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ARTICLE

Diversity of insect galls in *veredas* of the Brazilian Cerrado in Minas Gerais, Brazil

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Abstract. Brazilian *veredas* are hygrophilous communities with high species diversity, featuring many floristic studies but a still incipient number of faunistic studies. In the present study, we conducted an inventory of insect galls in four different *veredas* located in the Northern region of Minas Gerais, Brazil. Overall, we found 75 gall morphotypes, distributed across 50 host species representing 37 plant genera and 22 families. Fabaceae was the plant family with the greatest number of insect gall morphotypes (n = 21), followed by Malpighiaceae (n = 10). The plant genera that supported the highest diversity of insect galls were *Copaifera* (n = 8) and *Byrsomima* (n = 5). The plant species *Copaifera oblongifolia* (n = 6) and *Anacardium humile* (n = 4) exhibited the highest richness of insect galls. The leaves were the most attacked organs (89% of all galls). Most morphotypes are glabrous (83%), green (69%) and lenticular (60%). The taxa of gall-inducing insects were identified for 46 morphotypes (80%), and were recorded inducers from the orders Diptera, Lepidoptera, and Hymenoptera. Cecidomyiidae (Diptera) was the most representative galling group, with 42 morphotypes, making up 93.3% of the recorded inducers. Among the sampled *veredas* areas, the Vereda do Peruaçu presented the highest richness of insect gall morphotypes and host plant species. The faunistic similarity was higher in the Pedras and Tiririca *veredas,* followed by Almescla and Peruaçu *veredas.* This is the first systematic inventory of insect galls and their host plant in Brazilian *veredas.* The diversity of insect galls in the studied *veredas* is relatively high when compared to other Brazilian Cerrado vegetation types.

Keywords. Cecidomyiidae; Cerrado; Fabaceae; Galls; Host plants.

INTRODUCTION

Insect galls are abnormal modifications in plant tissues that result from mechanical and/or chemical stimulation, forming structures that provide the inducer with both nutrition and shelter (Tooker *et al.,* 2008). These modifications alter the entire structure of the affected plant organ, primarily due to the attack of gall-inducing insects (Shorthouse *et al.,* 2005). Galling insects are highly specialized herbivores and tend to be species-specific with their host plants (Stone & Schönrogge, 2003). Due to the high degree of specificity between the insect and its host, numerous inventories focusing on insect galls have been conducted across all Brazilian biomes, with a notable prevalence in the Cerrado biome, where most inventories have been documented (Araújo *et al.,* 2019).

The Cerrado is the second largest phytogeographical domain in Brazil, covering 23% of the national territory (Oliveira-Filho & Ratter, 2002). This biome is composed of various types of vegetation, forming a mosaic of different phytophysiognomies, including grasslands, savannas and forests (Ribeiro & Walter, 2008). Among the Cerrado vegetation types, the *veredas* are recognized as hygrophilous communities, featuring soils that are acidic, nutrient-poor, and have high levels of aluminum saturation (Ramos *et al.,* 2006). Due to these edaphic features, *veredas* are characterized by two vegetation strata, the tree stratum, dominated by palm *Mauritia flexuosa* L.f. (Arecaceae), known as *buriti,* and a shrubby-herbaceous grass-

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land that is typically very moist (Fagundes & Ferreira, 2016). In these environments, floristic diversity is influenced by a gradient of humidity related to changes in soil drainage, providing food, refuge, and habitats for a diverse array of fauna (Nunes *et al.,* 2022). However, these ecosystems completely unknown in terms of the fauna of galling insects associated with their host plant.

Studies of insect galls in the Cerrado has been growing in recent years (Cintra *et al.,* 2020). Despite this, some of its phytophysiognomies have been little studied (Araújo *et al.,* 2014a), such as the case of *veredas.* The *veredas* are a very common type of vegetation in the Cerrado of the Northern region of the state of Minas Gerais (Ávila *et al.,* 2021). In this region, anthropogenic pressures such as agriculture and livestock farming have led to a reduction in the water table level and the drying out of many *veredas* (Nunes *et al.,* 2022). Thus, in addition to understanding natural ecological processes, the study of *vereda* communities in the region is also important for comprehending how anthropogenic impacts affect the diversity of insect galls and host plants. Therefore, the objective of the present study was to conduct an inventory of galling insects and their host plants within the *veredas* of the Cerrado.

MATERIAL AND METHODS

The study was performed in *vereda* areas situated in the Northern region of the state of Minas Gerais, Brazil (Fig. 1). This region features a tropical climate classified as *Aw* according to the Köppen classification (Alvares *et al.,* 2013), characterized by dry winters and an average annual temperature ranging from 22.2 to 22.7°C. Annual precipitation in the region ranges from 1,008 and 1,073 milimeters. The studied landscape encompasses a blend of Cerrado and Caatinga transitional phytophysiognomies, resulting in a diverse mosaic of riparian forests, dry forests, savannas, and palm swamps commonly referred to as *veredas* (Ávila *et al.,* 2021). The *veredas* are characterized by different zones, namely the edge zone (transition with cerrado *sensu stricto*), middle zone (grassland vegetation), and back zone (tree vegetation with dominance of *Mauritia flexuosa*) (Nunes *et al.,* 2022).

Our data collection was conducted across four distinct *veredas* (Fig. 1): Vereda das Pedras (14°53′18″S and 45°20′31″W) and Vereda da Tiririca (14°53′2″S and 45°19′10″W), both situated within the RPPN Porto Cajueiro within the Cochá e Gibão Environmental Protection Area, located in the municipality of Januária; Vereda da

