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ECOSYSTEMS

Insect galls from the Serra Negra do Funil Natural Heritage Private Reserve, Rio Preto, MG (Southeastern Brazil)

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Abstract: Serra Negra do Funil Natural Heritage Private Reserve (NHPR), located in MG, was surveyed for insect galls monthly from October, 2015 to May, 2020. The local vegetation was examined. Dried branches of the host plants were prepared and identified by a botanical taxonomist. Galls were photographed, removed from the plants and taken to the laboratory. By rearing and gall dissection, inducing-insects and other dwellers were obtained. A total of 63 gall morphotypes were found on 48 plant species of 22 families. Fabaceae and Asteraceae harbored the greatest gall richness. Twelve host plants are endemic to Brazil, one in vulnerable and one near threatened. Most galls were induced on leaves, brown and green were the most frequent gall colors, and globoid was the most common gall shape. The majority were glabrous, one-chambered and induced by Cecidomyiidae. These results reinforce Brazilian patterns of gall morphology. The highest richness of galls on Fabaceae and Asteraceae, and on trees and shrubs adds evidence in favor of the plant richness and architectural complexity hypotheses. New plant-gall inducer associations were provided. The role of gall-inducers as ecosystem engineer was reinforced. The high number of endemism shows the importance of this NHPR for the biodiversity conservation.

Keys words: Atlantic Forest, gall richness, host plant, insect-plant interaction.

INTRODUCTION

The largest remnants of Atlantic Forest in Minas Gerais are found in Serra da Mantiqueira, the largest and most important mountain chain of the Southeast of the state (Costa & Herrmann 2006). This geological formation has a high biological importance due to its great diversity and numerous endemisms (Drummond et al. 2005, Stehmann & Sobral 2009).

Serra Negra da Mantiqueira (SNM) is part of the Southeast corridor of Complexo da Mantiqueira. Its vegetation comprises a mosaic of fragments with forest and shrub formations. The former includes dense Ombrophilous Forest and Seasonal Semideciduos Forest (Valente et al. 2011) and the latter broadleaved shrubs and rupestrian fields (Salimena et al. 2013). This mountain chain harbors so far 1,033 species of phanerogamic plant species of 469 genera and 121 families, 119 of Angiosperms and two of Gymnosperms. The climate is classified as Cwb (Köppen) with anual precipitation average of 1,886 mm.

Four areas of environmental protection were established in SNM: São Lourenço do Funil NHPR, Serra Negra NHPR, Serra Negra do Funil NHPR, and Serra Negra da Mantiqueira State Park. In spite of their biological importance, no insect gall inventories have been performed in this mountain chain.

A global decline of insect abundance and biodiversity was highlighted by Hallmann et

al. 2017, which reported a loss of 76 to 82% in flying insect biomass over 27 years of study. In this context, it is important to emphasize that gall-inducing insects are very sensitive to changes in the environment in which they occur (Toma et al. 2014). Loss of insects has adverse effects on ecosystem functioning, as insects play a central role in a variety of processes, including pollination, herbivory and detrivory, nutrient cycling and providing a food source for higher trophic levels (Hallmann et al. 2017). Gall-inducing insects play a role as ecosystem engineers, providing niches to further arthropods, which increases biodiversity with inquilines and successors (Jones et al. 1994). In the current scenario, where there is an urgency to address insect conservation and restoration global problems, to study all-inducers is very relevant.

The present study aims to inventory and characterize the insect galls of the Serra Negra do Funil NHPR (Minas Gerais, Brazil), contributing with new information about plant-gall inducer associations, level of endemism of the host plants, ecological services, geographic distribution, species way of life, and richness of species in space and time.

MATERIALS AND METHODS

Study area

Serra Negra do Funil NHPR (Fig. 1a), created in 2018 (Instituto Estadual de Floresta de Minas Gerais – IEF\MG - Port. 10 de 06\03\2018), is located in the southern part of "Zona da Mata" of Minas Gerais, between the municipalities of Lima Duarte, Rio Preto, Santa Bárbara do Monte Verde, and Olaria. This formation comprehends near 29 hectares, with altitudes ranging from 900 to 1, 200 meters. It is covered by native vegetation and crossed by a small stream that belongs to Rio Preto hydrographic basin, a tributary of Paraíba do Sul river.

Field procedure

Collecting

The Serra Negra do Funil NHPR was investigated monthly by one of the authors (BM) from October, 2015 to May, 2020. Each visit to the site lasted three days performing eight hours of field work per day. All five official trails (Figs. 1b-f) were surveyed along their entire length. In addition, collections were also done outside official trails. A similar methodology was adopted by the authors in the National Park of Itatiaia (Maia & Mascarenhas 2017). Herbs, bushes and trees (up to 2 m high) were examined. Leaves, buds, stems, tendrils, aerial roots, flowers, bud flowers, and fruits were investigated for galls. Galled branches were collected, packed and transported in labelled plastic bags. Each plastic bag contained samples of a single host plant and gall morphotype. Each host plant and gall morphotype were photographed. Dried branches of branches preferentially with galls, flowers and fruits of each host plant species were prepared.

Laboratory procedures

Laboratory procedures were conducted by one of the authors (VCM). Each gall morphotype was separated from one to another, then a part of these samples were dissected under a stereomicroscope in order to identify the inducers and obtain their immature stages, and part was kept in plastic pots padded with paper towel, covered by organza at room temperature, and labeled. These pots were examined every day (except weekends) for insect emergence. Whenever adults were obtained, these pots were kept for few minutes in the refrigerator to provoke their lethargy. Then, adults were collected with a wet brush, placed in a labeled

Figure 1. a-f. Serra Negra do Funil Natural Heritage Private Reserve (MG, Brazil). 1a, panoramic view, 1b-f, trails.

microvial with 70% ethanol and later identified by the VCM. Voucher material was deposited in the Entomological Collection of Museu Nacional (MNRJ)/ Universidade Federal do Rio de Janeiro.

Dried branches were examined, identified by botanist Dr. Ricardo Moura, and deposited in the herbarium of Museu Nacional (R)/Universidade Federal do Rio de Janeiro. Data on plant species (spelling, author, origin, conservation status and distribution) were retrieved from the site Flora do Brasil, 2020.

Our results were compared to those of other insect gall inventories in Brazil, mainly to those performed in other mountain areas of Minas Gerais. Previous records of insect galls on the same plant species were provided and new records were highlighted.

RESULTS

A total of 63 insect gall morphotypes were found on 48 plant species distributed in 42 genera and 22 host families (Table I). Fabaceae showed the greatest richness of galls (12 morphotypes), host plant genera (5) and species (8), followed by Asteraceae with 10 gall morphotypes, 5 host genera and 7 species, Euphorbiaceae with 6, 3 and 3, and Melastomataceae with 6, 5 and 6 and Myrtaceae, with 5, 2 and 2. These families together harbor about 61% of the gall richness of the study area. The other families host from three

to one gall morphotype. Among them 11 host only one (50% of the total). Although Fabaceae is the most important host, Myrtaceae showed the greatest average of galls per species (2.50), followed by Euphorbiaceae, and Primulaceae (2.00 each), while Fabaceae occupied the fourth position. Most families (about 73%) showed an average of 1.00.

