* (sucking insect) show that these arthropods can become pests in commercial *C. brasiliense* plantations. These arthropod groups had important natural enemies

including *Agistemus* sp. (mite predator), *Chrysoperla* sp. (aphid predator), *Sycophila* sp. (*Eurytoma* sp. parasitoid), and *Z. armillatus* (*Eurytoma* sp. predator). The possible competition between the galling insect *Eurytoma* sp. with defoliators and the mite *Eutetranychus* sp., *A. gossypii* with *Pseudococcus* sp. (sucking insects), and *Tetranychus* sp.1 with *Tetranychus* sp. is, for the first time, an inter-specific relationship reported between species in *C. brasiliense* monoculture system (orchard). Results obtained during the three years indicate that possible competitive interactions between arthropods herbivorous, predator and parasitoid may reduce *Eurytoma* sp. numbers, a potential pest for *C. brasiliense*, and other herbivores and predators on this plant. The hypothesis that competition affects *Eurytoma* sp. distribution in *C. brasiliense* can be verified with studies of arthropod interactions on trees of this species (e.g., exclusion experiments).

Acknowledgments

We thank Dr. A.L. Matioli and Dr. E.A. Ueckermann (Acari); Dr. I.C. Nascimento and Dr. C. Matrangolo (Formicidae); Dr. V.C. Maia (Diptera); Dr. A.L.B.G. Peronti, Dr. C.R.S. Silva, Dr. L.B.N. Coelho, and Dr. P.S.F. Ferreira (Hemiptera); Dr. M.A.P. de Azevedo and Dr. O.H.H. Mielke (Hymenoptera); and Dr. R.C. Monteiro (Thysanoptera) for the identification of the specimens collected. We also thank “Conselho Nacional de Desenvolvimento Científico e Tecnológico” (CNPq), “Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG)” and “Secretaria de Ciência e Tecnologia do Estado de Minas Gerais”. Dr. Phillip John Villani (University of Melbourne, Australia) revised and corrected the English language used in this manuscript.

Funding

“Conselho Nacional de Desenvolvimento Científico e Tecnológico” (CNPq: 305057/2018-9), “Fundação de Amparo à Pesquisa do Estado de Minas Gerais” (FAPEMIG: CAG - PPM-00080-17) and “Programa Cooperativo sobre Proteção Florestal (PROTEF) do Instituto de Pesquisas e Estudos Florestais (IPEF)”.

Conflicts of interest

The authors declare no conflicts of interest.

Author contribution statement

The study was conceived and designed by GLDL, data were collected by RVSV with support from GLDL, data analysis and writing was performed by GLDL, PGL, GWF and JCZ. Figures, tables and manuscript preparation was done by MAS. All authors contributed to writing, revisions and approve the final version of the manuscript.

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