

Insect gall occurrence in cerrado *sensu stricto* areas in the Parque Estadual Veredas do Peruaçu, Minas Gerais, Brazil

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ABSTRACT

In the present study, we present the first inventory of gall-inducing arthropods in cerrado *sensu stricto* areas of the Parque Estadual Veredas do Peruaçu, northern Minas Gerais, Brazil. Field surveys were conducted in 15 plots (10 × 10 m each) sampled in November 2018 (rainy season) and August 2019 (dry season) to record the diversity of galls and their host plants. A total of 33 gall morphotypes were recorded in 23 host plant species from 13 botanical families. Fabaceae (nine morphotypes), Vochysiaceae (six), and Malpighiaceae (five) were the most diverse families, and *Copaifera oblongifolia* was the plant species with the highest gall richness (five morphotypes). The majority of galls were globoid or lenticular in shape and occurred mainly on leaves. Dipterans of the family Cecidomyiidae were the most frequent gall inducers, representing 19 out of the 20 identified taxa. Despite the low number of morphotypes compared to other Cerrado inventories, this study records three host plant species of insect galls for the first time and adds seven new gall morphotypes to the literature. This study expands the geographical coverage of gall inventories in the Cerrado and contributes to a better understanding of host–gall inductor associations in an underexplored area, providing valuable baseline data for future ecological and conservation research.

Introduction

Galls are an unusual growth of plant tissues, usually on leaves and stems, induced through mechanical and chemical stimuli by different groups of organisms, especially insects (Price, 2005; Tooker et al., 2008). The galls provide a microhabitat for the inducers, serving as shelter and food source for the immature stages of endophagous arthropods (Raman et al., 2005; Araújo and Espírito-Santo Filho, 2012). Interactions between plants and their gall-inducing arthropods are usually species-specific (Stone and Schönrogge, 2003), although some plant species can act as super-hosts (Araújo et al., 2013; Fagundes et al., 2018). In this context, inventories of galling-arthropods are essential to describe their diversity and increase the knowledge on the biology of these associations.

The Cerrado is the second largest Brazilian biome, composed of a mosaic of distinctive vegetation types (Ribeiro and Walter, 2008). It is recognized as the most diverse savanna in the world, and is also considered a biodiversity hotspot (Damasco et al., 2018). Human activities like extensive monocultures, cattle stock, and anthropogenic fires, combined with climate change, have threatened the conservation

of the Cerrado (Coelho et al., 2020; Colli et al., 2020). The biome is also notable for its remarkable diversity and abundance of gall-inducing insects, which find in the Cerrado's structural and floristic complexity ideal conditions for diversification and host specialization with more than 505 species and 67 families of galling host plants (Cintra et al., 2020).

Regarding the knowledge of galling arthropods, the Cerrado has a large number of gall surveys (e.g. Urso-Guimarães and Scareli-Santos, 2006; Coelho et al., 2013; Araújo et al., 2020; Grandez-Rios et al., 2024). However, due to its vast geographic extent, many regions remain poorly known in terms of the diversity of their gall inducers (Urso-Guimarães et al., 2024). Among the Cerrado phytophysionomies, the Cerrado *sensu stricto* is characterized by sparse vegetation cover composed of shrubs and herbs, with tortuously ramified trees, usually with fire marks (Ribeiro and Walter, 2008). Although galling arthropod surveys have been conducted in areas of Cerrado *sensu stricto* in Goiás, Minas Gerais, and São Paulo states (e.g. Araújo et al., 2014; Silva et al., 2018; Campos et al., 2021), many regions still have undocumented gall-inducing communities.

Despite the growing number of inventories across the Cerrado, the northern region of Minas Gerais remains one of the least studied areas regarding galling arthropod diversity (Urso-Guimarães et al., 2024).

