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RESEARCH ARTICLE

Insights into Super-host Plant Species of Galling Insects in the Neotropical Region

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Abstract:

Background:

The term 'super host' plant is often used in the literature surrounding plant-galling interactions, but the different contexts in which the term is used generates doubt and confusion due to the absence of a systematic definition of the term's meaning.

Objective:

In this study, we used 60 well-defined plant-galling assemblages to propose a systematic definition of super-host plants at the local and regional level. In addition, we investigated factors that explain the number of galling species per host plant at different geographic scales.

Methods:

Plant-galling assemblages were compiled from an extensive literature review on insect gall inventories carried out in Brazil.

Results:

We found 888 host plant species belonging to 94 families and 340 genera hosting 2,376 insect gall morphotypes. At a local scale, 33.2% of host plant species harbored one insect gall morphotype and 12.2% hosted two gall morphotypes, making up 45.4% of the host plant species in each locality. At the regional scale, 51.5% of host plant species harbored one insect gall morphotype, and 17.9% of host plant species hosted two gall morphotypes, corresponding to 69.4% of all host plant species. Based on the average number of galling species per plant species, we classified the plant species into: 1) Host species; 2) Multi-host species and 3) Super-host species. The super-host plant species that showed the greatest richness of gall morphotypes at the local level were *Baccharis reticularia* and *Adenocalymma neoflavidu*. Furthermore, we found a positive relationship between plant life-form architectural complexity and the number of galling species at the local level. At the regional scale, we registered five super-host species (*Guapira opposita*, *Protium heptaphyllum*, *Copaifera langsdorffii*, *Myrcia splendens,* and *Byrsonima sericea*) which hosted 21 or more insect gall morphotypes. The number of galling species per host plant species at the regional scale was influenced positively by geographic distribution rank and number of biomes in which each species of the plant occurs.

Conclusion:

The present study stands out as the first of its kind to provide a systematic standardization for the super-host plants and to investigate factors influencing these species.

Keywords: Ecological interactions, Galling arthropods, Herbivory, Insect galls, Plant-animal interactions, Neotropical region.

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1. INTRODUCTION

Interactions involving host plants and galling insects are among the most diverse and specialized in nature [1, 2]. In the Neotropical region, a great diversity of plant-galling interactions has been studied in recent years [3 - 5]. Estimates indicate that more than 15,400 species of galling insects and more than 29,000 species of host plants exist in the neotropics [3]. Galling species tend to be species-specific with their hosts

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[6], but host plant species can host a variable number of galling insect species [7]. In most cases, the number of galling insect species per host plant species is usually one or two, although some host species can house more than 20 different galling species [8, 9].

In studies investigating plant-galling interactions in the Neotropical region, the term 'super-host' is frequently used to designate plant species that host a high richness of galling species [10]. For example, Costa *et al.* [11] defined *Copaifera langsdorffii* (Fabaceae) as a super-host because it houses 23 galling species. In a separate study, this same host species was recorded as a super-host while hosting 17 galling species [12]. *Copaifera oblongifolia*, another congeneric species was also named a super-host by Fagundes *et al*. [13] and Coutinho *et al*. [14], hosting 15 galling species. Goetz *et al*. [15] named *Piper aduncum* (Piperaceae) and *Mikania glomerata* (Asteraceae) super-hosts, harboring eight and six galling species, respectively. In another study, Maia and Oliveira [16] used the term super-host to describe *Guapira opposita* (Nyctaginaceae) which hosted four galling insect species. In an extreme case, Ribeiro *et al*. [17] defined *Moquiniastrum pulchrum* (Asteraceae) as a super-host plant, by housing two galling species. These examples illustrate how the term 'super-host' is frequently used in galling insect studies, often in an indiscriminate and non-standardized way.

