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Floristic diversity of vascular epiphytes occurring at the Federal Rural University of the Amazon, Belém – PA

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Abstract

Vascular epiphytes are an important component of tropical forest biodiversity and play essential ecological roles. This study aimed to characterize the floristic diversity and distribution patterns of vascular epiphytes at the Federal Rural University of the Amazon (UFRA), Belém–PA campus. Eleven plots of 200 × 10 m were sampled along 2.2 km, considering two vertical strata: tree trunks and canopies. A total of 17 species were identified, distributed among four families, with Orchidaceae and Bromeliaceae being the most representative. *Tillandsia bulbosa* and *Aechmea sp.* showed the highest abundance and broad vertical distribution. Most species were predominantly found in the canopy and all displayed aggregated distribution patterns, as indicated by the Morisita Index (Id > 1). The Shannon-Wiener diversity index (H' = 0.83) and Pielou's evenness index (J = 0.29) were considered low, suggesting dominance by a few species and the influence of microclimatic constraints. It is concluded that vertical structure and environmental heterogeneity significantly affect the composition and abundance of epiphytes, and that urban forest fragments such as UFRA's campus can serve as important areas for conservation and epiphytic flora research.

Keywords: *Aechmea sp.*, arboreal vegetation, plant diversity, spatial aggregation, *Tillandsia bulbosa*

Introduction

Epiphytes are plants that grow on other plants, mainly on trees, without maintaining a direct connection to the soil — or doing so only during the initial stages of their development. They constitute a significant component of tropical forest flora, playing important roles in the structure and diversity of these ecosystems (ZOTZ, 2016).

Recent evidence shows that epiphytism contributes substantially to vascular plant diversity in tropical forests; in some regions, this contribution can reach up to 39% of the local vascular flora (TAYLOR et al., 2022). Globally, it is estimated that about 10% of vascular plant species are epiphytes, totaling approximately 31,311 species according to the EpiList 1.0 compilation (ZOTZ et al., 2021). The most species-rich families include Orchidaceae, Bromeliaceae, and Araceae, which together comprise hundreds of genera and thousands of epiphytic species (MORAES et al., 2020).

Epiphytes exhibit a broad geographic distribution, being particularly diverse and abundant in tropical forests, especially in the Neotropical region (RIORDAN; GERST; RAMÍREZ; RUNDEL, 2023). Although less represented in temperate forests, this reduced occurrence may be associated with their sensitivity to temperature extremes and fluctuations in moisture availability, both of which vary according to local climatic conditions (EPIPHYTIC PLANTS, 2025). The distribution of epiphytes follows both vertical and horizontal patterns: factors such as the successional stage of the forest, structural characteristics of the host tree (including diameter and height), and the availability of light and moisture strongly influence the richness and composition of epiphytic communities (LIPPERT et al., 2022; WERNER; HOMEIER, 2024).

The high diversity of epiphytes in tropical regions is closely related to their ecophysiological adaptations to the particular conditions of tree canopies. In these

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microhabitats, the combination of strong light variation, limited nutrient input, and pronounced fluctuations in atmospheric humidity shapes both the distribution and performance of these plants. Numerous studies indicate that vascular epiphytes are particularly sensitive to water deficit, making water one of the main limiting factors for their development (WERNER; HOMEIER, 2024).

Microclimatic analyses also show that epiphytes experience rapid and intense fluctuations in water content, which directly affect their physiology and local occurrence. Thus, environments with higher relative humidity tend to favor their abundance and persistence (LÖBS et al., 2020).

The Belém campus of the Federal Rural University of the Amazon (UFRA) exhibits extensive tree cover and harbors a high abundance of epiphytic species, contributing not only to local biodiversity but also to the landscape's aesthetic value. Therefore, the objective of this study is to conduct a survey of the epiphytic flora present on the campus, aiming to evaluate the composition of the epiphytic guild, identify its distribution patterns, and determine the frequency and importance value of each species. These goals are essential for characterizing the environment, quantifying local biodiversity, and supporting conservation actions for the ecological services provided by these plants.

Materials and Methods

The study was conducted at the Federal Rural University of the Amazon (UFRA), located at the Belém campus (01°27'17.50" S; 48°26'45.46" W) (**Figure 1**).