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This portion of the biome includes extensive remnants of Cerrado *sensu stricto* and *vereda* formations (Grandez-Rios et al., 2024). The lack of taxonomic and ecological information for northern populations limits the understanding of distribution patterns, host associations, and the ecological processes driving galling insect diversity (Araújo et al., 2020). Considering the region's transitional position between the Cerrado and Caatinga domains and its increasing exposure to anthropogenic disturbances, documenting local galling communities is essential to fill biogeographical gaps and to provide a baseline for future ecological and conservation studies.

Thus, in order to advance in the knowledge about the galling arthropods community in the Cerrado, herein we present the first survey of gall-arthropods in area of cerrado *sensu stricto* for the Parque

Estadual Veredas do Peruçu (hereafter referred to as PEVP), located in the northern region of Minas Gerais, Brazil. Our study describes new records of host associations and local patterns of gall occurrence.

Materials and methods

Study area

The study was conducted in Cerrado *sensu stricto* areas in the PEVP, located in Northern region of Minas Gerais, Brazil (14°56'13" S, 44°37'44" W) (Fig. 1). This park spans the municipalities of Januária and Cônego Marinho, covers approximately 31,200 ha, and plays a crucial role in conserving the unique wetland ecosystems of the region.

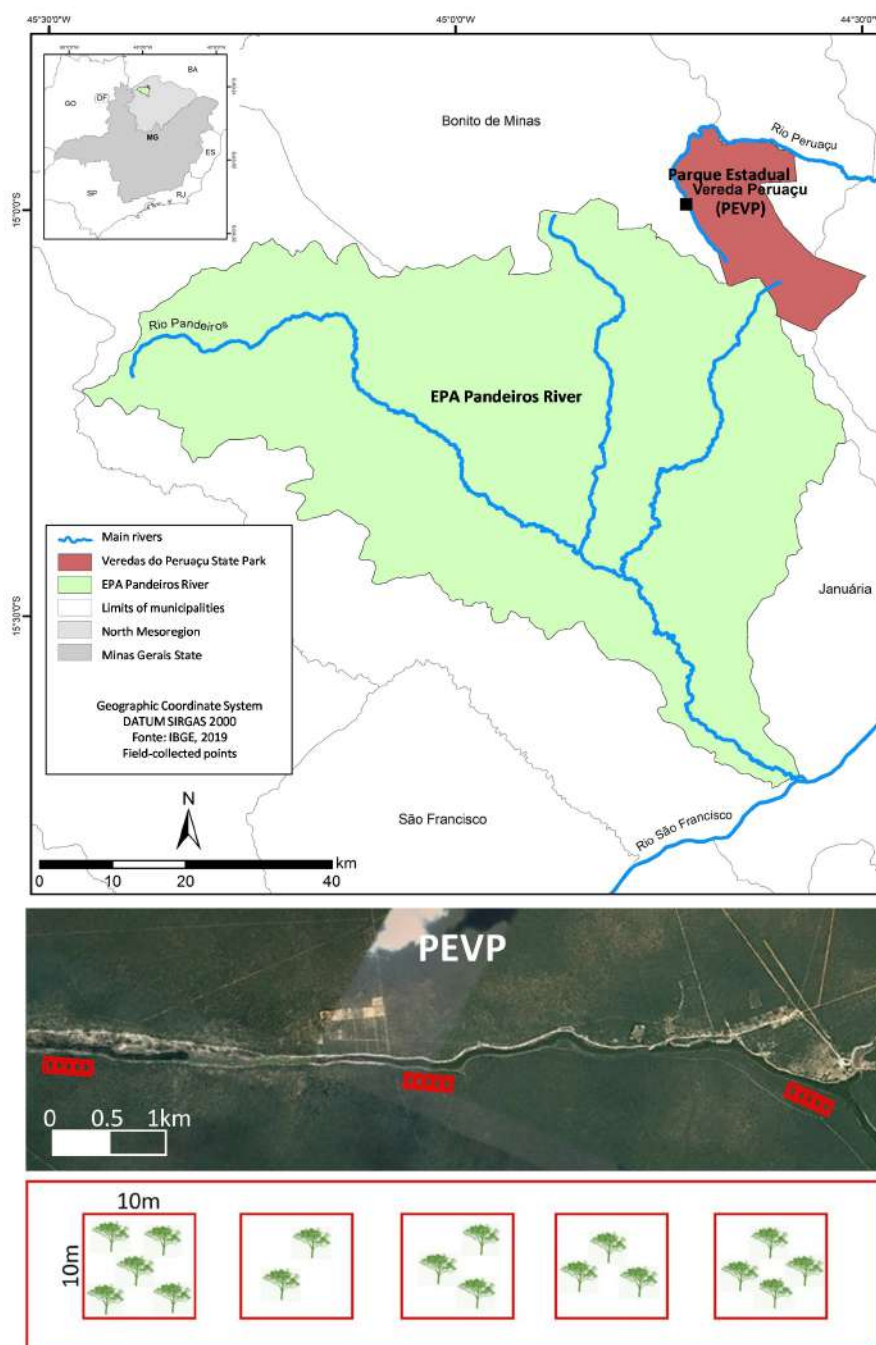


Figure 1 Location of the Parque Estadual Veredas do Peruçu (PEVP), northern Minas Gerais, Brazil, showing the three sampling areas and the arrangement of five 10 × 10 m plots in each area.

The study area is located within a complex of protected areas in northern Minas Gerais, comprising the Environmental Protection Area of the Pandeiros River (EPA Rio Pandeiros) and others. The park includes different Cerrado phytophysiognomies; however, the present study was conducted exclusively in areas of Cerrado *sensu stricto*, which is the predominant vegetation type in the sampled area. The park's relief is characterized by plateaus and residual hills with altitudes ranging from 850 to 900 meters, and the climate is tropical hot subhumid, with an average annual temperature between 22°C and 24°C, being classified as *Aw* (Alvares et al., 2013). Furthermore, the PEVP is a designated site of the Long-term Ecological Research Network (PELD-VERE) (Grandez-Rios et al., 2024).

