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Full Length Research Paper

Population of herbivores insects on different sides of *Caryocar brasiliense* (Caryocaraceae) trees in the Brazilian Cerrado region

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The goal of this work was to study the distribution of lepidopteran, coleopteran, and hymenopteran herbivores and their natural enemies within the canopy of *Caryocar brasiliense* (Caryocaraceae) trees in the Brazilian cerrado. We observed thirteen rare, two common, and one constant species of herbivores insects; and three rare, eight common, and one constant species of natural enemies on *C. brasiliense*. The diversity, number of individuals and species of herbivores, and their natural enemies were similar among the cardinal orientation of the branches of the host tree. However, the number of fruits bored by herbivores was smaller on the south side of the trees. Scraped fruits and Lepidoptera leaf mines were more numerous on the west side of the trees. In the case of natural enemies, ants and predator bugs presented highest abundance on the leaves in the eastern and northern sides of the trees, respectively. We argue that this differential distribution of natural enemies negatively influenced the defoliation and number of leaf mines. We also suggest that the speed and direction of wind may affect the distribution of insect herbivores on the different sides of the trees, with higher populations prevailing on the wind safe sites of the trees.

Key words: Beetles, canopy, caterpillars, insect distribution, natural enemies, pequi.

INTRODUCTION

The Brazilian savanna, called *cerrado,* occupies about 23% of the Brazilian territory (Da Silva and 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 selected as a biodiversity hotspot (Myers et al., 2000). The cerrado's primary use is for grain and cattle production (Aguiar and Camargo, 2004), as well as reforestation with exotic species, primarily eucalyptus (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 and Machado, 2005). Naturally, the cerrado is formed by a complex mosaic of phytophysiognomies that ranges from open savanic formations (*campo limpo*) to tall and woody forests of 10 to 15 m high, called *Cerradão* (Oliveira and 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

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farms and cities (urbanization). This is the case in Montes Claros in northern Minas Gerais State.

Caryocar brasiliense Camb. (Caryocaraceae) is a flag species of the cerrado; it presents wide distribution (Brandão and Gavilanes, 1992; Bridgewater et al., 2004; Leite et al., 2006) and can reach up to 10 m high, while the canopy may reach 6 m wide (Leite et al., 2006). Its fruits have 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 and Junqueira, 2007; Garcia et al., 2007; Khouri et al., 2007). This species represents the main source of income of many communities (Leite et al., 2006). *C. brasiliense* are protected by federal laws and hence are left in deforested areas of the Brazilian cerrado. Fruit collectors have stressed the leaves, flowers and fruits, isolated trees suffer high damage inflicted by beetles, caterpillar and wasps. On the other hand, the insects that damage *C. brasiliense* are poorly known (Freitas and Oliveira, 1996; Oliveira, 1997; Lopes et al., 2003; Boiça et al., 2004; Leite et al., 2009, 2011a, b). 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.

The diversity and abundance of arthropods can vary with the disposition of the branches in a tree. Some hypotheses have been raised to explain this trend: 1) Direction of wind may influence dispersion of insects (Feng et al., 2005; Leite et al., 2011b), and it can desiccate the leaves and reduce fruit production due to the fall of flowers and fruits (Leite et al., 2006); 2) greater exposure on the sun-exposed foliage may influence the quality of host plant tissues (Unsicker and Mody, 2005); 3) microclimate, and 4) to avoid natural enemies – enemy-free space (Unsicker and Mody, 2005). In addition, identification of potential pests and their spatial distribution on the crown of forest and agriculture plants is important for efficient sampling plans of pests (Nichols-Orians, 1991; Casas and Aiuja, 1997; Villanueva and Childers, 2005; Evans and Gregoire, 2007). As the Lepidoptera, Coleoptera, and Hymenoptera are represented by a specious fauna in the cerrado (Pinheiro et al., 2002; Zanetti et al., 2003; Zanuncio et al., 2003). They were reared on *C. brasiliense* in an attempt to support future management programs of pests of this species and to obtain data on their spatial distribution at tree level.

MATERIAL AND METHODS

Study area

This study was done in the municipality of Montes Claros, Minas Gerais state, Brazil, from January to December 2010, in a region with dry winter and rainy summer, which is classified as climate Aw: tropical cerrado according to Köppen (Vianello and Alves, 2000). The vegetation is comprised of Cerrado (savanna) (Longitude: 43° 55' 7.3" W, Latitude: 16° 44' 55.6" S and altitude: 943 m) with dystrophic yellow red latosoil (sandy texture). The density of *C. brasiliense* trees in the area reaches 13 individuals/ha (Leite et al., 2006, 2011a).

