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Research Article

Can host plant richness be used as a surrogate for galling insect diversity?

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Abstract

Galling insects are the only insects capable of manipulating plant tissues to form complex structures. The number of known species of galling insect is small compared to the large diversity that statistical estimates suggest for this group. The study of galling insect diversity can be a difficult task in mega-diverse environments such as in tropical regions, thus justifying the use of surrogates. This study investigated whether or not host plant richness and super-host taxa can be used as surrogates for galling insect diversity. Surveys were conducted in 15 areas of cerrado *sensu stricto* in different localities of the Brazilian Cerrado. The results showed that host plant richness was the main predictor of galling insect diversity. The plant genus *Qualea* (Vochysiaceae), with 18 galling species, was the super-host taxon used in the analyses. Despite the influence of genus on galling insect richness, the abundance of *Qualea* was not related to galling insect diversity. Surrogates can be a useful tool for estimating galling insect richness and diversity patterns, both of which are relevant for conservation assessments.

Key words: galls, indicator groups, Cerrado, plant richness, super-host taxa

Resumo

Insetos galhadores são os únicos insetos capazes de manipular os tecidos das plantas para formar estruturas complexas. O número de espécies de galhadores conhecidas é pequeno comparado à grande diversidade que estimativas estatísticas sugerem para o grupo. O estudo da diversidade de galhadores pode ser uma difícil tarefa em ambientes mega-diversos com as regiões tropicais, justificando o uso de substitutos. Esse estudo investiga se a riqueza de plantas e os táxons super-hospedeiros podem ser usados como substitutos para a diversidade de insetos galhadores. Levantamentos foram feitos em 15 áreas de cerrado *sensu stricto* em diferentes localidades do Cerrado brasileiro. Os resultados mostram que riqueza de plantas foi o principal preditor da riqueza de galhas. O gênero de planta *Qualea* (Vochysiaceae), com 18 espécies de galhadores, foi o táxon super-hospedeiro utilizado nas análises. Apesar da influencia do gênero sobre a riqueza de insetos galhadores, a abundância de *Qualea* não esteve relacionada à diversidade de insetos galhadores. Substitutos de diversidade podem ser usados para estimar a riqueza e padrões de diversidade de galhadores, ambos os aspectos são importantes para desenvolver estratégias conservacionistas.

Palavras-chave: Cerrado, galhas, grupos indicadores, riqueza de plantas, táxons super-hospedeiros

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Introduction

Galling insects are the most sophisticated herbivores in nature [1]. Strongly influenced by resource availability [3], they are capable of manipulating plant tissues to form complex structures [2] that are efficient both for nutrition [4] and for defense against the natural enemies of these insects [5]. All of these characteristics make this group one of the most diverse guilds of herbivorous insects [6].

Espírito-Santo and Fernandes [7] estimated that there may be more than 132,000 species of galling insects. The paper by Price [6] also supports this idea and shows that, in the majority of galling taxa, adaptive radiation is an opportunistic event. Studying this great diversity can be a difficult and expensive task, requiring a large spatial, sampling and temporal effort [7]. Thus, the use of indirect factors to predict the diversity of galling insects can be useful, especially for studies in regions with rich biodiversity, such as the vegetation of the tropics [8].

In the case of galling, two factors may cause variations in the diversity patterns of these insects: host plant richness and super-host taxa [10-12]. The first indicates that galling insect diversity is strongly dependent on the number of host species [13], suggesting that each plant species represents a potential niche for galling insects [11]. However, super-host taxa are species or genera of plants that have a high intrinsic diversity of galling insects [11], and their presence and abundance can affect the local diversity of insects independently of plant species richness [14]. This study tested the correlation between these two factors and galling diversity, and investigated whether or not host plant richness and super-host taxa can be used as surrogates for measuring galling insect richness.

Methods

Study areas

The surveys were conducted in 15 areas of the Brazilian Cerrado (Table 1, Fig. 1). This region presents a climate classified as Aw Köppen (tropical rain), with dry winters (April to September) and rainy summers (October to March) [15]. The vegetation studied was neotropical savanna (cerrado *sensu stricto*), which can have different forms and subtypes of vegetation, such as sparse cerrado, typical cerrado, dense cerrado and cerrado with rocky outcrops [15].

