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Characterization of entomogen galls from Mato Grosso do Sul, Brazil

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ABSTRACT

In this paper we performed a study of occurrence and characterization of entomogen galls from natural vegetation areas in Mato Grosso do Sul. We surveyed natural areas of four biomes from Mato Grosso do Sul State: Pantanal (Corumbá), Atlantic Forest (Bodoquena), Cerrado (Aquidauana), and Chaco (Porto Murtinho). We identified 186 morphotypes of galls in 115 host plant species from 35 families and 73 genera. The richest families were Fabaceae ($N = 34$), Sapindaceae ($N = 24$), Bignoniaceae ($N = 17$), and Myrtaceae ($N = 15$). Fifty morphotypes of insects (27%) were found in galls of 38 host plants, 78% of which belongs to Diptera, 10% to Hymenoptera, and the other 12% are divided among Hemiptera, Thysanoptera, Coleoptera, and Lepidoptera. In this study, the geographic distribution of gall morphotypes associated to the cecidomyiids *Youngomyia pouteriae* Maia, 2004, and *Trotteria quadridentata* Maia, 2004 (Diptera, Cecidomyiidae), and the wasp *Mononeuron duguetiae* Fischer, 1981 (Hymenoptera, Braconidae, Doryctinae) are expanded to the localities sampled in MS. In addition, four genera and 24 species of plants were recorded for the first time as hosts to entomogen galls. All occurrences of Cecidomyiidae in Mato Grosso do Sul's localities are new records for this family.

Introduction

Galls are structures formed via abnormal cell growth in response to stimulation caused by organisms such as insects, nematodes, fungi or bacteria (Carneiro et al., 2009a; Rohfritsch and Shorthouse, 1982). The global richness of insect galls has been estimated to be about 130,000 species (Espírito-Santo and Fernandes, 2007). Galls are unequivocal markers of species-specific relationships, since about 90% of all gall-forming species are monophagous (Carneiro et al., 2009a; Raman, 2010), thus they can be applied to understand relationships between gall-maker species richness and plant species diversity of a given area (Butterill and Novotný, 2015), with the potential use of galls as bioindicators (Julião et al., 2005).

The insect orders associated with gall formation are Diptera, Lepidoptera, Hymenoptera, Coleoptera, Hemiptera, and Thysanoptera. There is a large predominance of galls induced by Diptera, especially Cecidomyiidae, with over a thousand records of gall morphotypes in the Neotropical region (Maia, 2006; Maia et al., 2008), and a calculated average of 64% of the gall-inducing insect species in the world (Espírito-Santo and Fernandes, 2007). Cecidomyiidae is the main group of gall-forming insects in all zoogeographical regions, with around 4,800 described species of gall makers to the world (Gagné and Jaschhof, 2014).

Despite an increasing number of studies on the occurrence and characterization of galls in Brazil made by Tavares (1909, 1917, 1918, 1920, 1922, 1925), Houard (1933), and Occhioni (1979, 1981), some biomes remain poorly sampled, such as the Pantanal, Caatinga and the Amazonian forest (Julião et al., 2002, 2014; Carvalho-Fernandes et al., 2012; Santos et al., 2011; Maia, 2011; Maia et al., 2014). In this study, we contributed providing the first survey of the galls and gall makers of Mato Grosso do Sul, including four areas of natural vegetation in the Cerrado, Atlantic Forest, Pantanal and Chaco biomes, which compose the flora mosaic in Mato Grosso do Sul. We documented and characterized gall morphology and identified host plants. Gall makers were also identified or inferred when obtained.

Material and methods

Study areas

Mato Grosso do Sul State has an approximate area of 358 km^2, 4.2% of the total Brazilian territory. The relief of the state consists of plateaus, tablelands and levels, within the Paraná and Paraguay

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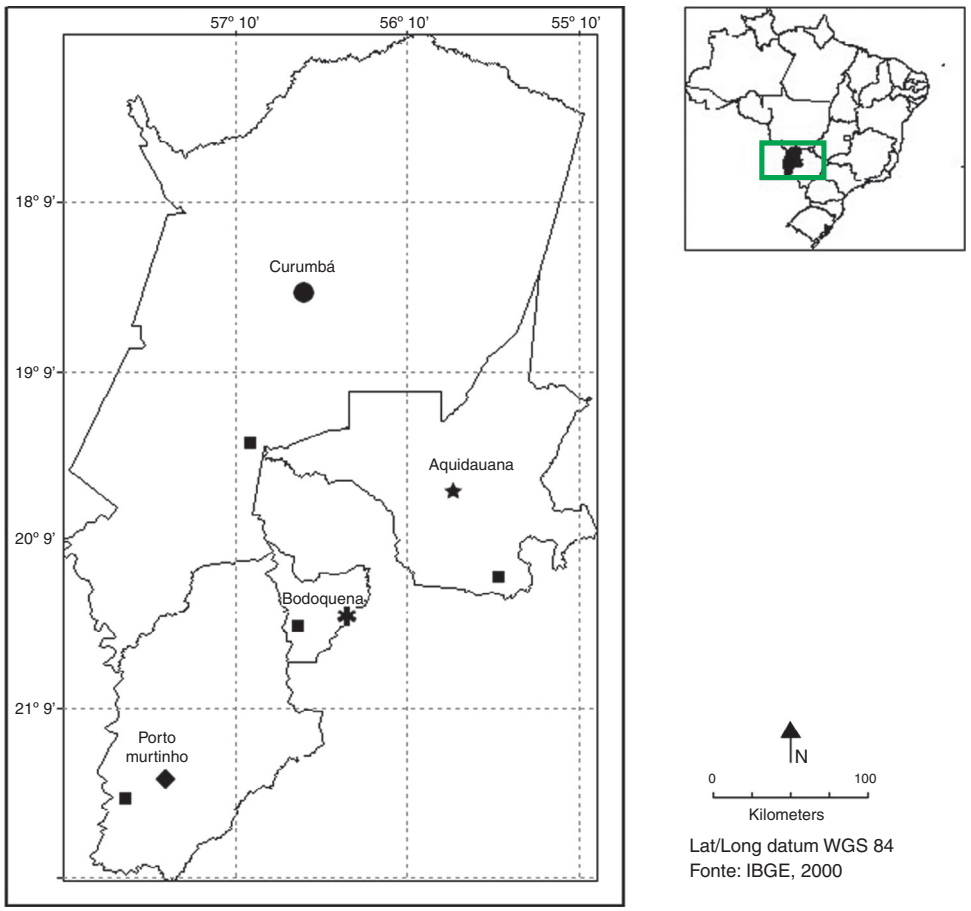


Fig. 1. Map of the sampling localities and their biomes of Mato Grosso do Sul State, Brazil. ■ sampling points in the municipality, ⋆ Cerrado, ✱ Atlantic Forest, ● Pantanal, ♦ Chaco.

river basins; elevation ranges from 200 m to 700 m (Governo do Mato Grosso do Sul, 2016). According to Köeppen's climate zone classification (Alvares et al., 2013), most of the state's territory is in the tropical climate zone. The following climate types occur in Mato Grosso do Sul: Af (tropical without dry season), Am (tropical monsoon), Aw (tropical with dry winter) and Cfa (humid subtropical with hot summer), with a rainy summer and a dry winter, characterized by average temperatures ranging from 25 °C in the lowlands of Paraguay to 20 °C in the plateau of Bodoquena and Maracaju, and mean annual precipitation of 1500 mm (Governo do Mato Grosso do Sul, 2016).

Vegetation includes Cerrado, Pantanal, Chaco, and Atlantic Forest biomes, with approximately 60% of the area occupied by Cerrado (Silva et al., 2011). The richest plant families in all biomes are Fabaceae, Sapindaceae, Bignoniaceae, and Myrtaceae (Damasceno et al., 2005; Pott and Pott, 1999; Frison, 2007). Fabaceae is the most speciose family in Mato Grosso do Sul (Frison, 2007; Mendonça et al., 2008; Baptista-Maria et al., 2009; Freitas et al., 2013).

Samplings were carried out in areas of natural vegetation remnants in four municipalities of Mato Grosso do Sul State (IBGE, 2000): Aquidauana, Bodoquena, Corumbá, and Porto Murtinho, in the Cerrado, Atlantic Forest, Pantanal, and Chaco biomes, respectively (Fig. 1).

Sampling

We selected eight areas for sampling, two areas for each biome: Cerrado, Atlantic Forest, Pantanal, and Chaco (Table 1 and Fig. 1). Samples were collected during three expeditions, April 2012, December 2012, and December 2013, according to a time-based method described by Price et al. (1998). Each area was sampled once, with sampling effort of two hours in each biome, totaling eight hours. According to Fernandes et al. (1995), there is no significant difference in gall abundance in different seasons, thus sampling during one season is sufficient to evaluate the number of galls per habitat. Galls are sessile and remain attached to the host plants, which makes it possible to detect galls even after adult emergence. All samples were collected at trail edges. This environment has high solar incidence and low humidity, with increased gall richness (Price et al., 1998), because galls occurence is associated with hygrothermal stress in several environments (Fernandes and Price, 1991; Julião et al., 2014). In addition, route length (L) of each area was measured to better understand gall richness in the sampled areas (Table 1).

We collected branches of gall-bearing plants, which were subsequently photographed, stored, and labeled in plastic bags. Morphological descriptions of galls and identification of host plants and gall makers were conducted in laboratory. Characterization of gall's morphological types followed Isaias et al. (2013). Gall-maker species not obtained by adult emergence were identified via comparisons to several studies of gall-maker's community characterization in dry vegetation (Julião et al., 2002; Malves and Frieiro-Costa, 2012; Urso-Guimarães et al., 2003; Maia and Fernandes, 2004; Urso-Guimarães and Scarelli-Santos, 2006; Carneiro et al., 2009b; Coelho et al., 2009; Maia, 2011; Santos et al., 2011; Saito and Urso-Guimarães, 2012; Araújo et al., 2014; Maia and Carvalho-Fernandes, 2016; Nogueira et al., 2016). Plant identification was performed using identification keys, comparison with herbarium material and consultations with experts, and the specimens were deposited in the Universidade Federal de São Carlos,

Table 1
Sampling localities of Mato Grosso do Sul State informing biomes per locality, coordinates of starting points, and route length. Atlantic Forest.

Biome	Locality	Coordinates	Route length
Cerrado	Aquidauana/Universidade Estadual de Mato Grosso do Sul (UEMS)	S 20° 27′ 21.4″, W 055° 39′ 46.1″	290 m
Cerrado	Aquidauana/Distrito de Camisão	S 20° 26′ 58.1″, W 055° 38′ 16.9″	300 m
Atlantic Forest	Bodoquena/Sede Fazenda Califórnia	S 20° 42′ 18.9″, W 56° 51′ 17.4″	320 m
Atlantic Forest	Bodoquena/Trilha da Gruta	S 20° 41′ 55.9″, W 56° 52′ 49.4″	517 m
Pantanal	Corumbá/Base de Estudos do Pantanal	S 19° 34′ 20.09″, W 057° 00′ 57.09″	400 m
Pantanal	Corumbá/Fazenda São Bento	S 19° 28′ 09.1″, W 057° 01′ 49.9″	110 m
Chaco	Porto Murtinho/Trilha Fazenda Retiro Conceição	S 21° 41′ 07.6″, W 57° 45′ 09.0″	662 m
Chaco	Porto Murtinho/Trilha Fazenda Campo Florido	S 21° 38′ 18.3″, W 57° 42′ 22.7″	550 m

campus Sorocaba Herbarium (SORO). The families are listed according to APG IV (2016). Portions of branches with galls were stored in plastic containers closed with fine mesh to obtain inductors or associated entomofauna. All insect material was stored in 70% ethanol. Gall makers and associated fauna were identified by specialists and were deposited in the Museu de Zoologia da Universidade de São Paulo (MZUSP).

