Richness of insect galls on shrub-tree restinga of a coastal plain of southern Brazil

Riqueza de galhas de insetos em restinga arbustivo-arbórea de uma planície costeira do sul do Brasil

Ígor Abba Arriola & João Carlos Ferreira de Melo Júnior

ABSTRACT

The restingas are coastal ecosystems over the sandy Quaternary plains. Their vegetation present flora and structure conditioned mainly by edaphic factors. They vary from grasslands, shrub lands up to woody forests. Their environmental conditions, such as water stress and high solar irradiance, may be associated to a high richness of galling. This study aims to identify the insect-plant interactions of the gall type, in a shrub-tree restinga formation at the Acaraí State Park, situated in São Francisco do Sul, Santa Catarina State. The survey was conducted in four plots of 250 x 5 m (5,000 m²) of the PELD/PPBio module, with a sample effort of 32 hours. There were found 56 morphospecies of galls in 31 species of host plants. Lauraceae, Myrtaceae, Melastomataceae, Nyctaginaceae and Calophyllaceae showed the highest number of interactions. Guapira opposita (Nyctaginaceae) and Calophyllum brasiliense (Calophyllaceae) were the major super-hosts. There was a predominance of isolated globoid galls on leaves, induced by Diptera – Cecidomyiidae. Galls on stems were less abundant. The focus of this inventory was restricted to the aerial parts of the plants, which limited the galls records on roots, for which there were records only in adventitious roots of the epiphyte Philodendron surinamense. The richness of galls seems to be proportional to the richness of plant species in this restinga formation.

Keywords: Cecidomyiidae; coastal vegetation; plant-insect interaction; super-hosts.

RESUMO

As restingas são ecossistemas costeiros que ocupam as planícies quaternárias arenosas. Sua vegetação apresenta flora e estrutura condicionada por fatores edáficos em maior grau. Várias de formações herbáceas, arbustivas, arbusto-arbóreas a florestas. Suas características ambientais estressantes, como a baixa disponibilidade hídrica e a alta radiação solar, propiciam uma elevada riqueza de insetos galhadores. O objetivo deste estudo foi reconhecer as interações inseto-planta, do tipo galha, na formação arbusto-arbórea da restinga do Parque Estadual Acaraí, situado em São Francisco do Sul, Santa Catarina. O levantamento foi realizado em quatro parcelas de 250 x 5 m (5.000 m²) do módulo PELD/PPBio, com esforço amostral de 32 horas. Encontraram-se 56 morfoespécies de galhas em 31 espécies de plantas hospedeiras. As famílias com maior número de interações foram Lauraceae, Myrtaceae, Melastomataceae, Nyctaginaceae e Calophyllaceae. As espécies Guapira opposita (Nyctaginaceae) e Calophyllum brasiliense (Calophyllaceae) foram as principais super-hospedeiras. Houve predominância de galhas globoides isoladas em folhas, induzidas por Diptera – Cecidomyiidae. Galhas em caules foram menos abundantes. O foco do inventário restringiu-se às partes aéreas das plantas, o que limitou o registro de galhas em raízes, sendo registradas apenas em raízes adventícias da epífita Philodendron surinamense. A riqueza de galhas parece ser proporcional à riqueza de espécies vegetais nesta formação de restinga.

Palavras-chave: Cecidomyiidae; interação inseto-planta; super-hospedeiras; vegetação costeira.
INTRODUCTION

The restingas, ecosystems in the domain of the Atlantic Forest, show in their composition mosaics of distinct plant communities that vary according to the edaphic gradient. They range from herbaceous and shrubby formations on sandy soils to forests associated with hydromorphic and/or organic soils, whose canopy can reach 15-20 m in height (SCARANO, 2002; MELO JÚNIOR & BOEGER, 2015). The shrub-tree formations fit in the restingas as vegetation installed on sandy soils of low fertility and more distant from the sea, being composed of plants with habits mainly shrubby and arboreal and 2-5 m height (MELO JÚNIOR & BOEGER, 2016). In addition to these characteristics, other environmental factors considered to be adverse, such as high salinity, soil acidity, water scarcity, high incidence of winds and solar irradiation, render restingas extremely fragile environments as regards their conservation (ROCHA, 2001).

