Insect galls from Serra dos Pireneus, GO, Brazil

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Abstract: In this study we recorded the occurrence of insect galls, inductors and parasitoids in plants of several physiognomies of Brazilian Cerrado in the Serra dos Pireneus, Goiás State, Brazil. We found 62 morphotypes of gall on 28 botanical families, comprising 44 genera and 51 species. The plant families that showed the greatest richness of galls were Fabaceae, with eight morphotypes, and Styracaceae with six. *Styrax pohlii* (Styracaceae) was the host plant species with the greatest gall richness, featuring five morphotypes. Most of galls occurred on the leaves (82.6%), 45.1% in vegetation of typical savanna and 35.4% in rocky savanna. Dipteran, Hemipteran and Lepidopteran galls were found, being 50.9% of them induced by Cecidomyiidae (Diptera). Several parasitoids were obtained, Eulophidae (Hymenoptera: Chalcidoidea) was the most representative group (occurring in approximately 40% of the galls). Nine species of plants were recorded for the first time in the Neotropical as host of gallers.
Keywords*: Cecidomyiidae, gall makers, host plants, parasitoids.*

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Resumo: Neste estudo, registramos a ocorrência de galhas, galhadores e parasitóides em plantas de várias fitofisionomias de Cerrado na Serra dos Pireneus, Estado de Goiás, Brasil. Foram encontrados 62 morfotipos de galhas em 28 famílias botânicas, compreendendo 44 gêneros e 51 espécies. As famílias botânicas que apresentaram maior riqueza de galhas foram Fabaceae, com oito morfotipos e Styracaceae com seis. *Styrax pohlii* (Styracaceae) foi a espécie de planta hospedeira mais rica em galhas, apresentando cinco morfotipos. A maioria das galhas ocorreu nas folhas (82,6%) e em fitofisionomias de cerrado típico (45,1%) e cerrado rupestre (35,4%). Galhas de Diptera, Hemiptera e Lepidoptera foram encontradas, sendo 50,9% induzidas por Cecidomyiidae (Diptera). Vários parasitóides obtidos, dentre eles, Eulophidae (Hymenoptera: Chalcidoidea) foram foi o grupo mais representativo (ocorrendo em aproximadamente 40% das galhas). Nove espécies de plantas são registradas pela primeira vez na região Neotropical como hospedeiras de galhadores.
Palavras-chaves*: Cecidomyiidae, insetos galhadores, plantas hospedeiras, parasitóides.*

Introduction

The gall formation on plants is characterized by abnormal growth of plant tissues by cell hypertrophy and hyperplasia (Mani 1964, Price 2005). These galls are the most sophisticated herbivore interactions of nature (Shorthouse et al. 2005). The gall-inducing insects have the ability to manipulate the development of plant tissue and promote its growth (Stone & Schönrogge 2003) and the development of these structures has been an adaptive strategy of many insects for their food and even protection against predators (Mani 1964, Stone & Schönrogge 2003).

Although they represent great benefits to insects, galls can cause severe damage to the host plant (Gallo et al. 1988). Usually, galling insects are associated with the conducting tissues drawing water and nutrients, causing deficiencies to the plant, compromising their development and reproduction (Butignol & Pedrosa-Macedo 2003). In some crops, some gall-midges (Cecidomyiidae: Diptera) can cause economic damage, as *Jatrophobia brasiliensis* (Rubsaamen, 1907) that forms galls on the upper surface of leaves of cassava, deforming them and hindering the normal development of the plant and *Contarinia sorghicola* (Coquillett, 1898) whose larvae feed on the floral ovary preventing the development of grain sorghum, and the considerable damage, where the panicles are fine and there are no grains formed (Nakano et al. 1981).

The early works on galls in Brazil date to the beginning of last century with Tavares (1906, 1917). However, since the late 1980s a series of inventory of galls has been developed in the Southeast (Fernandes et al. 1988, Fernandes et al. 1997, Maia 2001, Urso-Guimarães et al. 2003, Maia & Fernandes 2004, Oliveira & Maia 2004, Maia et al. 2008, Carneiro et al. 2009, Bregonci et al. 2010), South (Dalbem & Mendonça 2006), North (Julião et al. 2005), and Northeast (Fernandes et al. 2009) of the country. In the Midwest, specifically in the State of Goiás, ecological studies of galling (Araújo & Santos 2008, Araújo & Santos 2009a, b) and inventories of galls and host plants (Araújo et al. 2007, Santos et al. 2010) are more recent. In this paper, we report the morphotypes of galls, gall-inducing insects and host plants from Serra dos Pireneus, Goiás, Brazil.