For the floristic composition, all trees along the main road of the institution were considered as tree components. For the study, an area of 10 meters on each side of the road was delimited, totaling a sampling area of 2.2 km, divided into 11 plots of 200 x 10 m² each (**Figure 2**).

Botanical material was collected using pruning shears for specimens within arm's reach and long-handled pruning tools for those located higher in the canopy. When necessary, a folding ladder up to 5 meters in height was used to access more distant material. In each plot, all trees hosting epiphytic species had their circumference at breast height (CBH) measured in situ using a measuring tape, with the measurement taken at 1.30 meters above ground level. CBH values were subsequently converted to diameter at breast height (DBH). In cases where trees had multiple stems branching below 1.30 meters, each stem was measured and analyzed individually. The height of each phorophyte was estimated visually by the same researcher throughout all field campaigns to ensure consistency.

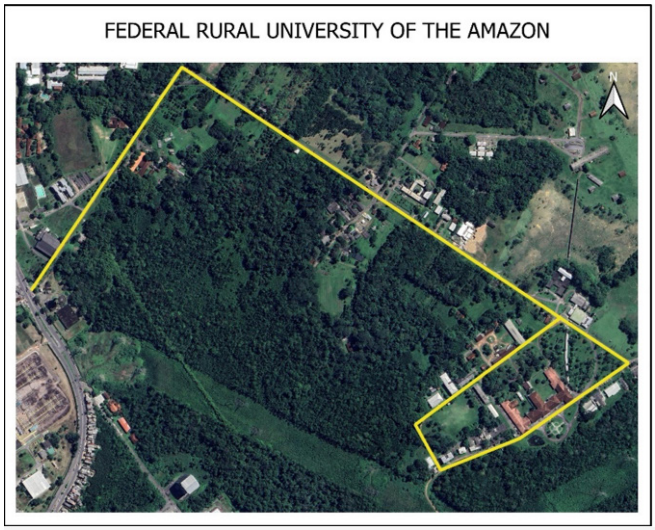

Fig. 1. Satellite image showing the boundaries of the sampling unit at Belém Campus – UFRA.

Fig. 2. Representation of plot division at Belém Campus – UFRA.

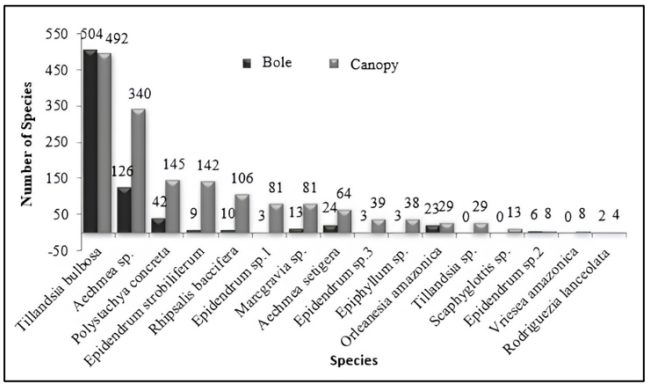

Fig. 3. Vertical distribution of vascular epiphyte species sampled on phorophytes at UFRA.

To assess the organizational pattern of the epiphytic community, a modified version of the method proposed by Johansson (1974) was used, based on the vertical division of the phorophyte (**Figure 3**). Each

tree was individually examined, with epiphytic species recorded and their abundance estimated within two distinct zones: Zone I – from the ground to the first branch bifurcation (trunk); and Zone II – from the first bifurcation to the top of the canopy. This division allowed for the quantification of epiphytes in different compartments of the phorophyte.

To analyze the spatial distribution pattern of epiphytes across the sampling unit plots, the Morisita Dispersion Index (Id) was applied, following the methodology described by Brower and Zar (1984).

$$Id = n \frac{\sum x^2 - N}{N\ (N-1)}$$

Where:
Id = Morisita's Dispersion Index
n = number of sampled plots
N = total number of individuals recorded across all sampled plots
x = number of individuals in each sampled plot

If Id = 1, the distribution is random; if Id < 1, the distribution is uniform; and if Id > 1, the distribution is aggregated.