System

The cerrado *stricto sensu* (a species-rich dense scrub of shrubs and trees, 8 to 10 m height, with a dense understory) has once occupied 22% of the Brazilian territory (Ribeiro and Walter, 1998; Durigan et al., 2002). Adult trees *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., 2006). The leaves of *C. brasiliense* are alternate, trifoliate and have high trichome density; the flowers are hermaphrodite but mostly cross pollinated. Fruit production is annual, and *C. brasiliense* blooms between July and September (dry period) with fructification from October and January (rainy season) (Leite et al., 2006). The fruit is a drupe with 1 to 4 seeds, weighing 158.49 ± 8.14 g (fresh weigh) and with a volume of 314.90 ± 20.93 cm^3 (Leite et al., 2006).

Study design

The design was completely randomized with 25 replicates (25 trees) in cerrado vegetation *stricto sensu*. The distribution of Lepidoptera and Coleoptera defoliators, percentage defoliation, flowers damaged by Hymenoptera, fruits scraped and bored by insects, and their arthropod natural enemies were recorded in three leaves (fully expanded), three curl of flower, and three fruits per cardinal orientation of branches (North, South, West, and East) of 25 *C. brasiliense* trees monthly in the morning (7 to 11 h) by direct visual observation (Horowitz, 1993).

Defoliation was determined visually by estimating the percentage of leaf area loss on a scale from 0 to 100% with increments of 5% of the total areas removed (Sastawa et al., 2004; Mizumachi et al., 2006). Insects present on the evaluated parts (leaves, flowers, fruits) were collected with tweezers, brush, or aspirators and preserved in vials with 70% alcohol for future identification.

In each cardinal orientation a total of 900 leaves (n sample), 225 flowers (n sample) (July to September), and 240 fruits (n sample) (September to January) of *C. brasiliense* were evaluated during the experimental period.

Statistical analysis

The abundance of herbivore and natural enemy individuals, species richness, and diversity were calculated in each cardinal orientation. The formula of Hill (Hill, 1973) was used to calculate the diversity, while Simpson indices were used to calculate the abundance and richness of species (Townsend et al., 2006; Lazo et al., 2007). The species of herbivores and natural enemies were classified as: a) constant (frequency ≥ 50%), b) common (10% < frequency ≤ 49%), and c) rare (frequency ≤ 10%) in the observed samples (Siqueira et al., 2008).

The effect of diversity index, number of individuals, and species of herbivore insects on the diversity index, number of individuals, and species of natural enemies; numbers of ants, predator thrips and bugs, spiders, ladybeetles, and green lacewing on the number of damaged fruits, percentage of defoliation, and number of Lepidoptera leaf miners were submitted for the analysis of variance (ANOVA) ($P < 0.05$) and simple regression analysis ($P < 0.05$). The effect of cardinal orientation of branches on the ecological indices, and number of individuals of each species of herbivore insects and

Table 1. Effect of cardinal orientation in the Hill's diversity index, number of individuals and of species of natural enemies and herbivore insects/tree (average ± standard error) of *Caryocar brasiliense*. Montes Claros, Minas Gerais State, Brazil.

Variables	North	South	West	East
Natural enemies				
Diversity index	5.35 ± 0.67	5.80 ± 0.78	6.63 ± 0.92	6.36 ± 0.82
No. of individuals	9.96 ± 1.77	8.48 ± 1.74	9.60 ± 2.10	11.16 ± 2.53
No. of species	2.96 ± 0.30	3.00 ± 0.33	3.28 ± 0.38	3.24 ± 0.35
Herbivores				
Diversity index	2.43 ± 0.33	2.44 ± 0.34	2.24 ± 0.34	2.64 ± 0.53
No. of individuals	5.32 ± 0.89	5.28 ± 0.94	6.60 ± 1.45	4.76 ± 1.04
No. of species	1.64 ± 0.23	1.52 ± 0.19	1.44 ± 0.19	1.56 ± 0.25

Non significant by ANOVA (P > 0.10).

natural enemies was tested with ANOVA (P < 0.05) with subsequent Tukey's test (P < 0.05).