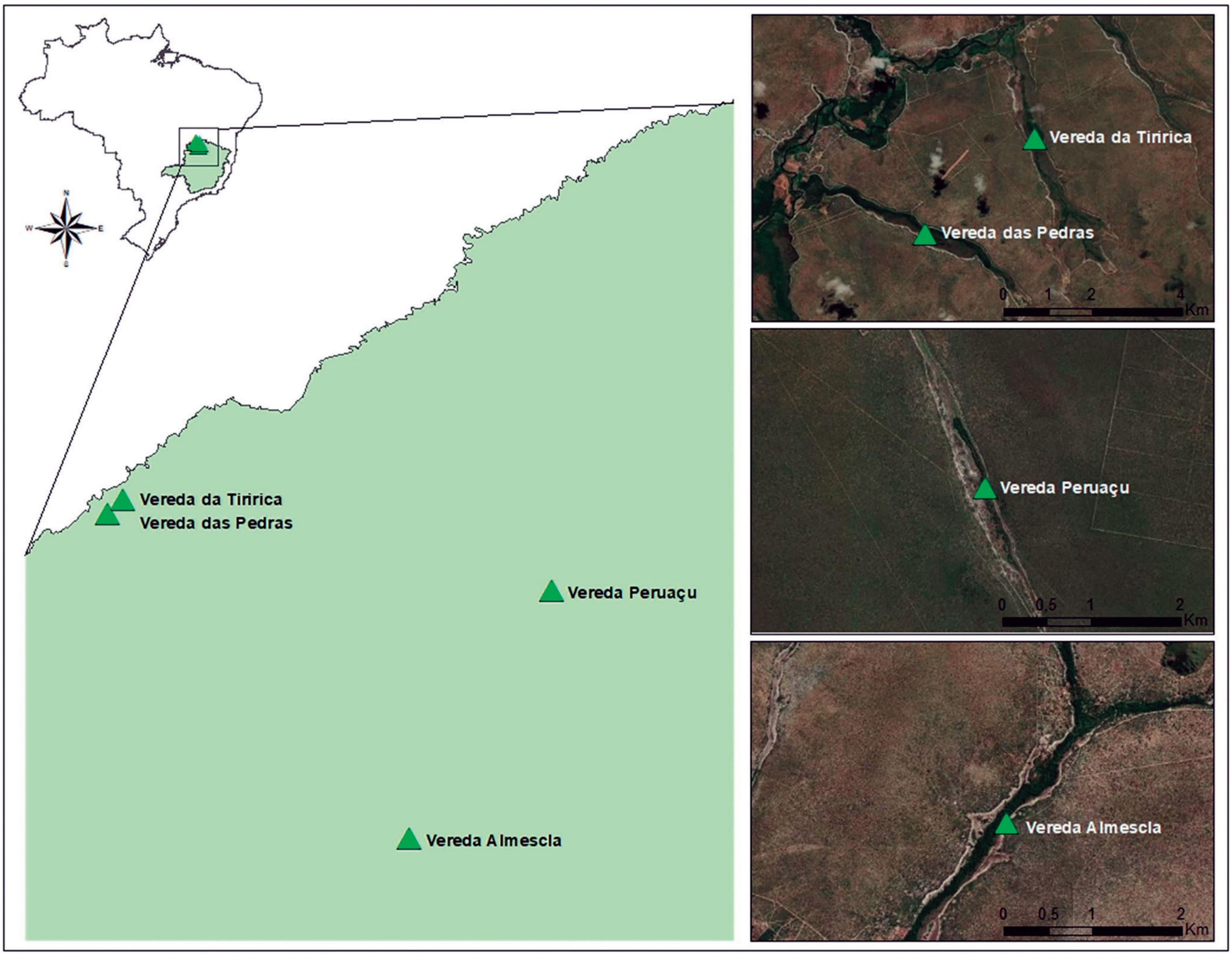

Figure 1. Location of the four *vereda* areas sampled in the Northern region of Minas Gerais, Brazil. Codes indicates Vereda das Pedras (VPed) and Vereda da Tiririca (VT) located at the RPPN Porto Cajueiro in the Cochá e Gibão Environmental Protection Area; Vereda da Almescla (VA), located in the Rio Pandeiros Environmental Protection Area, and Vereda do Peruaçu (VPer), situated in the Veredas do Peruaçu State Park.

Almescla (15°21′37″S and 44°54′45″W) positioned within the Rio Pandeiros Environmental Protection Area, situated in the municipality of Bonito de Minas; and Vereda do Peruaçu (14°56′13″S and 44°37′44″W) located in the Veredas do Peruaçu State Park, spanning the municipalities of Januária and Cônego Marinho. Each of the studied *vereda* area has approximately 6 kilometers in length, and the average altitude ranges from 800 to 900 meters.

Sampling of insect galls and host plants was performed in April 2023 (rainy season) and September 2023 (dry season). The sampling was carried out in each of the four *veredas,* covering the upstream, middle, and downstream sections of the *veredas.* Sampling was concentrated in the middle and back sections in each *vereda,* at the transition from grassy vegetation to woody vegetation. Insect gall collect was performed across random searches over a duration of one hour, with two individuals simultaneously conducting the survey. During this process, they meticulously scanned the vegetation up to a height of 3 meters, attentively observing for the presence of insect galls (Mendonça *et al.,* 2010). The sampled insect galls were classified into morphotypes based on the host plant species and their external characteristics (Araújo *et al.,* 2021), which include factors such as the location of occurrence, shape, color, pubescence, and size (Isaias *et al.,* 2013). Host plants were identified in the field or collected for identification in the laboratory through consultation of specialized literature. Gall-inducers were determined through gall dissection or consultation of the literature (Araújo *et al.,* 2021).

The data were analyzed through descriptive analyses. In addition, in order to comparing the *veredas,* a cluster analysis based on Jaccard index was performed using the unweighted pair-group average as grouping method. The analysis was performed using the *vegan* package in R software version 4.2.3 (R Development Core Team, 2023).

RESULTS

We found 75 insect gall morphotypes distributed across 22 botanical families, comprising 37 genera and 50 species (Table 1; Fig. 3 to Fig. 5). The average number of insect gall morphotypes per host plant species was 1.5. The plant families with the highest gall richness were Fabaceae, with 21 morphotypes, followed by Malpighiaceae with 10 morphotypes. The remaining families had less than 10 insect gall morphotypes each (Table 1).

The plant genus *Copaifera* L. (Fabaceae) hosted the highest number of insect galls, with eight distinct morphotypes. Other important genera were *Byrsonima* Rich. ex Kunth (Malpighiaceae), *Anacardium* L. (Anacardiaceae), and *Kielmeyera* Mart. & Zucc. (Calophyllaceae), each with five, four and four morphotypes, respectively. The plant species *Copaifera oblongifolia* Mart. ex Hayne. and *Anacardium humile* A. St.-Hil., with six and four morphotypes each, were the most diverse host plants. Other three plant species hosted three gall morphotypes, 11 plant species hosted two morphotypes and 34 plant species hosted only one morphotype (Table 2).

