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Effects of environmental and architectural diversity of *Caryocar brasiliense* (Malpighiales: Caryocaraceae) on *Edessa ruformaginata* (Hemiptera: Pentatomidae) and its biology

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ABSTRACT. We studied the effect of environmental complexity and plant architecture on the abundance and biology of *Edessa rufomarginata* (Hemiptera: Pentatomidae) bugs in pastures and cerrado areas. We observed higher numbers of bugs on *Caryocar brasiliense* (Malpighiales: Caryocaraceae) trees in the cerrado than in the pasture areas. The bugs were more abundant on leaves and branches than they were on fruits. The fruit production of *Caryocar brasiliense* was higher in the pastures than in the cerrado areas. The abundance of bugs was affect positively by aluminum, organic matter, and tree height but was affected negatively by soil pH. The productivity of *C. brasiliense* was correlated negatively with aluminum, pH, and number of bugs but was correlated positively with phosphorus and calcium. The number of eggs per clutch was 14.3, the viability was 93% and the embryonic period was 6.9 days. We observed four nymphal instars, the sex ratio was 0.43, and the duration of the life cycle of *E. rufomarginata* was 156 days. We did not obtain eggs from the adults (F1), which indicated that the leaves were not a good food resource. A diverse environment and high plant crown structure favored populations of *E. rufomarginata*. The abundance of and the damage caused by this insect indicate that *E. rufomarginata* is a potential pest on *C. brasiliense* trees.

Keywords: pequi, fruit production, soil, stink bug.

Efeito da diversidde ambiental e arquitetura de *Caryocar brasiliense* (Malpighiales: Caryocaraceae) em *Edessa ruformaginata* (Hemiptera: Pentatomidae) e sua biologia

RESUMO. Estudou-se o efeito de complexidade ambiental e arquitetura de plantas na abundância do percevejo *Edessa rufomarginata* (Hemiptera: Pentatomidae) em pastagens e cerrado e também sua biologia. Observou-se maior número de percevejos em *Caryocar brasiliense* (Malpighiales: Caryocaraceae) em cerrado do que em pastagens. Percevejos foram mais abundantes em folhas e ramos do que em frutos. Pequizeiro teve maior produção de frutos em pastagens do que em cerrado. A abundância de percevejos foi afetada positivamente com alumínio, matéria orgânica e altura de árvore, mas negativamente com pH. Produtividade de pequizeiros foi afetado negativamente com alumínio, pH e número de percevejos, mas positivamente com fósforo e cálcio. O número de ovos por postura foi de 14,3; com viabilidade de 93% e período embriônico de 6,9 dias. Observou-se quatro instares ninfais, razão sexual foi de 0,43 e a duração total do ciclo de vida de *E. rufomarginata* foi de 156 dias. Não se obteve ovos de adultos (F1), indicando que folhas não foram boas como recurso alimentar. Maior diversidade ambiental e de estrutura de copa da planta favoreceu populações de *E. rufomarginata*. Abundância e danos deste inseto indicam que é uma potencial praga para árvores de *C. brasiliense.*

Palavras-chave: pequi, produção de frutos, solo, percevejos.

Introduction

The trees of *Caryocar brasiliense* (Malpighiales: Caryocaraceae) are widely distributed in the cerrado (Bridgewater, Ratter, & Ribeiro, 2004; Leite, Veloso, Zanuncio, Fernandes, & Almeida, 2006) and can reach over 10 m in height and 6 m in width in the canopy (Leite et al., 2006). The internal mesocarp of the fruits is rich in oil, vitamins, and proteins, and it contains many compounds of medicinal importance. Moreover, humans use the fruits for food, in the production of cosmetics and lubricants and in the pharmaceutical industry (Ferreira & Junqueira, 2007; Garcia, Franco, Zuppa, Antoniosi Filho, & Leles, 2007; Khouri et al., 2007; Segall, Artz, Raslan, Ferraz, & Takahashi, 2005).

Federal laws protect the trees of *Caryocar brasiliense*, and the trees are thus left untouched in the deforested areas of the cerrado. The isolated plants of this species in the agro-landscape suffer from increased damage by the stinkbug *Edessa rufomarginata* (Hemiptera: Pentatomidae). For the fruit collectors, this stinkbug is an important pest on *C. brasiliense* (Leite et al., 2012a). Therefore, the biology and ecology of this insect on this valuable tree must be understood, including where the stinkbug occurs naturally and where it is found in plantations on the Brazilian cerrado.

