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ARTICLE

Insect galls of the Chapada Diamantina, Rio de Contas, Bahia, Brazil

Tainar de Jesus Araújo[1,4]; Valéria Cid Maia[2,5]; Marco Antonio Alves Carneiro[3,6] & Juliana Santos-Silva[1,7]

[1] Universidade do Estado da Bahia (UNEB), Departamento de Educação (DEDC),
Programa de Pós-Graduação em Biodiversidade Vegetal (PPGBVeg). Paulo Afonso, BA, Brasil.
[2] Universidade Federal do Rio de Janeiro (UFRJ), Museu Nacional (MN), Departamento de Entomologia,
Laboratório de Diptera. Rio de Janeiro, RJ, Brasil.
[3] Universidade Federal de Ouro Preto (UFOP), Instituto de Ciências Exatas e Biológicas (ICEB),
Departamento de Biodiversidade, Evolução e Meio Ambiente (DEBIO), Laboratório de Entomologia Ecológica. Ouro Preto, MG, Brasil.
[4] ORCID: 0000-0002-3894-0925. E-mail: thaina02_@hotmail.com
[5] ORCID: 0000-0001-9396-5618. E-mail: maiavcid@acd.ufrj.br
[6] ORCID: 0000-0003-3814-8118. E-mail: mcarneirinho@gmail.com
[7] ORCID: 0000-0003-0134-3438. E-mail: jussilva@uneb.br (corresponding author)

Abstract. We surveyed insect galls and their host plants in areas of Caatinga and Cerrado in the municipality of Rio de Contas, in the extreme south of the Chapada Diamantina (Bahia state), between 703 and 1,897 m altitude, in order to contribute to the knowledge and conservation of local biodiversity. The survey was conducted in eight locations, adopting the random walking methodology for sampling, four in Caatinga and four in Cerrado, covering distinct phytophysiognomies (cerrado *sensu stricto,* gallery forest, shrubby caatinga, riparian forest, and rocky field). Eighty-four different insect gall morphotypes were reported, 48 (57.14%) of them on 42 host species in Cerrado and 36 (42.86%) on 24 host species in Caatinga. Most galls occurred on leaves (48.72%) and were globoid (53.76%), glabrous (52.92%), isolated (55.44%), usually one-chambered (61.32%), and brown (25.2%). The gall-inducing insects identified belonged to Lepidoptera (n = 1), Thysanoptera (n = 1), Hemiptera (n = 2), and Diptera (Cecidomyiidae) (n = 16). This was the first inventory of galls in the Chapada Diamantina, so all records are new for the region. We also recorded the first occurrences of galls on two Cerrado plant species and on two in the Caatinga. We found a significant positive correlation between gall richness and plant species richness, suggesting that radiation of gall-inducing insects may be associated with plant species richness.

Keywords. Cecidomyiidae; Fabaceae; Gall-inducing insect; Host plant; Semi-arid.

INTRODUCTION

Gall inventories are essential to know the richness of gall-inducing insects and their host plants, moreover they provide reliable data on the identification of the host plants and of gall-inducing insects, plus the detailed characterization of the gall. As example, we can mention some recent inventories: Campos *et al.* (2021), Maia & Mascarenhas (2022), and Proença & Maia (2023). Furthermore, new species of gall-inducing insects (as *Clinodiplosis cecropiae* Proença & Maia, 2020 and *Distinctamyia matogrossensis* Proença & Maia, 2021, for example), as well as the associated fauna, can be discovered during these inventories (Campos *et al.,* 2021; Maia & Mascarenhas, 2022; Proença & Maia, 2023), thus contributing to knowledge about the biological interactions between different guilds. In addition, these studies increase knowledge of regional biodiversity and help in the search for patterns of distribution of the gall-inducing species involved; these data can be used in the preparation of management plans and biodiversity conservation of both natural and priority areas for conservation of flora and fauna (Silva *et al.,* 2011).

Investigations on the richness of gall-inducing insects and their host plants have been carried out in different phytophysiognomies in Brazil (Araújo *et al.,* 2019), including cerrado *s.s.* (*e.g.,* Araújo *et al.,* 2014; Campos *et al.,* 2021), caatinga (*e.g.,* Santos *et al.,* 2011a; Carvalho-Fernandes *et al.,* 2012), restinga (*e.g.,* Maia, 2001, 2018), rocky fields (*e.g.,* Carneiro *et al.,* 2009b; Coelho *et al.,* 2013a), dry tropical forest (Coelho *et al.,* 2009), montane fields (Coelho *et al.,* 2013b), and moist forest (*e.g.,* Julião *et al.,* 2005; Almada & Fernandes, 2011). There are still large gaps in our knowledge about the richness of gall-inducing insects of several phytophysiognomies of Northeastern Brazil, due to the large area and scattered studies con-

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centrated in two of its nine states, Bahia and Pernambuco (Santos *et al.*, 2011b; Carvalho-Fernandes *et al.*, 2012; Costa *et al.*, 2014a, b; Nogueira *et al.*, 2016; Alcântara *et al.*, 2017; Brito *et al.*, 2018; Santos *et al.*, 2018; Silva *et al.*, 2018; Vieira *et al.*, 2018; Santos *et al.*, 2019; Santana *et al.*, 2020; Campos *et al.*, 2021; Santos-Silva *et al.*, 2022). Recently, Cintra *et al.* (2021) compiled the occurrence of 100 host plant species and 156 morphospecies of gall-inducing insects for the Caatinga based on information available in the literature. The true numbers of gall-inducing insects and host plant species in the Caatinga, however, should be greater because many areas of the region have never been inventoried including the Chapada Diamantina (northern portion of the Espinhaço Range, Bahia).

The Chapada Diamantina, located between the Caatinga and Cerrado biomes, has different phytophysiognomies that change over short distances, including rocky fields, cerrado *s.s.*, caatinga and forest (Neves *et al.*, 2016). This mosaic of vegetation hosts a great wealth of species of fauna and flora important for the biodiversity of mountains in Brazil (Neves & Conceição, 2010) and for the study of how plants and gall-inducing insects interact. Despite this, the Chapada Diamantina was considered an extremely unknown region by the Ministério do Meio Ambiente (MMA, 2002) and therefore a priority for scientific research.

Given this context, the present study aimed to inventory for the first time the gall-inducing insects and their host plants in phytophysiognomies of the Cerrado and Caatinga biomes in the municipality of Rio de Contas, extreme south of the Chapada Diamantina, Bahia. Considering that gall-inducing insects are highly specialized on their host plants and dependent on the occurrence, abundance and distribution of plants (Cuevas-Reyes *et al.*, 2003; Carneiro *et al.*, 2009a, 2014), we evaluated if plant species richness is an important factor determining the species richness and composition of gall-inducing insects in adjacent habitats that differed in humidity, vegetation, and leaf phenology.

MATERIAL AND METHODS

The present study was carried out in the municipality of Rio de Contas (13°34′44″S, 41°48′41″W), which comprises 1,071 km^2 and is located in the extreme south of the Chapada Diamantina, in the state of Bahia (Fig. 1). This municipality has a mild mesothermal climate, Cwb type, characterized as semi-humid tropical, with rainy summers and dry winters. The rains occur more frequently in summer (November, December, and January), with a secondary peak from March to April; and the rains

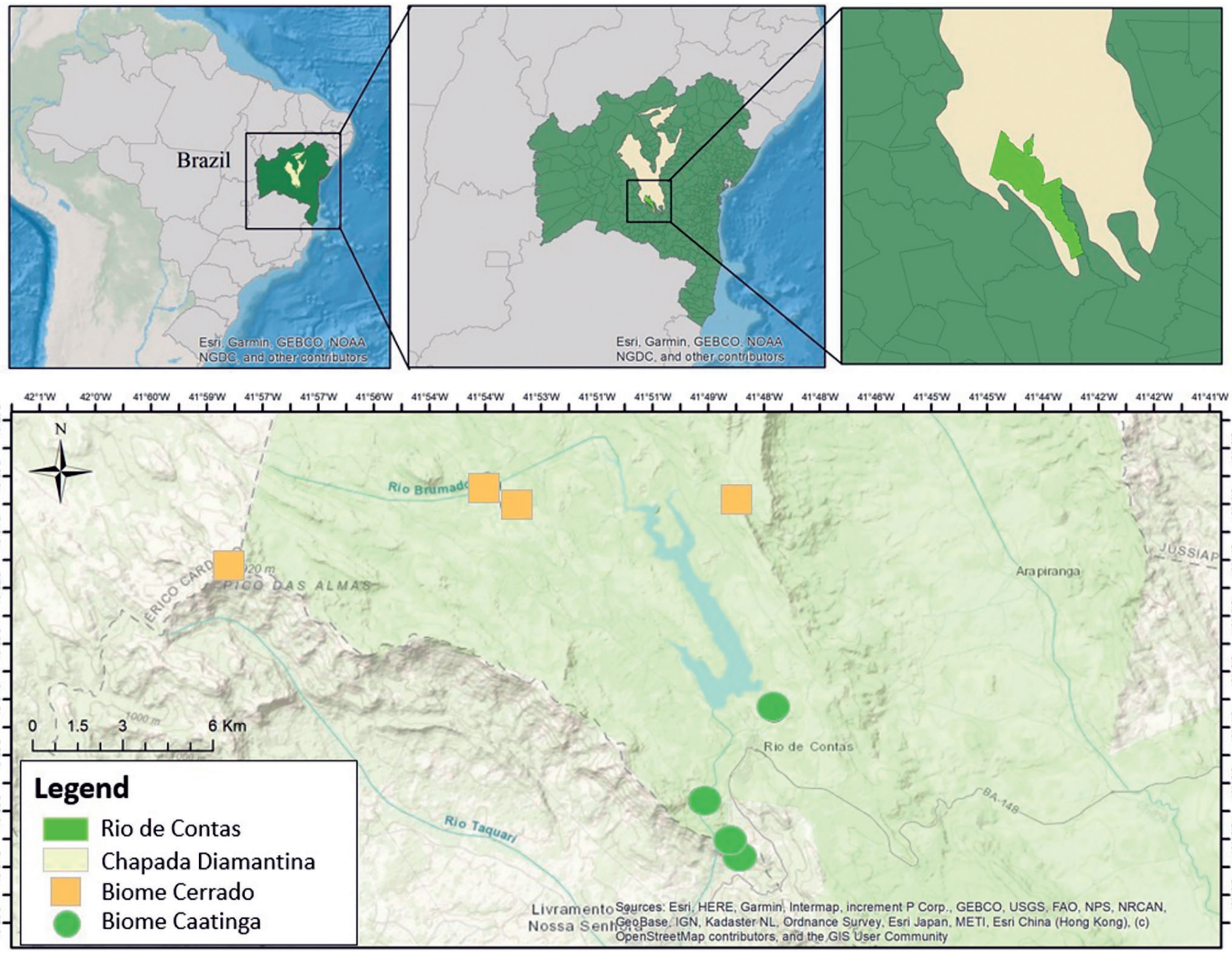

Figure 1. Geographical overview of the Chapada Diamantina, showing the location of the study areas.

