



Galls on Brazilian ferns: new records and notes

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Galls are abnormal growths of plant tissues generated from processes of hyperplasia and cellular hypertrophy, induced especially by insects and mites (detailed definition in Raman, 2007). Galls on ferns (i.e. seedless vascular plants) have been neglected in many inventories worldwide. In consequence, basic information such as the identity of gall host ferns, the frequency and locations of the interaction are still poorly known. Until present, only 16 fern species have been recorded as galls hosts in Brazil (see synopsis in Santos and Maia, 2018). In this note, we catalog ten ferns hosting galling agents, including four new records of galls, and report new locations to some ferns recorded as hosts, and characterize the morphology of the galls.

The study was conducted in five sites along the Atlantic Forest and Cerrado domain, situated in Southern and Southeastern Brazil: I - National Forest of São Francisco de Paula, municipality of São Francisco de Paula, Rio Grande do Sul State (29°25'28"S, 50°23'08"W, 906 m); II - Cambará site, municipality of Cambará do Sul, Rio Grande do Sul State (29°10'29"S, 50°01'58"W, 996 m); III - Serra da Bocaina National Park, municipality of São José do Barreiro, São Paulo State (22°44'03"S, 44°36'59"W, 1.520 m); IV - Serra do Tabuleiro, municipality of São Bonifácio, Santa Catarina State (27°49'01"S, 48°53'53"W, 1.165 m); and V - Ibitipoca State Park, municipality of Santa Rita do Ibitipoca, Minas Gerais State (21°42'32"S, 43°53'38"W, 1.345 m). All sites occur in highlands (800-1800 m.a.s.l.) and belong to Araucaria Forest (sites I, II and III), Rainforest (site IV) and "Campos Rupestres" (site V) phytogeography formations. The climatic conditions among the sites I, II, III and IV are the same, presenting annual rainfall above 2.400 mm, with the hottest month ≤ 22 °C and normally with occurrence of 20-30 frozen days a year, mild summers without a dry season (Type Cfb, Peel et al., 2007). At site V, the mean annual rainfall is over 2.000 mm, with the temperature of

the hottest month ≥ 22 °C, no occurrence of frozen days, dry winters and hot summers (Type Cwb, Peel et al., 2007). Eight collections were carried out between 2017 and 2018. The names of the authors of the ferns species were abbreviated according with the website Flora do Brasil 2020. All gall morphotypes were photographed and collected. Gall shapes were standardized in accordance with Isaías et al. (2013).

The ten host ferns here cataloged are represented by three families (Gleicheniaceae, Hymenophyllaceae and Polypodiaceae) and five genera (*Dicranopteris*, *Hymenophyllum*, *Campyloneurum*, *Niphidium* and *Pleopeltis*, Table 1). *Dicranopteris nervosa* (Figure 1A, B), *D. rufinervis* (Figure 2A, B), *H. plumosum* (Figure 3G, H) and *H. rufum* (Figure 4A, B) are registered as gall hosts for the first time. The other two records to *Hymenophyllum* fill the gap on the geographic distribution, not recorded in the seminal work performed by Houard (1933). The records of *N. crassifolium* (Figure 5A, B), *C. nitidum* (Figure 5C, D) and *P. hirsutissima* (Figure 5E, F) presented here were first obtained from tropical rain forests of Rio de Janeiro State (Santos and Maia, 2018), representing new locations to these gall host ferns. The galls observed in *H. pulchellum* (Figure 4C-F) and *H. hirsutum* (Figure 3A-F) were recorded in two locations in the South and Southeast region of São Paulo and Rio Grande do Sul States (Table 1). The latter gall morphotypes were reported in Brazil by Houard (1933), without details on geographic distribution.

The morphological characterization demonstrated the occurrence of leaf galls on all host ferns (Table 1, Figure 1-5). In the case of *Hymenophyllum* species, leaf galls occur on both the blade and the petiole (Table 1). In addition, *Hymenophyllum* galls also occurred in the stems (i.e. rhizome) as reported to other epiphytic ferns: *Microgramma squamulosa* (Kaulf.) de la Sota (Kraus et al., 1993) and *M. vacciniifolia* (Langsd. &

Fisch.) Copel. (Maia and Santos, 2011, 2015). Galls in the leaves and stems of *H. pulchellum* and *H. rufum* do not seem to present a different morphology (Figures 3 and 4).

