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SEASONAL ABUNDANCE OF GALLING INSECTS (HYMENOPTERA) ON CARYOCAR BRASILIENSE (MALPIGHIALES: CARYOCARACEAE) TREES IN THE CERRADO

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ABSTRACT

Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) trees have a wide distribution in the Cerrado, a tropical Brazilian savanna, with high diversity and endemism. This plant is protected by federal laws and is untouched in deforested areas of the Cerrado. This situation increases the damage to leaves from galling insects (Hymenoptera). We studied populations of galling insects and their natural enemies on C. brasiliense trees for 3 successive yr during each season in the Cerrado. A globose gall-inducing Eurytoma sp. (Hymenoptera: Eurytomidae) and its parasitoid Sycophila sp. (Hymenoptera: Eurytomidae) adults and predator Zelus armillatus (Lepeletier and Serville) (Hemiptera: Reduviidae) on the leaves were most abundant in the winter. The numbers of vein galls correlated negatively with the numbers of discoid and spherical galls, and the numbers of spherical galls correlated negatively with the numbers of discoid galls on C. brasiliense leaflets. Increased percentages of defoliation were correlated with reductions in the percentages of leaflets with total galls and leaflet area with total galls. Increased numbers of Sycophila sp. and decreased numbers of Ablerus magistretti Blanchard (Hymenoptera: Aphelinidae) were correlated with reduction in the numbers of Eurytoma sp. Numbers of Quadrastichus sp. (Hymenoptera: Eulophidae) and A. magistretti correlated negatively with the numbers of Sycophila sp. Increased numbers of Z. armillatus were correlated with reduction in the numbers of Eurytoma sp. and its galls and parasitoids. We concluded that this differential temporal distribution of galling insects and their natural enemies was influenced by plant phenology and time of colonization on C. brasiliense leaves.

Key Words: Eurytoma sp., Bruchophagus sp., natural enemies, seasons, pequi

RESUMEN

Los árboles de Caryocar brasiliense Camb. (Malpighiales: Caryocaraceae) tienen una amplia distribución en el Cerrado, una sabana tropical de Brasil, con alta diversidad y endemismo. Esta planta está protegida por la ley federal y se encuentra en áreas deforestadas del Cerrado. Esta situación aumenta el daño a las hojas de los insectos que causan agallas (Hymenoptera). Se estudiaron las poblaciones de insectos que causan agallas y sus enemigos naturales de los árboles de C. brasiliense durante 3 años consecutivos durante cada temporada en el Cerrado. Agallas globosas inducidas por Eurytoma sp. y su parasitoide Sycophila sp. (Hymenoptera: Eurytomidae) - adultos - y depredador Zelus armillatus (Lepeletier and Serville) (Hemiptera: Reduviidae) en las hojas fueron más abundantes en el invierno. El número
The Cerrado occupies about 23% of the Brazilian territory (Da Silva & Bates 2002) and is characterized by high diversity of plants and insects and present a high degree of endemism (Bridgewater et al. 2004). Due to increasing threats to is biodiversity the Cerrado has been elected as a biodiversity hotspot (Myers et al. 2000). The Cerrado primary use is for grain and cattle production (Aguiar & Camargo 2004), as well as reforestation with exotic species, primarily Euca- lyptus (Zanuncio et al. 2002). Through several governmental mechanisms and incentives the Cerrado has been devastated in the last five decades leaving only 20% of the land intact (Klink & Machado 2005). Naturally, the Cerrado is formed by a complex mosaic of phytophysignomies that range from open Cerrado formations (campo limpo) up to tall and woody forests of 10-15 meters high, called Cerradão (Oliveira & Marquis 2002). In southeastern Brazil large patches of this rich Cerrado is seen immersed in a matrix of agriculture (primarily soybean and sugar cane), cattle farms and cities (urbanization). This is the case in Montes Claros in northern Minas Gerais state.

_Caryocar brasiliense_ Camb. (Malpighiales: Caryocaraceae) is a flag species of the Cerrado, presents wide distribution (Brandão & Gavilanes 1992; Bridgewater et al. 2004; Leite et al. 2006a) and can reach up to 10 m high while the canopy may reach 6 m wide (Leite et al. 2006a, 2011a, 2012a). The leaves of _C. brasiliense_ are alternate, trifoliate and have high tri- chome density; the flowers are hermaphrodite but mostly cross pollinated. Fruit production is annual, and _C. brasiliense_ blooms between Jul and Sep (dry period) with fructification from Oct and Jan (rainy season) (Leite et al. 2006a). The fruit is a drupe with 1-4 seeds, weighing 158.49 ± 8.14 g (fresh weigh) and with a volume of 314.90 ± 20.93 cm³ (Leite et al. 2006a). Its fruits have an internal mesocarp rich in oil, vitamins, and proteins, and contain many compounds of medicinal importance. Not surprisingly, it is widely used by humans for food, production of cosmetics, lubricants, and in the pharmaceutical industry (Segall et al. 2005; Ferreira & Junqueira 2007; Garcia et al. 2007; Khouri et al. 2007).