The number of herbivorous insects hosted by host plants can be influenced by several factors at different scales [18]. At the local scale, studies have pointed to plant traits such as life-form as influencing the distribution of galling species, with trees usually hosting greater galling insect diversity than non-arboreal plants [19]. These results agree with the hypothesis that host plants with higher architectural complexity house more insect herbivore species [20, 21]. At the regional scale, the plant's geographic range has been hypothesized as an important predictor of the diversity of herbivorous insects hosted by a plant species [18]. This pattern can be explained by the fact that hosts with a wide distribution have contact with a greater diversity of herbivores, which promotes the accumulation of more interactions throughout their distribution [22]. The aforementioned factors (amongst others), may potentially explain the occurrence of super-host plant species, though this remains a knowledge gap of plant-galling interactions.

In this context, the standardized definition of the term 'super-host' and the investigation of factors influencing the occurrence of these species are important to guide studies of insect gall diversity in neotropical environments. In this study, we propose a definition to differentiate super-host plants at the local and regional level using a dataset compiled from the literature surrounding plant-galling inventories in Brazil. We aim to answer the following questions: 1) What defines super-host plants at the local level? 2) Do super-host plants vary locally? 3) Are there factors that explain the occurrence of super-host taxa at the local level? 4) What defines super-host plants at the regional level? 5) Are there factors that explain the occurrence of super-host taxa at the regional level?

2. METHODS

2.1. Data Compilation

We carried out a comprehensive literature search for studies reporting assemblages of gall insects associated with their host plant in the SciVerse Scopus, Portal Capes, and Google Scholar databases (until 2017), using the following combinations of keywords: (plant*) and (galls*) and (interaction* or web*) and (survey* or list*). It is important to note that we compiled only inventories of the richness of host plants and galling insects, and we did not consider literature focused on a single species of plant or galling insect, to ensure that all studies included had searched for all galls occurring in the community. Thus, only those studies with plant-gall insect assemblages that met all of the following criteria were included in our study: 1) At least 3 host plant species; 2) At least 3 host plants hosting a minimum of 3 galling insect species (*i.e*., insect gall morphotypes); and 3) An indication that all plants could potentially be utilized by the gall insect assemblages in the list (*i.e*., no spatial mismatch). Overall, 60 local plant-galling assemblages were selected from 31 studies (Supplementary Material 1). The latitudinal distri-bution of the plant-galling assemblages ranged from 1°20' S to 29°28' S, and their altitudes ranged from 10 to 1,860 m.a.s.l.

2.2. Plant Species

For each local plant-galling assemblage we checked the synonymy of host plant using "The Plant List" database (www.theplantlist.org). We also used additional information, such as the Tropicos (www.tropicos.org) databases to refine a list of each family, genus, and host plant species where they were sampled. Host plants that were taxonomically determined only at the genus level (*i.e*., species identified as "sp.") were also added to the list.

2.2.1. Local and Regional Gall Morphospecies Diversity

We used compiled data to calculate the richness of insect galls at local and regional levels. At the local level, we considered the number of gall morphotypes described in each host plant species within the community. For the categorization of the morphotypes, we considered the original morphological (*i.e*., plant organ, shape, color, and pilosity) description made by the authors of the studies. We did not consider the size of galls as an important character in our study due to the high variability in this characteristic. The use of morphotypes as a surrogate for the species of galling insects is widespread in the literature due to the high specificity of galls and the lack of taxonomic studies of gallers [5]. At the regional level, we considered the sum of unique morphotypes on each host plant species in the different plant-galling communities.

It is important to emphasize that our measure of gall richness at the regional level, is strongly dependent on sampling effort for each host plant species because plant species that have occurred in several communities are more likely to accumulate more galls over space [5]. However, we believe that as we adopt the criterion of compiling only studies that inventoried the entire plant community, this effect can be mitigated. Besides, the authors did not look a priori at specific plant species, they collected information for all plants in the community. Thus, it is expected that the plant species that are registered in different studies are species with wide distribution between habitats and localities.