Table 1. Collection sites of the galls and their host plants occurring in the municipality of Rio de Contas, extreme south of the Chapada Diamantina, Bahia, Brazil.

Biome	Phytophysiognomy	Locality	Coordinates	Altitude	Extension (round-trip on the trail)
Cerrado	Rupestrian field	Serra do Pico das Almas	13°31′34.68″S, 41°58′03.65″W	1,897 m	12 km
Cerrado	Riparian forest	Sítio das Cachoeirinhas	13°30′30.95″S, 41°52′59.26″W	1,203 m	2 km
Cerrado	Riparian forest	Sítio das Cachoeirinhas – Poço Preto	13°30′11.04″S, 41°53′28.01″W	1,189 m	3,4 km
Cerrado	Cerrado *s.s.*	Capela do Bom Jesus	13°34′10.04″S, 41°48′19.17″W	1,084 m	4 km
Caatinga	Shrubby caatinga	Cachoeira do Fraga	13°35′48.70″S, 41°49′37.59″W	978 m	4,7 km
Caatinga	Gallery forest	Cachoeira do Raposo	13°30′24.20″S, 41°48′59.18″W	931 m	1,4 km
Caatinga	Shrubby caatinga	Cachoeira do Rio Brumado (Véu da Noiva)	13°36′34.20″S, 41°49′04.11″W	760 m	3 km
Caatinga	Shrubby caatinga	Estrada Real	13°36′49.68″S, 41°48′55.01″W	703 m	9 km

decrease from August to November (Harley, 1995; Nascimento *et al.,* 2010). The vegetation is formed by shrubby caatinga, rocky fields, cerrado *sensu stricto,* and gallery and riparian forests, which grow on quartzite and sandstone soils, at altitudes from 700 m (SEI, 2016) to 1,970 m altitude (Pico das Almas – the third highest mountain in the Northeast region of Brazil).

In order to sample a large geographic area like the municipality of Rio de Contas, the sampling effort was distributed over as many phytophysiognomies as possible. The study areas are inserted in the Cerrado and Caatinga biomes, four in each biome, covering all the phytophysiognomies of the municipality, cerrado *sensu stricto,* gallery forest, shrubby caatinga, riparian forest, and rocky fields (Andrade-Lima, 1981; Ribeiro & Walter, 2008; Moro *et al.,* 2016; Table 1, Fig. 2). Ten collections were made along the trails at eight different locations during the period from July to October 2021 (Fig. 1). A team of three individuals spent four hours at each collection point, totaling a sampling effort of 40 hours. All plant habits (subshrubs, trees and creepers) up to 2 meters high were surveyed. When found, the galls were photographed, collected, stored, and labeled in plastic bags. All morphological information about the galls was recorded, including coloration, host organ, pilosity, and shape, using the terminology proposed by Isaias *et al.* (2013).

Some of the galls were stored in plastic containers in the laboratory together with moistened paper towels to maintain humidity. This allows the emergence of the gall-inducing insects and any associated fauna, which was classified according to Luz & Mendonça-Júnior (2017). Other samples were dissected under a stereomicroscope to determine the number of chambers in each gall and to extract the larvae. Both the larvae and the emerging winged insects were preserved in 70% ethanol. In the empty galls, the identifications of the insect species were undertaken by comparisons with the morphotypes of known gall-inducing insects in host plants species previously identified in Cerrado and Caatinga environments in Brazil (*e.g.,* Santos *et al.,* 2011a, b; Carvalho-Fernandes *et al.,* 2012; Costa *et al.,* 2014a; Nogueira *et al.,* 2016; Brito *et al.,* 2018; Vieira *et al.,* 2018).

The host plants were collected, field-pressed, dried, and mounted according to the methodology of Peixoto & Maia (2013). The identification of the plants was done with the help of analytical keys found in specialized literature, and by comparing with the existing material in the herbarium of the Universidade do Estado da Bahia (HUNEB – Caetité Collection). Plant nomenclature was verified in the Flora e Funga do Brasil (https://floradobrasil.jbrj.gov.br), and the names are presented in alphabetical order by family, following APG IV (2016). The circumscription of the Fabaceae family was based on classification proposed by LPWG (2017). The preliminary conservation status of the plant species was verified in the Flora e Funga do Brasil, and it was defined according to the categories proposed by IUCN (2022) (EN = endangered, LC = least concern, NE = not evaluated, NT = near threatened, VU = vulnerable).

The total number of plant species sampled was used as the explanatory variable of gall-inducing species richness (Carneiro *et al.,* 2014). To analyze the relationships between plant species richness and the gall-inducing species richness (y-axis) was adjusted using a zero-truncated model (Hilbe, 2014). The likelihood ratio test was used to compare goodness of fit of the models. The analyses were performed using the R software package (R Core Team, 2023).

RESULTS

We recorded 84 gall morphotypes on 42 species belonging to 37 genera, and 26 plant families along the eight trails of the Rio de Contas (Table 2, Figs. 3-8). Galls were recorded for the first time for Brazil on individuals of *Combretum glaucocarpum* Mart. (Combretaceae) (Table 2, Fig. 4H-I) and *Mimosa hypoglauca* Mart. (Fabaceae) (Table 2, Fig. 6O), both growing in caatinga vegetation, and on *Lippia alnifolia* Mart. & Schauer (Verbenaceae) (Table 2, Fig. 8H), and *Drimys brasiliensis* Miers (Winteraceae) (Table 2, Fig. 8K) both found in rocky fields. Most of the host species are native to Brazil, of which 12 are endemic (Table 3). In addition, a stem gall was recorded in the exotic species *Mangifera indica* L. (Anacardiaceae) (Table 2, Fig. 3B) in riparian forest. Concerning IUCN (2022) conservation categories, plant species were classified into NE (n = 35), LC (n = 5), VU (n = 1), and DD (n = 1) (Table 3).

The number of gall species increased with the number of plant species in the studied sites (equation: gall-inducing species = $\exp^{(1.01218+0.16583*\text{plant richness})}$, $X^2 = 18.170$; $p < 0.001$; Fig. 9). A total of 48 gall morphotypes was found in the Cerrado biome on 36 plant species belonging to 24 genera and 18 families (Table 2, Fig. 10). Species of the families Fabaceae (n = 11), Melastomata-

Figure 2. Sampled area of the Chapada Diamantina, Rio de contas, Bahia, Brasil. (A-C) Rupestrian field; (D-E) Riparian forest; (F) Cerrado *s.s.;* (G) Shrubby caatinga; (H) Gallery forest; (I-J) Shrubby caatinga. Photos: Tainar Araújo.

ceae (n = 4 species), Annonaceae (n = 3), and Asteraceae (n = 3) hosted the greatest gall richness with 19, four, four and three morphotypes, respectively. The genera with the greatest richness of gall morphotypes were *Copaifera* L. (Fabaceae) (n = 7), *Bauhinia* L. (Fabaceae) and *Mimosa* L. (Fabaceae) with four morphotypes each. The species with the highest richness of gall morphotypes was *Copaifera depilis* Dwyer (n = 4, Fig. 5G-K).

For the Caatinga biome, 36 gall morphotypes were found on 24 plant species belonging to 20 genera and

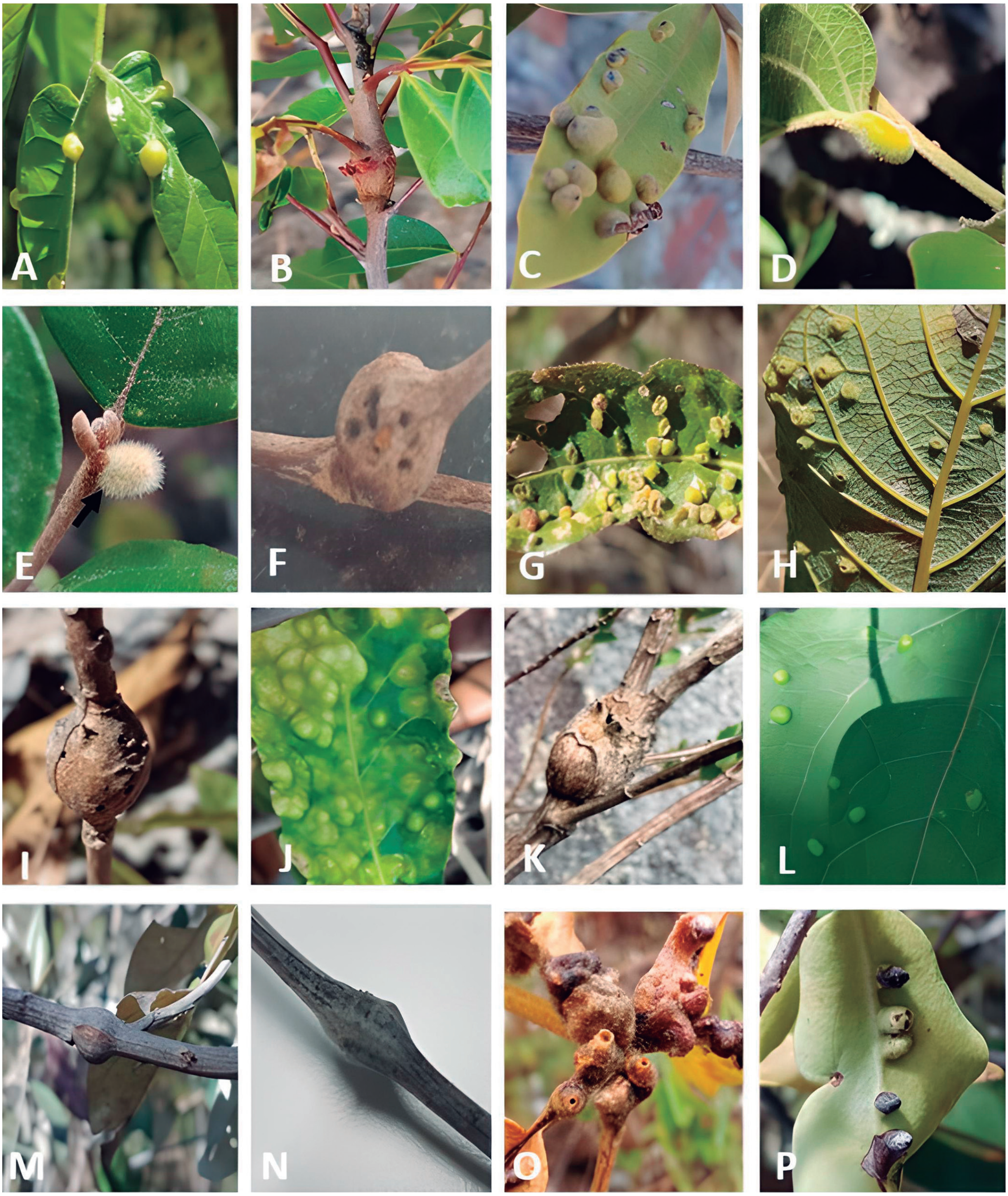

Figure 3. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. (A) *Astronium fraxinifolium* Schott ex Spreng.; (B) *Mangifera indica* L.; (C) *Duguetia furfuracea* (A. St.-Hil.) Saff.; (D) Annonaceae Indet.; (E-F) Annonaceae sp.; (G-J) *Aspidosperma tomentosum* Mart.; (K) *Baccharis minutiflora* Mart. ex Baker.; (L) *Mikania* sp.; (M) *Eremanthus erythropappus* (DC.) MacLeish; (N) *Moquiniastrum polymorphum* (Less.) G. Sancho; (O) Bignoniaceae indet.; (P) *Protium heptaphyllum* (Aubl.) Marchand. Photos: Tainar Araújo.

