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Gall-inducing insects from Campos de Altitude, Brazil

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COELHO, M.S., CARNEIRO, M.A.A., BRANCO, C., BORGES, R.A.X. & FERNANDES, G.W. **Gall-inducing insects from Campos de Altitude, Brazil**. Biota Neotrop. 13(4): http://www.biotaneotropica.org.br/v13n4/en/abstract?article+bn02513042013

Abstract: Gall-inducing insects are very specious in vegetations of southeastern Brazil. Our goal was describe the gall richness by characterizing their external forms and their patterns of occurrence on host plants. Samples were collected from Campos de Altitude at four regions of the Mantiqueira Range: 1) Parque Estadual da Serra do Brigadeiro, 2) Parque Nacional do Caparaó, 3) Parque Estadual do Ibitipoca, 4) Parque Nacional do Itatiaia. We found 93 gall species within 13 families, 30 genera and 50 host plant species. We recorded 38 gall species in Parque Estadual da Serra do Brigadeiro, 21 in Parque Nacional do Caparaó, 23 in Parque Estadual do Ibitipoca and 20 in Parque Nacional do Itatiaia. Asteraceae represented 33% of the species collected, followed by Melastomataceae at 17%; with each one concentrating 56% and 18% of the galling insects, respectively. 98% of galls were Cecydomiidae (Diptera). The most attacked organ was the stem (56%), followed by the leaf (23%). Only 12% of the galls described in our study had been already recorded in previous studies, thus reinforcing the need to increase the sampling effort toward a better understanding of the richness and the natural history of gall-inducing insects from Brazil.
Keywords: *biodiversity, biogeography, herbivory, host plant, altitude.*

COELHO, M.S., CARNEIRO, M.A.A., BRANCO, C., BORGES, R.A.X. & FERNANDES, G.W. **Insetos indutores de galhas de Campos de Altitude, Brazil**. Biota Neotrop. 13(4): http://www.biotaneotropica.org.br/v13n4/pt/abstract?article+bn02513042013

Resumo: Insetos indutores de galhas são muito ricos em espécies nas formações vegetais do sudeste do Brasil. O objetivo deste estudo foi descrever a riqueza de morfotipos de galha por meio da caracterização de suas formas externas e os padrões de ocorrência nas plantas hospedeiras. As amostragens foram realizadas em campos rupestres e altitudinais de quatro regiões da Serra da Mantiqueira: 1) campos de altitude do Parque Estadual do Brigadeiro e 2) Parque Nacional do Caparaó, 3) Parque Estadual do Ibitipoca e Parque Nacional do Itatiaia. Foram registradas 93 espécies de galhas induzidas por insetos em 13 famílias, 30 gêneros e 50 espécies de plantas hospedeiras. Sendo 38 a riqueza de insetos indutores de galhas do Parque Estadual do Brigadeiro, 21 do Parque Nacional do Caparaó, 23 do Parque Nacional do Caparaó e 20 do Parque Nacional do Itatiaia. As famílias com maior riqueza foram Asteraceae (33%) e Melastomataceae (17%). A família Cecydomiidae (Diptera) foi a mais frequente (98%). O órgão mais atacado foi o caule (56%) seguido de folha (23%). O fato de apenas 12% das galhas descritas neste estudo já terem sido registradas em trabalhos anteriores, reforça a necessidade em aumentar o esforço amostral na direção de um maior conhecimento sobre a riqueza e história natural dos insetos indutores de galhas no Brasil.
Palavras-chave: *biodiversidade, biogeografia, herbivoria, planta hospedeira, altitude*

Introduction

Galls are produced by an increase in the size (hypertrophy) and/or in the number of plant cells (hyperplasia), which results in the formation of symmetrical structures in one or more organs of the host plant (Mani 1964, Raman 2007). Gall-inducing insects are considered the most sophisticated and capable due to their ability to manipulate the host plants for their benefit (Abrahamson & Weis 1997, Shorthouse et al. 2005, Fernandes et al. 2010). Galls could be considered to be an extension of the inductor phenotype, since their morphological characteristics depend on the inductor genotype as well as on environmental factors such as heat, humidity, and soil (Weis et al. 1988). Galls can be induced by bacteria, fungi, algae, nematodes, rotifers, copepods, plant (Loranthaceae), however, the most common are those induced by insects (Raman et al. 2005). Recent estimates point to a richness of around 130,000 species of Gall-inducing insects on the face of the planet with approximations ranging from 5 to 30 million insect species (Espírito-Santo & Fernandes 2007). Despite the high richness of gall morphotypes recorded in several Brazilian ecosystems, only 159 species have been described in Brazil (Maia 2005); and, considering the height diversity of these ecosystems, very few studies have been conducted which focus on the natural history and descriptions of gall morphotypes. Some of the ecosystems were only recently sampled, while others are still awaiting research (Coelho et al. 2009). We are not aware of any studies conducted on Campos de Altitude from Serra da Mantiqueira.

The Campos de Altitude were named by Barreto (1949) of "Campos Alpinos" and by Rizzini (1963) of "Campos Altimontanos". However, these classifications include ecosystems that, despite their physiognomic similarities, differ in lithological characteristics, geological origins, surrounding matrix, as well as in biological characteristics, such as floristic composition (Rizzini 1979). As a result of said differences, the fields located at high altitudes were subdivided into "Campos Quartizíticos" and "Campos Altimontanos" by Rizzini (1979) and later into "Campos Rupestres" and "Campos de Altitude" by Ferri (1980).

Campos Rupestres are composed predominantly of quartzite and sandstone rocks and are mainly associated with the Cerrado, although they can be found immersed in matrices of other biomes (Caiafa & Silva 2005). Unlike the Campos Rupestres, the Altitudinal Fields occur predominantly on granite rocks and are immersed in a matrix of Atlantic Rainforest (Moreira & Camelier 1977). The vegetation of both physiognomies is predominantly dominated by herbs and shrubs, however, Asteraceae, Melastomataceae, Orchidaceae, Bromeliaceae are the most common families in Campos de Altitude whereas, Asteraceae, Xyridaceae, Velloziaceae, Cyperaceae, and Melastomataceae are the most common families in the Rupestrian Fields. Adding to their biological and geological importance, mountain environments from southeastern Brazil are headwaters regions. For example, the Campos de Altitude associated with "Serra do Mar" and the Mantiqueira Range are responsible for supplying the water needs of 25% of the Brazilian population which may explain, *per se* their conservation (Safford 1999). Furthermore, Campos de Altitude from Mantiqueira Range and their disjunctions are associated with the Cerrado and Atlantic Rain Forest biomes, two biodiversity hotspots (Myers et al. 2000).