This species represents the main source of income of many communities (Leite et al. 2006a). _Caryocar brasiliense_ are protected by federal laws and hence are left in deforested areas of the Cerrado. Isolated individuals of this plant in the agro-landscape suffer from increased leaf, flower, and fruit damage from insect herbivorous (i.e. Coleoptera, Lepidoptera, and Hemiptera), which affects their natural enemies (i.e. predators) (Leite et al. 2012b, c, d, e). Among these insects, there are four types of galling insects (Hymenoptera) found on the _C. brasiliense_ leaves (Leite et al. 2009, 2011c, d, e). These galls, principally galling _Eurytoma_ (Eurytomidae), can cause premature leaf abscis- sion when they are found at a high density on _C. brasiliense_ seedling and adult plants (Oliveira 1997, Leite et al. 2006b, 2009). But these studies with galling insects on _C. brasiliense_ were made with isolated species (no interactions among of them) and not showed the seasonality of these species of galling insects.

In order to better manage and protect the remaining _C. brasiliense_ in the wild and on plantations, it is necessary to understand the ecology of the insects that interact with this economically valuable tree. Our objective was to research the seasonality of galling insects (Hyme- noptera) and their natural enemies on this tree, in strict sense Cerrado (a species-rich dense scrub of shrubs and trees, 8-10 m high and a dense un- derstory) at Montes Claros in the state of Minas Gerais, Brazil.

**MATERIAL AND METHODS**

Study sites

The study was done in the municipality of Montes Claros (S 16° 44’ 55.6” W 43° 55’ 7.3”, at 943 m elevation), in the state of Minas Gerais,
Brazil, during 3 consecutive yr (Jun 2008 through Jun 2011). The region has dry winters and rainy summers, and is classified as climate Aw, i.e., tropical savanna according to Köppen (Vianello & Alves 2000). The area was a strict sense Cerrado having a dystrophic yellow red oxisol with sandy texture, and a density of 13 \textit{C. brasiliense} trees/ha (Leite et al. 2006a, 2011b).

The strict sense Cerrado (a species-rich thicket of shrubs and trees, 8-10 m high with a dense understory) is more typical of the Cerrado than grassland open forms (Ribeiro & Walter 1998; Durigan et al. 2002). Adult trees \textit{C. brasiliense} in the area were 4.07 ± 0.18 m (average ± standard error) in height and crown width of 2.87 ± 0.13 m (Leite et al. 2006a).

**Study Design**

The design was completely randomized with 27 replicates (1 tree/replicate) in cerrado vegetation. Each month we walked ~600 m in a straight line, and every 50 m we collected data on the \textit{C. brasiliense} tree (producing fruits) in Cerrado vegetation, totaling 27 trees per month. Despite the 27 trees, we collected data according to this design in 3 consecutive yr to capture the overwhelming majority of species of insects (i.e., rare species), since in a given yr some of them might not occur.

The distribution of galling insects and their galls, predators and parasitoids as well as percentages of defoliation and leaves with galls, numbers of sap sucking hemipterans and leafminers (Lepidoptera) were recorded in 4 fully expanded leaves on each of the 27 \textit{C. brasiliense} trees. This sampling was conducted in the morning (7-11 AM) by direct visual observation every month. Insects were collected with tweezers, brushes, or aspirators and preserved in vials with 70% alcohol for identification by taxonomists. These leaves were collected and transported to laboratory. The dimension of galls was measured using digital caliper. Leaves were scanned and the leaf area was calculated using a computer program, and then we calculated the area of each kind of gall occupied in each leaf. After, these leaves were put inside of a white plastic pot (temperature 25 °C), and we evaluated in each 2 days the emergence of galling insects, parasitoids, hyperparasitoids and inquilines for 30 days in each collected data. The emerged insects were collected and preserved as described above for identification by taxonomists.

**TABLE 1. NUMBERS OF GALLING INSECTS (HYMENOPTERA), OTHER INSECTS, NATURAL ENEMIES, AND INQUILINES PER TREE OF \textit{CARYOCAR BRASILIENSE} AT MONTES CLAROS, MINAS GERAIS STATE, BRAZIL, DURING AUTUMN 2008 TO AUTUMN 2011.**

| Galling insects | Spring | Summer | Autumn | Winter |
|-----------------|--------|--------|--------|--------|
| \textit{Eurytoma} sp.** | 0.29 ± 0.16 B | 1.23 ± 0.35 B | 1.23 ± 0.60 B | 3.49 ± 1.26 A |
| \textit{Bruchophagus} sp. n.s. | 0.00 ± 0.000 | 0.004 ± 0.003 | 0.000 ± 0.000 | 0.000 ± 0.000 |
| \textit{Eulophidae} n.s. | 0.006 ± 0.006 | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.001 ± 0.001 |
| \textit{Hymenoptera} n.s. | 0.000 ± 0.000 | 0.082 ± 0.080 | 0.069 ± 0.069 | 0.000 ± 0.000 |