2.3. Data Analyses

At the regional level, we used a Generalized Linear Model (GLM) to investigate plant-related factors (life-forms, endemism, geographic range, biome occurrence, vegetation occurrence) on the galling species richness. Predictive variables were ordered as ordinal (sequential) variables. For the plant life-form architectural complexity, we used the following categories: 1 = herb, 2 = liana, 3 = shrub and 4 = tree. With regards to endemism, we considered plant species with occurrence only in Brazil as endemic and species occurring in Brazil and other countries as non-endemic. The categories used for the geographical distribution area were: 1 = distribution restricted to a small area/locality, 2 = biome (in a single state), 3 = biome (occurring in several states), 4 = Brazil (occurring in different biomes in the same state) and 5 = Brazil (occurring in different biomes and states). For vegetation, we used the following categories: 1 = grassland, 2 = savanna and 3 = forest. We used this ranking because there is an increasing gradient of structural complexity (in terms of biomass, tree cover, and height of vegetation) grassland <savanna <forest. We also accounted for the number of biomes within which each plant species occurs. At the local level, we also used a GLM to investigate whether galling species richness is influenced by plant life-form using the same life-form categories as above. All of the models were built using the error of Poisson distribution. All statistical analyses were performed in R version 3.4.1 [23].

3. RESULTS

A total of 888 host plant species belonging to 94 families and 340 genera were analyzed hosting 2,376 insect gall morphotypes. The most important host plant family was Fabaceae, hosting 291 (12.2%) insect gall morphotypes, followed by Asteraceae (263; 11.0%), Myrtaceae (260; 10.9%), Melastomataceae (126; 5.3%), Malpighiaceae (111; 4.6%), and Burseraceae (100; 4.2%). The most important of host plant genera were *Myrcia* (Myrtaceae) with 106 (4.4%), *Protium* (Burseraceae) with 85 (3.6%), *Eugenia* (Myrtaceae) with 84 (3.5%), *Baccharis* (Asteraceae) with 81 (3.4%), and *Byrsonima* (Malpighiaceae) with 78 (3.2%) insect gall morphotypes.

At a local scale, 33.2 ± 10.5% of host plant species in each locality harbored one insect gall morphotype and 12.2 ± 4.8% hosted two gall morphotypes, totaling 45.4% of the host plant species (Fig. **1**; Table **1**). Considering all host plant species, the mean number of gall morphotypes per plant species was 2.67 ± 3.33. We considered plant-species with more than double of this mean (*i.e.*, six or more species) as super host plants at a local scale (Table **2**), which correspond to less than 1% of host plant species in each locality. For a given locality, the maximum number of insect gall morphotypes per plant species ranged between 3 and 10. Plant species that hosted between three and six insect gall morphotypes were categorized as multi-host plant species (Table **2**). Super-host plants at the local level were represented by 23 species occurring across 24 localities (Table **3**). The species that hosted the most gall morphotypes at individual sites were *Baccharis reticularia* with 10 insect gall morphotypes in the Parque Estadual do Itacolomi and *Adenocalymma neoflavidum* (Bignoniaceae) with nine gall morphotypes in the Floresta Nacional Saracá-Taquera. Host plant species more frequently listed in inventories of galling insects were *Guapira opposite* (eight studies), *Eremanthus erythropappus* (Asteraceae) (three studies) and *Protium heptaphyllum* (three studies) (Table **3**). We found a positive relationship between the life-form and the number of galling species at the local level (Deviance = 14.46, df = 1779, $p < 0.001$).