Houard (1933) also recorded galls on leaves and stems of *H. pulchellum*. This ability of the gall inducers to manipulate different organs in the same plant is occasionally

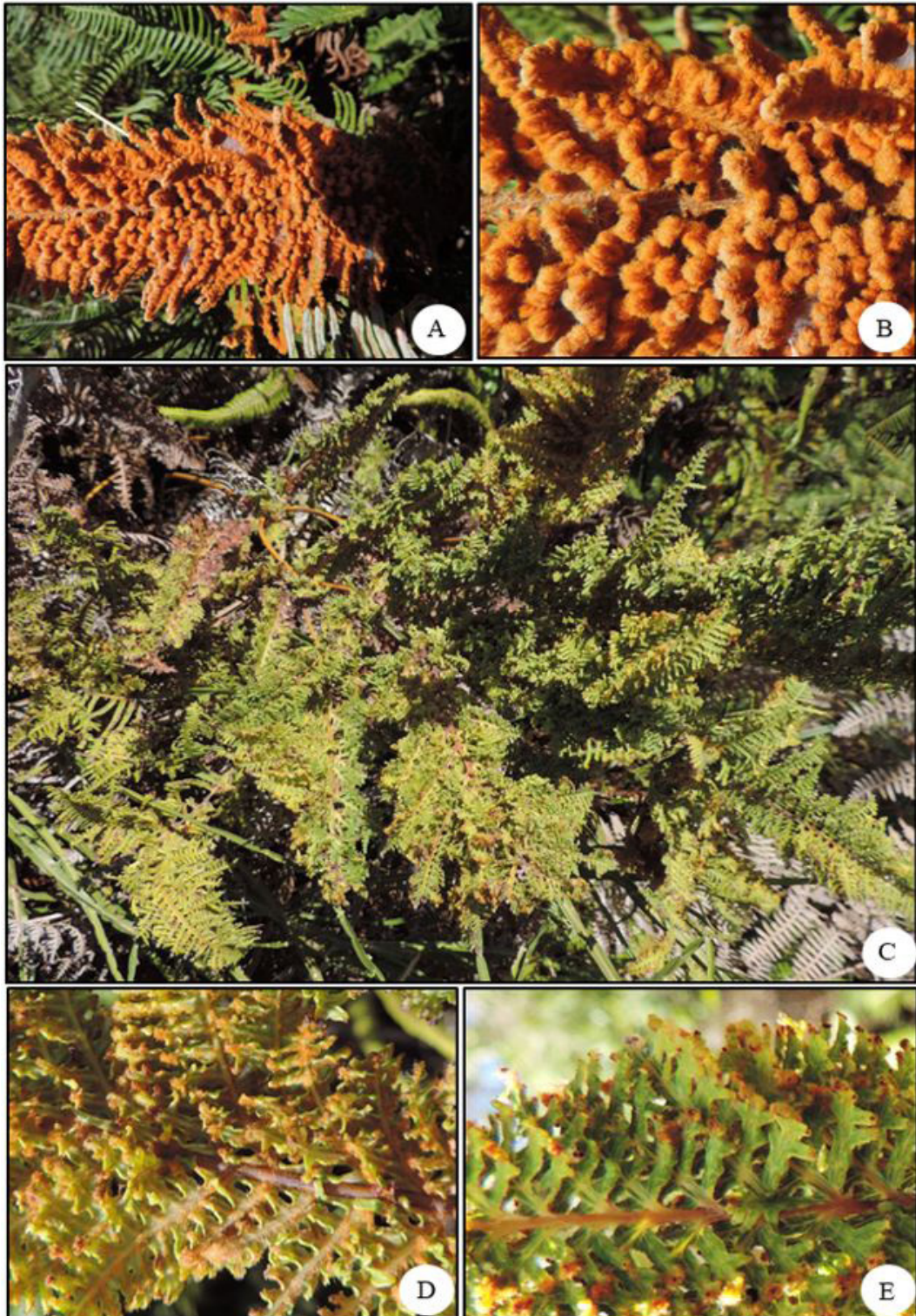


Figure 1. Galls on Gleicheniaceae family. *Dicranopteris nervosa*, (A, B) leaf gall. *Dicranopteris flexuosa*; (C-E) leaf gall.