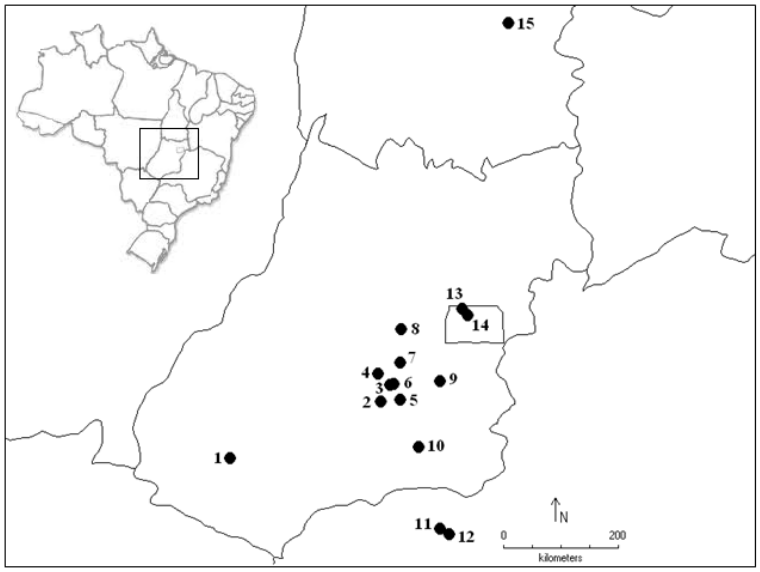

Fig. 1. Distribution map of sampling points in the Brazilian Cerrado. Legend: 1 = Fazenda Lageado, GO; 2 = Banana Menina, GO; 3 = Senador Canedo, GO; 4 = Residencial Itanhangá, GO; 5 = Cerrado Bela Vista, GO; 6 = Fazenda Bom Sucesso, GO; 7 = Reserva da UEG, GO; 8 = Pedreira, GO; 9 = Fazenda do Geraldo, GO; 10 = Cerrado Caldas Novas, GO; 11 = Caça e Pesca, MG; 12 = Floresta do Lobo, MG; 13 = APA Cafuringa, DF; 14 = Rebio Contagem, DF; 15 = Porto Real, TO.

Sampling and data analyses

Between February and May of 2010, we conducted inventories of galling insects and host plants from 10 plots (10 × 10m) randomly established in each study site. Sampling was performed once in each area and it involved only woody plants with a circumference greater than 15 cm at ground level. The plants were all identified in the field. Each plant included in the sample had the leaves, stems and flowers inspected to a height of 2.5 m in the search for galls. Gall morphotypes were used to survey the galling insects, assuming that each morphotype is unique (2) and that each galling species is specific to its host plant [16; 7; 17]. The morphological characteristics used in gall differentiation were gall occurrence, form, color, pubescence and size.

In order to test for super-host taxa as surrogates for galling insect diversity, we used the genus *Qualea* (Vochysiaceae). This genus has 11 species in the Cerrado [18], and most of them are widely distributed throughout the biome, particularly in cerrado *sensu stricto* [19]. Furthermore, a large diversity of galling insects has been documented associated with species of *Qualea* [20]. Species such as *Qualea grandiflora*, *Qualea multiflora*, and *Qualea parviflora*, all presenting associated galling species, were present in the areas sampled (Fig. 2).

The t test was used to test for effects of the presence and absence of *Qualea* on the local richness of galling insects. The abundance of individuals of the genus *Qualea* and the local richness of galling insects were correlated by linear regression. Linear regression analysis was used to correlate plant species richness with galling insect richness. Statistica 7.0 software was used for all tests.

Table 1. Characterization of the areas studied in the Brazilian Cerrado.