To assess the structure of the epiphytic guild in the studied areas, the following phytosociological parameters were calculated for each species, based on a modified methodology adapted from Giongo and Waechter (2004).

$$Ab = \frac{ni}{np}$$

$$Abr(\%) = \frac{Ab}{abt} \times 100$$

Where:
Absolute and relative abundance:
Ab = absolute abundance
Abr = relative abundance
ni = number of individuals per species
np = number of plots containing the species
abt = total abundance of all species

Absolute and relative frequency:

$$Fa = np$$

$$Fr(\%) = \frac{Fa}{ntp} \times 100$$

Where:
Fa = absolute frequency
Fr = relative frequency
np = number of plots containing the species
ntp = total number of plots

Absolute and relative frequency by phorophyte, trunk, and canopy:

$$Faf = nf$$

$$Frf(\%) = \frac{nf}{nft} \times 100$$

$$Frfu(\%) = \frac{nfu}{nft} \times 100$$

$$Frc(\%) = \frac{nft}{nc} \times 100$$

Where:
Faf = absolute frequency by phorophyte
Frf = relative frequency by phorophyte
Frfu = relative frequency by trunk
Frc = relative frequency by canopy
nf = total number of phorophytes where the species occurred
ntf = total number of trunks sampled
nfu = number of trunks where the species occurred
nc = number of canopies

Absolute and relative density:

$$Den = \frac{ni}{at}$$

$$Der = \frac{Den}{dt} \times 100$$

Where:
Den = absolute density
Der = relative density
ni = total number of individuals per species
at = total area sampled
dt = total density of all species

Epiphytic Importance Value:

$$VIe = \frac{Frc + Frfu}{2} \times 100$$

Where:
VI = Importance Value Index
Fr = relative frequency
Frc = relative frequency in the canopy
Frfu = relative frequency in the trunk

Floristic diversity was assessed using the Shannon-Wiener Species Richness Index (H') (Magurran, 1988; Krebs, 1999).

This method allows individuals to be randomly sampled from a large and infinite population, also assuming that all species are represented in the sample

(Dias, 2004). The formula used for the calculation was:

$$H' = - \Sigma (pi) (lnpi)$$

To calculate equitability, the Pielou index (E) (Odum, 1988) was used, expressed by the following formula:

$$E = \frac{H'}{In\ S}$$

Where:
H' = Shannon-Wiener diversity index
In = natural logarithm
S = number of species sampled

To calculate richness, a linear relationship between the number of individuals and species richness is assumed (Matos et al., 1999). It is a simple diversity index that considers the number of species (s-1) and the logarithm (base 10 or natural) of the total number of individuals (Gurevitch et al., 2009).

$$\alpha = \frac{s\ -\ 1}{\log\ N}$$

Where:
s = number of species sampled
N = total number of individuals across all species.

All collected material was identified to the species level (when possible) with the help of specialized literature and by comparing it with herbarium specimens held at the Herbarium of the Museu Paraense Emílio Goeldi.

Results and Discussion

Over the 2.2 km studied, 17 epiphytic species were recorded, distributed across 11 genera and four families. The most diverse family was Orchidaceae, with eight species and five genera, followed by Bromeliaceae, with five species and three genera. In terms of specimen abundance, Bromeliaceae accounted for 1,604 individuals, while Orchidaceae had 534 specimens, together representing 89.76% of the total specimens recorded. The Cactaceae family had 159 individuals, with *Rhipsalis baccifera* and *Epiphyllum* sp. being the most abundant species, respectively. Finally, the Marcgraviaceae family was represented by only one species, *Marcgravia sp*. **(Table 1)**.

The pattern recorded in this survey — with Orchidaceae as the most diverse family (eight species across five genera), followed by Bromeliaceae (five species in three genera) — is consistent with recent studies indicating that these groups are among the most species-rich within tropical epiphytic communities (TORRES et al., 2024; DIAS-PEREIRA et al., 2023). Species with broad geographical distributions also tend to occupy areas with greater environmental heterogeneity, a condition that frequently favors representatives of Bromeliaceae, particularly in altered landscapes (TORRES et al., 2024).

Table 1. Families and species of vascular epiphytes recorded at UFRA, Belém Campus, and their respective abundances.