The position of the branches in a tree affects the abundance of insects because of the following conditions: 1) wind, depending on the direction (Feng, Wu, Ni, Cheng, & Guo, 2005; Leite, D'ávila, Cerqueira, Nascimento, & Fernandes, 2011a; Leite, Nascimento, Jesus, Alves, & Fernandes, 2011b; Leite et al., 2011c), causes the desiccation of leaves and the drop of flowers and fruits (Leite et al., 2006); 2) exposure to the sun, which may influence the quality of host plant tissues (Unsicker & Mody, 2005); 3) microclimate (Leite et al., 2011c), and 4) preference by herbivores for parts of the plants with the lowest numbers of natural enemies (enemy-free space) (Leite et al., 2012b; Unsicker & Mody, 2005). Natural enemies have been reared on *C. brasiliense* to support pest management programs for this plant and to study their spatial distribution within individual trees. Some hypotheses were advanced to explain the different levels of insect abundance and diversity and include the following: 1) environments with increased complexity increase the diversity of herbivorous species associated with a host plant and, generally, decrease their abundance (Auslander, Nevo, & Inbar, 2003; Lazo, Valdes, Sampaio, & Leite, 2007); 2) host plants attributes, such as complex architecture, increase the diversity and abundance of herbivorous insects (Espírito-Santo, Neves, Andrade-Neto, & Fernandes, 2007; Leite et al., 2011c; d; 2012c; d); and 3) soil characteristics that favor trees indirectly effect the abundance of herbivorous insects (e.g. nutritional quality) (Auslander et al., 2003; Espírito-Santo et al., 2007; Leite et al., 2011d; 2012c; d).

We investigated the biology and the population dynamics of *E. rufomarginata* on this economically important species of plant, *C. brasiliense*. In this study, we provide data on the spatial distribution of *E. rufomarginata* on individual trees of *C. brasiliense* and on the effects of environmental and architectural diversity of this plant on the stinkbug populations in five different areas.

Material and methods

The study was performed in five rural communities in sub-basins of the river 'Rio dos Cochos', which were 'Bom Jantar' (S 15º 33' 52.0', W 44º 29' 19.0', 479 m asl), 'Morro Vermelho' (S 15º 27' 28.9', W 44º 28' 00.0', 585 m asl), 'Sambaíba' (S 15º 23' 47.2', W 44º 32' 12.1', 621 m asl) and 'Tabua' (S 15º 21' 57.7', W 44º 36' 58.0', 672 m asl) in Januária municipality Januária and 'Cabeceira dos Cochos' (S 15º 17' 57.7', W 44º 32' 12.8', 711 m asl) in Cônego Marinho municipality, Minas Gerais State, Brazil. The study was conducted from Aug to November 2007 and during the same period in 2008 (green fruits and fixed in the plants). The regions have dry winters and rainy summers, and the climate is designated as Aw (tropical savanna) according to the Köppen climate classification (Vianello & Alves, 2000). In each of the areas, 20 adult plants (marked with red paint and georeferenced) were sampled at random, with minimum distances of 30 m between the plants and approximately 10 Km between plant communities. The 'Cabeceira dos Cochos' and 'Tabua' sites were characterized as regenerating cerrado, and the 'Bom Jantar', 'Morro Vermelho' and 'Sambaíba' were pasture that only had trees of C. brasiliense.

We evaluated fruit production, the trunk diam at 0.10 and 1.50 m above the ground, the tree height and crown width on C. brasiliense plants, the physical and chemical characteristics of the soils, and the incidence of E. rufomarginata. The production of fruits/tree was estimated by the average estimates of all of the fruits obtained by three evaluators, once per year after natural untwining. The measurements of trunk diam were obtained (August, 2007) with measurements of the circumference 0.10 and 1.50 m above the ground. The height of the plants (HP) was measured (August, 2007) with an inclinometer, which measured the angle of inclination formed between the visual horizon of the reader and the highest branch of the plant. The height was calculated by applying the principle of tangent as follows: $HP = y/tg\partial + hL$ where HP is the height of the plant, y is the distance of the observer from the plant, $tg\partial$ is the ∂ tangent of the angle, measured with the inclinometer, and hL is the height of the eyes of the reader. The diam of the crown (August,

2007) was determined as the average of the values of its north-south and east-west diam. For the chemical and physical analyses of the soils, 3 samples were collected at the edge of the canopy of each C. brasiliense trees to a depth of 20 cm. These soils were forwarded to the Soil Laboratory of the Institute of Agricultural Sciences/Federal University of Minas Gerais (ICA/UFMG). The average numbers of E. rufomarginata (adults and nymphs) were evaluated monthly (in the morning) by 2 people who examined 5 branches, 5 leaves and 5 fruits for each cardinal direction (north, south, east, and west) of the 20 trees area-1.