Material and Methods

The study was conducted at Parque Estadual da Serra dos Pireneus (S 15° 48'; W 48º 52') located in the municipalities of Pirenópolis, Corumbá de Goiás and Cocalzinho of Goiás, about 18 km of Pirenópolis, Midwest of Brazil (Figure 1). The park area covers 2833.26 ha and includes regions of typical savanna ("cerrado *sensu stricto*"), rocky savanna ("cerrado rupestre"), gallery forest ("mata de galleria") and stational semidecidual forest ("mata estacional semidecidual"). The climate according to Köppen's classification is Aw with a dry season (April to September) and a rainy season (October to March) well defined.

Quarterly expeditions were conducted for the study area between August 2006 and July 2008. Surveys were conducted in different vegetation physiognomies and all plants with galls were sampled. Fragments of organs attacked and also samples of plant reproductive materials were collected to obtain the gall-inducing insects and identification of the host plant, respectively. When possible, the identification of plant species was done on site.

The collected galls were taken to the Entomology Laboratory of the Universidade Federal de Goiás (UFG) and packed in plastic container with moistened paper. Observations were made daily until emergence of insects. As they emerged, the bugs were fixed in 70% alcohol for further identification. After that, we analyzed the external characteristics of galls, such as colour, pubescence, leaf surface (adaxial or abaxial leaf) and internal ones (number of chamber and dwellers). The insects were identified in orders and families, using entomological keys (Triplehorn & Johnson 2005). The galling insects and parasitoids are fixed in 70% alcohol and deposited in the Entomology Laboratory of UFG.

The identification of the plants was made by comparison with the collections of UFG, herbarium, literature, as well as consultation with specialists. We followed the APG II classification system for all plant identifications (Souza & Lorenzi 2005). The botanical material was cataloged and stored in the Laboratory of Morphology and Plant Taxonomy of UFG.

Results

We found 62 gall morphotypes, distributed on 28 botanical families comprising 44 genera and 51 species (Table 1). The plant families that showed the greatest richness of galls were Fabaceae, with eight morphotypes, Styracaceae with six, Malpighiaceae with five, Euphorbiaceae and Vochysiaceae with four, Melastomataceae, Myrtaceae and Sapotaceae with three morphotypes. The remaining families had one or two gall morphotypes each (Table 1).

Gall morphotypes and their characteristics are listed in Table 2. *Styrax* L. (Styracaceae) and *Qualea* Aubl. (Vochysiaceae) were the richest genera in number of gall morphotypes (six and four, respectively). *Styrax pohlii* A.DC. (Styracaceae) was the super host

Table 1. Correlation of gall morphotypes, insect taxa (insect gall inducers and parasitoids) and host plants per plant family in areas of Cerrado from Serra do Pireneus, Goiás, Brazil.

Botanical family	Number of plant species	Number of insect taxa	Number of gall morphotypes
Fabaceae	6	3	8
Styracaceae	2	2	6
Malpighiaceae	5	3	5
Euphorbiaceae	4	2	4
Vochysiaceae	2	1	4
Melastomataceae	3	4	3
Myrtaceae	3	4	3
Sapotaceae	2	1	3
Asteraceae	2	2	2
Bignoniaceae	2	1	2
Caryocaraceae	1	2	2
Clusiaceae	2	1	2
Dilleniaceae	1	3	2
Malvaceae	2	3	2
Anacardiaceae	1	1	1
Annonaceae	1	2	1
Apocynaceae	1	1	1
Burseraceae	1	-	1
Combretaceae	1	-	1
Ebenaceae	1	2	1
Erytroxylaceae	1	1	1
Loranthaceae	1	1	1
Ochnaceae	1	1	1
Piperaceae	1	2	1
Proteaceae	1	1	1
Rubiaceae	1	1	1
Sapindaceae	1	1	1
Smilacaceae	1	1	1
Total	51	47	62

Table 2. Host plant characteristics (family, species and habit) and morphology of the galls collected in the typical savanna (TS), rocky savanna (RS), gallery forest (GF) and stational semidecidual forest (SF) in the Serra dos Pireneus, Goiás, Brazil.