Sites	City	Coordinates	Altitude (m)
APA Cafuringa	Brasília, DF	15°31'56" N, 47°57'57" W	873
REBio Contagem	Brasília, DF	15°37'15" N, 47°52'21" W	994
Banana Menina	Hidrolândia, GO	16°59'43" N, 49°14'22" W	893
Cerrado de Bela Vista	Bela Vista, GO	16°57'39" N, 48°56'58" W	809
Cerrado de Caldas	Caldas Novas, GO	17°42'40" N, 48°38'26" W	702
Fazenda Bom Sucesso	Senador Canedo, GO	16°42'39" N, 49°02'33" W	749
Fazenda do Geraldo	Silvânia, GO	16°40'9" N, 48°18'31" W	837
Fazenda Lajeado	Jataí, GO	17°53'7" N, 51°38'11" W	756
Pedreira da Prefeitura	Pirenópolis, GO	15°50'14" N, 48°55'32" W	840
Reserva da UEG	Anápolis, GO	16°22'54" N, 48°56'42" W	1097
Residencial Itanhangá	Goiânia, GO	16°33'56" N, 49°17'11" W	762
Zona Rural, Canedo	Senador Canedo, GO	16°43'15" N, 49° 6'23" W	774
Caça e Pesca	Uberlândia, MG	19°00'32" N, 48°18'48" W	864
Floresta do Lobo	Uberlândia, MG	19°05'28" N, 48° 9'11" W	948
Porto Real	Ponte Alta, TO	11° 00'13" N, 47°13'56" W	380

Results

Altogether we recorded 112 galling insect species in 64 plant species. Most galls (76%) occurred in leaves, followed by stems (22%), apical buds (1%) and petioles (1%). The plant families that were richest in galling insects were Vochysiaceae (19 species), Fabaceae (13) and Malpighiaceae (12). In most sites, gall sampling was relatively good in view of the large diversity of galling insects and host plants studied (Fig. 3). The mean number of galls/site was 16.6 (± 6.6); Fazenda Lajeado was the most diverse site, with 30 gall morphotypes, and REBio Contagen was the poorest with only 8 morphotypes.

Host plant richness was the best predictor of the galling insect diversity ($r^2 = 0.46$; $p < 0.01$; Fig. 4); however, host plant richness did not explain the frequency of plants with galls ($r^2 = 0.13$; $p = 0.17$).

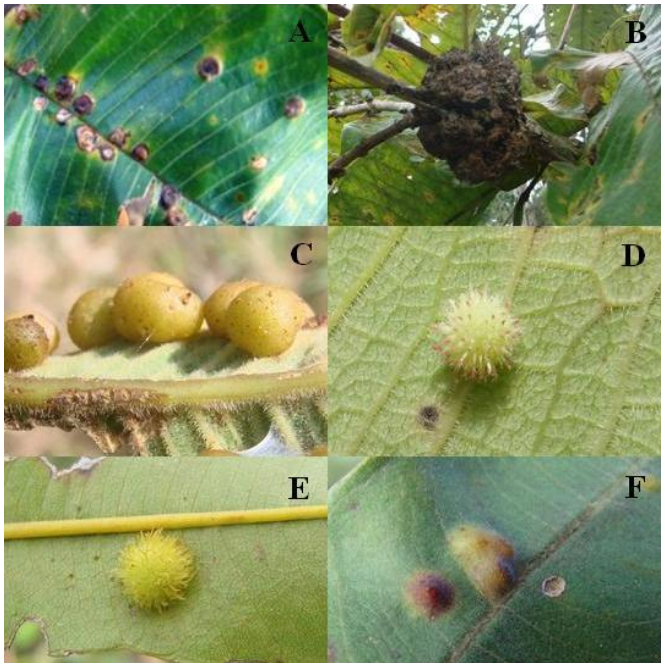

Fig. 2. Examples of gall morphotypes sampled in the *Qualea* species: A) discoid leaf gall in *Q. grandiflora*; B) globoid stem gall in *Q. grandiflora*; C) globoid leaf gall in *Q. multiflora*; D) starry leaf gall in *Q. multiflora*; E) starry leaf gall in *Q. parviflora* and F) discoid leaf gall in *Q. parviflora*.

The genus *Qualea* hosted 18 galling insect species and *Q. parviflora* hosted 8 species alone. The species *Q. parviflora* had no effect on local gall richness, but when all of the species of the genus were considered the effect was significant ($F_{2,23} = 32.92$; $p < 0.05$; Fig. 5). Areas where the genus *Qualea* occurred presented an average of 19.1 (± 5.05) galling insect species, and areas where this genus was absent had fewer than half this number of galling insect species (8.5 ± 0.5). There was no influence of the presence of super-host taxa on the number of plants with galls ($F_{2,23} = 440.27$; $p > 0.05$).