Other herbivore insects

| % of defoliation n.s. | 4.44 ± 0.66 | 5.46 ± 0.63 | 6.06 ± 0.71 | 3.79 ± 0.63 |
| **Leafminers (Lepidoptera)*** | 0.04 ± 0.01 B | 0.07 ± 0.01 AB | 0.13 ± 0.03 AB | 0.15 ±0.04 A |

Natural enemies/inquilines

| \textit{Sycophila} sp.** | 0.02 ± 0.01 B | 0.13 ± 0.03 B | 0.14 ± 0.05 B | 0.60 ± 0.23 A |
| \textit{Ablerus magistretti} n.s. | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.003 ± 0.002 | 0.198 ± 0.198 |
| Total ants* | 0.07 ± 0.01 A | 0.02 ± 0.01 B | 0.06 ± 0.01 AB | 0.09 ± 0.02 A |
| Spiders n.s. | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.02 ± 0.02 |
| \textit{Holothrips} sp. n.s. | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 |
| \textit{Zelus armillatus} n.s. | 0.02 ± 0.01 B | 0.01 ± 0.01 B | 0.02 ± 0.01 B | 0.07 ± 0.02 A |
| \textit{Epipolops} sp. n.s. | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 |
| \textit{Trybonia} spp. n.s. | 0.01 ± 0.01 | 0.03 ± 0.01 | 0.08 ± 0.05 | 0.02 ± 0.01 |
| \textit{Quadristichus} sp. n.s. | 0.002 ± 0.002 | 0.003 ± 0.002 | 0.002 ± 0.001 | 0.212 ± 0.195 |
| \textit{Alycaulini} n.s. | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.001 ± 0.001 | 0.000 ± 0.000 |

Means within a row followed by the same letter (average ± SE) are not different by the test of Tukey (* = P < 0.01 and ** = P < 0.05), n.s. = not significant by ANOVA (P > 0.05).
| Insects and theirs damages | Spring | Summer | Autumn | Winter |
|---------------------------|--------|--------|--------|--------|
| % of leaflet with total galls | 35.07 ± 4.06 | 40.26 ± 3.97 | 36.82 ± 3.95 | 39.36 ± 4.51 |
| % of leaflet area with total galls | 7.29 ± 3.64 | 5.08 ± 1.25 | 7.48 ± 1.96 | 8.86 ± 2.54 |
| % of leaflet area with discoid galls | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.01 ± 0.01 | 0.02 ± 0.01 |
| % of leaflet area with vein galls | 0.007 ± 0.003 | 0.010 ± 0.009 | 0.001 ± 0.001 | 0.005 ± 0.003 |
| % of leaflet area with spherical galls | 0.003 ± 0.001 | 0.000 ± 0.000 | 0.000 ± 0.000 | 0.001 ± 0.001 |
| % of leaflet area with globoid galls | 0.09 ± 0.01 | 0.09 ± 0.01 | 0.12 ± 0.04 | 0.15 ± 0.03 |
| % of leaflet area with conglomerate of globoid galls | 7.18 ± 4.05 AB | 4.98 ± 1.24 B | 7.35 ± 1.94 A | 8.68 ± 2.51 A |
| % of leaflet area with total globoid galls | 7.27 ± 4.05 AB | 5.07 ± 1.25 B | 7.47 ± 1.96 A | 8.83 ± 2.54 A |
| % of discoid galls/total galls | 5.43 ± 2.15 | 9.78 ± 2.71 | 9.18 ± 3.87 | 12.18 ± 4.36 |
| % of vein galls/total galls | 2.84 ± 1.46 | 2.44 ± 2.04 | 0.56 ± 0.45 | 1.26 ± 0.69 |
| % of spherical galls/total galls | 1.97 ± 1.00 | 0.52 ± 0.51 | 0.00 ± 0.00 | 4.21 ± 3.00 |
| % of globoid galls/total galls | 49.70 ± 3.87 | 50.86 ± 3.13 | 52.65 ± 3.18 | 48.34 ± 3.99 |
| % of conglomerate of globoid galls/total galls | 40.06 ± 3.59 | 36.40 ± 2.91 | 37.61 ± 2.77 | 34.01 ± 3.00 |
| % of total globoid galls/total galls | 89.76 ± 4.44 | 87.26 ± 3.75 | 90.26 ± 3.97 | 82.35 ± 6.04 |
| Number of discoid galls/leaflet | 0.50 ± 0.27 | 0.31 ± 0.08 | 0.30 ± 0.18 | 0.60 ± 0.24 |
| Number of vein galls/leaflet | 0.08 ± 0.04 | 0.10 ± 0.09 | 0.02 ± 0.01 | 0.06 ± 0.03 |
| Number of spherical galls/leaflet | 0.19 ± 0.11 | 0.02 ± 0.02 | 0.00 ± 0.00 | 0.10 ± 0.04 |
| Number of globoid galls/leaflet | 3.93 ± 0.66 | 3.83 ± 0.65 | 5.83 ± 2.11 | 4.12 ± 0.82 |
| Number of conglomerate of globoid galls/leaflet | 2.25 ± 0.37 | 2.59 ± 0.41 | 2.68 ± 0.48 | 2.95 ± 0.56 |
| Number of total globoid galls/leaflet | 6.18 ± 0.97 | 6.42 ± 1.01 | 8.51 ± 2.40 | 7.07 ± 1.35 |
| Area (mm²) of discoid galls | 2.43 ± 0.37 | 4.54 ± 0.57 | 3.62 ± 0.54 | 3.88 ± 0.71 |
| Area (mm²) of vein galls | 10.75 ± 3.60 | 11.42 ± 1.45 | 8.00 ± 4.00 | 11.50 ± 2.08 |
| Area (mm²) of spherical galls | 3.25 ± 1.03 | 0.79 ± 0.79 | 0.00 ± 0.00 | 1.16 ± 0.23 |
| Area (mm²) of globoid galls | 2.62 ± 0.21 B | 2.70 ± 0.24 B | 3.02 ± 0.24 AB | 4.66 ± 1.02 A |
| Area (cm²) of conglomerate of globoid galls | 0.23 ± 0.07 | 0.18 ± 0.02 | 0.26 ± 0.04 | 0.24 ± 0.03 |
| Area (cm²) of total globoid galls | 0.23 ± 0.07 | 0.18 ± 0.02 | 0.27 ± 0.04 | 0.25 ± 0.03 |
| Length (mm) of conglomerate of globoid galls | 22.07 ± 2.52 | 22.00 ± 1.97 | 23.06 ± 2.14 | 24.05 ± 2.17 |
| Width (mm) of conglomerate of globoid galls | 6.61 ± 0.78 AB | 5.61 ± 0.36 B | 7.25 ± 0.53 A | 7.02 ± 0.60 A |