14 families (Table 2, Fig. 10). The plant families that hosted the greatest richness of gall morphotypes were Fabaceae (n = 8 species, 14 morphotypes), Calophyllaceae (n = 1, 6), and Piperaceae (n = 1, 3). The plant genera with the highest richness of gall were *Calophyllum* L. (n = 6), *Copaifera* (n = 6), *Bauhinia* (n = 3), and *Piper* L. (n = 3). The superhost species was *Calophyllum brasiliense* Cambess (Fig. 4A-F) with six morphotypes.

Among the morphotypes found, four them were observed in both shrubby caatinga and cerrado *s.s.* (Fig. 10): the globoid leaf gall induced by *Myrciaryiamia admirabilis* Maia (2007) (Cecidomyiidae) on *Erythroxylum sub-*

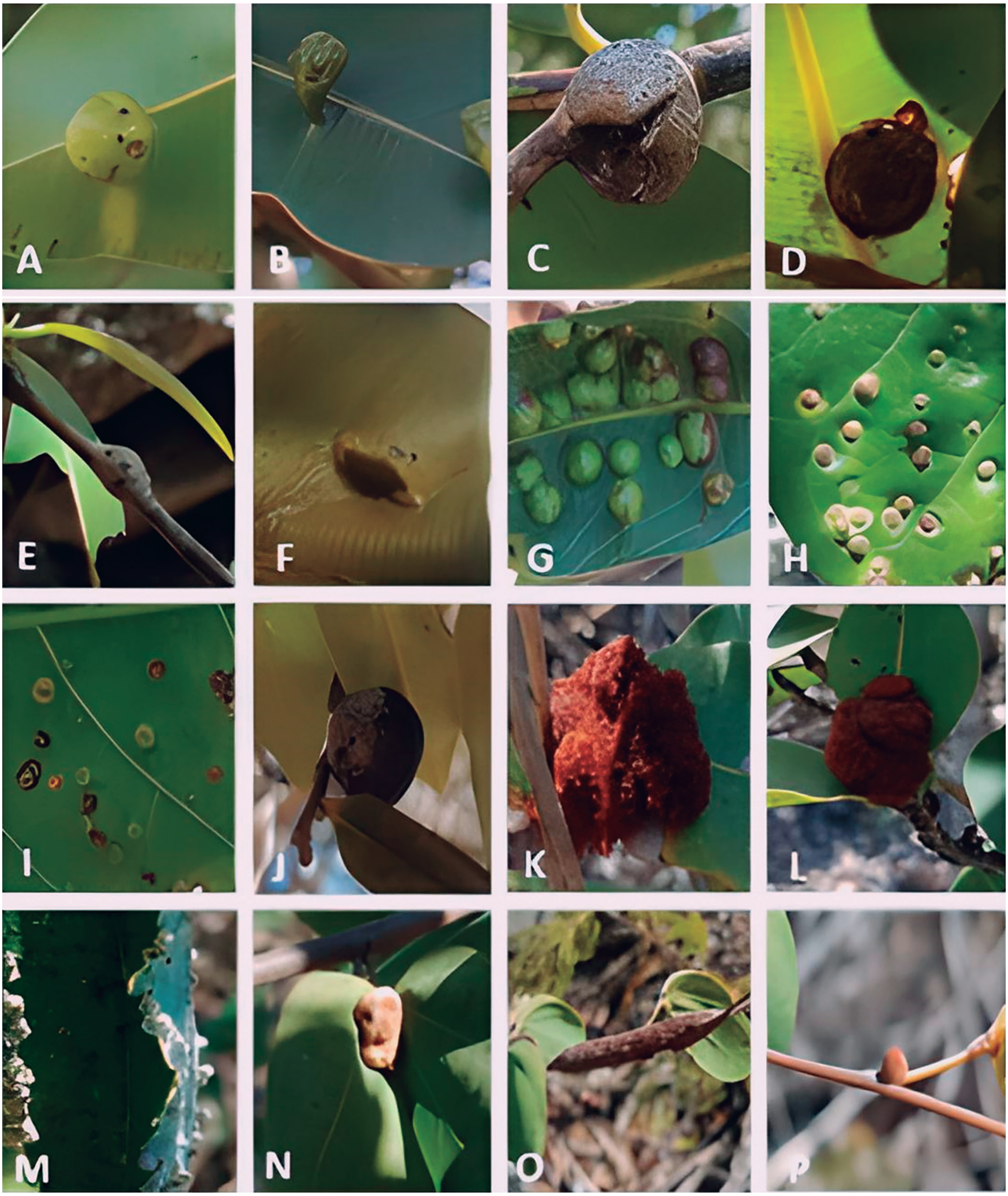

Figure 4. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. (A-F) *Calophyllum brasiliense* Cambess.; (G) *Parinari obtusifolia* Hook. f.; (H-I) *Combretum glaucocarpum* Mart.; (J) *Diospyros sericea* A.DC.; (K-L) *Erythroxylum suberosum* A. St.-Hil.; (M) *Croton adamantinus* Müll. Arg.; (N) *Bauhinia* sp.; (O-P) *Bauhinia catingae* Harms. Photos: Tainar Araújo.

erosum A. St.-Hil. (Erythroxylaceae), the globoid leaf gall on *Mimosa gemmulata* Barneby (Fabaceae), the globoid leaf gall on *Bauhinia pulchella* Benth. (Fabaceae), and the conical leaf gall on *Copaifera langsdorffii* Desf. (Fabaceae).

The greatest gall richness (36 morphotypes) by life form was found in shrubs, followed by subshrubs (30 morphotypes), trees (17 morphotypes), and liana (1 morphotype), represented by 24, 24, 6 and one plant species, respectively (Table 2). The average number of gall morphotypes by plant species was 1.5 in shrubs, 1.25 in subshrubs, 2.8 in trees and 1.0 in lianas.

Galls were found on vegetative and reproductive organs: leaves (n = 58, 30 in Caatinga and 28 in Cerrado);

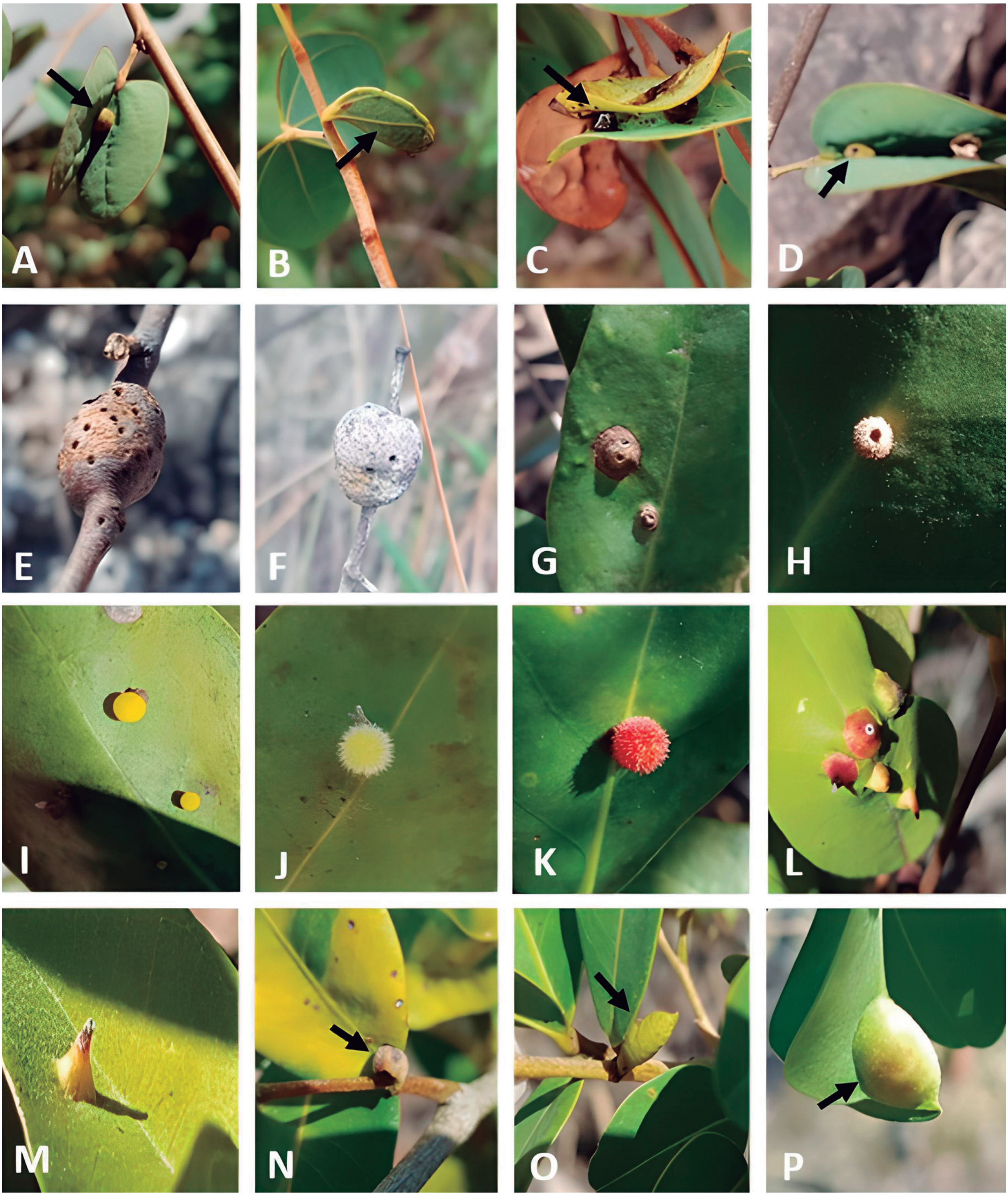

Figure 5. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. (A-D) *Bauhinia pulchella* Benth.; (E) *Calliandra* sp.; (F) *Calliandra dysantha* Benth.; (G-K) *Copaifera depilis* Dwyer.; (L-N) *Copaifera langsdorffii* Desf.; (O-P) *Copaifera luetzelburgii* Harms. Photos: Tainar Araújo.

