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Insect galls from Serra Geral, Caetité, BA, Brazil

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Abstract: We inventoried and characterized the kinds of gall, gall-inducing insects and host plants from Serra Geral between August 2013 and July 2014. Two phytophysiognomies, cerrado *sensu stricto* and caatinga-cerrado, were examined monthly along transects during ca. 4 hours per visit, totaling 48 hours of sampling effort. A total of 49 gall morphotypes were found on 14 species of host plants in 18 genera and 13 families. Fabaceae and Malpighiaceae were the families with the most galls, with 22 and 10 gall morphotypes, respectively. The genera of host plant with the greatest richness of galls were *Copaifera* L. (n = 10), *Bauhinia* Benth. (n = 6), and *Mimosa* L. (n = 5). Galls were found on leaves, buds and stems. The majority of the galls were globoid, glabrous, isolated, and one-chambered. The inducers belong to Coleoptera, Diptera, and Lepidoptera, Cecidomyiidae (Diptera) being the most frequent and diverse gall-inducers. The associated fauna included parasitoids (Hymenoptera), successors (Formicidae), and predators (Pseudoscorpiones), obtained from 13, 2, and 1 gall morphotypes, respectively. Five plant taxa are recorded as hosts of gall-inducing insects for the first time.
Keywords: *Caatinga, Cerrado, Fabaceae, host plant, insect-plant interaction.*

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Resumo: Inventariamos e caracterizamos os tipos de galhas, insetos galhadores e plantas hospedeiras da Serra Geral entre agosto de 2013 a julho de 2014. Duas fitofisionomias, cerrado *sensu stricto* e de transição caatinga-cerrado, foram examinadas ao longo de trilhas à procura de galhas entomógenas, durante quatro horas por visita, totalizando 48 horas de esforço amostral. Um total de 49 morfotipos de galhas foi encontrado em 14 espécies vegetais pertencentes a 18 gêneros e 13 famílias. Fabaceae e Malpighiaceae foram as famílias botânicas com maior riqueza de galhas, com 22 e 10 morfotipos, respectivamente. Os gêneros de planta hospedeira mais ricos em galhas foram *Copaifera* L. (n = 10), *Bauhinia* Benth. (n = 6) e *Mimosa* L. (n = 4). As galhas foram encontradas em folhas, gemas e caules. A maioria das galhas foram globoides, glabras, isoladas e uniloculares. Os galhadores pertencem às ordens Coleoptera, Diptera e Lepidoptera, sendo os insetos da família Cecidomyiidae (Diptera) os indutores mais frequentes e diversificados. A fauna associada incluiu parasitoides (Hymenoptera), sucessores (Formicidae, Hymenoptera) e predadores (Pseudoscorpiones), obtidos de 13, dois e um morfotipos de galhas, respectivamente. Cinco táxons de plantas são registrados como hospedeiras de galhas pela primeira vez.
Palavras-chave: *Caatinga, Cerrado, Fabaceae, plantas hospedeiras, interação inseto-planta.*

Introduction

Galls are the abnormal growth of plant tissues formed due to an increase in cell volume (hypertrophy) and/or cell number (hyperplasy) in response to feeding activity, chemical secretions and/or the mere presence of foreign organisms, usually insects or mites (Raman 2007). The gall-inducing species apparently derives all the benefit and the plant suffers loss of substance, deviations in the direction of growth, disturbances in sap flow, premature decay and other injuries (Stone & Schönrogge 2003).

Insect galls can be regarded as extended phenotypes of the inducers, unique in that the parasitic arthropod induces a characteristic adaptation within the host plant (Stone & Schönrogge 2003, Carneiro et al. 2009b). The gall morphology and location depend on the plant species and the kind of organism that is causing it. As a result of this high specificity, gall morphotypes can be used as a surrogate of the insect species (Price et al. 1998, Hanson & Gomez-Laurito 2005) and as tools for plant systematics (Abrahamson et al. 1998).

The history of gall studies in Brazil begins with the work of Tavares (1906). Since the late 1980s, numerous inventories of

galls have been developed in Brazil, in the Southeast (e.g., Carneiro et al. 2009a, Fernandes et al. 1988, Gonçalves-Alvim & Fernandes 2001, Maia 2013a, Rodrigues et al. 2014, Saito & Urso-Guimarães 2012), South (Toma & Mendonça Jr. 2013), Midwest (Araújo et al. 2014, Julião et al. 2002, Santos et al. 2010, Santos et al. 2012b), Northeast (Carvalho-Fernandes et al. 2012, Costa et al. 2014a, 2014b, Fernandes et al. 2009, Santos et al. 2011a, 2011b, Santos et al. 2012a, Silva et al. 2011b, Silva & Almeida-Cortez 2006) and North (Almada & Fernandes 2011, Araújo et al. 2012, Julião et al. 2005, Maia 2011, Silva et al. 2011a), Atlantic Forest and Cerrado being the environments most studied.