Host plant	Habit	Morphology					Vegetation
Family and species		Organ	Form	Color	Pubescence	Occurrence	
ANACARDIACEAE *Anacardium humile* A.St.-Hil.	Shrub	Leaf	Conical	Green	Glabrous	Isolated	TS, RS
ANNONACEAE *Annona coriacea* Mart.	Shrub	Leaf	Globoid	Green/Red	Glabrous	Isolated	TS
APOCYNACEAE *Aspidosperma tomentosum* Mart.	Shrub	Leaf	Discoid	Yellow	Glabrous	Isolated	RS
ASTERACEAE Asteraceae sp. 1	Shrub	Leaf	Globoid	Green	Hairy	Isolated	TS
Asteraceae sp. 2	Shrub	Leaf	Globoid	Green	Hairy	Isolated	TS
BIGNONIACEAE *Arrabidaea* sp.	Liana	Stem	Elipsoid	Green/White	Glabrous	Isolated	GF
Tabebuia sp.	Shrub	Leaf	Conical	Green/Yellow	Hairy	Isolated	RS
BURSERACEAE *Protium heptaphyllum* March.	Tree	Leaf	Conical	Green/Yellow	Glabrous	Isolated	SF
CARYOCARACEAE *Caryocar brasiliense* Camb.	Tree	Leaf	Globoid	Green	Hairy	Aggregate	TS
		Leaf	Globoid	Yellow	Glabrous	Isolated	TS
CLUSICEAE *Calophylum brasiliensis* Camb.	Tree	Leaf (adaxial)	Globoid	Green	Glabrous	Isolated	GF
Clusia sp.	Shrub	Leaf (abaxial)	Amorphous	Red	Hairy	Isolated	TS
COMBRETACEAE *Terminalia argentea* Mart. & Zucc.	Tree	Leaf (abaxial)	Globoid	Brown	Hairy	Isolated	TS
DILLENIACEAE *Davilla elliptica* A.St.-Hil.	Shrub	Leaf	Discoid	Green	Hairy	Isolated	TS
		Stem	Elipsoid	Brown	Hairy	Aggregate	TS
EBENACEAE *Dyospirus burchellii* D.C.	Shrub	Stem	Globoid	Green	Hairy	Isolated	TS
ERYTHROXYLACEAE *Erythroxylum suberosum* A.St.-Hil.	Shrub	Vein	Globoid	Green	Hairy	Isolated	RS
EUPHORBIACEAE *Manihot* sp. 1	Herb	Leaf	Globoid	Red	Glabrous	Isolated	RS
Manihot sp. 2	Herb	Leaf	Globoid	Brown	Glabrous	Isolated	RS
Manihot sp. 3	Herb	Leaf	Globoid	Red	Hairy	Isolated	RS
Sebastiania sp.	Shrub	Petiole	Globoid	Green	Hairy	Isolated	RS
FABACEAE *Acosmium dasycarpum* (Vogel) Yakovlev	Shrub	Leaf	Discoid	Green	Glabrous	Isolated	RS
Anadenanthera peregrina (L.) Spreng.	Tree	Leaf	Globoid	Red	Glabrous	Isolated	GF, SF
Andira paniculata Benth.	Shrub	Leaf	Elipsoid	Green	Glabrous	Isolated	RS
		Leaf	Amorfa	Green	Glabrous	Isolated	RS
		Leaf	Discoid	Green	Glabrous	Isolated	RS
Bauhinia ungulata L.	Tree	Vein	Globoid	Red	Hairy	Isolated	SF
Bauhinia sp.	Shrub	Leaf (abaxial)	Discoid	Green	Glabrous	Isolated	RS
Hymenaea stignocarpa Mart. ex Hayne	Tree	Leaf	Discoid	Green	Glabrous	Isolated	TS, RS
LORANTHACEAE *Struthanthus* sp.	Epiphyte	Leaf	Discoid	Brown	Glabrous	Isolated	TS
MALPIGHIACEAE *Byrsonima pachyphylla* Griseb.	Shrub	Leaf	Conical	Green	Glabrous	Isolated	TS
Byrsonima guilleminiana Brad. & Mark.	Shrub	Leaf	Discoid	Yellow	Glabrous	Isolated	TS

Table 2. Continued...