Leaves were the most frequent host plant organ with about 59% of the gall morphotypes, followed by stems with about 30% and buds with about 14%. One morphotype was found on leaves and stems, one on leaves and buds, and all others occurred on a single organ. No galls were found on reproductive organs (Table II).

Seven shapes of galls were found: conical, cylindrical, fusiform, globoid, lenticular, marginal roll, and ovoid (Table III). The most frequent were globoid (about 57%), followed by fusiform (about 35%). All other shapes were represented by a single or two gall morphotypes. Leaves showed the greatest variety of shapes, globoid being the most frequent, followed by fusiform, but the later were observed only on petioles

Table I. Richness of host genera, host species, gall morphotypes and host family in the Natural Heritage Private Reserve of Serra Negra do Funil (Minas Gerais, Brazil).

Host plant family	Number of host genera	Number of host species	Number of gall morphotypes	Average of gall morphotypes per host species
Asteraceae	5	7	10	1.42
Basellaceae	1	1	1	1.00
Bignoniaceae	2	2	2	1.00
Chrysobalanaceae	1	1	1	1.00
Convolvulaceae	2	2	2	1.00
Dilleniaceae	1	1	1	1.00
Euphorbiaceae	3	3	6	2.00
Fabaceae	**5**	**8**	**12**	1.50
Hypericaceae	1	1	1	1.00
Loganiaceae	1	1	1	1.00
Malpighiaceae	1	1	1	1.00
Melastomataceae	5	6	6	1.00
Moraceae	1	1	1	1.00
Myrtaceae	2	2	5	2.50
Onagraceae	1	1	1	1.00
Primulaceae	1	1	2	2.00
Rhamnaceae	1	1	1	1.00
Rubiaceae	3	3	3	1.00
Salicaceae	1	1	1	1.00
Sapindaceae	2	2	3	1.50
Solanaceae	1	1	1	1.00
Verbenaceae	1	1	1	1.00
Total	42	48	64	1.33

Table II. Richness of insect galls per host plant organ in the Natural Heritage Private Reserve of Serra Negra do Funil (Minas Gerais, Brazil).

Plant organ	Number of insect galls
Leaf	35
Stem	18
Leaf + stem	1
Bud	8
Bud + leaf	1

and veins. Most stem galls were fusiform, nevertheless globoid and ovoid galls were also observed, and finally bud galls were mainly globoid and a single morphotype was ovoid and another fusiform.

Galls showed collectively four different colors: green, brown, yellow and red (Table IV). Only two morphotypes showed color variation: from red to green and from red or green to brown. Brown and green galls were the most frequent colors (with about 41 and 44%, respectively), followed by yellow (about 14%), and red (about 5%). Green was the predominant color of leaf galls and brown of stem galls, yellow was observed only in leaf galls, and red in leaf, stem, and bud galls. Leaves showed the greatest range of colors.

Trichomes were found in 11 gall morphotypes (about 17%), mainly in leaf galls, but also in stem and bud galls. All other morphotypes were glabrous. All galls were one-chambered, except one morphotype on buds.

Gall-inducers of 42 morphotypes (about 67%) were determined. They are represented by Diptera (Cecidomyiidae and Tephritidae), Lepidoptera, and Hemiptera. Galls of Coleoptera, Thysanoptera, and Hymenoptera were not found. Cecidomyiidae induced about 59% of the reported galls and represented 88% of the determined inducers (Table V).

In addition to the inducers, other insects were found in six gall morphotypes: Lepidoptera (n=1), Thysanoptera (n=1), and Sciaridae (Diptera) (n=1) as cecidophages, Hymenoptera (n=2) as parasitoids, and Psocoptera and Thysanoptera in a same gall (n=1) as successors.

Galls were found on lianas, sub-shrubs, shrubs, and trees (Tables VI-VII). Most of them were observed on trees (n=19), and on host plant species that range from trees to shrubs (n=9), totaling about 44%. The remainder of the gall morphotypes was found on shrubs (n=6), lianas (n=6), species that range from shrubs to sub-shrubs (n=2), from sub-shrubs to lianas (n=1) and from trees and shrubs to lianas (n=1).

All host plant species are native to Brazil, except *Lantana camara* L., which is naturalized.

Table III. Richness of insect galls per host plant organ and shape in the Natural Heritage Private Reserve of Serra Negra do Funil (Minas Gerais, Brazil).

Shape Organ	Globoid	Fusiform	Conical	Ovoid	Lenticular	Cylindrical	Marginal roll
Leaf	25	6	1	0	1	1	1
Stem	3	14	0	2	0	0	0
Bud	7	1	1	0	0	0	0
Leaf + bud	1	0	0	0	0	0	0
Leaf + stem	0	1	0	0	0	0	0
Total	36	22	2	2	1	1	1

Table IV. Richness of insect galls per plant organ and color in the Natural Heritage Private Reserve of Serra Negra do Funil (Minas Gerais, Brazil).

Color Organ	Green	Brown	Yellow	Red	Green or red	Green, red or brown
Leaf	20	7	7	1	0	0
Stem	0	17	0	0	0	0
Bud	3	3	2	0	0	0
Leaf + bud	0	0	0	0	0	1
Leaf + stem	1	0	0	0	1	0
Total	24	27	9	1	1	1

Table V. Richness of insect galls per gall-inducing taxa and plant organ in the Natural Heritage Private Reserve of Serra Negra do Funil (Minas Gerais, Brazil).

Inducer Organ	Cecidomyiidae (Diptera)	Tephritidae (Diptera)	Lepidoptera	Hemiptera
Leaf	19	0	1	0
Stem	10	2	2	0
Bud	6	0	0	0
Leaf + bud	0	0	0	1
Leaf + stem	2	0	0	0
Total	37	2	3	1

Among native species, 12 are endemic to the country (Table VI) and harbor 16 gall morphotypes. Most hosts (n=30) have not yet been evaluated for their conservation status (Table VI), three species are in the category "least concern", *Apuleia leiocarpa* (Vogel) J. F. Macbr. (Fabaceae) is "vulnerable" and *Huberia nettoana* Brade is "near threatened". The last two harbor a single gall morphotype, each.

Galls are reported for the first time on 13 plant species in Brazil, *Baccharis punctulata* DC. and *Eremanthus incanus* (Less.) Less. (Asteraceae), *Anredera cordifolia* (Ten.) Steenis (Basellaceae), *Pleonotoma tetraquetra* (Cham.) Bureau (Bignoniaceae), *Hymenolobium janeirense* Kuhlm, *Machaerium brasiliense* Vogel. and *Machaerium ovalifolium* Glaz. ex Rudd (Fabaceae), *Vismia micrantha* A.St.-Hil. (Hypericaceae), *Clidemia hirta* (L.) D.Don b, *Huberia nettoana* Brade, and *Miconia cuspidata* Naudin (Melastomataceae), *Ludwigia peruviana* (L.) H. Hara (Onagraceae), and *Colubrina glandulosa* Perkins (Rhamnaceae), two genera, *Pleonotoma* Miers and *Colubrina* Rich. ex Brongn,, and one family, Basellaceae.

Data on host plants and galls are presented below, in alphabetical order of plant families. Previous records in Brazil are added whenever available.