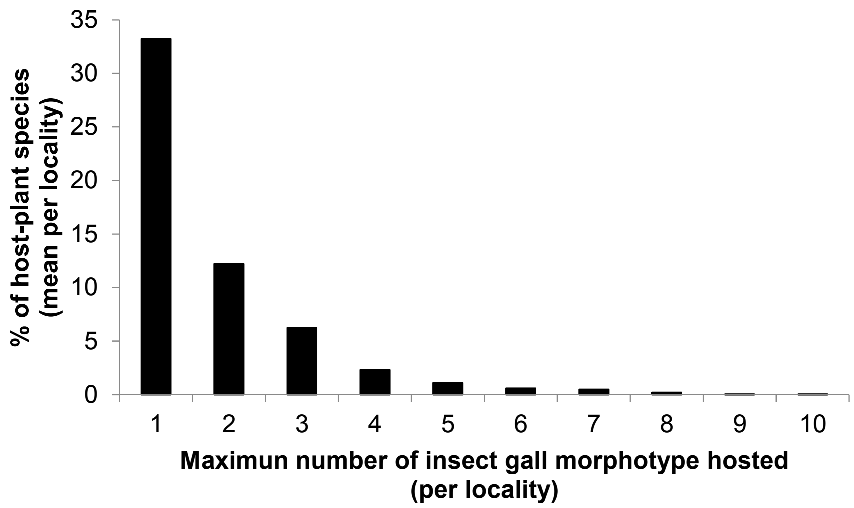

Fig. (1). Percentage of host plant species hosting different richness of galling species (maximum number of insect gall morphotype hosted).

Table 1. Range of galling insect richness (insect gall morphotypes) per host plant species.

Range (Gall Morphotypes per Plant Species)	Percent of Host Plant Species per Locality			
	Mean	SD	Max	Min
1	33.2	10.6	63.6	12.5
2	12.2	4.8	21.3	0
3	6.2	3.2	17.1	0
4	2.3	2.1	8.3	0
5	1.1	1.6	5.7	0
6	0.6	1.1	4.2	0
7	0.5	1.2	6.3	0
8	0.2	0.6	2.9	0
9	0.0	0.2	1.6	0
10	0.0	0.2	1.8	0

Table 2. Categorization of super-host plant species at the local and regional scales.

Ecological Scale	Range of Richness of Insect Gall Morphotypes	Category of Host Plant Species
Local scale	1 to 3	Host plant species
	3 to 6	Multi-host plant species
	6 or more	Super-host plant species
Regional scale	1 to 3	Host plant species
	6 to 20	Multi-host plant species
	21 or more species	Super-host plant species

Table 3. List of super-host plants at the local scale based on Brazilian plant-galling inventories.

Super-host Plant Species	Plant Family	Number of Insect Gall Morphotypes	Locality	References
Baccharis pseudomyriocephala	Asteraceae	10	Parque Estadual do Itacolomi	Carneiro *et al*. [24]
Adenocalymma neoflavidum	Bignoniaceae	9	Floresta Nacional Saracá-Taquera	Araújo *et al*. [25]
Baccharis platypoda	Asteraceae	8	Parque Estadual do Brigadeiro	Coelho *et al*. [26]
Protium heptaphyllum	Burseraceae	8	Serra de São José Cachoeira do Mangue	Maia and Fernandes [27]
Guapira opposita	Nyctaginaceae	8	Bertioga	Maia [28]
Mikania biformis	Asteraceae	8	Bertioga	Maia [28]
Guapira opposita	Nyctaginaceae	8	Maricá	Maia [28]
Copaifera langsdorfii	Fabaceae	8	Cachoeira da Lua	Maia [29]
Guapira opposita	Nyctaginaceae	8	Ilha da Marambaia - Armação	Rodrigues *et al*. [30]
Baccharis reticularia	Asteraceae	7	Parque Estadual do Itacolomi	Carneiro *et al*. [24]
Baccharis platypoda	Asteraceae	7	RPPN do Caraça	Carneiro *et al*. [24]
Baccharis reticularia	Asteraceae	7	RPPN do Caraça	Carneiro *et al*. [24]
Byrsonima coccolobifolia	Malpighiaceae	7	RPPN do Caraça	Carneiro *et al*. [24]
Protium sagotianum	Burseraceae	7	Platô Bacaba - Porto de Trombetas	Maia [31]
Myrcia splendens	Myrtaceae	7	Bertioga	Maia [28]
Ocotea pulchella	Lauraceae	7	Bertioga	Maia [28]
Eugenia astringens	Myrtaceae	7	Jurubatiba	Maia [28]
Guapira opposita	Nyctaginaceae	7	Jurubatiba	Maia [28]
Mikania biformis	Asteraceae	7	Guaratuba	Maia *et al*. [32]
Myrcia splendens	Myrtaceae	7	Praia do Itaguaré	Maia *et al*. [32]
Guapira opposita	Nyctaginaceae	7	Estação Biológica de Santa Lúcia	Maia *et al*. [33]
Mikania laevigata	Asteraceae	7	Parque Natural Municipal São Lourenço	Maia *et al*. [33]
Protium heptaphyllum	Burseraceae	7	Mata Semicaudicifolia - UFG	Silva *et al*. [34]
Styrax pohlii	Styracaceae	7	Mata Semicaudicifolia - UFG	Silva *et al*. [34]
Guapira opposita	Nyctaginaceae	7	Ilha da Marambaia - Sitio	Rodrigues *et al*. [30]