Host plant	Habit	Morphology					Vegetation
Family and species		**Organ**	**Form**	**Color**	**Pubescence**	**Occurrence**	
Byrsonima sp.	Shrub	Leaf	Conical	Yellow	Glabrous	Isolated	TS
Malpighiaceae sp. 1	Shrub	Leaf	Globoid	Green	Glabrous	Isolated	TS
Pterandra pyroidea A. Juss.	Shrub	Leaf	Globoid	Green	Glabrous	Isolated	SF
MALVACEAE							
Pseudobombax longiflorum (Mart. & Zucc.) A. Robyns	Tree	Leaf	Conical	Red	Glabrous	Isolated	TS
Sida micrantha A.St.-Hil	Herb	Leaf/Petiole/ Stem	Globoid	Yellow	Hairy	Isolated	TS
MELASTOMATACEAE							
Macairea radula (Bonpl.) DC.	Shrub	Leaf/Stem	Globoid	Yellow/Red	Hairy	Isolated	RS
Melastomataceae sp.	Shrub	Leaf	Globoid	Yellow	Hairy	Isolated	RS
Miconia albicans (Sw.) Triana	Shrub	Leaf	Globoid	Yellow	Glabrous	Isolated	SF
MYRTACEAE							
Eugenia punicifolia (Kunth) DC.	Herb	Leaf	Elipsoid	Green	Hairy	Aggregate	GF
Myrcia sp.	Tree	Leaf (abaxial)	Globoid	Brown	Glabrous	Isolated	GF
Psidium pohlianum O.Berg.	Shrub	Leaf	Globoid	Green	Glabrous	Isolated	TS, RS
OCHNACEAE							
Ouratea hexasperma (A. St. Hil.) Baill.	Shrub	Leaf	Discoid	Yellow	Glabrous	Isolated	TS
PIPERACEAE							
Piper arboreum Aubl.	Shrub	Leaf	Globoid	Green	Glabrous	Isolated	GF, SF
PROTEACEAE							
Roupala montana Aubl.	Shrub	Leaf	Globoid	Green/Red	Glabrous	Isolated	TS, RS
RUBIACEAE							
Palicourea rigida Kunt	Tree	Leaf	Globoid	Yellow	Hairy	Isolated	TS
SAPINDACEAE							
Serjania sp.	Liana	Vein	Elipsoid	Brown	Glabrous	Isolated	SF
SAPOTACEAE							
Micropholis sp.	Tree	Leaf	Globoid	Green	Glabrous	Isolated	GF
		Stem	Globoid	Brown	Glabrous	Isolated	GF
Pouteria ramiflora (Mart.) Radlk.	Shrub	Stem	Elipsoid	Brown	Glabrous	Isolated	RS
SMILACACEAE							
Smilax sp.	Shrub	Leaf	Globoid	Green	Glabrous	Isolated	TS
STYRACACEAE							
Styrax sp.	Shrub	Leaf	Globoid	Brown	Hairy	Isolated	TS
Styrax pohlii DC.	Tree	Leaf	Elipsoid	Green	Glabrous	Isolated	SF
		Leaf	Discoid	Green/ Purple	Glabrous	Isolated	SF
		Leaf	Discoid	Brown	Glabrous	Isolated	SF
		Stem	Globoid	Brown	Glabrous	Isolated	SF
		Stem	Elipsoid	Brown	Glabrous	Isolated	SF
VOCHYSIACEAE							
Qualea grandiflora Mart.	Tree	Leaf	Discoid	Green/Brown	Glabrous	Isolated	TS, RS
Qualea parviflora Mart.	Tree	Leaf	Globoid	Red	Hairy	Isolated	TS
		Leaf	Globoid	Green	Glabrous	Isolated	TS
		Leaf	Discoid	Green/Brown	Glabrous	Isolated	TS

plant species, featuring five morphotypes. *Andira paniculata* Benth. (Fabaceae) and *Qualea parviflora* Mart. (Vochysiaceae), had three morphotypes each and *Davilla elliptica* A.St.-Hill (Dilleniaceae), two. The remaining species had only one morphotype.

Most gall morphotypes were found in xeric environments, 28 occurred in typical savanna (45.1%) and 22 in rocky savanna (35.4%). In addition, there were 12 galls in stational semidecidual forest (19.3%) and eight in the gallery forest (12.9%) (Tables 2 and 3). The majority of the gall morphotypes was found 53.2% on shrubs, 33.8% on trees, 8.1% on herbs, 3.2% on lianas and 1.6% on epiphytes, as shown in Table 4.

Most galls occurred in the leaf surface (82.6%). Stem galls (11.2%) and less frequently vein galls (4.8%) and petiole gall (1.6%) were also found. All morphotypes occurred in only one plant organ, with the exception of galls on *Sida micrantha* A.St.-Hill. (Malvaceae) and *Macairea radula* (Bonpl.) DC. (Melastomataceae), which occurred in two organs (leaves and stems).