Data sampling

Sampling of insect galls and host plants was performed on two occasions, in November 2018 (rainy season) and August 2019 (dry season). Field surveys were conducted by two collectors in three sampling areas spaced approximately 2 km apart. In each area, five plots measuring 10 × 10 m were established, totaling 15 plots in the study, where all plants were systematically inspected for the presence of insect galls. In each area, plots were established at a minimum distance of 30 m from each other. Insect galls were photographed, collected and transported to the Laboratório de Interações Ecológicas e Biodiversidade – LIEB of the Universidade Estadual de Montes Claros – UNIMONTES. In the laboratory, specimens of each gall morphotype were dissected using a stylet to observe the immature insects (Araújo et al., 2021). The sampled insect galls were categorized into morphotypes based on the host plant

species and their external characteristics (Araújo et al., 2021), including occurrence location, shape, and color (Isaias et al., 2013). Host plants were identified either in the field or collected for laboratory identification using specialized literature. Identification of the gall-inducers was made by examination of immature insects (larvae and pupae) and consultation with the literature (Gagné, 1994; Costa et al., 2006).

Results

A total of 33 gall morphotypes were registered for 13 families, 19 genera and 23 species of host plants (Table 1). The most diverse plant families were Fabaceae with nine gall morphotypes (~27%), followed by Vochysiaceae with six morphotypes (~18%), and Malpighiaceae with five morphotypes (~15%). Other plant families presented only one or two gall morphotypes (Table 1). Concerning the plant species, *Copaifera oblongifolia* Mart. ex Hayne (Fabaceae) hosted more galls with five gall morphotypes (~15%), followed by *Byrsonima* sp. (Malpighiaceae) with four morphotypes (~12%). The resting of plant species presented only one or two gall morphotypes (Table 1).

