Biota Neotropica 23(4): e20231527, 2023
www.scielo.br/bn

biotaneotropica
ISSN 1676-0611 (online edition)
Inventory

Insect galls from the Serra da Bandeira (Barreiras, Western Bahia, Brazil)

***Jeferson Brito de Menezes*[1], *Valdeir Pereira Lima*[2*] & *Daniéla Cristina Calado*[1]**

[1]*Universidade Federal do Oeste da Bahia, Centro de Ciências Biológicas e da Saúde, Barreiras, BA, Brasil.*
[2]*Universidade Federal de Santa Catarina, Departamento de Fitotecnia, Florianópolis, SC, Brasil.*
[*]*Corresponding author: vallldeir@gmail.com*

MENEZES J.B., LIMA V.P., CALADO D.C. **Insect galls from the Serra da Bandeira (Barreiras, Western Bahia, Brazil)**. Biota Neotropica 23(4): e20231527. https://doi.org/10.1590/1676-0611-BN-2023-1527

Abstract: Understanding the diversity of insect galls is pivotal to the establishment of conservation planning in different Brazilian ecosystems. Here, we (1) characterize the insect galls found on plant host species, (2) identify the gall-inducing insects to the lowest possible taxonomic level, and (3) record the presence of gall-associated fauna. Our study was carried out monthly from August, 2017 to July, 2018 along nine trails in Serra da Bandeira, which is located in an area of Cerrado stricto sensu over a year. We found 48 distinct gall morphotypes, belonging to 12 botanical families. The most morphotypes commonly found were globoid (27.1%), lenticular (27.1%) and cylindrical (25%). The plant organs most affected by galling insects were the leaves (73%), followed by the stem (19%), flower (4%), inflorescence (2%) and fruits (2%). The host botanical families holding the highest number of galls were Fabaceae (26), Malpighiaceae (5) and Anacardiaceae, Combretaceae and Euphorbiaceae (3). We observed that the genus *Copaifera* Lindl. (Fabaceae) had the greatest diversity of gall morphotypes, harboring 19 morphotypes distributed in three species that occur sympatrically - *Copaifera sabulicola* J. Costa (Fabaceae), *Copaifera depilis* Dwyer (Fabaceae) and *Copaifera luetzelburgii* Harms (Fabaceae). For the first time in Brazil, we recorded the occurrence of galls on flowers of *Manihot caerulescens* (Euphorbiaceae), on inflorescences of *Mimosa acutistipula* (Fabaceae) and flower buds of *Anacardium humile* (Anacardiaceae), which were induced by Cecidomyiidae. Inducers of the order Diptera (Family Cecidomyiidae) were the most abundant, found in 14 morphotypes of galls. Regarding the associated fauna, we found insects primarily belonging the order Hymenoptera, and identified them as parasitoids. The information provided can be used highly by decision makers for conservation programs, as well as in other strategies for the conservation of biological diversity in the Brazilian Cerrado.
Keywords: *Cerrado; Cecidomyiidae; Gall inducing insects; Galling insects; Insect-plant interaction.*

Galhas de insetos da Serra da Bandeira (Barreiras, Oeste da Bahia, Brasil)

Resumo: Compreender a diversidade de galhas de insetos é fundamental para o estabelecimento de planos de conservação em diferentes ecossistemas brasileiros. Aqui, nós (1) caracterizamos as galhas de insetos encontradas em espécies de plantas hospedeiras, (2) identificamos os insetos indutores de galhas até o nível taxonômico mais baixo possível e (3) registramos a presença de fauna associada a galhas. Nosso estudo foi realizado mensalmente de agosto de 2017 a julho de 2018 ao longo de nove trilhas na Serra da Bandeira, que está localizada em uma área de Cerrado stricto sensu ao longo de um ano. Encontramos 48 morfotipos distintos de galhas, pertencentes a 12 famílias botânicas. Os morfotipos mais comumente encontrados foram globoide (27,1%), lenticular (27,1%) e cilíndrico (25%). Os órgãos vegetais mais afetados pelos insetos galhadores foram as folhas (73%), seguidas do caule (19%), flor (4%), inflorescência (2%) e frutos (2%). As famílias botânicas hospedeiras com maior número de galhas foram Fabaceae (26), Malpighiaceae (5) e Anacardiaceae, Combretaceae e Euphorbiaceae (3). Observamos que o gênero *Copaifera* Lindl. (Fabaceae) apresentou a maior diversidade de morfotipos de galhas, abrigando 19 morfotipos distribuídos em três espécies que ocorrem simpatriicamente – *Copaifera sabulicola* J. Costa (Fabaceae), *Copaifera depilis* Dwyer (Fabaceae) e *Copaifera luetzelburgii* Harms (Fabaceae). Pela primeira vez no Brasil, registramos a ocorrência de galhas em flores de *Manihot caerulescens* (Euphorbiaceae), em inflorescências de *Mimosa acutistipula* (Fabaceae) e em botões florais de *Anacardium humile* (Anacardiaceae), induzidas por Cecidomyiidae. Indutores da ordem Diptera (Família Cecidomyiidae) foram os mais abundantes, encontrados em 14 morfotipos de galhas. Em relação à fauna associada, encontramos insetos pertencentes principalmente à ordem Hymenoptera, e os identificamos como parasitóides. As informações fornecidas podem ser utilizadas por tomadores de decisão para programas de conservação, bem como em outras estratégias para a conservação da diversidade biológica no Cerrado brasileiro.
Palavras-chave: *Cerrado; Cecidomyiidae; Insetos indutores de galhas; Insetos galhadores; Interação inseto-planta.*

Introduction

Galling insects are specialized herbivores that redirect plant resources in order to develop themselves during their cycle in host plants (Marini-Filho & Fernandes 2012, Gagné & Jaschhof 2017, Lima & Calado 2020). Such development is an adaptive evolutionary strategy of certain groups for obtaining food and protection against predators (Gonçalves-Alvim & Fernandes 2001a). Insect galls are developed from tissue hyperplasia and cell hypertrophy (Martini et al. 2019, Isaias et al. 2013, Mani 1964) due to abnormal differentiation in mechanical and chemical response of inducers, resulting in characteristic growth that harbor gall-inducing insects (Santos-Silva & Araujo 2020). Currently, six orders of gall-inducing insects are known to science: Diptera, Hymenoptera, Thysanoptera, Coleoptera, Lepidoptera and Hemiptera (Maia & Monteiro 1999). Among Diptera, the Cecidomyiidae family is the main family of galling insects not only in the Neotropics, but also in other regions (Maia 2013a). To this date, 280 species and 103 genera have already been described belonging to the Cecidomyiidae family in Brazil (Maia 2023).

Many species of galling insects are economically important, inducing galls on cultivated plants used daily as food, such as *Anacardium humile* A.St.Hil. (Anacardiaceae), and *Caryocar brasiliense* Cambess (Caryocaraceae), as well as other medicinal and ornamental plants (Fernandes & Price 1988). Galling insects are recognized as ecosystem engineers, as they can directly or indirectly modulate the availability of resources for other species, responsible for modifying, creating and maintaining microhabitats (Jones et al. 1994). Furthermore, a large number of associated fauna (parasitoids, tenants, predators and successors) are regularly found in insect galls with great richness and abundance, thus increasing the ecological importance of galling insects (Maia & Monteiro 1999, Santos et al. 2018, Soares et al. 2021, Lima & Calado 2018, Maia 2013b).