This work is part of a project to describe the natural history of galling insects, their galls, and their host plants at Campos de Altitude from Serra da Mantiqueira and Espinhaço Range (Carneiro et al. 2009b). Our goal was describe the gall richness through the characterization of the shape and occurrence patterns of the gall as related to its host plants at four regions of Serra da Mantiqueira.

Material and Methods

Samples were collected in four Campos de Altitude from Mantiqueira Range: 1) Parque Estadual do Brigadeiro (PESB), 2) Parque Nacional do Caparaó (PNC), 3) Parque Estadual do Ibitipoca (PEIB) and 4) Parque Nacional do Itatiaia (PNI).

The PESB is located in the "Zona da Mata" of Minas Gerais, between the meridians 42° 20' and 42° 40' S and the parallels 20° 20' and 21° 00' (Engevix 1995). Its lithology consists largely of granite formations (Machado-Filho et al. 1983). The climate is classified as medium mesothermal (CW_b) with an annual average temperature and rainfall of 18 °C and 1,300 mm, respectively. The predominant vegetation is composed of secondary semi-deciduous forest fragments (Veloso et al. 1991) and altitudinal fields (Ferri 1980). A floristic survey carried out in Altitudinal Fields from PESB Caiafa & Silva (2005) recorded 81 vascular plant species, with Asteraceae and Orchidaceae standing out as the most representative families.

The PNE is located between the states of Minas Gerais and Espírito Santo (20° 25' S, 41° 48' W) (Safford 2001). The soil is predominantly composed of metamorphic rocks (Machado-Filho et al. 1983). The average temperature is 10.5 °C whereas the rainfall is 1800mm (Safford 2001). The vegetation is composed of secondary semi-deciduous forests fragments and Altitudinal Fields above 2250m (Safford 2001).

The PEIB is located in the southeast of Minas Gerais (21° 42' S, 43° 54' W). The soil is predominantly quartzitic (Fundação... 1983). The average temperature is 18.9 °C whereas the rainfall is 1395 mm (Lemos & Melo-Franco 1976). The climate is classified as medium mesothermal (CW_b) (Fundação... 1983) and the region hosts different vegetation types: grassy fields, Rupestrian Fields, Fields with shrubs and small trees and wet forests "Capões de Mata" (Andrade & Souza 1995). Previous floristic studies have demonstrated the great importance of the region for concentrate a high biodiversity and high number of endemic species (Rodela 1998).

The PNI (22° 21' S and 44° 40' W) is located in central Mantiqueira range with a marked seasonality of cold, dry winters and hot, wet summers. The average temperature and precipitation is 14 °C and 2400 mm, respectively (Ribeiro et al. 2007). The fields are located in heights above 2000 meters with 550 described species (Safford 1999), of which 11% are endemic.

Gall sampling was performed following the methodology described by Fernandes & Price (1988, but see also Price et al. 1998). At each sampling point a plot with 100 woody plants (between 0.3 and 2 m high) was arbitrarily selected, totaling 1,000 plants in each region and 4,000 plants overall. Each plant was sampled throughout the aerial part of the individual by direct counting of gall morphotypes. Forests, areas close to trails, or any areas with visible human interference were excluded from the sampling.

According to Carneiro et al. (2009a) gall description associated with the identification of host-plant species is a reliable richness indicator of the gall-inducing insects. About 95% of described species of Cecidomyiids from Brazil can be identified based on the external shape associated with the host plant on which it occurs, 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 host plant samples and their galls were mounted and deposited in the herbariums OUPR and 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 II (2003). The galls were photographed and categorized according to color, shape, presence or absence of hairs and in accordance to the organ where they occurred (see Carneiro et al. 2009b). Galling insects were always identified when possible.

Table 1. Host plants, description of gall-inducing insects at Campos de Altitude from four regions located at Serra da Mantiqueira (PEB = Parque Estadual do Brigadeiro, PNC = Parque Nacional do Caparaó, PIB = Parque Estadual do Ibitipoca, PNI=Parque Nacional do Itatiaia).

Host Plants	Likely gall maker taxa	Regions				Organ	Shape	Color	Pubescence	Chambers	Photos
		PESB	PNC	PEIB	PNI						
Asteraceae											
Aspilia foliosa (Gardner) Benth. & Hook.	Cecidomyiidae	x				leaf	rolled edge	brown	glabrous	1	1(a)
	Cecidomyiidae	x				terminal branch	fusiform	brown	glabrous	1	1(b)
Baccharis aracatubensis Malag. & Hatschb.	Lepdoptera		x			stem	clefform	brown	glabrous	1	1(c)
Baccharis brevifolia DC.	Cecidomyiidae				x	leaf	elliptical	green	glabrous	1	1(d)
Baccharis dubia Deble & An. S. de Oliveira	Cecidomyiidae				x	stem	globulous	brown	glabrous	1	1(e)
Baccharis itatiaiae Wawra	Cecidomyiidae				x	stem	intumescence	brown	glabrous	1	1(f)
	Cecidomyiidae				x	stem	fusiform	green	glabrous	1	1(g)
	Cecidomyiidae				x	leaf	discóide	gree	glabrous	1	1(h)
	Cecidomyiidae				x	terminal branch	intumescence	brown	glabrous	1	1(i)
Baccharis myriocephala DC.	Cecidomyiidae		x			leaf	rolled edge	green	glabrous	1	1(j)
Baccharis platypoda DC.	Cecidomyiidae	x	x			leaf	discoid	green	glabrous	1	1(k)
	Cecidomyiidae	x	x			stem	fusiform	brown	glabrous	1	1(l)
	Cecidomyiidae	x	x			stem	fusiform	green	glabrous	various	1(m)
	Cecidomyiidae	x	x			stem	intumescence	brown	glabrous	1	1(n)
	Cecidomyiidae	x	x			flower	globulous	green	glabrous	various	1(o)
	Cecidomyiidae	x	x			leaf	rolled edge	green	glabrous	1	1(p)
	Cecidomyiidae	x	x			leaf	elliptical	green	glabrous	1	1(q)
	Cecidomyiidae	x				terminal branch	intumescence	brown	glabrous	various	1(r)
Baccharis pseudomyriocephala I.L. Teodoro	Cecidomyiidae				x	stem	intumescence	green	glabrous	1	1(s)
	Tephritidae				x	stem	globulous	brown	glabrous	1	1(t)
	Cecidomyiidae				x	stem	fusiform	brown	glabrous	1	2(a)
	Cecidomyiidae				x	leaf	legume	green	glabrous	1	2(b)
Asteraceae											
	Cecidomyiidae				x	leaf	discoid	green	glabrous	1	2(c)
	Cecidomyiidae				x	terminal branch	rolled edge	brown	glabrous	various	2(d)
Baccharis reticularia DC.	Cecidomyiidae			x		stem		brown	glabrous	various	2(e)
	Cecidomyiidae			x		leaf	legume	brown	glabrous	1	2(f)
	Cecidomyiidae			x		leaf	discoid	green	glabrous	1	2(g)
	Cecidomyiidae			x		terminal branch	intumescence	brown	glabrous	1	2(h)
Baccharis salzmanii DC.	Cecidomyiidae	x		x		stem	fusiform	brown	glabrous	1	2(i)
	Cecidomyiidae			x		stem	globulous	brown	glabrous	1	2(j)
	Cecidomyiidae			x		stem	intumescence	brown	glabrous	1	2(k)
	Cecidomyiidae			x		leaf	claviforme	green	glabrous	1	2(l)
	Cecidomyiidae			x		leaf	discoid	green	glabrous	1	2(m)
	Cecidomyiidae			x		terminal branch	intumescence	brown	glabrous	various	2(n)
Baccharis stylosa Gardner	Cecidomyiidae	x				stem	fusiform	brown	glabrous	1	2(o)
	Cecidomyiidae	x				leaf	elliptical	brown	glabrous	1	2(p)
Baccharis trimera (Less.) DC	Cecidomyiidae			x		stem	intumescence	green	glabrous	1	2(q)