Table VI. Data on host plant species: architectural complexity, origin, conservation status and distribution in Brazil (states and biomes)

Host plant species	Architectural complexity	Origin/ Conservation status	Distribution in Brazil/Biomes
Baccharis punctulata DC.	Shrub Sub-shrub	Native to Brazil/ NE	MT, ES, MG, RJ, SP/Atlantic Forest, Cerrado, Pampa
Bidens segetum Mart. ex. Colla	Liana	Native to Brazil/ NE	BA, DF, GO, MS, MG, ES, RJ, SP, PR, SC, RS/Atlantic Forest, Cerrado
Eremanthus erythropappus (DC.) MacLeish	Tree	Endemic to Brazil/ NE	DF, GO, MG, ES, RJ, SP/Atlantic Forest, Cerrado
Eremanthus incanus (Less.) Less.	Tree	Native to Brazil/ NE	BA, MG/Atlantic Forest, Caatinga, Cerrado
Vernonanthura polyanthes (Sprengel) Vega & Dematteis	Shrub	Native to Brazil/NE	BA. MG. RJ, SP/not stated
Anredera cordifolia (Ten.) Steenis	Liana	Native to Brazil/NE	BA, CE, PE, MS, MG, ES, RJ, SP, PR, SC, RS/Atlantic Forest, Cerrado, Pampa
Pleonotoma tetraquetra (Cham.) Bureau	Liana	Endemic to Brazil/ NE	DF, GO, MG, RJ, SP/Atlantic Forest, Cerrado
Licania kunthiana Hook.f	Tree	Endemic to Brazil/ NE	RR, AMP, AM, PA, AC, RO, TO, MT, MS, DF, GO, MG, ES, RJ, SP BA, MA, PE, SE/Amazon Forest, Atlantic Forest, Caatinga, Cerrado
Davilla rugosa Poir	Sub-shrub Liana	Native to Brazil/NE	AM, PA, TO, PI, MA, PI, BA, MG, ES, RJ, SP, PR, SC/Amazon Forest, Atlantic Forest
Croton floribundus Spreng.	Tree	Native to Brazil/NE	CE, PE, PB, AL, BA, DF, MG, MS, MG, ES, RJ, MG, PR/ Atlantic Forest
Dalechampia triphylla Lam.	Liana	Endemic to Brazil/ NE	PA, BA, PE/Amazon Forest, Atlantic Forest, Caatinga
Sapium glandulosum (L.) Morong	Tree Shrub	Native to Brazil/NE	All Brazilian states/Amazon Forest, Atlantic Forest, Caatinga, Cerrado
Apuleia leiocarpa (Vogel) J.F.Macbr	Tree	Native to Brazil/VU	All Brazilian states, except AM and RR/Amazon Forest, Atlantic Forest, Caatinga, Cerrado
Bauhinia longifolia (Bong.) Steud.	Tree Shrub	Native to Brazil/NE	MT, MS, GO, DF, MG, ES, RJ, SP, PA, RO, BA, PR/ Atlantic Forest, Cerrado
Bauhinia ungulata L.	Tree Shrub Sub-shrub	Native to Brazil/NE	RR, AP, AM, PA, AC, RO, TO, MT, MS, DF, GO, MA, PI, CE, MG, SP/Amazon Forest, Atlantic Forest, Cerrado
Hymenolobium janeirense Kuhlm.	Tree	Endemic to Brazil/LC	PE, BA, MG, ES, RJ, SP/Atlantic Forest
Inga edulis Mart.	Tree	Native to Brazil/NE	AC, AM, AP, PA, RO, RR, BA, PB, PE, MT, MG, ES, RJ, SP, PR, SC/Amazon Forest, Atlantic Forest, Caatinga, Cerrado

Table VI. Continuation.

Machaerium brasiliense Vogel	Tree Shrub Liana	Native to Brazil/NE	AM, MA, PE, AL, BA, DF, GO, MT, all states of Southeast Region, PR/ Amazon Forest, Atlantic Forest, Caatinga, Cerrado
Machaerium ovalifolium Glaz. ex Rudd	Tree	Endemic to Brazil/ NE	BA, ES, MG/ Atlantic Forest, Caatinga
Vismia micrantha A.St.-Hil	Tree Shrub	Endemic to Brazil/ NE	MG, RJ, SP/ Atlantic Forest, Cerrado
Clidemia hirta (L.) D.Don	Shrub	Native to Brazil/NE	All Brazilian states, except RN/ Amazon Forest, Atlantic Forest, Caatinga, Cerrado
Huberia nettoana Brade	Tree	Endemic to Brazil/NT	MG, RJ, SP/ Atlantic Forest
Leandra aurea (Cham.) Cogn.	Tree Shrub	Native to Brazil/NE	BA, GO, MS, all states of Southeast and South regions/ Atlantic Forest, Cerrado
Miconia cuspidata Naudin	Tree	Native to Brazil/NE	AC, AM, AP, PA, RR, AL, PB, PE, DF, GO, MT, MG/Amazon Forest, Atlantic Forest, Cerrado
Miconia cf. latecrenata (DC.) Naudin	Tree Shrub	Endemic to Brazil/ NE	PE, BA, all states of Southeast and South regions/Atlantic Forest
Ficus enormis Mart. ex Miq.	Tree	Endemic to Brazil/ NE	PI, CE, PE, AL, SE, BA, GO, MT, MS, all states of Southeast and South regions/Atlantic Forest
Eugenia uniflora L.	Shrub	Native to Brazil/NE	BA, MS, all states of Southeast and South regions/Atlantic Forest, Cerrado, Pampa
Myrcia splendens (Sw.) DC.	Tree	Endemic to Brazil/ NE	All Brazilian states, except MA and PI/all biomes, except Pampa
Ludwigia peruviana (L.) H.Hara	Tree Shrub	Native to Brazil/NE	PA, MT, MS, MG, RJ, SP, all states of South Region/ Amazon Forest, Atlantic Forest, Pantanal
Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.	Tree Shrub	Native to Brazil/NE	PE, BA, MT, GO, MS, all states of Southeast and South regions/ Atlantic Forest, Cerrado
Colubrina glandulosa Perkins	Tree	Native to Brazil/LC	AC, AM, PA, RO, RR, MA, CE, PB, PE, DF, MT, MG, RJ, SP, all states of South Region/Amazon Forest, Atlantic Forest, Cerrado
Palicourea tetraphylla Cham. & Schltdl.	Shrub	Endemic to Brazil/ LC	All states of Southeast Region/ Atlantic Forest, Cerrado
Casearia sylvestris Sw.	Tree Shrub Sub-schrub	Native to Brazil/NE	All Brazilian states and biomes
Serjania lethalis A.St.-Hil.	Liana	Native to Brazil/NE	AC, AM, AP, TO, MA, PI, RN, CE, PE, PB, AL, BA, DF, GO, MT, MS, MG, ES, RJ, SP, PR, SC/ Amazon Forest, Atlantic Forest, Caatinga, Cerrado, Pantanal
Lantana camara L.	Shrub	Naturalized/NE	All Brazilian states/Amazon, Atlantic Forest, Caatinga, Cerrado

NE – not evaluated, VU – vulnerable, LC – least concern.

Table VII. Richness of gall morphotypes per plant architecture in the Natural Heritage Private Reserve of Serra Negra do Funil (Minas Gerais, Brazil).