Results and discussion

Overall 186 gall morphotypes (Table 2 and Figs. 2–185) were collected in 115 species of host plants belonging to 35 families and 73 genera. Nine of these species were identified only at the family level, and 20 at the genus level. The average number of gall morphotypes per plant species was 1.6 (Table 3). Despite adopting different methodologies, several authors have found similar results in other areas of Neotropical savannas and seasonally dry tropical forests, such as Goiânia ($x = 1.8$), Ecological Station of Jataí ($x = 1.7$), Vaçununga State Park ($x = 1.4$), Delfinópolis ($x = 1.2$), Boqueirão Biological Reserve ($x = 1.4$), Serra de São José ($x = 1.8$), Serra do Cipó ($x = 1.8$), Cadeia do Espinhaço ($x = 1.6$), Pernambuco ($x = 1.3$) (Table 3).

In our survey, the richest plant families in terms of gall morphotypes were Fabaceae ($N = 34$), Sapindaceae ($N = 24$), Bignoniaceae ($N = 17$), and Myrtaceae ($N = 15$), corroborating the hypothesis that families with the highest number of plant species also have the highest number of gall-forming species (Fernandes, 1992; Mendonça, 2007). As previously stated, local gall-forming species richness is closely related to the diversity of plant species (Butterill and Novotný, 2015). Fabaceae and Myrtaceae are among the ten most diversified families in Brasil (BFG, 2015) and studies of plant diversity in several vegetation types in Mato Grosso do Sul pointed out Fabaceae as the most species-rich family (Pott and Pott, 1999; Damasceno et al., 2005; Frison, 2007). The same applies to the Cerrado (Mendonça et al., 2008), the Atlantic Forest (Baptista-Maria et al., 2009), in forest patches of the Pantanal (Frison, 2007), and the Chaco (Freitas et al., 2013). Despite the different sampling effort, this average is closer to other studies in Cerrado, seasonally dry tropical forests, and dry tropical forests of Brazil (Table 3). Families and species with the highest number of morphotypes for Mato Grosso do Sul are presented in Table 4, which also contain the results for each biome in this study and the Julião et al. (2002) results. Although our aim was not to verify the hygrothermal hypothesis, the collections were conducted in biomes with marked differences in humidity. When the results of different biomes of MS were compared, we did not find increased gall richness in low-humidity environments as stated by Price et al. (1998), Fernandes and Price (1991), Julião et al. (2014) (Table 4), reinforcing the richness hypothesis to the MS environments (Fernandes, 1992; Mendonça, 2007).

The plant genera with the highest gall diversity in all biomes were *Serjania* Mill. ($N = 20$, Sapindaceae), *Eugenia* L. ($N = 11$, Myrtaceae), *Bauhinia* L. ($N = 8$, Fabaceae), and *Fridericia* Mart. ($N = 8$, Bignoniaceae). The composition of plant species, genera and families also highlights the specificities of each biome. Despite Fabaceae, Sapindaceae, Bignoniaceae, and Myrtaceae being the richest families in all biomes of MS (Pott and Pott, 1999; Damasceno et al., 2005; Frison, 2007), in the Atlantic Forest the richest families also included Asteraceae and Rubiaceae; and Apocynaceae in Pantanal and Chaco.

Serjania, with 20 morphotypes in MS, was recorded with 12 galls in Pantanal (Julião et al., 2002), and six gall morphotypes in rocky areas of Serra do Cipó, MG (Coelho et al., 2009). Eugenia, recorded with 11 morphotypes in MS, is most commonly found in restinga with 12 morphotypes (Maia et al., 2014). *Bauhinia*, with eight morphotypes in MS, appeared with ten galls in Serra do Cipó, MG (Coelho et al., 2009), three galls in the Cerrado of Santa Rita do Passa Quatro, SP (Urso-Guimarães and Scarelli-Santos, 2006), two in the Cerrado of Delfinópolis, MG (Urso-Guimarães et al., 2003) and two in the Caatinga of Pernambuco (Santos et al., 2011). The same occurs with *Fridericia*, with eight morphotypes in MS, also found in restinga with seven morphotypes (Maia et al., 2014). In addition, no survey of the Cerrado or Atlantic Forest presented *Eugenia* or *Fridericia* as superhost species before (Table 5).

The highest gall richness on plant species in MS were found in *Fridericia chica* (Bonpl.) L.G.Lohmann ($N = 7$, Bignoniaceae), *Serjania* cf. *glabrata* Kunth ($N = 7$, Sapindaceae), and *Eugenia florida* DC. ($N = 6$, Myrtaceae). There were no reports of *Fridericia chica* as superhost in the literature. *Eugenia florida* was recorded in studies in Southern Brazil (Mendonça et al., 2014) and *Serjania glabrata* in one leaf gall from Pernambuco (Santos et al., 2011).

In specific biomes the results were slightly different. The families and species with more morphotypes in Cerrado are Fabaceae and *Hymenaea stigonocarpa* Mart. ex Hayne, in Atlantic Forest are Bignoniaceae and *Friedericia chica*, in Pantanal are Sapindaceae and *Serjania* sp. 7, and in Chaco, Fabaceae and *Bauhinia ungulata* L. are the richest, followed by *Eugenia punicifolia* (Kunth) DC., *Forsteronia rufa* Müll.Arg., *Magonia pubescens* A.St.-Hil., and *Mimosa* sp. (details in Table 4).

Another pattern recovered in our results is the organ more frequent to gall occurrence: leaves (Mani, 1964). Eighty-five percent of galls occurred in leaves, leaflets or leaf veins, 14% in stems, and the other 2% in tendrils and inflorescences. Galls on fruits or aerial roots were not found. Only one morphotype occurred simultaneously in two plant organs: stem and leaf. The most common morphotypes of galls were lenticular (35%), corroborating the pattern found

Table 2
Characterization of insect galls recorded in the Mato Grosso do Sul Statebiomesby species of host plant. Figures refer to gall morphotype's picture.

Host family	Host species	Organ	Shape	Color	Pubescence	Locality/Biome	No. of figure
Annonaceae	*Annona emarginata* (Schltdl.) H.Rainer	Leaf	Cylindrical	Green	Yes	Aquidauana/Cerrado	2
Annonaceae	*Duguetia furfuracea* (A.St.-Hil.) Saff.	Leaf	Globoid	Yellow	Yes	Aquidauana/Cerrado	3
Annonaceae	*Duguetia furfuracea* (A.St.-Hil.) Saff.	Leaf	Lenticular	Yellow	No	Aquidauana/Cerrado	4
Annonaceae	Annonaceae sp.	Stem	Globoid	Green	No	Bodoquena/Atlantic Forest	5
Apocynaceae	*Aspidosperma cylindrocarpon* Müll.Arg.	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	6
Apocynaceae	*Aspidosperma olivaceum* Müll.Arg.	Leaf	Globoid	Yellow	No	Bodoquena/Atlantic Forest	7
Apocynaceae	*Aspidosperma olivaceum* Müll.Arg.	Leaf	Triangular	Green	No	Bodoquena/Atlantic Forest	8
Apocynaceae	*Aspidosperma subincanum* Mart.	Leaf	Lenticular	Yellow	No	Bodoquena/Atlantic Forest	9
Apocynaceae	*Forsteronia rufa* Müll.Arg.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	10
Apocynaceae	*Forsteronia rufa* Müll.Arg.	Leaf	Globoid	Green	Yes	Porto Murtinho/Chaco	11
Apocynaceae	*Forsteronia rufa* Müll.Arg.	Leaf	Globoid	Green	No	Porto Murtinho/Chaco	12
Apocynaceae	*Forsteronia rufa* Müll.Arg.	Leaf	Globoid	Green	No	Bodoquena/Atlantic Forest	13
Apocynaceae	*Forsteronia velloziana* (A.DC.) Woodson	Leaf	Lenticular	Yellow	No	Corumbá/Pantanal	14
Apocynaceae	*Forsteronia velloziana* (A.DC.) Woodson	Leaf	Globoid	Brown	No	Corumbá/Pantanal	14
Asteraceae	Asteraceae sp. 1	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	15
Asteraceae	Asteraceae sp. 2	Leaf	Wrinkle	Green	No	Bodoquena/Atlantic Forest	16
Asteraceae	*Mikania* sp.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	17
Asteraceae	*Vernonia polyanthes* Less	Stem	Globoid	Green	No	Bodoquena/Atlantic Forest	18
Asteraceae	*Vernonanthura brasiliana* (L.) H.Rob.	Leaf	Amorphous	Brown	No	Bodoquena/Atlantic Forest	19
Asteraceae	*Vernonanthura brasiliana* (L.) H.Rob.	Leaf	Lenticular	Yellow	No	Bodoquena/Atlantic Forest	20
Asteraceae	*Vernonanthura brasiliana* (L.) H.Rob.	Leaf	Globoid	Green	Yes	Bodoquena/Atlantic Forest	21
Asteraceae	*Vernonanthura brasiliana* (L.) H.Rob.	Stem	Globoid	Brown	No	Bodoquena/Atlantic Forest	22
Bignoniaceae	*Adenocalymma bracteatum* (Cham.) DC.	Leaf vein	Fusiform	Green	No	Corumbá/Pantanal	23
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Leaf	Lenticular	Cream	No	Bodoquena/Atlantic Forest	24
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	25
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Leaf	Lenticular	Cream	No	Bodoquena/Atlantic Forest	26
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Leaf	Globoid	Green	Yes	Bodoquena/Atlantic Forest	27
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Stem	Fusiform	Brown	No	Bodoquena/Atlantic Forest	28
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Stem	Globoid	Orange	No	Bodoquena/Atlantic Forest	29
Bignoniaceae	*Fridericia chica* (Bonpl.) L.G.Lohmann	Stem	Globoid	Brown	No	Bodoquena/Atlantic Forest	30
Bignoniaceae	*Fridericia caudigera* (S.Moore) L.G.Lohmann	Tendril	Fusiform	Green	No	Bodoquena/Atlantic Forest	31
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	Leaf	Lenticular	Green/brown	Yes	Aquidauana/Cerrado	32
Bignoniaceae	*Handroanthus ochraceus* (Cham.) Mattos	Leaf	Cylindrical	Green	Yes	Aquidauana/Cerrado	33
Bignoniaceae	*Handroanthus ochraceus* (Cham.) Mattos	Leaf	Globoid	Green	Yes	Aquidauana/Cerrado	34
Bignoniaceae	*Handroanthus heptaphyllus* (Vell.) Mattos	Leaf	Lenticular	Green	No	Corumbá/Pantanal	35
Bignoniaceae	*Handroanthus heptaphyllus (Vell.) Mattos*	Leaf/stem	Fusiform	Brown	No	Porto Murtinho/Chaco	36
Bignoniaceae	*Tabebuia roseoalba* (Ridl.) Sandwith	Leaf vein	Fusiform	Green	No	Bodoquena/Atlantic Forest	37
Bignoniaceae	*Tanaecium pyramidatum* (Rich.) L.G.Lohmann	Leaf vein	Fusiform	Cream	No	Aquidauana/Cerrado	38
Bignoniaceae	Bignoniaceae sp.	Leaf	Conical	Green	Yes	Aquidauana/Cerrado	39
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	Leaf	Globoid	Green	Yes	Aquidauana/Cerrado	40
Cannabaceae	*Celtis spinosa* Spreng.	Stem	Conical	Green	Yes	Bodoquena/Atlantic Forest	41
Cannabaceae	*Celtis spinosa* Spreng.	Stem	Fusiform	Brown	No	Porto Murtinho/Chaco	42
Caryocaraceae	*Caryocar brasiliense Cambess.*	Leaf	Lenticular	Yellow	Yes	Aquidauana/Cerrado	43
Combretaceae	*Terminalia argentea* Mart.	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	44
Combretaceae	*Terminalia* cf. *fagifolia*	Leaf	Globoid	Yellow	Yes	Aquidauana/Cerrado	45
Connaraceae	*Connarus* cf. *suberosus* Planch.	Leaf	Globoid	Cream	Yes	Aquidauana/Cerrado	46
Connaraceae	*Connarus* cf. *suberosus* Planch.	Leaf	Fusiform	Brown	No	Aquidauana/Cerrado	47
Convolvulaceae	*Ipomoea alba* L.	Stem	Fusiform	Brown	No	Bodoquena/Atlantic Forest	48
Dilleniaceae	*Davilla elliptica* A.St.-Hil.	Stem	Globoid	Brown	No	Bodoquena/Atlantic Forest	49
Erythroxylaceae	*Erythroxylum suberosum* A.St.-Hil.	Leaf	Amorphous	Brown	Yes	Aquidauana/Cerrado	50
Euphorbiaceae	*Manihot tripartita* (Spreng.) Müll.Arg.	Leaf	Cylindrical	Green/red	No	Aquidauana/Cerrado	51
Euphorbiaceae	*Croton floribundus* Spreng.	Leaf	Globoid	Green	No	Bodoquena/Atlantic Forest	52
Euphorbiaceae	*Croton* sp. 1	Stem	Fusiform	Brown	No	Bodoquena/Atlantic Forest	53
Euphorbiaceae	*Croton* sp. 2	Leaf vein	Fusiform	Green	No	Corumbá/Pantanal	54
Euphorbiaceae	*Croton* sp. 2	Leaf	Marginal roll	Green	No	Corumbá/Pantanal	55
Euphorbiaceae	*Sapium glandulosum* (L.) Morong	Leaf vein	Fusiform	Green	No	Porto Murtinho/Chaco	56
Fabaceae	*Anadenanthera peregrina* var. *falcata* (Benth.) Altschul	Leaflets	Globoid with spur	Brown	No	Porto Murtinho/Chaco	57
Fabaceae	*Bauhinia mollis* (Bong.) D.Dietr.	Leaf	Lenticular	Brown	No	Porto Murtinho/Chaco	58
Fabaceae	*Bauhinia holophylla* (Bong.) Steud.	Leaflets junction	Globoid	Green	No	Porto Murtinho/Chaco	59
Fabaceae	*Bauhinia holophylla* (Bong.) Steud.	Leaf	Lenticular	Cream	No	Aquidauana/Cerrado	60
Fabaceae	*Bauhinia holophylla* (Bong.) Steud.	Leaf	Globoid	Cream	Yes	Aquidauana/Cerrado	61
Fabaceae	*Bauhinia longifolia* (Bong.) Steud.	Stem	Amorphous	Brown	No	Aquidauana/Cerrado	62
Fabaceae	*Bauhinia ungulata* L.	Leaf	Conical	Brown	No	Porto Murtinho/Chaco	63
Fabaceae	*Bauhinia ungulata* L.	Leaf	Globoid	Green/red	No	Porto Murtinho/Chaco	64
Fabaceae	*Bauhinia ungulata* L.	Stem	Fusiform	Brown	No	Aquidauana/Cerrado	65
Fabaceae	*Copaifera langsdorffii* Desf.	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	66
Fabaceae	*Copaifera langsdorffii* Desf.	Leaf	Globoid	Yellow	No	Corumbá/Pantanal	67
Fabaceae	*Dipteryx alata* Vogel	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	68
Fabaceae	*Dipteryx alata* Vogel	Leaf	Wrinkle	Green	No	Aquidauana/Cerrado	69
Fabaceae	Fabaceae sp.	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	70
Fabaceae	*Galactia striata* (Jacq.) Urb.	Leaf vein	Fusiform	Green	Yes	Porto Murtinho/Chaco	71

