




Could epiphytes be xenophobic? Evaluating the use of native versus exotic phorophytes by the vascular epiphytic community in an urban environment

Pedro Luiz Sanglard Silva Martins¹ · Samyra Gomes Furtado^{1,2} · Luiz Menini Neto^{1,2,3} 

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Abstract

Epiphytes enrich the vegetation cover and provide relevant ecosystem services, which are very important in the urban environment for mitigating air pollution and effects such as heat islands. The majority of tree species used in the urban afforestation are exotic, and their capacity to provide a substratum for epiphytes is not thoroughly exploited. We tested an eventual preference of vascular epiphytes for exotic or native phorophytes in an urban area inside the Atlantic forest domain, evaluating the structure and composition of the studied community in four tree species. There was no preference for native or exotic trees, and the community showed a generalistic pattern in the choice of phorophytes. We hypothesized about other features which could be responsible for the distribution of epiphytes in the urban environment. This study showed that both exotic and native phorophytes can act as satisfactory substratum for the urban vascular epiphytes.

Keywords Atlantic forest · Epiphytic synusia · Urban green area

Introduction

Several ecosystem services can be provided by the vegetation cover in cities: improvement of the microclimate, decreasing the air, sound, and visual pollution, shelter for the fauna living in the city, qualification of the urban sites and its identity with the people. These improvements favor the space appropriation and the connection with the nature inside the urban environment (Basso and Corrêa 2014; Biondi 2015).

Epiphytes are part of this environment, enriching the vegetation cover. They are plants growing on other plants (phorophytes), but are not parasitic, and often do not have contact with the soil along the lifecycle (except for hemiepiphytes)

(Benzing 1990; Zotz 2016). Epiphytes broadly occupy the treetops in several cases, and are an important part of the forest canopy (Parker 1995), representing a relevant component of the ecosystem (Elias et al. 2006), providing resources to the fauna such as food and shelter (Benzing 1990; Cruz-Angón and Greenberg 2005), as well as are considered “biodiversity amplifiers” (Gonçalves-Souza et al. 2010).

Although there is not a high diversity of epiphytes in the urban environment, several species are abundant and play some ecological role (Lapo and Magenta 2014), often unknown. Some studies have shown that the presence of certain species in urban areas are relevant for evaluating the environmental quality of the city and surroundings (Graciano et al. 2003; Bermudez et al. 2009), however, we have limited knowledge about these plants considering their richness and wide distribution, and less is known about the urban environment (Fabricante et al. 2006; Krömer et al. 2014; Furtado and Menini Neto 2015).

Up to 80% of the plants used in urban afforestation in Brazil are represented by exotic species (Lorenzi et al. 2003). Exotic tree species often do not present a positive ecological role, acting as invasive to the natural environment and competing with the native species and/or not providing food resources to the fauna or being suitable for colonization of vascular epiphytes in secondary forests (Silva 2008;

✉ Luiz Menini Neto
menini.neto@gmail.com

¹ Universidade Federal de Juiz de Fora, Campus Universitário, Rua José Lourenço Kelmer S/Nº, São Pedro, Juiz de Fora, Minas Gerais CEP 36036-900, Brazil

² Departamento de Botânica da, Universidade Federal de Juiz de Fora, Juiz de Fora, Brazil

³ Programa de Pós-graduação da Universidade Federal de Juiz de Fora, Juiz de Fora, Brazil

Oliveira Neto et al. 2014; Instituto Hórus 2017; Ceballos 2019). However, the possibility of representing a habitat for the epiphytes in the urban environment was not satisfactorily exploited, once the studies about epiphytic flora have often concentrated in pristine natural environments (Zotz 2016).

Therefore, there is a necessity to understand the structure and composition of the epiphyte communities and their establishment on phorophyte species occurring in urban green areas, in addition to evaluating an eventual preference of this community by exotic or native phorophytes. Thus, we can help to identify suitable species of phorophytes to be used in urban afforestation, aiming to enhance the efficiency of the ecosystem services provided by the vegetation cover.

Materials and methods

Study area

The study was performed in planted trees of the Botanical Garden of the Universidade Federal de Juiz de Fora (BG-UFJF), in the municipality of Juiz de Fora, Minas Gerais, Brazil (21° 44' S, 43° 22' W). The area is part of the Atlantic Phytogeographic Domain and is located in Zona da Mata of Minas Gerais, in the Southeast Region of Brazil. It presents elevations between 670 and 750 m. The climate is Cwa (according to the Köppen classification). The annual mean rainfall is around 1500 mm, with greater indices in January (~290 mm), and the annual mean temperature is around 20.1 °C (Merkel 2019).

The BG-UFJF has an extension of approximately 86 ha, and is neighbor to the Environmental Protection Area of Krambeck, together representing a remnant of secondary seasonal semi-deciduous forest of 370 ha resulting from 70 years of regeneration after abandoning of a coffee plantation. This region has been suffering high anthropogenic pressure from the surrounding urbanization with fire, selective cutting of wood and introduction of exotic species (Fonseca and Carvalho 2012).

Data collection

The data collection was performed between September 2017 and April 2018. The sampled trees are planted in a row near the secondary forest border that has an extension of approximately 5 ha, composed of several native and exotic trees. We chose four phorophyte species according to the availability in the studied area, with two species being native to Atlantic forest and two exotic species (from Asia). The two native species were *Cedrela fissilis* Vell. (Meliaceae), popularly known as *cedro rosa* (represented

by 33 individuals) and *Piptadenia gonoacantha* (Mart.) J.F.Macbr. (Fabaceae), known as *pau-jacaré* (with 35 individuals), both deciduous plants. The two exotic species were *Mangifera indica* L. (Anacardiaceae), known as *mangueira* (mango tree) (with 33 individuals) and *Eriobotrya japonica* (Thunb.) Lindl. (Rosaceae), known as *ameixeira* (loquat) (with 35 individuals), both evergreen plants.