Although several inventories of insect galls have been carried out in Cerrado areas, particularly in the states of Minas Gerais and Goiás (Araújo 2018), few studies have covered the Cerrado of western Bahia (Lima & Calado 2018). Besides holding about 5% of the planet's biological diversity, the Cerrado is one of the 25 world biodiversity hotspots, due to the high diversity of endemic species and extensive loss of habitats through anthropogenic actions (MMA 2017). The vegetation of the Cerrado is diverse, presenting characteristics of forest, savannah and grassland formations. Among the various vegetation formations of the Cerrado, there is the Cerrado stricto sensu, which is characterized by trees randomly distributed on the ground in different densities, as well as by the presence of defined tree and shrub-herbaceous strata (Sano et al. 2008). It is estimated that the invertebrate fauna of the Cerrado is approximately 90 thousand species. However, this fauna is still poorly known (Oliveira & Frizzas 2008). Few efforts have sought to study the diversity of insects in Western Bahia, and these have been suffering significant declines mainly because of the destruction of their suitable habitats to meet the demand of agribusiness in the region (Soares et al. 2021, Lima & Calado 2018). Despite this chaotic scenario in the region, recent assessments in the region have characterized the ecology of galling species and described new species in heavily degraded areas (Garcia et al. 2017, Santos et al. 2018, Soares et al. 2021).

Besides their important role as bioindicators of environmental quality (Santana & Isaias 2014), understanding the diversity of galling insects and the associated flora in tropical Brazilian ecosystems is extremely important to comprehend the patterns of distribution and occurrence of these herbivores in the Cerrado of Western Bahia, which effectively contributes as a tool for ecological study and conservation. Here, we (1) characterize the insect galls found on plant host species, (2) identify the gall-inducing insects to the lowest taxonomic level, and (3) record the presence of gall-associated fauna.

Material and Methods

Our study was carried out along trails in the Serra da Bandeira (–12° 05' 29'S and –45° 02' 23'W), located in the municipality of Barreiras (Figure 1). The area has a typical Cerrado vegetation with herbaceous and shrubby vegetation, predominance of subshrubs and shrubs, and great diversity of pioneer species in the secondary phase of succession (Cruz Ruggiero et al. 2002). The region has a seasonal climate, with two well-defined seasons, a rainy one, lasting from October to March, and a dry one, which lasts from April to September. The average annual rainfall in this biome is 1,500mm and temperatures are generally mild throughout the year (Nascimento & Novais 2020).

The study area was monthly sampled by the first author throughout one year, between August 2017 and July 2018, through walks between trails lasting 2 hours, which is a method commonly used in inventories of galling insects in Brazil (Soares et al. 2021, Lima & Calado 2018, Bregonci et al. 2010, Maia & Fernandes 2004). All plant organs were inspected on the host plants from ground level to the top of the canopy for the presence of insect galls. We then photographed the galls found to better characterize the morphological characteristics such as shape, hairiness and distribution on the plant (Isaias et al. 2013). Next, branches containing flowers and fruits were collected from the host plant for further identification of the species. Collected specimens were stored and transported them to the Laboratory of Invertebrate Zoology at the Federal University of Western Bahia (UFOB). The plant samples collected were stored in newspapers and cardboard containing 70% alcohol for subsequent assembly of specimens. These samples were sent to the BRBA Herbarium of UFOB for species identification by botanical taxonomists and incorporated into the collection under numbers from 7657 to 7676.

In the laboratory, part of the collected galls was dissected using tweezers and a stereomicroscope (Leica S8-APO) to look for the inducer and its associated fauna. The remains were kept in plastic containers containing cotton moistened with water and were stored in a BOD (SL-224) oven at a temperature of approximately 25 ºC to obtain the insects in the adult phase. We monitored the containers daily for emergence of adult insects. The emerged adults' insects were used to mount permanent slides following the methodology proposed by Gagné (1994), and later identification using dichotomous keys (Gagné 1994) and other descriptive studies of galling insects. The associated fauna was preserved in 70% alcohol and identified at the lowest possible taxonomic level using identification keys from the Insects from Brazil: Diversity and Taxonomy (Rafael et al. 2012) and Luz & Mendonça Júnior (2019) as reference. Most of the associated fauna was obtained only at an immature stage and therefore we identified them only at the order level. Lastly, we summarized information on cecidomyids species, host plant species and associated fauna in a table.

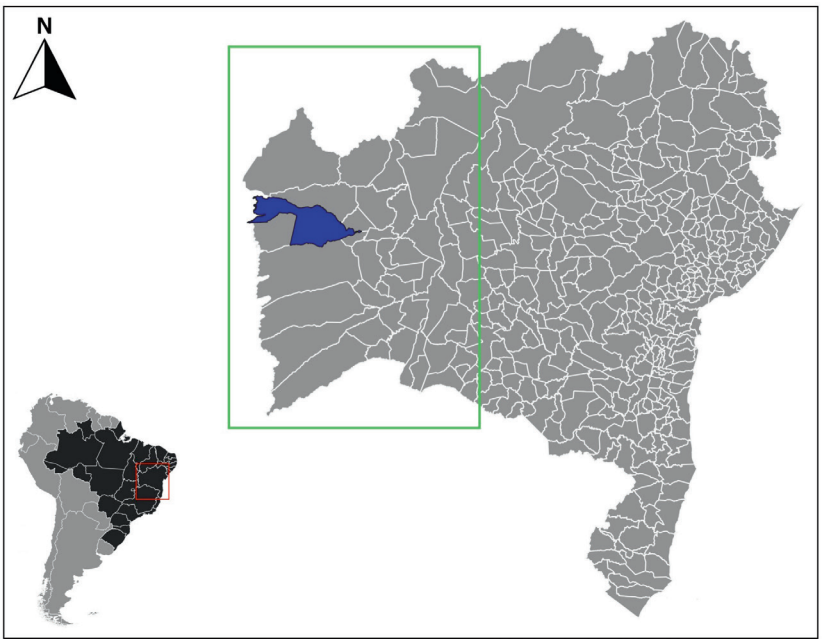

Figure 1. Study area. Location of the municipality of Barreiras, Bahia, Brazil depicted in blue. The west region of Bahia is highlighted in light green.

Results

We found and characterized 48 distinct gall morphotypes, belonging to 12 plant families (Figures 2, 3 and 4, Table 1). Insect galls showed different morphotypes such as globoid, cylindrical, lenticular, conical, fusiform and marginal leaf fold. The most commonly found were globoid (27.1%), lenticular (27.1%) and cylindrical (25%), followed by conical (12.5%) and fusiform (6.2%). The least abundant shape was marginal leaf fold (2.1%) (Figure 5). We observed insect galls developed on leaves, stems, flowers, inflorescences and fruits. The plant organs most affected by galling insects in the Serra da Bandeira were the leaves (73%), followed by the stem (19%), flower (4%), inflorescence (2%) and fruits (2%) (Figure 6). Green was the most frequent color found among the morphotypes (32), followed by brown (25) and red (11) (Table 1).