In relation to the gall morphotype shapes, the globoid shape was the most frequent representing ten morphotypes (~30%), followed by the lenticular shape with seven morphotypes (~27%), the clavate and fusiform shapes each with three morphotypes (~9%), the marginal roll shapes with two morphotypes (~6%), and the conical shape with one morphotype (~3%) (Figs. 2–3). On the other hand, five morphotypes (~15%) presented an amorphous shape. Leaves were the more frequent galled plant organ, hosting 26 gall morphotypes (~79%), followed by the stems with seven gall morphotypes (~21%) (Table 1).

Table 1

Characterization of insect galls recorded in the Parque Estadual Veredas do Peruáçu, Minas Gerais, Brazil.

Host family	Host species	Gall morphotype	Organ	Shape	Color	Gall-inducers	Figure
Anacardiaceae	<i>Anacardium nanum</i> A. St.-Hil.	1	Leaf	Lenticular	Yellow	Cecidomyiidae	1A
		2	Leaf	Globoid	Brown	Cecidomyiidae	1B
Araliaceae	<i>Schefflera</i> sp.	3	Leaf	Lenticular	Green	Lepidoptera	1C
Burseraceae	<i>Protium spruceanum</i> (Benth.) Engl.	4	Leaf	Clavate	Green	Cecidomyiidae	1D
		5	Leaf	Globoid	Green	Cecidomyiidae	1E
Caryocaraceae	<i>Caryocar brasiliense</i> Cambess.	6	Stem	Fusiform	Brown		1F
Dilleniaceae	<i>Davilla elliptica</i> A. St.-Hil.	7	Leaf	Lenticular	Green	Cecidomyiidae	1G
Fabaceae	<i>Bauhinia</i> sp.	8	Stem	Fusiform	Brown	Cecidomyiidae	1H
Fabaceae	<i>Bauhinia</i> sp. 1	9	Stem	Amorphous	Black	Cecidomyiidae	1I
Fabaceae	<i>Copaifera oblongifolia</i> Mart.	10	Leaf	Globoid	White		1J
		11	Leaf	Clavate	Brown		1K
		12	Petiole	Lenticular	Brown		1L
		13	Petiole	Globoid	Red		1M
		14	Leaf	Amorphous	White		1N
		15	Leaf	Globoid	Black		1O
		16	Leaf	Lenticular	Yellow		1P
Fabaceae	<i>Hymenaea stigonocarpa</i> Mart. ex Hayne	17	Leaf	Globoid	Brown	Cecidomyiidae	1Q
Fabaceae	<i>Machaerium</i> sp.	18	Leaf	Lenticular	Yellow		1R
Malpighiaceae	<i>Byrsonima pachyphylla</i> A. Juss.	19	Leaf	Globoid	Brown	Cecidomyiidae	1S
Malpighiaceae	<i>Byrsonima</i> sp.	20	Leaf	Globoid	Brown	Cecidomyiidae	1T
		21	Leaf	Globoid	Brown	Cecidomyiidae	2A
Malvaceae	<i>Eriotheca gracilipes</i> (K. Schum.) A. Robyns	22	Leaf	Amorphous	Green		2B
Myrtaceae	<i>Eugenia</i> sp.	23	Leaf	Clavate	Brown	Cecidomyiidae	2C
Myrtaceae	<i>Psidium</i> sp.	24	Leaf	Amorphous	Yellow	Cecidomyiidae	2D
Nyctaginaceae	<i>Guapira</i> sp.	25	Stem	Lenticular	Purple	Cecidomyiidae	2E
Ochnaceae	<i>Ouratea</i> sp.	26	Leaf	Lenticular	Brown	Cecidomyiidae	2F
Rubiaceae	<i>Tocoyena formosa</i> (Cham. & Schltdl.) K. Schum.	27	Leaf	Lenticular	Green		2G
Vochysiaceae	<i>Callisthene</i> sp.	28	Stem	Amorphous	Brown		2H
Vochysiaceae	<i>Qualea grandiflora</i> Mart.	29	Leaf	Lenticular	Green	Cecidomyiidae	2I
		30	Leaf	Globoid	Black	Cecidomyiidae	2J
Vochysiaceae	<i>Qualea</i> sp.	31	Stem	Fusiform	Brown	Cecidomyiidae	2K
Vochysiaceae	<i>Vochysia rufa</i> Mart.	32	Leaf	Marginal roll	Brown		2L
		33	Leaf	Marginal roll	Green		2M