The abundance of *Qualea* was not related to gall richness ($r^2 = 0.004$; $p = 0.81$) or frequency of plants with galls ($r^2 = 0.002$; $p = 0.86$). Similarly, no relationship was found between galling insect richness in the genus *Qualea* and total galling insect richness ($r^2 = 0.13$; $p = 0.18$), or between the abundance of *Qualea* plants and plant species richness, although there was a slight tendency of areas with fewer species to have a greater dominance of the genus *Qualea* ($r^2 = 0.007$; $p = 0.76$).

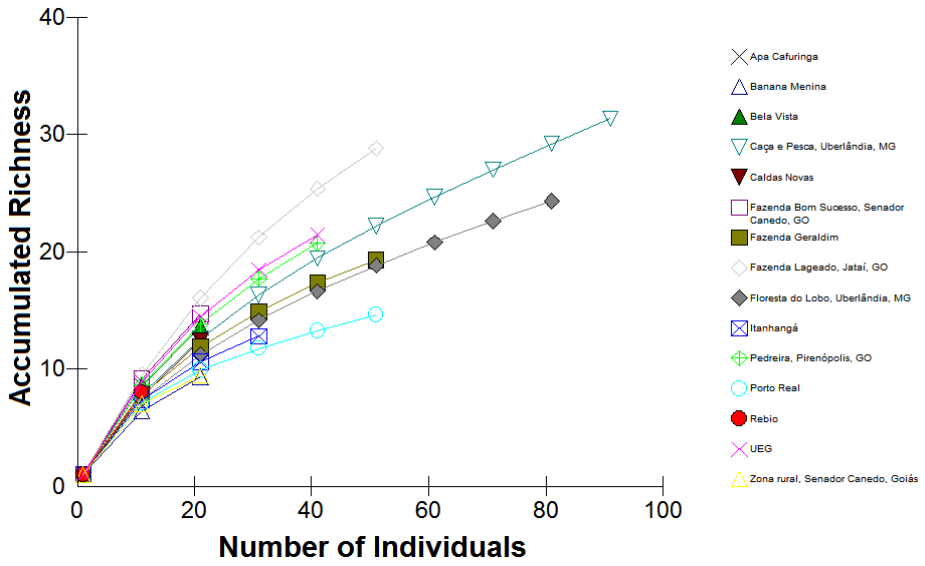

Fig. 3. Rarefaction curve of the accumulated richness of galling insects in relation to number of individuals sampled.

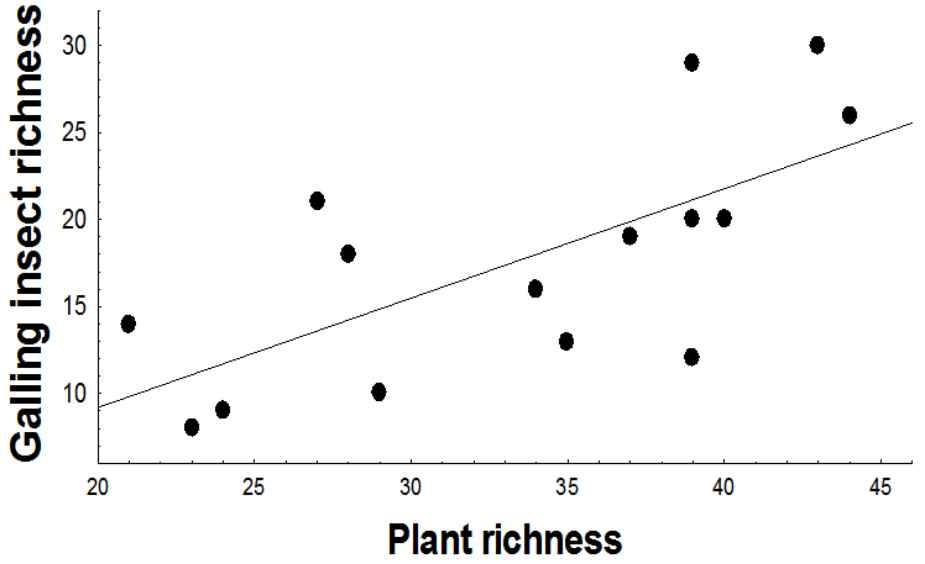

Fig. 4. Relationship between galling insect richness and plant richness (r^2 = 0.46; p < 0.01; y = -3.36 + 0.62x).