The host plant families with the highest number of gall morphotypes in Serra da Bandeira were Fabaceae (26), Malpighiaceae (5) and Anacardiaceae, Combretaceae and Euphorbiaceae (3) (Figure 7, Table 1). Furthermore, we found that the genus *Copaifera* Lindl. (Fabaceae) had the greatest diversity of gall morphotypes, harboring 19 morphotypes distributed in three species that occur sympatrically – *Copaifera sabulicola* J. Costa (Fabaceae), *Copaifera depilis* Dwyer (Fabaceae) and *Copaifera luetzelburgii* Harms (Fabaceae) (Table 1). Here, for the first time in Brazil, we recorded the occurrence of galls on flowers of *Manihot caerulescens* (Euphorbiaceae), on inflorescences of *Mimosa acutistipula* (Fabaceae) and flower buds of *Anacardium humile* (Anacardiaceae), which were induced by Cecidomyiidae. Galls on flowers of *Manihot caerulescens* Pohl (Euphorbiaceae) was induced by the species *Iatrophobia brasiliensis* (Rübsaamen, 1908).

Cecidomyiidae were found inducing galls in 14 morphotypes. Out of 48 morphotypes found in our study, inducers were not determined for 32 morphotypes. Additionally, we found Hymenoptera in 24 gall morphotypes, Lepidoptera in 2 gall morphotypes and Acari and Pseudoscorpiones in only one gall morphotype (Table 1).

Discussion

Inventories of gall-inducing insects in Brazil indicate Fabaceae as the most common host plant family for galling insects (Marinho et al. 2023, Maia 2013a, Lima & Calado 2018, Araujo et al. 2019), which confirms the richness hypothesis (Southwood 1960), also recorded in other studies carried out in the Cerrado (Gonçalves-Alvim & Fernandes 2001b, Santana & Isaias 2014). Among the Fabaceae family, *Copaifera* Lindl. (Fabaceae) had a great diversity of gall morphotypes, a result found by Santos et al. (2018), in the same area with three species of the *Copaifera* (*C. sabulicola C. depilis* and *C. luetzelburgii*). Furthermore, Nogueira et al. (2016), in a study in Serra Geral in the city of Caetité, Bahia, characterized ten morphotypes for *Copaifera langsdorffii* Desf. (Fabaceae) in transition areas between Cerrado and Caatinga. Therefore, our study contributes to scientific knowledge on insect galls by reinforcing that *Copaifera* species are super hosts of insect galls.

Here, we describe for the first time the occurrence of insect gall on flowers of *Manihot caerulescens* Pohl (Euphorbiaceae), which had not been observed in other studies carried out in different Brazilian ecosystems (Carneiro, Borges, et al. 2009, Araújo et al. 2011, Maia 2013a, Scareli-Santos et al. 2018, Saito & Urso-Guimarães 2012). Many studies have observed the occurrence of galls exclusively on leaves for the genus *Manihot* and the inducing insect has been identified as belonging to the genus *Iatrophobia* (Rübsaamen, 1915) (Diptera, Cecidomyiidae). The occurrence of the species *Iatrophobia brasiliensis* (Rübsaamen, 1908) in several species of the genus *Manihot* can be explained by the fact that the species is oligophagous. Carneiro et al. (2009) investigated the level of specificity of inducers and identified that about 5.6% of the 196 galling species studied are oligophagous, inducing galls on more than one host plant species of the same genus. Another new record is the occurrence of cylindrical and glabrous galls in the inflorescence of

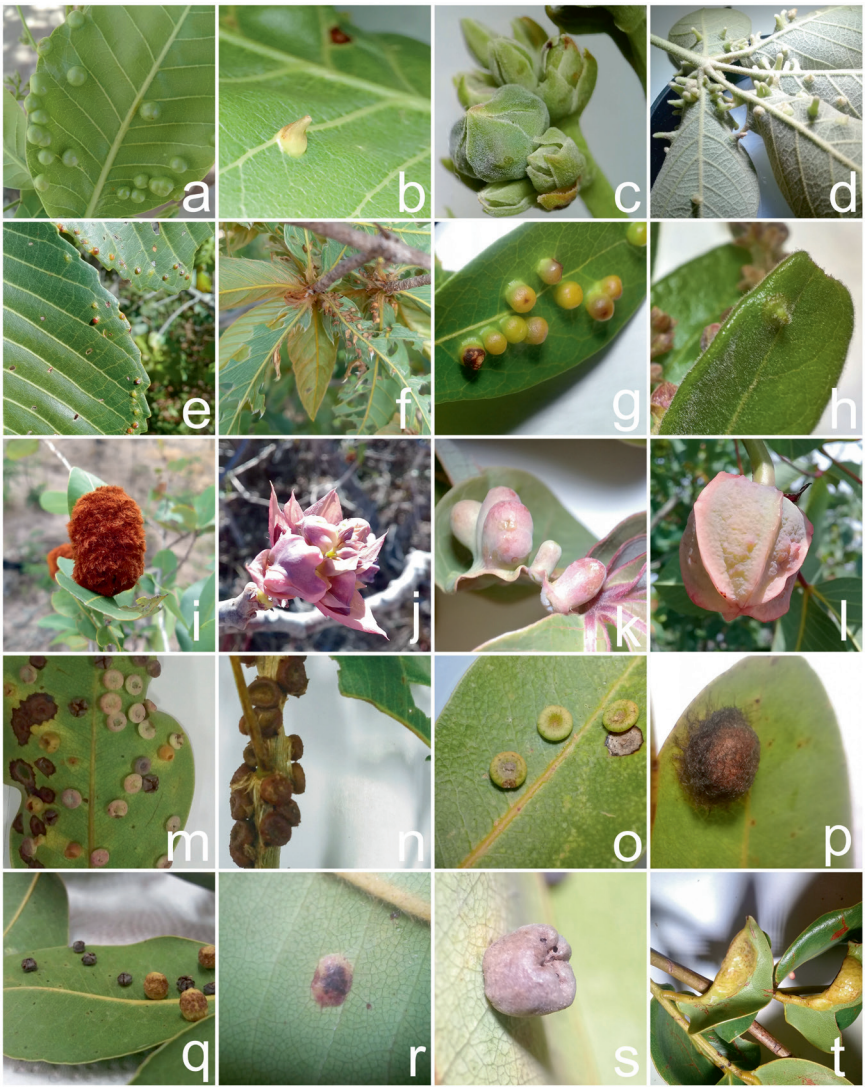

Figure 2. Insect galls found in the Serra da Bandeira (Barreiras, Bahia, Brazil). a. *Anacardium humile* – Globoid, b. *Anacardium humile* – Conical, c. *Anacardium humile* – Globoid, d. Bignoniaceae – Conical, e. *Caryocar brasiliense* – Globoid, f. *Terminalia fagifolia* – Conical, g. *Terminalia* sp. – Cylindrical, h. Combretaceae R. – Conical, i. *Erythroxylum* sp. – Globoid, j. *Manihot caerulescens* – Cylindrical, k. *Manihot caerulescens* – Cylindrical, l. *Manihot caerulescens* – Cylindrical, m. *Copaifera sabulicola* – Lenticular, n. *Copaifera sabulicola* – Lenticular, o. *Copaifera sabulicola* – Lenticular, p. *Copaifera sabulicola* – Globoid, q. *Copaifera sabulicola* – Globoid, r. *Copaifera sabulicola* – Lenticular, s. *Copaifera sabulicola* – Lenticular and t. *Copaifera sabulicola* – Marginal Leaf Fold.