RESULTS

The Hill's diversity index, number of individuals and species of herbivore insects, and natural enemies were similar (P > 0.10) among the cardinal sectors of *C. brasiliense* trees (Table 1). We observed thirteen rare, two common, and one constant species of herbivore insects; and three rare, eight common, and one constant species of natural enemies on *C. brasiliense* trees (Table 2).

The number of bored fruits was lower on the south side, number of scraped fruits, and Lepidoptera leaf mines were more numerous on the west side, while the defoliator *Naupactus* sp.3 (Coleoptera: Curculionidae) was more abundant on the south side on *C. brasiliense* trees (Tables 3 and 4). The natural enemies, *Crematogaster* sp. (Hymenoptera: Formicidae) and *Zelus armillatus* (Lep. and Servi) (Hemiptera: Reduviidae) presented highest abundance on the leaves on the east and north sides of *C. brasiliense* trees, respectively (Tables 4 and 5).

The increase in the diversity index and number of species of herbivore insects raised these same ecological parameters of the natural enemies. Higher number of ants was observed in damaged fruits. *C. brasiliense* leaves that presented large numbers of ants had a low percentage of defoliation and Lepidoptera leaf mines. The number of predator bugs correlated negatively with the percentage of defoliation (Figure 1).

DISCUSSION

We did not observe significant effect of the orientation of branches of *C. brasiliense* on the diversity index, number of individuals and species of Coleoptera, Lepidoptera, and Hymenoptera herbivores and their natural enemies. The lack of any relationship can perhaps be explained by the different colonization niches in the canopy of this tree and /or by the high number of rare species (57%) that prevented us to find any trend. Although environmental complexity and host plants attributes influence the diversity of arthropods, phytophagous and natural enemies (Gratton and Denno, 2003; Auslander et al., 2003; Coyle et al., 2005; Espírito Santo et al., 2007; Lazo et al., 2007; Leite et al., 2011a, b), no trend was observed in a large sample of the studied species. Future studies shall address this question in a broader area.

The higher number of scraped fruits and Lepidoptera leaf mines in the west and *Naupactus* sp. 3 in the south side of *C. brasiliense* trees may be explained by: 1) the direction of wind was prevalent from northeast to eastern (Leite et al., 2006, 2009, 2011b), 2) higher sunlight in the north side in Southern Hemisphere (Vianello and Alves, 2000), and 3) avoid natural enemies as ants and predator bugs in more number in the east and north sides of *C. brasiliense* trees, respectively. On the other hand, we observed small number of bored fruits in the south side, which had lower fruit production of this plant (Leite et al., 2006).

The direction of wind may influence dispersion of insects in their migrations (Pathak et al., 1999; Tixier et al., 2000; Auslander et al., 2003; Schooley and Wiens, 2003; Feng et al., 2004, 2005; Leite et al., 2009, 2011b) and pollination. The wind speed was over 2.0 m/s which reduced the visits of bees to flowers (Dutra and Machado, 2001). The desiccant effect of wind specially in regions with low relative humidity and high temperature, typical of cerrado vegetation of the semi-arid north of Minas Gerais State, Brazil, can reduce fruit production and photosynthesis causing bad formation or fall of flowers and fruits (Leite et al., 2006), which in turn influences insect attack. The desiccant effect of wind was higher on the east and north sides of *C. brasiliense* trees

Table 2. Order and family of species observed in *Caryocar brasiliense* tree and their feeding and frequency (during the day). Montes Claros, Minas Gerais State, Brazil.