This is the first report of galls occurrence for the Neotropical region on the following species of host plants: *Davilla elliptica* A.St.-Hill. (Dilleniaceae), *Andira paniculata* Benth. (Fabaceae), *Byrsonima pachyphylla* Griseb. (Malpighiaceae), *Byrsonima guilleminiana* Brad. & Mark. (Malpighiaceae), *Pterandra pyroidea* A.Juss. (Malpighiaceae), *Pseudobombax longiflorum* (Mart. & Zucc.) A. Robyns (Malvaceae), *Psidium pohlianum* O.Brerg. (Myrtaceae), *Pouteria ramiflora* (Mart.) Radlk. (Sapotaceae) and *Qualea grandiflora* Mart. (Vochysiaceae).

In this study we found gall-inducing insects belonging to Diptera (Cecidomyiidae), Hemiptera (Psyllidae) and Lepidoptera (Gelechiidae) (Table 5). The most common was Cecidomyiidae (Diptera), which induced galls on 26 plant species, representing 50.9% of the total. Galling of Lepidoptera and Hemiptera were also observed, being found in 9.8% and 5.8% of the plants, respectively.

Besides the gall makers, we obtained several parasitoids of five Hymenoptera families: Chalcididae, Encyrtidae, Eulophidae, Eupelmidae and Trichogrammatidae occurring in approximately 40% of galls (Table 6). Eulophidae was the most representative family (occurring in 19.6% of plants). In some species of plants, the parasitoids were found together with the galling (see Table 5). Already in 17.6% of plants were obtained only Hymenoptera, not observed any insect taxa galling (it is not known whether these Hymenoptera are parasitoids or galling agents.). Gall inducers or parasitoids were not obtained from 15.6% of the host plants (Table 6), possibly because the galls collected were already empty.

Discussion

Many inventories on the diversity of galls in the Cerrado indicate Fabaceae (Fernandes et al. 1997, Gonçalves-Alvim & Fernandes 2001, Maia & Fernandes 2004, Urso-Guimarães & Scareli-Santos 2006, Santos et al. 2010) and Asteraceae (Fernandes et al. 1996, Carneiro et al. 2009) as the most important host families. Similarly, in this study, Fabaceae was the most representative family, especially in the areas of Cerrado, both in savanna and in forest

Table 3. Correlation of gall morphotypes and vegetation physiognomy in the Serra dos Pireneus, Goiás, Brazil.

Vegetation physiognomy	Number of gall morphotypes
Typical savanna	28 (45,1%)
Rocky savanna	22 (35,4%)
Stational semidecidual forest	12 (19,3%)
Gallery forest	08 (12,9%)

The total represents more than 100% because some morphotypes occurred in more than one vegetation type.

Table 4. Correlation of gall morphotypes according to the habit of the host plant in the Serra dos Pireneus, Goiás, Brazil.

Habit	Number of gall morphotypes
Shrub	33 (53,2%)
Tree	21 (33,8%)
Herb	5 (8,1%)
Liana	2 (3,2%)
Epiphyte	1 (1,6%)