Mimosa acutistipula (Fabaceae), whose inducer is an undetermined species of Cecidomyiidae. Many studies have reported the occurrence of insect galls in species of the genus *Mimosa* on leaves and stems (Nogueira et al. 2018, Vieira et al. 2018, Nogueira et al. 2016, Costa et al. 2014, Coelho et al. 2013), however, none for the species *Mimosa acutistipula*. Thus, this is the first record of the insect gall on this plant species, which is rare in field.

Furthermore, we found an unprecedented record of galls on flower buds, induced by a cecidomyiids on *Anacardium humile* (Anacardiaceae), a species popularly known as cajuí or cajuzinho do Cerrado. The record of galls in the *Anacardium* genus is very common in leaves (Vieira et al. 2018, Araújo et al. 2011). Such occurrence on flowers is relevant due to the economic importance, since the insect galls caused deformities in the flower buds, preventing the opening of the flowers and, consequently, the formation of the accessory fruit and the fruit (chestnut). According to ethnobotanical studies, o cajuzinho do Cerrado creates income, serves as food for local communities and consequently improves people's livelihoods (Vieira et al. 2016). In this context, investigations on the phenology of the plant, aiming at a better understanding of the incidence of the infection, as well as the damage caused in fruits and pseudofruits, are fundamental.

About 65% of the inducer species have not yet been determined, due to the absence of individuals in the adult (male and female), pupa and larva stages. Maia (2013) highlights the need to obtain gallers at each stage of the life cycle, as this is the only way to describe new species. Inducers of the order Diptera (Family Cecidomyiidae) were the most abundant, found in 14 morphotypes of galls. Cecidomyiidae is the main family of gall-inducing insects throughout Brazil and the Neotropics (Gagné & Jaschhof 2017, Fernandes et al. 1988). The distribution of gallers in the different orders of insects and their host plants, observed

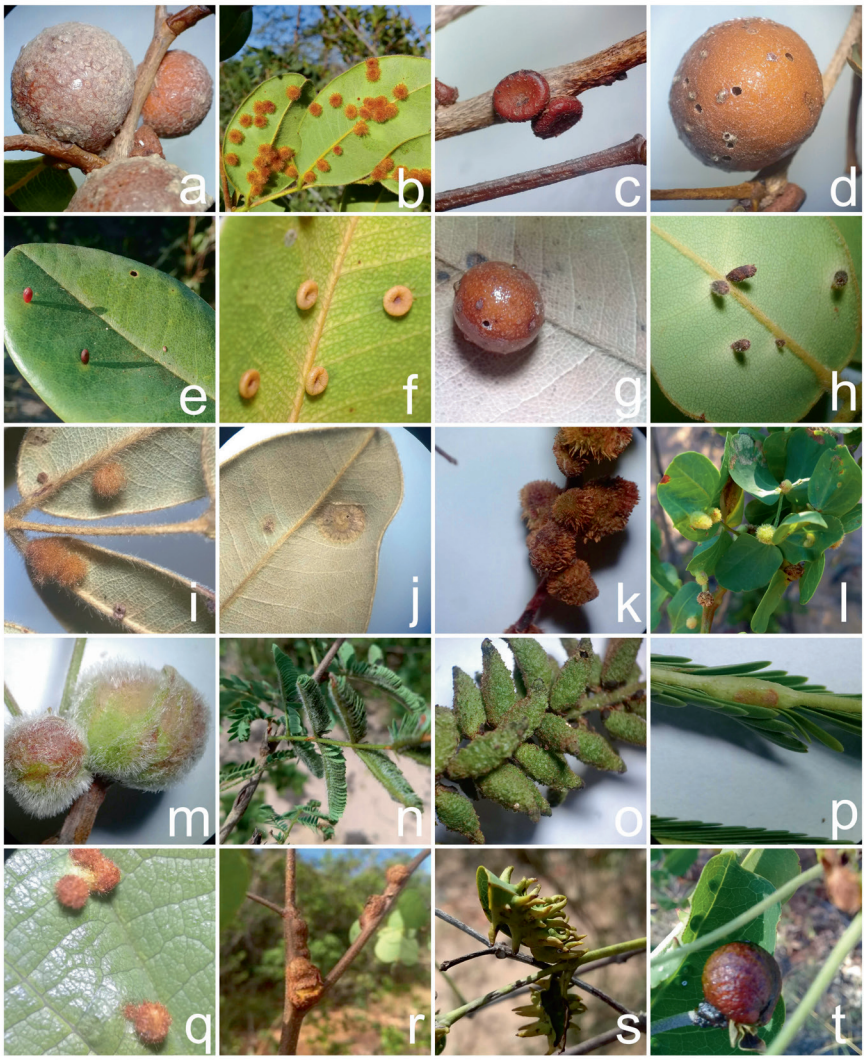

Figure 3. Insect galls found in the Serra da Bandeira (Barreiras, Bahia, Brazil). a. *Copaifera sabulicola* – Globoid, b. *Copaifera sabulicola* – Lenticular, c. *Copaifera depilis* – Lenticular, d. *Copaifera depilis* – Globoid, e. *Copaifera depilis* – Cylindrical, f. *Copaifera depilis* – Lenticular, g. *Copaifera depilis* – Globoid, h. *Copaifera luetzelburgii* – Cylindrical, i. *Copaifera luetzelburgii* – Lenticular, j. *Copaifera luetzelburgii* – Lenticular, k. *Mimosa sericantha* – Cylindrical, l. *Mimosa sericantha* – Cylindrical, m. *Caliandra* sp. – Globoid, n. *Caliandra* sp. – Fusiform, o. *Mimosa acutistipula* – Cylindrical, p. *Fabaceae* – Fusiform, q. *Bauhinia* sp1 – Globoid, r. *Bauhinia* sp2 – Fusiform, s. *Diplopterys* sp. – Conical and t. *Diplopterys* sp. – Globoid.

