Gall-inducing insects from Serra do Cabral, Minas Gerais, Brazil

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Abstract: Our goal was describe the gall richness through the characterization of their external shapes and occurrence patterns in their host plants from Parque Estadual da Serra do Cabral. In a universe of 34 families, 64 genera and 89 plant species, 47 gall-inducing insects in 21 families, 32 genera and 39 host plant species were recorded. The families, which hosted higher gall richness, were those with highest abundance. Asteraceae represented 33% of the species collected followed by Malpighiaceae 8% and Fabaceae 8%, each one concentrating 25%, 19% and 8% of gall-inducing insects, respectively. The organ most attacked was the leaf (51%), followed by the stem (42%) and the terminal branch (4%). Ninety-six percent (96%) of galls were glabrous. Only 25.5% of the galls described in our study have been already recorded in previous studies, reinforcing the need to increase the sampling effort toward a better understanding of the richness, distribution, and natural history of gall-inducing insects from Brazil.
Keywords: *biodiversity, biogeography, herbivore, host plant, insect-plant interaction.*

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Resumo: Objetivo deste estudo foi descrever a riqueza de morfotipos de galha por meio da caracterização de suas formas e os padrões de ocorrência em suas plantas hospedeiras no Parque Estadual da Serra do Cabral. Num universo de 34 famílias, 64 gêneros e 89 espécies de plantas, foram registradas 47 espécies de galhas induzidas por insetos em 21 famílias, 32 gêneros e 39 espécies de plantas hospedeiras. As famílias que concentraram maior riqueza de insetos galhadores foram as famílias mais abundantes. A família Asteraceae representou 33% das espécies coletadas, seguida das Malpighiaceae 8% e Fabaceae 8%, cada uma concentrando 25%, 19% e 8% das espécies de insetos galhadores, respectivamente. O órgão mais atacado foi a folha (51%), seguido do caule (42%) e ramo terminal (4%). Noventa e seis por cento (96%) das galhas foram glabras. O fato de apenas 25% das galhas descritas neste estudo já terem sido registradas em trabalhos prévios, reforça a necessidade em aumentar o esforço amostral na direção de um maior conhecimento sobre a riqueza, distribuição e história natural dos insetos indutores de galhas no Brasil.
Palavras-chave: *biodiversidade, biogeografia, herbivoria, planta hospedeira, interação inseto-planta.*

Introduction

Galls are anomalous structures from portions of organs or plant tissues that develop in response to the presence of an inducer organism, often an insect (Price 2005, Shorthouse et al. 2005). Gall development is the result of the interaction between the insect inductor and the host plant, where the insect acquires control over the host plant, diverting its resources away from growth, development and defense (Abrahamson & Weis 1997, Stone & Schönrogge 2003, Fernandes et al. 2010).

Gall-inducing insects and their host plants have been widely studied in recent decades in different Brazilian physiognomies, e.g.: Pantanal (Wetlands) (Julião et al. 2002), Amazon (Julião et al. 2005), Restinga (Brazilian Coastal Vegetation) (Maia 2001, 2005, Maia et al. 2002, Mendonça 2007, Oliveira & Maia; 2005), Atlantic Forest (Fernandes et al. 2001, Fernandes & Negreiros 2006, Santos et al. 2012), Cerrado (Brazilian Savannah) (Fernandes et al. 1988, Maia & Fernandes 2004, Gonçalves-Alvim & Fernandes 2001), Rupestrian Fields (Carneiro et al. 2009b), Tropical Dry Forest on Limestone Outcrops (Coelho et al. 2009) and Caatinga (Tropical Dry Forest) (Santos et al. 2011a). Despite this effort, some ecosystems were only recently sampled, such as the Tropical Dry Forest on Limestone Outcrops (Coelho et al. 2009), Altitude Wetland Forests (Santos et al. 2011b), Caatinga (Santos et al. 2011a) and Amazon (Almada & Fernandes 2011, Maia 2012).

The cerrado has the more galling surveys among Brazilian ecosystems, but due its large territory, there are many gaps to be filled to its local biodiversity. This work is part of a project with the goal of describing the natural history of gall-inducing insects, their galls, and their host plants from the Brazilian Cerrado and, in particular, from Rupestrian Fields. In a recent study, Carneiro et al. (2009b) recorded the gall richness in six distinct regions across the Espinhaço range, Minas Gerais. In this work, galls from Parque Estadual da Serra do Cabral (PESC) were described and characterized by their external morphology and their host plant occurrence.