reported for angiosperms (e.g. Maia and Oliveira, 2010). The predominance of galls on leaves is a common pattern of this plant-insect interaction, attributed to the greater abundance of nutrients and resources in this organ (Mani, 1964). In fact, the guild diversification of gallers has shown to be influenced by leaf variability, ranging from coriaceous leaves in semi-arid zones (e.g. Carvalho-Fernandes et al., 2012), to the typically one-cell thick and few-centimeter

long membranous leaves of filmy ferns (see Gonzatti and Windisch, 2018). Interestingly, in *H. pulchellum*, the galls are close to tufts of leaves (Figure 4C-E), which may be a source of nutrients to galling or only an error in the manipulation of plant systems. In Gleicheniaceae, galls induce a complete modification of leaf shape, the “witches’ broom” (Table 1), already described by Santos and Maia (2018) on *D. flexuosa* (Figure 1C-E) in Rio de Janeiro

Table 1. Records of host ferns species of galling from sites in southern-southern Brazil, and gall morphology.

Host plant (Ferns)	Organ with gall	Gall shape	Trichomes	Sites
Gleicheniaceae				
<i>Dicranopteris flexuosa</i> (Schrad.) Underw.	Leaf	“Witches’ broom” (amorphous)	-	III, IV
<i>Dicranopteris nervosa</i> (Kaulf.) Maxon *	Leaf	“Witches’ broom” (amorphous)	Present	III, IV
<i>Dicranopteris rufinervis</i> (Mart.) Ching*	Leaf	“Witches’ broom”(amorphous)	Present	V
Hymenophyllaceae				
<i>Hymenophyllum hirsutum</i> (L.) Sw.	Leaf	Lenticular	Present	II, III
<i>Hymenophyllum plumosum</i> Kaulf. *	Leaf	-	-	III
<i>Hymenophyllum pulchellum</i> Schldl. & Cham	Leaf/Stem (Rhizome)	Globoid/Amorphous (grouped)	Present	II, III
<i>Hymenophyllum rufum</i> Fée *	Leaf/Stem (Rhizome)	Lenticular	Present	II
Polypodiaceae				
<i>Campyloneurum nitidum</i> (Kaulf.) C. Presl	Leaf	Lenticular	Absent	I
<i>Niphidium crassifolium</i> (L.) Lellinger	Leaf	Clavate	Absent	I
<i>Pleopeltis hirsutissima</i> (Raddi) de la sota	Leaf	Globoid	Present	I

Sites: I = National Forest of São Francisco de Paula, Rio Grande do Sul State; II = A particular Forest fragment in Rio Grande do Sul State; III = Serra da Bocaina National Park, São Paulo State; IV = A particular Forest fragment in Santa Catarina State; and V = Ibitipoca State Park, Santa Rita do Ibitipoca, Minas Gerais. *Ferns recorded as gall host for the first time.



Figure 2. Galls on Gleicheniaceae family, *Dicranopteris rufinervis*, (A, B) leaf gall.

State, Brazil. The segments are wider and thicker than normal leaves, and more intensely divided (Figure 1 and 2).

The trichomes were present in *H. pulchellum*, *D. nervosa*, *D. rufinervis* and *P. hirsutissima* (Table 1). The presence

of trichomes in galls may have two implications, the first related to the protection of the gallier against parasitoids and/or small sucking herbivores (Fernandes et al., 1987), and the second related to water control and maintenance