The data were transformed with $\sqrt{x} + 0.5$ (when necessary) after testing with Liliefors (normal distribution) and Cochran and Bartellet (homogeneity of variances). The data were analyzed with ANOVA ($p < 0.05$) and subsequently with the Scott-Knott ($p < 0.01$). Multiple regressions were performed using the stepwise procedure with only the significant parameters of the equations ($p < 0.05$). To study the biology of E. rufomarginata, we manually collected 260 E. rufomarginata adults from C. brasiliense trees in 'Cônego Marinho' municipality, Minas Gerais State, Brazil, from Sep. 2008 to Mar. 2009. These insects were colocated in transparent white plastic pots (0.5 L) and subsequently transported to the ICA/UFMG laboratory. The insects were sexed and 13 pairs were put in a wooden cage covered with organza fabric (60 x 40 x 30 cm) at an average temperature of 25oC. In each cage, 5 seedlings of C. brasiliense were provided as food, and distilled water provided absorbed on a cotton swab. The seedlings and water were exchanged when necessary.

We conducted daily evaluations of the number of egg masses, the number of eggs/egg mass and the morphology of the eggs from 260 adults. The eggs were collected and placed in petri dishes in an incubator at 25±2°C with a 12:12 hour L:D cycle, and we evaluated the incubation period and the percentage hatch of the eggs daily. Five nymphs (first instars) from each of 69 egg masses (total 345 nymphs) obtained in the laboratory were placed in organza bags (40 x 25 cm) that covered the branches of C. brasiliense in the orchard of the ICA/UFMG. We evaluated the following characteristics of the nymphs: number of instars, longevity (days), width (cm) and length (cm; using a digital caliper), morphological characteristics (i.e. color) and survival (%) of the nymphs in each instar. After the insects transformed into adults, we recorded the following characteristics: length, width, and diam (cm; using a digital caliper), weight (mg; a digital scale with four digits), shape and color of the body, and sex ratio (gender was determined by examining the terminal part of the abdomen). Of these sexed adults (135 total), 2 females and one male were placed in an organza bag on a branch of a C. brasiliense tree (45 trees), and the longevity (days), number of egg masses and number of egg/egg mass were evaluated.

The data were transformed with $\sqrt{x} + 0.5$ (when necessary) after testing Liliefors (normal distribution) and Cochran and Bartellet (homogeneity of variances). The data were analyzed with ANOVA ($p < 0.05$) and subsequently with the Scott-Knott test ($p < 0.01$).

Results and discussion

We observed the highest number of E. rufomarginata on the leaves and branches on C. brasiliense trees at the 'Cabeceira dos Cochos' site, followed by the 'Tabua' site, and then the 'Bom Jantar', 'Morro Vermelho' and 'Sambaíba' areas in 2007 (Table 1). However, the highest numbers of this insect on the fruits of C. brasiliense were observed at the 'Tabua' site during this period. In the 2008-09 seasons, we observed the highest number of E. rufomarginata on the leaves and branches of C. brasiliense at the 'Morro Vermelho' site. In the second season, we did not observe differences among the areas in the number of insects on the fruits of C. brasiliense.

The numbers of the stinkbug Edessa rufomarginata were higher on the leaves, branches, and fruits on the C. brasiliense trees in 'Tabua' in 2007 than in 2008. The abundance of this insect was higher on the leaves and branches in 2008 than in 2007 in the 'Morro Vermelho' and 'Sambaíba' areas. However, for the 'Cabeceira dos Cochos' site, we observed the highest numbers of the stinkbug in the first year. We did not detect this pest in the 'Bom Jantar' area. In general, E. rufomarginata preferred to live on the leaves and branches instead of the fruits. However, in the 'Tabua' area, this insect was observed more on the branches than other areas. The C. brasiliense trees had greater fruit production in 2008 than in 2007 at the 'Sambaíba', 'Cabeceira dos Cochos' and 'Bom Jantar' sites but not at 'Morro Vermelho' in 2007. We did not observe difference between seasons in the fruit production at 'Tabua' (Table 2).

Table 1. Abundance of *Edessa ruformaginata* (average ± SE) on the leaves, branches, and fruits of *Caryocar brasiliense*, as a function of branch orientation and locations – reproductive period (August to November) in 2007 and 2008.