Material and Methods

Samples were collected in two physiognomies of Cerrado: open fields (*Campo Cerrado*) and shrubby fields (*Campo Sujo*) in Parque Estadual da Serra do Cabral (PESC), located between the coordinates 17° 03' S-18° 13' S and 44° 05' W-44° 52' W. An area of 250,000 ha, with an altitudinal ranging from 600 m to 1385 m, in the Minas Gerais state, Brazil. The PESC climate is classified as Aw (Köppen classification), with two well defined seasons, hot and rainy summers, and cold and dry winters; an annual rainfall average of 750 mm and an average temperature of 22 °C. Samples were collected in April, 2008, the end of the rainy season. As part of the Espinhaço Range, PESC presents typical Cerrado physiognomies, rupestrian fields, gallery forests and Altitude Fields (Hatschbach et al. 2006).

Sampling was carried out according to standard methodology used to study galls diversity in Rupestrian Fields and Cerrado (Fernandes & Price 1988, Carneiro et al. 2009b). Along the altitudinal gradient, 10 points were arbitrarily defined ranging from 879 m to 1.255 m, with an altitude range of 376 m. The samples at higher altitudes were conducted in areas covered by Rupestrian Fields; at intermediate and low altitudes, samples were conducted on areas covered by Cerrado, Rupestrian Fields and Open Fields (*Campo Cerrado*). Forests, areas close to trails and any areas with visible human interference were excluded from the sampling.

Gall sampling was performed following the methodology described by Fernandes & Price (1988, but see Price et al. 1998). At each sampling point, a plot with 100 woody plants of shrub stature (between 0.3 and 2 m high) was arbitrarily selected, totaling 1,000 plants across the mountain. Each plant was sampled throughout the aerial part of the individual by counting directly the number of galls. According to Carneiro *et al.* (2009a) gall description associated with the identification of the host-plant species is a reliable indication of the galling insect richness. About 95% of described species of Cecidomyiidae from Brazil can be identified based on their external shape associated with the host plant on which they occur, reinforcing the use of this methodology as reliable in galling studies (Price et al. 1998, Blanche 2000, Cuevas-Reyes et al. 2003, 2004, Oyama et al. 2003). The sampled host plants and their galls were mounted and deposited in the herbariums OUPR e BHCB (acronyms according to Holmgren et al. 1990). The collected plants were separated into families and were then identified by specialists to the lowest taxonomic level possible. The classification of plant species followed the system proposed by Angiosperm Phylogeny Group III (2009). The galls were photographed and characterized according to the color, shape, presence or absence of hairs, and plant organ where they occur (see Carneiro et al. 2009b). Galling insects taxa were always identified when possible.

Results

In PESC 47 gall species within 21 families, 32 genera and 39 species of host plants have been found. In total, 34 families, 64 genera and 89 species of plants were sampled (Table 1, 2, Figure 1-3). The most abundant families hosted the highest gall richness. Asteraceae represented 33% of the species collected, followed by Malpighiaceae 8% and Fabaceae 8%, each one concentrating 25%, 19% and 8% of gall species, respectively. The genera that concentrated the highest richness of galls were *Byrsonima* (Malpighiaceae) with 13% and *Lessingianthus* (Asteraceae) with 8%. The species with the greatest galls richness was *Byrsonima guilleminiana* A.Juss. with 3 galls (6%). The genera and species that concentrated the most gall richness belong to the plant families with the highest occurrence, Asteraceae (33%), Fabaceae (8%) and Malpighiaceae (29%). The Cecidomyiidae (Diptera) family was the most frequent (93%), followed by Coleoptera (4%) and Hymenoptera (2%). The most common gall shapes were discoid (15%), fusiform (23%), globulous (23%), intumescence (10%), rolled edge (10%), elliptical (6%), terminal branch (4%) conical (6%) and rolled (2%). The organ most attacked was the leaf (51%), followed by the stem (42%) and the terminal branch (4%). Ninety-six percent (96%) of galls were glabrous.