Order	Family	Specie	Feeding	Abundance
Coleoptera	Alticidae	*Oedionychus* sp.	Leaves	Rare-L
	Carabidae	*Calosoma* sp.	Predator	Rare-L
	Chrysomelidae	*Diabrotica speciosa* Germar	Leaves	Rare-L
	Coccinellidae	*Neocalvia fulgurata* Mulsant	Predator	Rare-L
	Curculionidae	*Naupactus* sp. 1	Fruits	Rare-Fr
			Leaves	Rare-L
		Naupactus sp. 2	Fruits	Rare-Fr
		Naupactus sp. 3	Leaves	Rare-L
		Rhinochenus stigma (L.)	Leaves	Rare-L
	Elateridae	*Apoptus* sp.	Leaves	Common-L
	Tenebrionidae	*Camaria* sp.	Leaves	Rare-L
Lepidoptera	NI*	NI – leaf miner	Leaves	Constant-L
	Arctiidae	NI	Leaves	Rare-L
	Ctenuchiidae	NI	Leaves	Rare-L
	Nymphalidae	*Eunica bechina* Talbot	Leaves	Rare-L
	Oecophoridae	NI	Leaves	Rare-L
	Sesiidae	*Carmenta* sp.	Fruits	Common-Fr
Hemiptera	Geocoridae	*Epipolops* sp.	Predator	Common-L
	Reduviidae	*Zelus armillatus* (Lep. and Servi)	Predator	Common-L
Hymenoptera	Apidae	*Trigona spinipes* Fabr.	Pollinator	Rare-Fl
	Formicidae	*Crematogaster* sp.	Generalist	Constant–L
			Generalist	Common-Fl
			Generalist	Common-Fr
		Pseudomyrmex termitarius Smith	Predator	Common-L
			Predator	Rare-Fr
Neuroptera	Chrysopidae	*Chrysoperla* sp.	Predator	Common-L
Orthoptera	Tettigoniidae	*Oxyprora flavicornis* Redtenb.	Leaves	Rare-L
Thysanoptera	Phlaeothripidae	*Holopothrips* sp.	Predator	Common-L
		Trybonia intermedius Bagnall	Predator	Common-L
		Trybonia mendesi Moulton	Predator	Common-L
Araneae	**	Complex of spiders	Predator	Common-L
				Rare-Fl

*NI = none identified. **complex of spiders = *Cheiracanthium inclusum* Hentz (Miturgidae); *Peucetia rubrolineata* (Keyserling) (Oxyopidae); *Anelosimus* sp., *Achaearanea hirta* (Taczanowski) (Theridiidae); *Gastromicans albopilosa* Simon, *Chira bicirculigera* Soares and Camargo, *Rudra humilis* Mello-Leitão, *Thiodina melanogaster* Mello-Leitão and *Lyssomanes pauper* Galiano (Salticidae); *Dictyna* sp. and sp.1 (Dictynidae); *Tmarus* sp. and sp.1 (Thomisidae); *Argiope argentata* (Fabr.), *Gasteracantha cancriformes*, *Argiope* sp., *Parawixia* sp. and sp.1 (Araneidae); and Anyphaenidae. L = leaves, Fl = flowers, and Fr = fruits

but different sun exposure may influence the quality of host plant tissues for insects (Fernandes, 1990; Fernandes et al., 2000; Unsicker and Mody, 2005). Richardson showed a lower number of species and individuals of insects on the sunny side of Australian *Melaleuca* trees (Richardson et al., 1999).

Table 3. Effect of cardinal orientation in the number of bored fruits, scraped fruits, and damaged flowers per tree, and percentages of defoliation per leave, bored and scraped fruits, and damaged flowers, number of *Naupactus* sp.1 on the fruits and on the leaves, *Naupactus* sp.2 on the fruits, *Naupactus* sp. 3, *Apoptus* sp., *Rhynochenus* stigma, *Oxyprora flavicornis*, Lepidoptera leaf miners, *Eunica bechina*, Ctenuchiidae, Oecophoridae, Arctiidae, *Camaria* sp., *Oedionychus* sp., and *Diabrotica speciosa* on the leaves, and *Trigona spinipes* in the flowers/tree on *Caryocar brasiliense*. Montes Claros, Minas Gerais State, Brazil.