The characteristics of the restinga environments make these local ecosystems propitious to the concentration of a great richness of galling insects, which are endophytic herbivores inducing neoplasias in vegetal tissues, characterized by hypertrophy and/or cell hyperplasia (MANI, 1964; SHORTHOUSE et al., 2005). Through this interaction, these insects obtain shelter, food and protection against adverse environmental conditions and natural enemies (FERNANDES & PRICE, 1988; PRICE et al., 1987; PRICE, 2005). In these relationships, the specificity of insect-plant systems generates phenotypes capable of indicating taxonomically the organisms involved (ISAIAS et al., 2013; 2014), even when there are different interactions induced on the same host species, the so-called "super host plants" (ARAÚJO et al., 2013). This diversity of gall phenotypes may be used as an indicator of the local richness of galling insects (FLOATE et al., 1996; CARNEIRO et al., 2009), as well as of the diversity of organisms of other associated trophic levels (MAIA, 2001; STONE & SCHONROGGE, 2000).

Studies done in the southeastern region of Brazil have shown the richness of entomogenic galls in restingas (Bregonci et al., 2010; MAIA et al., 2008; MAIA et al., 2014; RODRIGUES et al., 2014) and have described a large diversity of galling insects (MAIA, 1995, 2001, 2007). In general, there are few studies with a focus on richness of gall-inducing insect in the coastal region of southern Brazil, except the articles of Mendonça Jr. et al. (2010), performed in restingas of Rio Grande do Sul, and Arriola et al. (2016), in restinga formations occurring on dunes in the northeastern portion of the state of Santa Catarina.

In addition, anthropogenic pressures such as urbanization of coastal lines, construction of roads, trampling and car traffic over the vegetation of restinga, garbage disposal and other actions, make these environments a significantly threatened portion of the rain forest (ROCHA, 2003; THOMAZI et al., 2013), opposing to their importance as a kind of vegetation that controls the effects of erosive processes of coastal regions and as an ecosystem that maintains the local biodiversity (KUKI et al., 2008).

Thus, the present study aims to contribute to the knowledge about the richness of insect galls of southern Brazil restingas, employing the concept of “morphospecies” used by Portugal-Santana and Isaias (2014), as a tool for the record of these interactions in the shrub-tree restinga physiognomy of the Acaurai State Park (PEA), in São Francisco do Sul, Santa Catarina State, Brazil.

MATERIAL AND METHODS

The study area comprises a restinga remnant located in the municipality of São Francisco do Sul, in the coastal plain of Santa Catarina State, Brazil (48°33' W – 26°17' S). Considered as a priority area for biodiversity conservation (PROBIO, 2003), the PEA region was transformed into a conservation unit in 2005 and covers a total area of 6,667 ha (FATMA, 2008; figure 1).
The PEA is characterized by the presence of restingas, which vary as herbaceous formations (figure 1B) in the post-beach region and dunes, shrubs, shrubs-trees (figure 2) and transitional forests, as well as other less expressive formations such as floodplains, mangroves and submontane forest (FATMA, 2008).

The local flora covers 319 species, distributed in 215 genera and 82 families.

Among these, the most representative families in number of species are: Asteraceae (35), Fabaceae (30), Myrtaceae (20), Rubiaceae (18) and Poaceae (13) (MELO JÚNIOR & BOEGER, 2015). The climate of the region is classified as Cfa de Köppen (subtropical climate, with hot summer), influenced by the maritime humidity, with annual average temperature of 20.3°C and relative humidity of 1.874 mm/ year (KNIE, 2002). Soil is classified as a ferrihumulvic spodossol in the shrub-arboreal formation of restinga (OLIVEIRA & VIEIRA, 2008).
RESULTS

The present work registered a total of 56 gall morphospecies in 31 plant species from 21 botanical families (table 1, figures 3 to 58).