We sampled phorophytes with perimeter at breast height (PBH) equal or larger than 30 cm and the height was estimated by only one person. The phorophytes were divided into three strata, with the basal half and upper half of the trunk identified as A and B, respectively, and the crown as stratum C. The occurrence of vascular epiphytes for each phorophyte and stratum was recorded through binoculars, and we consulted the literature, specialists and the collection of the Herbarium CESJ for the identification (acronym according to Thiers 2019).

Data analysis

The epiphytes were classified according to Benzing (1990) as characteristic holoepiphytes, facultative epiphytes, accidental epiphytes, and hemiepiphytes, and the dispersal types were obtained in specific literature of each family. The absolute and relative frequencies of the epiphytes were calculated for the community for each phorophyte and each stratum.

We calculated the Shannon diversity (H') and Pielou evenness (J) indices of the epiphytic assemblage for each phorophyte species, strata and for all of the community. The Shannon diversity index was compared through the Hutcheson t test. A graph with curves for each phorophyte species was constructed to illustrate the distribution occurrence in the epiphytic assemblages of each of them to complement the aforementioned analyzes.

A similarity analysis between the phorophyte species was performed using the UPGMA and Jaccard similarity index, and the cophenetic correlation was calculated. The richness of epiphytes that inhabit each phorophyte species was compared using rarefaction curves. Two taxonomic diversity indices were calculated in order to evaluate eventual discrepancies in the distribution of taxa between the phorophyte species, average taxonomic distinctness (Δ^+) and variation in taxonomic distinctness (Λ^+), according to Warwick and Clarke (1995, 1998). A simple linear regression was performed to verify any influence of PBH and height on the richness of epiphytes.

Similarity, rarefaction, taxonomic diversity and regression analyses were performed without the accidental epiphytes. The analyses were performed using the Microsoft Excel 2007, PAST v.3 (Hammer et al. 2001), EstimateS 9 and PRIMER 6 software programs.

Results

We sampled 136 phorophytes and recorded 693 occurrences of epiphytes distributed in 47 species, 35 genera and 16 families, in addition to seven unidentified accidental epiphytes. The richest family was Polypodiaceae (10 species), followed by Bromeliaceae and Orchidaceae (nine species each), totaling 28 species or 52% of the recorded richness. The richest genus was *Tillandsia* L. (Bromeliaceae) with five species, followed by *Pleopeltis* Humb. and *Serpocaulon* A.R.Sm. (Polypodiaceae), with three species each. The most frequent species of the epiphytic community was *Microgramma squamulosa* (Kaulf.) de la Sota, with 79 records (approximately 11.5%), followed by *Portea petropolitana* (Wawra) Mez (with 75 records), *Pleopeltis astrolepis* (Liebm.) E.Fourn. (with 68 records) and *Billbergia horrida* Regel (with 67 records).

Twenty-seven (27) recorded epiphytes were characteristic holoepiphytes (~52%), followed by accidental epiphytes (with 19 species), hemiepiphytes (five species) and facultative epiphytes (three species). The most common dispersal type among those identified (44 species) was anemochoric, represented by 28 species (or approximately 64%), followed by zoochoric (15 species) and autochoric with only one species (Table 1).

The 35 non-accidental species of epiphytes were distributed in the phorophytes as follows: 11 species were restricted to only one phorophyte species and the others were equally distributed across two, three and four species of phorophytes, with eight epiphytes in each one. The mango tree was the phorophyte with the most exclusive epiphytes with five species, while *cedro* presented three species, *pau-jacaré* two species, and loquat one species.

The average PBH and height for each phorophyte species were 227 cm and 13 m for the mango tree, 131 cm and 14 m for the *cedro*, 123 cm and 11 m for the *pau-jacaré*, and 53 cm and 8 m for the loquat, respectively. The H' and J indices for the community were 3.05 and 0.76, respectively. Mango tree was the most diverse phorophyte ($H' = 2.94$) and significant different from loquat and *pau-jacaré* and the C stratum was the most diverse in all four phorophyte species (Table 2). Figure 1 presents the distribution occurrences of the epiphyte species in each phorophyte, visually complementing the evaluation of the Pielou evenness (J).

The similarity analysis resulted in a high fit between the dendrogram and matrix, with a correlation coefficient of 0.98. The highest similarity value found was 56% between *cedro* and *pau-jacaré* (both native phorophyte species), and the lowest value was 41% between mango tree and loquat (both exotic phorophyte species) (Fig. 2).

The richest phorophyte species (excluding accidental epiphytes) was the mango tree with 26 species

(approximately 74%), followed by *cedro* with 22 species (approximately 63%), *pau-jacaré* with 20 species (approximately 57%), and loquat, with 15 species (approximately 43%). There was only a significant difference between the mango tree and loquat (Fig. 3).

Cedro presented an average taxonomic distinctness value above the expected, and loquat was below the expected (Fig. 4). It is possible to observe that loquat and *pau-jacaré* presented the highest values for variation in taxonomic distinctness, representing an imbalance in the distribution of epiphytic taxa in both phorophyte species, mainly in *pau-jacaré*, which presented a value above the expected (Fig. 5).

The simple linear regression analysis performed using all phorophytes resulted in a positive correlation between the morphometric parameters and species richness (PBH: $r = 0.70$, $p < 0.0001$; estimated height: $r = 0.41$, $p < 0.0001$) (Fig. 6a, b). The same analysis performed using each phorophyte species separately resulted in significant positive correlation between PBH and richness (for mango tree, *cedro* and *pau-jacaré*) and between height and richness (for *cedro* and *pau-jacaré*) (Table 3).

Discussion

Despite the present sampling being performed on trees cultivated in an urban green area, the three richest families of vascular epiphytes found in this study (Polypodiaceae, Bromeliaceae and Orchidaceae) represent a pattern also often seen in natural environments, both in Neotropical Region (Gentry and Dodson 1987; Hietz and Hietz-Seifert 1995; Arévalo and Betancur 2004; Francisco et al. 2018) and in the Atlantic forest (Alves and Menini Neto 2014; Barbosa et al. 2014; Freitas et al. 2016), although the order of the richest families may be different in some cases. Urban remnants of the Atlantic forest also can present such a pattern with the three aforementioned richest families (Dettke et al. 2008; Flores et al. 2013; Oliveira et al. 2013; Alves et al. 2014; Becker et al. 2015; Santana et al. 2017), with some richness variations which may denote anthropic impacts such as the Orchidaceae family which is an indicator of conserved remnants, but due to its ornamental value is often the object of predatory collection in environments with greater degree of use and human occupation (Dislich and Mantovani 1998; Borgo and Silva 2003).