Herbivores	North	South	West	East
No. of bored fruits	0.88 ± 0.28[a]	0.16 ± 0.09[b]	1.16 ± 0.36[a]	0.72 ± 0.23[a]
No. of scraped fruits	5.70 ± 0.67[ab]	4.40 ± 0.47[ab]	6.40 ± 0.73[a]	4.00 ± 0.42[b]
No. of damaged flowers*	0.60 ± 0.37	0.08 ± 0.05	0.20 ± 0.12	0.16 ± 0.12
% of defoliation*	2.79 ± 0.31	2.57 ± 0.27	3.22 ± 0.52	2.65 ± 0.28
% of bored fruits*	10.12 ± 2.62	13.03 ± 3.50	17.68 ± 4.64	13.92 ± 3.68
% of scraped fruits*	26.67 ± 4.33	29.78 ± 4.68	30.65 ± 5.21	26.57 ± 4.62
% damaged flowers*	1.91 ± 1.11	0.43 ± 0.33	0.81 ± 0.51	0.93 ± 0.71
Naupactus sp.1-Fr*	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Naupactus sp.1-L*	0.04 ± 0.03	0.08 ± 0.05	0.08 ± 0.05	0.08 ± 0.05
Naupactus sp.2-Fr*	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.03
Naupactus sp.3-L	0.08 ± 0.05[ab]	0.52 ± 0.30[a]	0.00 ± 0.00[b]	0.04 ± 0.03[b]
Apoptus sp.-L*	0.16 ± 0.07	0.04 ± 0.03	0.12 ± 0.08	0.16 ± 0.07
Rhynochenus stigma-L*	0.04 ± 0.03	0.08 ± 0.05	0.00 ± 0.00	0.04 ± 0.03
Oxyprora flavicornis-L*	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Lepidoptera miners-L	6.50 ± 0.66[ab]	6.00 ± 0.68[ab]	8.60 ± 1.14[a]	4.00 ± 0.91[b]
Eunica bechina-L*	0.00 ± 0.00	0.12 ± 0.06	0.04 ± 0.03	0.04 ± 0.03
Ctenuchiidae-L*	0.08 ± 0.05	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Oecophoridae-L*	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.03	0.04 ± 0.03
Arctiidae-L*	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.03
Camaria sp.-L*	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.03	0.00 ± 0.00
Oedionychus sp.-L*	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.04	0.00 ± 0.00
Diabrotica speciosa-L*	0.00 ± 0.00	0.04 ± 0.03	0.00 ± 0.00	0.04 ± 0.03
Trigona spinipes-Fl*	0.00 ± 0.00	0.40 ± 0.03	0.00 ± 0.00	0.00 ± 0.00

Means followed by the same letter (± standard error) in the line are not different by the test of Tukey (P < 0.05).* non significant by ANOVA. L = leaves, Fl = flowers, and Fr = fruits.

The lower number of ants and predator bugs may explain the higher number of Lepidoptera leaf mines and defoliation on the west and south sides of *C. brasiliense* trees. This could difficult the colonization of *C. brasiliense* trees by Lepidoptera and Coleoptera herbivores on these sides of the *C. brasiliense* canopy. Predators can respond to local increases on vegetation complexity and alternative prey, with higher efficiency against herbivores (Auslander et al., 2003). The ants may reduce the infestation of *Eunica bechina* Talbot (Lepidoptera: Nymphalidae) and *Edessa rufomarginata* (De Geer) (Hemiptera: Pentatomidae), *Prodiplosis floricola* Felt (Diptera: Cecidomyiidae), and petiole gall insects (Hymenoptera: Chalcidoidae) (Freitas and Oliveira, 1996; Oliveira, 1997), as observed on *C. brasiliense* trees. The east side of trees was apparently more unfavorable to insect herbivores in the African Savanna with higher leaf damage on west and north sides of them. A possible explanation for these findings could be related to species specific reactions (plants and herbivores) and to non biotic environment conditions (Unsicker and Mody, 2005). Also, the distribution of herbivores could reflect the need to avoid predators (that is, to seek enemy free space) besides reactions to chemical composition of host plant or microclimate (Unsicker and Mody, 2005).

The Coleoptera and Lepidoptera species with higher potential to become pests in commercial *C. brasiliense* plantations are *Apoptus* sp. (Coleoptera: Curculionidae) and Lepidoptera miners on leaves, and *Carmenta* sp. (Lepidoptera: Sesiidae) on fruits.

The speed and direction of the wind and sun-exposed can affect the distribution of Lepidoptera and Coleoptera herbivores in the savanna, where they avoid the side of *C. brasiliense* trees crown more exposed to wind and sun.

These insects were also affected by predators on this plant. Besides, it reinforces the importance of defoliator and woodborer insects and the necessity of studying population dynamics of these organisms in arboreal systems of the Brazilian savanna.

Table 4. Effect of cardinal orientation of *Caryocar brasiliense* branches on the ecological indices and abundance of herbivores and natural enemies by ANOVA. Montes Claros, Minas Gerais State, Brazil.