Table 1. Number of host plant species and insect gall morphotypes per host plant family recorded in the studied *veredas.*

Host family	Number of plant genera	Number of plant species	Number of gall morphotypes
Anacardiaceae	1	2	5
Annonacecae	2	2	2
Apiaceae	1	1	1
Asteraceae	0	1	1
Calophyllaceae	1	2	4
Caryocaraceae	1	1	2
Chrysobalanaceae	1	1	1
Combretaceae	1	2	2
Connaraceae	1	1	1
Dilleniaceae	2	2	2
Euphorbiaceae	1	1	1
Fabaceae	9	11	21
Lythraceae	1	1	1
Malpighiaceae	4	7	10
Melastomataceae	3	3	4
Myrtaceae	1	1	1
Nyctaginaceae	1	1	1
Ochnaceae	1	2	3
Opiliaceae	1	1	3
Sapindaceae	1	1	2
Sapotaceae	1	1	1
Vochysiaceae	2	5	6
Total	37	50	75

Gall-inducing insects were identified for 46 morphotypes (80%). The most representative group was Cecidomyiidae (Diptera) with 42 morphotypes, accounting for 93.3% of the recorded inducers. In addition to cecidomyiids, two morphotypes of galls induced by Hymenoptera and two induced by Lepidoptera were recorded. For 43 morphotypes, the inducers were identified at the order or family level, and only for four morphotypes were the gall-inducers identified at the genus and species level. This was the case with the cecidomyiid species *Jatrophobia brasiliensis* (Rubsaamen, 1907) and *Bruggamannia elongata* (Maia & Couri, 1993), which induced galls in *Manihot* sp. (Euphorbiaceae), and *Guapira opposita* (Vell.) Reitz (Nyctaginaceae), respectively. The lepidopteran *Palaeomystella oligophaga* Becker & Adamski, 2008 (Agonoxenidae), which induced galls in *Macairea radula* (Bonpl.) DC. (Melastomataceae), and the hymenopteran *Eurytoma* sp. (Eurytomidae), which induced galls in *Caryocar brasiliense* Camb. (Caryocaraceae).

Galls were found in leaves (n = 68), stems (n = 6) and fruits (n = 1), with predominance of 91% of leaf galls. Eight distinct gall shapes were found: lenticular, globose, conical, fusiform, cylindrical, amorphous, clavate and cup. The lenticular and globose shapes were the most frequent, with 45 and 17 morphotypes, respectively, followed by conical and fusiform, each with four morphotypes, cylindrical (n = 2) and others (n = 1). The gall morphotypes exhibited various colors, including green, brown, red, yellow, and black, with green being the most predominant (69%), followed by brown (24%). The majority of insect galls were glabrous with 62 morphotypes (83%), while the remainders galls were hairy, with 13 morphotypes (17%).

Table 2. Characterization of insect galls recorded in the studied *veredas* in Minas Gerais, Brazil. Legend: VA = Vereda da Almescla, VPed = Vereda das Pedras, VPer = Vereda do Peruaçu, and VT = Vereda da Tiririca.

Host family	Host species	Organ	Shape	Color	Pubescence	*Vereda* area	Gall-inducers	Morphotype number
Anacardiaceae	*Anacardium humile* A. St.-Hil.	Leaf	Lenticular	Green	No	VT	Cecidomyiidae	1
		Leaf	Globoid	Green	No	VT	Cecidomyiidae	2
		Leaf	Fusiform	Green	No	VPer	Cecidomyiidae	3
		Leaf	Lenticular	Green	No	VPer	Cecidomyiidae	4
	Anacardiaceae sp.	Leaf	Conical	Green	No	VPer	Cecidomyiidae	5
Annonacecae	*Annona coriacea* Mart.	Leaf	Lenticular	Green	No	VA		6
	Xylopia aromatica (Lam.) Mart.	Leaf	Lenticular	Green	No	VA		7
Apiaceae	*Arracacia xanthorrhiza* Bancr.	Leaf	Clavate	Yellow	No	VPer		8
Asteraceae	Asteraceae sp.	Leaf	Lenticular	Yellow	Yes	VPer	Cecidomyiidae	9
Calophyllaceae	*Kielmeyera coriacea* Mart. & Zucc.	Leaf	Globoid	Brown	No	VPed/VT/VA	Cecidomyiidae	10
		Leaf	Lenticular	Green	No	VPer	Cecidomyiidae	11
	Kielmeyera sp.	Leaf	Lenticular	Green	No	VPed/VT	Cecidomyiidae	12
		Leaf	Fusiform	Green	No	VPed/VT	Cecidomyiidae	13
Caryocaraceae	*Caryocar brasiliense* Cambess.	Leaf	Globoid	Green	Yes	VPed/VT/VA/VPer	*Eurytoma* sp. (Eurytomidae, Hymenoptera)	14
		Leaf	Lenticular	Green	No	VA/VPer	Hymenoptera	15
Chrysobalanaceae	*Hirtella glandulosa* Spreng.	Leaf	Lenticular	Green	No	VA		16
Combretaceae	*Terminalia corrugata* (Ducke) Gere & Boatwr.	Leaf	Globoid	Green	Yes	VA/VPer	Cecidomyiidae	17
	Terminalia fagifolia Mart. & Zucc.	Leaf	Conical	Brown	Yes	VPer	Cecidomyiidae	18
Connaraceae	*Connarus suberosus* Planch.	Leaf	Lenticular	Green	No	VT	Cecidomyiidae	19
Dilleniaceae	*Curatella americana* L.	Leaf	Lenticular	Brown	No	VA		20
	Davilla elliptica A. St.-Hil.	Leaf	Lenticular	Green	No	VT/VPeru/VA	Cecidomyiidae	21
Euphorbiaceae	*Manihot* sp.	Leaf	Lenticular	Green	No	VPed	*Jatrophobia brasiliensis* (Rubsaamen, 1907) (Cecidomyiidae)	22
Fabaceae	*Andira vermifuga* Mart. ex Benth.	Leaf	Globoid	Green	Yes	VPed/VPer	Cecidomyiidae	23
		Leaf	Amorphous	Brown	No	VA/VPer	Cecidomyiidae	24
		Leaf	Lenticular	Green	No	VA	Cecidomyiidae	25
	Bauhinia forficata Link	Leaf	Lenticular	Green	No	VPer	Cecidomyiidae	26
	Copaifera langsdorffii Desf.	Leaf	Lenticular	Green	No	VA	Cecidomyiidae	27
		Leaf	Cylindrical	Green	No	VPer	Cecidomyiidae	28
	Copaifera oblongifolia Mart.	Leaf	Lenticular	Brown	No	VA		29
		Leaf	Globoid	Brown	No	VA	Cecidomyiidae	30
		Leaf	Cup	Red	No	VA		31
		Stem	Lenticular	Brown	No	VA	Cecidomyiidae	32
		Stem	Globoid	Brown	No	VA		33
		Leaf	Lenticular	Green	No	VA		34
	Dimorphandra mollis Benth.	Leaf	Lenticular	Brown	No	VA/VPer		35
	Machaerium opacum Vogel	Leaf	Lenticular	Green	No	VPed	Cecidomyiidae	36
		Leaf	Lenticular	Black	No	VA	Cecidomyiidae	37
	Senna occidentalis (L.) Link	Leaf	Globoid	Green	No	VA		38
	Bowdichia sp.	Leaf	Lenticular	Green	No	VPer	Cecidomyiidae	39
	Mimosa sp.	Fruit	Lenticular	Green	Yes	VA/VPer		40
	Poecilanthe sp.	Leaf	Lenticular	Green	No	VA/VPer		41
	Fabaceae sp.	Leaf	Lenticular	Green	No	VPed/VT		42
		Leaf	Cylindrical	Green	No	VPer		43
Lythraceae	*Lafoensia pacari* A. St.-Hil.	Leaf	Lenticular	Brown	No	VPer		44
Malpighiaceae	*Banisteriopsis campestris* (A. Juss.) Little	Leaf	Globoid	Green	Yes	VA	Cecidomyiidae	45
		Leaf	Lenticular	Green	Yes	VPer	Cecidomyiidae	46
	Byrsonima subterranea Brade & Markgr.	Leaf	Conical	Brown	Yes	VT	Cecidomyiidae	47
	Byrsonima verbascifolia (L.) DC.	Leaf	Globoid	Brown	Yes	VPer	Cecidomyiidae	48
	Heteropterys byrsonimifolia A. Juss.	Leaf	Fusiform	Green	No	VPer	Cecidomyiidae	49
	Byrsonima sp.	Stem	Globoid	Brown	No	VPer	Cecidomyiidae	50
		Leaf	Conical	Green	Yes	VPed/VT		51
		Leaf	Globoid	Brown	No	VPer		52
	Peixotoa sp.	Leaf	Lenticular	Green	No	VT		53
	Malpighiaceae sp.	Leaf	Lenticular	Red	No	VPer		54