The great richness of the *Tillandsia* genus is probably due to the urban environment where their species are frequent, since they show high tolerance to air pollution, are commonly used as bioindicators of the air quality (Graciano et al. 2003; Alves et al. 2008; Bermudez et al. 2009). Additionally, the species of *Tillandsia* resist to environments which are often hostile for several epiphytic species due to the reduced moisture (Benzing 1990; Zotz 2016).

Table 1 Vascular epiphytic species recorded on four tree species (of which two are natives of Atlantic forest, *cedro* and *pau-jacaré*, and two are exotic, from Asia, mango tree and loquat) occurring in an urban environment of the Brazilian Atlantic forest

Species	Families	EC	Disp	Mangifera indica (mango tree)			Cedrela fissilis (cedro)			Eriobotrya japonica (loquat)			Piptadenia gono-achanta (pau-jacaré)			Total
				N	AF	RF	N	AF	RF	N	AF	RF	N	AF	RF	
				<i>Microgramma squamulosa</i> (Kaulf.) de la Sota	Polyp	CHL	A	21	63.64	7.64	27	81.82	16.46	6	17.14	
<i>Portea petropolitana</i> (Wawra) Mez	Bromel	FE	Z	19	57.58	6.91	18	54.55	10.98	9	25.71	8.57	29	82.86	19.46	75
<i>Pleopeltis astrolepis</i> (Liebm.) E.Fourn.	Polyp	CHL	A	20	60.61	7.27	21	63.64	12.80	22	62.86	20.95	5	14.29	3.36	68
<i>Billbergia horrida</i> Regel	Bromel	CHL	Z	15	45.45	5.45	14	42.42	8.54	7	20	6.67	31	88.57	20.81	67
<i>Tillandsia geminiflora</i> Brongn.	Bromel	CHL	A	33	100	12	9	27.27	5.49	9	25.71	8.57	1	2.86	0.67	52
<i>Tillandsia recurvata</i> (L.) L.	Bromel	CHL	A	30	90.91	10.91	15	45.45	9.15	5	14.29	4.76	1	2.86	0.67	51
<i>Tillandsia polystachia</i> (L.) L.	Bromel	CHL	A	29	87.88	10.55	5	15.15	3.05	6	17.14	5.71	0	0	0	40
<i>Polystachya esrellensis</i> Rehb.f.	Orech	CHL	A	20	60.61	7.27	15	45.45	9.15	0	0	0	4	11.43	2.68	39
<i>Comperettia coccinea</i> Lindl.	Orech	CHL	A	0	0	0	0	0	0	25	71.43	23.81	0	0	0	25
<i>Rhipsalis lindbergiana</i> K.Schum.	Cact	CHL	Z	6	18.18	2.18	4	12.12	2.44	0	0	0	12	34.29	8.05	22
<i>Microgramma vacciniifolia</i> (Langsd. and Fisch.) Copel.	Polyp	CHL	A	21	63.64	7.64	1	3.03	0.61	0	0	0	0	0	0	22
<i>Pleopeltis hirsutissima</i> (Raddi) de la Sota	Polyp	CHL	A	9	27.27	3.27	7	21.21	4.27	0	0	0	5	14.29	3.36	21
<i>Tillandsia stricta</i> Sol.	Bromel	CHL	A	0	0	0	7	21.21	4.27	7	20	6.67	3	8.57	2.01	17
<i>Campylocentrum spannagelii</i> Hoehne	Orech	CHL	A	6	18.18	2.18	2	6.06	1.22	4	11.43	3.81	1	2.86	0.67	13
<i>Catasetum cernuum</i> (Lindl.) Rehb.f.	Orech	CHL	A	1	3.03	0.36	2	6.06	1.22	0	0	0	6	17.14	4.03	9
<i>Epiphyllum phyllanthus</i> (L.) Haw.	Cact	CHL	Z	3	9.09	1.09	1	3.03	0.61	0	0	0	4	11.43	2.68	8
<i>Tillandsia tricholepis</i> Baker	Bromel	CHL	A	5	15.15	1.82	0	0	0	1	2.86	0.95	1	2.86	0.67	7
<i>Ficus adhatodifolia</i> Schott in Spreng.	Mor	HEM	Z	1	3.03	0.36	3	9.09	1.83	1	2.86	0.95	2	5.71	1.34	7
<i>Eurystyles actinosophila</i> (Barb.Rodr.) Schltr.	Orech	CHL	A	5	15.15	1.82	0	0	0	1	2.86	0.95	0	0	0	6
<i>Encyclia patens</i> Hook.	Orech	CHL	A	4	12.12	1.45	1	3.03	0.61	0	0	0	0	0	0	5
<i>Callisia repens</i> (Jacq.) L.	Comm	AE	-	4	12.12	1.45	0	0	0	0	0	0	0	0	0	4
<i>Hemionitis tomentosa</i> (Lam.) Raddi	Pterid	AE	A	1	3.03	0.36	3	9.09	1.83	0	0	0	0	0	0	4
<i>Serpocaulon latipes</i> (Langsd. and Fisch.) A.R.Sm.	Polyp	CHL	A	0	0	0	0	0	0	0	0	0	4	11.43	2.68	4
<i>Pleopeltis pleopeltifolia</i> (Raddi) Alston	Polyp	CHL	A	1	3.03	0.36	0	0	0	0	0	0	2	5.71	1.34	3
<i>Syngonium angustatum</i> Schott	Arac	HEM	Z	3	9.09	1.09	0	0	0	0	0	0	0	0	0	3
<i>Billbergia zebrina</i> (Herb.) Lindl.	Bromel	CHL	Z	2	6.06	0.73	0	0	0	0	0	0	1	2.86	0.67	3
<i>Phlebodium pseudoaureum</i> (Cav.) Lellinger	Polyp	FE	A	0	0	0	1	3.03	0.61	0	0	0	2	5.71	1.34	3
<i>Isochilus linearis</i> (Jacq.) R.Br.	Orech	CHL	A	0	0	0	3	9.09	1.83	0	0	0	0	0	0	3
<i>Impatiens walleriana</i> Hook.f.	Bals	AE	Au	1	3.03	0.36	1	3.03	0.61	0	0	0	1	2.86	0.67	3
<i>Trichocentrum pumilum</i> (Lindl.) M.W.Chase and N.H.Williams	Orech	CHL	A	1	3.03	0.36	0	0	0	1	2.86	0.95	0	0	0	2
<i>Epidendrum pseudodiforme</i> Hoehne and Schltr.	Orech	CHL	A	0	0	0	1	3.03	0.61	1	2.86	0.95	0	0	0	2
<i>Tradescantia zebrina</i> Heynh. ex Bosse	Comm	AE	-	1	3.03	0.36	0	0	0	0	0	0	1	2.86	0.67	2
<i>Monstera deliciosa</i> Liebm.	Arac	HEM	Z	2	6.06	0.73	0	0	0	0	0	0	0	0	0	2