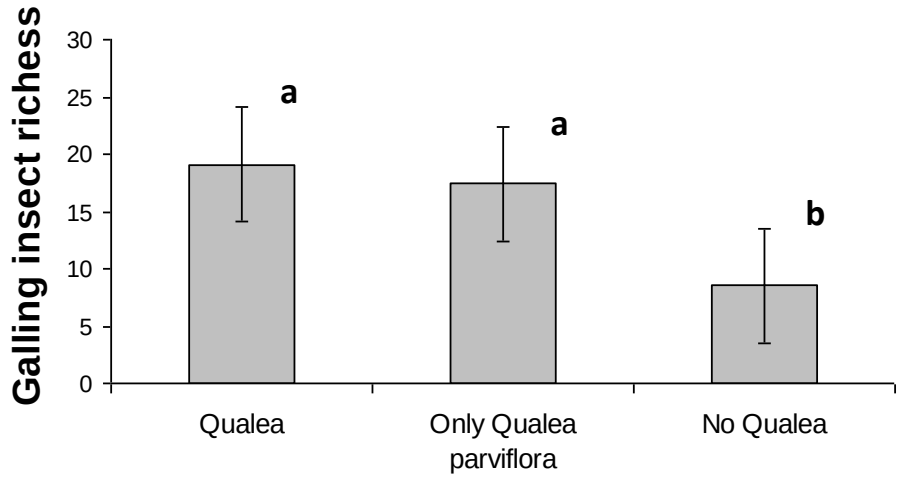

Fig. 5. Galling insect richness between areas with presence of genus *Qualea,* only *Qualea parviflora* and areas where *Qualea* not occurred. Means with different letters reflect significant differences with *P* < 0.05.

Discussion

Whether or not plant diversity influences the richness of herbivorous insects is one of the most discussed issues in insect-plant interaction ecology, especially where galling insects are concerned [11, 14, 21-23]. Among these influences, host plant richness has received most attention, resulting in studies that are favorable [10, 22, 24] or opposed [13, 25, 26] to this hypothesis. Our results show that the local richness of gall morphotypes is positively influenced by host plant richness, suggesting that this is a good predictor of galling insect diversity.

Most galling species have a species-specific relationship with their host [17], supporting the hypothesis of a relationship with plant richness [27]. Bräuniger et al. [28] also showed that plant species richness might be a good surrogate for predicting galling insect diversity. Usually, when one factor is correlated with the presence of certain taxa, this factor can be considered a surrogate for the diversity of this taxon [24, 29, 30].

The presence of *Qualea* increased the local galling insect richness, but the abundance of species of this genus was not associated with galling insect richness. One explanation for these results could be that the local abundance of *Qualea* is not dependent on plant richness and tends to be inversely proportional to this factor. For this reason, areas with higher plant species richness, and consequently galling, showed a low abundance of *Qualea*. The species of this genus are some of the most common in the vegetation of cerrado *sensu stricto* [31], showing a relatively high level of dominance in the sites where they are present [32]. Thus, the super-host taxa were not a good surrogate for galling insect diversity.

Sclerophyllous vegetation (on poor soils with little water) probably has more galling insect species per plant species than wetland vegetation [7]. Therefore, the number of plant species can increase to a greater level than galling insect richness [33]. Similarly, tropical regions have a high floristic diversity and host most of the galling insect species [7]. In these environments, the use of surrogates can be a useful tool for estimating galling insect richness and diversity patterns. Here, we also need to consider that other factors related to plant diversity could also be used as effective surrogates for galling insect richness, such as the size, density, architecture, and vegetation cover of taxa [12].

Implications for conservation

A large number of galling species has been described in recent decades [34] and estimates indicate that the number of species yet to be described could significantly exceed the number of known species [7]. The use of surrogates such as host plant richness seems to be a good tool for predicting galling insect richness and surveys using this approach could obtain relevant quantitative and qualitative results for the selection of priority areas for the conservation of galling insects.

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