Discussion

In this study, we found 47 of galling insect species, and only 12 (25.5%) had been reported in previous studies. Previous studies have reported *Duguetia furfuracea* [Table 1, Figure 1b, Urso-Guimarães et al. 2003, Urso-Guimarães & Scareli-Santos 2006, Malves & Frieiro-Costa 2012, Saito & Urso-Guimarães 2012], *Aspidosperma tomentosum* [Table 1, Figure 1c, Gonçalves-Alvim & Fernandes 2001, Araújo et al. 2011)], *Baccharis salzmannii* [Table 1, Figure 1f, Carneiro et al. 2009b], *Eremanthus erythropappus* [Table 1, Figure 1h, Carneiro et al. 2009b, Saito & Urso-Guimarães 2012], *Lessingianthus tomentellus* [Table 1, Figure 1m, Carneiro et al. 2009b], *Jacaranda paucifoliata* [Table 1, Figure 1p, Carneiro et al. 2009b], *Tabebuia ochracea* (Cham.) Standl. [Table 1, Figure 1q, Urso-Guimarães et al. 2003], *Kielmeyera coriacea* [Table 1, Figure 2a, Carneiro et al. 2009b], *Microlicia confertiflora* [Table 1, Figure 3a, Carneiro et al. 2009b], *Eugenia punicifolia* [Table 1, Figure 3b, Carneiro et al. 2009b, Saito & Urso-Guimarães 2012], *Palicourea rigida* [Table 1, Figure 3e], and *Vochysia elliptica* [Table 1, Figure 3g, Carneiro et al. 2009b], all with one gall mosphotype. The fact that only 23% of the galls described in this study had been recorded in

Table 1. Host plants, description of galls at a Cerrado from Serra do Cabral, Minas Gerais, Brazil.

Host Plants	Likely gall maker taxa	Organ	Shape	Color	Pubescence	Chambers	Photos
Annonaceae							
Duguetia furfuracea (A. St.-Hil.) Saff.	Cecidomyiidae	leaf	elliptical	green	glabrous	1	1(a)
	Cecidomyiidae	leaf	globulous	green	glabrous	1	1(b)
Apocynaceae							
Aspidosperma tomentosum Mart.	Cecidomyiidae	leaf	discoid	green	glabrous	1	1(c)
Asteraceae							
Acritopappus longifolius (Gardner) R.M. King & H. Rob.	Cecidomyiidae	stem	rolled edge	green	glabrous	1	1(d)
Aspilia jolyana G. M. Barroso	Cecidomyiidae	leaf	rolled edge	green	glabrous	1	1(e)
Baccharis salzmannii DC.	Cecidomyiidae	stem	fusiform	brown	glabrous	1	1(f)
	Cecidomyiidae	leaf	elliptical	green	glabrous	1	1(g)
Eremanthus erythropappus (DC.) MacLeish	*Asphondylia serrata*	leaf	globulous	brown	glabrous	1	1(h)
	Cecidomyiidae	stem	fusiform	brown	glabrous	1	1(i)
Lessingianthus coriaceus (Less.) H. Rob.	Cecidomyiidae	leaf	globulous	green	glabrous	1	1(j)
	Cecidomyiidae	stem	intumescence	brown	glabrous	various	1(k)
Lessingianthus hoveaefolius (Gardner) H. Rob.	Cecidomyiidae	leaf	globulous	green	glabrous	1	1(l)
Lessingianthus tomentellus (Mart. ex DC.) H. Rob.	Cecidomyiidae	stem	terminal branch	brown	glabrous	various	1(m)
Lychnophoriopsis heterotheca Sch. Bip.	Cecidomyiidae	stem	globulous	brown	glabrous	1	1(n)
Piptocarpha rotundifolia (Less.) Baker	Cecidomyiidae	leaf	discoid	green	glabrous	1	1(o)
Bignoniaceae							
Jacaranda paucifoliata Mart. ex DC.	Cecidomyiidae	stem	rolled	green	glabrous	1	1(p)
Tabebuia ochracea (Cham.) Standl.	Cecidomyiidae	leaf	intumescence	brown	hairy	1	1(q)
Bixaceae							
Cochlospermum regium (Schrank) Pilg.	Cecidomyiidae	leaf	conical	green	glabrous	1	1(r)
Chrysobalanaceae							
Licania humilis Cham. & Schltdl.	Cecidomyiidae	leaf	discoid	brown	glabrous	1	1(s)
Licania nitida Hook. f.	Cecidomyiidae		rolled edge	green	glabrous	1	1(t)
Clusiaceae							
Kielmeyera coriacea Mart. & Zucc.	Cecidomyiidae	leaf	discoid	brown	glabrous	1	2(a)
Convolvulaceae							
Merremia tomentosa Hallier	Cecidomyiidae	leaf	rolled edge	green	glabrous	1	2(b)
Erythroxylaceae							
Erythroxylum campestre A. St.-Hil.	Cecidomyiidae	stem	globulous	brown	glabrous	1	2(c)
Euphorbiaceae							
Maprounea guianensis Aubl.	unidentified	leaf	rolled edge	green	glabrous	various	2(d)
Fabaceae							
Calliandra asplenioides (Nees) Benth. ex Jackson	Cecidomyiidae	stem	fusiform	brown	glabrous	1	2(e)
Chamaecrista geminata (Benth.) H.S. Irwin & Barneby	Cecidomyiidae	stem	intumescence	brown	glabrous	1	2(f)
Machaerium opacum Vogel	Cecidomyiidae	stem	fusiform	brown	glabrous	1	2(g)
Mimosa polycarpa Kunth	Cecidomyiidae	leaf	globulous	green	hairy	1	2(h)
Lamiaceae							
Hyptis eriophylla Pohl ex Benth.	Cecidomyiidae	stem	fusiform	green	glabrous	1	2(i)
Lauraceae							
Ocotea lancifolia (Schott) Mez	Cecidomyiidae	leaf	globulous	green	glabrous	1	2(j)
Lythraceae							
Diplusodon uninervius Koehne	Cecidomyiidae	stem	fusiform	brown	glabrous	1	2(k)
Malpighiaceae							
Banisteriopsis campestris (A. Juss.) Little	Cecidomyiidae	leaf	discoid	green	glabrous	1	2(l)