Means within a row followed by the same letter (average ± SE) are not different by the test of Tukey (* = P < 0.01 and ** = P < 0.05). n.s. = not significant by ANOVA (P > 0.05).
Averages were realized reducing the data per tree in each season. Correlations of number of galling insects and their galls with natural enemies, and other groups of herbivores were subjected to analysis of variance (ANOVA) \( (P < 0.05) \) and simple regression analysis \( (P < 0.05) \). The effect of the seasons of the yr on the number of galling insects and their galls, natural enemies, and other groups of herbivores (transformed by \( \sqrt{x} + 0.5 \) or arcsine for percentage data) was tested with ANOVA \( (P < 0.05) \) with subsequent Tukey’s test \( (P < 0.05) \).

**RESULTS**

Globoid gall-inducing *Eurytoma* sp. (Hymenoptera: Eurytomidae) adults were most abundant \( (df = 78, F = 5.28, P < 0.003) \) in winter on *C. brasiliense* leaves. However, we did not observe significant differences \( (P > 0.05) \) among seasons in relation to other galling insect adults as follow: discoid gall-inducing *Hymenoptera* (not identified), spherical gall-inducing *Elaphidieae* (Hymenoptera), and vein gall-inducing *Bruchophagus* sp. (Hymenoptera: Eurytomidae) (Table 1). Percentages of leaflet areas with conglomerates \( (df = 78, F = 3.44, P < 0.021) \) and total of globoid galls \( (df = 78, F = 3.76, P < 0.014) \) were lowest in the summer. However, we did not observe significant differences \( (P > 0.05) \) among seasons in relation the percentages of leaflet with total galls; and percentages of leaflet areas with total galls, with discoid galls, with vein galls, with spherical galls, and with globoid galls. For percentages of discoid galls/total galls; vein galls/total galls; spherical galls/total galls; and globoid, conglomerate, and total globoid/total galls were similar \( (P > 0.05) \) among the seasons of the year. The similar results were observed \( (P > 0.05) \) in relation the numbers of all kinds of galls per leaflet. The greatest area \( (mm^2) \) of globoid galls \( (df = 78, F = 2.99, P < 0.036) \) and lowest width \( (mm) \) of conglomerate of globoid galls \( (df = 78, F = 3.28, P \)
Fig. 2. Relationships between numbers of spiders and *Eurytoma* sp., *Sycophila* sp., and conglomerate of globoid galls/leaflet; numbers of spiders and percentages of leaflet with total galls, leaflet area with total galls, leaflet area with conglomerate of globoid galls, and leaflet area with globoid galls/leaflet; and number of spiders and area (mm$^2$) of conglomerate of globoid galls/leaflet on *Caryocar brasiliense* trees in Montes Claros, Minas Gerais State, Brazil.
Fig. 3. Relationships between numbers of *Zelus armillatus* and *Eurytoma* sp., *Sycophila* sp., conglomerate of globoid galls, and globoid galls/leaflet; number of *Z. armillatus* and percentage of leaflet area with globoid galls/leaflet; number of total ants and percentage of leaflet area with spherical galls/leaflet; and numbers of *Holoprothrips* sp. and *Trybonia* sp. and area (mm$^2$) of spherical galls/leaflet on *Caryocar brasiliense* trees in Montes Claros, Minas Gerais State, Brazil.
< 0.026) were noted on C. brasiliense leaflets in the winter and summer, respectively. However, we did not find significant differences (P > 0.05) among seasons of the yr in relation the areas (mm²) of discoid, vein, spherical, conglomerate and total globoïd galls, as well as length (mm) of conglomerate of globoïd galls (Table 2). With respect to other herbivore insects, the numbers of individuals sap sucking (Hemiptera) and defoliators – defoliation percent – (Coleoptera and Lepidoptera) were similar (P > 0.05) among the seasons of the yr, but lepidopteran leaf miners had lowest (df = 78, F = 5.85, P < 0.002) numbers in spring (Table 1).