(Table 3) contd.....

Super-host Plant Species	Plant Family	Number of Insect Gall Morphotypes	Locality	References
Eremanthus erythropappus	Asteraceae	6	Parque Estadual do Itacolomi	Carneiro *et al.* [24]
Byrsonima coccolobifolia	Malpighiaceae	6	Parque Estadual do Biribiri	Carneiro *et al.* [24]
Eremanthus erythropappus	Asteraceae	6	RPPN do Caraça	Carneiro *et al.* [24]
Eremanthus erythropappus	Asteraceae	6	Serra do Ouro Branco	Carneiro *et al.* [24]
Copaifera langsdorffii	Fabaceae	6	Campus Pampulha - UFMG	Fernandes *et al.* [35]
Copaifera langsdorffii	Fabaceae	6	Serra de São José Cachoeira do Mangue	Maia and Fernandes [27]
Myrcia multiflora	Myrtaceae	6	Restinga de Carapebus	Maia [36]
Miconia stenostachya	Melastomataceae	6	Platô Bacaba - Porto de Trombetas	Maia [31]
Tetragastris panamensis	Burseraceae	6	Platô Bacaba - Porto de Trombetas	Maia [31]
Myrcia sylvatica	Myrtaceae	6	Cachoeira da Lua	Maia [29]
Eugenia astringens	Myrtaceae	6	Carapebus	Maia [29]
Myrcia multiflora	Myrtaceae	6	Carapebus	Maia [29]
Calophyllum brasiliense	Calophyllaceae	6	Vale das Borboletas	Maia [29]
Guapira opposita	Nyctaginaceae	6	Praia do Itaguaré	Maia *et al.* [32]
Psychotria vellosiana	Rubiaceae	6	Estação Biológica de Santa Lúcia	Maia *et al.* [33]
Guapira opposita	Nyctaginaceae	6	Parque Natural Municipal São Lourenço	Maia *et al.* [33]
Protium heptaphyllum	Burseraceae	6	Reserva Ecologica de Saltinho	Santos *et al.* [37]

Table 4. List of super-host plants at the regional scale based on Brazilian plant-galling inventories.

Super-Host Plant Species	Plant Family	Number of Insect Gall Morphotypes	References
Guapira opposita	Nyctaginaceae	40	Bregonci *et al.* [38], Maia [36], Rodrigues *et al.* [30], Maia *et al.* [32], Santos *et al.* [37], Maia and Carvalho-Fernandez [39], Maia and Silva [40], Maia [28], Maia *et al.* [33].
Protium heptaphyllum	Burseraceae	35	Maia [36], Maia and Fernandes [27], Santos *et al.* [37], Silva *et al.* [34], Fernandes *et al.* [41], Maia and Carvalho-Fernandes [39], Maia [29], Santana and Isaias [42].
Copaifera langsdorffii	Fabaceae	27	Maia [29], Santos *et al.* [43], Fernandes *et al.* [35], Urso-Guimarães and Scareli-Santos [44], Coelho *et al.* [45], Fernandes *et al.* [46], Maia and Fernandes [27], Silva *et al.* [34], Luz *et al.* [47], Santana and Isaias [42].
Myrcia splendens	Myrtaceae	23	Rodrigues *et al.* [30], Coelho *et al.* [45], Fernandes *et al.* [46], Maia *et al.* [32], Maia [29], Santana and Isaias [42].
Byrsonima sericea	Malpighiaceae	22	Bregonci et al. [38], Maia [36], Oliveira and Maia [48], Rodrigues *et al.* [30], Santos *et al.* [37], Maia and Carvalho-Fernandes [39], Maia and Silva [40], Maia [28].