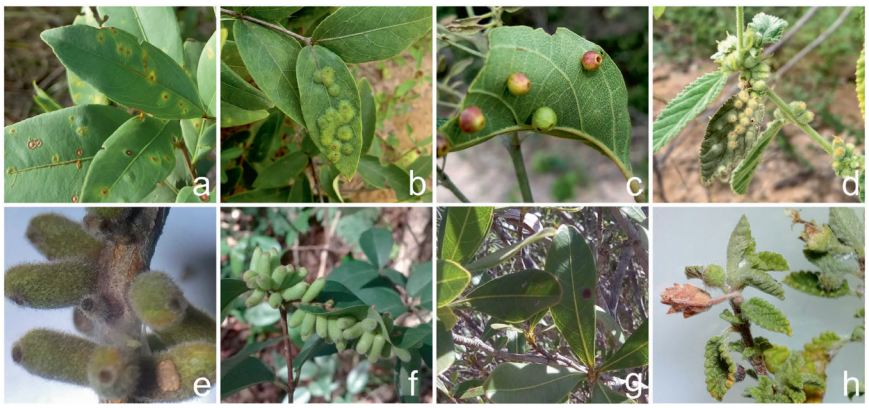

Figure 4. Insect galls found in the Serra da Bandeira (Barreiras, Bahia, Brazil). a. *Byrsonima* sp. – Lenticular, b. Malpighiaceae sp1 – Lenticular, c. Malpighiaceae sp2 – Conical, d. Malvaceae – Cylindrical, e. *Eugenia* sp. – Cylindrical, f. *Eugenia* sp. – Cylindrical, g. *Ouratea* sp. – Lenticular and h. Verbenaceae – Globoid.

http://www.scielo.br/bn

https://doi.org/10.1590/1676-0611-BN-2023-1527

Table 1. Characterization of insect galls found in Serra da Bandeira, Barreiras, Bahia, Brazil.

Gall	Host plant	Organ	Shape	Foliar surface	Color	Trichomes	Occurrence	Inducer	Associated fauna	Fig.
ANACARDIACEAE										
1	*Anacardium humile* A.St.Hil	Leaf	Globoid	Abaxial	Green	Absent	Grouped	Cecidomyiidae	Hymenoptera	1a
2	*Anacardium humile* A.St.Hil	Leaf	Conical	Abaxial	Green	Absent	Isolated	Not determined	–	1b
3	*Anacardium humile* A.St.Hil	Flower	Globoid	–	Green	Absent	Isolated	Cecidomyiidae	–	1c
BIGNONIACEAE										
4	Bignoniaceae Juss.	Leaf	Conical	Both	Green	Absent	Grouped	Not determined	Hymenoptera	1d
CARYOCARACEAE										
5	*Caryocar brasiliense* Cambess	Leaf	Globoid	Adaxial	Green/Brown	Absent	Grouped	Not determined	–	1e
COMBRETACEAE										
6	*Terminalia fagifolia* Mart.	Leaf	Conical	Both	Brown	Present	Grouped	Not determined	–	1f
7	*Terminalia* sp. L.	Leaf	Cylindrical	Adaxial	Green	Absent	Grouped	Not determined	–	1g
8	Combretaceae R. Br.	Leaf	Conical	Abaxial	Green/Red	Absent	Grouped	Not determined	Hymenoptera	1h
ERYTHROXYLACEAE										
9	*Erythroxylum* sp Kunth	Leaf	Globoid	Adaxial	Red	Present	Grouped	Cecidomyiidae	Hymenoptera	1i
EUPHORBIACEAE										
10	*Manihot caerulescens* Pohl.	Flower	Cylindrical	–	Green/Red	Absent	Grouped	*Iatrophobia brasiliensis* (Rübsaamen, 1908)	Hymenoptera	1j
11	*Manihot caerulescens* Pohl.	Leaf	Cylindrical	Adaxial	Green/Red	Absent	Grouped	*Iatrophobia brasiliensis* (Rübsaamen, 1908)	Hymenoptera	1k
12	*Manihot caerulescens* Pohl.	Fruit	Cylindrical	–	Green/Red	Absent	Grouped	Cecidomyiidae	–	1l
FABACEAE										
13	*Copaifera sabulicola* J. Costa	Leaf	Lenticular	Extralaminar	Green/Red	Absent	Grouped	Not determined	–	1m
14	*Copaifera sabulicola* J. Costa	Stem	Lenticular	–	Brown	Absent	Grouped	Not determined	–	1n
15	*Copaifera sabulicola* J. Costa	Leaf	Lenticular	Extralaminar	Green	Absent	Grouped	Not determined	–	1o
16	*Copaifera sabulicola* J. Costa	Leaf	Globoid	Abaxial	Brown	Present	Isolated	Not determined	–	1p
17	*Copaifera sabulicola* J. Costa	Leaf	Globoid	Abaxial	Brown	Absent	Grouped	Hymenoptera	Hymenoptera	1q

Continue...

https://doi.org/10.1590/1676-0611-BN-2023-1527

http://www.scielo.br/bn

...Continuation

Gall	Host plant	Organ	Shape	Foliar surface	Color	Trichomes	Occurrence	Inducer	Associated fauna	Fig.
18	*Copaifera sabulicola* J. Costa	Leaf	Lenticular	Intralaminar	Brown	Absent	Isolated	Not determined	Hymenoptera/ Acari	1r
19	*Copaifera sabulicola* J. Costa	Leaf	Globoid	Abaxial	Green/Brown	Absent	Isolated	Not determined	Hymenoptera	1s
20	*Copaifera sabulicola* J. Costa	Leaf	Leaf Fold	Both	Green/Brown	Absent	Isolated	Not determined	Hymenoptera	1t
21	*Copaifera sabulicola* J. Costa	Stem	Globoid	–	Brown	Absent	Grouped	Not determined	Hymenoptera	2a
22	*Copaifera sabulicola* J. Costa	Leaf	Lenticular	Extralaminar	Brown	Present	Isolated	Not determined	–	2b
23	*Copaifera depilis* Dwyer	Stem	Lenticular	–	Brown	Absent	Grouped	Not determined	Hymenoptera	2c
24	*Copaifera depilis* Dwyer	Stem	Globoid	–	Red/Brown	Absent	Isolated	Not determined	Hymenoptera	2d
25	*Copaifera depilis* Dwyer	Leaf	Cylindrical	Both	Red/Brown	Absent	Isolated	Not determined	Hymenoptera	2e
26	*Copaifera depilis* Dwyer	Leaf	Lenticular	Extralaminar	Green/Brown	Absent	Grouped	Not determined	Hymenoptera	2f
27	*Copaifera depilis* Dwyer	Leaf	Globoid	Abaxial	Brown	Absent	Isolated	Not determined	Hymenoptera	2g
28	*Copaifera luetzelburgii* Harms	Leaf	Cylindrical	Abaxial	Red/Brown	Present	Grouped	Not determined	Hymenoptera	2h
29	*Copaifera luetzelburgii* Harms	Leaf	Lenticular	Extralaminar	Brown	Present	Grouped	Not determined	Hymenoptera	2i
30	*Copaifera luetzelburgii* Harms	Leaf	Lenticular	Intralaminar	Green/Brown	Absent	Isolated	Cecidomyiidae	Hymenoptera	2j
31	*Mimosa sericantha* Benth	Stem	Cylindrical	–	Green/Brown	Present	Grouped	Cecidomyiidae	Hymenoptera	2k
32	*Mimosa sericantha* Benth	Leaf	Cylindrical	Adaxial	Green/Brown	Present	Grouped	Cecidomyiidae	Hymenoptera	2l
33	*Caliandra* sp. Benth	Stem	Globoid	–	Green/Red/ Brown	Present	Grouped	Hymenoptera	Lepidoptera	2m
34	*Caliandra* sp. Benth	Leaf	Fusiform	Both	Green	Absent	Grouped	Not determined	Lepidoptera	2n
35	*Mimosa acutistipula* Benth	Inflorescence	Cylindrical	–	Green	Absent	Grouped	Cecidomyiidae	Hymenoptera	2o
36	Fabaceae Lindl.	Leaf	Fusiform	–	Green	Present	Isolated	Not determined	–	2p

Continue...