Plant Architecture	Number of gall morphotypes
Liana	6
Shrub	6
Tree	19
Tree and Shrub	9
Tree, shrub, and sub-shrub	2
Tree, shrub, and liana	1
Shrub and sub-shrub	2
Sub-shrub and liana	1

Asteraceae

Baccharis punctulata DC.

Gall (Fig. 2a): on leaf, globoid, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae (Diptera).

Gall (Fig. 2b): on stem, fusiform, brown, with sparse trichomes, with a big opening. Gall-inducer: probably Tephritidae (Diptera).

First gall record on this host.

Baccharis sp.

Gall (Fig. 2c): on leaf midvein, globoid, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae.

Many authors recorded insect galls on several species of *Baccharis* in BA (Tavares 1915), MG (Gagné 1994, Fernandes et al. 1997, 2001, Maia & Fernandes 2004, Maia et al. 2008, Carneiro et al. 2009, Coelho et al. 2009, 2013b, Malves & Frieiro-Costa 2012, Maia 2014), ES (Maia et al. 2014a), SP (Tavares 1917b), SC (Melo-Júnior et al. 2018), and RS (Toma & Mendonça-Júnior 2013).

Bidens segetum Mart. ex Colla

Gall (no fig.): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: not determined (galls with feces and exuvial fragments). Maia & Mascarenhas 2017 reported this gall in Parque Nacional do Itatiaia/ Southeastern Brazil.

Eremanthus erythropappus (DC.) MacLeish

Gall (Fig. 2d): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: *Neolasioptera* sp. (Cecidomyiidae). This morphotype was previously recorded by some authors in MG as Coelho et al. 2009, 2013a, Carneiro et al. 2009, and Maia et al. 2014b.

Eremanthus incanus (Less.) Less.

Gall (Fig. 2e): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: not determined. First gall record on this plant.

Mikania sp.

Gall (Fig. 2f): on leaf, globoid, yellow, with short trichomes, one-chambered. Gall-inducer: Cecidomyiidae.

Gall (Fig. 2g): on leaf petiole and stem, fusiform, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Several authors reported galls on this plant genus in several localities in Brazil: AM (Rübsaamen 1908b, 1916), PE (Santos et al. 2011, 2012), MG (Fernandes et al. 2001, Maia 2014b, Maia & Fernandes 2004, Malves & Frieiro-Costa 2012, Carneiro et al. 2009, Coelho et al. 2013b, Maia 2013a), ES (Maia et al. 2014a), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), RJ (Rübsaamen 1908a, Maia 2013b, Rodrigues et al. 2014, Carvalho-Fernandes et al. 2016, Maia & Siqueira 2020), SP (Ansaloni et al. 2018), PR (Santos & Ribeiro 2015), SC (Melo-Júnior et al. 2018), and RS (Tavares 1909, Toma & Mendonça-Júnior 2013, Goetz et al. 2018).

Vernonanthura polyanthes (Sprengel) Vega & Dematteis

Gall (Fig. 2h): on leaf midvein, fusiform, yellow, glabrous, one- chambered. Gall-inducer: not determined. Coelho et al. 2009 recorded other leaf gall on this plant species in MG.

Gall (Fig. 2i): on stem, globoid, brown, glabrous, one-chambered. Gall-inducer: Tephritidae.

Basellaceae

Anredera cordifolia (Ten.) Steenis

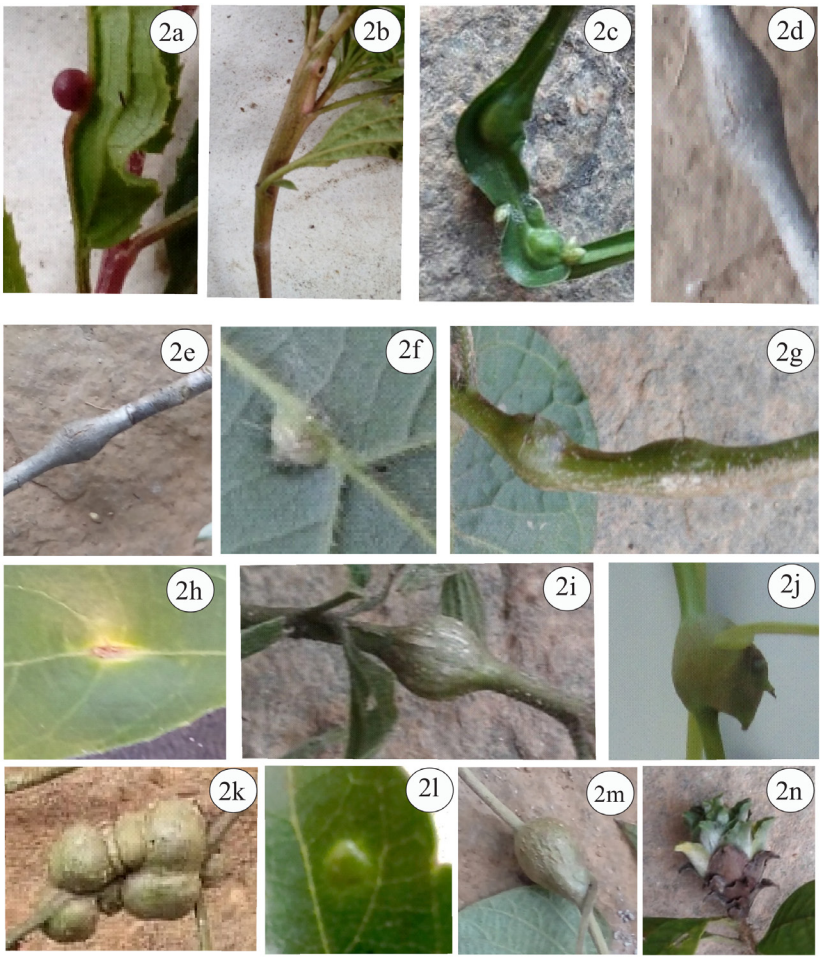

Figure 2. a-n. Insect galls found in the Serra Negra do Funil Natural Heritage Private Reserve (MG, Brazil). 2a-i, on Asteraceae, 2a-b, on *Baccharis punctulata* DC., 2a, leaf gall, 2b, stem gall, 2c, on *Baccharis* sp., leaf gall, 2d, on *Eremanthus erythropappus* (DC.) MacLeish, stem gall, 2e, on *Eremanthus incanus* (Less.) Less., stem gall, 2f-g, on *Mikania* sp., 2f, leaf gall, 2g, leaf petiole and stem gall, 2h-i, on *Vernonanthura polyanthes* (Sprengel) Vega & Dematteis, 2h, leaf midvein gall, 2i, stem gall, 2j, on *Anredera cordifolia* (Ten.) Steenis (Basellaceae), bud gall, 2k, on *Pleonotoma tetraquetra* (Cham.) Bureau (Bignoniaceae), bud gall, 2l, on *Licania kunthiana* Hook. f. (Chrysobalanaceae), leaf gall, 2m, on Convolvulaceae Gall (Fig. 13): on *Jacquemontia* sp., stem gall, 2n, on *Davilla rugosa* Poir. Gall (Dilleniaceae), bud gall.

Gall (Fig. 2j): on bud, globoid, brownish, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this plant family.

Bignoniaceae

Adenocalymma sp.