Table 1. Continued...

Host Plants	Likely gall maker taxa	Regions				Organ	Shape	Color	Pubescence	Chambers	Photos
		PESB	PNC	PEIB	PNI						
Baccharis uncinella DC.	Cecidomyiidae				x	leaf	legume	brown	glabrous	1	2(r)
	Cecidomyiidae				x	terminal branch	intumescence	brown	glabrous	1	2(s)
Cyrtocymura scorpioides (Lam.) H. Rob.	Cecidomyiidae	x				stem	globulous	brown	glabrous	various	2(t)
	Cecidomyiidae	x				stem	fusiform	brown	glabrous	1	3(a)
	Cecidomyiidae	x				stem	intumescence	brown	glabrous	various	3(b)
Grazielia gaudichaudeana (DC.) R.M. King & H. Rob.	Cecidomyiidae				x	stem	intumescence	brown	glabrous	1	3(c)
Hololepis pedunculata (DC. ex Pers.) DC.	Cecidomyiidae	x				stem	fusiform	brown	glabrous	1	3(d)
Asteraceae											
Mikania reticulata Gardner	Cecidomyiidae			x		leaf	discoid	green	glabrous	1	3(e)
Pseudobrickellia angustissima (Spreng. ex Baker)	Cecidomyiidae			x		stem	globulous	brown	glabrous	1	3(f)
Symphyopappus brasiliensis (Gardner) R.M. King & H. Rob.	Cecidomyiidae		x			stem	fusiform	brown	glabrous	1	3(g)
	Cecidomyiidae		x			stem	globulous	green	glabrous	1	3(h)
	Cecidomyiidae		x			leaf	elliptical	green	glabrous	1	3(i)
Symphyopappus itatiayensis (Hieron.) R.M. King & H. Rob.	Cecidomyiidae				x	stem	globulous	brown	glabrous	1	3(j)
Erementhus erythropappa (DC.) Sch. Bip.	Cecidomyiidae			x		stem	globulous	brown	glabrous	1	3(k)
	Cecidomyiidae			x		leaf	legume	green	glabrous	1	3(l)
Ericaceae											
Gaylussacia decipiens Cham.	Cecidomyiidae	x				terminal branch	intumescence	red	hairy	1	3(m)
Euphorbiaceae											
Croton buxifolius (Baill.) Müll. Arg.	Cecidomyiidae	x				stem	intumescence	brown	glabrous	1	3(n)
	Cecidomyiidae	x				leaf	elliptical	brown	glabrous	1	3(o)
Croton dichrous Müll. Arg.	Cecidomyiidae				x	leaf	discoid	brown	glabrous		3(p)
Croton migrans Casar.	Cecidomyiidae	x	x			stem	fusiform	red	glabrous	1	3(q)
Croton splendidus Mart. ex Colla	Cecidomyiidae		x			leaf	discoid	green	glabrous	1	3(r)
Fabaceae											
Dalbergia sp.	Cecidomyiidae	x				stem	intumescence	brown	glabrous	1	3(s)
Lamiaceae											
Hyptis monticola Mart. ex Benth.	Cecidomyiidae			x		stem	intumescence	brown	glabrous	1	3(t)
Hyptis racemulosa Mart. ex Benth.	Cecidomyiidae		x			stem	fusiform	red	glabrous	1	4(a)
sp1	Cecidomyiidae	x				leaf	discoid	green	hairy	1	4(b)
Lauraceae											
Ocotea tristis (Nees & C. Mart.) Mez	Cecidomyiidae			x		stem	globulous	brown	glabrous	1	4(c)
Diplusodon buxifolius Cham. & Schltdl.	Cecidomyiidae			x		stem	intumescence	brown	glabrous	1	4(d)
Malpighiaceae											
Byrsonima variabilis Juss.	Cecidomyiidae			x		stem	fusiform	brown	glabrous	1	4(e)
Melastomataceae											
Camponanesia rufa (O.Berg)	Cecidomyiidae			x		stem	intumescence	brown	glabrous	various	4(f)
Lavoisiera compta DC.	Cecidomyiidae	x				stem	globulous	brown	glabrous	1	5(g)
Leandra áurea (Cham.)	Cecidomyiidae			x		leaf	globulous	red	hairy	1	4(h)

Table 1. Continued...