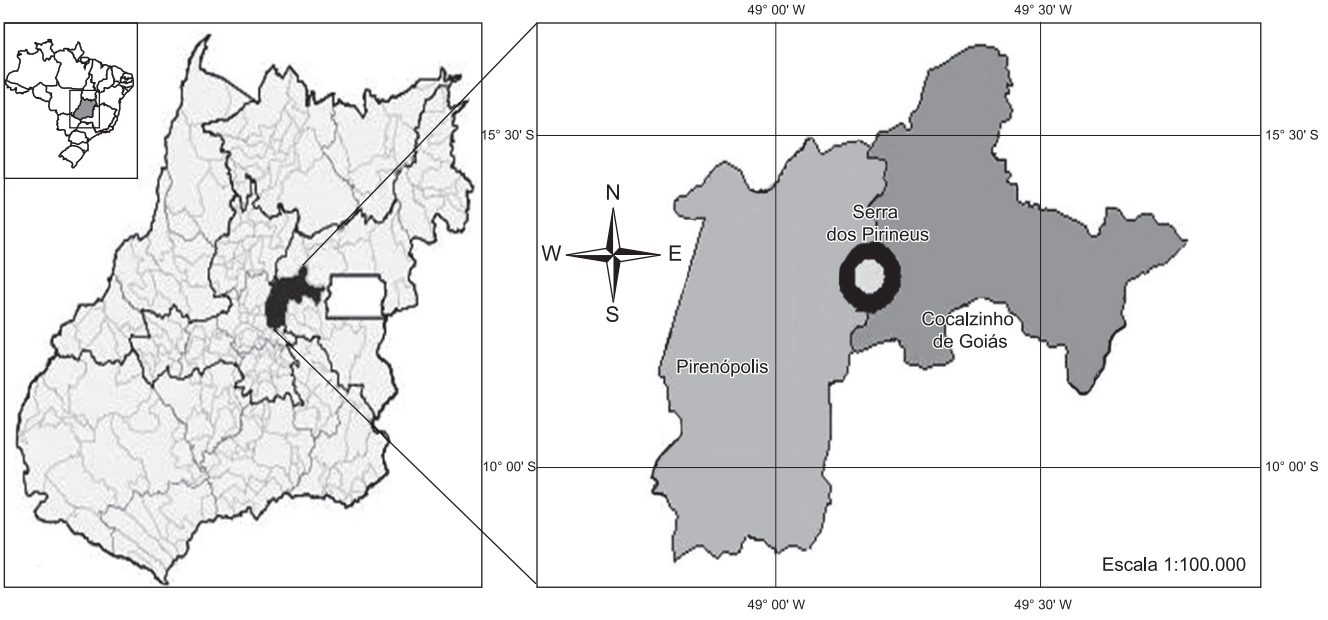

Figure 1. Localization of State Park of the Serra dos Pireneus in the municipalities of Pirenópolis, Corumbá de Goiás and Cocalzinho of Goiás, Midwest, Brazil.

Table 5. Occurrence of gall-inducing insects and parasitoids in observed plant species in areas of Cerrado from Serra dos Pireneus, Goiás, Brazil.

Host plant		Gall-inducing insects	Parasitoids insects
Family	**Species**		
ANACARDIACEAE	*Anacardium humile* A.St.-Hil.	Cecidomyiidae	-
ANNONACEAE	*Annona coriacea* Mart.	Cecidomyiidae	Eulophidae
APOCYNACEAE	*Aspidosperma tomentosum* Mart.	Hemiptera	-
ASTERACEAE	Asteraceae sp. 1	Cecidomyiidae	-
	Asteraceae sp. 2	Cecidomyiidae	Encyrtidae
BIGNONIACEAE	*Arrabidaea* sp.	Cecidomyiidae	-
	Tabebuia sp.	Cecidomyiidae	-
BURSERACEAE	*Protium heptaphyllum* March.	Indeterminate	-
CARYOCARACEAE	*Caryocar brasiliense* Camb.	Cecidomyiidae	-
CLUSIACEAE	*Calophylum brasiliensis* Camb.	Indeterminate	-
	Clusia sp.	Cecidomyiidae	-
COMBRETACEAE	*Terminalia argentea* Mart. & Zucc.	Indeterminate	-
DILLENIACEAE	*Davilla elliptica* A.St.-Hil.	Cecidomyiidae	Eulophidae
		Lepidoptera	-
EBENACEAE	*Dyospirus burchellii* D.C.	Lepidoptera	Hymenoptera
ERYTROXYLACEAE	*Erythroxylum suberosum* A.St.-Hil.	Cecidomyiidae	-
EUPHORBIACEAE	*Manihot* sp. 1	Cecidomyiidae	-
	Manihot sp. 2	Indeterminate	Eulophidae
	Manihot sp. 3	Cecidomyiidae	-
	Sebastiania sp.	Cecidomyiidae	Eulophidae
FABACEAE	*Acosmium dasycarpum* (Vogel) Yakovlev	Cecidomyiidae	-
	Anadenathera peregrina (L.) Spreng.	Indeterminate	-
	Andira paniculata Benth.	Cecidomyiidae	Encyrtidae
	Bauhinia ungulata L.	Cecidomyiidae	-
	Bauhinia sp.	Indeterminate	Eulophidae
	Hymenaea stygnocarpa (Mart) ex Hayne.	Cecidomyiidae	-
LORANTHACEAE	*Struthanthus* sp.	Indeterminate	Hymenoptera
MALPIGHIACEAE	*Byrsonima pachyphylla* (Sw.) DC	Cecidomyiidae	-
	Byrsonima guilleminiana Brad.& Mark.	Indeterminate	-
	Byrsonima sp.	Cecidomyiidae	Trichogrammatidae
	Malpighiaceae sp. 1	Cecidomyiidae	Eulophidae
	Pterandra pyroidea A. Juss.	Indeterminate	-
MALVACEAE	*Pseudobombax longiflorum* (Mart. & Zucc.) A. Robyns	Lepidoptera	Hymenoptera
	Sida micrantha A.St.-Hil	Cecidomyiidae	Hymenoptera
MELASTOMATACEAE	*Macairea radula* (Bonpl.) DC.	Gelechiidae	Chalcididae
	Melastomataceae sp.	-	Hymenoptera
	Miconia albicans (Sw.) Triana	Cecidomyiidae	-
MYRTACEAE	*Eugenia punicifolia* (Kunth) DC.	-	Hymenoptera
	Myrcia sp.	Cecidomyiidae	Hymenoptera
	Psidium pohlianum O.Berg.	Psyllidae	Eulophidae
OCHNACEAE	*Ouratea hexasperma* (A. St. Hil.) Baill.	Lepidoptera	-
PIPERACEAE	*Piper arboreum* Aubl.	-	Eulophidae
PROTEACEAE	*Roupala montana* Aubl.	Psyllidae	-
RUBIACEAE	*Palicourea rigida* Kunt	-	-
SAPINDACEAE	*Serjania* sp.	Cecidomyiidae	-
SAPOTACEAE	*Micropholis* sp.	-	-
	Pouteria ramiflora (Mart.) Radlk.	Cecidomyiidae	-
SMILACACEAE	*Smilax* sp.	-	-
STYRACACEAE	*Styrax* sp.	-	Eupelmidae
	Styrax pohlii DC.	Cecidomyiidae	-
VOCHYSIACEAE	*Qualea grandiflora* Mart.	-	Eulophidae
	Qualea parviflora Mart.	-	Eulophidae