For Eurytoma parasitoids, Sycophila sp. (Hymenoptera: Eurytomidae) adults were also most abundant (df = 78, F = 6.49, P < 0.001) in the winter, but differences were not found (P > 0.05) for Ablerus magistretti Blanchard (Hymenoptera: Aphelinidae). Quadrastichus sp. (Hymenoptera: Eulophidae) adults – hyperparasitoids of Sycophila sp – and individual adults belonging to the tribe Alycauline (Diptera) – inquiline of Eurytoma galls – showed similar numbers (P > 0.05) of adults across of the seasons of the yr. For predators, the lowest numbers of total ants, Crematogaster sp. and Pseudomyrmex termitarius Smith (Hymenoptera: Formicidae), were observed (df = 78, F = 4.38, P < 0.007) in C. brasiliense leaflets in the summer; and Zelus armillatus (Lepeletier and Serville) (Hemiptera: Reduviidae) on leaves were most abundant (df = 78, F = 3.74, P < 0.015) in the winter (Table 1). With respect to other arthropod predators, the numbers of individual spiders Cheiracanthium inclusum Hentz (Miturgidae) (most frequent); Peucetia rubrolineata (Keyserling) (Oxyopidae); Anelosimus sp., Achaearanea hirta (Taczanowski) (Theridiidae); Gastromicans albopilosa Simon, Chiro bicirculigera Soares and Camargo, Ruda humilis Mello- Leitão, Thiodina melano- gaster Mello-Leitão and Lyssomanes pauper Galiano (Salticidae); Dictyna sp. and sp.1 (Dic-
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Tynidae); Tmarus sp. and sp.1 (Thomisidae); Argoipe argentata (Fabr.), Gasteracantha cancriformes, Argoipe sp., Parawixia sp. and sp.1 (Araneidae); and Anyphaenidae; Holopothrips sp., Trybonia intermedius Bagnall and Trybonia mendesi Moulton (Thysanoptera: Phlaeothripidae); and Epipolops sp. (Hemiptera: Geocoridae) on *C. brasiliense* leaflets were similar ($P > 0.05$) among the seasons of the yr.

Increased numbers of Sycophila sp. and decreased numbers of *A. magistretti* were correlated with reduction in the numbers of *Eurytoma* sp. on *C. brasiliense* leaflets. Numbers of *Quadrastichus* sp. and *A. magistretti* correlated negatively with the numbers of *Sycophila* sp. (Fig. 1). Numbers of spiders on *C. brasiliense* leaflets correlated positively with the numbers of *Eurytoma* sp., *Sycophila* sp., and conglomerate of globoid galls; percents of leaflet with total galls, leaflet area with total galls, leaflet areas with conglomerate and globoid galls; and area ($\text{mm}^2$) of conglomerate of globoid galls (Fig. 5).
2). On the other hand, increased numbers of Z. armillatus on C. brasiliense leaflets were correlated with reduction in the numbers of Eurytoma sp., Sycophila sp., conglomerate of globose galls, and globoid galls per leaflet; and percentage of leaflet area with globoid galls. Numbers of total ants and Holopothrips sp. correlated positively with percentage of leaflet area with spherical galls and area (mm²) of spherical galls, respectively; and Trybonia spp. correlated negatively with area (mm²) of this last kind of gall (Fig. 3).

The numbers of vein galls correlated negatively with the numbers of discoid and spherical galls per leaflet as well as the number of spherical galls correlated negatively with the numbers of discoid galls on C. brasiliense leaflets. Increased area (mm²) of spherical galls was correlated with reduction in the area (mm²) of conglomerate of globose galls (Fig. 4). Numbers of lepidopteran leaf miners correlated negatively with the numbers of conglomerate of globose galls per leaflet; and area (mm²) of vein galls per leaflet (Fig. 5).

DISCUSSION

The higher numbers of Eurytoma sp. adults and percentages of leaflet areas with theirs galls as well as lepidopteran leaf miners in the winter were probably due to longer time of exposure of the C. brasiliense leaves to the colonization by these herbivorous insects. Greater numbers of globose, discoid, and vein galls were found in the interior than on the border of the tree crown (Leite et al. 2009, 2011c, d) and these authors suggested that the most distal leaves - interior of the tree crown - (leaves 1 and 2) were too young to be found by the gallers, while leaves 3 and 4 (interior of the tree crown) were exposed to gall ing insects for a longer period (Leite et al. 2009). Another possibility is a reduction in the number of C. brasiliense leaves available due to their gradual loss during the dry period and by the end of the dry season (Leite et al. 2006a), which results in a concentration of herbivore insects per leaf in this plant, such as observed for coleopteran, lepidopteran and hemipteran insects in this plant (Leite et al. 2012e, d). The greatest numbers of Sycophila sp. and Z. armillatus, parasitoids and predators of Eurytoma sp., respectively, in the winter probably indicate that their populations depend on their prey and follows those of the galling insects (Oberg et al. 2008; Venturino et al. 2008; Leite et al. 2012d, e).