Table 2 (*Continued*)

Host family	Host species	Organ	Shape	Color	Pubescence	Locality/Biome	No. of figure
Fabaceae	*Guibourtia hymenaeifolia* (Moric.) J.Léonard	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	72
Fabaceae	*Guibourtia hymenaeifolia* (Moric.) J.Léonard	Leaf vein	Fusiform	Green	No	Aquidauana/Cerrado	73
Fabaceae	*Guibourtia hymenaeifolia* (Moric.) J.Léonard	Leaf	Globoid	Brown	No	Aquidauana/Cerrado	74
Fabaceae	*Hymenaea stigonocarpa* Mart. ex Hayne	Leaf	Lenticular	Green	Yes	Aquidauana/Cerrado	75
Fabaceae	*Hymenaea stigonocarpa* Mart. ex Hayne	Leaf vein	Lenticular	Green	No	Aquidauana/Cerrado	76
Fabaceae	*Hymenaea stigonocarpa* Mart. ex Hayne	Leaf	Globoid	Brown	No	Aquidauana/Cerrado	77
Fabaceae	*Hymenaea stigonocarpa* Mart. ex Hayne	Leaf	Lenticular	Green	No	Aquidauana/Cerrado	78
Fabaceae	*Inga vera* Willd.	Leaf	Globoid	Brown	No	Corumbá/Pantanal	79
Fabaceae	*Inga vera* Willd.	Leaf	Lenticular	Green	No	Aquidauana/Cerrado	80
Fabaceae	*Inga vera* Willd.	Leaf	Lenticular	Green	No	Corumbá/Pantanal	81
Fabaceae	*Inga vera* Willd.	Leaf	Globoid	Red	Yes	Bodoquena/Atlantic Forest	82
Fabaceae	*Machaerium amplum* Benth.	Leaf	Lenticular	Yellow	No	Aquidauana/Cerrado	83
Fabaceae	*Mimosa* sp. 1	Stem	Fusiform	Green	No	Aquidauana/Cerrado	84
Fabaceae	*Mimosa* sp. 2	Leaflets	Fusiform	Green/red	No	Porto Murtinho/Chaco	85
Fabaceae	*Mimosa* sp. 2	Stem	Fusiform	Brown	No	Porto Murtinho/Chaco	86
Fabaceae	*Mimosa* sp. 3	Leaflets	Leaflets junction	Green	No	Porto Murtinho/Chaco	87
Fabaceae	*Peltogyne confertiflora* (Mart. ex Hayne) Benth.	Leaf	Lenticular	Green	Yes	Aquidauana/Cerrado	88
Fabaceae	*Peltogyne confertiflora* (Mart. ex Hayne) Benth.	Leaf	Globoid	Brown	No	Aquidauana/Cerrado	89
Fabaceae	*Senna velutina* (Vogel) H.S.Irwin & Barneby	Leaf	Lenticular	Brown	Yes	Aquidauana/Cerrado	90
Lamiaceae	*Hyptis brevipes* Poit.	Inflorescence	Floral tube	Not apply	Not apply	Corumbá/Pantanal	91
Lamiaceae	*Hyptis* sp	Leaf	Globoid	Green	Yes	Corumbá/Pantanal	92
Lauraceae	Lauraceae sp.	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	93
Lauraceae	*Persea* sp.	Leaf	Triangular	Green	No	Corumbá/Pantanal	94
Loganiaceae	*Strychnos parvifolia* A.DC.	Leaf	Globoid	Green	Yes	Bodoquena/Atlantic Forest	95
Malpighiaceae	*Amorimia pubiflora* (A.Juss.) W.R.Anderson	Leaf	Lenticular	Green	No	Aquidauana/Cerrado	96
Malpighiaceae	*Amorimia pubiflora* (A.Juss.) W.R.Anderson	Leaf	Triangular	Green	No	Aquidauana/Cerrado	97
Malpighiaceae	*Amorimia pubiflora* (A.Juss.) W.R.Anderson	Leaf	Globoid with spur	Green	No	Aquidauana/Cerrado	98
Malpighiaceae	*Byrsonima crassifolia* (L.) Kunth	Leaf	Lenticular	Red	Yes	Aquidauana/Cerrado	99
Malpighiaceae	*Bunchosia paraguariensis* Nied.	Leaf	Globoid	Brown	Yes	Aquidauana/Cerrado	100
Malpighiaceae	*Mascagnia cordifolia* (A.Juss.) Griseb.	Leaf	Globoid	Green	Yes	Aquidauana/Cerrado	101
Malpighiaceae	*Mascagania sepium* (A.Juss.) Griseb.	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	102
Malpighiaceae	Malpighiaceae sp	Leaf	Wrinkle	Brown	No	Corumbá/Pantanal	103
Malvaceae	*Luehea divaricata* Mart. & Zucc.	Leaf	Globoid	Cream	Yes	Aquidauana/Cerrado	104
Malvaceae	Malvaceae sp.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	105
Malvaceae	*Byttneria dentata* Pohl	Leaf	Globoid	Green	Yes	Corumbá/Pantanal	106
Malvaceae	*Waltheria indica* L.	Stem	Fusiform	Brown	No	Porto Murtinho/Chaco	107
Melastomataceae	Melastomataceae sp.	Leaf	Lenticular	Green	Yes	Aquidauana/Cerrado	108
Meliaceae	*Guarea guidonia* (L.) Sleumer	Leaf vein	Globoid	Cream	No	Aquidauana/Cerrado	109
Menispermaceae	*Cissampelos pareira* L.	Stem	Fusiform	Brown	No	Aquidauana/Cerrado	110
Moraceae	*Brosimum gaudichaudii* Trécul	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	111
Myrtaceae	*Campomanesia pubescens* (Mart. ex DC.) O.Berg	Leaf	Riniform	Green/red	Yes	Aquidauana/Cerrado	112
Myrtaceae	*Eugenia bimarginata* DC.	Leaf	Lenticular	Yellow	No	Aquidauana/Cerrado	113
Myrtaceae	*Eugenia florida* DC.	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	114
Myrtaceae	*Eugenia florida* DC.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	115
Myrtaceae	*Eugenia florida* DC.	Leaf	Globoid	Brown	No	Bodoquena/Atlantic Forest	116
Myrtaceae	*Eugenia florida* DC.	Leaf	Marginal roll	Green/red	No	Bodoquena/Atlantic Forest	117
Myrtaceae	*Eugenia florida* DC.	Leaf	Cylindrical	Green	No	Corumbá/Pantanal	118
Myrtaceae	*Eugenia florida* DC.	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	119
Myrtaceae	*Eugenia punicifolia* (Kunth) DC.	Leaf	Lenticular	Black	No	Aquidauana/Cerrado	120
Myrtaceae	*Eugenia punicifolia* (Kunth) DC.	Leaf	Lenticular	Black	No	Porto Murtinho/Chaco	121
Myrtaceae	*Eugenia punicifolia* (Kunth) DC.	Stem	Fusiform	Brown	No	Aquidauana/Cerrado	122
Myrtaceae	*Eugenia punicifolia* (Kunth) DC.	Stem	Fusiform	Brown	No	Porto Murtinho/Chaco	123
Myrtaceae	*Myrcia* sp.	Leaf	Lenticular	Green	No	Aquidauana/Cerrado	124
Myrtaceae	*Myrcia* sp.	Stem	Globoid	Red	No	Aquidauana/Cerrado	125
Myrtaceae	*Psidium guajava* L.	Leaf	Marginal roll	Brown	Not apply	Bodoquena/Atlantic Forest	126
Onagraceae	*Ludwigia longifolia* (DC.) H.Hara	Leaf	Lenticular	Green	No	Porto Murtinho/Chaco	127
Piperaceae	*Piper* sp.	Leaf	Marginal roll	Green	Not apply	Bodoquena/Atlantic Forest	128
Proteaceae	*Roupala montana* Aubl.	Leaf	Lenticular	Brown	No	Aquidauana/Cerrado	129
Rubiaceae	*Bathysa* sp.	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	130
Rubiaceae	*Guettarda pohliana* Müll.Arg.	Stem	Fusiform	Green	No	Bodoquena/Atlantic Forest	131
Rubiaceae	*Psychotria carthagenensis* Jacq	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	132
Rubiaceae	*Psychotria carthagenensis* Jacq	Leaf	Globoid	Orange	No	Bodoquena/Atlantic Forest	133
Rubiaceae	*Psychotria carthagenensis* Jacq	Leaf	Globoid	Red	Yes	Bodoquena/Atlantic Forest	134
Rubiaceae	*Psychotria carthagenensis* Jacq.	Leaf	Globoid	Yellow	No	Bodoquena/Atlantic Forest	135
Rubiaceae	*Psychotria carthagenensis* Jacq.	Leaf	Fusiform	Brown	No	Bodoquena/Atlantic Forest	136
Rubiaceae	*Randia armata* (Sw.) DC.	Leaf vein	Lenticular	Green	No	Bodoquena/Atlantic Forest	137
Rubiaceae	*Randia armata* (Sw.) DC.	Leaf	Globoid	Brown	No	Corumbá/Pantanal	138
Rubiaceae	Rubiaceae sp. 1	Stem	Fusiform	Brown	No	Porto Murtinho/Chaco	139
Rubiaceae	Rubiaceae sp. 2	Stem	Fusiform	Brown	No	Bodoquena/Atlantic Forest	140
Rutaceae	*Zanthoxylum* sp.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	141