Family	Species	Abundance	Total
Bromeliaceae	Aechmea setigera	88	1604
	Aechmea sp.	477	
	Tillandsia bulbosa	1002	
	Tillandsia sp.	29	
	Vriesea amazonica	8	
Cactaceae	*Epiphyllum* sp.	41	159
	Rhipsalis baccifera	116	
	Rhipsalis sp.	2	
Marcgraviceae	*Marcgravia* sp.	92	92
Orchidaceae	*Epidendrum* sp.1	84	534
	Epidendrum sp.2	14	
	Epidendrum sp.3	42	
	Epidendrum strobiliferum	153	
	Orleanesia amazonica	52	
	Polystachya concreta	171	
	Rodriguezia lanceolata	5	
	Scaphyglottis sp.	13	
Total		2389	2389

The predominance of these two families in humid environments, also observed in this study, reflects patterns documented across several tropical regions. Here, the genera Tillandsia and Aechmea (Bromeliaceae) were represented by two species each, while Epidendrum (Orchidaceae) included four taxa. This composition resembles regional surveys carried out in nearby areas, where similar climatic conditions tend to shape epiphytic assemblages with comparable species concentrations (DIAS-PEREIRA et al., 2023).

Regarding vertical distribution, 15 of the 17 recorded species occurred on the trunk and 16 in the canopy, with some showing clear preference for specific strata — for instance, Tillandsia sp. and Vriesea amazónica were more common on the trunk. This arrangement reflects the influence of vertical gradients on epiphytic community structure, as factors such as microclimate, humus accumulation on branches, branch diameter, and host-tree architecture explain much of the observed variation (CRUZ et al., 2022).

Morphophysiological traits such as succulent leaves, pseudobulbs, or CAM metabolism tend to be more common in more exposed canopy strata, where they confer tolerance to water deficit and high irradiance (GUZMÁN-JACOB et al., 2022). However, the higher abundance of Tillandsia bulbosa in the basal

trunk suggests that local microvariations — including light availability, humidity, bark texture, and host architecture — can modulate general trends and produce exceptions to commonly observed functional patterns (TAY, 2023; VERGARA-TORRES et al., 2021).

The vertical distribution of vascular epiphytes recorded at UFRA revealed a predominance of individuals in the canopy of the phorophytes compared to the trunk (figure 3). Among the sampled species, Tillandsia bulbosa was the most abundant, with 504 individuals on the trunk and 492 in the canopy. Aechmea sp. accounted for 340 individuals in the canopy and 126 on the trunk, followed by Polystachya concreta (145 in the canopy and 42 on the trunk) and Epidendrum strobiliferum (142 in the canopy and 9 on the trunk), both with a strong presence in the upper stratum. Other species, such as Epidendrum sp. (106 on the trunk and 10 in the canopy) and Rhipsalis baccifera (81 on the trunk and 13 in the canopy), showed greater occurrence in the lower stratum. Species like Tillandsia bulbosa and Rhipsalis baccifera exhibited a relatively balanced distribution between the two strata. In contrast, species such as Rodriguezia lanceolata, Vriesea amazonica, and Scaphyglottis sp. were recorded in low abundance, with fewer than 10 individuals each.

Tillandsia bulbosa was the only species that showed greater abundance in Zone I (trunk), a pattern that may indicate high ecological plasticity or specific physiological adaptations. Recent studies on epiphytic bromeliads demonstrate that some Tillandsia species are capable of colonizing multiple vertical strata, occupying both lower regions and the canopy, likely due to their tolerance to microclimatic variation (TORRES et al., 2024). Thus, the broad vertical distribution of T. bulbosa may be related to its ability to establish under different conditions of light, humidity, and temperature.

The other species were more abundant in the canopy, which may be associated with the greater availability of organic matter, mosses, and debris accumulated on branches—resources that contribute to epiphyte attachment and nutrition (WOODS, 2015). Furthermore, the canopy provides more favorable light conditions combined with a relatively stable microclimate, which benefits the establishment of various epiphytic species.

The dominance of species such as Aechmea and certain orchid genera in the canopy may reflect a preference for more illuminated environments and a lower dependence on constant humidity. This pattern has also been reported in studies on the vertical distribution of bromeliads (TORRES et al., 2024) and orchids with specific ecophysiological adaptations (JOYA et al 2025).

The marked decline in the number of individuals among the less frequent species may indicate more specialized ecological requirements, lower dispersal efficiency, or greater sensitivity to environmental variation—factors widely discussed in research on epiphytic community structure (CRUZ et al., 2022). These findings reinforce the idea that the vertical structural heterogeneity of the phorophyte (trunk versus canopy) plays a key role in shaping these communities, as different species respond distinctly to gradients of light, humidity, and microclimate.