Table 6. Correlation of insect orders and number of host plant species in the Serra dos Pireneus, Goiás, Brazil.

Insect order	Number of host plant species
Diptera (Cecidomyiidae)	22 (50,9%)
Lepidoptera	5 (9,8%)
Hemiptera	3 (5,8%)
Hymenoptera (Eulophidae)	10 (19,6%)
Hymenoptera (others)	12 (23,5%)
Unknown	8 (15,6%)

The total represents more than 100% because in some plants there is more than one taxon of insect.

(Mendonça et al. 1998, Silva-Júnior et al. 2001). Asteraceae, despite being the second largest family in number of species of the Cerrado (Mendonça et al. 1998), was ninth in gall diversity. This family seems to be quite representative of the diversity of galls in Southern (Mendonça 2007) and Southeast (Carneiro et al. 2009) Brazil.

Styrax and *Qualea* were the plant genera with the highest gall diversity in this study. At lower taxonomic levels, there may be a large concentration of galls in some taxa, these being known as super-hosts (Veldtman & McGeoch 2003). According to Mendonça (2007), there are both super-hosts species and genera of plants, presenting such a wealth and abundance of galls morphotypes. This pattern was observed in this study, where the genus *Styrax* and specie *Styrax pohlii*, hosted respectively six and five gall types. Other super-host genera listed for Brazil and the Neotropical region are: *Baccharis* (Fernandes et al. 1996), *Copaifera* (Oliveira et al. 2008), *Eugenia* (Maia 2001), *Miconia* (Maia & Fernandes 2004), *Mikania* (Mendonça 2007) and *Myrcia* (Maia et al. 2008).

Most galls of the Serra dos Pireneus were found in the vegetation of savanna and rocky savanna. The preference of galling in xeric environments can be explained by the hypothesis of nutritional stress, as described by Fernandes & Price (1988). According to these authors, the galling richness is directly related to the nutritional stress of the environment. This is due to the large investment of plants in nutritionally stressed environments, lipids storage, carbohydrates and low in protein production. Under these conditions the plants are more sclerophyllous, with coriaceous leaves and stems, high hairiness, which reduces the probability of abscission. Thus, the plants become large food reserves and also give shelter and protection for insects, a fact responsible for the evolutionary success of gall-inducing insects (Fernandes et al. 1996, Allain et al. 1998, Gonçalves-Alvim & Fernandes 2001).