Orientation	Januária				C. Marinho
	Pasture	Pasture	Pasture	Cerrado	Cerrado
	Morro Vermelho	Sambaíba	Bom Jantar	Tabua	Cabeceira dos Cochos
			Edessa ruformaginata/leaf – 2007		
North	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.45±0.16Ab	8.25±1.62Aa
South	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.55±0.27Ab	9.85±2.13Aa
East	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.50±0.27Ab	9.70±1.53Aa
West	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.70±0.29Ab	8.90±1.60Aa
Average	0.0±0.0c	0.0±0.0c	0.0±0.0c	0.55±0.12b	9.18±0.85a
			Edessa ruformaginata/leaf – 2008		
North	0.30±0.20Aa	0.0±0.0Aa	0.0±0.0Aa	0.05±0.05Aa	0.30±0.17Aa
South	0.90±0.54Aa	0.10±0.10Aa	0.0±0.0Aa	0.0±0.0Aa	0.15±0.10Aa
East	0.35±0.19Aa	0.25±0.17Aa	0.0±0.0Aa	0.0±0.0Aa	0.15±0.10Aa
West	1.60±0.82Aa	0.15±0.10Ab	0.0±0.0Ab	0.0±0.0Ab	0.25±0.25Ab
Average	0.79±0.25a	0.13±0.05b	0.0±0.0b	0.01±0.01b	0.21±0.08b
			Edessa ruformaginata/branch – 2007		
North	0.0±0.0Ac	0.0±0.0Ac	0.0±0.0Ac	1.85±0.59Bb	6.85±1.93Aa
South	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	8.85±3.49Aa	5.90±1.12Aa
East	0.0±0.0Ac	0.0±0.0Ac	0.0±0.0Ac	3.25±1.22Bb	5.60±1.43Aa
West	0.0±0.0Ac	0.0±0.0Ac	0.0±0.0Ac	3.70±1.97Bb	6.95±1.61Aa
Average	0.0±0.0c	0.0±0.0c	0.0±0.0c	4.41±1.08b	6.33±0.76a
			Edessa ruformaginata/branch – 2008		
North	0.35±0.25Aa	0.20±0.09Aa	0.0±0.0Aa	0.0±0.0Aa	0.20±0.15Aa
South	0.30±0.25Aa	0.05±0.05Aa	0.0±0.0Aa	0.10±0.10Aa	0.15±0.10Aa
East	1.25±0.59Aa	0.35±0.30Ab	0.0±0.0Ab	0.0±0.0Ab	0.05±0.05Ab
West	0.35±0.18Aa	0.05±0.05Aa	0.0±0.0Aa	0.0±0.0Aa	0.25±0.14Aa
Average	0.56±0.18a	0.16±0.08b	0.0±0.0b	0.03±0.02b	0.16±0.06b
			Edessa ruformaginata/fruit – 2007		
North	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.40±0.18Aa	0.0±0.0Ab
South	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa	0.55±0.28Aa	0.45±0.44Aa
East	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.75±0.27Aa	0.15±0.14Ab
West	0.0±0.0Ab	0.0±0.0Ab	0.0±0.0Ab	0.40±0.19Aa	0.0±0.0Ab
Average	0.0±0.0b	0.0±0.0b	0.0±0.0b	0.53±0.11a	0.15±0.11b
			Edessa ruformaginata/fruit – 2008		
North	0.0±0.0Aa	0.05±0.05Aa	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa
South	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa	0.30±0.29Aa
East	0.005±0.05Aa	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa
West	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0Aa
Average	0.01±0.01a	0.01±0.01a	0.0±0.0a	0.0±0.0a	0.08±0.07a

Means followed by the same capital letter in each column or the same lower letter in each row (± standard error) are not significantly different according to the Scott-Knott test ($p < 0.01$).

The highest contents of potassium, calcium, and magnesium, the sum of bases, the capacity for cationic exchange, the cation exchange capacity at a natural pH of 7.0, and the percentage of soil base saturation of the capacity for cationic exchange at a pH of 7.0 were observed in the soils from the 'Bom Jantar' and 'Cabeceira dos Cochos' areas (Table 3). The soils of 'Cabeceira dos Cochos' had the highest pH values; the soils of 'Sambaíba' had the highest contents of phosphorus-Mehlich; and the soils of 'Sambaíba', 'Bom Jantar', and 'Cabeceira dos Cochos' had the highest contents of phosphorus-remaining. In contrast to the other sites, the soils of the 'Morro Vermelho' and 'Tabua' sites had highest contents of aluminum and H + aluminum. The aluminum saturation in the capacity of cationic exchange and the organic matter content were higher in the 'Tabua' and 'Bom Jantar' soils, respectively, than in the soils of the other sites. The gross sand content was the highest in the 'Morro Vermelho' soils; the fine sand was the highest in the 'Tabua' soils; the silt was the highest in the 'Bom Jantar' soils; and the clay content was highest in the soils of the 'Morro Vermelho', 'Sambaíba', and 'Cabeceira dos Cochos' sites. All soils were of sandy texture and were classified as dystrophic Yellow Red Latossol (Table 3).