Gall (no fig.): on leaf, globoid, green, with trichomes. Galler: Lepidoptera. Other insects: Hymenoptera – parasitoids. Other galls were reported on this plant genus by Maia et al. 2014a in ES, Urso-Guimarães et al. 2017 in MS, and Maia & Siqueira 2020 in RJ.

Pleonotoma tetraquetra (Cham.) Bureau

Gall (Fig. 2k): on bud, globoid, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this plant genus.

Chrysobalanaceae

Licania kunthiana Hook. f.

Gall (Fig. 2l): on leaf, lenticular, green, glabrous, one-chambered. Gall-inducer: not determined. First gall record on this host. Several authors have been recorded galls on other species of this genus in PA (Almada & Fernandes 2011, Maia 2011, Araújo et al. 2012), GO (Araújo et al. 2015), MG (Maia & Fernandes 2004, Coelho et al. 2013a, Maia 2014, Maia et al. 2014b), SP (Maia et al. 2008), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), RJ (Maia & Siqueira 2020), and MS (Ascendino & Maia 2018).

Convolvulaceae

Ipomoea sp.

Gall (no fig.): on stem, ovoid, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae.

Rübsaamen 1908a and Maia & Siqueira 2020 reported a stem gall on this plant genus in RJ, Julião et al. 2002 and Urso-Guimarães et al. 2017 in MS, Ansaloni et al. 2018 in SP, and Melo-Júnior et al. 2018 in SC.

Jacquemontia sp.

Gall (Fig. 2m): on stem, ovoid, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Carneiro et al. 2009 recorded similar gall in MG.

Dilleniaceae

Davilla rugosa Poir.

Gall (Fig. 2n): on bud, conical, green, glabrous. Gall-inducer: Cecidomyiidae. This same gall was reported in MG (Fernandes et al. 2001) and RJ (Rodrigues et al. 2014, Maia & Siqueira 2020).

Euphorbiaceae

Croton floribundus Spreng.

Gall (Fig. 3a): on leaf, globoid, brown, with trichomes, one-chambered. Gall-inducer: Cecidomyiidae. Other dwellers: Lepidoptera (cecidophage), Hymenoptera (parasitoid). The same gall was recorded in MG (Urso-Guimarães et al. 2003, Maia et al. 2014b), ES (Maia et al. 2014a), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), RJ (Rodrigues et al. 2014), and PR (Santos & Ribeiro 2015).

Gall (Fig. 3b): on leaf, marginal roll, green, glabrous, one-chambered. Gall-inducer: not determined. This gall was recorded in MG (Maia et al. 2014b), RJ (Rodrigues et al. 2014), and Parque Nacional do Itatiaia (Maia & Mascarenhas 2017)

Figure 3. a-l. Insect galls found in the Serra Negra do Funil Natural Heritage Private Reserve (MG, Brazil). 3a-f, on Euphorbiaceae, 3a-c, on *Croton floribundus* Spreng., 3a, leaf gall (with trichomes), 3b, marginal roll, 3c, leaf gall (glabrous), 3d, on *Dalechampia triphylla* Lam., leaf gall, 3e-f, on *Sapium glandulosum* (L.) Morong, 3e, bud, leaf petiole and vein gall, 3f, leaf vein gall, 3g-l, on Fabaceae, 3g, on *Apuleia leiocarpa* (Vogel) J.F.Macbr., leaf gall, 3h, on *Bauhinia longifolia* (Bong.) Steud., stem gall, 3i, *Bauhinia ungulata* L., stem gall, 3j-l, on Fabaceae (not determined), 3j, leaf gall (with trichomes), 3k, leaf gall (glabrous), 3l, leaf gall (conical).

Gall (Fig. 3c): on leaf, globoid, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Urso-Guimarães et al. 2017 reported a similar gall in MS.

These three morphotypes were reported in MG by Maia & Fernandes 2004 and Ribeiro et al. 2019.

Dalechampia triphylla Lam.

Gall (Fig. 3d) on leaf, globoid, green, with trichomes, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this plant. Few authors reported galls on this genus in SP (Maia et al. 2008), RJ (Maia & Oliveira 2010, Carvalho-Fernandes et al. 2016), and Parque Nacional do Itatiaia (Maia & Mascarenhas 2017).

Sapium glandulosum (L.) Morong

Gall (Fig. 3e): on bud, leaf petiole and vein, globoid, green, red or brow, glabrous. Gall-inducer: Hemiptera. Other dwellers: Thysanoptera and Psocoptera (successors). This gall was recorded by Toma & Mendonça-Júnior 2013 in RS.

Gall (Fig. 3f): on leaf vein, fusiform, green, glabrous, one-chambered. Gall-inducer: not determined.

Fabaceae

Apuleia leiocarpa (Vogel) J. F. Macbr. (Fabaceae)

Gall (Fig. 3g): on leaf, globoid, yellow, with trichomes, one-chambered. Galler: Cecidomyiidae. Costa & Araújo 2019 reported other gall on this plant species in MG.

Bauhinia longifolia (Bong.) Steud.

Gall (Fig. 3h) on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae.

Coelho et al. 2009 reported this gall in MG, Ansaloni et al. 2018 in SP, and Urso-Guimarães et al. 2017 recorded other galls in MS.

Bauhinia ungulata L.

Gall (Fig. 3i) on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Urso-Guimarães et al. 2003 reported this gall in MG.

Fabaceae (not determined)

Gall (Fig. 3j): on leaf, globoid, yellow, with red trichomes, one-chambered. Gall-inducer: Cecidomyiidae.

Gall (Fig. 3k): on leaf, globoid, brown, glabrous, one-chambered. Gall-inducer: not determined.

Gall (Fig. 3l): on leaf, conical green, glabrous, one-chambered. Gall-inducer: not determined.

Gall (Fig. 4a): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: not determined.

Hymenolobium janeirense Kuhlm

Gall (Fig. 4b): on leaf midvein or petiole, globoid, yellowish, with scarce trichomes, one-chambered. Gall-inducer: not determined. First gall record on this host species. Almada & Fernandes 2011 recorded a leaf gall on *H. excelsium* Ducke in PA.

Inga edulis Mart.

Gall (Fig. 4c): on leaf, globoid, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae.

Similar galls were reported on this plant species in MG (Urso-Guimarães et al. 2003) and RJ (Maia & Siqueira 2020).

Machaerium brasiliense Vogel

Gall (Fig. 4d): on leaf midvein, fusiform, yellow, one-chambered. Gall-inducer: Cecidomyiidae. First record on this host species.

Machaerium ovalifolium Glaz. ex Rudd

Gall (Fig. 4e): on bud, globoid, brown, glabrous, multichambered. Gall-inducer: not determined.

Gall (Fig. 4f): on leaf, globoid, yellow, glabrous, one-chambered. Gall-inducer: not determined.

First record on this host species.