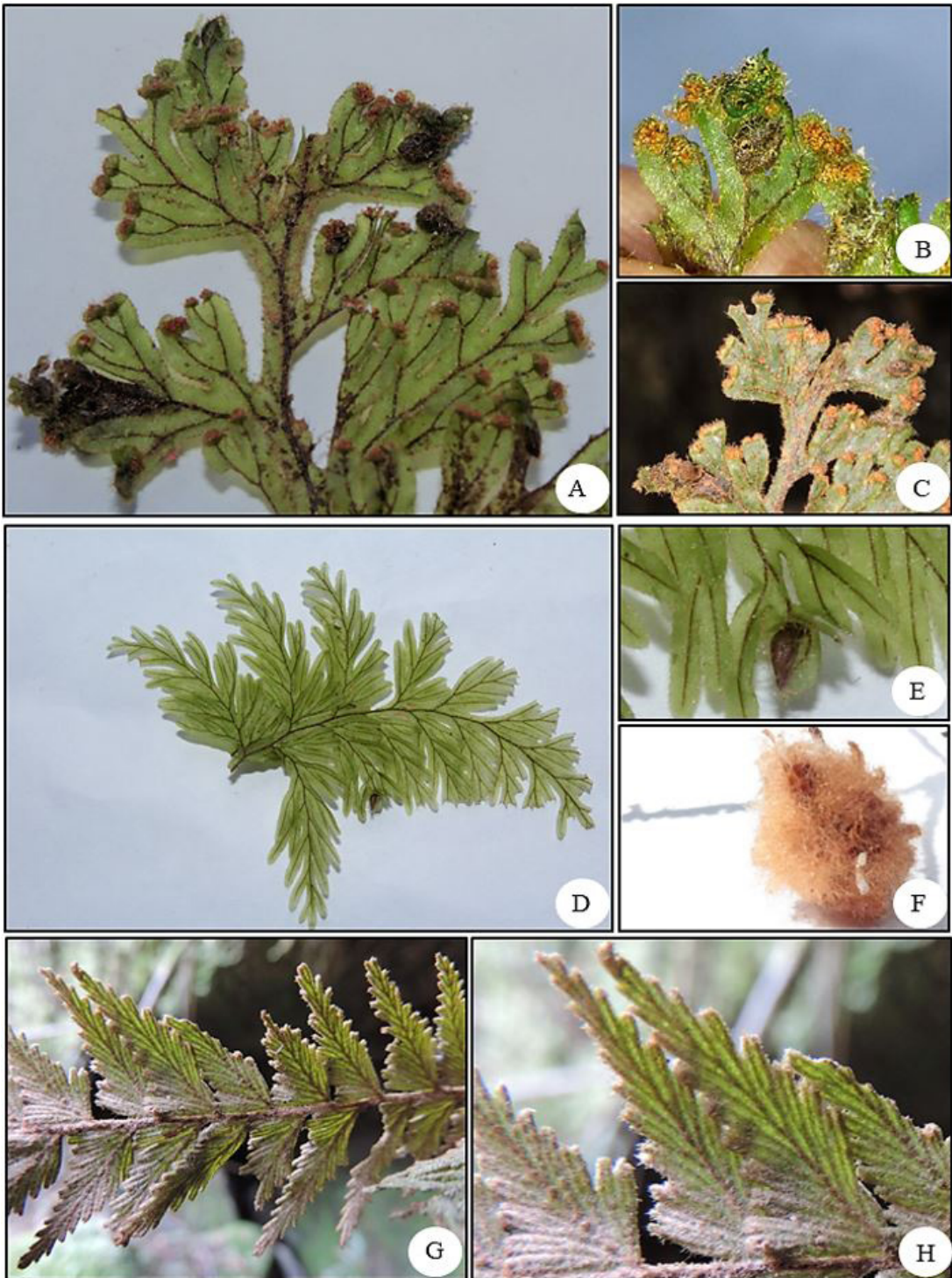


Figure 3. Galls on Hymenophyllaceae family. *Hymenophyllum hirsutum*, (A-E) leaf gall and (F) stem gall. *Hymenophyllum plumosum*; (G, H) leaf gall.

of the internal temperature (Stone and Schönrogge, 2003). The gall morphotypes were variable and included lenticular (three morphotypes), globoid (two), “Witches’ broom”, completely amorphous (three), and clavate (one) shapes (Table 1). Additionally, globoid galls in *H. pulchellum*

may be grouped, generating an amorphous structure (Figure 4C-F).

Galls on *P. hirsutissima* are induced by a Cecidomyiidae (Diptera) not yet identified, while the gall inducer on *C. nitidum* and *N. crassifolium* remains unknown (see Santos