These morphospecies were classified into seven gall morphotypes, of which the most abundant was the globule with 37.5% of occurrences, followed by lenticular (26.79%) and fusiform (23.21%). The least frequent morphotypes were conical (5.36%), rosette (3.57%), foliar winding and nailing (1.79% each). Galls occurring in isolation were more frequent (87.5% of cases) than the coalescing morphotypes (12.5%). Galls morphotypes occurred predominantly in leaves (71.43%), occurring with a lower incidence in stems (25%). Galls in roots were also observed (3.57%) but, due to the focus of work in the aerial parts of the plants, they show a low proportion of records. The galls varied in color, with predominantly green morphotypes (67.86%), followed by brown (23.21%), yellow (5.36%), white and red (1.79% each). Galls exhibiting ornamentation/pubescence occurred in about 22% of the morphotypes found. The most representative botanical families in gall morphotypes were: Lauraceae (10), Myrtaceae...
The species diagnosed as the main local super host were *Calophyllum brasiliense* Cambess. (Calophyllaceae) and *Guapira opposita* (Vell.) Reitz (Nyctaginaceae), each hosting four distinct morphotypes of galls. The galling insects were identified at least at the order level in about 60% of the cases. The Diptera: Cecidomyiidae taxon was the most representative, with 48.21% of occurrences. Other less representative groups were Hemiptera (7.14%), Lepidoptera (3.57%) and Coleoptera (1.79%). The remaining 40% remained undetermined.

Table 1 - Characterization of gall morphotypes and their respective host-plants occurring in the shrub-tree restinga of Parque Estadual Acaraí, São Francisco do Sul municipality, Santa Catarina, Brazil.

<table>
<thead>
<tr>
<th>Family</th>
<th>Plant species</th>
<th>Morphotype</th>
<th>Host organ / Oviposition site</th>
<th>Color</th>
<th>Pubescence</th>
<th>Gall-inducer*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anacardiaceae</td>
<td><em>Schinus terebinthifolius</em> Raddi</td>
<td>extralaminar</td>
<td>leaf / median vein</td>
<td>green</td>
<td>no</td>
<td><em>Calophya terebinthifolii</em> Burckhardt &amp; Basset, 2000 (Psylloidae, Hemiptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lenticular</td>
<td>extralaminar vein</td>
<td>green</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Annonaceae</td>
<td><em>Guatteria australis</em> A.St.-Hil.</td>
<td>fusiform</td>
<td>stem</td>
<td>brown</td>
<td>yes</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>globoid</td>
<td>leaf / secondary vein</td>
<td>green</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lenticular</td>
<td>leaf / secondary vein</td>
<td>green</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fusiform</td>
<td>root / adventitious root / grampiform</td>
<td>green</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td>Araceae</td>
<td><em>Philodendron surinamense</em> (Miq.) Schott.</td>
<td>fusiform to coalescent</td>
<td>root / adventitious root</td>
<td>green</td>
<td>no</td>
<td><em>Cecidomyiidae</em> (Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lenticular</td>
<td>leaf / secondary vein</td>
<td>green</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>extralaminar</td>
