Morphological Variations of Oak Leaf Fern Living in Epiphytic, Epilithic and Terrestrial Habitats in Dili, Timor Leste

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ABSTARCT

This study examined the morphological variations of *Aglaomorpha quercifolia* across three habitats: epiphytic, epilithic, and terrestrial in Dili, Timor-Leste. The study aimed to 1.) identify and describe the morphological characteristics of *A. quercifolia* in different habitats; 2.) assess the statistical variations of these morphological characteristics among different habitat conditions; and 3.) evaluate the extent of morphological variations of *A. quercifolia* across different habitats based on statistical analysis. Specimens were collected through transect walks and visual searches. Both qualitative (e.g., frond color and texture) and quantitative (e.g., frond and rachis size) data were recorded and analyzed using MANOVA in Jamovi. Results showed that all specimens shared key characteristics such as creeping rhizomes, dimorphic fronds, and scaly stipes, confirming they belong to the same species. However, significant differences in size and shape were observed across habitats. Epiphytic *A. quercifolia* had the greatest dimension of fertile and sterile fronds. Epilithic ferns were smallest in all measured traits. Statistical analysis confirmed a strong effect of habitat on morphology ($F = 57.1$, $p < 0.001$), with fertile frond and rachis length showing the most variation. The findings suggest that while *A. quercifolia* maintains core species traits, its morphology is significantly influenced by habitat. Epiphytic forms appeared best adapted, with larger fronds aiding nutrient collection. Further research is recommended to include anatomical and physiological studies and environmental monitoring to better understand the species' adaptability.

Keywords: Aglaomorpha quercifolia, Fern, Habitat, Morphological variation

INTRODUCTION

Aglaomorpha quercifolia (L.) Hovenkamp & S. Linds., [syn. (*Drynaria quercifolia* (L.) J.Sm., J. Bot. (Hooker)] (Lindsay et al., 2017) is a member of the Polypodiaceae family and is commonly referred to as the "oak-leaf basket fern" (Rodriguez et al., 2014). This species is distinguished by its dimorphic fronds, which include both fertile foliage fronds and sterile nest fronds. The fertile fronds are green, long-stalked, deeply lobed, and pinnatifid, exhibiting a leathery or membranous texture. These fronds bear sori on their undersides, either dispersed or arranged in two consistent rows between the secondary veins. In contrast, the sterile fronds begin as green but turn shiny brown upon maturity. Positioned at the base of the foliage fronds, they remain attached to the creeping rhizome after senescence. These sterile fronds are leathery, rough, and rigid, resembling oak leaves, which contribute to their characteristic "basket" shape. Their primary function is to trap debris and organic matter from canopy water runoff, which decomposes into humus, thereby supplying nutrients to the plant (Rodriguez et al., 2014; Sridhar et al., 2006; Lubos & Amoroso, 2011; Dickason, 1946; Janarthanan et al., 2016; Simpson, 2010; Anuja et al., 2014).

Another defining characteristic of *A. quercifolia* is its thick, "wooly" rhizome (Rodriguez et al., 2014), from which both types of fronds emerge. This rhizome may take on different forms, depending on environmental conditions—it can be either short-creeping (Costa et al., 2021) or long-creeping (Lubos & Amoroso, 2011). It is densely enveloped in soft, copper-colored, velvet-like scale leaves that offer protection and insulation

(Janarthanan et al., 2016; Sunil et al., 2020). The presence of this thick rhizome, along with its protective scale leaves, enhances the plant's ability to survive in diverse habitats.

Aglaomorpha quercifolia is typically found in cool, moist, and shaded environments. While it is commonly an epiphyte, it can also grow as an epilithic or, in some cases, a terrestrial pteridophyte (Lubos & Amoroso, 2011; Anuja et al., 2014; Janarthanan et al., 2016). This wide ecological adaptability may explain its diversity. Terrestrial plants mainly derive their nutrients from the soil in which they grow (Chapin III et al., 2002). However, epiphytic and epilithic species—growing on tree trunks and wet rocks, respectively—obtain nutrients through different means. They rely on atmospheric deposition, stem flow, canopy soils, and trapped organic debris for sustenance (Winkler & Zotz, 2010), as observed in *A. quercifolia*. These habitat variations necessitate morphological and physiological adjustments that enhance the plant's adaptability to diverse environments (Sultan, 1995).