Table 1. Continued...

Host Plants	Likely gall maker taxa	Organ	Shape	Color	Pubescence	Chambers	Photos
Banisteriopsis laevifolia (A. Juss.) B. Gates	Cecidomyiidae	stem	globulous	brown	glabrous	1	2(m)
	Coleoptera	stem	fusiform	brown	glabrous	1	2(n)
Byrsonima crassa Nied.	Cecidomyiidae	leaf	discoid	green	glabrous	1	2(o)
Byrsonima guilleminiana A. Juss.	Cecidomyiidae	leaf	discoid	green	glabrous	1	2(p)
	Cecidomyiidae	leaf	elliptical	brown	glabrous	1	2(q)
	Cecidomyiidae	stem	intumescence	brown	glabrous	1	2(r)
Byrsonima pachyphylla A. Juss.	Coleoptera	stem	intumescence	brown	glabrous	1	2(s)
Byrsonima sp.	Cecidomyiidae	leaf	discoid	green	glabrous	1	2(t)
Melastomataceae							
Microlicia confertiflora DC.	Cecidomyiidae	stem	fusiform	brown	glabrous	1	3(a)
Myrtaceae							
Eugenia punicifolia (Kunth) DC.	Hymenoptera	stem	fusiform	brown	glabrous	1	3(b)
Nyctaginaceae							
Guapira noxia (Netto) Lundell	Cecidomyiidae	stem	globulous	brown	glabrous	various	3(c)
	Cecidomyiidae	leaf	discoid	green	glabrous	1	3(d)
Rubiaceae							
Palicourea rigida Kunth	Cecidomyiidae	leaf	discoid	green	glabrous	1	3(e)
Verbenaceae							
Lippia microphylla Cham.	Cecidomyiidae	terminal branch	intumescence	brown	glabrous		3(f)
Vochysiaceae						1	
Vochysia elliptica Mart.	Cecidomyiidae	stem	fusiform	brown	glabrous	1	3(g)

Table 2. Number of gall-inducing insects associated with its plant families at a Cerrado from Serra do Cabral, MG. Families without galls were listed as "other families".