Host Plants	Likely gall maker taxa	Regions				Organ	Shape	Color	Pubescence	Chambers	Photos
		PESB	PNC	PEIB	PNI						
Marcetia taxifolia (A. St.-Hil.) DC.	Cecidomyiidae	x				stem	fusiform	brown	glabrous	various	4(i)
Microlicia sp.	Cecidomyiidae		x			stem	fusiform	brown	glabrous	various	4(j)
	Cecidomyiidae		x			stem	fusiform	brown	hairy	1	4(k)
Tibouchina faveolata Cogn.	Cecidomyiidae	x				stem	globulous	brown	glabrous	1	4(l)
	Cecidomyiidae	x				stem	fusiforme	brown	glabrous	various	4(m)
	Cecidomyiidae	x				leaf	conical	yellow	glabrous	1	4(n)
	Cecidomyiidae	x				terminal branch	fusiform	brown	glabrous	1	4(o)
Tibouchina collina Cogn.	Cecidomyiidae			x		stem	intumescence	brown	hairy	1	4(p)
Tibouchina hospita Cogn.	Cecidomyiidae				x	stem	intumescence	brown	hairy	1	4(q)
Tibouchina martiusiana (DC.) Cogn.	Cecidomyiidae			x		stem	fusiforme	brown	glabrous	1	4(r)
Tibouchina multiflora Cogn.	Cecidomyiidae	x				stem	intumescence	brown	hairy	various	4(s)
	Cecidomyiidae	x				leaf	discoid	red	hairy	1	4(t)
	Cecidomyiidae	x				terminal branch	intumescence	brown	glabrous	1	5(a)
Tibouchina sp.	Cecidomyiidae		x			stem	fusiform	brown	hairy	1	5(b)
Myrsinaceae											
Myrsine coriacea (Sw.) R. Br. ex Roem. & Schult.	Cecidomyiidae		x			leaf	elliptical	green	glabrous	1	5(c)
	Cecidomyiidae		x			leaf	rolled edge	green	glabrous	1	5(d)
Orchidaceae											
Epidendrum secundum Jacq.	Cecidomyiidae	x				stem	intumescence	brown	glabrous	1	5(e)
	Cecidomyiidae	x				leaf	discoid	green	glabrous	1	5(f)
Pentaphyllacaceae											
Ternstroemia brasiliensis Cambess.	Cecidomyiidae	x				stem	globulous	brown	glabrous	1	5(g)
	Cecidomyiidae	x				leaf	discoid	brown	glabrous	1	5(h)
Poaceae											
Chusquea pinifolia (Nees) Nees	Cecidomyiidae		x			stem	fusiforme	brown	glabrous	1	5(i)
Verbenaceae											
Lantana sp1	Cecidomyiidae	x				leaf	intumescence	green	glabrous	1	5(j)
	Cecidomyiidae	x				stem	fusiform	brown	glabrous	1	5(k)
sp1	Cecidomyiidae				x	stem	fusiform	brown	glabrous	various	5(l)
sp2	Cecidomyiidae				x	stem	globulous	brown	glabrous	1	5(m)

Results

In a universe of 51 families, 118 genera and 222 plant species, 93 gallind species in 13 families, 30 genera and 50 host plant species were recorded (Table 1 and 2, Figure 1-5). There were 38 gall species in PESB, 23 in PNC, 21 in PEIB and 20 in PNI. The families that concentrated the highest gall richness were those with the largest number of records. Asteraceae represented 33% of plant species collected followed by Melastomataceae, with 17%, and each concentrated 56% and 18%, of gall species, respectively.

Again, the genera and species that concentrated the greatest gall richness belong to the plant families with the highest occurrence, Asteraceae (33%) and Melastomataceae (17%). The genera that concentrated the most gall richness were *Baccharis* (Asteraceae) 40% followed by *Tibouchina* (Melastomataceae) (12%). The species with the greatest gall richness were *Baccharis platypoda* DC. (9%), *Baccharis salzmanii* DC. (6%), *Baccharis pseudomyriocephala* (6%), *Baccharis reticularia* DC. (4%), *Baccharis itatiaie* (4%), *Tibouchina faveolata* (4%). The family Cecidomyiidae (Diptera) was the most frequent (98%), followed by Tephritidae (Diptera) (1%) and the order Lepidoptera (1%).

The most common gall shapes were intumescence (26%), fusiform (25%), globose (16%) and discoid (13%). The most attacked organ was the stem (56%), followed by the leaf (32%) and the terminal branch (11%). Eighty-nine percent (89%) of galls were glabrous.

Tabela 2. Number of gall-inducing insects associated to plant families at Campos de Altitude from Serra da Mantiqueira, Minas Gerais. Families without galls were listed as "other families" (Amaryllidaceaem, Apocynaceae, Asclepiadaceae, Celastraceae, Cunnonaceae, Dennstaldtaliaceae, Escalloniaceae, Gesnariaceae, Lycopodiaceae, Lythraceae, Myrtaceae, Onagraceae, Orabanchaceae, Oxalacidaceae, Phyllanthaceae, Piperaceae, Proteaceae, Rubiaceae, Salicaceae, Scrophulariaceae, Solanaceae, Turneraceae, Velloziaceae).

Families	Host plants		Galls	
	Richness	%	Richness	%
Asteraceae	61	32.6	52	55.9
Ericaceae	9	4.8	1	1.1
Euphorbiaceae	8	4.3	5	5.4
Fabacae	6	3.2	1	1.1
Lamiaceae	8	4.3	3	3.2
Lauraceae	2	1.1	2	2.2
Malpighiaceae	1	0.5	1	1.1
Melastomataceae	33	17.6	17	18.3
Myrsinaceae	5	2.7	2	2.2
Orchidaceae	2	1.1	2	2.2
Pentaphyllacaceae	2	1.1	2	2.2
Poaceae	3	1.6	1	1.1
Verbenaceae	6	3.2	4	4.3
Outras famílias	41	21.9	0	0
Total	187	100	93	100

Discussion

Gall-inducing insects and their host plants have been widely studied in recent decades in different Brazilians vegetation types, e.g.: Pantanal (Julião et al. 2002), Amazon (Julião et al. 2005, Almada & Fernandes 2011, Maia 2012), Restinga (Maia 2001, 2005, Maia et al. 2002, Mendonça 2007, Oliveira & Maia 2005), Cerrado (Fernandes & Price 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 (Santos et al. 2011). This is the first study that describes the galls and host plants of Campos de Altitude.