Table 1 (continued)

Species	Families		EC	Disp	Mangifera indica (mango tree)		Cedrela fissilis (cedro)		Eriobotrya japonica (loquat)		Piptadenia gonolobifolia (pau-jacaré)		Total			
	N	AF			N	RF	N	AF	N	RF	N	AF		N	RF	
<i>Astraea lobata</i> (L.) Klotzsch	Euph	AE	Z	0	0	0	0	0	0	0	0	2	5.71	1.34	2	
<i>Vriesea grandiflora</i> Leme	Bromel	CHL	A	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Solanum cernuum</i> Vell.	Solan	AE	Z	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Urera baccifera</i> (L.) Gaudich. ex Wedd.	Urtic	AE	Z	0	0	0	0	0	0	0	0	1	2.86	0.67	1	
<i>Christella dentata</i> (Forssk.) Brownsey and Jermy	Thelyp	AE	A	0	0	0	0	0	0	0	0	1	2.86	0.67	1	
<i>Serpocaulon menisicifolium</i> (Langsd. and Fisch.) A.R.Sm.	Polyp	CHL	A	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Hedychium coccineum</i> Buch.-Ham. ex Sm.	Zingib	AE	Z	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Epipremnum pinnatum</i> (L.) Engl.	Arac	HEM	Z	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Oxalis triangularis</i> A.St.-Hil.	Oxalid	AE	-	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Phlebodium aureum</i> (L.) J.Sm.	Polyp	FE	A	0	0	0	0	0	0	0	0	1	2.86	0.67	1	
<i>Ficus</i> sp.2	Mor	HEM	Z	0	0	0	1	3.03	0.61	0	0	0	0	0	0	1
<i>Syagrus</i> sp.	Arec	AE	Z	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
<i>Nephrolepis exaltata</i> (L.) C.Presl	Pterid	AE	A	0	0	0	0	0	0	0	0	1	2.86	0.67	1	
<i>Serpocaulon triseriale</i> (Sw.) A.R.Sm.	Polyp	CHL	A	0	0	0	1	3.03	0.61	0	0	0	0	0	0	1
Eudicot indet 1	-	AE	-	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
Eudicot indet 2	-	AE	-	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
Eudicot indet 3	-	AE	-	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
Eudicot indet 4	-	AE	-	1	3.03	0.36	0	0	0	0	0	0	0	0	0	1
Eudicot indet 5	-	AE	-	0	0	0	1	3.03	0.61	0	0	0	0	0	0	1
Eudicot indet 6	-	AE	-	0	0	0	0	0	0	0	0	1	2.86	0.67	1	
Eudicot indet 7	-	AE	-	0	0	0	0	0	0	0	0	1	2.86	0.67	1	

EC, Ecological category: AE, accidental epiphytes; CHL, characteristic holoepiphyte; FE, facultative epiphyte; HEM, hemiepiphyte. Families: Arac, Araceae; Arec, Arecaceae; Bals, Balsaminaceae; Bromel, Bromeliaceae; Cact, Cactaceae; Comm, Commelinaceae; Euph, Euphorbiaceae; Mor, Moraceae; Orch, Orchidaceae; Oxalid, Oxalidaceae; Polyp, Polypodiaceae; Pterid, Pteridaceae; Solan, Solanaceae; Thelyp, Thelypteridaceae; Urtic, Urticaceae; Zingib, Zingiberaceae. Disp: dispersal types—A, anemochoric; Au, autochoric; Z, zoochoric. N: number of phorophytes in which the epiphyte species occurs. AF: absolute frequency; RF: relative frequency

Table 2 Values of Shannon diversity (H') and Pielou evenness (J) for each phorophyte species and strata, and comparison between phorophytes through Hutcheson t-test

Total	Mi	Cf	Ej	Pg	Stratum A	Mi	Cf	Ej	Pg
Mi	2.94/0.81	0.0763	<i>2.35E-06</i>	<i>0.0157</i>	Mi	2.39/0.93	<i>0.0102</i>	–	0.2813
Cf		2.68/0.83	<i>0.0015</i>	0.3653	Cf		2.15/0.90	–	0.5078
Ej			2.27/0.84	0.0691	Ej			0.64/0.92	–
Pg				2.54/0.76	Pg				2.24/0.79
Stratum B	Mi	Cf	Ej	Pg	Stratum C	Mi	Cf	Ej	Pg
Mi	2.57/0.91	<i>0.0087</i>	<i>6.45E-24</i>	<i>3.01E-07</i>	Mi	2.91/0.81	<i>0.0356</i>	<i>3.72E-06</i>	<i>0.0003</i>
Cf		2.27/0.86	<i>1.53E-12</i>	<i>0.005</i>	Cf		2.62/0.85	<i>0.0034</i>	<i>0.0469</i>
Ej			1.56/0.97	<i>0.0025</i>	Ej			2.24/0.83	0.6028
Pg				1.90/0.76	Pg				2.32/0.74