Table 2 (*Continued*)

Host family	Host species	Organ	Shape	Color	Pubescence	Locality/Biome	No. of figure
Rutaceae	*Zanthoxylum* sp.	Leaf	Lenticular	White	No	Bodoquena/Atlantic Forest	142
Rutaceae	*Zanthoxylum* sp.	Stem	Fusiform	Green	No	Bodoquena/Atlantic Forest	143
Rutaceae	*Zanthoxylum riedelianum* Engl.	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	144
Salicaceae	*Casearia* sp.	Leaf vein	Fusiform	Green	No	Bodoquena/Atlantic Forest	145
Salicaceae	*Casearia gossypiosperma* Briq.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	146
Salicaceae	*Casearia sylvestris* Sw.	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	147
Salicaceae	*Casearia sylvestris* Sw.	Leaf	Triangular	Green	No	Bodoquena/Atlantic Forest	148
Salicaceae	*Casearia sylvestris* Sw.	Stem	Fusiform	Brown	No	Bodoquena/Atlantic Forest	149
Salicaceae	*Xylosma* sp.	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	150
Sapindaceae	*Magonia pubescens* A.St.-Hil.	Leaf	Globoid	Green	No	Aquidauana/Cerrado	151
Sapindaceae	*Magonia pubescens* A.St.-Hil.	Leaf	Globoid	Green	No	Porto Murtinho/Chaco	152
Sapindaceae	*Magonia pubescens* A.St.-Hil.	Leaf	Globoid	Green	No	Porto Murtinho/Chaco	153
Sapindaceae	*Matayba guianensis* Aubl.	Leaf	Lenticular	Green	Yes	Aquidauana/Cerrado	154
Sapindaceae	*Serjania* cf. *caracasana* (Jacq.) Willd.	Leaf	Lenticular	Green	No	Corumbá/Pantanal	155
Sapindaceae	*Serjania* cf. *caracasana* (Jacq.) Willd.	Leaf	Globoid	Green	No	Corumbá/Pantanal	156
Sapindaceae	*Serjania* cf. *crassifolia* Radlk.	Leaf	Globoid	Green	No	Aquidauana/Cerrado	157
Sapindaceae	*Serjania* cf. *crassifolia* Radlk.	Leaf	Amorphous	Green	No	Aquidauana/Cerrado	158
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf vein	Fusiform	Green	No	Aquidauana/Cerrado	159
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf	Cylindrical	Green	Yes	Bodoquena/Atlantic Forest	160
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	161
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf	Lenticular	Green	No	Corumbá/Pantanal	162
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf vein	Globoid	Green	No	Bodoquena/Atlantic Forest	163
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf	Globoid	Brown	No	Bodoquena/Atlantic Forest	164
Sapindaceae	*Serjania* cf. *glabrata* Kunth	Leaf	Conical	Green	No	Bodoquena/Atlantic Forest	165
Sapindaceae	*Serjania* sp. 1	Leaf	Globoid	Green	No	Aquidauana/Cerrado	166
Sapindaceae	*Serjania* sp. 2	Leaf	Cylindrical	Brown	No	Corumbá/Pantanal	167
Sapindaceae	*Serjania* sp. 2	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	168
Sapindaceae	*Serjania* sp. 2	Leaf	Conical	Green	Yes	Corumbá/Pantanal	168
Sapindaceae	*Serjania* sp. 2	Tendril	Fusiform	Green	Yes	Corumbá/Pantanal	169
Sapindaceae	*Serjania* sp. 3	Leaf	Lenticular	Cream	No	Corumbá/Pantanal	170
Sapindaceae	*Serjania* sp. 3	Leaf	Globoid	Brown	No	Corumbá/Pantanal	171
Sapindaceae	*Serjania* sp. 4	Leaf	Cylindrical	Green/pink	No	Aquidauana/Cerrado	172
Sapindaceae	*Serjania* sp. 4	Leaf	Lenticular	Brown	Yes	Aquidauana/Cerrado	173
Sapotaceae	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	174
Sapotaceae	*Pouteria torta* (Mart.) Radlk.	Leaf	Cylindrical	Green	Yes	Aquidauana/Cerrado	175
Smilacaceae	*Smilax polyantha* Griseb.	Leaf	Amorphous	Green	No	Aquidauana/Cerrado	176
Smilacaceae	*Smilax* sp. 1	Leaf	Lenticular	Brown	No	Bodoquena/Atlantic Forest	177
Smilacaceae	*Smilax* sp. 2	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	178
Solanaceae	*Cestrum strigilatum* Ruiz & Pav.	Leaf	Lenticular	White	No	Bodoquena/Atlantic Forest	179
Solanaceae	*Cestrum* sp.	Leaf	Globoid	Brown	No	Aquidauana/Cerrado	180
Solanaceae	*Solanum paniculatum* L.	Leaf	Globoid	Yellow	Yes	Bodoquena/Atlantic Forest	181
Solanaceae	Solanaceae sp. 1	Leaf	Lenticular	Brown	No	Corumbá/Pantanal	182
Solanaceae	Solanaceae sp. 2	Leaf	Lenticular	Green	No	Bodoquena/Atlantic Forest	183
Vochysiaceae	*Qualea grandiflora* Mart.	Leaf	Lenticular	Green	No	Aquidauana/Cerrado	184
Vochysiaceae	*Qualea multiflora* Mart.	Leaf	Globoid	Green	No	Aquidauana/Cerrado	185

by Fernandes and Negreiros (2006), Bregonci et al. (2010), Santos et al. (2011), Saito and Urso-Guimarães (2012), followed by globoid (30%), and fusiform (17%); 80% of the galls were glabrous, corroborating the findings of Urso-Guimarães et al. (2003), which refuted the idea of trichomes as a defense against immature gall-makers (Table 6).

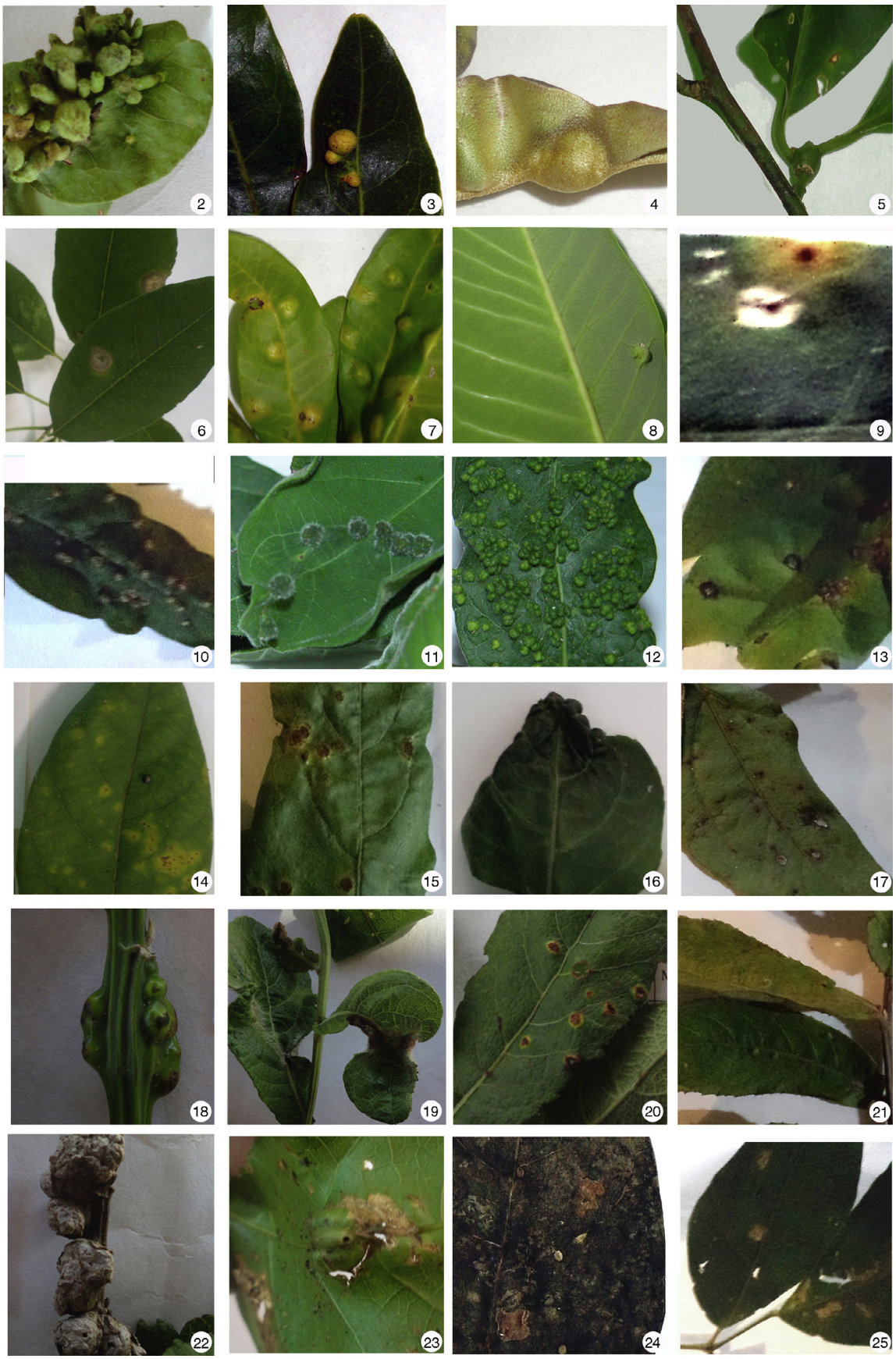
In the biomes, the numbers were slightly different (Table 6). Leaf remains as the most frequent organ attacked by galls, but the percentages ranged from 71% to 93%. Lenticular gall shape was the most common in Pantanal (41%), Cerrado (38%), and Atlantic Forest (38%), but not in Chaco, where the shape most commonly found was fusiform (43%). Chaco is a very dry biome, and the fusiform and globoid shapes are often the swelling of plant tissue, resulting in galls with thicker walls. In our opinion, those swollen galls are the less susceptible to desiccation of immatures than any other gall shape, which can explain the high number of them in a dry environment. The absence of trichomes in galls predominated in all vegetation types, with presence ranging only between 9.5% and 35%.