...Continuation

Gall	Host plant	Organ	Shape	Foliar surface	Color	Trichomes	Occurrence	Inducer	Associated fauna	Fig.
37	*Bauhinia* sp1 L.	Leaf	Globoid	Adaxial	Brown	Present	Grouped	Not determined	–	2q
38	*Bauhinia* sp2 L.	Stem	Fusiform	–	Brown	Absent	Grouped	Cecidomyiidae	–	2r
MALPIGHIACEAE										
39	*Diplopterys* sp. A. Juss.	Leaf	Conical	Abaxial	Green	Absent	Grouped	Not determined	Hymenoptera/ Pseudoscorpiones	2s
40	*Diplopterys* sp. A. Juss.	Stem	Globoid	–	Green/Red	Absent	Grouped	Not determined	Hymenoptera	2t
41	*Byrsonima* sp. Rich	Leaf	Lenticular	Intralaminar	Green/Brown	Absent	Isolated	Not determined	–	3a
42	Malpighiaceae sp1 Juss	Leaf	Lenticular	Intralaminar	Green	Absent	Grouped	Not determined	–	3b
43	Malpighiaceae sp2 Juss	Leaf	Conical	Adaxial	Green	Present	Isolated	Not determined	–	3c
MALVACEAE										
44	Malvaceae Juss	Leaf	Cylindrical	Adaxial	Green	Present	Grouped	Cecidomyiidae	–	3d
MYRTACEAE										
45	*Eugenia* sp. L.	Stem	Cylindrical	Abaxial	Green	Present	Grouped	Cecidomyiidae	–	3e
46	*Eugenia* sp. L.	Leaf	Cylindrical	–	Green	Present	Grouped	Cecidomyiidae	–	3f
OCHNACEAE										
47	*Ouratea* sp. Aubl.	Leaf	Lenticular	Intralaminar	Green/Brown	Absent	Grouped	Not determined	–	3g
VERBENACEAE										
48	Verbenaceae J. St.–Hill	Leaf	Globoid	Adaxial	Green	Present	Isolated	Not determined	–	3h

http://www.scielo.br/bn

https://doi.org/10.1590/1676-0611-BN-2023-1527

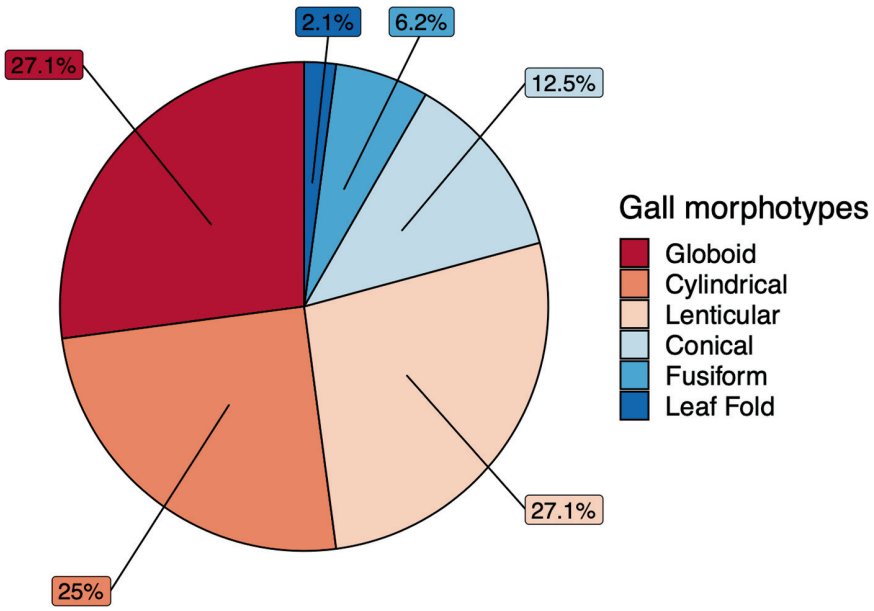

Figure 5. Percentage of gall morphotypes found in the Serra da Bandeira (Barreiras, Bahia, Brazil).

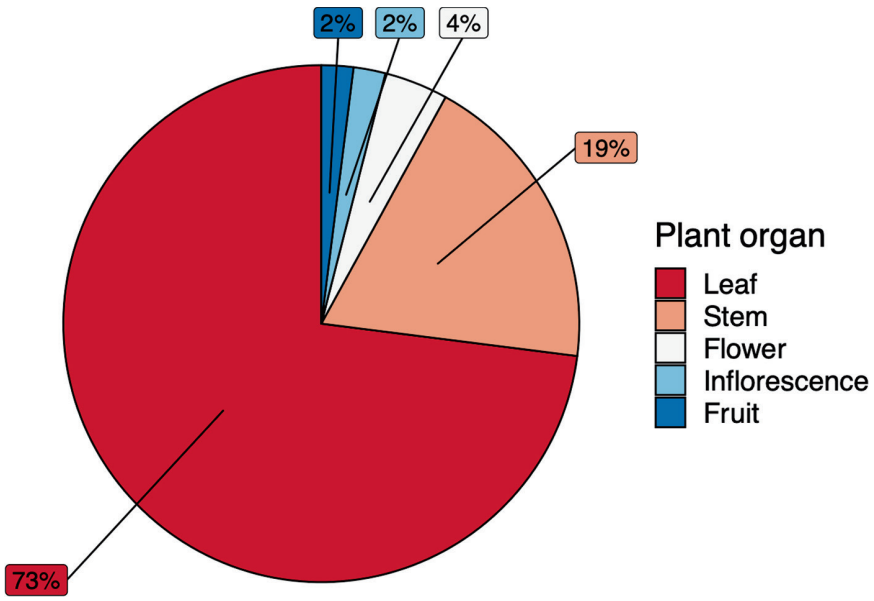

Figure 6. Percentage of plant organs affected by galling insects in the Serra da Bandeira (Barreiras, Bahia, Brazil).

in this study, has also been detected by other authors (Carneiro et al. 2009, Araújo et al. 2011, Maia 2013a, Scareli-Santos et al. 2018, Saito & Urso-Guimarães 2012), confirming that the cecidomyids are the main group of galling insects in the Cerrado.

We showed that the leaf was the organ with the highest number of registered galls as shown in other inventories in the Cerrado (Marinho et al. 2023, Maia 2013a). Such preference has been justified due to the availability of resources in the leaves being constantly abundant (Maia 2001). For this study, the globoid and cylindrical morphotypes were the most expressive, similar to studies conducted by Maia (2014). Bregonci et al. (2010) found that the majority of galls had the same color as the plant organ, with a predominance of green color as in the leaves. Here, we observe my pattern and that the coloration of some morphotypes can vary over time. Regarding the associated fauna, we found insects primarily belonging the order Hymenoptera, and identified them as parasitoids. According to Gagné (1994), hymenoptera are the main natural enemies of the Cecidomyiidae family. Further, the presence of these parasitoids has been considered a problem for obtaining insect galls at different stages of development and subsequent description (Maia 2013). Although we noticed a pseudoscorpion in the conical morphotype on *Diplopterys* sp. A. Juss, the occurrence of pseudoscorpions in Brazilian inventories seems to be scarce. Nogueira et al. 2016 also observed the presence of pseudoscorpions in a single gall morphotype and highlighted this likely scarcity.