In this study, we documented 93 gall-inducing insects, from those only 23 (23%) had been previously recorded. Previous studies have reported *Baccharis platypoda* DC. (Table 1, Figure 1(k, l, m, n, o) with 5 galls (Fernandes et al. 1996, Carneiro et al. 2009b); *Baccharis pseudomyriocephala* (Table 1, Figure 1(s, t), 2(a, b, c, d) with 6 galls (Araújo et al. 2003); *Baccharis reticularia* (Table 1, Figure 2(e,f,g,h) with 4 galls (Carneiro et al. 2009b); *Baccharis salzmanii* DC. (Table 1, Figure 2(k,m) with 2 galls (Carneiro et al. 2009b); *Baccharis trimera* (Table 1, Figure 2(q) with 1 gall (Carneiro et al. 2009b), *Hololepis penduculata* (Table 1, Figure 3(d)) with 1 gall (Carneiro et al. 2009b); Mikania meticulata (Table 1, Figure 3(e)) with 1 gall (Carneiro et al. 2009b); *Symphyopappus brasiliensis* (Table 1, Figure 3(g,h)) with 2 galls (Carneiro et al. 2009b). The fact that only 23% of the galls described in this study have already been recorded in previous studies reinforces the need to increase the sampling efforts of gall-inducing insects in Brazil.

The families Asteraceae and Melastomataceae are the richest and most abundant in Altitudinal and Rupestrian Fields in Brazil (Martinelli 1996). In this study, the family Asteraceae was also the most frequent, representing 33% of the plants collected, followed by the Melastomataceae (17%). These results corroborate data of Safford (1999) from Campos de Altitude. The author demonstrates that Asteraceae represents (20%) of all the floristic richness, whereas the genus *Baccharis* is responsible for 5% of it. The host plant pattern was the same. Asteraceae responded for 56% of total host plants followed by Melastomataceae (18%).

Gall-inducing insects are commonly found in plant families and genera richest in species (Fernandes 1992, Blanche & Westoby 1995). Although the families Asteraceae and Melastomataceae concentrated 74% of the gall-inducing insects, only two genera, *Baccharis* (Asteraceae) (42%) and *Tibouchina* (Melastomataceae) (12%) responded for 54% of the total. Previous studies have shown that some taxa concentrate a large number of galls (Fernandes & Price 1988, Fernandes et al. 1996, Blanche 2000). Some genera have been considered super-hosts. Working with *Baccharis*, Fernandes et al. (1996) reported 121 gall species in only 40 host plant species. In another study, Carneiro et al. (2009b) recorded that *Baccharis* has the highest number of gall-inducing insects in Rupestrian Fields from the Espinhaço Range. Thus, *Baccharis* may be the taxon that hosts the greatest number of gall-inducing insects in the Neotropics.

Investigating the correlation of the effects of soil fertility on gall-inducing insect richness in Australian National Parks, Blanche & Westoby (1995) found a negative correlation, however spurious. The authors argue that the genus *Eucalyptus* (Myrtaceae) is richer and more abundant on infertile environments and for concentrate a greater galling insect richness would be the main cause of the pattern. Other genera, such as *Salix* (Salicaceae) and *Quercus* (Fagaceae), are known to host great galling insect richness (Price 1992). One of the factors that contributes to the genera *Eucalyptus*, *Quercus*, *Salix* concentrating a greater galling richness is the fact that they recover quickly from impacts such as fire, severe droughts, as well as intense herbivory (Price 1992, Blanche & Westoby 1995). The same can be said about the genera *Baccharis* and *Eremanthus* in Rupestrian Fields of the Espinhaço Range (M.A.A. Carneiro Personal Observation. But see also Carneiro et al. 2009b). However, further studies are needed in order to find factors that explain the high galling insect richness associated with these super diverse genera. In our study, 98% of galling species belong to the family Cecidomyiidae (Diptera); this reflects the great richness of this family in Brazil and in the Neotropics (Gagné 1994, Fernandes et al. 2001, Cuevas-Reyes et al. 2004).

Figure 1. Host plants and their galls at Campos de Altitude from four regions located at Serra da Mantiqueira, Minas Gerais. PEB = Parque Estadual do Brigadeiro, PNC = Parque Nacional do Caparaó, PIB = Parque Estadual do Ibitipoca, PNI=Parque Nacional do Itatiaia. Asteraceae (*Aspilia foliosa* (a-b), *Baccharis aratatubensis* (c), *Baccharis brevifolia* (d), *Baccharis dubia* (e), *Baccharis itatiaiae* (f-i), *Baccharis myriocephala* (j), *Baccharis platypoda* (k-r), *Baccharis pseudomyriocephala* (s-t)).