Mi: *Mangifera indica* (mango tree); Cf: *Cedrela fissilis* (cedro); Ej: *Eriobotrya japonica* (loquat); Pg: *Piptadenia gonoachantha* (pau-jacaré); Values of H' and J , respectively are represented in bold; the columns, above diagonal, present the comparisons of Hutcheson t-test and those written in italic are significant between the pairs ($p < 0.05$)

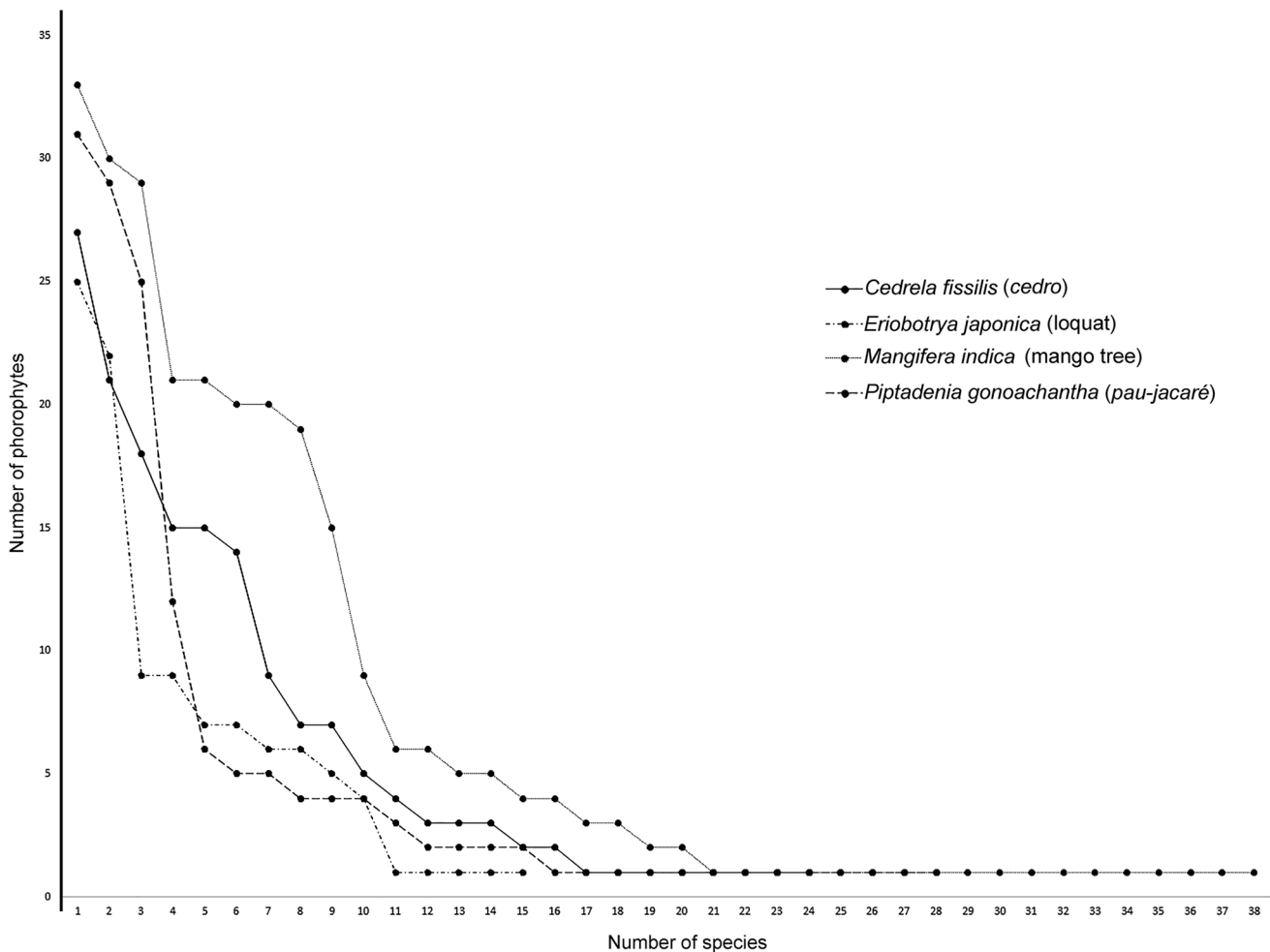


Fig. 1 Species sequences from most common to rarest, expressed as the number of absolute occurrences in all sampled phorophytes

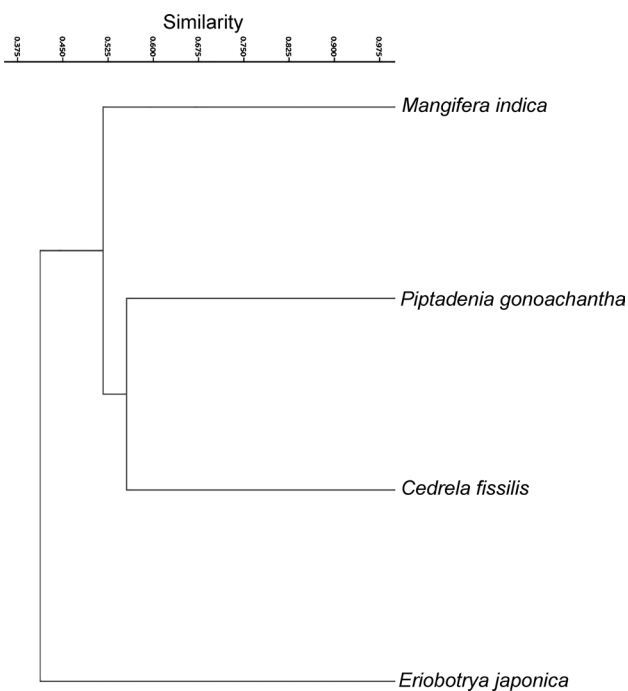


Fig. 2 Dendrogram resulting from the cluster similarity analysis of four phorophyte species using UPGMA and Jaccard index. Cophenetic coefficient = 0.98

There is no difference between the two most diverse phorophyte species, showed by the Hutcheson t-test, the mango tree (exotic) and *cedro* (native). The strata with the highest diversity in both the aforementioned species were B (upper half of the trunk) and C (crown). The C stratum was the most diverse in all four phorophyte species, probably due to the complex architecture of the crown in comparison with the trunk, with several horizontal branches, providing more micro-habitats and allowing the occurrence of exclusive species (Izuddin and Webb 2015; Woods et al. 2015).