In short, we characterized the insect galls found on plant host species, identified the gall-inducing insects to the lowest taxonomic

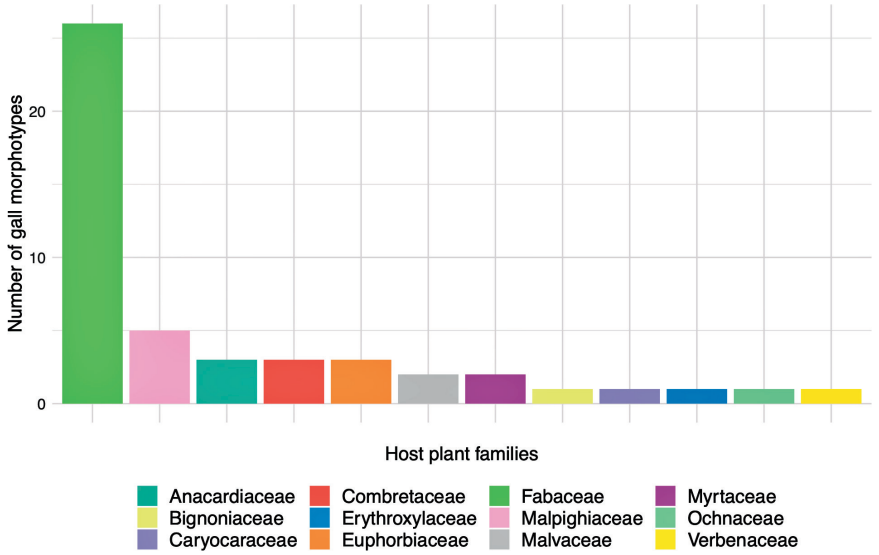

Figure 7. Distribution of insect galls in host plant families found in Serra da Bandeira (Barreiras, Bahia, Brazil).

level, and recorded the presence of gall-associated fauna. The information provided can be used highly by decision makers for conservation programs, as well as in other strategies for the conservation of biological diversity in the Brazilian Cerrado.

Acknowledgments

We thank the Federal University of Western Bahia (UFOB) for the structure provided and the Bahia State Research Support Foundation (FAPESB) for the master's scholarship (Term of grant BOL0374/2020).

Associate Editor

Gustavo Graciolli

Author Contributions

Jeferson Brito de Menezes: design of the study, data collection, data analysis and interpretation, manuscript preparation, critical revision, adding intellectual content.

Valdeir Pereira Lima: design of the study, data analysis and interpretation, manuscript preparation, critical revision, adding intellectual content.

Daniéla Cristina Calado: design of the study, data analysis and interpretation, manuscript preparation, critical revision, adding intellectual content.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethics

This study did not involve human subjects or clinical trials which require authorization by an Institutional Committee.

Data Availability

Codes are available on https://doi.org/10.5281/zenodo.8104868

References

ARAÚJO, W.S. de. 2018. 30 years of research on insect galls in Brazil: a scientometric review. Pap. Avulsos Zool. 58:e20185834.

ARAÚJO, W.S. de, SANTOS, B.B. dos & GOMES-KLEIN, V.L. 2011. Insect galls from Serra dos Pireneus, GO, Brazil. Biota Neotrop. 11(2):357–365.

ARAUJO, W.S., FERNANDES, G.W. & SANTOS, J.C. 2019. An overview of inventories of gall-inducing insects in Brazil: looking for patterns and identifying knowledge gaps. An. Acad. Bras. Cienc. 91(1):e20180162.

BREGONCI, J. de M., POLYCARPO, P.V. & MAIA, V.C. 2010. Galhas de insetos do Parque Estadual Paulo César Vinha (Guarapari, ES, Brasil). Biota Neotrop. 10(1):265–274.

CARNEIRO, M.A.A., BORGES, R.A.X., ARAÚJO, A.P.A. & FERNANDES, G.W. 2009. Insetos indutores de galhas da porção sul da Cadeia do Espinhaço, Minas Gerais, Brasil. Rev. Bras. Entomol. 53(4):570–592.

CARNEIRO, M.A.A., BRANCO, C.S.A., BRAGA, C.E.D., ALMADA, E.D., COSTA, M.B.M., MAIA, V.C. & FERNANDES, G.W. 2009. Are gall midge species (Diptera, Cecidomyiidae) host-plant specialists? Rev. Bras. Entomol. 53(3):365–378.

COELHO, M.S., CARNEIRO, M.A.A., BRANCO, C.A. & FERNANDES, G.W. 2013. Gall-inducing insects from Serra do Cabral, Minas Gerais, Brazil. Biota Neotrop. 13(3):102–109.

COSTA, E.C., CARVALHO-FERNANDES, S.P. & SANTOS-SILVA, J. 2014. Galhas de insetos em uma área de transição caatinga-cerrado no Nordeste do Brasil. Sitientibus série Ciências Biológicas. 14:10.13102/scb481

CRUZ RUGGIERO, P.G., BATALHA, M.A., PIVELLO, V.R. & MEIRELLES, S.T. 2002. Soil-vegetation relationships in cerrado (Brazilian savanna) and semideciduous forest, Southeastern Brazil. Plant Ecol. 160(1):1–16.

FERNANDES, G.W. & PRICE, P.W. 1988. Biogeographical gradients in galling species richness - Tests of hypotheses. Oecologia. 76:161–167.

FERNANDES, G.W.A., TAMEIRÃO NETO, E. & MARTINS, R.P. 1988. Ocorrência e caracterização de galhas entomógenas na vegetação do campus pampulha da Universidade Federal de Minas Gerais. Rev. Bras. Zool. 5(1):11–29.

GAGNÉ, R.J. 1994. The gall midges of the Neotropical Region. University Pres, Ithaca.

GAGNÉ, R.J. & JASCHHOF, M. 2017. A Catalog of the Cecidomyiidae (Diptera) of the World Fourth Edition Digital.

GARCIA, C. de A., LIMA, V.P., CALADO, D.C. & URSO-GUIMARÃES, M.V. 2017. New species of *Lopesia* Rübsaamen (Diptera: Cecidomyiidae) associated with *Andira humilis* Mart. ex Benth. (Fabaceae). Rev. Bras. Entomol. 61(3):239–242.

GONÇALVES-ALVIM, S.J. & FERNANDES, G.W. 2001a. Biodiversity of galling insects: Historical, community and habitat effects in four neotropical savannas. Biodivers. Conserv. 10:79–98.

GONÇALVES-ALVIM, S.J. & FERNANDES, G.W. 2001b. Comunidades de insetos galhadores (Insecta) em diferentes fisionomias do cerrado em Minas Gerais, Brasil. Rev. Bras. Zool. 18(1):289–305.