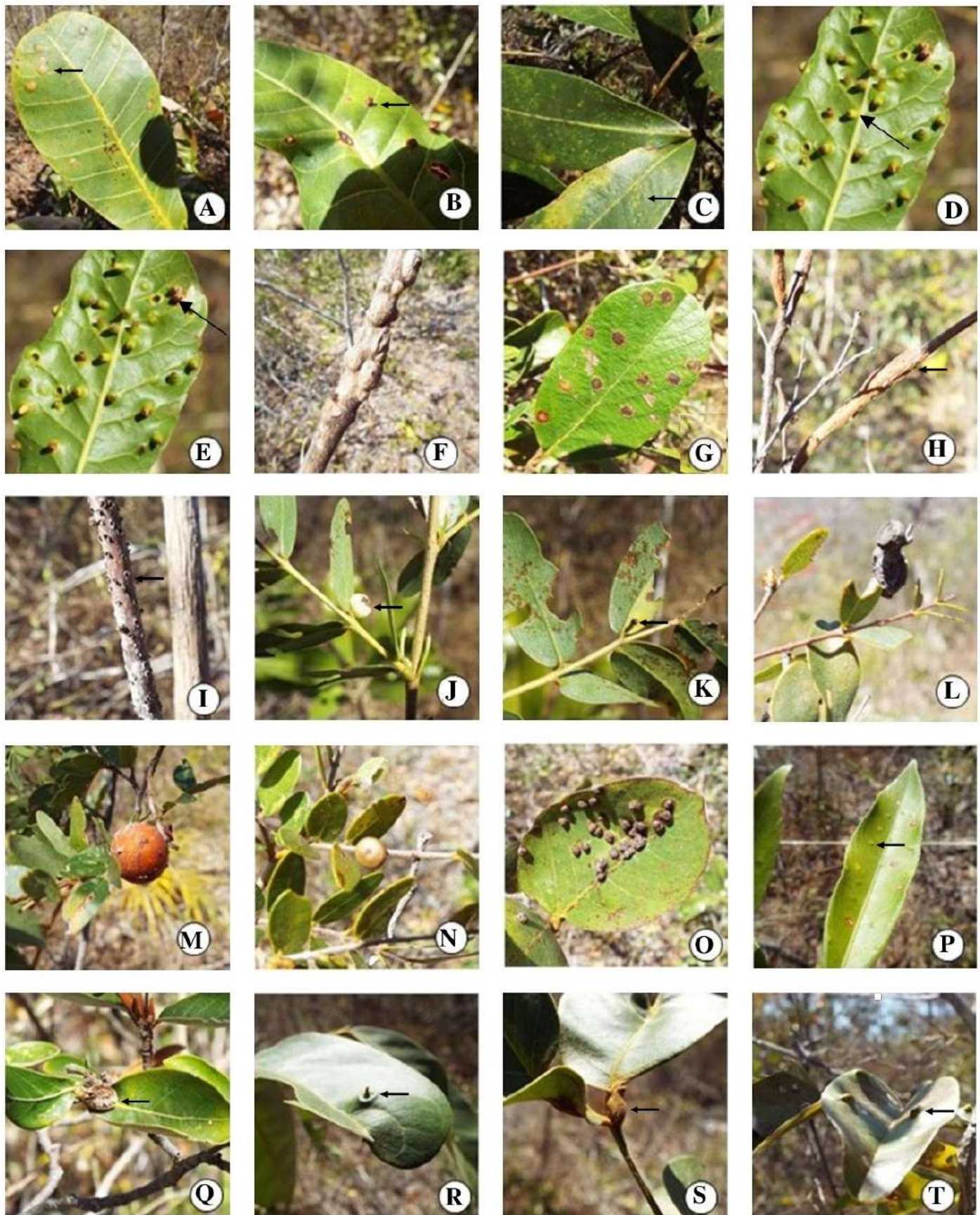


Figure 2 Galls found in the Parque Estadual Veredas do Peruaçu, Minas Gerais, Brazil. *Anacardium nanum*: A. lenticular, B. globose; *Schefflera* sp.: C. lenticular; *Protium spruceanum*: D. clavate, E. globose; *Caryocar brasiliense*: F. fusiform; *Davilla elliptica*: G. lenticular; *Bauhinia* sp.: H. fusiform; *Bauhinia* sp.: I. amorphous; *Copaifera oblongifolia*: J. globose, K. clavate, L. lenticular, M. globose, N. amorphous; *Hymenaea stigonocarpa*: O. globose; *Machaerium* sp.: P. lenticular; *Byrsonima pachyphylla*: Q. globose; *Byrsonima* sp.: R. conical, S. globose, T. globose.