We found that aluminum, organic matter, tree height, pH, and H + aluminum affected the abundance of *E. rufomarginata* on *C. brasiliense* trees: y = 37.60 + 114.09 xaluminum + 9.48 xorganic matter + 2.44 xtree height – 12.05 xH + aluminum - 10.79 xpH ($R^2 = 0.49$, F = 17.65, p = 0.0000). The factors affecting tree height were expressed in the following equation: y = 33.34 + 3.38 xphosphorus-Mehlich + 1.66 xcalcium – 5.83 xaluminum – 4.16 xpH ($R^2 = 0.24$, F = 7.52, p = 0.0000); and for trunk diameter at the height of 0.10 m, the factors were expressed by the equation: y = 1.91 + 0.43 xcalcium + 0.13 xorganic matter + 0.003 xphosphorus-Mehlich – 0.53 xaluminum – 0.30 xsum of bases – 0.27 xpH (R^2 = 0.38, F = 9.30, p = 0.0000). For tree canopy size, the factors were expressed by the equation: y = 56.12 + 3.41 xcalcium + 0.04 xphosphorus-Mehlich – 8.99 xaluminum – 7.94 xpH (R^2 = 0.39, F = 14.89, p = 0.0000); and for fruit production, by the equation: y = 339.63 + 84.75 xtrunk diameter at the height of 1.50 m + 73.82 xcalcium – 38.16 xpH – 9.88 xH + aluminum – 1.88 xphosphorus-Mehlich – 1.82 xaluminum saturation in the capacity of cationic exchange – 1.15 xpotassium – 0.20 x*E. rufomarginata*/branch (R^2 = 0.48, F = 10.32, p = 0.0000).

Table 2. Abundance of *Edessa ruformaginata* and fruis/tree (average ± SE) on *Caryocar brasiliense*, as a function of plant location in five different areas - reproductive period (August to November) in 2007 and 2008.

Part of the Plant	2007	2008	Average
Morro Vermelho			
Bugs/Leaf	0.0±0.0Ab	0.79±0.27Aa	0.40±0.15A
Bugs/Branch	0.0±0.0Ab	0.56±0.20Aa	0.28±0.10A
Bugs/Fruit	0.0±0.0Aa	0.01±0.01Ba	0.01±0.01B
Fruit/tree	48.95±8.74a	28.07±17.88b	38.51±9.96
Sambaíba			
Bugs/Leaf	0.0±0.0Ab	0.13±0.08Aa	0.06±0.04A
Bugs/Branch	0.0±0.0Ab	0.16±0.10Aa	0.08±0.05A
Bugs/Fruit	0.0±0.0Aa	0.01±0.01Aa	0.01±0.01A
Fruit/tree	155.11±28.20b	263.33±54.02a	210.61±31.76
Bom Jantar			
Bugs/Leaf	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0A
Bugs/Branch	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0A
Bugs/Fruit	0.0±0.0Aa	0.0±0.0Aa	0.0±0.0A
Fruit/tree	223.40±23.52b	601.45±94.48a	412.43±56.79
Tabua			
Bugs/Leaf	0.55±0.12Ba	0.01±0.01Ab	0.28±0.08B
Bugs/Branch	4.41±1.08Aa	0.03±0.02Ab	2.22±0.86A
Bugs/Fruit	0.53±0.11Ba	0.00±0.00Ab	0.26±0.07B
Fruit/tree	2.20±1.02a	2.48±1.49a	2.34±0.89
Cabeceira dos Cochos			
Bugs/Leaf	9.18±0.85Aa	0.21±0.09Ab	4.69±1.01A
Bugs/Branch	6.33±0.77Aa	0.16±0.10Ab	3.24±0.79A
Bugs/Fruit	0.15±0.11Ba	0.08±0.07Aa	0.11±0.06B
Fruit/tree	66.55±16.18b	140.80±28.55a	103.67±9.96
Average among areas			
Bugs/Leaf	1.95±0.25Aa	0.23±0.05Ab	1.09±0.24A
Bugs/Branch	2.15±0.29Aa	0.18±0.04Ab	1.17±0.25A
Bugs/Fruit	0.14±0.03Ba	0.02±0.01Bb	0.08±0.02B
Fruit/tree	98.67±11.30b	207.23±31.25a	153.22±17.08

Means followed by the same capital letter in each column or the same lower letter in each row (± standard error) are not significantly different according to the Scott-Knott test (p < 0.01).

Table 3. Physical and chemical analyses of the soil during the experimental period for the five different areas.