The knowledge about galls on plants and gall-inducing organisms in Bahia is scarce. Tavares (1915-1922) was the first to collect galls in this state. He recorded 20 gall-inducing species of Diptera associated with plants. More recent inventories of insect galls and host plants from Bahia are restricted to three studies that focused mainly on caatinga (Carvalho-Fernandes et al. 2012) and caatinga-cerrado physiognomies (Costa et al. 2014a, 2014b). In addition, four gall midge species of Cecidomyiidae were recorded for the first time in the State of Bahia (Maia 2014). Clearly, a concerted effort is needed to know the gall-inducing fauna and host plant. Thus, this study aims at making an inventory of kinds of galls, gall-inducing insects and host plants from Serra Geral, a cerrado and caatinga-cerrado transition area in Caetité (BA).

Material and Methods

The study was conducted at Serra Geral (14° 04' S and 42° 29' W), located in the municipality of Caetité, Bahia, Brazil. The Serra area covers 4 km^2 and includes regions of cerrado *sensu stricto* and caatinga-cerrado transition. The highest altitude is 1,064 m. The climate is semi-arid with a well-defined dry season (April to October) and rainy season (November to March) (CEI 1994).

Monthly expeditions were conducted in the study area between August 2013 to July 2014. The different vegetation physiognomies of Serra Geral were examined in search of gall-inducing insects during four hours per visit, totaling 48 hours of sampling effort. All plant organs were investigated, except for the roots. Only plants infested by galls were marked with numbered tags, collected and later pressed in the Laboratory of Botany of the Universidade do Estado da Bahia (UNEB). The vouchers of the host plants were deposited in the HUNEB Hebarium, Caetité Collection. All host plants and gall morphotypes were photographed in field. Samples of attacked organs were collected and transported in numbered plastic bags. In the laboratory, each gall morphotype was dissected under a stereoscopic microscope in order to obtain the gall-inducing insects and characterize the external morphology of the galls (shape, color, and presence/absence of trichomes) and number of internal chambers following Isaias et al. (2013). Pupal exuviae, adults and associated fauna were obtained by keeping samples of each gall morphotype individually in plastic pots covered by absorbent paper. All pots were examined daily for emergence of adults. The emerged insects were collected and preserved in 70% alcohol for identification.

The identification of host plants was made by comparison with specimens deposited in the HUNEB, Caetité Collection and HUEFS, use of taxonomic literature, and consultation with specialists. The list of taxa is organized in alphabetical order by family, genus and species, following the classification system of APG III (2009). The insect were identified based on gall shape, host plant and original description. All material is deposited in the collection of Museu Nacional - Universidade Federal do Rio de Janeiro.

Results

This study in Serra Geral found 49 gall morphotypes on 14 species of host plant distributed in 18 genera and 13 families (Table 1; Figures 1-3). Fabaceae was the plant family with the most galls, followed by Malpighiaceae, with 22 and 10 gall morphotypes, respectively. The genera of host plant with the greatest richness of galls were *Copaifera* L. (n = 10), *Bauhinia* Benth. (n = 6), and *Mimosa* L. (n = 4).

As there were no previous data of host plant of gall-inducing insects from Serra Geral, all records presented here are new to the region. The galls observed on *Byrsonima stannardii* W.R. Anderson (Figure 2I), *Calliandra sessilis* Benth. (Figure 2C), *Eremanthus capitatus* (Spreng.) MacLeish (Figure 1B), *Thryallis* sp. (Figure 2J), and *Ruellia bahiensis* (Nees) Morong are the first records of galls in these taxa.