Families	Plants		Galls	
	Richness	%	Richness	%
Annonaceae	1	1.3	2	4.3
Apocynaceae	1	1.3	1	2.1
Asteraceae	26	33.3	12	25.5
Bignoniaceae	2	2.6	2	4.3
Bixaceae	1	1.3	1	2.1
Chrysobalanaceae	2	2.6	2	4.3
Clusiaceae	1	1.3	1	2.1
Convolvulaceae	1	1.3	1	2.1
Erythroxylacee	1	1.3	1	2.1
Euphorbiaceae	3	3.8	1	2.1
Fabaceae	6	7.7	4	8.5
Lamiaceae	2	2.6	1	2.1
Lauraceae	1	1.3	1	2.1
Lythraceae	1	1.3	1	2.1
Malpighiaceae	6	7.7	9	19.1
Melastomataceae	3	3.8	1	2.1
Myrtaceae	3	3.8	1	2.1
Nyctaginaceae	1	1.3	2	4.3
Rubiaceae	1	1.3	1	2.1
Verbenaceae	2	2.6	1	2.1
Vochysiaceae	1	1.3	1	2.1
Outras famílias	12	15.4	0	0.0
Total	78	100	47	100

previous studies reinforces the need to increase the sampling efforts of gall-inducing insects in the Espinhaço Range.

Using the same methods Carneiro et al. (2009b) recorded higher gall-inducing insects richness at different regions along the Espinhaço Range (PE Rio Preto = 75, RPPN Caraça = 71, PE Biribiri = 63, PE Itacolomi = 59, PE Serra do Ouro Branco= 50) than PE Serra do Cabral (= 47), except for PE Grão Mogol (= 18). Thus, the PESC is the area with the second lowest richness of gall-inducing insects in the Espinhaço Range. This fact can be partly explained by the absence of super hosts, species that concentrate a large number of gall-inducing insects (*sensu* Veldtman & McGeoch 2003). The regions with lower gall-inducing insect richness from the Espinhaço Range, PESC and PE Grão Mogol (Carneiro et al. 2009b) are also areas where species of the genus *Baccharis* were represented by only one host plant species [*B. platypoda*, (PESC) or where they were absent (PE Grão Mogol)]. *Baccharis* is an important genus that concentrates much of the galling insect richness of the Rupestrian Fields (Carneiro et al. 2009b).

The families Asteraceae, Fabaceae, Melastomataceae, Malpighiaceae and Myrtaceae are the most frequent in different Brazilian Cerrado physiognomies (Giulietti et al. 1987, Giulietti & Pirani 1988) as well as in PESC (Hatschbach et al. 2006). These families alone concentrated 52% of the gall insect richness from PESC. Some studies report greater gall-inducing insect richness in families and genera richest in host species (Fernandes 1992, Blanche & Westody 1995). Studies in other Brazilian ecosystems have shown similar patterns, such as Cerrado (Gonçalves-Alvim & Fernandes 2001), Rupestrian Fields (Maia & Fernandes 2004, Carneiro et al. 2009b), Atlantic Forests (Fernandes et al. 2001), Tropical Dry Forests (Coelho et al. 2009), Seasonal Sub-tropical Forest (Mendonça 2007).