stems (n = 23, 18 in Cerrado and 5 in Caatinga); buds (n = 2, one in Cerrado and one in Caatinga) and fruit (n = 1 in Caatinga). The most frequent shapes were globoid (n = 64, 39 in Cerrado and 25 in Caatinga); conical (n = 7, five in Caatinga and two in Cerrado), and fusiform (n = 5, three in Caatinga and two in Cerrado). Most of the galls were glabrous (n = 63, 35 in Cerrado and 28 in Caatinga), one-chambered (n = 73, 40 in Cerrado and 33 in Caatinga), and isolated (n = 66, 38 in Cerrado and 28 in Caatinga). The colors of the galls were brown, green, yellow, white, gray, black or rarely red or pink, brown being the most frequent color (n = 30, 18 in Cerrado and 12 in

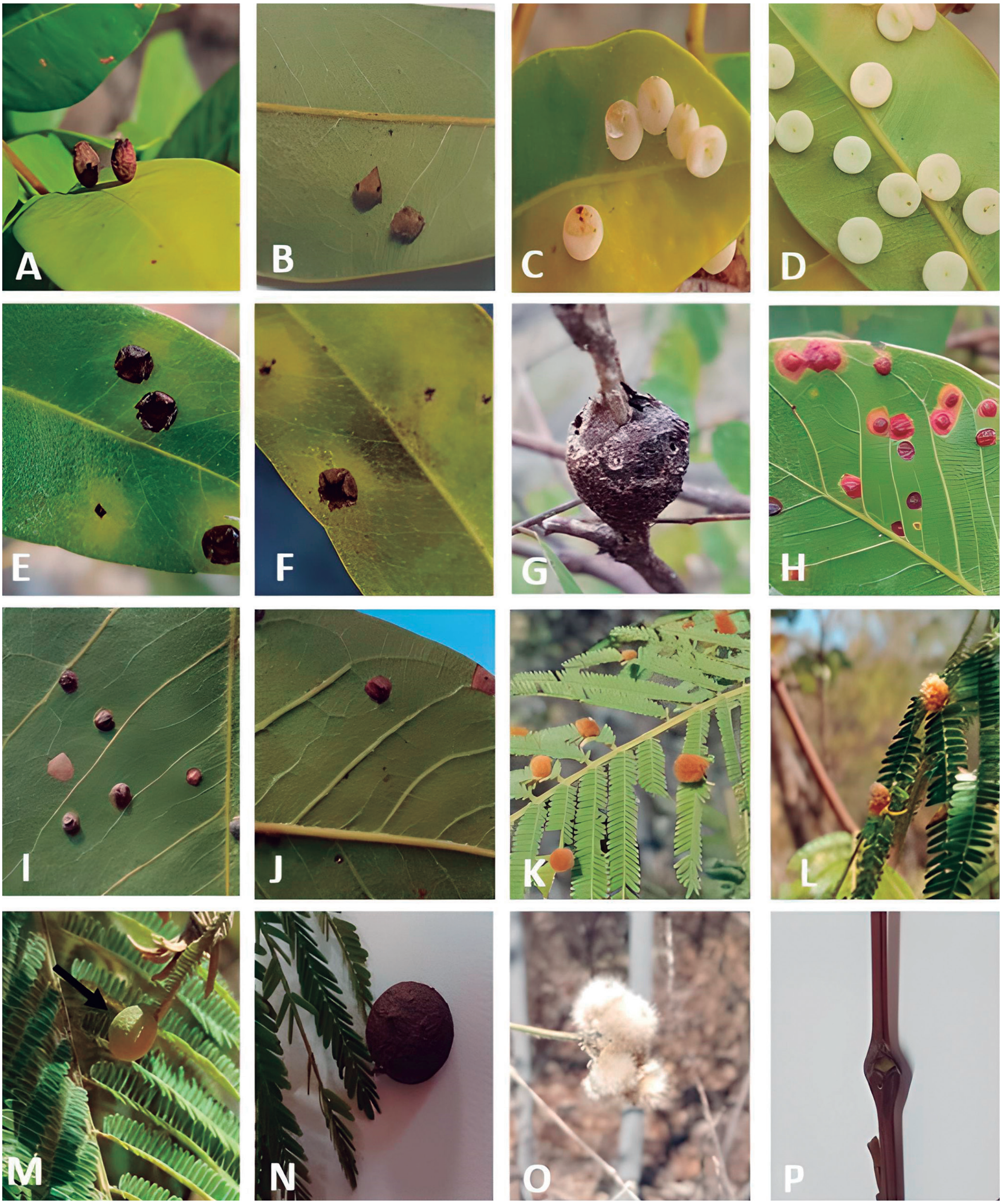

Figure 6. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. (A-B) *Copaifera luetzelburgii* Harms.; (C-F) *Copaifera sabulicola* A.S. Costa & L.P. Queiroz; (G) *Dalbergia miscolobium* Benth.; (H) *Hymenaea courbaril* L.; (I-J) *Hymenaea martiana* Hayne; (K-N) *Mimosa gemmulata* Barneby.; (O) *Mimosa hypoglauca* Mart.; (P) *Mimosa tenuiflora* (Willd.) Poir. Photos: Tainar Araújo.

Caatinga). Some galls may change color during their development. The conical leaf gall on *Protium heptaphyllum* (Aubl.) Marchand (Burseraceae) can be black or green (Fig. 3P) and the color of the lenticular leaf gall on *Copaifera sabulicola* A.S. Costa & L.P. Queiroz (Fabaceae) varies from white to black (Figs. 6C-F).

The identified inducing insects belonged to the orders Diptera (Cecidomyiidae) (n = 19, eight in Caatinga and eight in Cerrado), Hemiptera (n = 2 in Cerrado), Lepidoptera (n = 1 in Cerrado), and Thysanoptera (n = 1 in Cerrado) (Table 2). The associated fauna was found in 12 morphotypes (n = 10 in Caatinga and eight in Cerra-

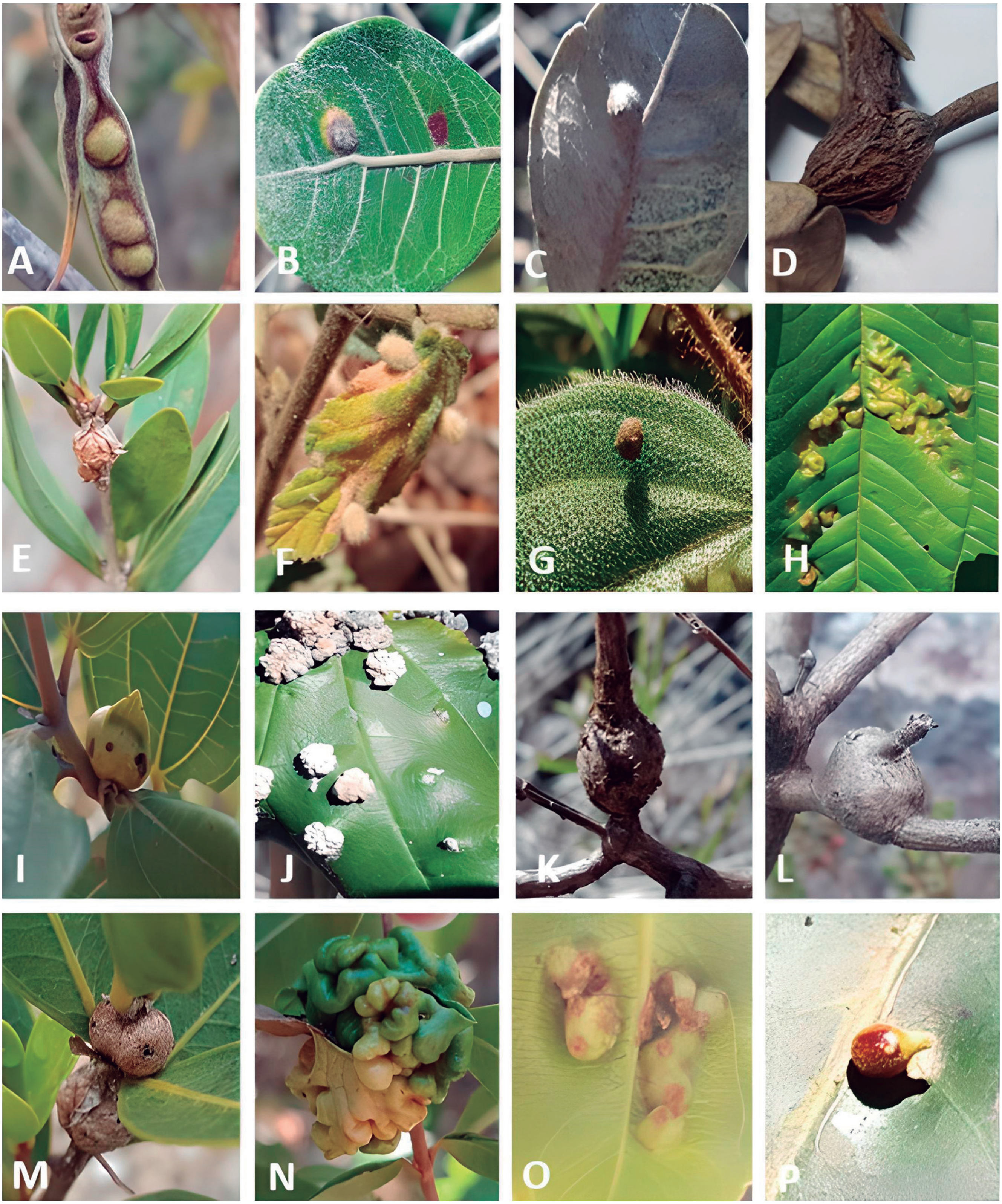

Figure 7. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. (A) Fabaceae Indet.; (B-D) *Byrsonima guilleminiana* A. Juss.; (E) Malpighiaceae Indet.; (F) *Sida cordifolia* L.; (G) *Leandra reversa* DC.) Cogn.; (H) *Miconia ibaguensis* (Bonpl.) Triana; (I) *Miconia* sp.; (J) *Miconia alborufescens* Naudin; (K) *Pleroma stenocarpum* (Schrank et Mat. ex. DC.) Triana; (L) *Tibouchina* sp.; (M) Myrsinaceae Indet.; (N) *Myrcia tomentosa* (Aubl.) DC.; (O) *Ouratea* sp.; (P) *Piper* sp. Photos: Tainar Araújo.