ISAIAS, R.M.S., CARNEIRO, R.G.S., OLIVEIRA, D.C. & SANTOS, J.C. 2013. Illustrated and Annotated Checklist of Brazilian Gall Morphotypes. Neotrop. Entomol. 42(3):230–239.

JONES, C.G., LAWTON, J.H. & SHACHAK, M. 1994. Organisms as Ecosystem Engineers. Oikos 69(3):373.

LIMA, V.P. & CALADO, D. 2018. Morphological characterization of insect galls and new records of associated invertebrates in a Cerrado area in Bahia State, Brazil. Brazilian J. Biol. 78(4):636–643.

LIMA, V.P. & CALADO, D.C. 2020. Mapping the habitat suitability of *Andira humilis* Mart. ex Benth. (Fabaceae) as a means to detect its associated galling species in Brazil. Acta Sci. Biol. Sci. 42(1):e48809.

LUZ, F.A. & MENDONÇA JÚNIOR, M. de S. 2019. Guilds in Insect Galls: Who is Who. Florida Entomol. 102(1):207.

MAIA, V.C. 2001. New genera and species of gall midges (Diptera, Cecidomyiidae) from three restingas of Rio de Janeiro State, Brazil. Rev. Bras. Zool. 18(1):1–32.

MAIA, V.C. 2013. Galhas de insetos em restingas da região sudeste do Brasil com novos registros. Biota Neotrop. 13(1):183–209.

MAIA, V.C. 2014. Insect galls of Itamonte (Minas Gerais, Brazil): characterization and occurrence. Biota Neotrop. 14(1):e20133839.

MAIA, V.C. 2023 http://fauna.jbrj.gov.br/ Retrieved October 13, 2023

MAIA, V.C. & FERNANDES, G.W. 2004. Insect galls from Serra de São José (Tiradentes, MG, Brazil). Brazilian J. Biol. 64(3):423–445.

MAIA, V.C. & MONTEIRO, R.F. 1999. Espécies cecidógenas (Diptera, Cecidomyiidae) e parasitóides (Hymenoptera) associadas a *Guapira opposita* (Vell.) Reitz: (Nyctaginaceae) na Restinga da Barra de Maricá, Rio de Janeiro. Rev. Bras. Zool. 16(2):483–487.

MANI, M.S. 1964. Ecology of Plant Galls. Springer Netherlands, Dordrecht.

MARINHO, R.A., MAIA, V.C. & BARBOSA, M.R. de V. 2023. Entomogenous galls and their associated fauna in deciduous dry forest and woodland vegetation remnants (Caatinga) in the Northern Depressão Sertaneja, Brazil. Biota Neotrop. 23(1):e20221428.

MARINI-FILHO, O.J. & FERNANDES, G.W. 2012. Stem galls drain nutrients and decrease shoot performance in *Diplusodon orbicularis* (Lythraceae). Arthropod. Plant. Interact. 6(1):121–128.

MARTINI, V.C., MOREIRA, A.S.F.P., KUSTER, V.C. & OLIVEIRA, D.C. 2019. Galling insects as phenotype manipulators of cell wall composition during the development of galls induced on leaves of *Aspidosperma tomentosum* (Apocynaceae). South African J. Bot. 127226–233.

MMA. 2017. https://www.gov.br/mma/pt-br Retrieved October 13, 2023

NASCIMENTO, D.T.F. & NOVAIS, G.T. 2020. Clima do Cerrado: dinâmica atmosférica e características, variabilidades e tipologias climáticas. Élisée – Rev. Geogr. da UEG 9(2):e922021.

NOGUEIRA, R.M., COSTA, E.C., CARVALHO-FERNANDES, S.P. & SANTOS-SILVA, J. 2016. Insect galls from Serra Geral, Caetité, BA, Brazil. Biota Neotrop. 16(1):e20150035.

NOGUEIRA, R.M., COSTA, E.C., SILVA, J.S. & ISAIAS, R.M. dos S. 2018. Structural and histochemical profile of *Lopesia* sp. Rübsaamen 1908 pinnula galls on *Mimosa tenuiflora* (Willd.) Poir. in a Caatinga environment. Hoehnea 45(2):314–322.

OLIVEIRA, C.M. & FRIZZAS, M.R. 2008. Insetos de Cerrado: distribuição estacional e abundância. Planaltina- DF. In: Embrapa Cerrados, 2008.

RAFAEL, J.A., MELO, G.A.R., CARVALHO, C.J.B. de, CASARI, S.A. & CONSTANTINO, R. 2012. Insetos do Brasil: Diversidade e Taxonomia. Holos, Editora, Ribeirão Preto.

SAITO, V.S. & URSO-GUIMARÃES, M.V. 2012. Characterization of galls, insect galls and associated fauna of Ecological Station of Jataí (Luiz Antônio, SP). Biota Neotrop. 12(3):99–107.

SANO, S.M.., ALMEIDA, S.P. de; & RIBEIRO, J.F. 2008. Cerrado: ecologia e flora. Brasília, DF: Embrapa Informação Tecnológica; Planaltina, DF: Embrapa Cerrados, 2008.

SANTANA, A.P. & ISAIAS, R.M. dos S. 2014. Galling insects are bioindicators of environmental quality in a Conservation Unit. Acta Bot. Brasilica 28(4):594–608.

SANTOS-SILVA, J. & ARAUJO, T.J. 2020. Are Fabaceae the principal super-hosts of galls in Brazil? An. Acad. Bras. Cienc. 92(2):e20181115.

SANTOS, I.M. dos, LIMA, V.P., SOARES, E.K.S., PAULA, M. de & CALADO, D.C. 2018. Insect galls in three species of *Copaifera* L. (Leguminosae, Caesalpinioideae) occurring sympatrically in a Cerrado area (Bahia, Brazil). Biota Neotrop. 18(1):e20170356.

SCARELI-SANTOS, C., SILVA, P.C., CARNEIRO, A.S. & DANTAS, S.P. 2018. Galhas em *Manihot esculenta* Crantz (Euphorbiaceae): Avaliação dos impactos na arquitetura e na produtividade da planta Hospedeira. Rev. Desafios 5(2):51–59.

SOARES, E.K.S., OLIVEIRA, A.B. de, LIMA, V.P. & CALADO, D. 2021. Insect galls associated with *Copaifera sabulicola* J.A.S Costa & L.P Queiroz (Fabaceae): Characterization and new records. Rev. Bras. Entomol. 65(4):e20210107.

SOUTHWOOD, T.R.E. 1960. The abundance of the Hawaiian trees and the number of their associated insect species. Proc. Hawaiian Entomol. Soc. 17299–303.

VIEIRA, L.G., NOGUEIRA, R.M., COSTA, E.C., CARVALHO-FERNANDES, S.P. & SILVA, J.S. 2018. Insect galls in Rupestrian field and Cerrado stricto sensu vegetation in Caetité, Bahia, Brazil. Biota Neotrop. 18(2):e20170402.

VIEIRA, R.F., CAMILLO, J. & CORADIN, L. 2016. Espécies Nativas da Flora Brasileira de Valor Econômico Atual ou Potencial Plantas para o Futuro – Região Centro – Oeste. Ministério do Meio Ambiente, Brasília, DF.

Received: 01/07/2023

Accepted: 16/10/2023

Published online: 13/11/2023