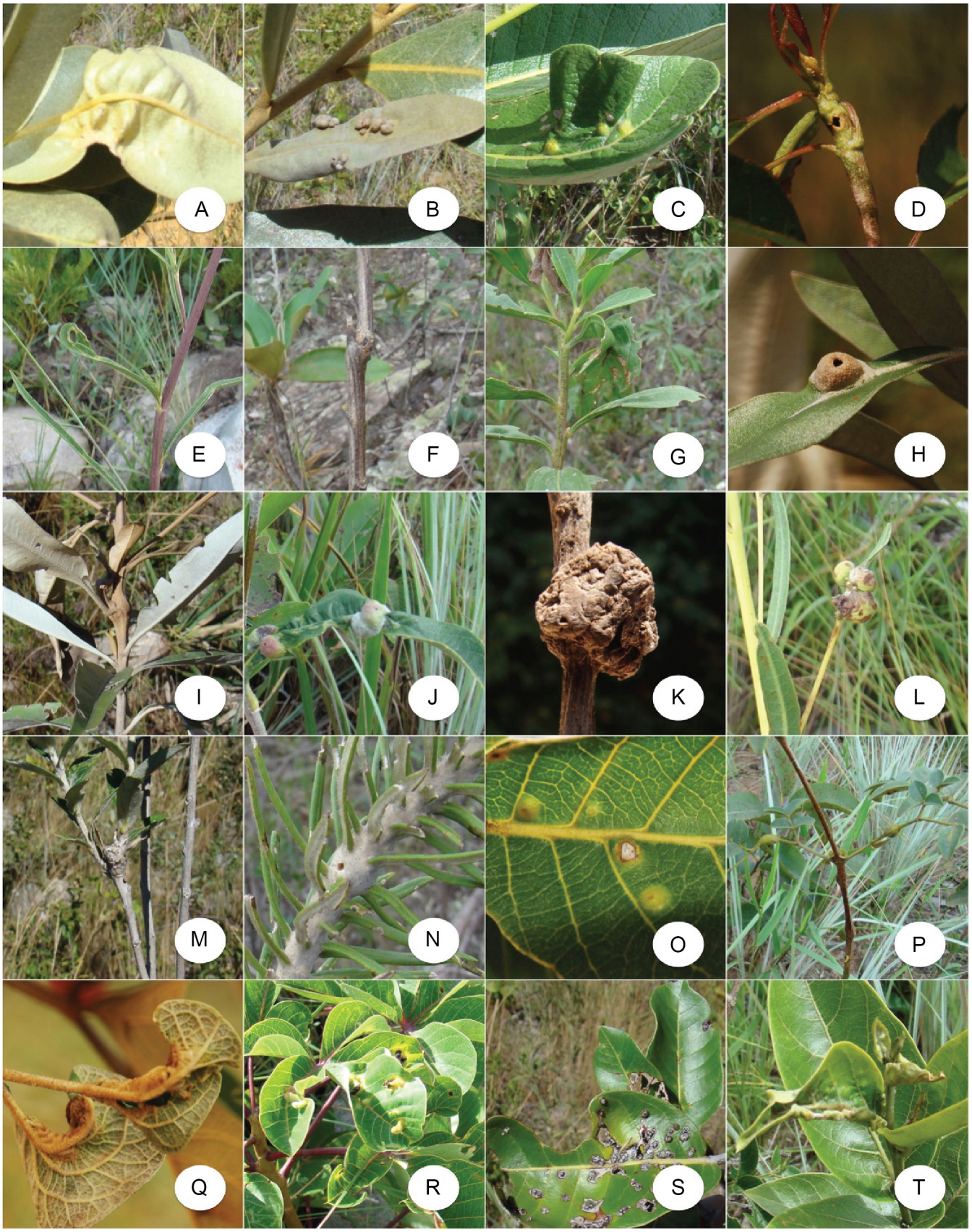

Figure 1. Host plants and its galls at a Cerrado from Serra do Cabral, Minas Gerais, Brazil. Annonaceae [*Duguetia furfuracea* (a-b)], Apocynaceae [*Aspidosperma tomentosum* (c)], Asteraceae [*Acritopappus longifolius* (d), *Aspilia jolyana* (e), *Baccharis salzmanii* (f-g), *Eremanthus erythropappus* (h-i), *Lessingianthus coriaceus* (j-k), *Lessingianthus hoveaefolius* (l), *Lessingianthus tomentellus* (m), *Lychnophoriopsis heterotheca* (n), *Piptocarpha rotundifolia* (o)], Bignoniaceae [*Jacaranda paucifoliata* (p), *Tabebuia ochracea* (q)], Bixaceae [*Cochlospermum regium* (r)], Chrysobalanaceae [*Licania humilis* (s), *Licania nitida* (t)].