Table 2. Continued.

Host family	Host species	Organ	Shape	Color	Pubescence	*Vereda* area	Gall-inducers	Morphotype number
Melastomataceae	*Macairea radula* (Bonpl.) DC.	Stem	Globoid	Brown	Yes	VPed/VT/VPer/VA	*Palaeomystella oligophaga* Becker & Adamski, 2008 (Agonoxenidae, Lepidoptera)	55
	Miconia albicans (Sw.) Steud.	Leaf	Lenticular	Green	No	VT		56
		Leaf	Lenticular	Green	No	VA		57
	Tibouchina sp.	Leaf	Lenticular	Green	No	VT	Lepidoptera	58
Myrtaceae	*Eugenia dysenterica* DC.	Leaf	Lenticular	Green	No	VA	Cecidomyiidae	59
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	Leaf	Lenticular	Green	No	VPer	*Bruggamannia elongata* Maia & Couri, 1993 (Cecidomyiidae)	60
Ochnaceae	*Ouratea hexasperma* (A. St.-Hil.) Baill.	Leaf	Lenticular	Green	No	VPed/VT/VPer/VA	Cecidomyiidae	61
	Ouratea sp.	Leaf	Lenticular	Green	No	VT/VPer/VPed	Cecidomyiidae	62
		Leaf	Globoid	Green	No	VPer	Cecidomyiidae	63
Opiliaceae	*Agonandra brasiliensis* Benth. & Hook. f.	Stem	Globoid	Brown	No	VPer		64
		Leaf	Lenticular	Green	No	VPer		65
		Stem	Globoid	Green	No	VPer		66
Sapindaceae	*Serjania* sp.	Leaf	Lenticular	Green	No	VA/VPer	Cecidomyiidae	67
		Leaf	Fusiform	Brown	No	VA	Cecidomyiidae	68
Sapotaceae	*Pouteria* sp.	Leaf	Lenticular	Green	No	VT		69
Vochysiaceae	*Qualea grandiflora* Mart.	Leaf	Globoid	Green	No	VA	Cecidomyiidae	70
	Qualea parviflora Mart.	Leaf	Lenticular	Green	No	VT/VPer	Cecidomyiidae	71
		Leaf	Lenticular	Green	Yes	VPer	Cecidomyiidae	72
	Vochysia rufa Mart.	Leaf	Lenticular	Green	No	VA		73
	Vochysia tucanorum Mart.	Leaf	Lenticular	Green	No	VPer		74
	Vochysia sp.	Leaf	Lenticular	Brown	No	VT		75

Table 3. Richness of insect gall morphotypes, host plant species and mean number of galls per host plant species in the studied *veredas* in the Brazilian Cerrado in Minas Gerais, Brazil.

Veredas type	Richness of insect gall morphotypes	Richness of host plant species	Mean of gall morphotypes per host species
Vereda do Peruaçu	39	31	1.26
Vereda da Almescla	32	24	1.33
Vereda da Tiririca	20	18	1.11
Vereda das Pedras	12	11	1.09

The Vereda do Peruaçu showed the greatest diversity of insect galls and host plants, with 39 different morphotypes found on 31 host plant species. This was followed by Vereda da Almescla, Vereda da Tiririca and Vereda das Pedras, which had 32, 20 and 12 insect gall morphotypes, respectively, hosted by 24, 18 and 11 host plant species, respectively (Table 3). Furthermore, the sampling areas that showed the highest faunal similarity were the Pedras and Tiririca *veredas,* followed by Almescla and Peruaçu *veredas* (Fig. 2)