Several authors reported galls on *Machaerium* spp. in PA (Almada & Fernandes 2011), GO (Araújo et al. 2015), PR (Santos & Ribeiro

Figure 4. a-l. Insect galls found in the Serra Negra do Funil Natural Heritage Private Reserve (MG, Brazil). 4a-f, on Fabaceae, 4a, on Fabaceae (not determined), stem gall, 4b, on *Hymenolobium janeirense* Kuhlm., leaf midvein and petiole gall, 4c, on *Inga edulis* Mart., leaf gall, 4d, on *Machaerium brasiliense* Vogel, leaf midvein gall, 4e-f, on *Machaerium ovalifolium* Glaz. ex Rudd,, 4e. leaf gall, 4f, bud gall, 4g, on *Vismia micrantha* A.St.-Hil. (Hypericaceae), stem gall, 4h, on *Strychnos* sp. (Loganiaceae), bud gall, 4i, on *Niedenzuella* sp. (Malpighiaceae), leaf gall, 4j-l, on Melastomataceae, 4j, on *Clidemia hirta* (L.) D.Don b, leaf and stem gall, 4k, on *Miconia cuspidata* Naudin, leaf gall, 4l, on *Miconia cf. latecrenata* (DC.) Naudin, leaf gall.

2015), MG (Gonçalves-Alvim & Fernandes 2001, Fernandes et al. 2001, Fernandes & Negreiros 2006, Luz et al. 2012, Malves & Frieiro-Costa 2012, Coelho et al. 2013a), ES (Maia et al. 2014a), RJ (Maia & Carvalho-Fernandes 2016, Carvalho-Fernandes et al. 2016), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), SP (Maia et al. 2008), and RS (Goetz et al. 2018).

Hypericaceae

Vismia micrantha A.St.-Hil.

Gall (Fig. 4g): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this host species. Some galls were reported on this plant genus in PA (Almada & Fernandes 2011), MG (Fernandes et al. 2001), PE (Santos et al. 2012), and ES (Maia et al. 2014a).

Loganiaceae

Strychnos sp.

Gall (Fig. 4h): on bud, globoid, yellow, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. A similar gall was reported by Urso-Guimarães et al. 2017 on *S. parvifolia* A. DC. in MS. Other galls were described on *Strychnos* spp. by Fernandes et al. 1997, Luz et al. 2012, and Costa & Araújo 2019 in MG, Saito & Urso-Guimarães 2012 in SP, and Araújo et al. 2015 in GO.

Malpighiaceae

Niedenzuella sp.

Gall (Fig. 4i): on leaf, globoid, brown, glabrous, one-chambered. Gall-inducer: not determined. Maia & Mascarenhas 2017 reported a similar gall

on *Niedenzuella acutifolia* (Cav.) W.R.Anderson in Parque Nacional do Itatiaia.

Melastomataceae

Clidemia hirta (L.) D.Don b

Gall (Fig. 4j): on leaf and/or stem, globoid, green or red, with long trichomes, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this host species.

Several galls have been recorded on this genus in CE (Alcântara et al. 2017), PE (Fernandes et al. 2009, Santos et al. 2011), MG (Fernandes et al. 2001, Maia 2014, Maia et al. 2014b), ES (Maia et al. 2014a), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), and SP (Maia et al. 2008).

Gall (no fig.): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Lepidoptera. Maia et al. 2008 described other galls on *H. ovalifolia* DC. in SP. First gall record on this species.

Leandra aurea (Cham.) Cogn.

Gall (no fig.): on leaf, globoid, green, with trichomes, one-chambered. Gall-inducer: Cecidomyiidae. This gall was recorded by Coelho et al. 2013b in MG.

Miconia cuspidata Naudin

Gall (Fig. 4k): on leaf, globoid, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this plant species.

Miconia cf. latecrenata (DC.) Naudin

Gall (Fig. 4l): on leaf, cylindrical, green, glabrous, one-chambered. Gall-inducer: not determined. Fernandes et al. 2001 reported a different gall on *Miconia latecrenata* in MG.

Tibouchina sp.

Gall (Fig. 5a): on leaf midvein, fusiform, green, glabrous, one-chambered. Gall-inducer: not determined. Several galls were recorded on this genus in MG (Fernandes et al. 2001, Maia & Fernandes 2004, Maia et al 2004a, Carneiro et al. 2009, Coelho et al. 2013b, Maia 2013a, 2014b), RJ (Rübsaamen 1908b, Tavares 1917a, Maia & Siqueira 2020), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), SP (Maia et al. 2008), PR (Santos & Ribeiro 2015), SC (Melo-Júnior et al. 2018), and RS (Toma & Mendonça-Júnior 2013).

Moraceae

Ficus enormis Mart. ex. Miq.

Gall (Fig. 5b): on leaf, lenticular, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. This gall was recorded by Maia et al. 2008 in SP.

Myrtaceae

Eugenia uniflora L.

Gall (Fig. 5c): on leaf, globoid, red, glabrous, one-chambered. Gall-inducer: not determined. Other galls were recorded on this host in MG (Maia 2014), ES (Maia 2019), RJ (Monteiro et al. 1994, 2004, Maia 2001, Oliveira & Maia 2005, Maia & Souza 2013, Rodrigues et al. 2014, Carvalho-Fernandes et al. 2016), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), SP (Maia et al. 2008), and RS (Goetz et al. 2018).

Myrcia splendens (Sw.) DC.

Gall (Fig. 5d): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Similar galls were recorded in PE (Santos et al. 2012), MG (Coelho et al. 2009, Maia 2013a), and Parque Nacional do Itatiaia (Maia & Mascarenhas 2017).

Gall (Fig. 5e): on bud, globoid, green, glabrous. Gall-inducer: Cecidomyiidae. This gall was recorded by Maia & Mascarenhas 2017 in the Parque Nacional do Itatiaia and by Maia & Siqueira 2020 in RJ.

Gall (Fig. 5f): on leaf midvein, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Maia & Mascarenhas 2017 reported a similar gall in the Parque Nacional do Itatiaia and Ansaloni et al. 2018 in SP.

Gall (Fig. 5g): on leaf, globoid, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. This gall was recorded in RJ by Rodrigues et al. 2014 and Maia & Siqueira 2020, and in the Parque Nacional do Itatiaia by Maia & Mascarenhas