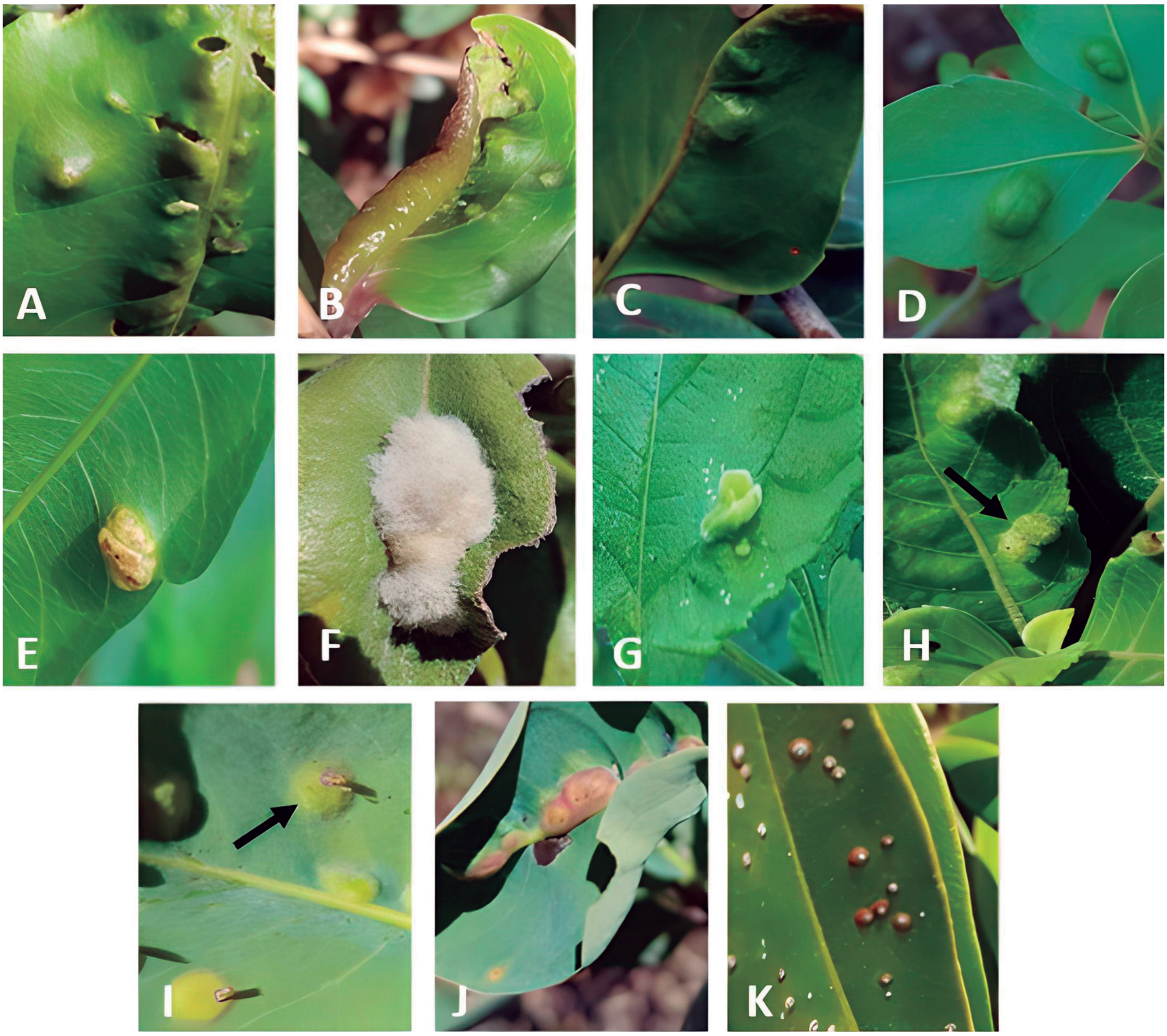

Figure 8. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. (A-B) *Piper* sp.; (C) *Roupala montana* Aubl.; (D) *Serjania glabrata* Kunth.; (E) *Serjania erecta* Radlk.; (F) *Trigonia nivea* Cambess.; (G) *Lantana camara* L.; (H) *Lippia alnifolia* Mart. & Schauer; (I-J) *Vochysia elliptica* Mart.; (K) *Drimys brasiliensis* Miers. Photos: Tainar Araújo.

do) composed of parasitoids (Hymenoptera n = 9, five in Caatinga and four in Cerrado), inquilines (Coleoptera [n = 2, one in Cerrado and one in Caatinga], Lepidoptera [n = 3, two in Caatinga and one in Cerrado], Thysanoptera [n = 1 in Caatinga]), and successors (Formicidae n = 2 in Cerrado; Psocoptera n = 1 in Cerrado). Moreover, pseudoescorpions were observed in marginal roll galls induced on *Piper* sp. (Piperaceae) in Caatinga.

DISCUSSION

The Cerrado biome in the municipality of Rio de Contas showed a higher density of galls than the Caatinga of the same region, corroborating studies confirming that the Cerrado biome is the richest in terms of gall morphotypes among Brazilian biomes (Araújo, 2018; Cintra *et al.,* 2020). To date, it is estimated that the Cerrado has approximately 968 gall morphotypes induced on 505 host plant species (Cintra *et al.,* 2020). In contrast, Caatinga has 156 distinct morphotypes of gall and 100 host plant species (Cintra *et al.,* 2021). The difference in the richness of gall-inducing insects between these biomes can be explained by several factors. The first factor is the difference in sampling effort, in other words, differences in sampling effort confound comparisons of species richness between local habitats or on large scales. For example, there are more than 32 inventories of galls for the Cerrado in Brazil (Cintra *et al.,* 2020), while there are only ten one-off studies inventories for the Caatinga (Santos *et al.,* 2011a; Carvalho-Fernandes *et al.,* 2012; Luz *et al.,* 2012; Costa *et al.,* 2014a, b; Nogueira *et al.,* 2016; Alcântara *et al.,* 2017; Brito *et al.,* 2018; Costa & Araújo, 2019; Santos-Silva *et al.,* 2022). The second factor is the lower plant richness in the Caatinga; for Cintra *et al.* (2021), the smaller number of plant species that make up the biome may explain the lower numbers of galls. Gall-inducing insects are host-specific, and therefore one would expect a

Table 2. Insect gall of the da Chapada Diamantina, Rio de Contas, Bahia, Brazil. PA = Pico das Almas. CBJ = Capela do Bom Jesus. SC = Sitio das Cachoeirinhas. CF = Cachoeira do Fraga. CR = Cachoeira do Raposo. CVN = Cachoeira Véu da Noiva. ER = Estrada Real.

Family	Specie	Plant lifeform	Organ	Surface	Shape	Color	Pilose	Occurrence	Chambers	Galling-inducing insects	Associated fauna	Phytophysiognomy	Locality	Figures
Anacardiaceae	*Astronium fraxinifolium* Schott	Tree	Leaf	Adaxial	Globoid	Yellow	No	Isolated	One-chambered	—	—	Gallery forest	CR	3A
	Mangifera indica L.	Shrub	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Riparian forest	SC	3B
Annonaceae	*Duguetia furfuracea* (A. St.-Hil.) Saff.	Shrub	Leaf	Adaxial	Globoid	Green	Yes	Grouped	One-chambered	*Bruggmanniella* sp. (Cecidomyiidae)	Hymenoptera (parasitoids)	Cerrado *s.s.*	CBJ	3C
	Annonaceae Indet. 1	Subshrub	Bud	—	Fusiform	Green	Yes	Isolated	One-chambered	Hemiptera	—	Cerrado *s.s.*	PA	3D
	Annonaceae Indet. 2	Subshrub	Stem	—	Globoid	White	Yes	Isolated	One-chambered	—	—	Cerrado *s.s.*	PA	3E
			Stem	—	Globoid	Brown	No	Grouped	Multichambered	—	—	Rupestrian field	PA	3F
Apocynaceae	*Aspidosperma tomentosum* Mart. & Zucc.	Shrub	Leaf	Adaxial/Abaxial	Globoid	Green	Yes	Isolated	One-chambered	Hemiptera	Psocoptera	Riparian forest	SC	3G-H
			Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Riparian forest	SC	3I
			Leaf	Adaxial	Globoid	Yellow	No	Grouped	One-chambered	—	—	Shrubby caatinga	CF	3J
Asteraceae	*Baccharis minutiflora* Mart. ex Baker.	Subshrub	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Rupestrian field	PA	3K
	Mikania sp.	Liana	Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	—	—	Shrubby caatinga	CF	3L
	Eremanthus erythropappus (DC.) MacLeish	Shrub	Stem	—	Globoid	Cinza	No	Isolated	One-chambered	Lepidoptera	—	Cerrado *s.s.*	PA	3M
	Moquiniastrum polymorphum (Less.) G. Sancho	Shrub	Stem	—	Globoid	Gray	No	Isolated	One-chambered	—	—	Riparian forest	SC	3N
Bignoniaceae	Bignoniaceae Indet.	Subshrub	Stem	—	Fusiform	Brown	No	Grouped	One-chambered	—	—	Riparian forest	SC	3O
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	Shrub	Leaf	Abaxial	Conical	Black/Green	No	Grouped	One-chambered	—	—	Shrubby caatinga	CF	3P
Calophyllaceae	*Calophyllum brasiliense* Cambess.	Tree	Leaf	Adaxial/	Globoid	Green	No	Grouped	Multichambered	*Lopesia conspicua* Maia, 2003 (Cecidomyiidae)	—	Shrubby caatinga	CF	4A
			Leaf	Adaxial	Fusiform	Green	No	Isolated	One-chambered	*Lopesia linearis* Maia, 2003 (Cecidomyiidae)	Hymenoptera (parasitoids); Thysanoptera (inquiline); Lepidoptera (inquiline)	Shrubby caatinga	CF	4B
			Stem		Globoid	Grey	No	Isolated	Multichambered	—	—	Shrubby caatinga	CF	4C
			Leaf	Abaxial	Globoid	Brown	No	Isolated	One-chambered	Cecidomyiidae	—	Shrubby caatinga	CVN	4D
			Stem	—	Globoid	Brown	No	Isolated	One-chambered	*Lopesia caulinaris* Maia, 2003 (Cecidomyiidae)	—	Shrubby caatinga	CVN	4E
			Leaf	Adaxial	Fusiform	Green	No	Isolated	One-chambered	*Lopesia linearis* Maia, 2003 (Cecidomyiidae)	—	Shrubby caatinga	CVN	4F
Chrysobalanaceae	*Parinari obtusifolia* Hook. f.	Shrub	Leaf	Adaxial/Abaxial	Conical	Green	No	Isolated	One-chambered	Cecidomyiidae	Hymenoptera	Shrubby caatinga	CF	4G
Combretaceae	*Combretum glaucocarpum* Mart.	Tree	Leaf	Adaxial/Abaxial	Globoid	Green	Yes	Isolated	One-chambered	—	—	Shrubby caatinga	CVN	4H-I
Ebenaceae	*Diospyros sericea* A. DC.	Shrub	Stem	—	Globoid	Brown	No	Isolated	Multichambered	—	Hymenoptera/Formicidae	Riparian forest	SC	4J
Erythroxylaceae	*Erythroxylum suberosum* A. St.-Hil.	Shrub	Leaf	Adaxial	Globoid	Brown	Yes	Grouped	One-chambered	*Myrciaryiamia admirabilis* Maia, 2007 (Cecidomyiidae)	Coleoptera (inquiline); *Erytoma* sp. (Hymenoptera) (parasitoids); Lepidoptera (inquiline)	Cerrado *s.s.*	PA	4K
			Leaf	Adaxial	Globoid	Brown	Yes	Grouped	One-chambered	—		Shrubby caatinga	CF	4L
Euphorbiaceae	*Croton adamantinus* Müll. Arg.	Shrub	Leaf	Abaxial	Globoid	White	Yes	Isolated	One-chambered	Cecidomyiidae	—	Shrubby caatinga	CR	4M
Fabaceae	*Bauhinia* sp.	Shrub	Leaf	Adaxial	Globoid	Brown	No	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	4N
	Bauhinia catingae Harms	Shrub	Stem	—	Fusiform	Brown	No	Grouped	One-chambered	Cecidomyiidae	Hymenoptera	Shrubby caatinga	ER	4O
			Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	4P
	Bauhinia pulchella Benth.	Subshrub	Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	Cecidomyiidae	—	Cerrado *s.s.*	CBJ	5A