In Timor-Leste, studies have explored *A. quercifolia*, particularly its ecological role, traditional uses, and potential applications. Traditionally, the Timorese people use it as a remedy or food source. Costa et al. (2021) reported that local communities consume the fern's rhizome, believing that a broth made from it enhances milk production in new mothers. Additionally, the young fronds of this fern are boiled and eaten with rice by locals. Several compounds have also been reported for the first time in this species, and the findings contribute to confirming its nutritional value.

Despite being a well-documented fern species, the majority of research on *Aglaomorpha quercifolia* has primarily focused on its morphology, anatomy, species diversity, nutritional value, and phytochemical properties (Lubos & Amoroso, 2011; Janarthanan et al., 2016; Rodriguez et al., 2014; Morakjar et al., 2015). However, there is a significant knowledge gap regarding how this species locally adapts to different habitats. Given its presence across epiphytic, epilithic, and terrestrial environments, it is imperative to explore how its morphological traits vary across these distinct habitats and how such differences contribute to its survival and ecological success.

Objectives

The study aimed to investigate the morphological variations of *A. quercifolia* living in epiphytic, epilithic, and terrestrial habits. Specifically, it attempted to:

1. Identify and describe the morphological characteristics (e.g., leaf size, shape, stem diameter) of *A. quercifolia* in different habitats.
2. Assess the statistical variation of these morphological characteristics among different habitat conditions.
3. Evaluate the extent of morphological variation of *A. quercifolia* across different habitats based on statistical analysis.

Research Hypothesis

The following hypotheses were tested to determine whether the observed morphological variations of *Aglaomorpha quercifolia* across different habitats are statistically significant:

H_{o1}: There is no significant difference in the morphological characteristics of *A. quercifolia* across different habitats.

H_{a1}: There is a significant difference in the measurable morphological characteristics of *A. quercifolia* across different habitats.

H_{o2}: The morphological characteristics of *A. quercifolia* do not significantly vary among different habitat conditions.

H_{a2}: The morphological characteristics of *A. quercifolia* significantly vary among different habitat conditions.

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H_{o3}: There is no significant degree of morphological variation of *A. quercifolia* across different habitats based on statistical analysis.

H_{a3}: There is a significant degree of morphological variation of *A. quercifolia* across different habitats based on statistical analysis.

METHODOLOGY

Sampling Methods

The population of this study consists of *Aglaomorpha quercifolia* specimens found in three different habitats: epiphytic, epilithic, and terrestrial environments within the selected study in Dili, Timor Leste. A transect walk method was employed along the main trails and areas to systematically observe and record specimens. Additionally, opportunistic sampling, or the visual encounter method, was utilized to collect data beyond the predefined transects.

Documentation, Examination and Identification of Specimens

A. quercifolia specimens were documented and examined in their natural habitat using a phone camera. Each specimen's character was examined and documented more closely to provide a clearer image. To ensure consistency in data collection, a total of 5 individual plants was sampled per habitat, resulting in 15 specimens overall. This approach ensures a balanced representation of morphological variations across different environments

To verify the identification of the specimen, the researchers used the Synonymic checklist and distribution of ferns and lycophytes of the world published by Hassler (2022). In addition, since the species of *A. quercifolia* are widely distributed in Asia and in Timor Leste (Hassler, 2022; Costa et al., 2021), Co's Digital Flora of the Philippines (2011-onwards) was used to confirm identification of the specimens.

Data Collection

The morphological traits were examined and divided into quantitative and qualitative. The variation data collected as quantitative traits/characters include length and width of the fertile and sterile fronds, and length of the stipe and rachis. This was obtained by measuring each specimen's character with three repetitions using a measuring tape in centimeters (cm).

The qualitative morphological characters include: branching pattern and color of the rhizome and its scales, color, and texture of fertile fronds, color, shape, texture, and apex shape of sterile frond/blade, color of the frond stipe and rachis. Observation of qualitative characters were carried out with three repetitions for each specimen. Other gross morphological characters of the species were also noted.

Data Analysis

The collected morphological data of *Aglaomorpha quercifolia* from different habitats (epiphytic, epilithic, and terrestrial) was analyzed using Jamovi software. Descriptive statistics, including mean, standard deviation, and range, were computed to summarize the variations in morphological characteristics. Jamovi, built on the R programming language, provides an intuitive interface for performing various statistical analyses, including descriptive statistics (Jamovi, 2024). The research team collaborated with a statistician from Timor-Leste Adventist International School who oversaw the final data interpretation.