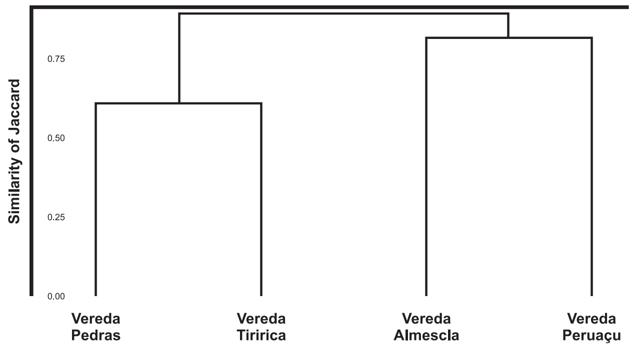

Figure 2. Cladogram of faunal similarity utilizing the Jaccard method for the different studied *veredas.*

DISCUSSION

In the present study we recorded 75 gall morphotypes in the four studied *veredas.* Although there are no previous studies in other Brazilian *veredas* for direct comparison, the richness observed here is relatively high when compared to other Cerrado vegetation types. For example, in a previous study performed in an area of cerrado *sensu stricto* in the EPA of Rio Pandeiros were recorded 40 gall morphotypes (Araújo *et al.,* 2020). In other study, 62 gall morphotypes were recorded in different vegetation types of the Cerrado in the Serra dos Pireneus, Goiás (Araújo *et al.,* 2011). Similarly, 56 morphotypes were recorded in the cerrado *sensu strito* in Caldas Novas, Goiás (Santos *et al.,* 2012) and 22 morphotypes in areas of cerrado, gallery forest and rocky field in Delfinópolis, Minas Gerais (Urso-Guimarães *et al.,* 2003). When reviewing the literature, it becomes evident that only a small number of studies in Cerrado vegetation show a higher richness than what was observed in this study. For example, Maia & Fernandes (2004) recorded 137 morphotypes in Serra de São José, Minas Gerais, while Araújo *et al.* (2014b) documented 97 morphotypes in Parque Nacional das Emas, Goiás, and Gonçalves-Alvim & Fernandes (2001) reported 92 morphotypes in Estação Ecológica de Pirapitinga, Minas Gerais (Table 4).

We also found that the average number of gall morphotypes per plant species was 1.5, which also was high when compared to other Cerrado areas. In the geograph-

Table 4. Richness of insect gall morphotypes, host plant species and mean number of galls per host plant species in different localities studied in the Brazilian Cerrado.

Locality	Richness of insect gall morphotypes	Richness of host plant species	Mean of gall morphotypes per host species	Reference
Veredas – MG	75	50	1.50	Present study
EPA of Rio Pandeiros – MG	40	29	1.38	Araújo *et al.* (2020)
Serra dos Pireneus – Go	62	51	1.22	Araújo *et al.* (2011)
Parque Nacional das Emas – GO	97	44	2.20	Araújo *et al.* (2014b)
Delfinópolis – MG	22	19	1.16	Urso-Guimarães *et al.* (2003)
Santa Rita do Passa Quatro – SP	36	24	1.50	Urso-Guimarães & Scareli-Santos (2006)
Morro do Camisão – MS	68	50	1.36	Urso-Guimarães *et al.* (2017)
Parque Nacional da Chapada dos Guimarães – MT	295	139	2.10	Urso-Guimarães *et al.* (2021)
Campus Pampulha – MG	37	22	1.68	Fernandes *et al.* (1988)
Serra do Cabral – MG	47	39	1.21	Coelho *et al.* (2013)
Caldas Novas – GO	56	34	1.65	Santos *et al.* (2012)
Estação Ecológica de Pirapitinga – MG	92	62	1.48	Gonçalves-Alvim & Fernandes (2001)
Serra de São José – MG	137	73	1.88	Maia & Fernandes (2004)
Campus Samambaia – GO	42	22	1.91	Silva *et al.* (2015)
Estação Ecológica de Jataí – SP	69	41	1.68	Saito & Urso-Guimarães (2012)
Floresta Nacional de Silvania – GO	186	61	3.05	Bergamini *et al.* (2017)

ically closest study to ours, Araújo *et al.* (2020) recorded that the average number of gall morphotypes per host plant species was 1.37. In other studies, in cerrado *sensu stricto* areas, average values of 1.2 and 1.3 were recorded (Araújo *et al.,* 2011; Malves & Friero-Costa, 2012). These results indicate that in *vereda* plants, the number of gall morphotypes per plant is slightly higher than that observed for other Cerrado vegetation types, such as cerrado *sensu stricto* (Table 4).

The gall-inducing insect fauna found in the *veredas* consisted of various significant galling groups, with Cecidomyiidae being the predominant one. Gall-midges are the largest and most diverse group of gall-inducing insects worldwide (Gagné & Jaschhof, 2021). In gall surveys conducted in Brazil, this family has demonstrated considerable diversity and abundance, as summarized in Araújo *et al.* (2019). On the other hand, gall-inducing insects from the Hymenoptera and Lepidoptera orders are less commonly found in the Neotropical region (Araújo *et al.,* 2021). This aligns with the findings of the current study, where these groups collectively accounted for less than 7% of determined gall-inducers.

The galling insect species recorded in our study are also found in other phytogeographic domains and vegetations. For example, *Jatrophobia brasiliensis* was reported in the Amazonian and Atlantic Forest regions (Maia, 2021), as well as in areas of cerrado *sensu stricto* in Minas Gerais (Durães & Araújo, 2020). The species *Bruggmannia elongata* was previously recorded in the Atlantic Forest (Maia, 2021), and *Eurytoma* sp. and *Palaeomystella oligophaga* in different areas of the Brazilian Cerrado (Leite *et al.,* 2009; Araújo *et al.,* 2015). This broader distribution underscores the ecological relevance and potential impact of these species in various ecosystems.