Table 2. Continued.

Family	Specie	Plant lifeform	Organ	Surface	Shape	Color	Pilose	Occurrence	Chambers	Galling-inducing insects	Associated fauna	Phytophysiognomy	Locality	Figures
			Leaf	Adaxial	Leaf fold	Green	No	Isolated	One-chambered	Cecidomyiidae	—	Riparian forest	SC	5B
			Leaf	Adaxial	Globoid	Black	No	Isolated	One-chambered	—	—	Riparian forest	SC	5C
			Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	—	—	Shrubby caatinga	CF	5D
	Calliandra sp.	Subshrub	Stem	—	Globoid	Grey	No	Isolated	Multichambered	—	—	Cerrado s.s.	CBJ	5E
	Calliandra dysantha Benth.	Subshrub	Stem	—	Globoid	Grey	No	Isolated	Multichambered	—	—	Rupestrian field	PA	5F
	Copaifera depilis Dwyer.	Shrub	Leaf	Adaxial	Lenticular	Black	No	Isolated	One-chambered	—	—	Riparian forest	SC	5G
			Leaf	Adaxial	Globoid	Brown	Yes	Isolated	One-chambered	—	—	Riparian forest	SC	5H
			Leaf	Abaxial	Globoid	Yellow	Yes	Isolated	One-chambered	—	—	Riparian forest	SC	5I
			Leaf	Abaxial	Globoid	Yellow	Yes	Isolated	One-chambered	—	—	Riparian forest	SC	5J
	Copaifera langsdorffii Desf.	Shrub	Leaf	Adaxial	Conical	Red	No	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	5K
			Leaf	Adaxial	Conical	Pink	No	Isolated	One-chambered	—	—	Shrubby caatinga	CVN	5L
			Leaf	Abaxial	Globoid	Yellow	No	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	5M
	Copaifera luetzelburgii Harms.	Tree	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	5N
			Bud	—	Leaf fold	Green	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	5O
			Leaf	—	Leaf fold	Green	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	5P
			Leaf	Adaxial	Conical	Brown	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	6A
			Leaf	Abaxial	Globoid	Brown	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	6B
	Copaifera sabulicola J. Costa & L.P. Queiroz	Shrub	Leaf	Adaxial/Abaxial	Lenticular	White/Black	No	Isolated	One-chambered	—	—	Riparian forest	SC	6C-F
	Dalbergia miscolobium Benth.	Shrub	Stem	—	Globoid	Brown	No	Grouped	Multichambered	—	—	Riparian forest	SC	6G
	Hymenaea courbaril L.	Tree	Leaf	Adaxial	Globoid	Brown	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	6H
	Hymenaea martiana Hayne	Shrub	Leaf	Adaxial/Abaxial	Globoid	Brown	No	Isolated	One-chambered	Cecidomyiidae	Hymenoptera	Shrubby caatinga	CF	6I-J
	Mimosa gemmulata Barneby	Shrub	Leaf	Adaxial	Globoid	Red	Yes	Isolated	One-chambered	Cecidomyiidae	—	Shrubby caatinga	ER	6K
			Leaf	Adaxial	Globoid	Brown	Yes	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	6L
			Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	6M
			Leaf	Adaxial	Globoid	Black	No	Isolated	One-chambered	*Lopesia* sp. (Cecidomyiidae)	—	Cerrado s.s.	CBJ	6N
	Mimosa hypoglauca Mart.	Shrub	Leaf	—	Globoid	White	Yes	Grouped	Multichambered	—	—	Shrubby caatinga	ER	6O
	Mimosa tenuiflora (Willd.) Poir.	Shrub	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	6P
	Fabaceae Indet.	Subshrub	Fruit	—	Globoid	Green	Yes	Isolated	One-chambered	—	—	Riparian forest	SC	7A
Malpighiaceae	*Byrsonima guilleminiana* A. Juss.	Subshrub	Leaf	Abaxial/	Conical	Brown	Yes	Isolated	One-chambered	Cecidomyiidae	—	Cerrado s.s.	PA	7B-C
			Stem	Adaxial	Globoid	Brown	No	Isolated	One-chambered	—	—	Cerrado s.s.	PA	7D
	Malpighiaceae Indet.	Subshrub	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Riparian forest	SC	7E
Malvaceae	*Sida cordifolia* L.	Subshrub	Leaf	Adaxial	Globoid	White	Yes	Isolated	One-chambered	—	—	Shrubby caatinga	ER	7F
Melastomataceae	*Leandra reversa* (DC.) Cogn.	Subshrub	Leaf	Adaxial	Globoid	Brown	Yes	Isolated	One-chambered	—	—	Shrubby caatinga	CF	7G
	Miconia ibaguensis (Bonpl.) Triana	Shrub	Leaf	Adaxial	Globoid	Yellow	No	Grouped	One-chambered	—	—	Shrubby caatinga	CF	7H
	Miconia sp.	Shrub	Leaf	Abaxial/Adaxial	Globoid	Yellow	No	Isolated	One-chambered	—	—	Cerrado s.s.	PA	7I
	Miconia alborufescens Naudin	Shrub	Leaf	Adaxial	Globoid	Grey	No	Grouped	One-chambered	—	—	Cerrado s.s.	CBJ	7J
	Pleroma stenocarpum (Schrank et Mart. ex DC.) Triana	Shrub	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Cerrado s.s.	PA	7K
	Tibouchina sp.	Subshrub	Stem	—	Globoid	Brown	No	Isolated	One-chambered	—	—	Rupestrian field	PA	7L
Myrsinaceae	Myrsinaceae Indet.	Subshrub	Stem	—	Globoid	Brown	No	Isolated	Multichambered	—	—	Riparian forest	SC	7M

Table 2. Continued.

Family	Specie	Plant lifeform	Organ	Surface	Shape	Color	Pilose	Occurrence	Chambers	Galling-inducing insects	Associated fauna	Phytophysiognomy	Locality	Figures
Myrtaceae	*Myrcia tomentosa* (Aubl.) DC.	Subshrub	Leaf	Adaxial/Abaxial	Globoid	Green	No	Grouped	Multichambered	Thysanoptera	Formicidae	Cerrado s.s.	CBJ	7N
Ochnaceae	*Ouratea* sp.	Subshrub	Leaf	Adaxial	Globoid	Green	No	Grouped	One-chambered	—	—	Cerrado s.s.	PA	7O
Piperaceae	*Piper* sp.	Tree	Leaf	Adaxial	Conical	Brown	No	Isolated	One-chambered	—	—	Gallery forest	CR	7P
			Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	—	—	Gallery forest	CR	8A
			Leaf	Adaxial	Marginal roll	Green	No	Isolated	One-chambered	—	Pseudoescorpiones	Gallery forest	CR	8B
Proteaceae	*Roupala montana* Aubl.	Subshrub	Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	—	—	Rupestrian field	PA	8C
Sapindaceae	*Serjania glabrata* Kunth	Subshrub	Leaf	Adaxial	Globoid	Green	No	Isolated	One-chambered	—	—	Shrubby caatinga	ER	8D
	Serjania erecta Radlk.	Subshrub	Leaf	Adaxial	Globoid	Yellow	No	Isolated	One-chambered	—	—	Shrubby caatinga	CF	8E
Trigoniaceae	*Trigonia nivea* Cambess.	Subshrub	Leaf	Adaxial	Globoid	White	Yes	Grouped	Multichambered	Cecidomyiidae	—	Cerrado s.s.	CBJ	8F
Verbenaceae	*Lantana camara* L.	Subshrub	Leaf	Adaxial	Globoid	Green	Yes	Grouped	One-chambered	*Schismatodiplosis lantanae* Rübsaamen, 1908 (Cecidomyiidae)	—	Shrubby caatinga	ER	8G
	Lippia alnifolia Mart. & Schauer	Subshrub	Leaf	Adaxial	Globoid	Green	Yes	Isolated	One-chambered	Cecidomyiidae	—	Rupestrian field	PA	8H
Vochysiaceae	*Vochysia elliptica* Mart.	Subshrub	Leaf	Abaxial	Lenticular	Yellow	No	Isolated	One-chambered	—	—	Cerrado s.s.	CBJ	8I
			Leaf	Adaxial	Globoid	Pink	No	Grouped	One-chambered	—	—	Cerrado s.s.	CBJ	8J
Winteraceae	*Drimys brasiliensis* Miers	Subshrub	Leaf	Adaxial	Lenticular	Red	No	Isolated	One-chambered	—	Hymenoptera	Rupestrian field	PA	8K