At the regional scale, 51.5% of host plant species harbored one insect gall morphotype, and 17.9% of host plant species hosted two gall morphotypes, corresponding to 69.4% of all host plant species in this study. We considered plant-species with more than double the mean of insect gall morphotypes per host plant species (2.67 ± 3.33) as multi-host plants (*i.e.,* host plants with six or more insect gall morphotypes) (Table **2**), which correspond to 91 host plant species with a mean of 10.20 ± 5.82 gall morphotypes. Plant species with more than double the mean number of galls of multi-host plants (*i.e*., 21 or more insect gall morphotypes) were considered as super-host plants (Table **2**). This classification resulted in a total of five super-host plant-species at the regional level: *Guapira opposita* (40 insect gall morphotypes), *Protium heptaphyllum* (35), *Copaifera langsdorffii* (27), *Myrcia splendens* (23), and *Byrsonima sericea* (22) (Table **4**). Super-host plant species had a mean of 29.4 ± 7.82 insect gall morphotypes. The number of galling insect species per host plant species at the regional scale was influenced positively by life-form (Deviance = 5.13, df = 845, $p = 0.02$), geographic distribution rank (Deviance = 68.93, df = 841, $p < 0.001$), number of biomes (Deviation = 74.41, df = 840, $p < 0.001$) and by increased vegetation complexity (Deviation = 87.14, df = 823, $p < 0.001$).

4. DISCUSSION

In this study, we adopted the reasoning that super-host species are those that have a greater variety of insect galls compared to the average galling species richness per plant species occurring within the community. The criterion adopted in our study indicates that super-hosts at a local level are the species with six or more galling species, which represent twice the average diversity of galling species per plant species. Our criterion at the regional level was more rigorous because on a macroscale all plant species accumulate more species of herbivorous insects than on a local scale [18]. Thus, we refer to the plant species that at the regional level have an intermediate species richness of insect galls as multi-hosts and we consider super-hosts to be only those species that have more than twice the average galling species richness of multi-hosts. Thus, at the regional level, we considered super-host plants to be the only species that hosted 21 or more species of galling insects. Based on the criteria presented here, our study represents the first systematized definition of super-host plants both at the community (local scale) and the macrogeographic level (regional scale).

Our approach revealed, from a wide range of data, that the species of super-host plants can vary greatly over different geographic scales. Although 23 species can be considered super-hosts at the local level (*i.e*., had six species of galling insects or more), we observed that some species are frequently listed as super-hosts such as *Guapira opposita*. We also found that at the local scale plants with a high diversity of insect galls tend to be more complex, that is, they have arboreal life-form [19]. The architectural complexity of trees tends to be higher compared to other plant life-forms because trees have higher height, the number of shoots, branches, and leaves with the crown volume [20]. In addition, the trees are larger and have greater biomass than other life-forms which allows a greater accumulation of herbivorous insects [19]. These different parameters positively influence the richness of insect galls as they represent a greater availability of resources (*i.e*., biomass) and oviposition sites (*i.e*., types of tissues) for galling insects [11, 19]. At the regional level, super-host plant (*i.e*., had 21 species of galling insects or more) were represented by only five plant species, with *Guapira opposita* and *Protium heptaphyllum* that hosted the highest numbers of insect galls. Our results show that, in general, super-host plants on a macrogeographic scale are those with a greater range of distribution and that occur in a greater number of biomes.