Loquat is the most discrepant phorophyte with the lowest richness and similarity in comparison with the other three species (mango tree, *cedro*, and *pau-jacaré*). In the dendrogram it is possible to observe the highest proximity between the last two phorophytes species, constituting the native ones. The variation in taxonomic distinctness corroborated the discrepancy of the loquat regarding the phorophyte species as the most unsuitable to shelter an epiphytic flora. On the other hand, the average taxonomic distinctness showed that *cedro* must be considered an important phorophyte, as it can provide substratum for a higher diversity of taxonomic groups of the studied community.

Pau-jacaré presented the lowest average taxonomic distinctness, that is probably due to the rhytidoma peeling present in this species. Although there are contradictory pieces of evidence regarding peeling as a determinant

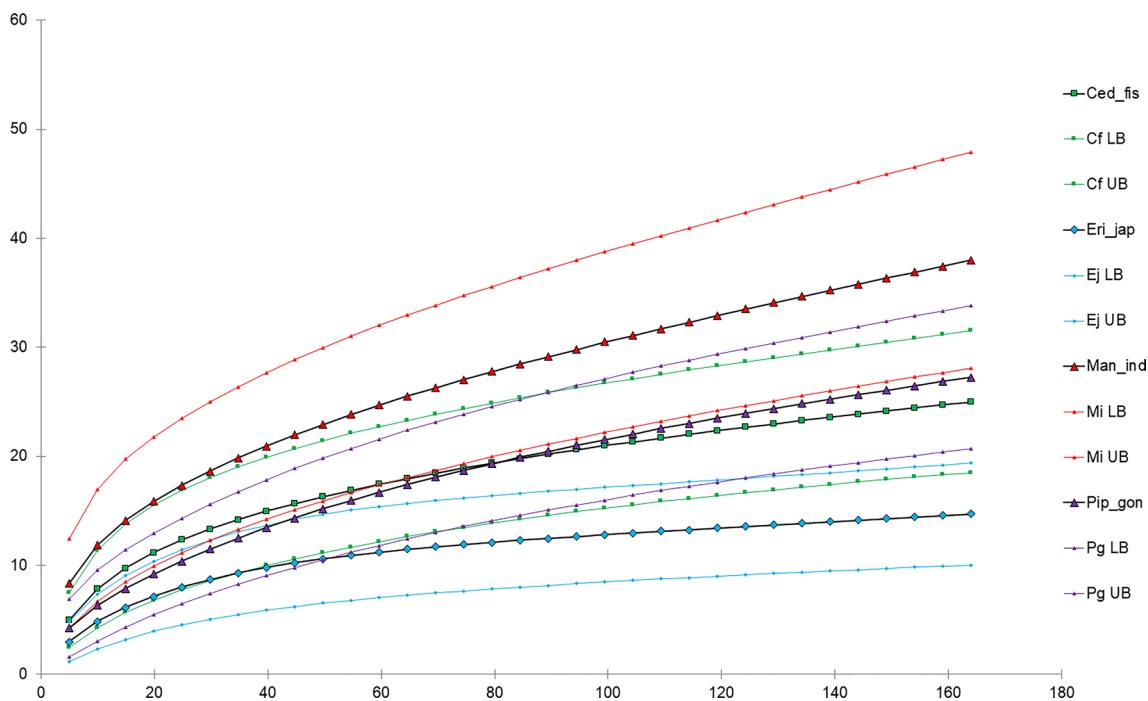


Fig. 3 Rarefaction curves comparing the richness of vascular epiphytes in four studied phorophyte species (Ced_fis: *Cedrela fissilis*—*cedro*; Eri_jap: *Eriobotrya japonica*—loquat; Man_ind: *Mangifera indica*—mango tree; Pip_gon: *Piptadenia gonoachantha*—*pau-jac-*

aré). The lines with small symbols corresponds to the 95% confidence limit for each phorophyte species, according to the respective colors

Fig. 4 Values of average taxonomic distinctness (Δ^+) of the phorophyte species (CF: *Cedrela fissilis*—cedro; EJ: *Eriobotrya japonica*—loquat; MI: *Mangifera indica*—mango tree; PG: *Piptadenia gonolobifolia*—pau-jacaré)