Many inventories assessing gall diversity across various vegetation types within the Cerrado biome indicate that Fabaceae is the predominant host plant family (Fernandes *et al.,* 1997; Maia & Fernandes, 2004; Santos *et al.,* 2010, Araújo *et al.,* 2011), as also observed in the present study. Araújo *et al.* (2014a) suggested that the main reason for the great gall richness hosted by the Fabaceae is its high species number, because Fabaceae is the most speciose family in Brazilian Cerrado (Mendonça *et al.,* 2008). In addition to the high diversity of species, Fabaceae also presents the super-host genus *Copaifera*. This genus is reported as a super-host in different areas of the Brazilian Cerrado (Costa *et al.,* 2010), being the plant genus with the highest gall diversity in the present study. Recent studies have documented *Copaifera* as a highly diverse host plant genus for insect galls, likely due to the genus being very speciose (Grandez-Rios *et al.,* 2020). The species *Copaifera oblongifolia* has also been previously identified as an important host for insect galls (Araújo *et al.,* 2020). Fagundes *et al.* (2019) recorded 15 gall morphotypes on this species at the transition between the Cerrado and Caatinga biomes. Furthermore, this particular species is also classified as a super-host (Grandez-Rios *et al.,* 2020), indicating its exceptional significance in supporting a diverse array of insect gall species. Therefore, the super-host genera and species contribute to the wide diversity of galling insect in the Brazilian *veredas.*

Among the host plant species listed in the studied *veredas* the plants *Arracacia xanthorrhiza, Terminalia corrugata, Curatella americana, Senna occidentalis, Lafoensia pacari, Banisteriopsis campestris,* and *Byrsonima subterranea,* have been recorded for the first time in Brazil as hosting insect galls. Registering these species as hosts is of great significance as it provides crucial information about the interactions between plants and gall-inducing insects. This understanding is fundamental for comprehending the ecology of these particular ecosystems and for their long-term conservation in these areas.

Leaves were the most frequently galled plant organ in our study. This pattern was observed in previous studies, including inventories carried out in the Cerrado areas (Araújo *et al.,* 2014b, Bergamini *et al.,* 2017). This is likely due to leaves being an abundant and renewable resource available to gall-inducers (Maia, 2011). The most common shapes were globoid and lenticular, accompanied by a green color and glabrous surface. These prevalent characteristics are also consistent with findings from previous studies in the Cerrado phytophysiognomies (e.g., Araújo *et al.,* 2019, Urso-Guimarães *et al.,* 2021).

The remarkable variety of galling insects found in the studied *veredas* can be attributed to the fact that these areas are undergoing a drying-out process, largely due to human activities like deforestation and the expanding agriculture. These actions can alter water flow through

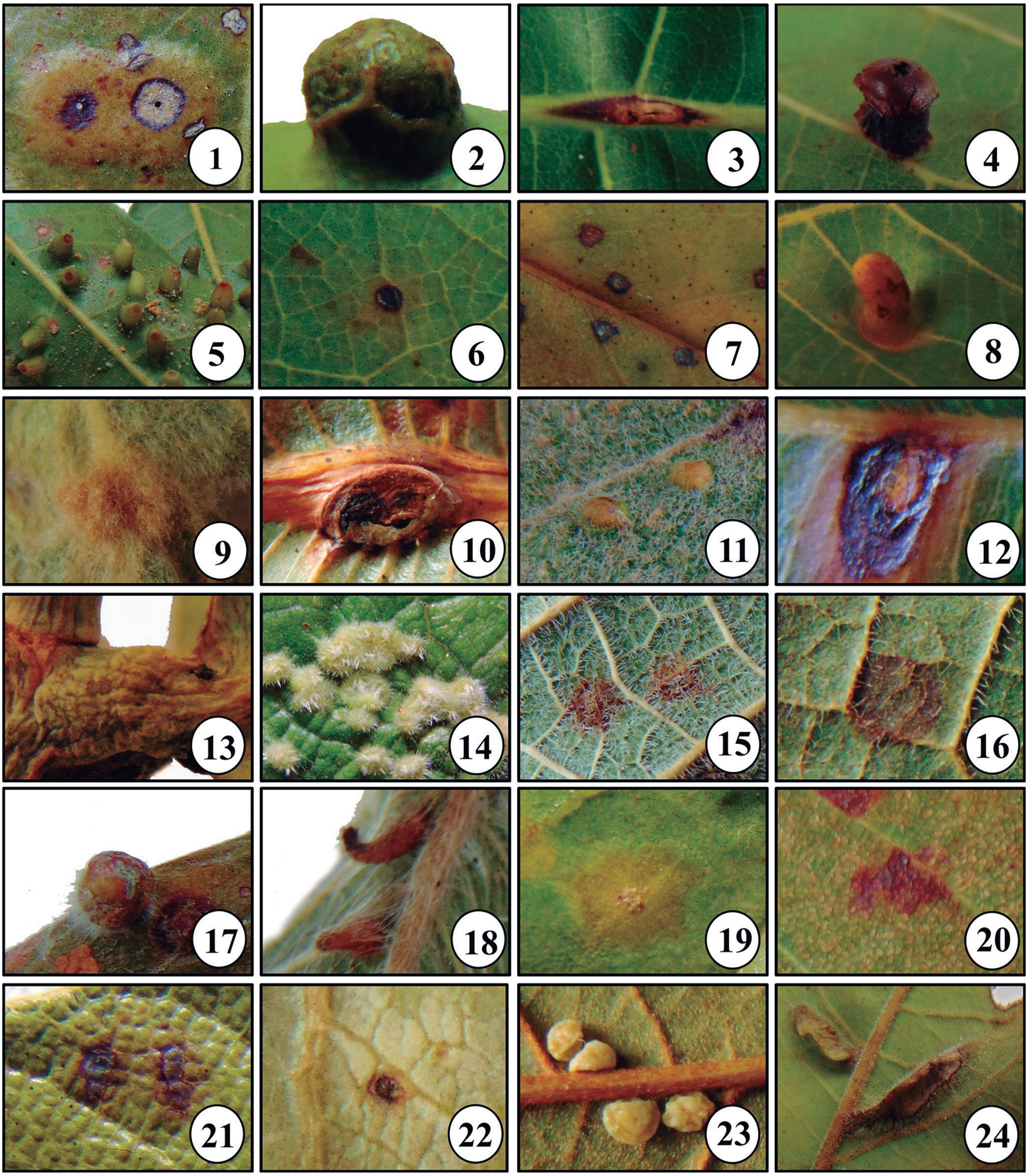

Figure 3. Galls found in four *veredas* types in the in the Northern region of the state of Minas Gerais, Brazil. (1-4) *Anacardium humile:* (1) lenticular-leaf, (2) globoid-leaf, (3) fusiform-leaf, (4) lenticular-leaf); (5) Anacardiaceae sp. (conical-leaf), (6) *Annona coriacea* (lenticular-leaf), (7) *Xylopia aromatica* (lenticular-leaf), (8) *Arracacia xanthorrhiza* (clavate-leaf), (9) Asteraceae sp. (lenticular-leaf), (10-11) *Kielmeyera coriacea:* (10) globoid-leaf, (11) lenticular-leaf); (12-13) *Kielmeyera* sp.: (12) lenticular-leaf, (13) fusiform-leaf; (14-15) *Caryocar Brasiliense:* (14) globoid-leaf, (15) lenticular-leaf); (16) *Hirtella glandulosa* (lenticular-leaf); (17) *Terminalia corrugata* (globoid-leaf); (18) *Terminalia fagifolia* (conical-leaf); (19) *Connarus suberosus* (lenticular-leaf), (20) *Curatella americana* (lenticular-leaf); (21) *Davilla elliptica* (lenticular-leaf); (22) *Manihot* sp. (lenticular-leaf); (23-24) *Andira vermifuge:* (23) globoid-leaf, (24) amorphous-leaf.