Galls were recorded on stems, buds and leaves, the last one being the plant organ with the most galls, with ca. 57% of the total of the gall morphotypes. Flower and fruit galls were not found. Regarding the shape of the galls sampled, about 53% were globoid, 20.4% lenticular, 12.3% fusiform, 6.2% conical, 4.1% marginal leaf roll, 2% bivalve-shaped and 2% cylindrical. The majority of the galls were glabrous (83.7%), isolated (77%), and one-chambered (73.5%) (Table 1; Figures 1-3)

Most galls exhibited the same coloration as the plant organ. Green galls predominated on leaves, but was also observed on stems (*Bauhinia acuruana* Moric.; Figure 1F). Brown galls were frequent on stems, but were also verified on leaves of *Duguetia furfuracea* (A.St.-Hil.) Saff. (Figure 1A), *Combretum leprosum* Mart. (Figure 1C) and *Copaifera langsdorffii* Desf. (Figures 1L-2A).

Of six orders of gall-inducing insects (Diptera, Coleoptera, Lepidoptera, Hymenoptera, Thysanoptera, and Hemiptera) three were present in this study: Coleoptera, Diptera, and Lepidoptera. The Cecidomyiidae (Diptera) comprised the most frequent gall-inducing taxon, being responsible for 18.4% of the morphotypes, followed by Lepidoptera (4.1%) (Table 1). The gall-inducers of 73.4% of the morphotypes could not be determined, because the gall samples were collected without dwellers or were occupied by parasitoids and predators. The associated fauna included parasitoids (Hymenoptera), successors (Formicidae), and predators (Pseudoscorpiones), obtained from 13, 2, and 1 gall morphotypes, respectively (Table 1).

Discussion

In several surveys of insect galls from different Brazilian ecosystems, Fabaceae was indicated as the richest plant family in number of gall morphotypes, as in areas of cerrado (Minas Gerais - Gonçalves-Alvim & Fernandes 2001; Goiás - Araújo et al. 2014, Santos et al. 2012b) and caatinga-cerrado transition (Minas Gerais - Luz et al. 2012; Bahia - Costa et al. 2014b). Fabaceae is one of the predominant families of the cerrado and caatinga flora (Queiroz 2009) and is one of the best-represented plant families in Serra Geral. According to the plant diversity hypothesis proposed by Fernandes (1992), the greatest richness of galls is shown by the most speciose plant families of each area. The present study adds more evidences to the previous knowledge about super-host families and the plant richness hypothesis.

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Table 1. Morphological description of insect galls in semi-arid environments from Serra Geral, Caetité, Bahia, Brazil. Abbreviations: Pa: parasitoid, Su: successor, Pr: predator.

Host plant Family	Host plant species	Organ	Side	Shape	Color	Pubescense	Group	Chambers	Gall maker	Associated fauna	Figures	Area
Annonaceae	*Duguetia furfuracea* (A.St. Hil.) Saff.	Leaf	Adaxial	Globoid	Green/ Brown	Yes	Grouped	Various	Not identified	Hymenoptera (Pa)	1 A	Cerrado
Acanthaceae	*Ruellia bahiensis* (Nees) Morong	Leaf	Adaxial	Lenticular	White	Yes	Isolated	1	Not identified		-	Cerrado
		Leaf	Adaxial	Globoid	Brown	No	Isolated	1	Not identified		-	Cerrado
Asteraceae	*Eremanthus capitatus* (Spreng.) MacLeish	Stem	-	Globoid	Brown	No	Isolated	1	Coleoptera	Formicidae, Hymenoptera (Su)	1 B	Caatinga-Cerrado
Combretaceae	*Combretum leprosum* Mart.	Leaf	Adaxial	Globoid	Brown	No	Isolated	1	Cecidomyiidae	Hymenoptera (Pa)	1 C	Cerrado
Icacinaceae	*Emmotum* sp.	Stem	-	Globoid	Brown	No	Isolated	1	Not identified	Hymenoptera (Pa) Formicidae (Su)	1 D	Cerrado
		Leaf (petiole)		Globoid	Brown	No	Isolated	1	Lepidoptera		1 E	Cerrado
Fabaceae - Caesalpinioideae	*Bauhinia acuruana* Moric.	Stem	-	Fusiform	Brown	No	Isolated	Various	Not identified		1 F	Cerrado
		Stem	-	Globoid	Green	No	Isolated	1	Cecidomyiidae		1 G	Cerrado
		Stem	-	Globoid	Brown	No	Grouped	Various	Not identified		1 H	Cerrado
		Leaf	Adaxial	Lenticular	Green	No	Isolated	1	Cecidomyiidae		1 I	Cerrado
		Stem	-	Fusiform	Brown	No	Isolated	Various	Not identified		1 J	Cerrado
	Bauhinia pulchella Benth.	Leaf	Adaxial	Globoid	Green	No	Isolated	1	Not identified		1 K	Cerrado
	Copaifera langsdorffii Desf.	Stem	-	Globoid	Orange/ Brown	No	Isolated	Various	Cecidomiiydae	Hymenoptera (Pa)	1 L	Caatinga-Cerrado
		Leaf	Adaxial/ Abaxial	Globoid	Grey/ Black	No	Isolated	1	Not identified		1 M	Caatinga-Cerrado
		Leaf	Adaxial	Globoid	Black	No	Isolated	Various	Not identified		1 N	Caatinga-Cerrado

Continued on next page

Table 1. Continued.