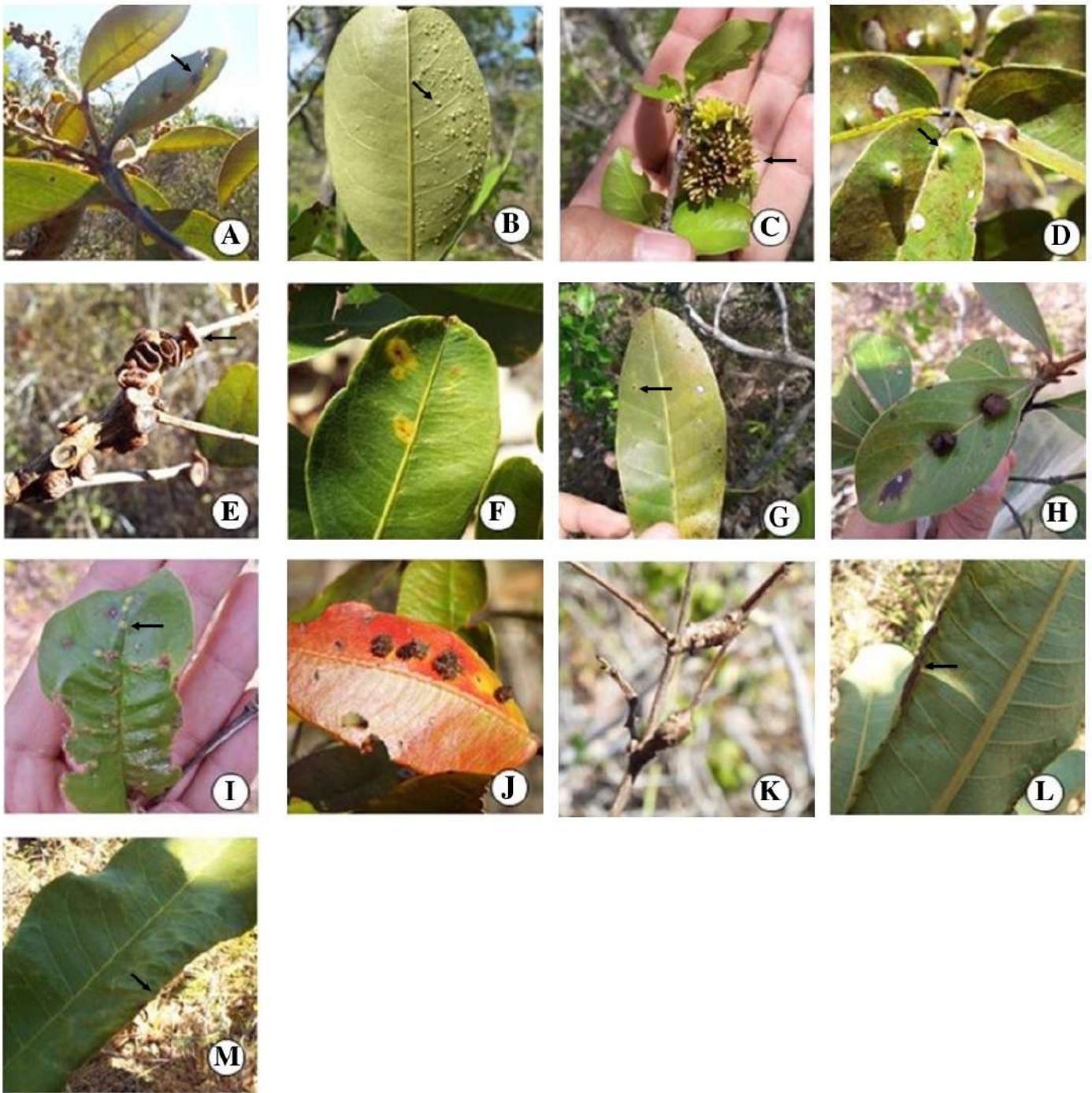


Figure 3 Galls found in the Parque Estadual Veredas do Peruáçu, Minas Gerais, Brazil. *Byrsonima* sp.: A. globoid; *Eriotheca gracilipes*: B. amorphous; *Eugenia* sp.: C. clavate; *Psidium* sp.: D. amorphous; *Guapira* sp.: E. lenticular; *Ouratea* sp.: F. lenticular; *Tocoyonea formosa*: G. lenticular; *Callisthene* sp.: H. amorphous; *Qualea grandiflora*: I. lenticular, J. globoid; *Qualea* sp.: K. fusiform; *Vochysia rufa*: L. marginal roll, M. marginal roll.

Among the gall inducers, 20 galling species were identified to the family level, while 13 were not identified. Cecidomyiidae (Diptera) was the most diverse family of gall-inducing insects with 19 gall morphotypes, whereas Lepidoptera accounted for a single morphotype (Table 1, Figs. 2–3).

To the best of our knowledge, *Anacardium nanum* A. St.-Hil. (two morphotypes), *Protium spruceanum* (Benth.) Engl. (two), and *Tocoyena formosa* (Cham. & Schltdl.) K. Schum. (one) were recorded here for the first time as host plants of insect galls, totaling five gall morphotypes. In addition, marginal roll gall morphotypes were recorded for the first time on *Vochysia rufa* Mart.

Discussion

Our results demonstrate a low number of morphotypes (33) when compared with other studies performed in Cerrado *sensu stricto* areas. For example, Campos et al. (2021) registered 98 gall morphotypes in Caetité (Bahia), while Araújo et al. (2020) registered 40 morphotypes in Bonito de Minas (Minas Gerais). This number variation may be associated with many factors, such as vegetation structure, seasonality, sampling effort, and other regional features. In its turn, Grandez-Rios et al. (2024) in a gall survey focused on areas of *veredas*, registered

39 gall morphotypes, considering only the area sampled in the Parque Estadual Veredas do Peruáçu. The lower gall richness observed may be explained by the plot-based sampling design, which limits the number of host plant species surveyed and, consequently, the diversity of gall morphotypes recorded. Differences in sampling effort, spatial scale, and survey methods among studies are likely important drivers of the observed variation in gall richness.