We obtained and identified the inducers of 50 morphotypes of galls in 38 host plants (20%), 78% of which belongs to Diptera (Cecidomyiidae), 10% to Hymenoptera, and the other 12% are divided among Hemiptera, Thysanoptera, Coleoptera, and Lepidoptera (Table 7). The gall makers of 136 morphotypes could not be determined, because gall samples were collected empty, old, or senescent.

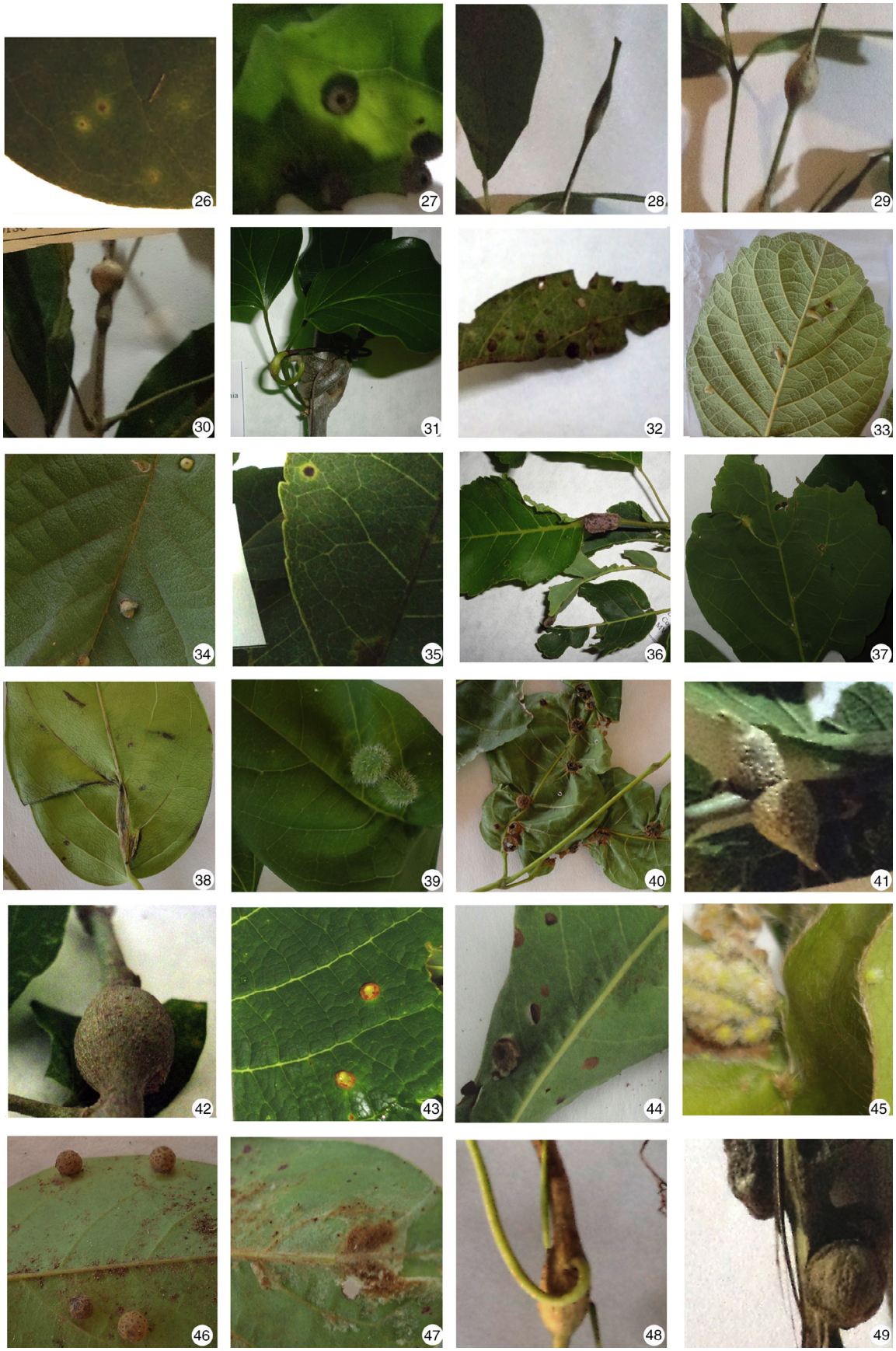
The Cecidomyiidae was the dominant family in Diptera. We identified five species of Cecidomyiidae present in galls, the gall makers *Contarinia* sp. And *Youngomyia pouteriae* Maia, 2004, and the inquilines *Trotteria quadridentata* Maia, 2004, *Camptoneuromyia* sp 1, and *Camptoneuromyia* sp 2. The hymenopterans obtained were from four morphotypes, *Mononeuron duguetiae* Fischer, 1981 (Braconidae), associated with leaf galls of *Duguetia furfuracea* (A.St.-Hil.) Saff., and three parasitoid species from the Chalcidoidea superfamily. Additional information about associated fauna is presented in Table 8.

The geographic distribution of gall morphotypes associated with the cecidomyiids *Youngomyia pouteriae* and *Trotteria quadridentata*, and the wasp *Mononeuron duguetiae* were expanded to the localities sampled in Mato Grosso do Sul. In MS, the host plant of *Youngomyia pouteriae* is *Pouteria torta*, as opposed to the originally described host plant (*Pouteria caimito*) in the restinga.

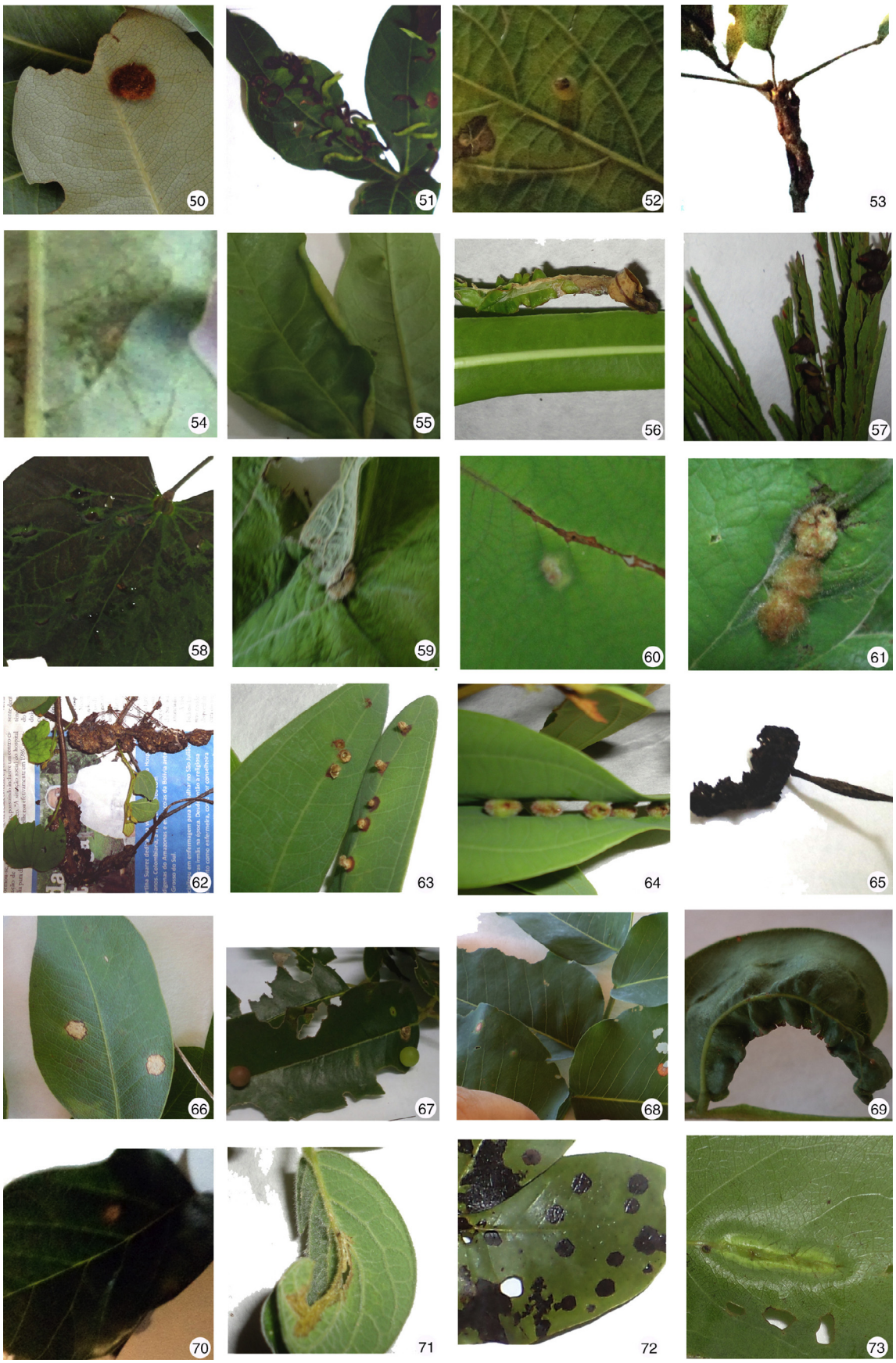
All occurrences of Cecidomyiidae in Mato Grosso do Sul localities are new records. We identified four new records of host plant genera: *Byttneria*, *Galactia*, *Guibourtia*, *Tanaecium*; and



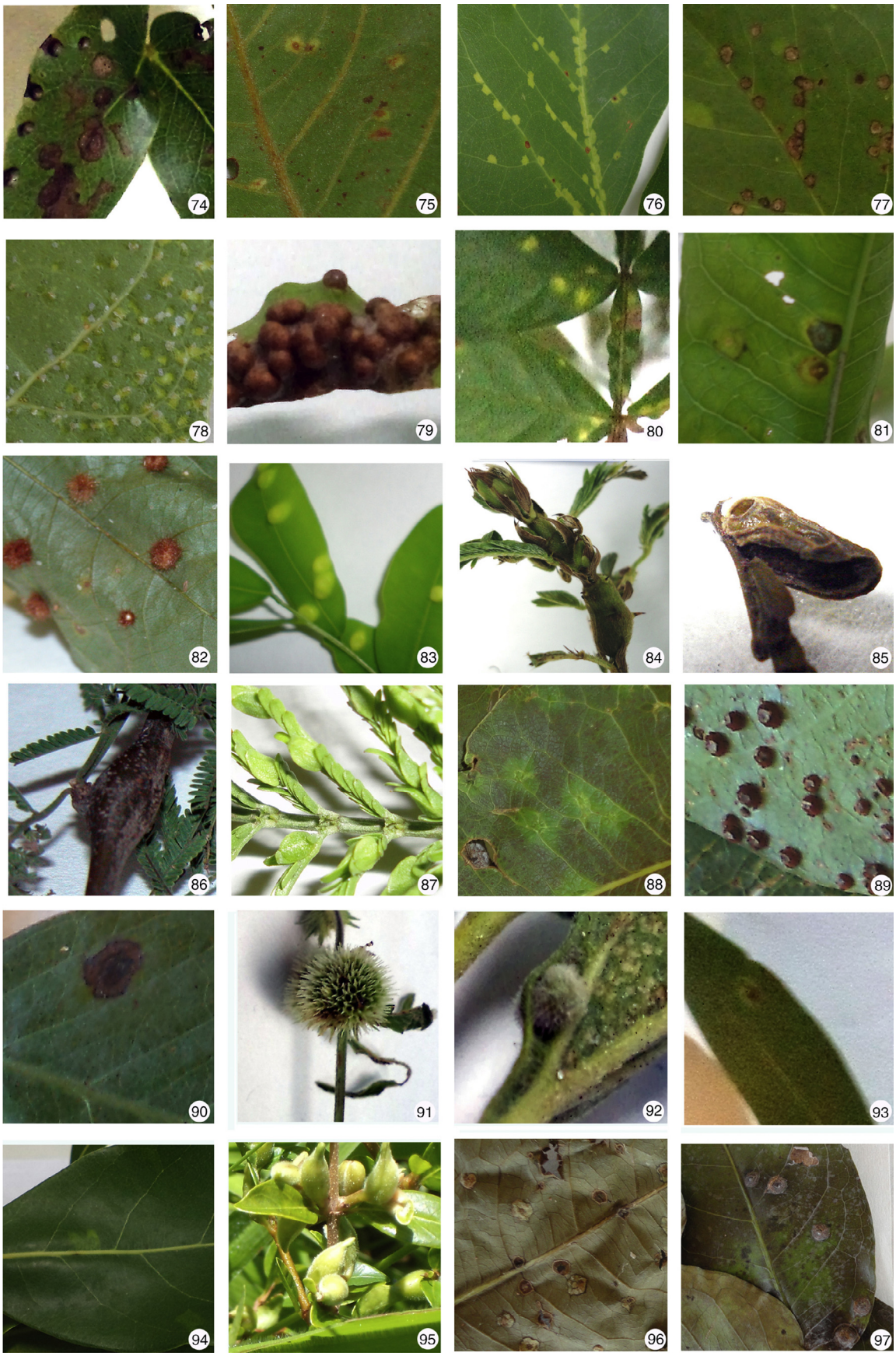
Figs. 2–25. Insect galls of Mato Grosso do Sul in host plants indicated. 2. *Annona emarginata*; 3 and 4. *Duguetia furfuracea*; 5. *Annonaceae* sp.; 6. *Aspidosperma cylindrocarpon*; 7 and 8. *Aspidosperma olivaceum*; 9. *Aspidosperma subincanum*; 10–13. *Forsteronia rufa*; 14. *Forsteronia velloziana*; 15. *Asteraceae* sp. 1; 16. *Asteraceae* sp. 2; 17. *Mikania* sp.; 18. *Vernonia polyanthes*; 19–22. *Vernonanthura brasiliana*; 23. *Adenocalymma bracteatum*; 24 and 25. *Fridericia chica*.