Variables	ANOVA		Variables	ANOVA	
Natural enemies	**F**	**P**	**Herbivores**	**F**	**P**
Diversity index	NS	NS	No. of scraped fruits	2.303	0.08421
No. of individuals	NS	NS	No. of damaged flowers	NS	NS
No. of species	NS	NS	% of defoliation	NS	NS
Crematogaster sp.-L	4.269	0.00785	% of bored fruits	NS	NS
Crematogaster sp.-Fl	NS	NS	% of scraped fruits	NS	NS
Crematogaster sp.-Fr	NS	NS	% damaged flowers	NS	NS
P. termitarius-L	NS	NS	*Naupactus* sp. 1-Fr	NS	NS
*P. termitarius*Fr	NS	NS	*Naupactus* sp. 1-L	NS	NS
Spiders-L	NS	NS	*Naupactus* sp. 2-Fr	NS	NS
Spiders-Fl	NS	NS	*Naupactus* sp. 3-L	3.411	0.02341
Zelus armillatus-L	2.597	0.04892	*Apoptus* sp.-L	NS	NS
Epipolops sp.-L	NS	NS	*Rhynochenus stigma*-L.	NS	NS
Neocalvia fulgurate-L	NS	NS	*Oxyprora flavicornis*-L	NS	NS
Chrysoperla sp.-L	NS	NS	Lepidoptera miners-L	2.535	0.07786
Calosoma sp.-L	NS	NS	*Eunica bechina*-L	NS	NS
Holopothrips sp.-L	NS	NS	Ctenuchiidae-L	NS	NS
Trybonia sp.-L	NS	NS	Oecophoridae-L	NS	NS
Herbivores	NS	NS	Arctiidae-L	NS	NS
Diversity index	NS	NS	*Camaria* sp.-L	NS	NS
No. of individuals	NS	NS	*Oedionychus* sp.-L	NS	NS
No. of species	NS	NS	*Diabrotica speciosa*-L	NS	NS
No. of bored fruits	4.838	0.00400	*Trigona spinipes*-Fl	NS	NS

NS = non significant. L = leaves, Fl = flowers, and Fr = fruits.

Table 5. Effect of cardinal orientation in the number of *Crematogaster* sp. and *Pseudomyrmex termitarius* on the leaves, flowers, and fruits, and complex of spiders on the leaves and in the flowers, *Zelus armillatus*, *Epipolops* sp., *Neocalvia fulgurata*, *Chrysoperla* sp., *Calosoma* sp., *Holopothrips* sp., and *Trybonia intermedius* + *Trybonia mendesi* on the leaves/tree on *Caryocar brasiliense*. Montes Claros, Minas Gerais State, Brazil.

Natural enemies	North	South	West	East
Crematogaster sp.-L	1.72 ± 0.34[b]	2.24 ± 0.47[ab]	1.64 ± 0.47[b]	3.76 ± 0.95[a]
Crematogaster sp.-Fl*	1.72 ± 0.75	1.40 ± 0.88	2.76 ± 1.53	2.48 ± 1.08
Crematogaster sp.-Fr*	0.88 ± 0.36	0.44 ± 0.40	0.44 ± 0.20	0.84 ± 0.58
P. termitarius-L*	0.12 ± 0.06	0.16 ± 0.07	0.24 ± 0.08	0.20 ± 0.08
P. termitarius-Fr*	0.00 ± 0.00	0.04 ± 0.03	0.00 ± 0.00	0.00 ± 0.00
Spiders-L*	0.68 ± 0.21	0.56 ± 0.16	0.48 ± 0.11	0.60 ± 0.18
Spiders-Fl*	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.03	0.08 ± 0.05
Zelus armillatus-L	2.16 ± 1.08[a]	0.60 ± 0.27[ab]	1.48 ± 0.61[ab]	0.36 ± 0.15[b]
Epipolops sp.-L*	0.16 ± 0.09	0.32 ± 0.17	0.16 ± 0.09	0.20 ± 0.08
Neocalvia fulgurate-L*	0.12 ± 0.08	0.08 ± 0.05	0.16 ± 0.12	0.24 ± 0.14
Chrysoperla sp.-L*	0.84 ± 0.62	0.36 ± 0.25	0.88 ± 0.61	0.28 ± 0.16
Calosoma sp.-L*	0.00 ± 0.00	0.00 ± 0.00	0.08 ± 0.05	0.00 ± 0.00
Holopothrips sp.-L*	0.32 ± 0.09	0.32 ± 0.12	0.28 ± 0.12	0.20 ± 0.08
Trybonia sp.-L*	1.24 ± 0.46	1.96 ± 0.91	0.96 ± 0.39	1.92 ± 0.98

Means followed by the same letter (± standard error) in the line are not different by the test of Tukey ($P < 0.05$).* non significant by ANOVA. L = leaves, Fl = flowers, and Fr = fruits.