intense drainage in the *veredas,* leading to shifts in soil moisture and plant species that grow there (Nunes *et al.*, 2022). As these places transform from being wetlands to becoming drier, more open environments resembling to savannas, it creates better conditions for galling insects. This shift in habitat could potentially be a reason for the increasing numbers of gall-inducing insects in these areas. Corroborating this, our results showed that Vereda do Peruaçu and Vereda da Almescla exhibited the highest diversity of gall morphotypes and host plant species.

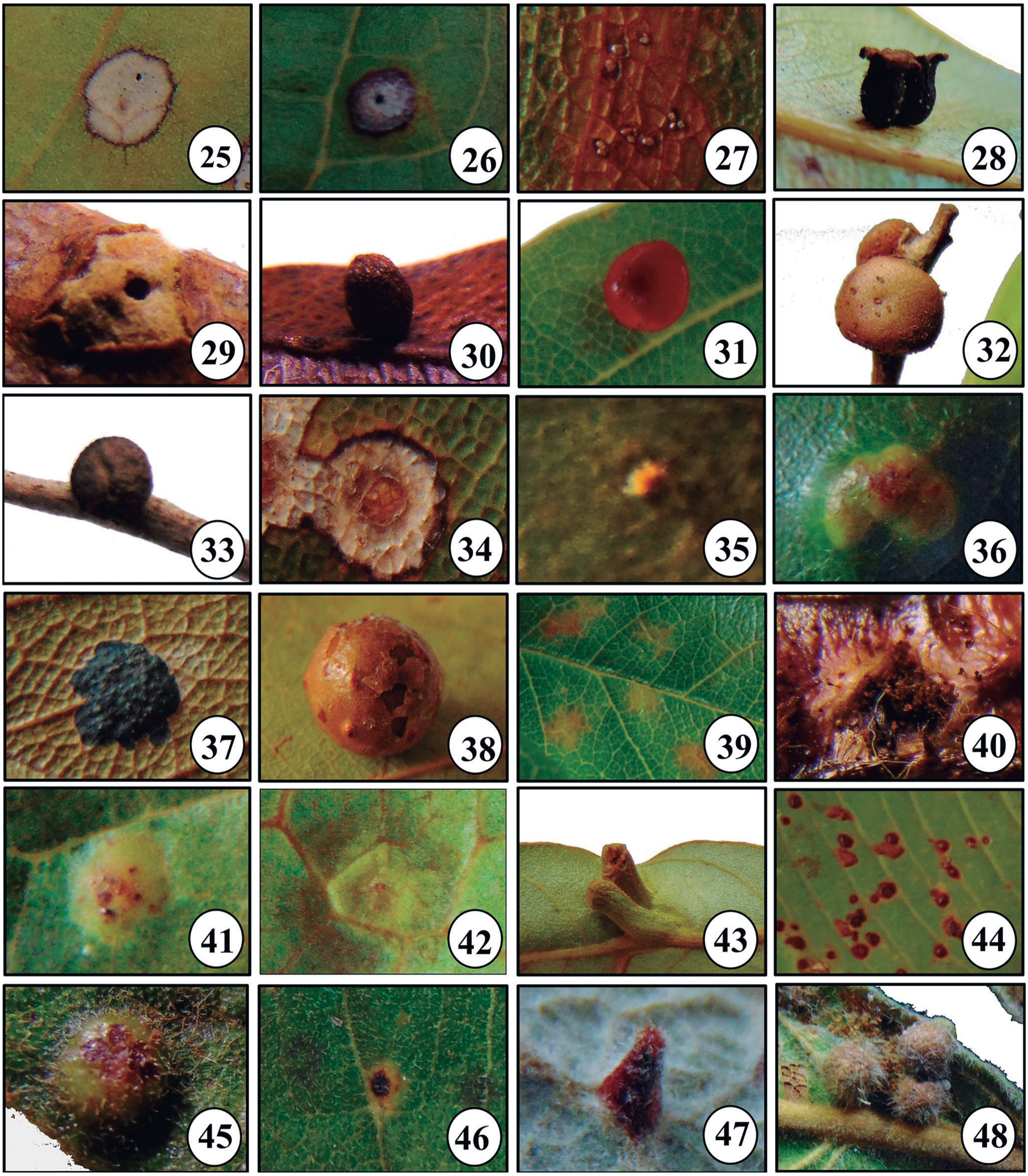

Figure 4. Galls found in four *veredas* types in the in the Northern region of the state of Minas Gerais, Brazil. (25) *Andira vermifuga* (lenticular-leaf); (26) *Bauhinia forficata* (lenticular-leaf); (27-28) *Copaifera langsdorffii:* (27) lenticular-leaf, (28) cylindrical-leaf); (29-34) *Copaifera oblongifolia:* (29) lenticular-leaf, (30) globoid-leaf, (31) cup-leaf, (32) lenticular-stem, (33) globoid-stem, (34) lenticular-leaf; (35) *Dimorphandra mollis* (lenticular-leaf); (36-37) *Machaerium opacum:* (36) lenticular-leaf, (37) lenticular-leaf; (38) *Senna occidentalis* (globoid-leaf); (39) *Bowdichia* sp. (lenticular-leaf); (40) *Mimosa* sp. (lenticular-fruit); (41) *Poecilanthe* sp. (lenticular-leaf); (42-43) Fabaceae sp.: (42) lenticular-leaf, (43) cylindrical-leaf); (44) *Lafoensia pacari* (lenticular-leaf); (45-46) *Banisteriopsis campestris:* (45) globoid-leaf, (46) lenticular-leaf); (47) *Byrsonima subterranea* (conical-leaf); (48) *Byrsonima verbascifolia* (globoid-leaf).