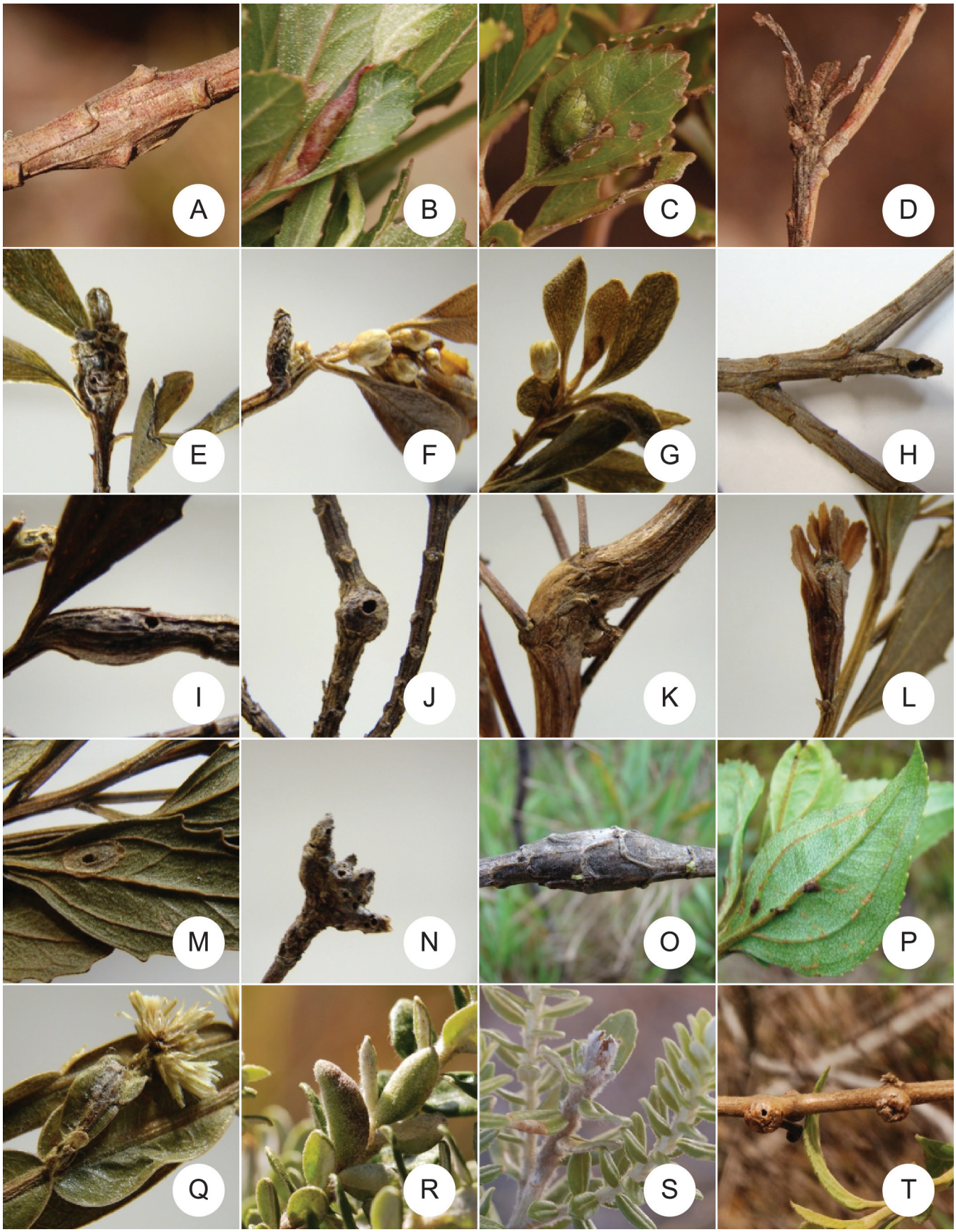

Figure 2. Host plants and their galls at Campos de Altitude from four regions located at Serra da Mantiqueira, Minas Gerais. PEB = Parque Estadual do Brigadeiro, PNC = Parque Nacional do Caparaó, PIB = Parque Estadual do Ibitipoca, PNI=Parque Nacional do Itatiaia. Asteraceae (*Baccharis pseudomyriocephala* (a-d), *Baccharis reticularia* (e-h), *Baccharis salzmanii* (i-n), *Baccharis stylosa* (o-p), *Baccharis trimera* (q), *Baccharis uncinella* (r-s), *Cyrtocymura scorpioides* (t).