<td>conical / stem</td>
<td>green</td>
<td>no</td>
<td><em>Liodiplosis cylindrica</em> Gagné, 2001 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Asteraceae</td>
<td><em>Mikania trinervis</em> Hook. &amp; Arn.</td>
<td>globoide</td>
<td>leaf / median vein-petiole</td>
<td>green</td>
<td>no</td>
<td><em>Liodiplosis sp.</em> (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>globoide to coalescent</td>
<td>stem</td>
<td>green / red</td>
<td>no</td>
<td><em>Mikanadiopsis sp.</em> (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Family</td>
<td>Plant species</td>
<td>Morphotype</td>
<td>Host organ / Oviposition site</td>
<td>Color</td>
<td>Pubescence</td>
<td>Gall-inducer*</td>
</tr>
<tr>
<td>------------</td>
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</tr>
<tr>
<td>Calophyllaceae</td>
<td><em>Calophyllum brasiiliense</em> Cambess.</td>
<td>leaf rolling</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td><em>Cecidomyiidae</em> (Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fusiform</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td><em>Lopesia linearis</em> Maia, 2003 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>globoid to coalescent</td>
<td>stem</td>
<td>brown</td>
<td>no</td>
<td><em>Lopesia caulinaris</em> Maia, 2003 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>intralaminar lenticular</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td><em>Lopesia elliptica</em> Maia, 2003 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Celastraceae</td>
<td><em>Maytenus glazioviana</em> Loes.</td>
<td>lenticular</td>
<td>leaf / secondary vein</td>
<td>green</td>
<td>no</td>
<td><em>Mayteniella robusta</em> Maia, 2001 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Clusiaceae</td>
<td><em>Clusia criuva</em> Cambess.</td>
<td>fusiform intralaminar</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td><em>Lepidoptera</em></td>
</tr>
<tr>
<td></td>
<td><em>Andira fraxinifolia</em> Benth.</td>
<td>fusiform</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>yes</td>
<td><em>Cecidomyiidae</em> (Diptera)</td>
</tr>
<tr>
<td>Fabaceae</td>
<td><em>Dalbergia frutescens</em> (Vell.) Britton</td>
<td>globoid</td>
<td>leaf / secondary vein</td>
<td>yellow</td>
<td>no</td>
<td><em>Asphondyliina</em> sp. (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td></td>
<td><em>Alouea saligna</em> Meisn.</td>
<td>clavate</td>
<td>leaf / secondary vein</td>
<td>green</td>
<td>yes</td>
<td><em>Lopesia grandis</em> Maia, 2001 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Lauraceae</td>
<td><em>Endlicheria paniculata</em> (Spreng.) J.F.Macbr.</td>
<td>fusiform, isolated or coalescent</td>
<td>stem</td>
<td>brown</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td><em>Nectandra grandiflora</em> Nees</td>
<td>globoid</td>
<td>leaf / leaf lamina</td>
<td>brown</td>
<td>yes</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td><em>Nectandra oppositifolia</em> Nees</td>
<td>lenticular</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td>Unknown</td>
</tr>
</tbody>
</table>
### Richness of insect galls on shrub-tree restinga of a coastal plain of southern Brazil