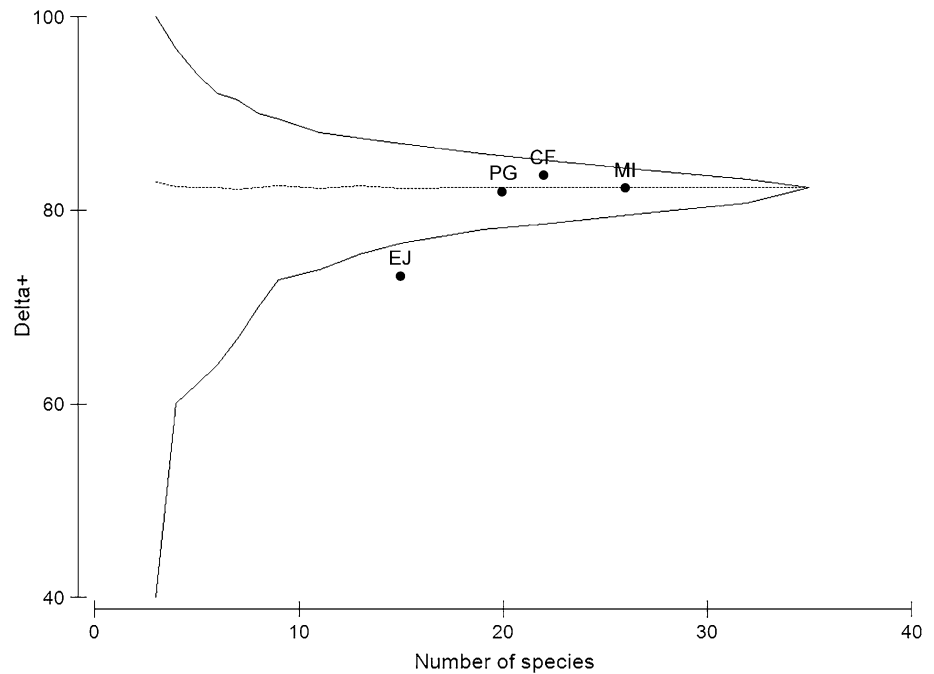
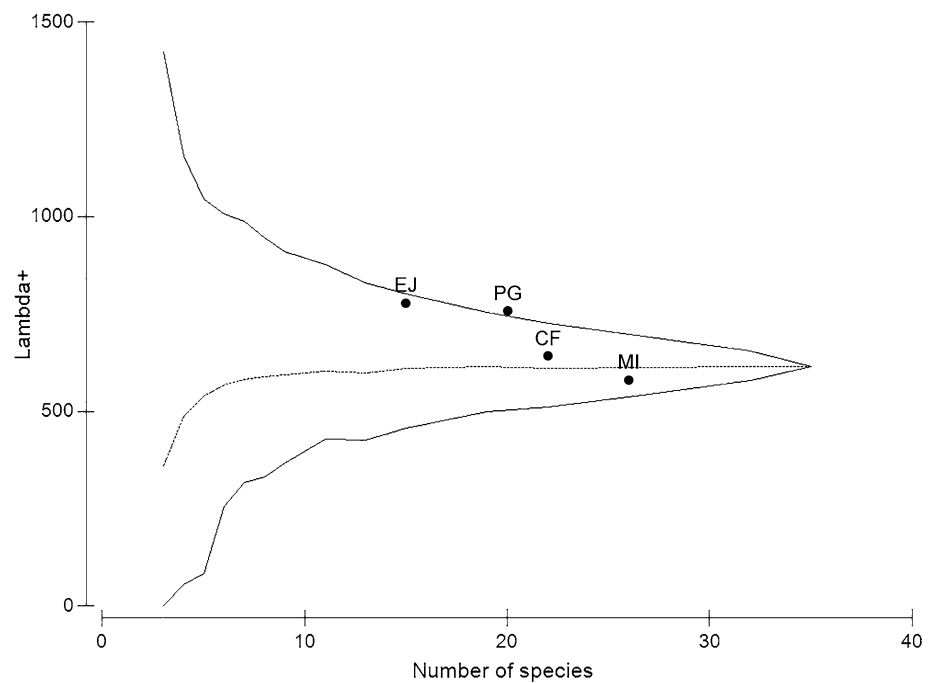


Fig. 5 Values of variation in taxonomic distinctness (Λ^+) of the phorophyte species (CF: *Cedrela fissilis*—cedro; EJ: *Eriobotrya japonica*—loquat; MI: *Mangifera indica*—mango tree; PG: *Piptadenia gonolobifolia*—pau-jacaré)



feature in the occurrence of epiphytes (Zimmerman and Olmsted 1992; Talley et al. 1996; Wyse and Burns 2011; Jiménez-Salmerón et al. 2017). Wyse and Burns (2011) highlighted some resistant species to this physical disturbance which predominated in phorophytes with a high peeling rate. In the present study, we found some epiphytic species that apparently resist to the rhytidoma peeling of the trees of *pau-jacaré*, resulting in the lowest J values,

both in general and in the strata, and suggesting a dominance of its epiphytic flora.

The literature shows that the morphometric structure of the phorophyte, represented here by PBH and estimated height, play an important role in the establishment of epiphytes in phorophytes, and PBH is often positively correlated with species richness (Hietz and Hietz-Seifert 1995; Woods et al. 2015; Zhao et al. 2015; Francisco et al. 2018),