The plant *Guapira opposita* was also the super-host species at the local level most frequently recorded in our database, being recorded eight times. This species is a tree widely distributed across South America, and in Brazil is registered in Amazonia, Caatinga, Cerrado, and Atlantic Forest [49]. With regards to vegetation types, *Guapira opposita* is registered in riparian forest, seasonal semideciduous forest, rainforest, mixed rainforest, restinga, and vegetation on rocky outcrops [49]. In Brazil, this species has been registered as a super-host in areas of restinga and coastal vegetation [28, 30, 33]. The compiled database showed that this super-host plant presents an elevated alpha diversity of galling insects across several Brazilian locations. This can be explained by their structural architecture, given that trees tend to host a greater diversity of herbivorous insects compared to other plant life-forms [20]. Besides, we hypothesized that the great diversity of galling insects associated with *Guapira opposita* is related to the adaptive irradiation of gall-midges (Cecidomyiidae, Diptera) on this plant. For example, there is evidence of the occurrence of many species of *Bruggmania* associated with this host [50], which indicates that processes of sympatric speciation happened during the evolutionary history of this system.

Other important super-host plant species at the local scale were *Eremanthus erythropappus* and *Protium heptaphyllum*, which were each recorded three times. *Eremanthus erythropappus* is an endemic tree in Brazil that occurs in Cerrado and Atlantic Forest, and being frequently recorded in rocky savanna, typical savanna, riparian forest, and seasonal semideciduous forest [51]. This species has been recorded as a super-host in different areas of the Espinhaço Range [24]. *Protium heptaphyllum* is a neotropical tree registered in Brazil, in the Amazonia, Caatinga, Cerrado, and Atlantic Forest. Among the types of vegetation that *Protium heptaphyllum* occurs are campinarana, riparian forest, terra firme forest, rainforest, restinga, and savannah [52]. This species has been registered as a super-host in the Atlantic Forest [37], Semidecidual forest [34], and Cerrado [27].

At the regional level, *Guapira opposita* with 40 insect gall morphotypes and *Protium heptaphyllum* with 35, were the most important super-host plants. As previously indicated, these plant species were also the most recurrent super-hosts at the local level. This result indicates that in addition to a high alpha diversity locally, these super-host species also have a high beta diversity, due to the replacement of galling species throughout space [53]. Our results also indicate that breadth of geographic distribution and number of biomes positively influenced the number of galling insect species per host plant species at the regional scale. In a broad review, Nyman [22] argues that hosts with a wide range of distribution tend to accumulate more species of herbivorous insects as a result of added possibilities for local adaptation. The high numbers of galling species hosted by *Guapira opposita* and *Protium heptaphyllum* can be explained by the wide-ranging distribution of these species across the Neotropical region [49, 52], given that the two species occur across different countries in Latin America, and are registered in several biomes in Brazil.

CONCLUSION

Based on our initial questions and results, we conclude that in tropical and sub-tropical Brazil: 1) Super-host plants at the local level are species that host six or more galling species; 2) Species of super-host plants vary widely between communities, but some species are recurrently registered as super-hosts, such as *Guapira opposita*; 3) Plant life-form influences the richness of insect galls that they host, with super-hosts tending to be arboreal; 4) On a regional scale, super-host plants are those species that host 21 or more galling insect species; 5) Species of super-host plants at the regional level tend to have a wider range of geographic distribution and occur across several different biomes. The present study stands out as the first to provide a systematic standardization for super-host plants and to investigate factors influencing these species.

AUTHORS' CONTRIBUTIONS

JMGR and WSA designed the experiment. JMGR and CGHP performed the data compilation. WSA performed statistical analyses. All authors prepared the manuscript.

ETHICAL APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

No animals/humans were used for studies that are the basis of this research.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author [W.S.A] on request.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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