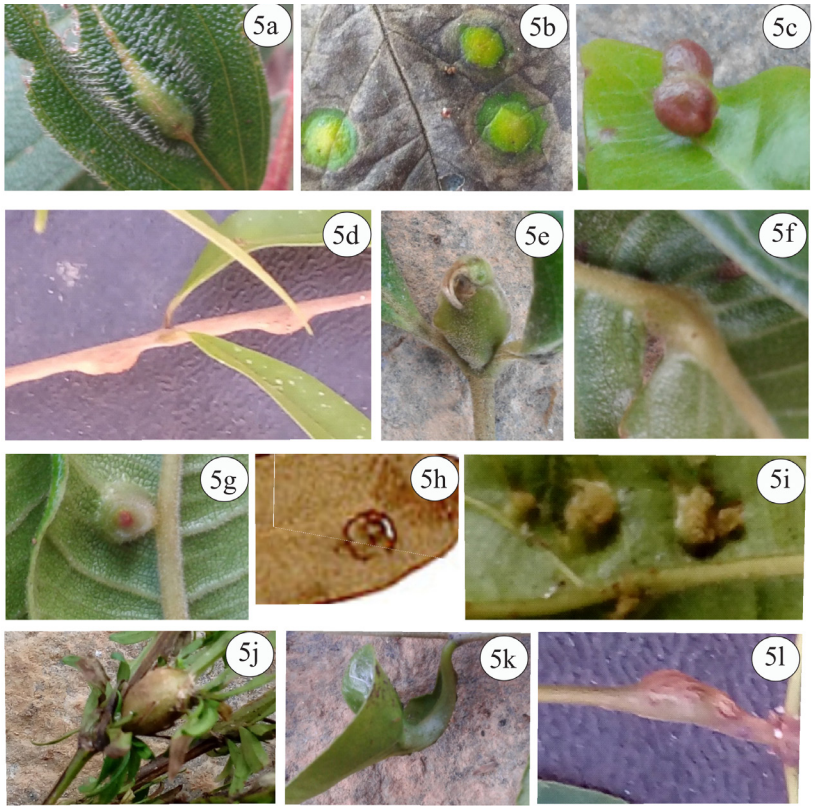

Figure 5. a-l. Insect galls found in the Serra Negra do Funil Natural Heritage Private Reserve (MG, Brazil). 5a, on *Tibouchina* sp. (Melastomataceae), leaf midvein gall, 5b, on *Ficus enormis* Mart. ex. Miq. (Moraceae), leaf gall, 5c-g, on Myrtaceae, 5c, on *Eugenia uniflora* L., leaf gall, 5d-g, on *Myrcia splendens* (Sw.) DC., 5d, stem gall, 5e, bud gall, 5f, leaf midvein gall, 5g, leaf gall, 5h, on *Myrsine coriacea* (Sw.) R.Br. ex Roem. & Schult. (Primulaceae), leaf gall, 5i, on *Colubrina glandulosa* Perkins (Rhamnaceae), leaf gall, 5j-k, on Rubiaceae, 5j, on *Borreria* sp., stem gall, 5k, on *Casearia sylvestris* Sw. (Salicaceae), leaf midvein gall, 5l, on *Serjania lethalis* A.St.-Hil. (Sapindaceae), stem gall.

2017. Malves & Frieiro-Costa 2012 recorded two other galls in MG.

Onagraceae

Ludwigia peruviana (L.) H. Hara

Gall (no fig.): on bud, fusiform, green, with short whitish trichomes, one-chambered. Gall-inducer: Cecidomyiidae. Maia et al. 2008 recorded a bud gall on *L. octovalvis* (Jacq.) P. H. Raven in SP and Urso-Guimarães et al. 2017 a leaf gall on *L. longifolia* (DC.) H. Hara in MS. This is the first gall record on *L. peruviana*.

Primulaceae

Myrsine coriacea (Sw.) R.Br. ex Roem. & Schult.

Gall (Fig. 5h): on leaf, lenticular, green, glabrous, one-chambered. Gall-inducer: not determined.

Gall (no fig.): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Lepidoptera. Maia & Mascarenhas 2017 reported this gall in the Parque Nacional do Itatiaia, Ansaloni et al. 2018 in SP, Toma & Mendonça-Júnior 2013 and Goetz et al. 2018 in RS.

Rhamnaceae

Colubrina glandulosa Perkins

Gall (Fig. 5i): on leaf, globoid, green, glabrous, one-chambered. Gall-inducer: not determined. First gall record on this plant genus.

Rubiaceae

Borreria sp.

Gall (Fig. 5j): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Other dwellers: Sciaridae and Thysanoptera (both cecidophages). Galls on this plant genus were reported by several authors in RJ (Rübsaamen 1905, 1908a, Maia 2001, Rodrigues et al. 2014, Carvalho-Fernandes et al. 2016, and Maia & Siqueira 2020), MG (Fernandes et al. 2001, Maia & Fernandes 2004, and Maia 2013a), and Parque Nacional do Itatiaia (Maia & Mascarenhas 2017).

Palicourea tetraphylla Cham. & Schltdl.

Gall (no fig.): on leaf, globoid, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. First gall record on this host. Galls on this plant genus have been reported by several authors in several localities: PA (Almada & Fernandes 2011, Maia 2011, Araújo et al. 2012), PE (Santos et al. 2012), GO (Araújo et al. 2015, Bergamini et al. 2017), MG (Fernandes et al. 1997, 2001, Maia & Fernandes 2004, Carneiro et al. 2009, Coelho et al. 2013a, Maia 2013a), and ES (Maia et al. 2014a).

Psychotria sp.

Gall (no fig.): on leaf vein, globoid, brown, glabrous, one-chambered. Galler: Cecidomyiidae. Several authors recorded galls on this plant genus in MS (Julião et al. 2002, Urso-Guimarães et al. 2017), MG (Fernandes et al. 2001, Maia et al. 2014b), RJ (Tavares 1909, 1922, Carvalho-Fernandes et al. 2016, Maia & Siqueira 2020), and RS (Rübsaamen 1908b).

Salicaceae

Casearia sylvestris Sw.

Gall (Fig. 5k): on leaf midvein, fusiform, green, glabrous, one-chambered. Gall-inducer: not determined.

Other galls were reported on this plant species in PE (Santos et al. 2012), GO (Araújo et al. 2015, Bergamini et al. 2017), MS (Urso-Guimarães et al. 2017), MG (Luz et al. 2012), and Parque Nacional do Itatiaia (Maia & Mascarenhas 2017).

Sapindaceae

Cupania sp.

Gall (no fig.): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Some authors reported galls on this plant genus in PA (Maia 2011), PE (Santos et al. 2011, 2012), GO (Araújo et al. 2015), MG (Coelho et al. 2009), RJ (Maia & Siqueira 2020), and Parque Nacional do Itatiaia (Maia & Mascarenhas 2017).

Serjania lethalis A.St.-Hil.

Gall (Fig. 5l): on stem, fusiform, brown, glabrous, one-chambered. Gall-inducer: Cecidomyiidae.

Gall (Fig. 6a): on leaf vein, globoid, green, glabrous, one-chambered. Gall-inducer: Cecidomyiidae. Other dwellers: Hymenoptera (parasitoids).

Other gall morphotypes were reported in GO (Araújo et al. 2015), MG (Fernandes et al. 2001, Luz et al. 2012), RJ (Maia & Siqueira 2020), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), and SP (Ansaloni et al. 2018).

Solanaceae

Solanum sp.

Gall (Fig. 6b): on bud, globoid, yellow, with trichomes, one-chambered. Gall-inducer: not determined.

Several authors recorded galls on this plant genus in GO (Araújo et al. 2015), BA (Tavares 1918), MS (Urso-Guimarães et al. 2017), MG (Fernandes et al. 2001, Luz et al. 2012, Malves & Frieiro-Costa 2012, Maia 2013b, 2014), RJ (Rübsaamen 1908b, Carvalho-Fernandes et al. 2016, Maia 2013b, Maia & Siqueira 2020), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), PR (Santos & Ribeiro 2015), SC (Melo-Júnior et al. 2018), and RS (Toma & Mendonça-Júnior 2013).

Verbenaceae

Lantana camara L.

Gall (Fig. 6c): on leaf, globoid, green, with trichomes, one-chambered. Gall-inducer: *Schismatodiplosis lantanae* (Rübsaamen, 1908a) (Cecidomyiidae). This gall is widely distributed in Brazil, with occurrence from north to south, in RO (Proença & Maia 2014), PA (Proença & Maia 2014), PE (Santos et al. 2011), MG (Fernandes & Negreiros 2006), RJ (Maia 2013b, Rodrigues et al. 2014, Carvalho-Fernandes et al. 2016, Maia & Siqueira 2020), Parque Nacional do Itatiaia (Maia & Mascarenhas 2017), and SC (Rübsaamen 1908a).