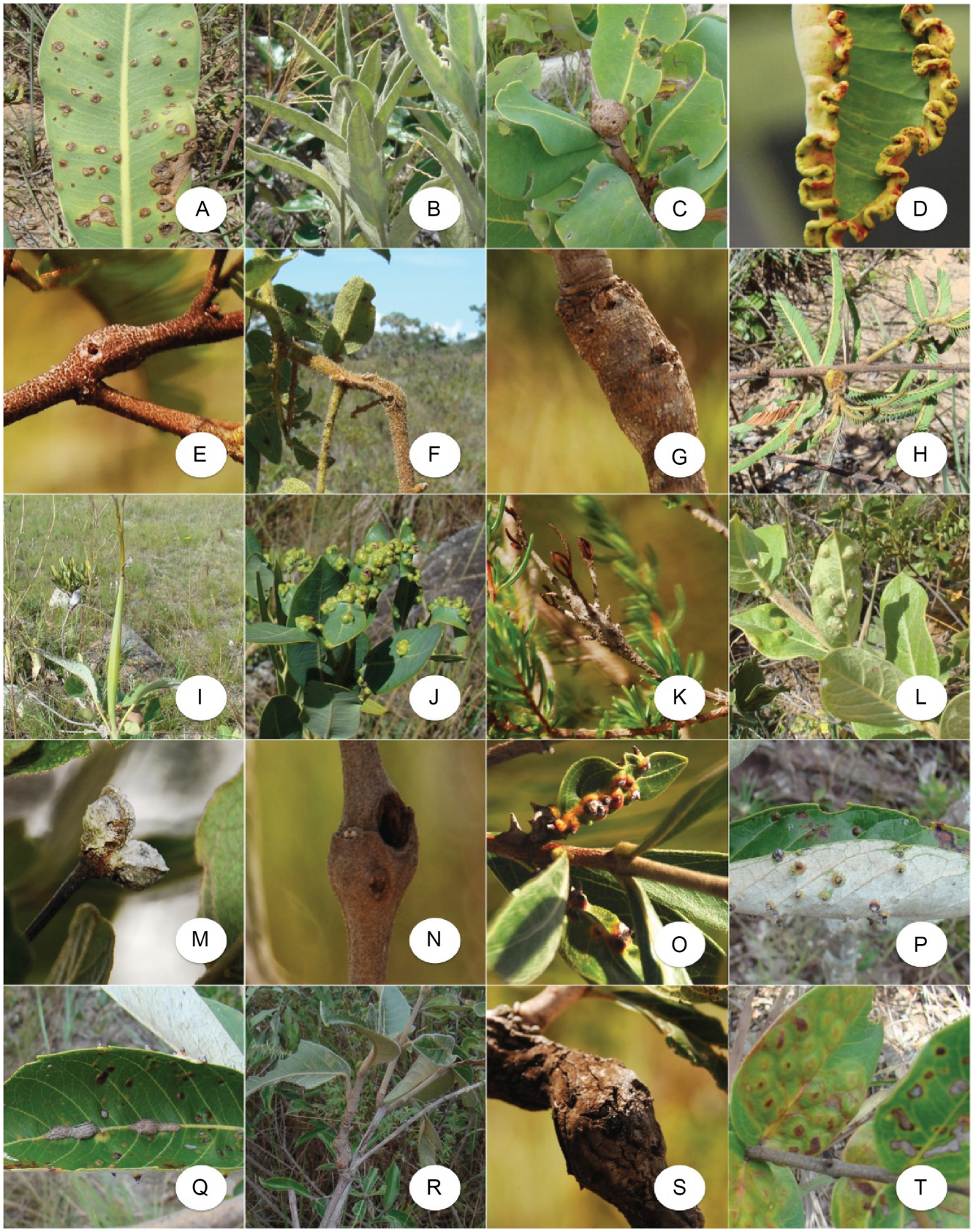

Figure 2. Host plants and its galls at a Cerrado from Serra do Cabral, Minas Gerais, Brazil. Clusiaceae [*Kielmeyera coriacea* (a)], Convolvulaceae [*Merremia tomentosa* (b)], Erythroxylaceae [*Merremia tomentosa* (c)], Euphorbiaceae [*Maprounea guianensis* (d)], Fabaceae [*Calliandra asplenioides* (e), *Chamaecrista geminata* (f), *Machaerium opacum* (g), *Mimosa polycarpa* (h)], Lamiaceae [*Hyptis eriophylla* (i)], Lauraceae [*Ocotea lancifolia* (j)], Lythraceae [*Diplusodon uninervius* (k)], Malpighiaceae [*Banisteriopsis campestris* (l), *Banisteriopsis laevifolia* (m, n), *Byrsonima crassa* (o), *Byrsonima guilleminiana* (p, q, r), *Byrsonima pachyphylla* (s), *Byrsonima* sp. (t)].