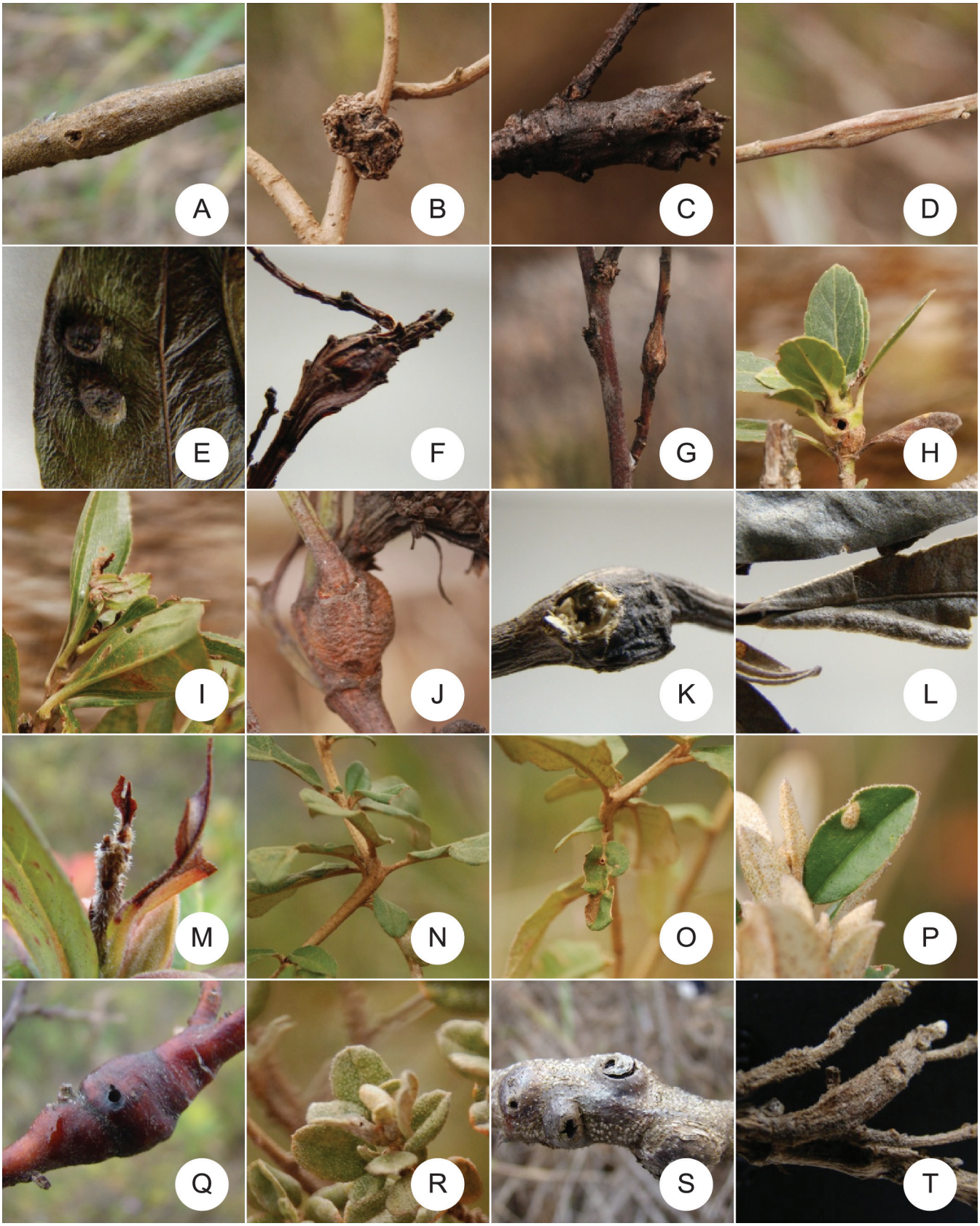

Figure 3. Host plants and their galls at Campos de Altitude from four regions located at Serra da Mantiqueira, Minas Gerais. PEB = Parque Estadual do Brigadeiro, PNC = Parque Nacional do Caparaó, PIB = Parque Estadual do Ibitipoca, PNI=Parque Nacional do Itatiaia. Asteraceae (*Cyrtocymura scorpioides* (a-b), *Grazielia gaudichaudeana* (c), *Hololepis pedunculata* (d), *Mikania reticulata* (e), *Pseudobrickellia angustissima* (f), *Symphyopappus brasiliensis* (g-i), *Symphyopappus itatiayensis* (j), *Erementhus erythropappa* (k-l)), Ericaceae (*Gaylussacia decipiens* (m)), Euphorbiaceae (*Croton buxifolius* (n-o), *Croton dichrous* (p), *Croton migrans* (q), *Croton splendidus* (r)), Fabaceae (*Dalbergia* sp. (s)), Lamiaceae (*Hyptis monticola* (t)).

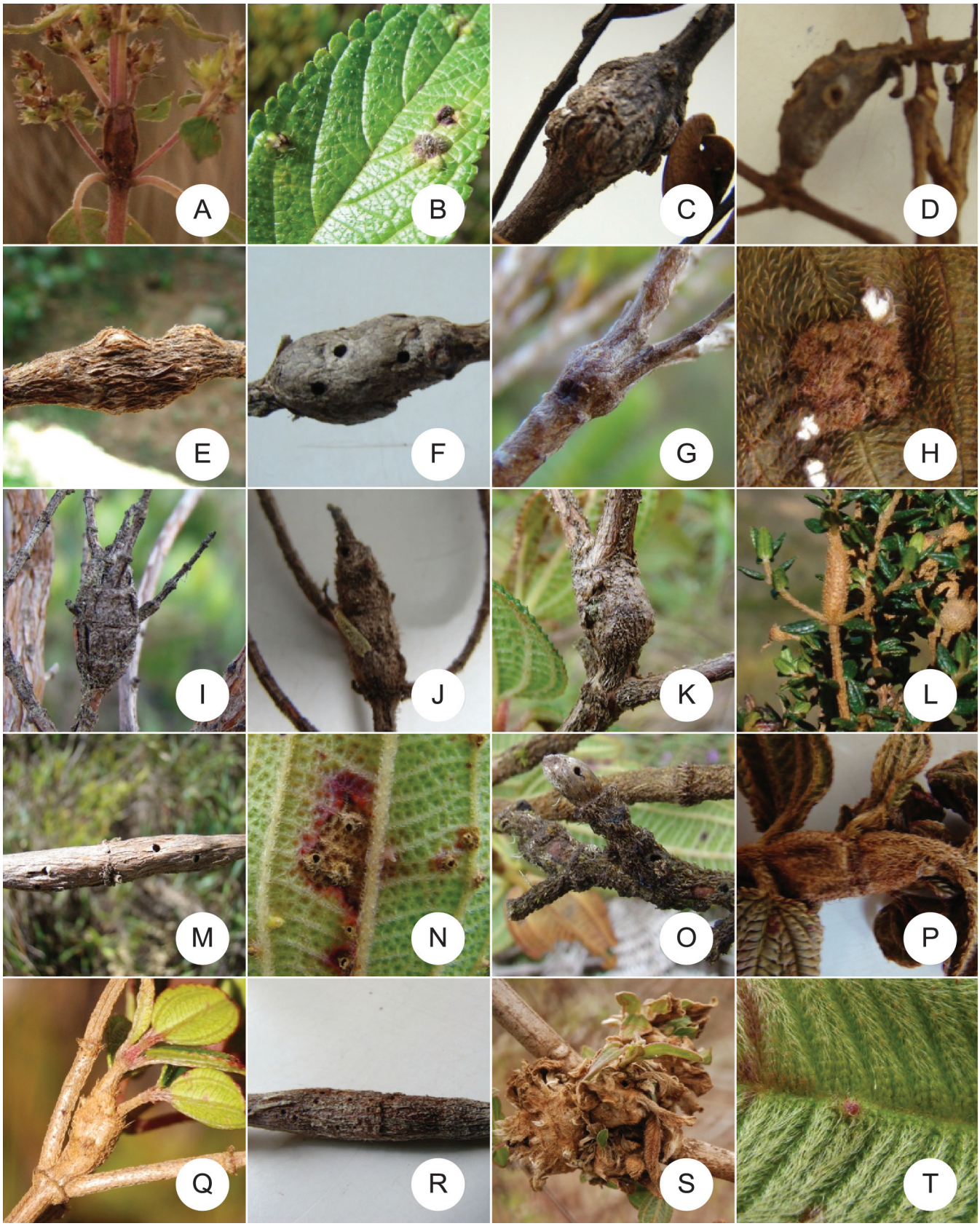

Figure 4. Host plants and their galls at Campos de Altitude from four regions located at Serra da Mantiqueira, Minas Gerais. PEB = Parque Estadual do Brigadeiro, PNC = Parque Nacional do Caparaó, PIB = Parque Estadual do Ibitipoca, PNI=Parque Nacional do Itatiaia. Lamiaceae (*Hyptis racemulosa* (a), sp1 (b)), Lauraceae (*Ocotea tristis* (c), *Diplusodon buxifolius* (d), Malpighiaceae (*Byrsonima variabilis* (e)), Melastomataceae (*Camponanesia rufa* (f), *Lavoisiera compta* (g), *Leandra aurea* (h), *Marcetia taxifolia* (i), *Microlicia* sp. (j-k), *Tibouchina faveolata* (l-o), *Tibouchina collina* (p), *Tibouchina hospita* (q), *Tibouchina martiusiana* (r), *Tibouchina multiflora* (s-t).