**Family** | **Plant species** | **Morphotype** | **Host organ/Oviposition site** | **Color** | **Pubescence** | **Gall-inducer**
---|---|---|---|---|---|---
Lauraceae | *Nectandra membranacea* (Sw.) Griseb. | conical | leaf / median vein | green | yes | Unknown
| | | globoïd | leaf / secondary vein | green | no | Unknown
| | | globoïd | leaf / secondary vein | brown | yes | Unknown
| *Ocotea catharinensis* Mez | globoïd | leaf / median vein-secundária | red | no | Neolasioptera sp. (Cecidomyiidae, Diptera)
| *Ocotea pulchella* (Nees & Mart.) Mez | intralaminar lenticular | leaf / secondary vein | green | no | Coccidae (Hemiptera)
| | rosette | stem / meristem | green | no | Clinodiplosis sp. (Cecidomyiidae, Diptera)
Malvaceae | *Pavonia* sp. | globoïd | leaf / median and secondary vein | green | yes | Cecidomyiidae (Diptera)
| | *Miconia pussiliiflora* (DC.) Naudin. | fusiform | stem | brown | no | Unknown
| | | fusiform | leaf / median vein | green | no | Unknown
Melastomataceae | *Tibouchina pulchra* Cogn. | globoïd to coalescent | stem | brown | no | Lepidoptera
| | | fusiform | leaf / median vein | green | yes | Curculionidae (Coleoptera)
| | | fusiform | stem | brown | no | Cecidomyiidae (Diptera)
| | | fusiform | leaf / median vein | green | yes | Neolasioptera sp. (Cecidomyiidae, Diptera)
Meliaceae | *Guarea macrophylla* Vahl | fusiform | leaf / median vein | green | yes | Sphaeromyia flava Maia, 2007 (Cecidomyiidae, Diptera)
| | | globoïd | leaf / leaf lamina | green / yellow | yes | |
| *Myrtaceae sp.* 01 | lenticular | leaf / secondary vein | green | no | Unknown
| | | globoïd | stem | brown | no | Unknown
Myrtaceae | *Myrcia pulchra* (O.Berg) Kiaersk. | lenticular | leaf / leaf lamina | yellow | yes | Unknown
| | | lenticular | leaf / secondary vein | branca | no | Unknown
<table>
<thead>
<tr>
<th>Family</th>
<th>Plant species</th>
<th>Morphotype</th>
<th>Host organ / Oviposition site</th>
<th>Color</th>
<th>Pubescence</th>
<th>Gall-inducer*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myrtaceae</td>
<td>Psidium cattleianum Sabine</td>
<td>globoid extralaminar</td>
<td>leaf / secondary vein / secondary vein</td>
<td>yellow</td>
<td>no</td>
<td>Nothotrioza cattleiani Burckhardt, 2013 (Psylloidae, Hemiptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>intralaminar</td>
<td>leaf / median and secondary vein</td>
<td>green</td>
<td>no</td>
<td>Tectococcus ovatus Hempel., 1900 (Eriococcidae, Hemiptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>lenticular</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td>Cecidomyiidae (Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>fusiform</td>
<td>stem</td>
<td>brown</td>
<td>no</td>
<td>Proasphondylia formosa Maia, 1993 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>globoid, predom. coalescent</td>
<td>stem</td>
<td>brown</td>
<td>no</td>
<td>Proasphondylia guapiarei Maia &amp; Couri, 1993 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Nyctaginaceae</td>
<td>Guapira opposita (Vell.) Reitz</td>
<td>lenticular</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td>Bruggmannia elongata Maia &amp; Couri, 1993 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rosette</td>
<td>stem / meristem</td>
<td>green</td>
<td>no</td>
<td>Pisphondylia braziliensis Couri &amp; Maia, 1992 (Cecidomyiidae, Diptera)</td>
</tr>
<tr>
<td>Orchidaceae</td>
<td>Vanilla chamissonis Klotzsch</td>
<td>globoidosolmianum C.DC.</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td>Piperaeae</td>
<td>Piper solmianum C.DC.</td>
<td>globoidosolmianum C.DC.</td>
<td>leaf / secondary vein</td>
<td>green</td>
<td>yes</td>
<td>Cecidomyiidae (Diptera)</td>
</tr>
<tr>
<td>Rubiaceae</td>
<td>Psychotria carthagenaensis Jacq.</td>
<td>conical</td>
<td>leaf / median and secondary vein</td>
<td>green</td>
<td>no</td>
<td>Cecidomyiidae (Diptera)</td>
</tr>
<tr>
<td>Sapindaceae</td>
<td>Paullinia trigonia Vell.</td>
<td>globoidosolmianum C.DC.</td>
<td>leaf / leaf lamina</td>
<td>green</td>
<td>no</td>
<td>Cecidomyiidae (Diptera)</td>
</tr>
<tr>
<td>Sapotaceae</td>
<td>Pouteria beaurepairei (Glaz. &amp; Raunk.) Baehni</td>
<td>globoidosolmianum C.DC.</td>
<td>leaf / stem</td>
<td>brown</td>
<td>no</td>
<td>Unknown</td>
</tr>
<tr>
<td>Smilacaceae</td>
<td>Smilax campestris Griseb.</td>
<td>lenticular</td>
<td>leaf / leaf lamina / black</td>
<td>green</td>
<td>no</td>
<td>Smilasioptera sp. (Cecidomyiidae, Diptera)</td>
</tr>
</tbody>
</table>
Family | Plant species | Morphotyoe | Host organ / Oviposition site | Color | Pubescence | Gall-inducer*
---|---|---|---|---|---|---
Solanaceae | *Solanum pseudoquina* A.St.-Hil. | globoid, coalescent | stem / meristem | brown | no | Unknown
 |  | lenticular | leaf / leaf lamina | green | no | Unknown