Caryocar brasiliense loses its leaves in Aug/Sep with new ones in the end of Sep, which is a period without rainfall, strong wind and high sunlight (Leite et al. 2006a). We observed higher numbers of Eurytoma sp. and its parasitoid Sycophila sp., and discoid galls in Aug; and greater numbers of lepidopteran leaf miners, predators Z. armillatus and Eupholus sp., and percentage of leaflet with total galls in Sep, a period when C. brasiliense trees have old leaves (Leite et al. 2006a). However, lower numbers of herbivorous hemipterans were observed in Sep. On the other hand, in Oct when C. brasiliense trees have new leaves (Leite et al. 2006a), higher abundance of sap sucking and vein and spherical galls were observed in this plant, but lower numbers of Eurytoma sp. and their galls, Sycophila sp., Trybonia sp., discoid galls, lepidopteran leaf miners, and percentages of leaflet with total galls, leaflet area with total galls, and defoliation.

We observed a negative correlation between the predator Z. armillatus and the parasitoid Sycophila sp. with Eurytoma sp. These natural enemies can be important in the control of Eurytoma sp. on C. brasiliense trees (Leite et al. 2007, 2009, 2012e). Positive relationships were found between indole butyric acid (phytohormone) concentrations and successfully induced globose galls, and also between the number of adults of the galling Eurytoma sp. and its major parasitoid, Sycophila sp. and the higher concentrations of this hormone on the C. brasiliense plants (Leite et al. 2007). These data indicate that the galling insects may select plant modules or plants with higher hormone concentrations and that indole butyric acid may play a role in gall induction (Leite et al. 2007). Further studies are also needed to address hormonal roles in gall formation and their indirect effect on the community of associated parasitoids (Leite et al. 2007). Leite et al. (2012e) asserted that highest number of the predator Z. armillatus in C. brasiliense trees on the university campus might be due to these trees having more leaves galled by Eurytoma sp. than in pastureland and in the cerrado. Zelus armillatus was seen preying upon Eurytoma sp. in these trees, which can colonize up to 70% of the leaf area with galls (Leite et al. 2006b, 2007, 2009). The galls can support higher diversity of natural enemies, and they can cause much mortality—top down impact of natural enemies—(Price et al. 2004; McGeoch and Price 2005; Price 2005).

The decrease in Eurytoma sp. abundance as numbers another galling insect increased may have resulted from competition among these insects. Almost always galling insects prefer the leaves of C. brasiliense that are most exposed to the wind and sunshine and that are on the interior of the branch; and galling insects pre-
for the border and median of the leaves (Leite et al. 2009, 2011c, d, e). However, with larger populations of *Eurytoma* sp., other galling insects attack other parts of *C. brasiliense* leaves, and thereby avoid competition. *Eurytoma* sp. seems to be the fastest to colonize plants—being the first to arrive at the plant—and to have greater biotic potential. As for other galls, they only choose areas that are not populated by *Eurytoma* sp. (Leite et al. 2009, 2011c, d, e). *Caryocar brasiliense* trees that were more frequently attacked by *Eurytoma* sp. were rarely colonized by other galling insects. In addition, we observed one *C. brasiliense* tree that was strongly attacked by spherical galls in which *Eurytoma* sp. was not detected, and we observed this tree for 4 yr (unpublished data). Perhaps there is a chemical or visual marker that indicates that a species of galling insect dominates a particular ecological niche (i.e., part of a leaf, branch or even a tree). Another possibility is that there are genetic differences among *C. brasiliense* plants that are responsible for this process or differences in the chemical or morphological composition in different parts of a leaf or in leaves at different positions on a branch, differences in exposure to the sun/wind, or differences in the relationship with other arthropods (i.e., natural enemies).

The decrease in gall abundance as numbers of lepidopteran and coleopteran defoliators and lepidopteran leaf-miners increased may have resulted from competition between the two groups. Also our data suggest competition between lepidopteran leaf miners and defoliators on *C. brasiliense* trees. *Eurytoma* sp. and *A. gossypii* were very abundant on the leaves both of seedlings and adult of *C. brasiliense* trees on the university campus area (Leite et al. 2006b, 2007). The low numbers of coleopteran and lepidopteran defoliators on the university campus may have been caused by competition for food and space with galling insects and aphids in this area (Leite et al. 2012e). Spiders, ants, and *Holopothirps* sp. can reduce defoliation and lepidopteran leaf miners (Leite et al. 2012b, c, d, e), and these factors may favor the colonization of the leaves of this plant by galling insects (free space).