Host plant Family	Host plant species	Organ	Side	Shape	Color	Pubescense	Group	Chambers	Gall maker	Associated fauna	Figures	Area
		Stem	-	Lenticular	Brown	No	Grouped	1	Cecidomyiidae	Hymenoptera (Pa)	1O	Caatinga-Cerrado
		Leaf	Abaxial	Globoid	Brown	Yes	Isolated	1	Not identified		1P	Caatinga-Cerrado
		Leaf	Adaxial	Globoid	Brown	No	Isolated	Various	Not identified		1Q	Caatinga-Cerrado
		Leaf	Adaxial	Globoid	Brown	No	Isolated	Various	Not identified	Hymenoptera (Pa)	1R	Caatinga-Cerrado
		Leaf	Adaxial/ Abaxial	Lenticular	Green	No	Isolated	1	Not identified		1S	Caatinga-Cerrado
		Leaf	Adaxial	Cylindrical	Green	No	Isolated	1	Not identified	Hymenoptera (Pa)	1T	Caatinga-Cerrado
		Leaf	-	Marginal roll	Green	No	Isolated	1	Not identified		2A	Cerrado
Fabaceae – Mimosoideae	*Calliandra dysantha* Benth.	Bud	-	Globoid	Brown	Yes	Grouped	Various	Not identified		2 B	Cerrado
	Calliandra sessilis Benth.	Stem	-	Globoid	Brown	No	Isolated	Various	Not identified		2 C	Cerrado
	Mimosa gemmulata Barneby	Leaf	Adaxial	Globoid	Brown	Yes	Isolated	1	Cecidomyiidae		2 D	Cerrado
		Bud	Adaxial	Globoid	Green	No	Grouped	1	Not identified		2 E	Cerrado
		Leaf	-	Marginal roll	Green	No	Isolated	1	Not identified		2 F	Cerrado
		Stem	-	Fusiform	Brown	No	Isolated	1	Not identified	Hymenoptera (Pa)	2 G	Cerrado
Malpighiaceae	*Banisteriopsis* sp.	Stem	-	Globoid	Brown	No	Isolated	1	Lepidoptera		2 H	Cerrado
	Byrsonima starnnardii W. R.Anderson	Leaf	Abaxial	Conical	Green	Yes	Isolated	1	Cecidomyiidae	Hymenoptera (Pa)	2I	Caatinga-Cerrado
	Thryallis sp.	Leaf	Abaxial	Lenticular	White	Yes	Grouped	1	Not identified	Hymenoptera (Pa)	2 J	Caatinga-Cerrado
	Malpighiaceae sp. 1	Stem	-	Fusiform	Brown	No	Grouped	1	Cecidomyiidae		2K	Caatinga-Cerrado
	Malpighiaceae sp. 1	Leaf	Abaxial	Globoid	Green	No	Isolated	Various	Not identified		2 L	Caatinga-Cerrado

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Table 1. Continued.