Testing the hypothesis of nutritional stress in the Serra dos Pireneus, Araújo & Santos (2008) compared the richness of galling between xeric (typical savanna) and mesic (stational semidecidual forest) environments, but no significant differences were found between these two vegetation types. They found an average of 19.7 morphotypes per sample in the savanna and 19.2 in the stational semidecidual forest. According to the authors, the structural complexity of forest formation increases the diversity of this environment, making it equivalent in richness to the xeric environment. The authors also point to the importance of seasonality for the distribution of galling site, and in the dry season peak abundance of these insects.

Most galls were recorded in leaves (82.6%), a pattern observed in most studies (Urso-Guimarães et al. 2006, Maia et al. 2008, Santos et al. 2010). In the Serra dos Pireneus, galls were more frequent in shrubs (53.2%) than in trees (33.8%), in accordance with the results of Oliveira & Maia (2005) for areas of restinga. Much of the dominant vegetation in the Cerrado consists of shrubs, like in restingas, which may have influenced this pattern.

According to Maia et al. (2008), in the Neotropics, six orders of insects have gall inducing representatives: Diptera, Lepidoptera, Hymenoptera, Coleoptera, Hemiptera and Thysanoptera. Among these, there is a significant dominance of galls induced by Diptera, with registration of over a thousand morphotypes, mainly driven by Cecidomyiidae.

Cecidomyiidae, which was the most important galling group in Serra dos Pireneus, is a diversified family of basal Diptera. The Neotropical Cecidomyiidae fauna is poorly known and includes about 500 species in 170 genera (Gagné 1994, Gagné 2010). There are 159 species placed in 75 genera recorded for Brazil, 95 of these species and 47 of the genera occur in the State of Rio de Janeiro, representing 60% of the total for Brazil (Maia 2005).

We observed a high infestation of parasitoid insects in the galls studied (approximately 40%). The micro-hymenoptera parasitoids are the most important natural enemies of gall-inducing insects, especially Cecidomyiidae (Maia & Azevedo 2009). In the restingas on the coast of Brazil the rate of parasitism can reach 60% of the galls (Maia 2001, Maia et al. 2008). Maia & Monteiro (1999) recorded 30 species of parasitoids in only three species of *Bruggmannia* (Cecidomyiidae) that galls *Guapira opposita* (Nyctaginaceae) in Restinga da Barra de Maricá, RJ. Micro-hymenoptera are also very common gall in the Brazilian cerrado. For example, Urso-Guimarães et al. (2003) found parasitoids of the families Braconidae, Eulophidae, Eurytomidae, Pteromalidae and Torymidae in a savanna of Delfinópolis, MG. On the other hand, Maia & Fernandes (2004) recorded the parasitoids occurrence to be almost 35% of the gall morphotypes from Serra de São José, MG.

The number of gall-inducing insects species obtained in this study (62) is intermediate when compared to other studies. On one hand Carneiro et al. (2009) recorded 241 gall species in the rocky field of Cadeia do Espinhaço, MG. Maia & Fernandes (2004) in a similar study of the Serra de São José, Brazil, recorded 137 gall morphotypes. On the other hand, Urso-Guimarães & Scareli-Santos (2006), found 36 species in the Pé-de-Gigante, SP. In an area of savanna and forest in Belo Horizonte, MG, Fernandes et al. (1988) recorded 37 gall types. In another study, Urso-Guimarães et al. (2003) recorded only 22 morphotypes in areas of savanna, gallery forest and rocky field in Delfinópolis, MG. Factors such as richness and composition of host plants (Oyama et al. 2003), habitat type (Gonçalves-Alvim & Fernandes 2001) and environmental conditions (Fernandes & Price 1988) may influence patterns of local and regional distribution of these insects.

Gall studies in Brazil have been growing in recent years (Moreira 2006). Gall inventories are relatively common in Brazil, mainly in the Cerrado (Fernandes et al. 1997, Urso-Guimarães et al. 2003, Maia & Fernandes 2004, Urso-Guimarães & Scareli-Santos 2006, Santos et al. 2010) and in the Atlantic Forest (Maia 2001, Oliveira & Maia 2005, Maia et al. 2008, Fernandes et al. 2009, Bregonci et al. 2010). In this context, several galls and gall-inducing insects have been described and new host plants are being recorded. Nevertheless, the vast majority of studies are concentrated in the Southeast region, whereas studies are still incomplete in the remaining regions of Brazil. The new records presented in this work indicates the importance of this type of study to inventory the diversity present in regions not sampled, such as the Cerrado of Central Brazil.

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