Parameters of the soil	Januária				C. Marinho
	Pasture	Pasture	Pasture	Cerrado	Cerrado
	Morro Vermelho	Sambaíba	Bom Jantar	Tabua	Cabeceira dos Cochos
pH in water	4.83±0.06d	5.86±0.09b	5.87±0.04b	5.37±0.02c	6.41±0.06a
Phosphorus-Mehlich 1 (mg dm^{-3})	2.42±0.17c	20.79±4.28a	8.58±1.47c	1.51±0.08c	12.05±1.75b
Phosphorus-remaining (mg L^{-1})	43.38±2.13b	49.54±0.55a	52.20±0.39a	46.40±0.62b	52.10±0.01a
Potassium (MG dm^{-3})	17.85±1.32b	26.90±4.03b	33.10±3.48a	20.45±2.46b	37.60±3.39a
Calcium ($cmol_c$ dm^{-3})	0.33±0.01c	1.03±0.14b	1.89±0.11a	0.20±0.00c	1.72±0.16a
Magnesium ($cmol_c$ dm^{-3})	0.17±0.01c	0.44±0.04b	0.80±0.06a	0.10±0.00c	0.73±0.06a
Aluminum ($cmol_c$ dm^{-3})	0.47±0.03a	0.01±0.01b	0.00±0.00c	0.43±0.01a	0.00±0.00c
H + Al ($cmol_c$ dm^{-3})	3.02±0.16a	1.98±0.08b	1.67±0.07c	2.76±0.14a	1.38±0.04c
Summ of bases ($cmol_c$ dm^{-3})	0.54±0.02c	1.53±0.19b	2.77±0.15a	0.35±0.01c	2.54±0.21a
t ($cmol_c$ dm^{-3})**	1.01±0.03c	1.61±0.18b	2.77±0.15a	0.78±0.01c	2.54±0.21a
m (%)**	46.45±1.84b	7.60±1.86c	0.00±0.00d	54.65±1.12a	0.00±0.00d
T ($cmol_c$ dm^{-3})**	3.56±0.17b	3.51±0.17b	4.44±0.17a	3.09±0.14b	3.92±0.20a
V (%)**	15.50±0.65c	41.20±3.32b	61.75±1.76a	11.90±0.72c	62.85±2.12a
Organic matter (dag kg^{-1})	2.03±0.04b	1.77±0.08c	2.30±0.09a	1.46±0.04d	1.90±0.10b
Gross sand (dag kg^{-1})***	52.05±1.85a	20.75±1.50c	44.55±1.81b	10.70±0.65d	21.40±1.30c
Fine sand (dag kg^{-1})	32.90±2.05c	64.35±1.37b	36.90±1.60c	78.70±1.28a	62.10±1.36b
Silt (dag kg^{-1})	5.80±0.54c	6.90±0.49c	12.05±0.70a	4.20±0.43d	10.00±0.73b
Clay (dag kg^{-1})	9.30±0.39a	8.10±0.46a	6.10±0.33b	6.40±0.42b	6.60±0.32a
Texture	Sandy	Sandy	Sandy	Sandy	Sandy
Soil classification	dystrophic Yellow Red Latosol				

*Means followed by the same letter in a row are not significantly different according to the Scott-Knott test at 1% probability. **t = Capacity of cationic exchange; m = Aluminum saturation in the capacity of cationic exchange; T = Cation exchange capacity at a natural pH of 7.0; V = Percentage of soil base saturation of the capacity of cationic exchange at a pH of 7.0. ***Gross sand (2–0.2 mm; dag kg^{-1}), Fine sand (0.2–0.02 mm; dag kg^{-1}), Silt (0.02–0.002 mm; dag kg^{-1}), Clay (< 0.002 mm; dag kg^{-1}).

In 2007, the highest number of *E. rufomarginata* occurred on the south side of *C. brasiliense* trees in the 'Tabua' area. We did not observe any other significant effects of the orientation of the branches on *C. brasiliense* trees in others areas in either year on the abundance of *E. rufomarginata* (Table 1).

The shortest trees of *C. brasiliense* were observed in the 'Tabua' area. In contrast, the tallest tree canopies and the largest trunk diameters at the height of 1.50 m were observed in the 'Morro Vermelho' and 'Bom Jantar' areas, and the largest trunk diameters at the height of 0.10 m were observed in the 'Morro Vermelho', 'Sambaíba', and 'Bom Jantar' areas. In general, the greatest fruit production was observed in the 'Bom Jantar' area (Table 4).