The analysis of the spatial dispersion of epiphytic species at UFRA, Belém Campus, using the Morisita Dispersion Index (Id), revealed that all species had values greater than 1, indicating an aggregated distribution pattern. *Aechmea* sp. was the species with the highest dispersion value (Id = 7.32), followed by *Tillandsia bulbosa* (Id = 6.43), *Polystachya concreta* (Id = 6.06), and *Epidendrum strobiliferum* (Id = 2.28). Other species, such as *Rhipsalis baccifera* (Id = 2.22) and *Epidendrum* sp. (Id = 1.99), also demonstrated aggregated distribution, albeit with relatively lower values. In total, 18 species were sampled, all exhibiting a spatial aggregation pattern according to the Id values obtained (**Table 2)**.

Table 2. Spatial distribution of epiphytic species at UFRA, Belém Campus. N = number of species; Id = Morisita's dispersion index.

Species	N	Id
Aechmea setigera	37	16,24
Aechmea sp.	477	2,29
Epidendrum sp.1	84	3,62
Epidendrum sp.2	14	5,08
Epidendrum sp.3	42	6,61
Epidendrum strobiliferum	153	6,12
Epiphyllum sp.	41	2,75
Marcgravia sp.	92	2,45
Orleanesia amazonica	52	3,01
Polystachya concreta	171	1,96
Rhipsalis baccifera	116	1,80
Rhipsalis sp.	2	11,00
Rodriguezia lanceolata	5	6,60
Scaphyglottis sp.	13	4,37
Tillandsia bulbosa	1002	3,72
Tillandsia sp.	29	6,45
Vriesea amazonica	8	4,32

These results highlight a recurrent pattern among vascular epiphytes: a tendency toward aggregated distribution, likely associated with their dependence on specific microenvironments for germination and establishment. Such aggregation may reflect the structural heterogeneity of host plants — including differences in substrate type, such as exposed bark, the

presence of mosses, or accumulations of organic matter — as well as local variations in humidity and light (SHEN et al., 2022). Species such as *Aechmea* sp. and *Polystachya concreta*, which exhibited the highest Id values, tend to concentrate in portions of the host where moisture retention and resource availability are more favorable, facilitating their development and promoting dense clustering.

In addition, dispersal limitations — whether mediated by wind, animals, or species-specific reproductive strategies — may further reinforce this pattern, as suggested by recent evidence (SHEN et al., 2022). Even species with relatively low dispersal efficiency, including some rarer epiphytes, still form clusters, underscoring the strong influence of microenvironmental factors on their distribution. Microclimatic studies show that small variations in humidity along the trunk and canopy affect the physiology and occurrence of these plants (LÖBS et al., 2020), supporting the notion that aggregation represents an adaptive response to the spatial variability of favorable habitat conditions.

Table 3 presents the phytosociological parameters of the epiphytic species recorded at the Federal Rural University of the Amazon (UFRA), Belém campus. A total of 17 species were recorded, with *Aechmea* sp. showing the highest frequency across sample plots (Frp = 90.91%), and significant values in other parameters, such as absolute frequency in the canopy (Fac = 346) and Epiphytic Importance Value (VIe = 124.2%).

This broad distribution may be related to the species' high adaptive capacity under different environmental conditions. Many epiphytic bromeliads exhibit specialized morphophysiological traits, such as rosette-arranged leaves capable of storing water and organic matter, as well as highly developed trichomes that enhance the absorption of moisture and nutrients directly from the atmosphere (REYES-GARCÍA et al., 2022). Recent studies also demonstrate that these trichomes optimize water uptake under fog or dew conditions, particularly in more exposed microhabitats (CSIRO Publishing, 2025).

In addition to *Aechmea* sp., *Tillandsia bulbosa* stood out as the most ecologically relevant species, showing a balanced distribution between the trunk and canopy. This vertical plasticity indicates strong tolerance to environmental stresses such as high solar radiation and low humidity, characteristics commonly associated with pioneer species (REYES-GARCÍA et al., 2022).