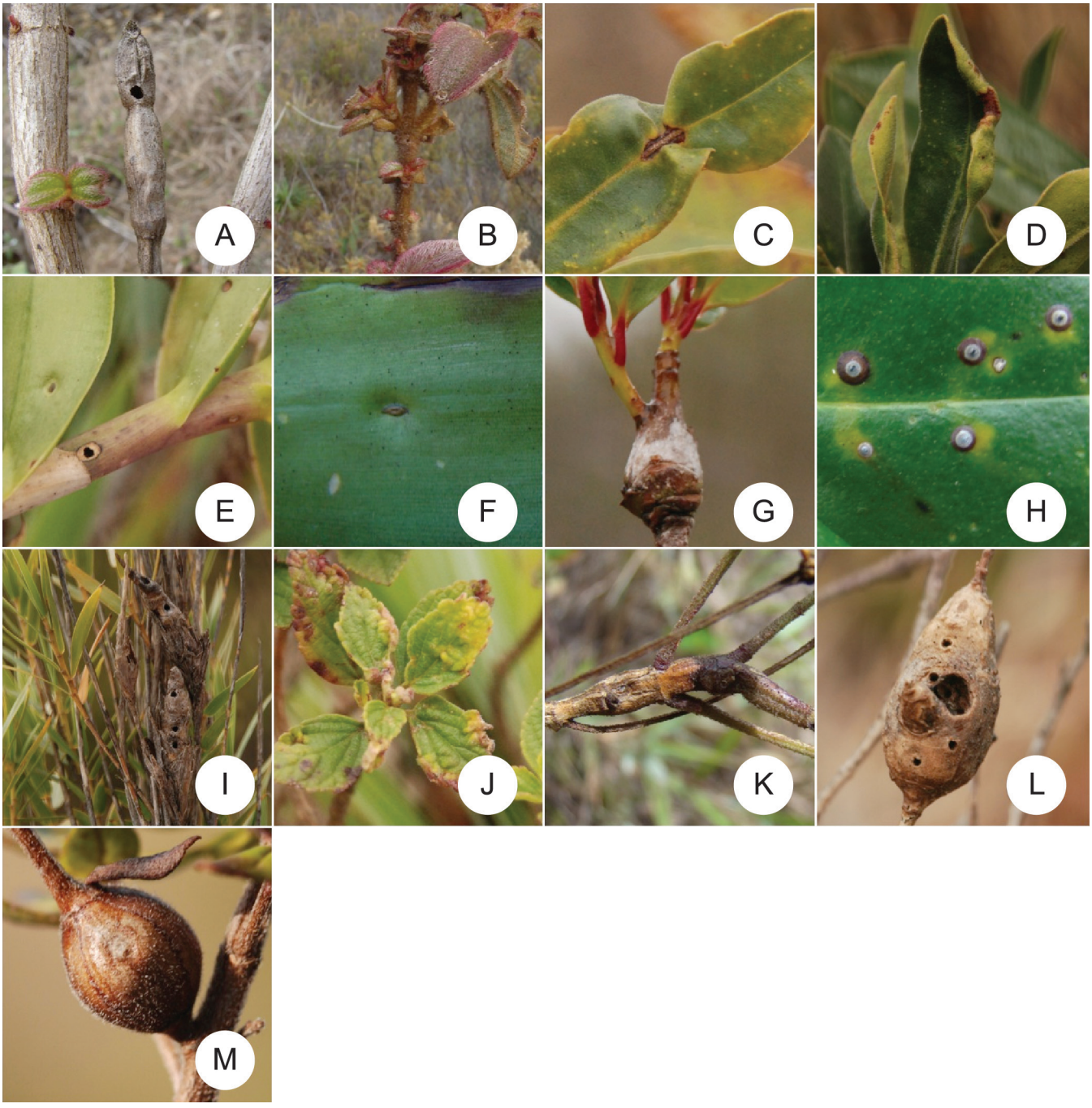

Figure 5. Host plants and their galls at Campos de Altitude from four regions located at Serra da Mantiqueira, Minas Gerais. PEB = Parque Estadual do Brigadeiro, PNC = Parque Nacional do Caparaó, PIB = Parque Estadual do Ibitipoca, PNI=Parque Nacional do Itatiaia. Melastomataceae (*Tibouchina multiflora* (a), *Tibouchina* sp. (b) Myrsinaceae (*Myrsine coriacea* (c-d)), Orchidaceae (*Epidendrum secundum* (e-f)), Pentaphylacaceae (*Ternstroemia brasiliensis* (g-h), Poaceae (*Chusquea pinifolia* (i)), Verbenaceae (*Lantana* sp1 (j-k), sp1 (l), sp2 (m)).

Descriptive studies of gall-inducing insects in Brazil have a pattern that relates to the host plant organs most often attacked. 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) point to higher gall richness on leaves. However, in our study, 56% of the galls concentrated on stems, while only 32% concentrated on leaves. These results differ from most studies to date. Working in Rupestrian Fields across the Espinhaço Range, Carneiro et al. (2009b) also found the same pattern of high gall richness on stems. The authors argue that insects hosted in the plant stems have a greater resistance to mechanical damage and availability of tissues of higher nutritional quality than those on leaves (see also Veldtman & McGeoch 2003, Inbar et al. 2004, Price 2005). Protection against external factors is one of the main selective pressures for the gall-inducing insects (Price et al. 1987). However, it is unclear as to why the results from Rupestrian Fields and Campos de Altitude were the only ones to show this pattern in Brazil. Perhaps, since these sites are more exposed to abiotic factors such as wind, temperature variations and high fire frequency (Giulietti et al. 1987, Giulietti & Pirani 1988, Safford 1999,

2001), different from other Brazilian ecosystems, (Julião et al. 2002, Fernandes & Negreiros 2006) there exists a selective pressure that favors a greater number of stem galls.

Studies relating to richness patterns and to natural history of gall-inducing insects in Brazil are still incipient (Maia 2005). This is the first study that describes the galls and their host plants from Altitudinal Fields. Among the seven priorities for research and conservation of Campos de Altitude traced by Safford (1999), stands out the need for increased efforts in floristic and faunal inventories. Poor understanding of the biological resources from conservation units as well as the lack of knowledge of what is endemic or what is threatened hinders the proper management of natural resources and prevents the mapping, endemism analysis, geographical distribution as well as diversity patterns, essential for the development of conservation strategies. Therefore, further research is required in order to reach a better understanding of gall-inducing insect richness, given the importance of this guild for biodiversity conservation and its significance as a model for ecological studies.

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