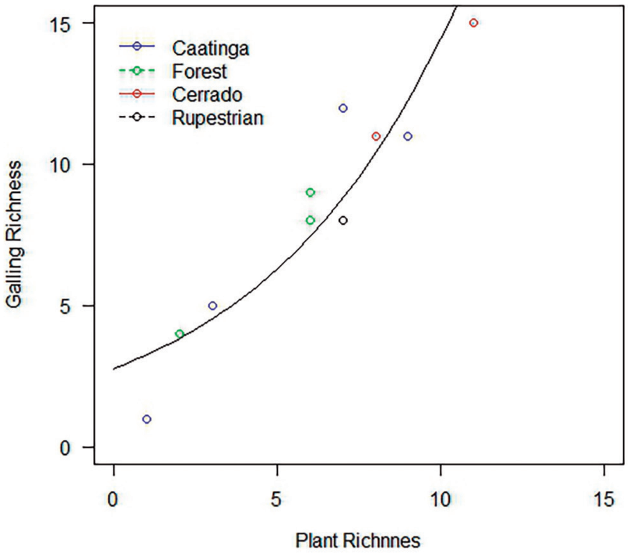

Figure 9. The relationship between richness of gall-inducing insects and plant richness (equation: gall-inducing species = $\exp^{(1.01218+0.16583*\text{plant richness})}$, $X^2 = 18.170$; $p < 0.001$) for area of Caatinga and Cerrado in the municipality of Rio de Contas, extreme south of the Chapada Diamantina, Bahia, Brazil.

positive correlation between gall-inducing richness and plant richness (see below). The Caatinga has *ca.* 4,891 plant species belonging to 1,232 genera and 176 families, compared to the Cerrado, which has 12,420 plant species in 1,662 genera and 187 families. Finally, the third factor is temporal changes (seasonality). The Caatinga biome is a complex of semi-arid habitats, with low, often irregular rainfall, in which many plant species are strongly deciduous (Queiroz *et al.*, 2017). These peculiarities of the Caatinga cause a drastic reduction in the quantity and quality of available resources for insects that induce galls preferentially on leaves (Maia *et al.*, 2014).

Our findings indicate that there is a positive correlation between local gall-inducing insect richness and plant richness, implying that plant species can effectively predict gall-inducing species richness. Most gall-inducing insect species have a species-specific relationship with their hosts (Carneiro *et al.*, 2009a) and, consequently, an increase in plant richness is directly related to an increase in niches available for female oviposition, and to the richness of gall-inducing insects (Strong *et al.*, 1984; Carneiro *et al.*, 2014). Many studies have corroborated the positive correlations of host plants richness on gall-inducing insect richness in several phytophysiognomies (Araújo, 2011; Gonçalves-Alvim & Fernandes, 2001; Oyama *et al.*, 2003; Cuevas-Reyes *et al.*, 2004; Carneiro *et al.*, 2014; Coelho *et al.*, 2017), while such a correlation was not found by others (*e.g.*, Fernandes & Price, 1988; Blanche, 2000; Lara *et al.*, 2002; Araújo, 2013). The few studies that do not corroborate the positive relationships between plant species richness and gall-inducing species richness are explained by local effect of superhost taxa (see Carneiro *et al.*, 2014).

Most of the Caatinga areas investigated are concentrated at lower altitudes ranging from 132 to 554 m, and this study is the first to be carried out in environments located above 930 m altitude (Santos *et al.*, 2011a; Car-

Table 3. Origin and endemism in Brazil of the host plants of galling insects occurring in Chapada Dimantina, Rio de Conta, Bahia State, Brazil. NE = Not Evaluated, DD = Data Deficient, LC = Least Concern, VU = Vulnerable.

Family	Species	Origen	Endemism	Conservation Status
Anacardiaceae	*Astronium fraxinifolium* Schott	Native	No	LC
	Mangifera indica L.	Cultivated	No	NE
Annonaceae	*Duguetia furfuracea* (A. St.-Hil.) Saff.	Native	No	NE
Apocynaceae	*Aspidosperma tomentosum* Mart. & Zucc.	Native	No	LC
Asteraceae	*Baccharis minutiflora* Mart. ex Baker.	Native	Yes	NE
	Eremanthus erythropappus (DC.) MacLeish	Native	Yes	NE
	Moquiniastrum polymorphum (Less.) G. Sancho	Native	No	NE
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	Native	No	DD
Calophyllaceae	*Calophyllum brasiliense* Cambess.	Native	No	NE
Chrysobalanaceae	*Parinari obtusifolia* Hook. f.	Native	No	NE
Combretaceae	*Combretum glaucocarpum* Mart.	Native	No	NE
Ebenaceae	*Diospyros sericea* A. DC.	Native	No	NE
Erythroxylaceae	*Erythroxylum suberosum* A. St.-Hil.	Native	No	NE
Euphorbiaceae	*Croton adamantinus* Müll. Arg.	Native	Yes	NE
Fabaceae	*Bauhinia catingae* Harms	Native	Yes	NE
	Bauhinia pulchella Benth.	Native	No	NE
	Calliandra dysantha Benth.	Native	No	NE
	Copaifera depilis Dwyer.	Native	Yes	NE
	Copaifera langsdorffii Desf.	Native	No	NE
	Copaifera luetzelburgii Harms.	Native	Yes	NE
	Copaifera sabulicola J. Costa & L.P. Queiroz	Native	Yes	NE
	Dalbergia miscolobium Benth.	Native	Yes	NE
	Hymenaea courbaril L.	Native	No	LC
	Hymenaea martiana Hayne	Native	No	LC
	Mimosa gemmulata Barneby	Native	No	NE
	Mimosa hypoglauca Mart.	Native	Yes	NE
	Mimosa tenuiflora (Willd.) Poir.	Native	No	NE
Malpighiaceae	*Byrsonima guilleminiana* A. Juss.	Native	Yes	NE
Malvaceae	*Sida cordifolia* L.	Native	No	NE
Melastomataceae	*Leandra reversa* (DC.) Cogn.	Native	No	NE
	Miconia ibaguensis (Bonpl.) Triana	Native	No	NE
	Miconia alborufescens Naudin	Native	No	NE
	Pleroma stenocarpum (Schrank et Mart. ex DC.) Triana	Native	No	NE
Myrtaceae	*Myrcia tomentosa* (Aubl.) DC.	Native	No	NE
Proteaceae	*Roupala montana* Aubl.	Native	No	NE
Sapindaceae	*Serjania erecta* Radlk.	Native	No	NE
	Serjania glabrata Kunth	Native	No	NE
Trigoniaceae	*Trigonia nivea* Cambess.	Native	No	NE
Verbenaceae	*Lantana camara* L.	Naturalized	No	NE
	Lippia alnifolia Mart. & Schauer	Native	Yes	VU
Vochysiaceae	*Vochysia elliptica* Mart.	Native	Yes	NE
Winteraceae	*Drimys brasiliensis* Miers	Native	No	LC

valho-Fernandes *et al.,* 2012; Alcântara *et al.,* 2017; Brito *et al.,* 2018; Santos-Silva *et al.,* 2022). The richness of galls in lower altitudinal strata ranged from 2 to 33 morphotypes, lower than that observed in the Caatinga areas in the present study (n = 36).

Our results do not add evidence for the altitudinal gradient hypothesis that argues that the richness of gall-inducing insects decreases with increasing altitude (Lara *et al.,* 2002). Altitudes above 1,000 meters also do not limit the species richness of gall-inducing insects in the Cerrado biome of the Chapada Diamantina. Altitude is an important factor in the spatial distribution of insects as a whole (Freitas *et al.,* 2007). Many of the species are widely distributed along altitudinal gradients so that their populations live at extremely low or high elevations, experiencing vastly different environmental conditions (Hodkinson, 2005). Few empirical studies have addressed how altitude impacts the species richness of gall-inducing insects on a local scale. However, prior research (Araújo & Guilherme, 2012; Coelho *et al.,* 2017) indicates that gall-inducing insect richness was not correlated with altitude. Peaks in species richness can occur at different altitudinal points. This suggests that factors such as habitat, floristic diversity, and insect population complexity may have greater impact on gall-inducing insect richness.

In this study, the Fabaceae hosted the highest number of galls in the physiognomic forms studied in the municipality of Rio de Contas. In other regions sampled in

Northeastern Brazil, this family also showed higher richness of gall-inducing insects and host plants in Caatinga habitats (Santos *et al.,* 2011a; Carvalho-Fernandes *et al.,* 2012), Cerrado (Silva *et al.,* 2018; Campos *et al.,* 2021; Santana *et al.,* 2020). Fabaceae is among the main host families of gall inducers in Brazil together with Asteraceae (Flor *et al.,* 2022), with a total of 438 gall morphotypes found on 178 host species, holding the largest number of host plant species (Santos-Silva & Araújo, 2020).

Among the genera of the Fabaceae, some are considered superhosts because they present a higher number of gall-inducing insects and gall morphotypes in different Brazilian biomes (Santos-Silva & Araújo, 2020); these genera includeas *Copaifera, Bauhinia,* and *Mimosa,* which hosted the highest richness of galls in the phytophysiognomies studied in Rio de Contas. These three genera combined have 25 host species in the Brazilian flora (Santos-Silva & Araújo, 2020), in which some species are reported to be superhosts of gall-inducing-insects, such as *Copaifera langsdorffii* Desf. (n = 28), *Bauhinia brevipes* Vogel (n = 17), *Copaifera sabulicola* J.A.S. Costa & L.P. Queiroz (n = 12) (Santos-Silva & Araújo, 2020), and *Mimosa gemmulata* Barneby (Costa *et al.,* 2021).

Twelve of the host plant species studied are endemic to Brazil. The gall-inducers associated with them are proposed as co-endemic due to their high host specificity. Therefore, 22 gall-inducing species are co-endemic. *Lippia alnifolia* Mart. & Schauer (Verbenaceae) is endemic and vulnerable. This plant harbors a species of Cecidomyiidae, considered co-vulnerable, for the same reason. Because of poor taxonomic knowledge of gall-inducers in Brazil, none of them have been identified, which strengthens the need for conservation of the Chapada Diamantina.