Host plant Family	Host plant Species	Organ	Side	Shape	Color	Pubescense	Group	Chambers	Gall maker	Associated fauna	Figures	Area
	Malpighiaceae sp. 2	Bud	-	Bivalve shaped	Orange	No	Isolated	1	Coleoptera		2 M	Cerrado
	Malpighiaceae sp. 3	Stem	-	Conical	Brown	No	Isolated	Various	Not identified		-	Cerrado
	Malpighiaceae sp. 3	Leaf (petiole)	-	Globoid	Green	No	Isolated	1	Not identified		2 N	Cerrado
	Malpighiaceae sp. 4	Stem	-	Conical	Brown	No	Isolated	Various	Not identified	Pseudoscorpiones (Pr)	-	Cerrado
	Malpighiaceae sp. 5	Leaf (vein)	Abaxial	Globoid	Red	No	Grouped	1	Not identified	Hymenoptera(Pa)	2 O	Caatinga-Cerrado
Myrtaceae	*Eugenia punicifolia* (Kunth) DC.	Leaf	Adaxial	Lenticular	Black	No	Grouped	1	Not identified		2P	Caatinga-Cerrado
		Stem	-	Fusiform	Brown	No	Isolated	1	Not identified		2 Q	Caatinga-Cerrado
Nyctaginaceae	Nyctaginaceae sp.	Stem	-	Fusiform	Brown	No	Isolated	1	Not identified		2R	Caatinga-Cerrado
Ochnaceae	*Ouratea* sp.	Leaf	Adaxial	Lenticular	Green	No	Isolated	1	Not identified		2S	Caatinga-Cerrado
		Leaf	Adaxial	Lenticular	Green	No	Grouped	1	Not identified		2T	Cerrado
Rubiaceae	*Cordiera* sp.	Bud	-	Globoid	Green/ Black	No	Isolated	1	Not identified		3 A-B	Caatinga-Cerrado
	Rubiaceae sp.1	Leaf	Adaxial	Lenticular	Green	No	Isolated	1	Not identified		3 C	Cerrado
	Rubiaceae sp.2	Stem	-	Globoid	Brown	No	Grouped	1	Not identified		3 D	Cerrado
Trigoneaceae	*Trigonea nivea* Cambess.	Leaf	Abaxial	Globoid	White	Yes	Isolated	1	Cecidomyiidae	Hymenoptera (Pa)	3 E	Cerrado
Vochysiaceae	*Qualea parviflora* Mart.	Leaf	Adaxial	Lenticular	Green	No	Isolated	1	Not identified		3 F	Caatinga-Cerrado

Figure 1. Insect galls from Serra Geral, Caetité, Bahia, Brazil. A. *Duguetia furfuracea* (A.St. Hil.) Saff. B. *Eremanthus capitatus* (Spreng.) MacLeish. C. *Combretum leprosum* Mart. D-E. *Emmotum* sp. F-J. *Bauhinia acuruana* Moric. K. *Bauhinia pulchella* Benth. L-T. *Copaifera langsdorffii* Desf.

Copaifera and *Bauhinia* were the plant genera with the highest gall diversity in this study. These two genera were already indicated in other gall inventories as super hosts in the caatinga, cerrado and caatinga-cerrado transition (Santos et al. 2011a, Luz et al. 2012, Costa et al. 2014b). The *Copaifera* is reported as super hosts in other vegetation types, such as cerrado (Fernandes et al. 1988, Fagundes 2014) and atlantic forest (Maia 2013b). In some taxa, at lower taxonomic levels, there may be a large concentration of galls, these being known as super hosts (Veldtman & McGeoch 2003). There are a several examples of these in the literature (*Baccharis*: Fernandes et al. 1996, *Copaifera*: Costa et al. 2010; Maia 2013b, *Eugenia*: Mendonça 2007).

The super-host species was *Copaifera langsdorffii* (Fabaceae). This species was considered a super-host in other ecosystems as well, such as the atlantic forest (Maia 2013b), cerrado (Maia & Fernandes 2004) and caatinga-cerrado transition (Costa et al. 2014b). This species has great morphogenetic potential and responds differently to the stimuli of more than 20 gall-inducing insects (Oliveira et al. 2008, Costa et al. 2010).

Leaf and stem were the organs most commonly attacked by gall makers throughout Brazil (e.g., Santos et al. 2011a, Carvalho-Fernandes et al. 2012, Maia 2013b, Costa et al. 2014a, 2014b). It is a widespread pattern pointed by Felt (1940) and confirmed in this study. This preference can be explained because the leaves are abundant and constant resources (Maia 2001).

Globoid, lenticular and fusiform galls were predominant. The predominance of these morphotypes has been also pointed

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Figure 2. Insect galls from Serra Geral, Caetité, Bahia, Brazil. A. *Copaifera langsdorffii* Desf. B. *Calliandra dysantha* Benth. C. *Calliandra sessilis* Benth. D-G. *Mimosa gemmulata* Barneby. H. *Banisteriopsis* sp. I. *Byrsonima starnnardii* W.R.Anderson. J. *Thryallis* sp. K-O. Malpighiaceae Indet. sp. 1-4. P-Q. *Eugenia punicifolia* (Kunth) DC. R. Nyctaginaceae Indet. S-T. *Ouratea* sp.

in other inventories (e.g., Costa et al. 2014b, Maia 2013, 2014, Coelho et al. 2013, Urso-Guimarães et al. 2003). This diversity of forms is related to the high specificity of gall-inducing insects and their host plants (Carneiro et al. 2009b), but also with the high phenotypic plasticity to which the tissues of these plants have to be subjected, resulting in injuries during gall formation. The majority of the galls were glabrous, isolated, and one-chambered. Other gall inventories held in Brazil (Pernambuco - Santos et al. 2011a, b, 2012a; Minas Gerais - Luz et al. 2012; Rio de Janeiro - Maia & Souza 2013; Bahia - Costa et al. 2014a, 2014b) corroborate the results of this study.