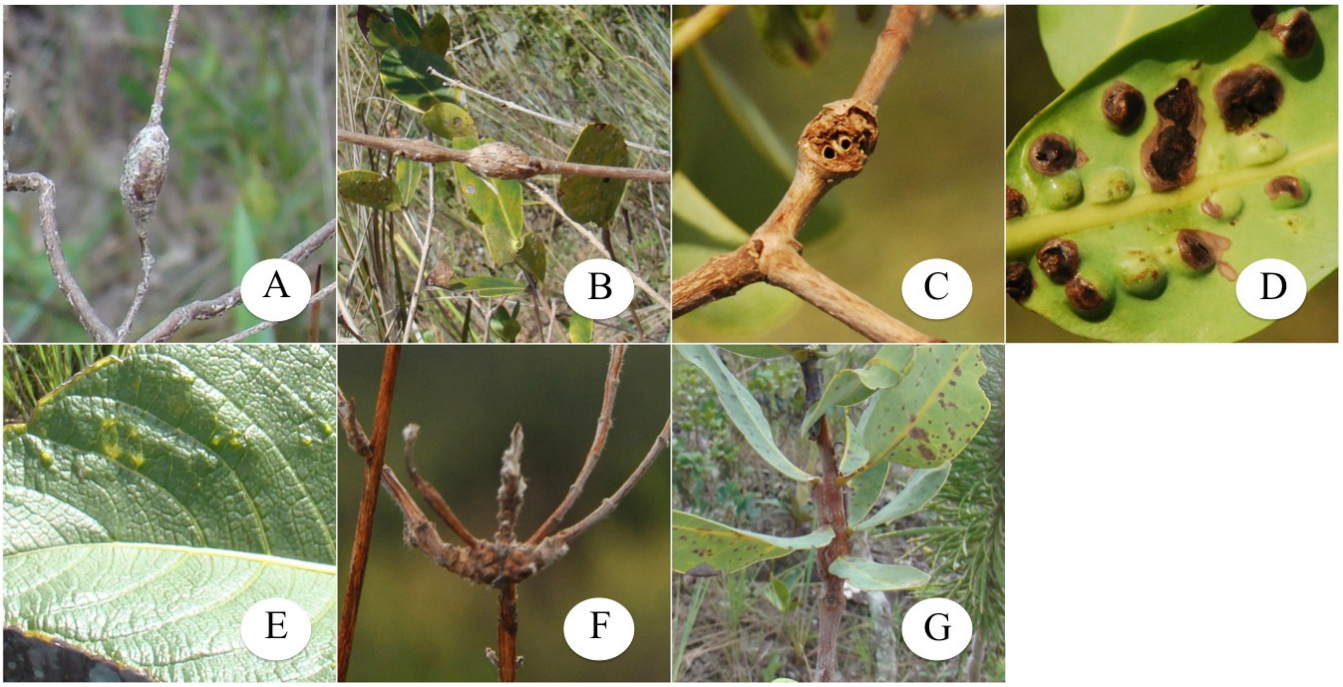

Figure 3. Host plants and its galls at a Cerrado from Serra do Cabral, Minas Gerais, Brazil. Melastomataceae [*Microlicia confertiflora* (a)], Mystaceae [*Eugenia punicifolia* (b)], Nyctaginaceae [*Guapira noxia* (c-d)], Rubiaceae [*Palicourea rigida* (e)], Verbenaceae [*Lippia microphylla* (f)], Vochysiaceae [*Vochysia elliptica* (g)].

In this study, 93% of galling species belong to the Cecidomyiidae (Diptera) family, reflecting the great species richness of this family in Brazil, and in the Neotropics (Gagné 1994, Fernandes et al. 2001, Julião et al. 2002, Cuevas-Reyes et al. 2004, Maia 2005). As in other studies conducted in different biomes, such as Cerrado (Maia & Fernandes 2004), Atlantic Rain Forest (Fernandes & Negreiros 2006), Pantanal (Julião et al. 2002), Tropical Dry Forests (Coelho et al. 2009), 51% of galling insects occurred on leaves.

Studies relating to richness patterns and to the natural history of gall-inducing insects in Brazil are still incipient (Maia 2005). A study on global richness of gall-inducing insects estimated the existence of 21,000 to 211,000 species (Espírito-Santo & Fernandes 2007). This inaccuracy is probably due to the lack of more studies thoughout the many ecosystems around the globe. Every new study focusing on gall-inducing insects inventories reports to science at least a 50% of new species (see Coelho et al. 2009). Therefore, further studies are needed in order to achieve a better understanding of the gall-inducing insect distribution in different Brazilian ecosystems.

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