* Based on Maia (2013) and Gagné & Jaschhof (2014)

DISCUSSION

The flora of the shrub-tree physiognomy of the PEA restinga is composed of 110 species, distributed in 81 genera and 47 families (MELO JÚNIOR & BOEGER, 2015), of which 31 plant species, 28% of the floristic diversity of this formation accumulate a wealth of 56 morphospecies of galls. The families that added the most gall (51.8%) in the formation of restinga studied also stand out in the flora of the PEA as those with the greatest species richness, or with species of greater representativeness in the community structure of the restinga formations of this park (MELO JÚNIOR & BOEGER, 2015). In this way, the greater diversity presented or the greater abundance of a given taxon can be positively related to the supply of host plants (MENDONÇA JR., 2007; ARAÚJO, 2011). In the herbaceous formation of the PEA, 15 morphospecies of gall were recorded, occurring in 8 species of host plants (ARRIOLA et al., 2015), a number considerably lower than that recorded in this study. This difference between gall richness formations can be explained by the difference in the local floristic richness, corroborating the hypotheses that relate the greatest plant richness to the greatest wealth of galling insects (MENDONÇA JR., 2007; ARAÚJO, 2011).

The globular morphotype occurred in 37.5% of the galls recorded in this restinga formation, standing out as the most common morphotype of Brazilian flora (ISAIAS et al., 2013, 2014). In addition to this, the lenticular morphotype, one of the main morphotypes of local galls (ARRIOLA et al., 2015), and the fusiform, a predominant morphotype in stems (FORMIGA et al., 2015), were prominent in this restinga formation. Other less frequent morphotypes in Brazilian biomes were also recorded, such as the conical, rosette, foliar winding and nailing (ISAIAS et al., 2013, 2014). In general, the dominance
pattern of globular, lenticular and fusiform gall morphotypes of this restinga is in agreement with the patterns found in other restingas of the Southeast region (MAIA, 2013), corroborating the neutrality of this environment in relation to its morphogenetic effects on the formation of galls (ARRIOLA et al., 2015). It is a consensus in literature that the morphotypes are conditioned by the plastic capacity of the plant tissue and by the genetic interaction between insect-plant, and there is no environmental variable that determines the morphotypes (STONE & SCHONROGGE, 2003; FORMIGA et al., 2015).

The occurrence of isolated gall morphotypes was greater than that of coalescing galls, the latter occurring exclusively in stems and roots. Isolated galls on leaves appear to be a guarantee for the development of the gall since there is a considerable reduction of the impact of the gall on the morphophysiological characteristics of the parasitized leaf. However, coalescent galls or the massive occurrence of galls on the same leaf can cause, by the leaf deformation, the reduction of the specific leaf area and an early leaf senescence (CONSTANTINO et al., 2009).

The leaf, as the most frequent host organ, is considered the part of the plant that most houses galling insects in the flora in general (ISAIAS et al., 2013, 2014). The lower frequency of galls in stems, as well as the smaller variety of morphotypes occurring in this organ, may be associated with the lower plastic response potential of the tissues to the stimulation of the gall (FORMIGA et al., 2015). Galls in roots were recorded only in the epiphytic species Philodendron surinamense (Araceae), occurring in adventitious roots. In general, root-induced insect galls are poorly recorded, although they occur in roots of epiphytic species of other families such as Orchidaceae and Polypodiaceae (TANOUE et al., 2004; MAIA & SANTOS, 2015). Underground roots aggregate gallers from other organisms, such as bacteria and nematodes (MANI, 1964) and are often the focus of agronomic science studies.

As to the coloration and ornamentation of the galls, the distinction in relation to the surrounding plant tissues confers alert signaling characteristics as protection against herbivory (IMBAR et al., 2010). Thus, the predominance of green coloration (67.86%) indicates the variation in the accumulation of pigments during the senescence process of the gall, occurring the greater accumulation of chlorophyll in galls in later stages of development (Dias et al., 2013).

Superhosts families and species are those capable of harboring three or more gall morphotypes, indicating their ability to react to the stimulus of more than one inducer, which contributes to the increase of galling insects diversity in an ecosystem (ARAÚJO et al., 2013). In the present study, the super-host species added around 16% of the total number of galls found, demonstrating their importance for the diversity of galling insects. Similarly, studies performed by Arriola et al. (2015, 2016) also indicated the species Guapira opposita (Nyctaginaceae) and Calophyllum brasiliense (Calophyllaceae) as important super-host galls in the PEA flora.

The predominant group of inductors in this study was the Cecidomyiidae family (Diptera), which corroborates the assumption that it is the largest and most specialized group of forming galls herbivores (MAIA, 2013; GAGNÉ & JASCHHOF, 2014). The indeterminate taxa, which represented 40% of the total observed, can be considered, due to these species-specific interactions, to be new species of inductors to be described and known by science (ESPIRITO-SANTO & FERNANDES, 2007; CARNEIRO et al., 2009).

This first galls inventory focused on the shrub-arboreal vegetation of the PEA restinga showed the increasing diversity of specialized herbivory interactions (insect-plant) when compared to the inventories made in herbaceous vegetation of restinga (MENDONÇA JR. et al., 2010, ARAÚJO, 2011; ARRIOLA et al., 2015), as well as contributed to the design of research protocols linked to long-term ecological works developed within the PPBio Mata Atlântica network.

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Richness of insect galls on shrub-tree restinga of a coastal plain of southern Brazil

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