The inducers were represented by Diptera, Lepidoptera, and Coleoptera. Cecidomyiidae (Diptera) were the most frequent and diverse gall-inducers. This result confirms other data recorded in different Brazilian ecosystems, indicating Cecidomyiidae as the main family of gall-inducing insects (Carneiro et al. 2009a, Santos et al. 2011a, 2011b, Maia 2013a, 2013b, Costa et al. 2014b). Moreover, it is the richest gall-inducing taxon in the world (Gagné & Jaschhof 2014), demonstrating the importance of the family in the community of gall-makers.

The associated fauna included parasitoids (Hymenoptera), inquilines (Lepidoptera and Thysanoptera), successors (Formicidae, Hymenoptera), and predators (Pseudoscorpiones). The presence of parasitoids of the order Hymenoptera has been widely reported in galls as the main factor of the inducers' mortality (Maia 2001, 2013a). In other Brazilian inventories, this

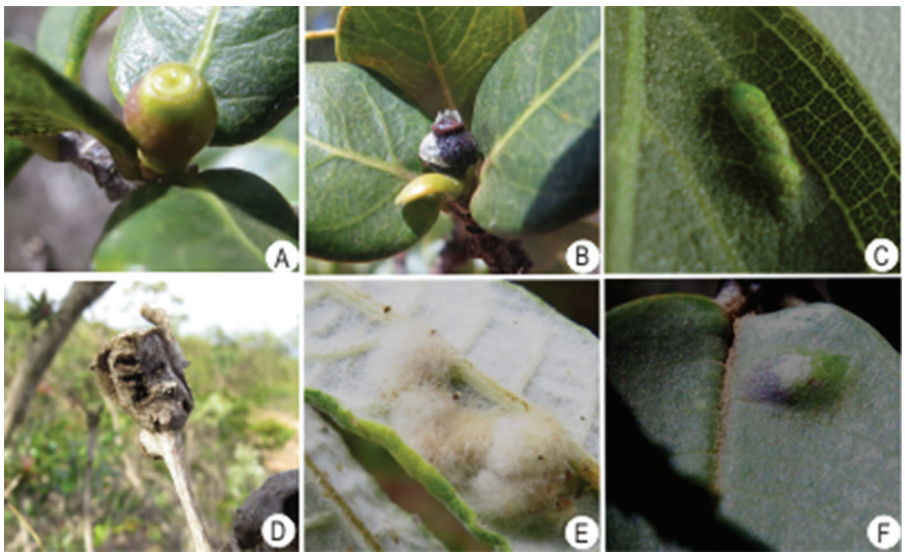

Figure 3. Insect galls from Serra Geral, Caetité, Bahia, Brazil. A-B. *Cordiera* sp. C-D. Rubiaceae sp. 1-2. E. *Trigonea nivea* Cambess. F. *Qualea parviflora* Mart.

order has also been registered with the same habits seen in this study (Maia 2001, Maia & Fernandes 2004, Maia et al. 2008).

In Serra Geral, predators (pseudoscorpions) were recorded in a single gall morphotype. The occurrence of pseudoscorpions in Brazilian surveys is very rare. Only five previous records are known, on bud galls of *Eugenia astringens* Cambess. - Myrtaceae (Maia 2001), stem galls of *Combretum leprosum* Mart & Eicher - Combretaceae (Maia 2002), *Handroanthus* sp. – Bignoniaceae (Maia 2013b), *Calophyllum brasiliense* Cambess – Calophyllaceae (Maia & Souza 2013) and *Myrcia tomentosa* (Aubl.) DC. – Myrtaceae (Costa et al. 2014b).

The five new records of species of host plant presented in this work show the importance of this type of study to increase the knowledge of the richness of gall-inducing insects present in not sampled regions, such as the cerrado and caatinga-cerrado transition areas located in Northeast Brazil.

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