The body of the adult insects was oval with the ventral surface slightly more convex than the dorsum. The adult bugs were light brown with a brownish belly and membranous wings that were dark brown and slightly translucent. The males averaged 15.82 long and 8.64 mm wide, and females averaged 17.26 long and 9.12 mm wide (Table 5). The sex ratio was 0.43. The duration of the life cycle of *E. rufomarginata* was 156 days. The number of eggs per clutch was 14.29±0.41, with a clear preponderance of hatching and adult emergence that occurred in the evening and in the night. The eggs were laid in double rows, and the egg masses were placed everywhere and were easily visible in the cage. The eggs of *E. rufomarginata* were spheroidal, greenish and bright and were found in all parts of the breeding cages. For the eggs, we observed (n = 946) a viability of 92.75%, and the embryonic period was 6.94±0.14 days. We observed that 1st instar nymphs had traces of small pits. The newly emerged 1st instars were a translucent light green color with a yellow spot on the dorsum of the abdomen that was visible through the colorless integument. During the development, the 1st instars became oval in shape with a mean length of 3.33 mm and a mean width of 2.44 mm. The second instar nymphs were oval-shaped and bright orange in color, they averaged 4.05 long and 2.99 mm wide. The 3rd instar nymphs were a bright light brown, ovoid-shaped and 6.7 long and 3.01 mm wide. The 4th instar nymphs were shaped and colored very similar to the 3rd instars, but they were 11.46 long and 3.47 mm wide. The complete nymphal period (1-4 instars) was approximately 101 days, and the rate of survival from first instar to adults was approximately 39%. The highest mortalities occurred in the transition of the nymphs from the 3rd to the 4th instar, which reached 40%, and in the passage from the last nymph stage to adults (≈50% mortality). We did not obtain eggs from the 135 F1 adults that were reared on *C. brasiliense* leaves, with the longevity of these adults reaching 47.6±6.31 days (Table 5).

Table 4. Fruit production/tree, tree height, tree canopy size, and trunk diameter at heights of 0.10 and 1.50 m (average±SE) during the experimental period for the five different areas.

Parameters of the tree	Januária				C. Marinho
	Pasture	Pasture	Pasture	Cerrado	Cerrado
	Morro Vermelho	Sambaíba	Bom Jantar	Tabua	Cabeceira dos Cochos
Tree height (m)	12.41±0.60a	11.06±0.65a	12.26±0.57a	7.41±0.49b	10.27±0.47a
Tree canopy size (m)	16.34±0.87a	13.17±0.78b	15.97±0.89a	8.73±0.51c	11.87±0.77b
Trunk diameter -0.10 m (m)	0.69±0.03a	0.60±0.04a	0.63±0.02a	0.34±0.02b	0.43±0.02b
Trunk diameter – 1.50 m (m)	0.36±0.03a	0.24±0.03b	0.36±0.03a	0.14±0.01c	0.23±0.01b
		Fruit production/tree			
Fruits/tree (2007)	49.0±8.7Ab	155.1±28.2Ba	223.4±23.5Ba	2.2±1.0Ac	66.6±16.2Bb
Fruits/tree (2008)	28.07±17.88Bc	263.3±54.0Ab	601.5±94.5Aa	2.5±1.5Ac	140.8±28.6Ab
Fruits/tree (average)	38.5±10.00d	210.6±31.8b	412.4±56.8a	2.3±0.9e	103.7±10.0c

*Means followed by the same letter in a row are not significantly different according to the Scott-Knott test at 1% probability.

Table 5. Length and width (mm), longevity (days) and viability (%) of nymphs, and length, width and diameter (mm), and weight (mg) (average ± SE) of *Edessa rufomarginata* adults in field conditions (September 2008 to March 2009).

Instars	Parameter			
	Lenght	Width	Longevity	Viability
First	3.32±0.55D	2.44±0.05C	16.33±0.80B	93.33±2.30A
Second	4.05±0.03C	2.56±0.03C	19.36±2.38B	85.50±5.77A
Thirth	6.70±0.06B	2.99±0.04B	33.24±4.24A	60.00±13.77B
Fourth	11.46±0.12A	3.47±0.03A	32.25±4.23A	50.77±13.70B
Adults	Lenght	Width	Diameter	Weight
Male	15.82±0.11B	8.64±0.11B	4.74±0.07B	0.2023±0.0027B
Female	17.26±0.09A	9.12±0.11A	5.19±0.07A	0.2556±0.0071A

Means followed by the same letter in the same column are not significantly different according to the Scott-Knott test ($p < 0.01$).

We observed the premature fall of flowers and fruits from *C. brasiliense* caused by the attack of *E. rufomarginata*, as reported by Silva and Oliveira (2010). Additionally, Leite et al. (2012a) reported on the high potential of *E. rufomarginata* to be a pest in commercial *C. brasilienses* plantations on flowers and fruits. The 'Bom Jantar' (pasture) area did not have *E. rufomarginata*, and the *C. brasiliense* trees had the highest production of fruits. However, the soils in this area had the highest contents of organic matter and silt and the largest *C. brasiliense* trees, which might also explain the highest fruit production. In general, we noted positive effects of phosphorus, calcium and organic matter and the negative effects of aluminum and pH on the size of *C. brasiliense* trees and that size of the trees was directly related to the production of fruit. Similary, Leite et al. (2006) observed more production of *C. brasiliense* fruits for the pasture trees (biggest trees) than for the trees on the cerrado (smallest trees) in Montes Claros, Minas Gerais State. Moreover, the farmers left forest reserves in areas with soils with poor physical structure (sandy or rocky) in the cerrado in the north of Minas Gerais State, Brazil which reduced production and the natural regeneration of *C. brasiliense* (Leite et al., 2006, 2011d).