Another worrisome result was the occurrence of galls on an introduced exotic plant, *Mangifera indica,* in riparian forest areas, which may reveal a potential conservation problem in Chapada Diamantina and a threat to the specialization of plant-gall-inducing insect networks. The presence of exotic species might reduce the interaction number for native species, which would lead to changes in the specialization of plant-gall-inducing insect networks (Araújo *et al.,* 2017). The effects of exotic host plant species in the structure of network of gall-inducing insects associated has been poorly investigated. In the only study available on this topic, it was demon-

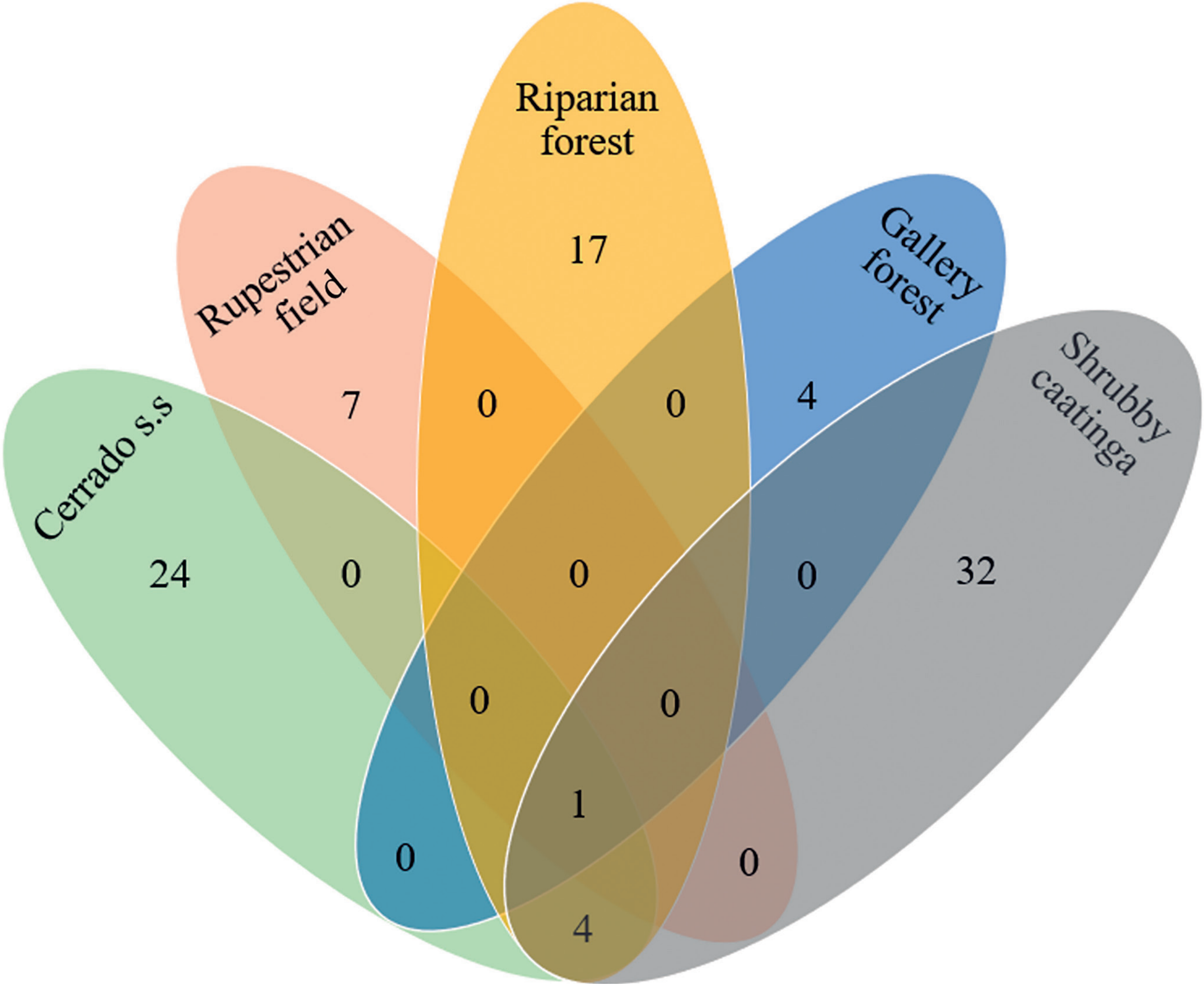

Figure 10. A Venn diagram representing the number of insect gall morphotypes exclusive and common to the cerrado *sensu stricto* (green), gallery forest (blue), shrubby caatinga (grey), rupestrian field (orange), and riparian forests (yellow), Chapada Diamantina, Bahia, Brazil.

strated that native insect herbivores were significantly more frequent on native host plant species, while exotic herbivores occurred mostly on exotic host plant species, suggesting very specific interactions even for exotic plants and insects, which results in plant-gall-inducing insect networks very specialized and similarly structured independently of exotic species presence (Araújo *et al.,* 2017). However, this pattern should be investigated in future studies including other groups of gall-inducing arthropods and/or higher trophic levels.

Our results indicated that gall composition in Caatinga areas is clearly distinct from that in Cerrado areas, as only four gall morphotypes were shared. So, both phytogeographic domains contribute to the gall richness of the Chapada Diamantina. Although the largest number of gall morphotypes was found in shrubs and subshrubs, the highest average of gall morphotypes was reported in trees. These results favored the plant architecture hypothesis that predicts the most complex plants host the highest gall richness, since they offer the greatest number of niches for the insects (Lawton, 1983).

In this study, the galls were induced mainly on leaves, being less frequent on fruits. Only a single globoid gall was induced on the fruits of an unidentified Fabaceae species occurring in Riparian Forest (Cerrado biome). The presence of galls on reproductive structures was observed on 128 host plant species, belonging mainly to Fabaceae (78 species) (Cocoletzi *et al.,* 2019). Galls can be induced on any vegetative structure (leaves, stems, branches and roots) or reproductive organ (flowers, fruits and seeds) (Mani, 1964). However, buds, flowers, and fruits are poorly represented as host organs, since these structures depend on the phenological stage of the plant. Gall induction on fruits should start inside the ovary where the cells are not yet differentiated, producing galls mainly without seeds, consequently the normal structure of the fruit is modified (Cocoletzi *et al.,* 2019). Thus, the presence of galls on these organs could represent serious threats to the plants due to the impact they would have on plant performance and fitness (Fernandes, 1987).

In gall inventories for the Neotropical region, green galls are the most frequent, followed by brown. However, in the present study an inversion occurred and brown coloration was the most observed, followed by green, as was also observed in transition vegetation between caatinga and cerrado (Luz *et al.,* 2012), caatinga (Brito *et al.,* 2018), and cerrado *s.s.* (Campos *et al.,* 2021). Galls are colorful as a result of accumulation of plant-derived pigments in their tissue and therefore can be distinguished from the surrounding host plant organs. The pigmentation is not a fixed trait and notable polymorphism can be observed (Inbar *et al.,* 2009). Some galls may change color during their development, from lighter to darker, such as observed here and previously recorded on leaf galls induced on *Lippia microphylla* Cham. by Cecidomyiidae (from green to brown; Vieira *et al.,* 2018); leaf galls on *Eugenia* sp. (Myrtaceae) (from yellow to reddish-yellow to black; Santana *et al.,* 2020) and stem galls on *Copaifera langsdorffii* (Fabaceae; from orange to brown) (Nogueira *et al.,* 2016). These color changes are probably associated with the developmental stages of the galls, the growth of the inducer insects and/or the action of other trophic levels (Dias *et al.,* 2013).

The habit of inducing galls has been recorded for the orders Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Thysanoptera (Maia, 2013). In this study, representatives of four of these orders, Diptera, Hemiptera, Lepidoptera and Thysanoptera, induced galls in the phytophysiognomies investigated. Some 49.56% of the galls waere empty and with only immature stages, which made it impossible to identify many of the inducing insects. Those that could be identified belong to the family Cecidomyiidae (Diptera). This family is responsible for inducing galls in other inventories conducted in different Brazilian ecosystems (Santos *et al.,* 2011b; Maia & Silva, 2016; Urso-Guimarães *et al.,* 2017; Lima & Calado, 2018; Vieira *et al.,* 2018; Campos *et al.,* 2021). The family Cecidomyiidae is very diverse with more than 6,500 species, most of which are gall-inducing (Gagné & Jaschhof, 2021). For Brazil, about 265 species of Cecidomyiidae are known (Maia, 2021), of which 44 species of 28 genera have been recorded in Bahia (Maia & Silva, 2020).

The gall-inducing insects are defined as guild of herbivores that to complete its life cycle necessarily develops a pathological modification in the tissue of the host plant (gall), as a result of hypertrophy and/or hyperplasia of the plant tissue, which arises from the interaction between the insect and the host plant (Weis *et al.,* 1988). In addition to the inducing insects, other organisms can be found inside the galls that are considered as parasitoids, inquilines, cecidophages, kleptoparasites, predators, and successors. These organisms belong to the orders Coleoptera, Hymenoptera, Lepidoptera, Pseudoescorpiones, and Diptera (Maia, 2001), Hymenoptera being the most frequent parasitoids of the Brazilian flora (Maia & Azevedo, 2009). Inhabitants occurred in a single fusiform morphotype on *Calophyllum brasiliense* (Calophyllaceae) induced by Lepidoptera and in two globoid galls on *Erythroxylum suberosum* A. St.-Hil. (Erythroxylaceae) induced by Coleoptera and Lepidoptera. Hymenoptera parasitoids were also found associated with seven gall morphotypes. Successors, belonging to Psocoptera, were found in only one morphotype of gall induced on *Aspidosperma tomentosum* Mart. (Apocynaceae). In the literature, Psocoptera have been recorded as successors of caulinary galls on *Senegalia langsdorffii* (Benth.) Seigler & Ebinger and *Senegalia paganuccii* Seigler, Ebinger & P.G. Ribeiro in a different area of caatinga (Brito *et al.,* 2018).

CONCLUSIONS

This study was the first to document gall and gall host richness in the Chapada Diamantina. Moreover, our results add evidences to the plant richness hypothesis, which suggests that an increase in the number plant species may be responsible for higher gall-inducing species richness at local habitats or different plant formations.

The plant richness hypothesis may be the general explanation for the distribution of gall-inducing species in the Espinhaço Range, now also found in its northern portion (= Chapada Dimantina). The occurrence of endemic and/or vulnerable plants possibly supporting unique gall-inducing insects, that is, a highly correlated fauna of endemic and/or vulnerable gall-inducing insects reinforces the importance of the Chapada Diamantina for the preservation of Brazil's biodiversity. Considering the geological, biological and ecological uniqueness of the Chapada Diamantina, as well as its extension, which reaches about 50.000 km², it is necessary to direct new efforts to document the richness of gall-inducers from other regions of the Chapada Diamantina.

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