Figs. 26–49. Insect galls of Mato Grosso do Sul in host plants indicated. 26–29. *Fridericia chica*; 31. *Fridericia caudigera*; 32. *Handroanthus chrysotrichus*; 33 and 34. *Handroanthus ochraceus*; 35 and 36. *Handroanthus heptaphyllus*; 37. *Tabebuia roseoalba*; 38. *Tanaecium pyramidatum*; 39. *Bignoniaceae* sp.; 40. *Protium heptaphyllum*; 41 and 42. *Celtis spinosa*; 43. *Caryocar brasiliense*; 44. *Terminalia argentea*; 45. *Terminalia* cf. *fagifolia*; 46. *Connarus* cf. *suberosus*; 47. *Connarus* cf. *suberosus*; 48. *Ipomoea alba*; 49. *Davilla elliptica*.

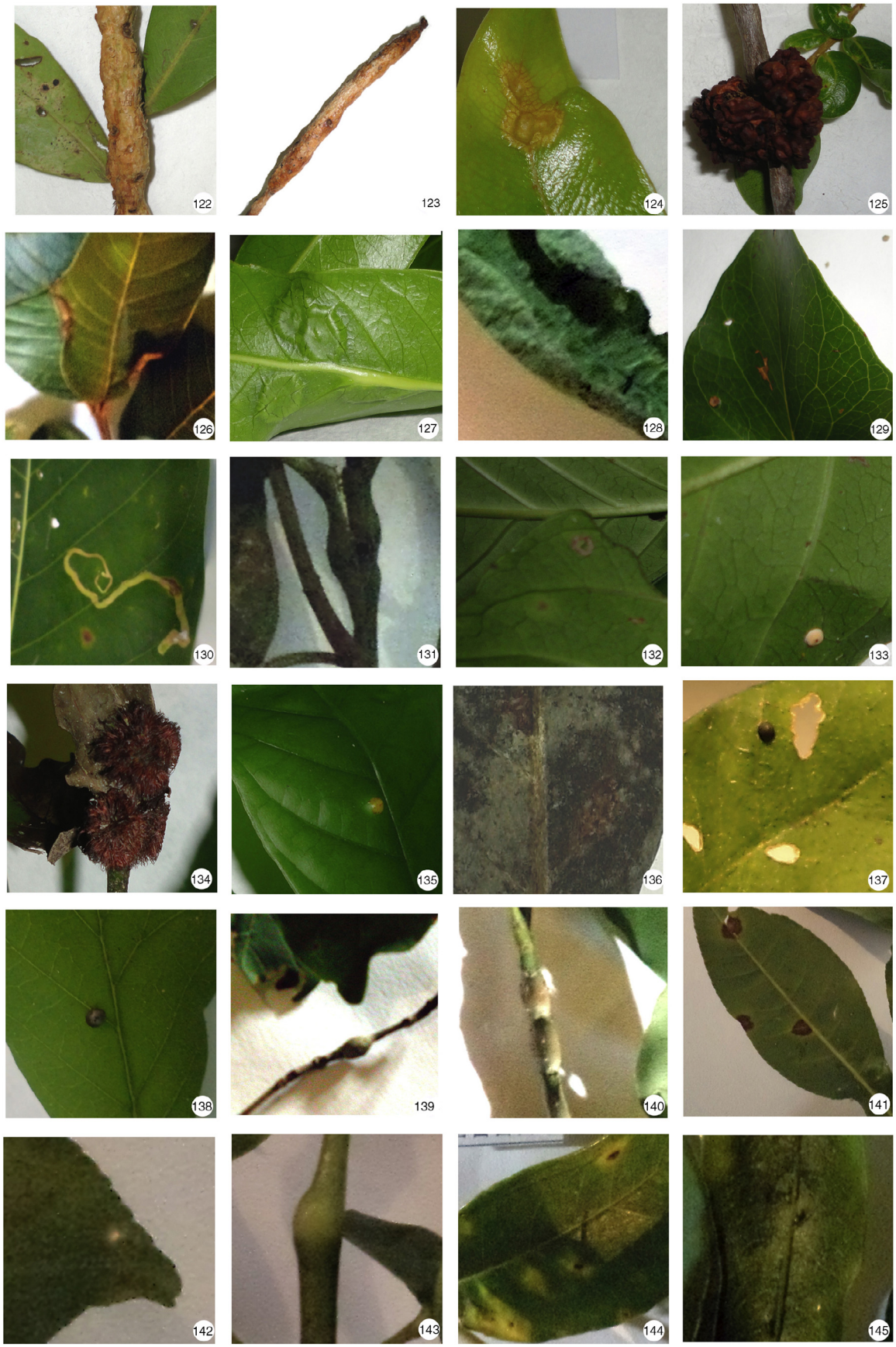


Figs. 50–73. Insect galls of Mato Grosso do Sul in host plants indicated. 50. *Erythroxylum suberosum*; 51. *Manihot tripartite*; 52. *Croton floribundus*; 53. *Croton* sp. 1; 54 and 55; *Croton* sp. 2; 56. *Sapium glandulosum*; 57. *Anadenanthera peregrina* var. *falcate*; 58. *Bauhinia mollis*; 59. *Bauhinia holophylla*; 60 and 61. *Bauhinia holophylla*; 62. *Bauhinia longifolia*; 63–65. *Bauhinia ungulate*; 66 and 67. *Copaifera langsdorffii*; 68 and 69. *Dipteryx alata*; 70. Fabaceae sp.; 71. *Galactia striata*; 72 and 73. *Guibourtia hymenaeifolia*.

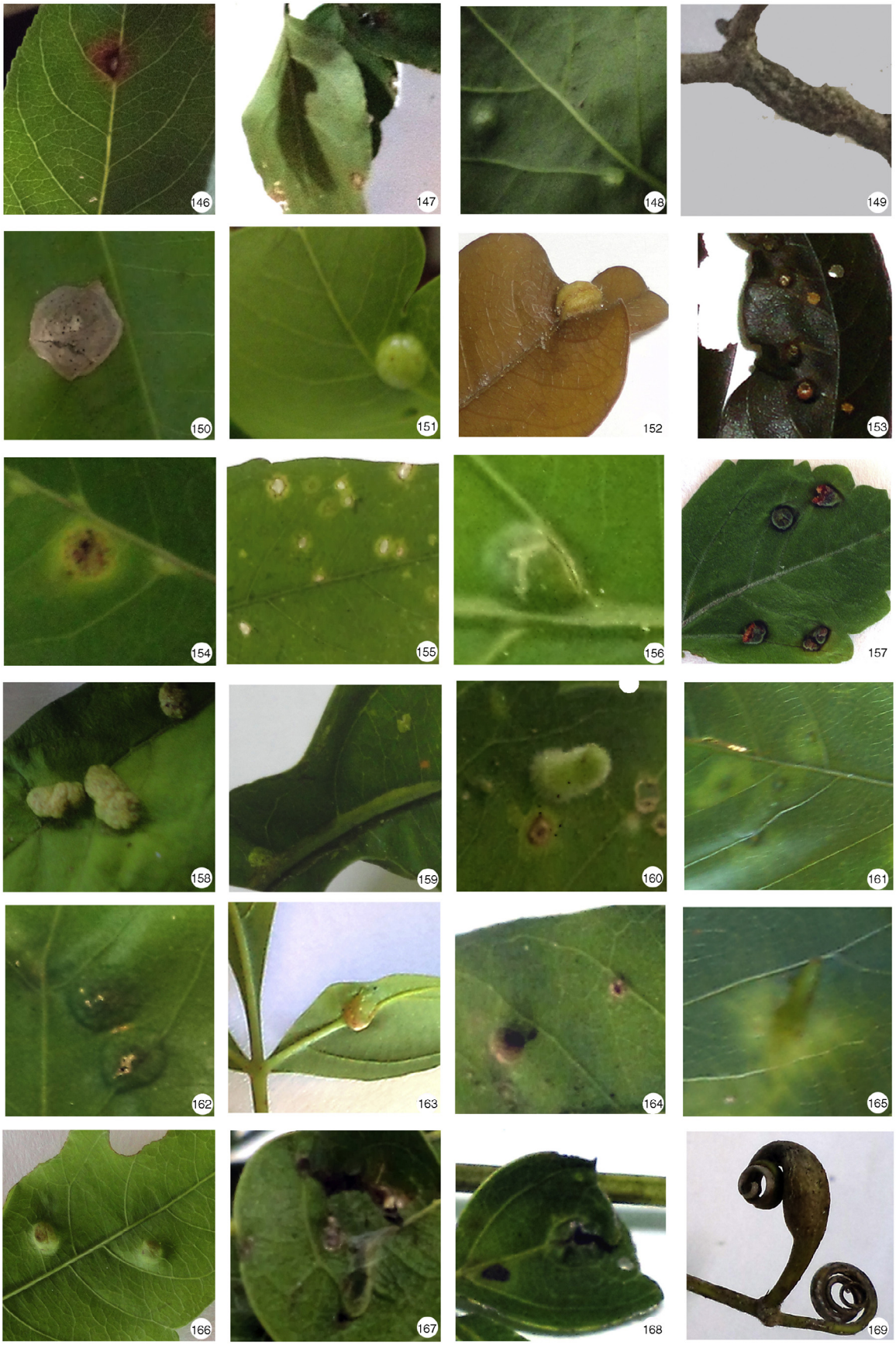


Figs. 74–97. Insect galls of Mato Grosso do Sul in host plants indicated. 74. *Guibourtia hymenaeifolia*; 75–78. *Hymenaea stigonocarpa*; 79–82. *Inga vera*; 83. *Machaerium amplum*; 84. *Mimosa* sp. 1; 85 and 86. *Mimosa* sp. 2; 87. *Mimosa* sp. 3; 88 and 89. *Peltogyne confertiflora*; 90. *Senna velutina*; 91. *Hyptis brevipes*; 92. *Hyptis* sp.; 93. Lauraceae sp.; 94. *Persea* sp.; 95. *Strychnos parvifolia*; 96 and 97. *Amorimia pubiflora*.