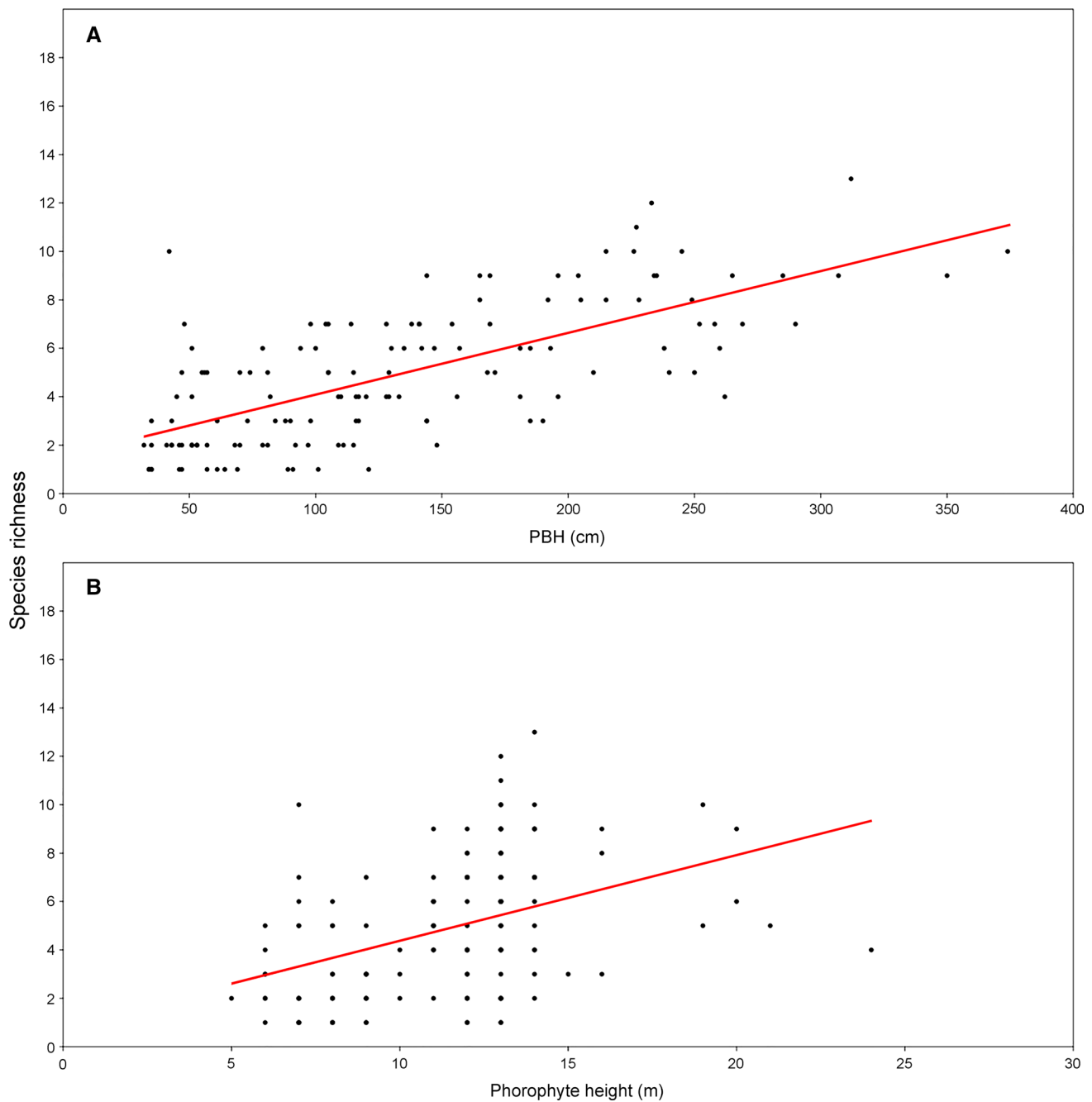


Fig. 6 Linear regression for the phorophytes (considering all species). **a** between the perimeter at breast height and richness of vascular epiphytes; **b** between the height of trees and richness of vascular epiphytes

as well as with the maintenance of an ecological network between the epiphytes of the community (Sáyago et al. 2013; Ceballos et al. 2016; Francisco et al. 2018). Such features are considered related to the higher probability of common occurrence of epiphytes in more trees with higher PBH, mainly due to the time available for colonization, complexity of crown architecture, extension of substratum and the number of available micro-habitats (Benzing 1990; Hietz and Hietz-Seifert 1995; Woods et al. 2015). This

study corroborates such statements if all evaluated phorophytes were considered, but individually we can observe some particularities, once the height of the mango tree and both the PBH and height in loquat did not present significant correlation with richness. Thus, regarding phorophyte features, we must also consider other characteristics such as the texture and chemical composition of the bark which can influence the establishment and maintenance of

Table 3 Values of the linear regression between richness and morphometric parameters for each species

	PBH	h
Mango tree	r=0.54/p=0.0009	r=0.21/p=0.2247
<i>Cedro</i>	r=0.62/p=0.00007	r=0.42/p=0.0121
Loquat	r=0.18/p=0.3076	r=-0.21/p=0.2169
<i>Pau-jacaré</i>	r=0.36/p=0.0337	r=0.34/p=0.0431

PBH: Perimeter at breast height; h: estimated height of the phorophytes. r=Pearson coefficient (r). Shade cells are the significant values ($p < 0.05$)

epiphytes on the phorophyte (Benzing 1990; Sáyago et al. 2013; Zhao et al. 2015).

We found Orchidaceae among the most representative families in the present study, and it also worth mentioning that *Comparettia coccinea* was exclusive to the loquat, with a frequency of 71% in this phorophyte species. It is interesting to notice that this phorophyte presents the smoothest bark compared with the other three sampled species, which is a physical characteristic which often hinders the establishment of epiphytes (and can even be a reason for the low richness found for this species). However, Hietz and Hietz-Seifert (1995) stated that fissured bark, which is mechanically suitable to lodge the seeds, is not always sufficient for establishing epiphytes. For instance, they showed that the bark of *Pinus* L. (Pinaceae) species presents this feature, but also presents a chemical composition with a high content of phenolic compounds and resin, thereby hindering or impeding the growth of epiphytes. This is particularly true for orchids, since the proliferation of mycorrhizal fungi is hindered by those chemicals. Thus, despite the smooth bark of the loquat, it probably provides a good environment for the development of mycorrhizal fungi which are indispensable to the germination of the orchid seeds, thereby enabling the pronounced occurrence of *Comparettia coccinea*.

Hietz and Hietz-Seifert (1995), Woods et al. (2015) and Francisco et al. (2018) found a pattern in which some epiphyte species were exclusive to the largest phorophytes. Francisco et al. (2018) also showed that the most robust phorophyte specimen studied presented an exclusive interaction with 45% of the sampled epiphytes, reinforcing that morphometric parameters of the phorophyte were more determinant in the epiphytic richness than the phorophyte species. This pattern is also present in this study, since the mango tree (which has the greatest average PBH) was the phorophyte with the greater number of exclusive species and was also the richest species. The loquat conversely presented the lowest average PBH, as well as the number of exclusive species and richness, confirming such a distribution pattern of epiphytes.

We can conclude that there is no preference of the epiphytic community regarding native or exotic phorophyte

species sampled, reinforcing a generalist pattern of the vascular epiphytes in the relationship with the phorophytes (Hietz and Hietz-Seifert 1995; Sáyago et al. 2013; Ceballos et al. 2016; Francisco et al. 2018). We found that both mango tree and *cedro* (respectively, exotic and native species) can be good species to compose urban green areas, providing a suitable habitat for the epiphytic community, which can directly or indirectly help in improving the urban environment due to the ecosystem services provided by these plants.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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