Figure 6. a-c. Insect galls found in the Serra Negra do Funil Natural Heritage Private Reserve (MG, Brazil). 6a, on *Serjania lethalis* A.St.-Hil. (Sapindaceae), leaf vein, 6b, on *Solanum* sp. (Solanaceae), bud gall. 6c, on *Lantana camara* L. (Verbenaceae), leaf gall.

DISCUSSION

A total of 63 insect gall morphotypes were found in the study area. In other insect gall inventories in mountains of Minas Gerais, the gall richness ranged from 137 to 15 (Table VIII). The Serra Negra do Funil NHPR is in fifth place, among 13 surveyed localities. But, its total area is the lowest with only 29 hectares, while the others ranged from 1,500 to 100,000 hectares (Table VIII). It is important to point out that these inventories adopted different collecting methods which resulted in different collecting effort. Furthermore, the plant species richness of these surveyed localities are different from each other. The Serra Negra do Funil NHPR showed one of the lowest averages of gall morphotypes per plant species (Table VIII). This value can be explained by the absence of super host species, differing from the other inventories where several superhosts were recorded.

In our study, Fabaceae and Asteraceae showed the greatest richness of galls. Both are among the most speciose families of angiosperms in the Serra Negra da Mantiqueira (Salimena et al. 2013) as well as in Brazil (Forzza et al. 2010), indicating that richest plant taxa harbor the greatest gall richness, as proposed by the plant richness hypothesis (Southwood 1960, 1961). These families are also highlighted as the most important hosts of insect galls in other inventories in mountains of MG (e. g. Serra de São José, Serra do Cabral, Serra do Cipó, and Serra do Espinhaço) (Maia & Fernandes 2004, Coelho et al. 2013a, 2009, Carneiro et al. 2009).

Most galls were induced on leaves, as in Serra do Cipó, Serra do Cabral, and many other localities in Brazil (Coelho et al. 2013a, Rodrigues et al. 2014, Ascendino & Maia 2018). The highest frequency of leaf galls is a world pattern indicated by Felt 1940. This can be explained by the fact that leaves are the most plastic host organ (Isaías et al. 2013), as well as an abundant and predictable resource (Maia 2001).

Most galls were globoid, followed by fusiform. This result was also found in Serra do Cipó, Serra do Cabral and many others localities in Brazil (e.g. Isaías et al. 2013, Carvalho-Fernandes et al. 2016, Maia & Mascarenhas 2017). Globoid galls were more common on leaves, while fusiform

Table VIII. Data on gall richness, number of host plants and average of gall morphotypes per species in other study areas in Minas Gerais, Brazil.

Study area	Total area (hectares)	Host plant		Nr. gall morphotypes	Average galls/species	Reference
		Nr. families	Nr. species			
Serra de São José	5,000	30	73	137	1.88	Maia & Fernandes 2004
Serra do Cipó	100,000	19	59	92	1.56	Coelho et al. 2009
Rio Preto State Park	12,000	22	54	75	1.39	Carneiro et al. 2009
Serra do Caraça National Park	11,000	12	36	71	1.97	Carneiro et al. 2009
NHPR of Serra Negra do Funil	**29**	**22**	**48**	**66**	**1.37**	**Present study**
Biribiri State Park	17,000	12	41	63	1.54	Carneiro et al. 2009
Itacolomi State Park	7,500	7	29	59	2.03	Carneiro et al. 2009
Serra Ouro Branco State Park	1,600	9	35	50	1.49	Carneiro et al. 2009
Serra do Cabral State Park	23,500	21	39	47	1.20	Coelho et al. 2013a
Serra do Brigadeiro State Park	15,000	11	18	38	2.11	Coelho et al. 2013b
Ibitipoca State Park	1,500	5	12	21	1.75	Coelho et al. 2013b
Grão Mogol	28,000	7	11	18	1.64	Carneiro et al. 2009
Caparaó State Park	11,000	7	11	15	1.36	Coelho et al. 2013b

on stems and veins than on other plant organs. This differentiated frequency is related to the host organ ability to alter its morphogenesis under external stimuli (Arriola et al. 2015).

Brown and green galls predominated. This result reflects the colors of the most galled plant organs, stems and leaves, respectively. Most galls were glabrous and one-chambered, as in all other inventories in Brazil (Maia & Mascarenhas 2017).

Cecidomyiidae were the most frequent gall-inducing insects. In fact, this family stands out as the richest one in number of gall-inducing species throughout the world (Gagné & Jaschhof 2017).

Six gall morphotypes harbored other insects in addition to the inducer, all previously reported as part of the associated fauna in Brazil (e.g. Maia 2001, Maia & Fernandes 2004, Maia & Siqueira 2020). The frequency of these dwellers (9%) was very low in comparison with other inventories, as in Maricá and Carapebus (both in RJ) or in Serra de São José (MG), where the frequency was 56% (Maia 2001) and 35% (Maia & Fernandes 2004), respectively. Nevertheless, the presence of cecidophages and successors emphasized the role of gall-inducing insects as ecosystem engineers.

The majority of galls were induced on trees and shrubs, indicating a positive relationship between plant architectural complexity and insect gall richness, as proposed by the architectural complexity hypothesis (Lawton 1983).

All host plant species are native to Brazil, except *Lantana camara* L., including 12 that are endemic to the country. Serra Negra do Funil NHPR also includes one vulnerable and another

near threatened plant species. The high number of endemic plants as well as the presence of vulnerable and near threatened species reveals the importance of this NHPR to the conservation of the Brazilian flora. Based on the species-specificity of the gall-inducers, they can be considered as endemic, vulnerable and near threatened when associated with host plants classified in these categories.

Thirteen plant species, two genera, and one family are reported for the first time as hosts of galling-insects, adding new data on insect-plant interactions in Atlantic Forest areas and in Brazil. All galls were recorded for the first time in Serra Negra do Funil NHPR since this is the first local inventory.

The lack of data on taxonomy (Linnean shortfall), geographic distribution (Wallacean shortfall), ways of life and sensitivities to habitat changes (Hutchinsonian shortfall), species abundance and their change in space and time (Prestonian shortfall), and ecological services hamper insect conservation (Cardoso et al. 2011). This paper contributes with new data on several of these aspects, providing information about ecosystem engineers (ecological services), gall-induction and endophagous parasitism (ways of life), and new records of gall occurrence (geographic distribution). Furthermore, this paper covers several years of sampling (change in time). Unfortunately, only one gall midge species was identified, which is related to the high number of undescribed species (Linnean shortfall).

CONCLUSIONS

The Serra Negra do Funil NHPR harbors a rich fauna of gall-inducing insects and a high number of endemic host plants. Fabaceae and Asteraceae are the most important host families. Leaves are the most attacked plant organ. The predominance of globoid, brown and green, glabrous and one-chambered galls was observed. The majority of them were induced on trees and shrubs. Cecidomyiidae were the most frequent gall-inducing insects. Our results reinforce the patterns already pointed out in Brazil and add evidence in favor of the plant richness and architectural complexity hypotheses. The presence of endemic, vulnerable and near threatened plants reveals the importance of the Serra Negra do Funil NHPR to the conservation of the Brazilian biodiversity. New data on insect-plant interactions in Atlantic Forest areas are provided, adding to the ecological importance of them. New data can be useful for insect conservation.

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