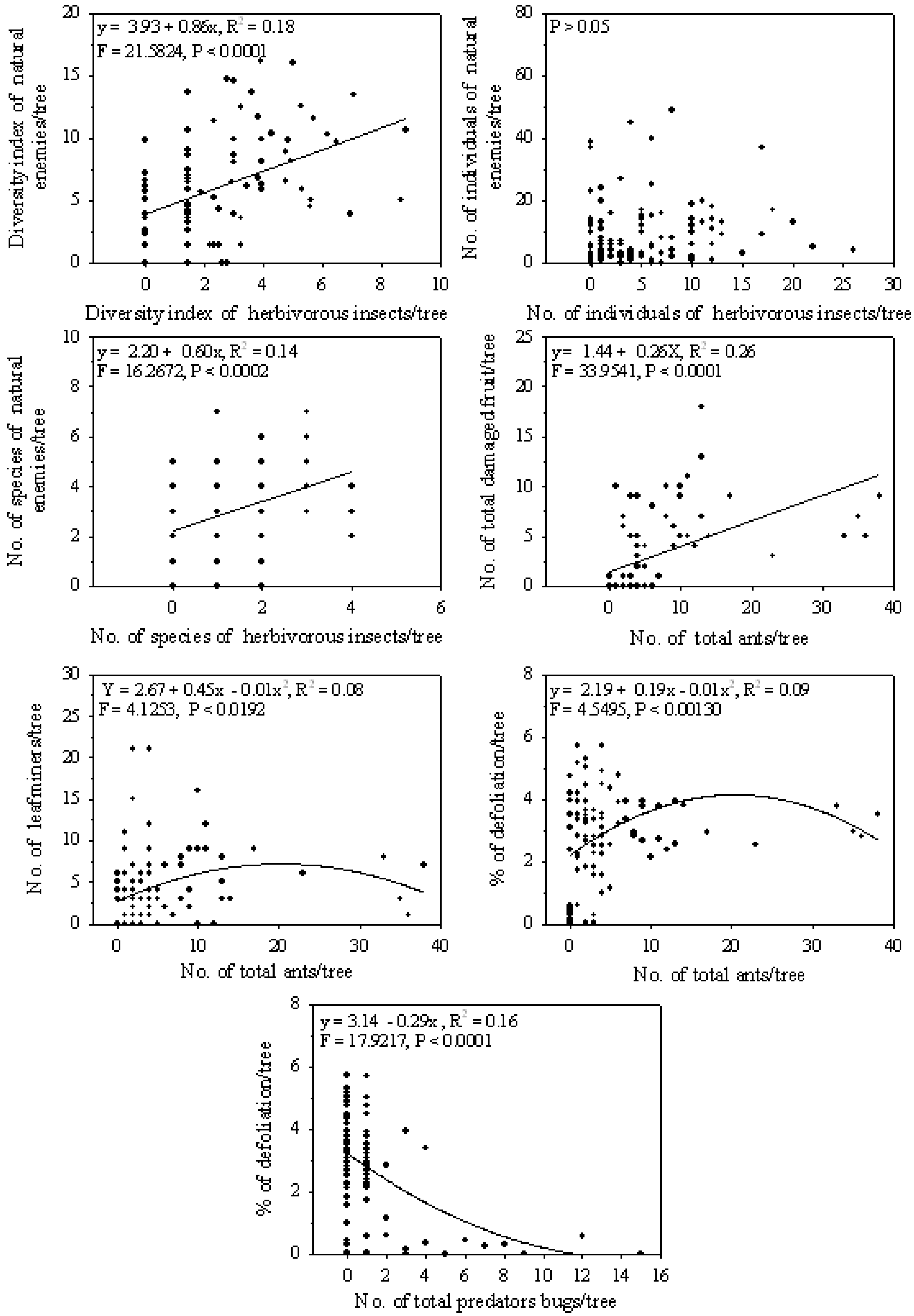

Figure 1. Effect of diversity index, number of individuals and, species of herbivore insects on the diversity index, number of individuals, and species of natural enemies, numbers of total ants on the number of damaged fruits, percentage of defoliation, and number of Lepidoptera leaf miners/tree, and number of total predator bugs on the percentage of defoliation. Montes Claros, Minas Gerais State, Brazil. The symbols represent the averages.

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