The abundance of *E. rufomarginata* was correlated positively with aluminum and organic matter contents and negatively with pH values. Leite et al. (2012d) found a positive effect of aluminum concentration on the percentage of defoliation and on the number of lepidopteran leaf miners but found a negative correlation with soil pH and the percentage of defoliation and the number of lepidopteran leaf miners on *C. brasiliense* trees. The higher numbers of *E. rufomarginata* were observed on the *C. brasiliense* trees that had the largest canopies. The larger *C. brasiliense* trees had more food resources than other trees did for insects to increase diversity and abundance, as was observed for wood-borers (Lepidoptera: Cossidae) and populations of defoliators (Coleoptera and Lepidoptera) (Leite et al., 2011d; 2012c; d).

The higher numbers of *E. rufomarginata* on the south side of *C. brasiliense* trees than in the other directions in the 'Tabua' community might be explained by 1) the prevalent wind direction being from the northeast to the east (Leite, Veloso, Silva, Guanabens, & Fernandes, 2009; Leite et al., 2006; 2011a; b; c; 2012b) and 2) the greater amount of sunlight on the north side in the Southern Hemisphere (Vianello & Alves, 2000). Typical of the cerrado vegetation of the semiarid north of Minas Gerais State, Brazil, the desiccant effects of wind are higher in regions with low relative humidity and high temperature than in contrasting regions; these winds can reduce fruit production, photosynthesis, cause the early fall of flowers and fruits, and lead to poor formation of fruits (Leite et al., 2006), all of which can influence insect populations. The influence of sun exposure on the quality of host plants to insects might explain the higher desiccant effects of wind on the east and north sides of *C. brasiliense* trees than on the other sides (Leite et al., 2009, 2011a; b; 2012b; Leite, Cerqueira, D'ávila, Magalhães, & Fernandes, 2011e; Unsicker & Mody, 2005). Richardson, Azarbayjani, Shelley and Richardson (1999) found a lower number of species and individuals of insects on the sunny side of Australian *Melaleuca* trees. Furthermore, Leite et al. (2012b) observed higher number of scraped fruits and lepidoptera leaf mines on the west side and of *Naupactus* sp. 3 on the south side of *C. brasiliense* trees. We did not observe a significant effect of the orientation of branches of *C. brasiliense* trees in the others communities, which was because of the absence of *E. rufomarginata* in the pasture areas and the high numbers of this insect in the 'Cabeceira dos Cochos' areas, resulting in the uniform colonization of niches in the canopy of these trees.

In general, the morphological characteristics (i.e. color and size) and the viability of adults, eggs and nymphs of this study were similar to the observations of other authors (Fortes & Grazia, 1990; Rizzo & Saini, 1987; Silva & Oliveira, 2010). In this study, *E. rufomarginata* had four nymphal instars, not the five reported in the literature (Fortes & Grazia, 1990; Rizzo & Saini, 1987), it might be difficult to evaluate the biological characteristics directly in the field. We suspect that the first instar, which remains in the egg and feeds on the remnants of the eggs, might have been overlooked. Another possibility was that this insect suppressed one of the five nymphal stages; this possibility had support because we did not obtain eggs from the adults (F1) reared on the leaves, which indicated that the leaves were not a good food resource for this insect. Silva and Oliveira (2010) reported that this insect did not feed on *C. brasiliense* leaves but instead used these structures as resting and protection sites against natural enemies. At the end of their experiment, Fortes and Grazia (1990) obtained only a pair of *E. rufomarginata* reared on seedlings of *Solanum sisymbriifolium* Lam. (Solanaceae). The increased abundance of *E. rufomarginata* egg masses and nymphs was clearly associated with the reproductive phases of *C. brasiliense* (Silva & Oliveira, 2010). The adults and nymphs of *E. rufomarginata* were frequently observed feeding on mature and young stems, whereas floral buds and fruits were rarely used as food resources by this insect (Silva & Oliveira, 2010). These same authors provide snapshots showing that adults and nymphs both tented to be more abundant on mature stems than other locations on *C. brasiliense* trees.

Conclusion

We did not obtain eggs from the adults (F1), which indicated that the leaves were not a good food resource. The highest populations of *E. rufomarginata* were found in the sites of the trees that were safe from the prevailing winds. A more diverse environment and structure of the plant crown (complexity of the architecture) favored populations of *E. rufomarginata*. The abundance and damage of this insect indicates that it has the potential to be a pest on *C. brasiliense* trees. When the *C. brasiliensis* trees lose their leaves during the dry season, *E. rufomarginata* populations are found concentrated in old and dry fallen leaves on the ground. Therefore, a measure of control for this insect would be to collect and destroy these leaves and stinkbugs (e.g., controlled incineration).

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