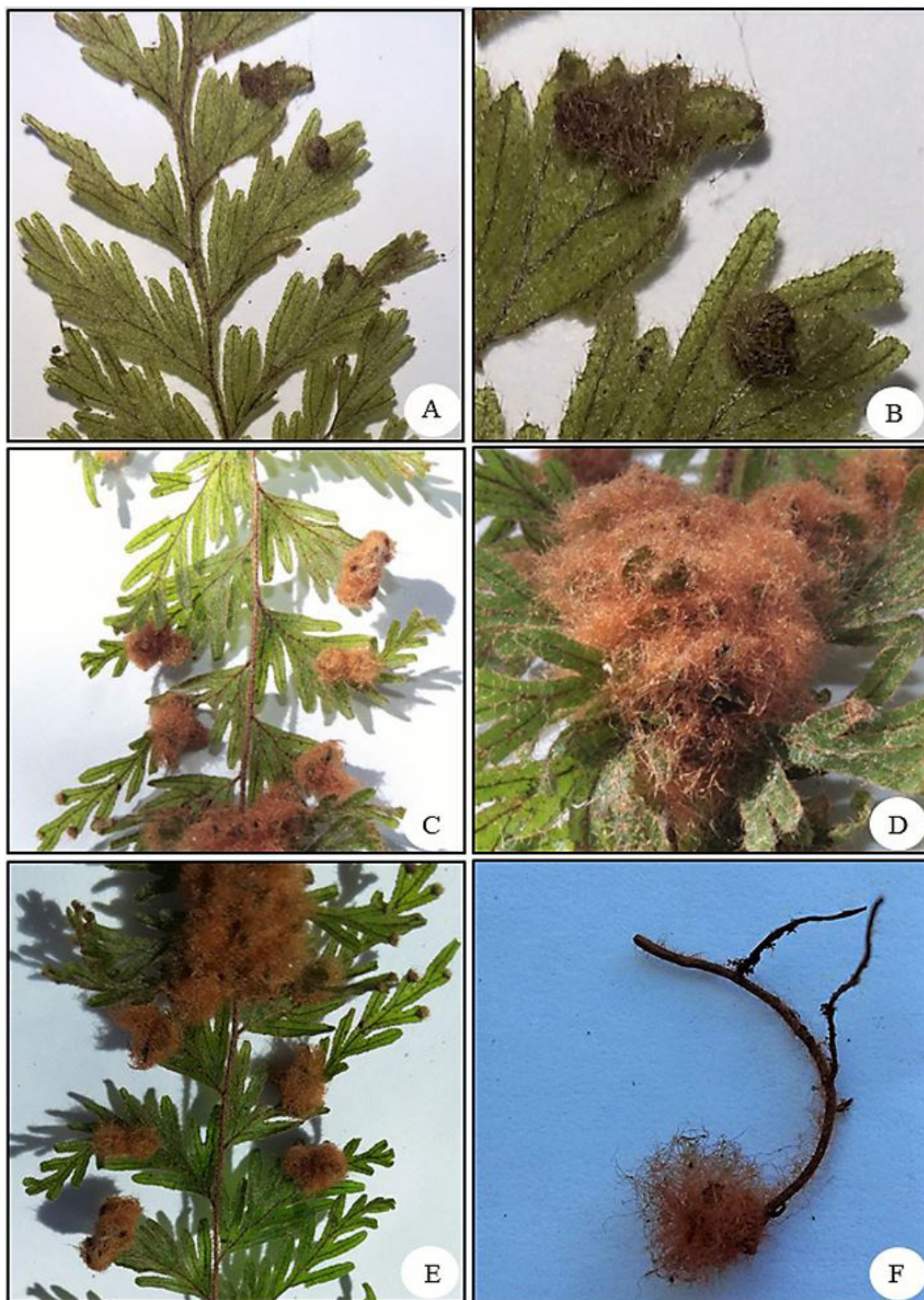


Figure 4. Galls on Hymenophyllaceae family. *Hymenophyllum rufum*, (A, B) leaf gall. *Hymenophyllum pulchellum*; (C-E) leaf gall; and (F) stem gall.