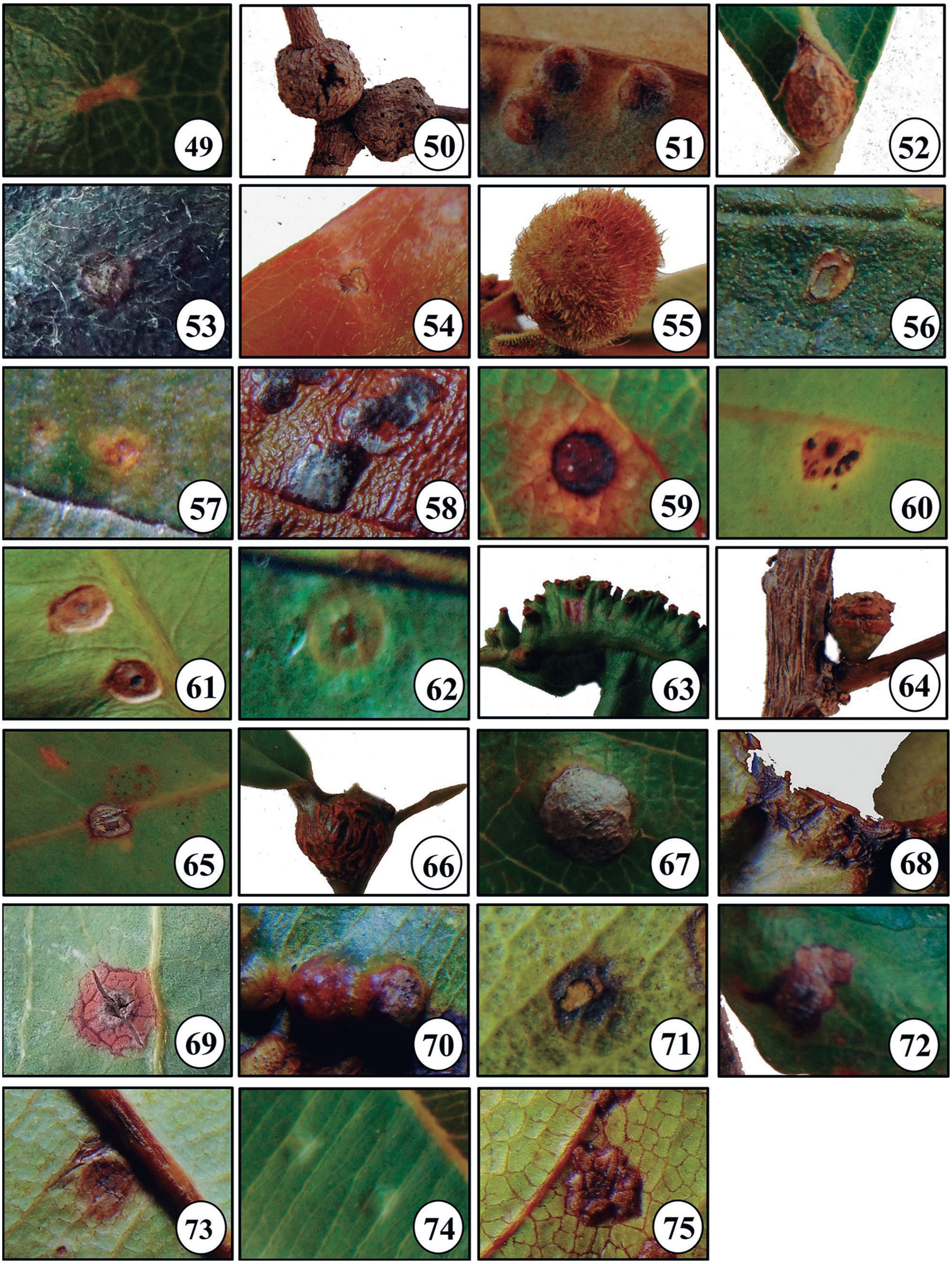

Figure 5. Galls found in four *veredas* types in the in the Northern region of the state of Minas Gerais, Brazil. (49) *Heteropterys byrsonimifolia* (fusiform-leaf); (50-52) *Byrsonima* sp.: (50) globoid-stem, (51) conical-leaf, (52) globoid-leaf); (53) *Peixotoa* sp. (lenticular-leaf); (54) Malpighiaceae sp. (lenticular-leaf); (55) *Macairea radula* (globoid-stem); (56-57) *Miconia albicans:* (56) lenticular-leaf, (57) lenticular-leaf); (58) *Tibouchina* sp. (lenticular-leaf); (59) *Eugenia dysenterica* (lenticular-leaf); (60) *Guapira opposita* (lenticular-leaf); (61) *Ouratea hexasperma* (lenticular-leaf); (62-63) *Ouratea* sp.: (62) lenticular-leaf, (63) globoid-leaf); (64-66) *Agonandra brasiliensis:* (64) globoid-stem, (65) lenticular-leaf, (66) globoid-stem); (67-68) *Serjania* sp.: (67) lenticular-leaf, (68) fusiform-leaf); (69) *Pouteria* sp. (lenticular-leaf); (70) *Qualea grandiflora* (globoid-leaf); (71-72) *Qualea parviflora:* (71) lenticular-leaf, (72) lenticular-leaf); (73) *Vochysia rufa* (lenticular-leaf); (74) *Vochysia tucanorum* (lenticular-leaf); (75) *Vochysia* sp. (lenticular-leaf).

This can be attributed to the anthropogenic pressures in these areas, which have resulted in a reduction of the water table level and the subsequent drying out of these *veredas* (Nunes *et al.,* 2022). The results of the faunistic similarity analysis corroborate this, as the drying-out *veredas* showed the highest similarity (Vereda da Almescla and Vereda do Peruaçu), indicating that these areas have a fauna distinct from the other *veredas.*

CONCLUSION

This is the first systematic study on insect galls in Brazilian *veredas.* This survey contributes to increasing our knowledge of gall diversity and their host plants, considering the few surveys conducted in the area so far. However, additional studies focusing on gall characterization in this environment should be carried out. The study of insect gall diversity is particularly important in *vereda* ecosystems due to recent threats of drought in these environments. Such conditions can induce stress in plants and create more favorable microclimates for gall-inducing insects, thereby leading to an increase in the diversity of gall-inducing insects. Therefore, understanding the diversity of insect galls in *vereda* ecosystems that maintain wet conditions is crucial to comprehend how this diversity changes during the drying process.

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