Similarly, the number of host plant species (23) and host plant families (13) recorded in our study was a little lower than other gall surveys, e.g. Campos et al. (2021) recorded 42 host plant species of 22 families, and Araújo et al. (2020) recorded 29 host plant species in 17 families. Consistent with our findings, Fabaceae presented the greatest gall morphotype number in these two studies. Fabaceae stands out as the most important host plant family in other studies with gall inducitors in the Cerrado and other Brazilian biomes (Araújo et al., 2019; Cintra et al., 2020). Possibly, the high gall richness registered in Fabaceae is straightly related to its own richness (Mendonça, 2007; Araújo, 2017; Santos-Silva and Araújo, 2020). The most frequent host plant species recorded, *Copaifera oblongifolia*, has a great range distribution (Freitas and Oliveira, 2002), besides functioning as a super-host species with over 20 different gall morphotypes (Costa et al., 2010). No single host plant was characterized as super-hosts (*sensu* Grandez-Rios and Araújo, 2024).

Concerning the gall shapes, the most frequent types, globoid and lenticular, usually are the predominant shapes in gall surveys performed in other Cerrado *sensu stricto* areas in Brazil (Maia, 2013; Vieira et al., 2018; Campos et al., 2021). The leaves were the most frequent galled organ in our survey, a similar pattern observed in previous works performed in Cerrado areas (Araújo et al., 2014; Grandez-Rios et al., 2024). This pattern may be explained by the higher plasticity of leaf tissues compared to stems, combined with the greater abundance and exposure of leaves, which increases both the availability of suitable sites and the detectability of galls (Maia, 2011; Castro et al., 2012). In addition, the high nutritional input associated with photosynthetic activity makes leaves the main target organ for gall induction.

Among the gall-inducing arthropods identified, members of the family Cecidomyiidae overwhelmingly dominated, accounting for 19 of the 20 recognized inducers. This nematoceran family is well known for its evolutionary specialization toward gall induction, with numerous species exhibiting intricate life cycles tightly linked to host-plant tissues (Maia, 2005). Our findings are consistent with patterns report throughout the Neotropical region and across all major zoogeographic regions, where Cecidomyiidae consistently represent the most diverse and ecologically dominant lineage of gall inducers (Gagné and Jaschhof, 2025).

The new gall–host associations reported here highlight important gaps in the knowledge of galling insect diversity in the Cerrado. This study records three host plant species (*Anacardium nanum*, *Protium spruceanum*, and *Tocoyena formosa*) for the first time as hosts of insect galls, comprising five gall morphotypes, and adds two additional marginal roll gall morphotypes recorded for the first time on *Vochysia rufa*. Altogether, the records of the present study add seven new gall occurrences to the literature. These findings reinforce the importance of regional inventories for revealing previously undocumented gall diversity, particularly in poorly studied areas such as northern Minas Gerais.

Conclusion

This is the first galling arthropod inventory in areas of cerrado *sensu stricto* of Parque Estadual Veredas do Peruáçu, Northern region of Minas Gerais, Brazil. Although the number of gall morphotypes recorded was lower than that reported for other Cerrado *sensu stricto* areas, this study provides the first baseline data on galling arthropods for the northern region of Minas Gerais, thereby advancing knowledge of the local galling

arthropod community. The importance of this contribution lies in its novelty and in filling a significant geographical gap in gall inventories within the Cerrado biome, rather than in direct comparisons of species richness. Besides, our gall community characterization reinforces many patterns found in other studies conducted in areas of Cerrado. By documenting previously unrecorded host–gall associations in this region, our results represent essential information for future ecological and conservation-oriented studies. We hope for more studies focused on describing the galling arthropods communities in other Cerrado *sensu stricto* areas, as well as other unexplored Cerrado and Brazilian regions.

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Data statement

All data underlying this study were included in the article itself.

Conflicts of interest

The authors declare there are no conflicts of interest.

Author contribution statement

JOSJ – Conceptualization, Writing – original draft, review & editing; JMGR – Conceptualization, Writing – original draft, review & editing; BMO, and KCSC – Conceptualization, Methodology, Writing – review & editing; WSA – Conceptualization, Methodology, Supervision, Writing – review & editing.

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