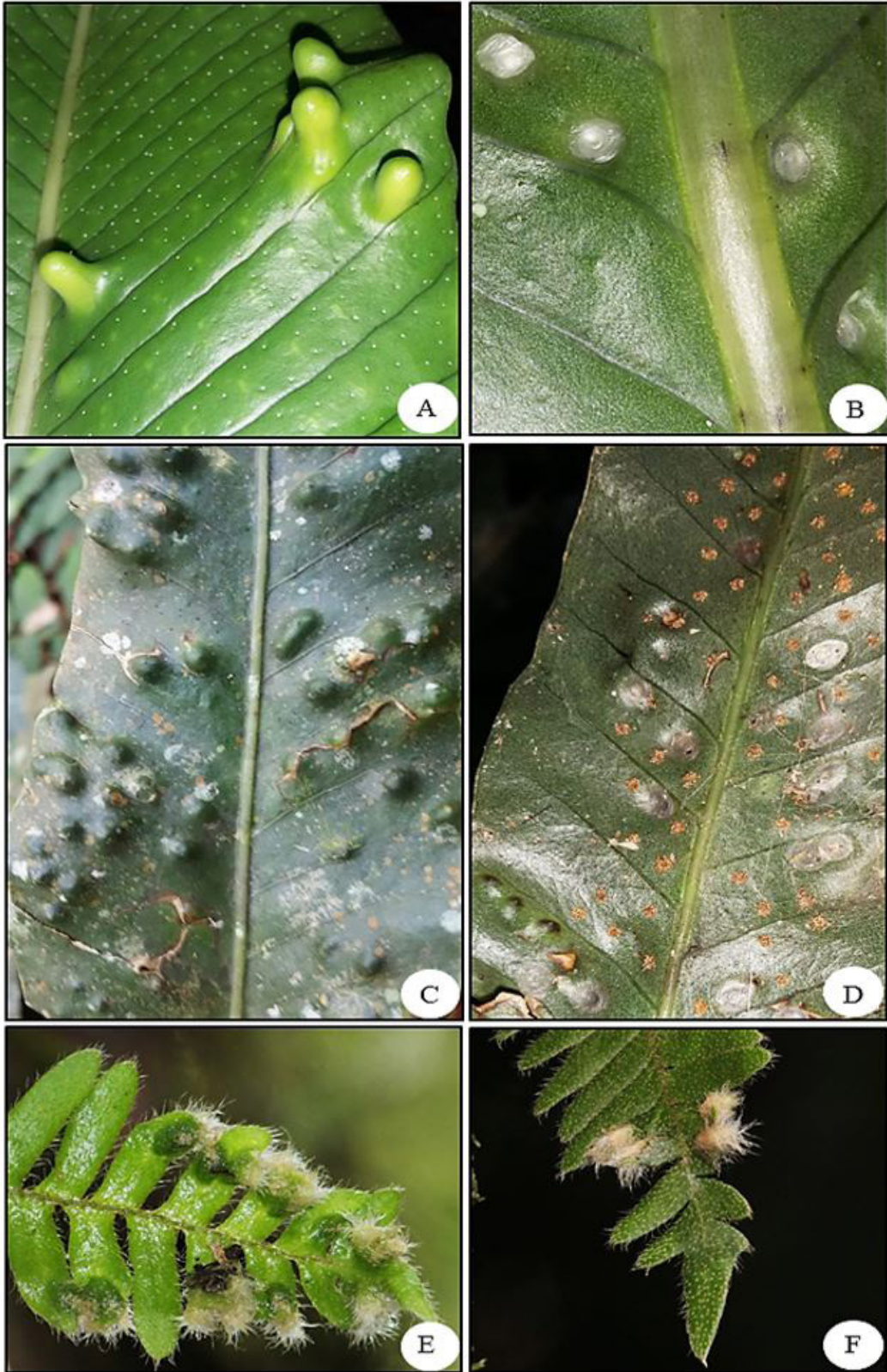


Figure 5. Leaf galls on Polypodiaceae family. *Niphidium crassifolium*, (A) adaxial side of the leaf and (B) abaxial side of the leaf. *Campyloneurum nitidum*; (C) adaxial side of the leaf and (D) abaxial side of the leaf. *Pleopeltis hirsutissima*; (E, F) both on the adaxial side of the leaf.

and Maia, 2018 for more details). Houard (1933) reports Diptera species as gallers of *H. hirsutum* and *H. pulchellum*. Santos and Maia (2018) suggested mites as inducers of the “witches’ broom” galls on *D. flexuosa*, an assumption extended to *D. nervosa* and *D. rufinervis*. Efforts must be directed to identify all these organisms.

The list of fern species hosting galling agents presented here, including four new records of galls, increases the knowledge of the richness of gall-inducing herbivores in ferns. It also shows the high potential of new interactions in fern lineages in unexplored sites. Results as these come to change the rather widespread thought that ferns do not have interactions with herbivores. As the knowledge on host plant species is fundamental for forthcoming studies (Araújo et al., 2015), we encourage descriptions of the inducing species, and biogeographic and ecological approaches of ferns. Future histological studies aiming to understand the changes caused by gallers in those plants, and comparisons with the available information about galls in angiosperms are also necessary. Finally, we highlight that Brazil may be at the forefront of the knowledge about interactions between ferns and gall inducers provided sampling efforts in different ecosystems are undertaken (e.g. Amazonian, Cerrado and Caatinga domains) as well as teamwork among botanists, ecologists and entomologists.

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