Figs. 98–121. Insect galls of Mato Grosso do Sul in host plants indicated. 99. *Amorimia pubiflora*; 99. *Byrsonima crassifolia*; 100. *Bunchosia paraguariensis*; 101. *Mascagnia cordifolia*; 102. *Mascagania sepium*; 103. Malpighiaceae sp.; 104. *Luehea divaricata*; 105. Malvaceae sp.; 106. *Byttneria dentata*; 107. *Waltheria indica*; 108. *Melastomataceae* sp.; 109. *Guarea guidonia*; 110. *Cissampelos pareira*; 111. *Brosimum gaudichaudii*; 112. *Campomanesia pubescens*; 113. *Eugenia bimarginata*; 114–119. *Eugenia florida*; 120 and 121. *Eugenia punicifolia*.



Figs. 122–145. Insect galls of Mato Grosso do Sul in host plants indicated. 122 and 123. *Eugenia punicifolia*; 124 and 125. *Myrcia* sp.; 126. *Psidium guajava*; 127. *Ludwigia longifolia*; 128. *Piper* sp.; 129. *Roupala montana*; 130. *Bathysa* sp.; 131. *Guettarda pohliana*; 132–136. *Psychotria carthagenensis*; 137 and 138. *Randia armata*; 139. *Rubiaceae* sp. 1; 140. *Rubiaceae* sp. 2; 141–143. *Zanthoxylum* sp.; 144. *Zanthoxylum riedelianum*; 145. *Casearia* sp.



Figs. 146–169. Insect galls of Mato Grosso do Sul in host plants indicated. 146. *Casearia gossypiosperma*; 147–149. *Casearia sylvestris*; 150. *Xylosma* sp.; 151–153. *Magonia pubescens*; 154. *Matayba guianensis*; 155 and 156. *Serjania* cf. *caracasana*; 157 and 158. *Serjania* cf. *crassifolia*; 159–165. *Serjania* cf. *glabrata*; 166. *Serjania* sp. 1; 167–169. *Serjania* sp. 2.

Table 3
Richness of insect galls in several localities of biomes of Atlantic Forest, Cerrado, Seasonally Tropical Dry Forests (STDF), and Dry Tropical Forests (DTF) of Brazil.

Locality	Number of gall morphotypes	Number galled plant families	Number galled plant genera	Number galled plant species	Average number of gall/host plant species	Biome
Mato Grosso do Sul (this study)	186	35	73	115	1.6	Cerrado, Atlantic Forest, Pantanal, Chaco
Pantanal do Abobral, MS (Julião et al., 2002)	133	37	60	75	1.7	Pantanal
Goiânia, GO (Araújo et al., 2014)	97	24	37	55	1.8	Cerrado
Estação Ecológica do Jataí, Luiz Antônio, SP (Saito and Urso-Guimarães, 2012)	69	24	35	41	1.7	Cerrado
Parque Estadual de Vaçununga, Santa Rita do Passa Quatro, SP (Urso-Guimarães and Scarelli-Santos, 2006)	35	16	24	25	1.4	Cerrado
Delfinópolis, MG (Urso-Guimarães et al., 2003)	22	16	19	19	1.2	Cerrado, rupestrian fields (STDF), riparian forest
Reserva Biológica Boqueirão, Ingaí, MG (Malves and Frieiro-Costa, 2012)	36	14	18	26	1.4	Cerrado, rupestrian fields (STDF), riparian forest
Serra de São José, Tiradentes, MG (Maia and Fernandes, 2004)	137	47	30	73	1.8	Cerrado, rupestrian fields (STDF)
Serra do Cipó, MG (Coelho et al., 2009)	92	19	37	51	1.8	Rupestrian fields (STDF)
Cadeia do Espinhaço, MG (Carneiro et al., 2009b)	241	29	78	142	1.6	Rupestrian fields (STDF)
Serra do Caitité, BA (Nogueira et al., 2016)	49	13	18	27	1.8	Cerrado, Caatinga (TDF)
Pernambuco (Santos et al., 2011)	64	17	31	48	1.3	Caatinga (TDF)
Serra do Cabral, MG (Coelho et al., 2013)	47	21	32	39	1.2	Cerrado, rupestrian fields (STDF)

Table 4
Richness of insect galls per biomes in Mato Grosso do Sul.

Locality/Biome	Richest plant families	Super host genera	Super host species	Total of galls
Mato Grosso do Sul (this study)	Fabaceae (34) Sapindaceae (24) Bignoniaceae (17) Myrtaceae (15)	*Serjania* (20) *Eugenia* (11) *Bauhinia* (8) *Fridericia* (8)	*Fridericia chica* (7) *Serjania* cf. *glabrata* (7) *Eugenia florida* (6)	186
Aquidauana/Cerrado (this study)	Fabaceae (20) Sapindaceae (8) Myrtaceae (7)	*Serjania* (6) *Bauhinia* (4) *Eugenia* (4) *Hymenaea* (4)	*Hymenaea stigonocarpa* (4) *Guibourtia hymenaeifolia* (3)	68
Atlantic Forest (this study)	Bignoniaceae (9) Asteraceae (8) Rubiaceae (8)	*Fridericia* (8) *Casearia* (5) *Serjania* (5)	*Fridericia chica* (7) *Serjania* cf. *glabrata* (5)	65
Corumbá/Pantanal (this study)	Sapindaceae (9) Apocynaceae (3)	*Serjania* (9)	*Serjania* sp. 7 (4)	32
Porto Murtinho/Chaco (this study)	Fabaceae (9)	*Bauhinia* (4) *Mimosa* (3)	*Bauhinia ungulata* (2) *Eugenia punicifolia* (2) *Forsteronia rufa* (2) *Magonia pubescens* (2) *Mimosa* sp. 3 (2)	21
Pantanal do Abobral/Pantanal (Julião *et al.*, 2002)	Bignoniaceae (18) Fabaceae (13) Sapindaceae (11) Hippocrateaceae (7)	*Serjania* (12) *Hippocratea* (6)	*Hippocratea volubilis* (6) *Inga vera* (5)	133

24 new records of host plant species: *Adenocalymma bracteatum*, *Annona emarginata*, *Aspidosperma olivaceum*, *Aspidosperma subincanum*, *Bauhinia mollis*, *Brosimum gaudichaudii*, *Byttneria dentata*, *Casearia gossypiosperma*, *Celtis spinosa*, *Cestrum strigilatum*, *Forsteronia rufa*, *Forsteronia velloziana*, *Galactia striata*, *Guettarda pohliana*, *Guibourtia hymenaeifolia*, *Hymenaea martiana*, *Ipomoea alba*, *Mascagnia cordifolia*, *Peltogyne confertiflora*, *Smilax polyantha*, *Solanum paniculatum*, *Strychnos parvifolia*, *Tanaecium pyramidatum* and *Zanthoxylum riedelianum*.

Our most relevant findings include the survey of 186 gall morphotypes in MS; leaves remain as the organ most frequently attacked by galls, and the most common gall shape was lenticular in Pantanal (41%), Cerrado (38%), and Atlantic Forest (38%), and fusiform (43%) in Chaco. The galls were found in 115 plant

Table 5
Richness of gall morphotypes in host plants in several localities of dry vegetation of Brazil. STDF, Seasonally Tropical Dry Forest; TDF, Tropical Dry Forest.

Locality	Biomes	Richest families	Richest genera (superhosts)	Richest species (superhosts)
Mato Grosso do Sul (this study)	Cerrado, Atlantic Forest, Pantanal, Chaco	Fabaceae (34) Sapindaceae (24) Bignoniaceae (17) Myrtaceae (15)	*Serjania* (20) *Eugenia* (11) *Bauhinia* (8) *Fridericia* (8)	*Fridericia chica* (7) *Serjania* cf. *glabrata* (7) *Eugenia florida* (6)
Pantanal do Abobral, MS (Julião et al., 2002)	Pantanal	Bignoniaceae (18) Fabaceae (13) Sapindaceae (11) Hyppocrateaceae (7)	*Serjania* (12) *Hippocratea* (6)	*Hippocratea volubilis* (6) *Inga vera* (5)
Goiânia, GO (Araújo et al., 2014)	Cerrado	Myrtaceae (17) Fabaceae (14)	*Myrcia* (10) *Qualea* (10)	*Andira cujabensis* (4) *Myrcia guianensis* (4)
Estação Ecológica do Jataí, Luiz Antônio, SP (Saito and Urso-Guimarães, 2012)	Cerrado	Annonaceae (10) Malpighiaceae (9) Fabaceae (6)	*Byrsonima* (6) *Duguetia* (5)	*Byrsonima* cf. *intermedia* (6) *Duguetia furfuracea* (5)
Parque Estadual de Vaçununga, Santa Rita do Passa Quatro, SP (Urso-Guimarães and Scarelli-Santos, 2006)	Cerrado	Myrtaceae (5) Fabaceae (5)	*Myrcia* (4) *Bauhinia* (3)	*Myrcia bella* (3) *Bauhinia rufa* (3)
Delfinópolis, MG (Urso-Guimarães et al., 2003)	Cerrado, rupestrian fields (STDF), riparian forest	Fabaceae (5)	*Bauhinia* (2) *Chomelia* (2) *Qualea* (2)	*Bauhinia ungulata* (2) *Chomelia pohliana* (2) *Qualea parviflora* (2)
Reserva Biológica Boqueirão, Ingaí, MG (Malves and Frieiro-Costa, 2012)	Cerrado, rupestrian fields (STDF), riparian forest	Asteraceae (6) Myrtaceae (5) Melastomataceae (3)	*Miconia* (5) *Eugenia* (5)	*Croton* sp. (4)
Serra de São José, Tiradentes, MG (Maia and Fernandes, 2004)	Cerrado, rupestrian fields (STDF)	Fabaceae (20) Myrtaceae (18) Asteraceae (16) Melastomataceae (14)	*Protium* (7) *Baccharis* (6) *Copaifera* (6) *Myrcia* (6)	*Protium heptaphyllum* (7) *Copaifera langsdorffii* (6) *Myrcia* sp. (6) *Croton floribundus* (5) *Miconia theaezans* (5)
Serra do Cipó, MG (Coelho et al., 2009)	Rupestrian fields (STDF)	Fabaceae (22) Myrtaceae (11) Asteraceae (8)	*Bauhinia* (10) *Myrcia* (7) *Baccharis* (6) *Celtis* (6) *Serjania* (6)	*Baccharis dracunculifolia* (5) *Celtis brasiliensis* (5)
Cadeia do Espinhaço, MG (Carneiro et al., 2009b)	Rupestrian fields (STDF)	Asteraceae (39) Melastomataceae (26) Malpighiaceae (22) Fabaceae (21)	*Baccharis* (92) *Byrsonima* (17) *Microlicia* (10) *Lessingianthus* (10) *Lychnophora* (10)	*Baccharis pseudomyriocephala* (10) *Byrsonima coccolobifolia* (8)
Serra do Caitité, BA (Nogueira et al., 2016)	Cerrado, Caatinga (TDF)	Fabaceae (22) Malpighiaceae (10)	*Copaifera* (10) *Bauhinia* (6) *Mimosa* (4)	*Copaifera langsdorffii* (9) *Bauhinia acuruana* (5)
Pernambuco (Santos et al., 2011)	Caatinga (TDF)	Fabaceae (15) Euphorbiaceae (9) Boraginaceae (4) Malpighiaceae (4) Myrtaceae (4)	*Croton* (4) *Cnidoscolus* (3) *Bauhinia* (2) *Byrsonima* (2)	*Bauhinia cheilantha* (4)
Serra do Cabral, MG (Coelho et al., 2013)	Cerrado, rupestrian fields (STDF)	Asteraceae (70) Malpighiaceae (17) Fabaceae (17)	*Byrsonima* (27) *Lessingianthus* (17)	*Byrsonima guilleminiana* (3)