Our data also suggest competition between the *Eurytoma* sp. parasitoids, *A. magistretti* and *Sycophila* sp. for their host, and the negative effect of the possible hyperparasitoid, *Quadrantrichus* sp., on its host *Sycophila* sp. However, more research is needed to elucidate this hypothesis. Competition between galls and other phytophagous insects (defoliators, aphids, leafhoppers, miners and mites) and natural enemies shows the importance of this last group on host-plants in the tropics (Morris et al. 2004). The study of food webs is complex due to interactions among host plants, phytophagous insects, predators, parasitoids, and soil and climate conditions (Gratton & Denno 2003). Few studies have examined food webs in complex ecosystems (Gratton & Denno 2003; Morris et al. 2004) such as the Cerrado (Marquis et al. 2001).

The galling insect genus with higher potential to become a pest in commercial *C. brasiliense* plantations is *Eurytoma* because it is the most abundant and causes premature leaf abscission when it is found at a high density on *C. brasiliense* seedling and adult plants (Oliveira 1997; Leite et al. 2006b, 2009). The galling insects were affected by the phenology of the host plant, and by their predators and parasitoids and competition among species of galling insects seems to occur.

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**References Cited**

AGUIAR, L. M. S., and CAMARGO, A. J. A. 2004. Cerrado: Ecologia e caracterização. Planaltina, EMBRAPA – CPAC.

BRANDÃO, M., and GAVILANES, M. L. 1992. Espécies padronizadoras do Cerrado mineiro e sua distribuição no estado. Inf. Agrop. 16: 5-11.

BRIDGEMEATER, S., RATTER, J. A., and RIBEIRO, J. F. 2004. Biogeographic patterns, β-diversity and dominance in the Cerrado biome of Brazil. Biodiv. Conserv. 13: 2295-2318.

DA SILVA, J. M. C., and BATES, J. M. 2002. Biogeographic patterns and conservation in the South American Cerrado: A tropical savanna hotspot. BioScience 52: 225-233.

DURIGAN, G., NISHIKAWA, D. L. L., ROCHA, E., SILVEIRA, E. R., PULITANO, F. M., REGALODO, L. B., CARVALHAES, M. A., PARANAGUA, P. A., and RANGIERI, V. E. L. 2002. Caracterização de dois estratos da vegetação paulista em uma área de Cerrado no município de Brotas, SP Brasil. Acta Bot. Brasilica 16: 251-262.

FERREIRA, L. C., and JUNQUEIRA, R. G. 2007. Microbiological evaluation of pequi (*Caryocar brasiliense* Camb.) preserves made from a typical Brazilian fruit. World J. Microbiol. Biotechnol. 23: 1179–1181.
GARCIA, C. C., FRANCO, B. I. P. M., ZUPPA, T. O., ANTONIOISI FILHO, N. R., AND LELES, M. I. G. 2007. Thermal Stability Studies of Some Cerrado Plant Oils. J. Therm. Anal. Cal. 87: 645–648.

GRATTON, C., AND DENNO, R. F. 2003. Seasonal shift from bottom-up to top-down impact in phytophagous insect populations. Oecologia 134: 487-495.

KHOURI, J., RESCK, I. S., POÇAS-FONSECA, M., SOUSA, T. M. M., PEREIRA, L. O., OLIVEIRA, A. B. B., AND GRISOLIA, C. K. 2007. Anticlastogenic potential and antioxidant effects of an aqueous extract of pulp from the pequi tree (Caryocar brasiliense Cambess. (Caryocaraceae)). Arq. Inst. Biol. 75: 365-370.

KLING, C. A., AND MACHADO, R. B. 2005. A conservação do Cerrado brasileiro. Megadiversidade 1: 147-155.

LEITE, G. L. D., VELOSO, R. V. S., ZANUNCIO, J. C., FERNANDES, L. A., AND ALMEIDA, C. I. M. 2006a. Phenology of Caryocar brasiliense in the Brazilian Cerrado Region. Forest Ecol. Mgt. 236: 286-294.

LEITE, G. L. D., VELOSO, R. V. S., REDOAN, A. C. M., LOPES, P. S. N., AND MACHADO, M. M. L. 2006b. Artrópodes (Arthropoda) associados à mudas de pequi (Caryocar brasiliense Cambess. (Caryocaraceae)). Rev. Brasileira Entomol. 55: 396-400.

LEITE, G. L. D., ALVES, S. M., NASCIMENTO, A. F., LOPES, P. S. N., FERREIRA, P. S. F., AND ZANUNCIO, J. C. 2011a. Identification of the wood borer and the factors affecting its attack on Caryocar brasiliense trees in the Brazilian Savanna. Acta Sci. Agron. 33: 589-566.

LEITE, G. L. D., ALVES, S. M., NASCIMENTO, A. F., LOPES, P. S. N., FERREIRA, P. S. F., AND ZANUNCIO, J. C. 2011b. Factors affecting Constrictotermes cyphergaster (Isoperta: Termitidae) nesting on Caryocar brasiliense trees in the Brazilian savanna. Sociobiology 57: 165–180.