In contrast, *Rhipsalis* sp. exhibited a restricted distribution, which may reflect microclimatic conditions specific to the study area that hinder colonization by species requiring greater shade or possessing lower tolerance to environmental fluctuations.

The vertical distribution pattern revealed a general preference for the canopy (approximately 68% of the species), suggesting adaptation to more illuminated environments with greater exposure to suspended particles that facilitate nutrient acquisition. However, species-specific responses were evident: *T. bulbosa* showed a uniform distribution across strata, whereas *Aechmea* sp. exhibited a strong preference for the canopy, indicating distinct reactions to light and humidity availability.

These differences in frequency between trunk and canopy highlight the role of ecological filtering imposed

Table 3. Phytosociological parameters of epiphytic species sampled at UFRA, Belém Campus.

Species	Fao	Fro (%)	Faf	Frf (%)	Fac	Frc (%)	Fafu	Frfu (%)	VIe (%)
Aechmea setigera	8	72.73	25	13.158	64	33.68	24	12.632	23.16
Aechmea sp.	10	90.91	108	56.842	346	182.1	126	66.316	124.2
Epidendrum sp.1	6	54.55	21	11.053	81	42.63	3	1.579	22.11
Epidendrum sp.2	3	27.27	5	2.632	8	4.211	6	3.158	3.684
*Epidendrum*sp.3	3	27.27	12	6.316	39	20.53	3	1.579	11.05
Epidendrum strobiliferum	4	36.36	18	9.474	144	75.79	9	4.737	40.26
Epiphyllum sp.	7	63.64	17	8.947	38	20	3	1.579	10.79
Marcgravia sp.	8	72.73	33	17.368	81	42.63	13	6.842	24.74
Orleanesia amazonica	6	54.55	13	6.842	29	15.26	23	12.105	13.68
Polystachya concreta	9	81.82	35	18.421	145	76.32	42	22.105	49.21
Rhipsalis baccifera	8	72.73	35	18.421	106	55.79	8	4.211	30
Rhipsalis sp.	1	9.091	1	0.526	0	0	2	1.053	0.526
Rodriguezia lanceolata	2	18.18	3	1.579	4	2.105	2	1.053	1.579
Scaphyglottis sp.	3	27.27	4	2.105	13	6.842	0	0.000	3.421
Tillandsia bulbosa	8	72.73	123	64.737	496	261.1	506	266.316	263.7
Tillandsia sp.	2	18.18	5	2.632	29	15.26	0	0.000	7.632
Vriesea amazonica	3	27.27	6	3.158	7	3.684	1	0.526	2.105

Fa = absolute frequency per plot; Frp = relative frequency per plot; Faf = absolute frequency per phorophyte; Frf = relative frequency per phorophyte; Fac = absolute frequency per crown; Frc = relative frequency per crown; Fafu = absolute frequency per bole; Frfu = relative frequency per bole; VIe = Epiphytic Importance Value.

by the vertical structure of phorophytes. Variations in humidity, light, and bark characteristics within the canopy likely shape the composition and structure of epiphytic communities (DIVERSITY BEGETS DIVERSITY, 2024).

The low diversity observed (Shannon index = 0.83) may be associated with sampling limitations or with specific microclimatic features of the area, which appears to have reduced moisture-retention capacity. Likewise, the low evenness among species (Pielou's index = 0.29) indicates dominance by a few species, likely resulting from strong microenvironmental filtering.

In environments with higher humidity and denser canopy cover, epiphyte richness tends to be greater, whereas more open and dry forests exhibit lower water-retention capacity, which limits epiphytic diversity. In these more exposed zones, increased solar radiation and canopy heating tend to constrain the establishment of species that are less tolerant to water stress (REYES-GARCÍA et al., 2022).

Conclusion

Seventeen epiphytic species were recorded, with Orchidaceae and Bromeliaceae being the most representative families. *Tillandsia bulbosa* and *Aechmea sp.* stood out due to their abundance and broad vertical distribution.

Most species were found in the canopy, showing an aggregated distribution pattern influenced by microenvironmental factors. The low diversity (H' = 0.83) and evenness (J = 0.29) indices indicate dominance by a few species and potential local environmental limitations.

Further studies with broader spatial and temporal coverage, including microclimatic and structural variables, are recommended to enhance understanding of the factors influencing epiphyte diversity and distribution in tropical environments.

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