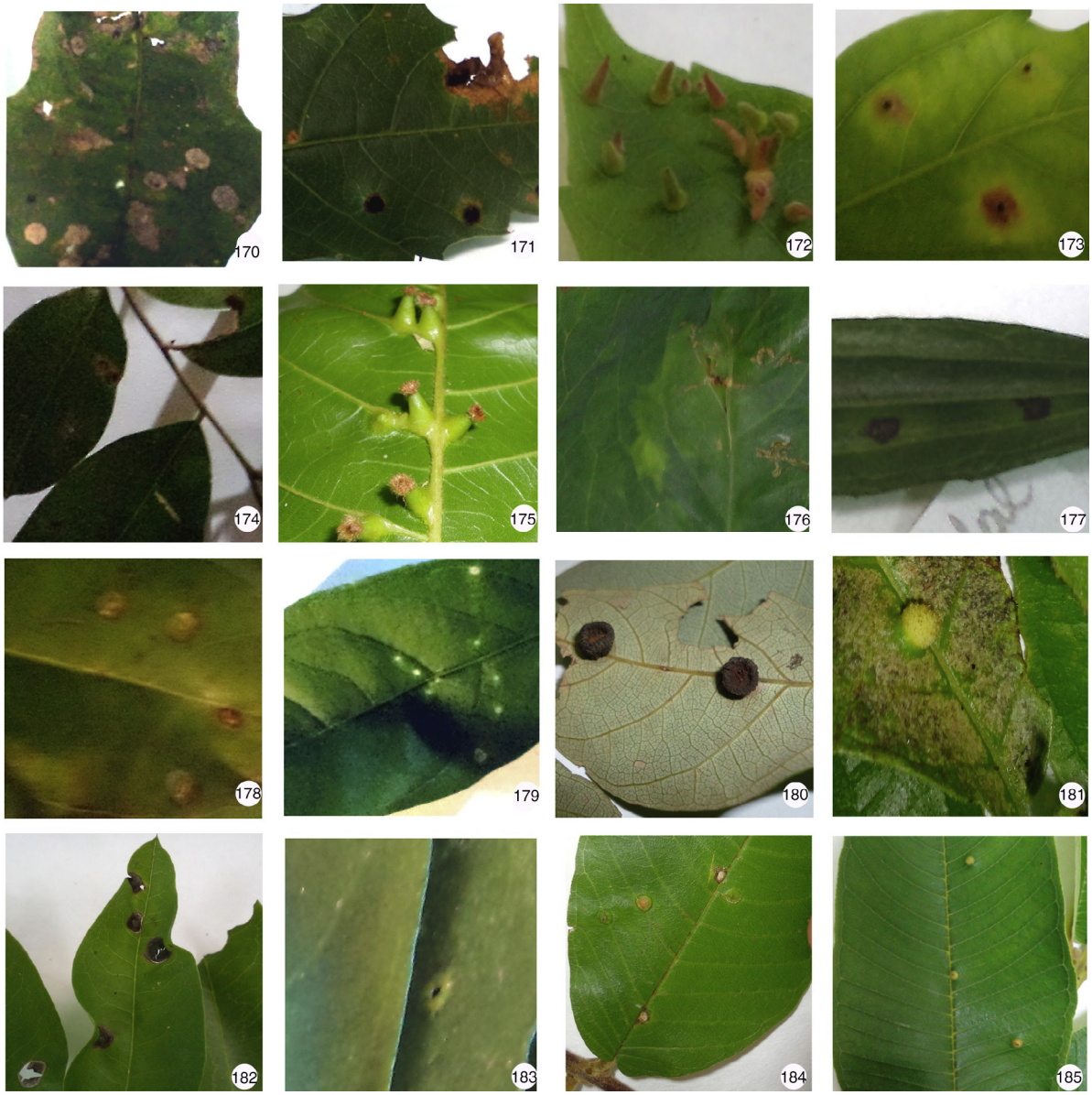
Table 6
Description of predominant gall morphotypes recorded in the Mato Grosso do Sul (Brazil) and in each biome.

Locality/Biome	Number of morphotypes	Organ more afected	Shape more frequent	Pubescence	Predominant color of galls
Mato Grosso do Sul	186	Leaf (85%)	Lenticular (35%), globoid (30%), fusiform (17%)	20%	Green (47%)
Aquidauana/Cerrado	68	Leaf (93%)	Lenticular (38%), globoid (30%), fusiform (12%)	35%	Green (48%)
Bodoquena/Atlantic Forest	65	Leaf (77%)	Lenticular (37%), globoid (30%), fusiform (18.5%)	11%	Green (46%)
Corumbá/Pantanal	32	Leaf (94%)	Lenticular (41%), globoid (28%), fusiform (9%)	16%	Green (44%)
Porto Murtinho/Chaco	21	Leaf (71%)	Fusiform (43%), globoid (33%), lenticular (13%)	9.5%	Green (52%)

Table 7
Gall makers and associated fauna in galls of Mato Grosso do Sul biomes.

Associated fauna	Number of morphotypes obtained	Percentual
Diptera	39	78%
Hymenoptera	5	10%
Hemiptera	2	4%
Thysanoptera	2	4%
Coleoptera	1	2%
Lepidoptera	1	2%

species, with host families and species richness varying according to the biome: Cerrado - Fabaceae and *Hymenaea stigonocarpa*; Atlantic Forest: Bignoniaceae and *Friedericia chica*; Pantanal: Sapindaceae and *Serjania* sp. 7; and Chaco: Fabaceae and *Bauhinia ungulata*. Although we did not aim to verify the hygrothermal hypothesis, our surveys were conducted in biomes with marked differences in humidity. As supplementary information, when different biomes of MS were compared, we did not find an increase in gall richness in low-humidity environments as stated by Price et al. (1998), Fernandes and Price (1991), Julião et al. (2014) (Table 4),



Figs. 170–185. Insect galls of Mato Grosso do Sul in host plants indicated. 170 and 171. *Serjania* sp. 3; 172 and 173. *Serjania* sp. 4; 174. *Chrysophyllum marginatum*; 175. *Pouteria torta*; 176. *Smilax polyantha*; 177. *Smilax* sp. 1; 178. *Smilax* sp. 2; 179. *Cestrum strigilatum*; 180. *Cestrum* sp.; 181. *Solanum paniculatum*; 182. Solanaceae sp. 1; 183. Solanaceae sp. 2; 184. *Qualea grandiflora*; 185. *Qualea multiflora*.

Table 8
Insect fauna obtained in the galls sampled in the Mato Grosso do Sul environments and their habits. Figures refer to gall morphotype's image.

Host family	Host species	Insects	Habit	Figure
Annonaceae	*Annona emarginata*	Diptera (Phoridae, adult)	inquiline	2
Annonaceae	*Duguetia furfuracea*	Hymenoptera (Braconidae, Doryctinae, adult)	parasitoid	3
Annonaceae	*Duguetia furfuracea*	Diptera (Cecidomyiidae, Cecidomyiidi, larva)	gall maker	4
Asteraceae	Asteraceae sp.2	Thysanoptera (adult)	gall maker	16
Bignoniaceae	*Fridericia chica*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	28
Bignoniaceae	*Fridericia chica*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	28
Bignoniaceae	*Handroanthus* cf. *ochraceus*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	33
Cannabaceae	*Celtis spinosa*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	41
Cannabaceae	*Celtis spinosa*	Lepidoptera (exuvia, adult)	inquiline	42
Caryocaraceae	*Caryocar brasiliense*	Hemiptera (Diaspididae, adult)	gall maker	43
Combretaceae	*Terminalia* cf. *fagifolia*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	45
Convolvulaceae	*Ipomoea alba*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	48
Dilleniaceae	*Davilla elliptica*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	49
Erythroxylaceae	*Erythroxylum suberosum*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	50
Euphorbiaceae	*Manihot tripartita*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	51
Euphorbiaceae	*Manihot tripartita*	Diptera (Cecidomyiidae, *Camptoneuromyia*, adult)	inquiline	51
Euphorbiaceae	*Croton floribundus*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	52
Euphorbiaceae	*Croton floribundus*	Hymenoptera (Chalcidoidea, adult)	parasitoid	52

Table 8 (*Continued*)

Host family	Host species	Insects	Habit	Figure
Fabaceae	*Guibourtia hymenaeifolia*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	72
Fabaceae	*Guibourtia hymenaeifolia*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	74
Fabaceae	*Hymenaea stigonocarpa*	Hymenoptera (Chalcidoidea, adult)	inquiline	75
Fabaceae	*Inga vera*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	79
Fabaceae	*Inga vera*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	80
Fabaceae	*Inga vera*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	81
Fabaceae	*Inga vera*	Coleoptera (larva)	inquiline	81
Fabaceae	*Inga vera*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	82
Fabaceae	*Inga vera*	Diptera (Cecidomyiidae, *Camptoneuromyia*, larva, exuvia, adult)	inquiline	82
Fabaceae	*Inga vera*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	82
Fabaceae	*Mimosa* sp.2	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	85
Fabaceae	*Mimosa* sp.3	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	87
Lamiaceae	*Hyptis brevipes*	Hymenoptera (Chalcidoidea, adult)	parasitoid	91
Loganiaceae	*Strychnos parvifolia*	Diptera (Cecidomyiidae, *Contarinia*, larva)	gall maker	95
Malpighiaceae	*Amorimia pubiflora*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	96
Malpighiaceae	*Amorimia pubiflora*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	97
Malpighiaceae	*Amorimia pubiflora*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	98
Malpighiaceae	*Amorimia pubiflora*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	inquiline	98
Malpighiaceae	*Mascagnia cordifolia*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	101
Malpighiaceae	*Mascagnia cordifolia*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	inquiline	101
Malvaceae	*Waltheria indica*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	107
Meliaceae	*Guarea guidonia*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	109
Myrtaceae	*Psidium guajava*	Thysanoptera (adult)	gall maker	126
Sapindaceae	*Magonia pubescens*	Hymenoptera (Chalcidoidea, adult)	parasitoid	151
Sapindaceae	*Serjania* cf. *glabrata*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	160
Sapotaceae	*Pouteria torta*	Cecidomyiidae (*Youngomyia pouteriae*, larva)	gall maker	175
Sapotaceae	*Pouteria torta*	Cecidomyiidae (*Trotteria quadridentata*, pupa, adult)	inquiline	175
Solanaceae	*Cestrum* sp.	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	180
Solanaceae	*Cestrum* sp.	Hemiptera (Physilidae, nymph)	inquiline	180
Solanaceae	*Solanum paniculatum*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	181
Solanaceae	Solanaceae sp.2	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	183
Vochysiaceae	*Qualea grandiflora*	Diptera (Cecidomyiidae, Cecidomyiinae, larva)	gall maker	184

reinforcing the richness hypothesis (Fernandes, 1992; Mendonça, 2007). In addition, we presented four new records of host plant genera, with *Eugenia* and *Fridericia* described as superhost species for the first time. The gall makers are mostly represented by Diptera, mainly Cecidomyiidae species recorded for the first time in Mato Grosso do Sul. We also found that *Youngomyia pouteriae* is no longer a monophagous species, since we found this gall-maker in *Pouteria torta* rather than in the originally described host plant (*Pouteria caimito*).

Conflicts of interest

The authors declare no conflicts of interest.

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