LEITE, G. L. D., LOPES, E. F., ZANETTI, R., PRAITIS-SOLI, D., AND COUTO, L. 2002. Spatial distribution of herbivores insects on different sides of Caryocar brasiliense (Caryocaraceae) trees in northern Minas Gerais State, Brazil. Acta Sci. Agron. 34: 131-137.

LEITE, G. L. D., VELOSO, R. V. S., MARTINS, E. R., ZANUNCIO, J. C., FERNANDES, G. W., ALMEIDA, C. I. M., RAMALHO, F. S., AND SERRÃO, J. E. 2012b. Population of herbivores insects on different sides of Caryocar brasiliense (Caryocaraceae) trees in the Brazilian Cerrado Region. J. Med. Plants Res. 6: 5557-5565.

LEITE, G. L. D., VELOSO, R. V. S., ZANUNCIO, J. C., ALMEIDA, C. I. M., FERREIRA, P. S. F., SERRÃO, J. E., AND RAMALHO, F. S. 2012e. Seasonal damage caused by herbivorous insects on Caryocar brasiliense (Caryocaraceae) trees in the Brazilian savanna. Rev. Colombiana Entomol. 38: 35-46.

LEITE, G. L. D., VELOSO, R. V. S., ZANUNCIO, J. C., FERNANDES, G. W., ALMEIDA, C. I. M., FERREIRA, P. S. F., LAZO, J. A., AND SERRÃO, J. E. 2012d. Seasonal abundance of hemipterans on Caryocar brasiliense (Malpighiales: Caryocaraceae) trees in the Cerrado. Florida Entomol. 95(4): 862-872.

LEITE, G. L. D., VELOSO, R. V. S., ZANUNCIO, J. C., ALMEIDA, C. I. M., FERREIRA, P. S. F., FERNANDES, G. W., AND SOARES, M. A. 2012e. Habitat complexity and Caryocar brasiliense herbivores (Insecta; Arañiida; Araneae). Florida Entomol. 95(4): 819-830.

MARQUIS, R. J., DINIZ, I. R., AND MORAIS, H. C. 2001. Patterns and correlates of the interspecific variation in foliar insect herbivory and pathogen attack in Brazilian Cerrado. J. Trop. Ecol. 17: 127-148.

MCGEACH, M. A., AND PRICE, P. W. 2005. Scale-dependent mechanisms in the population dynamics of an insect herbivore. Oecologia 144: 278-288.

MORRIS, R. J., LEWIS, O. T., AND GODFRAY, H. C. J. 2004. Experimental evidence for apparent competition in a tropical forest food web. Nature 428: 310-313.

MYERS, N., MITTERMEIER, R. A., MITTERMEIER, C. G., FONSECA, G. A. B., AND KENT, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

OBERG, S., MAYR, S., AND DAUBER, J. 2008. Landscape effects on recolisation patterns of spiders in arable fields. Agric. Ecos. Environ. 123: 211-218.

OLIVEIRA, P. S. 1997. The ecological function of extra-floral nectaries: herbivore deterrence by visiting ants and reproductive output in Caryocar brasiliense (Caryocaraceae). Func. Ecol. 11: 323-330.

OLIVEIRA, P. S., AND MARQUIS, R. J. 2002. The Cerrados of Brazil: ecology and natural history of a neotropical savanna. New York, Columbia University Press.

PRICE, P. W., OHGUISHI, T., RONINNEN, H., IISHIHARA, M., CRAIG, T. P., TAHVANAINEN, J., AND FERRIER, S. M. 2004. Release of phylogenetic constraints through low resource heterogeneity: the case of gall-inducing sawflies. Ecol. Entomol. 29: 467-481.

PRICE, P. W. 2005. Adaptive radiation of gall-inducing insects. Basic Appl. Ecol. 6: 413-421.

RIBEIRO, J. F., AND WALTER, B. M. T. 1998. Fitofisionomias do Bioma Cerrado. In Cerrado: Ambiente e Flora. Planaltina, EMPRAPA - CPAC.

SEGALL, S. D., ARTZ, W. E., RASLAN, D. S., FERRAZ, V. P., AND TAKAHASHI, J. A. 2005. Triacylglycerol analysis of pequi (Caryocar brasiliense Camb.) oil by electrospray and tandem mass spectrometry. J. Sci. Food Agric. 85: 445-452.

ZANUNCIO, J. C., LOPES, E. F., ZANETTI, R., PRATISSOLI, D., AND COUTO, L. 2002. Spatial distribution...
of nests of the leaf cutting ant *Atta sexdens rubropilosa* (Hymenoptera: Formicidae) in plantations of *Eucalyptus urophylla* in Brazil. Sociobiology 39: 231-242.

**Venturino, E., Isaia, M., Bona, F., Chatterjee, S., and Badino, G.** 2008. Biological controls of intensive agroecosystems: Wanderer spiders in the *Langa astigiana*. Ecol. Complex. 5: 157-164.

**Vianello, R. F., and Alves, A. R.** 2000. Meteorologia básica e aplicações. Viçosa, UFV.