RESULTS AND DISCUSSION

Morphology of *Aglaomorpha quercifoli*a in different habitats

Based on the examination, the following are the morphological descriptions of *Aglaomorpha quercifolia* in epiphytic, epilithic, and terrestrial habitats:

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Epiphytic *A. quercifolia* (Fig 1A). Rhizome brown, fleshy, thick, woody, long-creeping, branched, and covered with reddish brown scales. Fronds are dimorphic. Sterile frond green when young, ashy brown when mature, about 12-21 cm long and 11-17 cm wide, leathery, rough and stiff, shallowly lobed, apex acute. Fertile fronds are green, typically leathery, lobed, about 52-93 cm long and 18-46 cm wide. Stipes brown to green adaxially and black to brown abaxially, about 21-24 cm long. Rachis usually brownish black and sometimes transition from brown to green, 31-70 cm long.

Epilithic *A. quercifolia* (Fig 1B). Rhizome brown, fleshy, thick, woody, long-creeping, branched, and covered with brown scales. Fronds are dimorphic. Sterile frond green when young, ashy brown when mature, about 8-11 cm long and 5-9 cm wide, leathery, rough and stiff, shallowly lobed, apex acute. Fertile fronds are green, usually leathery, lobed, about 14-26 cm long and 11-16 cm wide. Stipes brown to green adaxially and black to brown abaxially, about 9-22 cm long. Rachis usually brownish black and green, 3-8 cm long.

Terrestrial *A. quercifolia* (Fig 1C). Rhizome fleshy, thick, woody, long-creeping, abundantly covered with brown scales. Fronds are dimorphic. Sterile fronds are green when young, light brown when mature, about 19-23 cm long and 9-12 cm wide, leathery, rough and stiff, shallowly lobed, apex acute. Fertile fronds green, shiny and leathery, deeply lobed, about 62-74 cm long and 39-42 cm wide. Stipes blackish brown adaxially and green abaxially, 18-25 cm long. Rachis usually brown to green, but sometimes entirely green, 37-48 cm long.

Figure 1. Aglaomorpha quercifolia in different habitats. (A) Epiphytic, (B) Epilithic, (C) Terrestrial

Morphological Similarities of *Aglaomorpha quercifolia* in different habitats

Based on the descriptions above, one can easily identify that the specimens belong to the same species due to the morphological similarities. These similarities were observed in the following: rhizome, sterile frond, fertile frond, and stipe

The rhizomes of the examined *A. quercifolia* are fleshy, thick, woody, long-creeping. All specimens have green fertile fronds that are leathery in texture, and lobed. The sterile fronds are all green when young, and brown, leathery, stiff, and shallowly lobed, and acute of shape when mature. The stipes are mostly brown to green adaxially and blackish brown abaxially. Some of these characteristics are observed in the studies of Kandhasamy et al. (2008), Janarthanan et al. (2016), and Lubos & Amoroso (2011).

The described similar characteristics of *A. quercifolia* are what distinguish the species from other species. Some are common characteristics among the members of the family Polypodiaceae. Having scaly rhizomes is a common characteristic among the members of the family Polypodiaceae, as stated by Simpson (2019). *Dynaria*, the synonymous genus of *A. quercifolia*, is characterized by leaf/frond dimorphism with shallowly lobed sterile fronds and deeply lobed foliage fronds, and the leathery texture of the fronds (Ngatinem-Praptosuwiryo, 2003, de Winter & Amoroso, 2003), which were also observed in all investigated specimens of this study. The presence of scaly rhizomes, which gives it a woolly appearance, and its regular rows of sori distinguish *A. quercifolia* from *A. sparsisora* (Fig. 2) and that without the rhizome, it’s almost impossible to distinguish the two species from one another (Ngatinem-Praptosuwiryo, 2003).

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Figure 2. Observed Aglaomorpha sparsisora at one of the sampling sites.

The shape of the sterile fronds may differ in specimens occurring in different habitats, but they are more or less ovate. De Winter and Amoroso (2003) described the sterile fronds of *A. quercifolia* with a more or less ovate shape. Rajesh (n.d.) described the shape of the sterile fronds of *A. quercifolia* as ovate to ovate-lanceolate, while Lubos and Amoroso (2011) described it as having broadly-ovate shape.

Variations of Qualitative Characters

Aglaomorpha quercifolia exhibits notable qualitative morphological differences across its epiphytic, epilithic, and terrestrial growth forms. These variations reflect the species' adaptability to diverse environmental conditions and are evident in structures such as rhizomes, fronds, stipes, and rachises.

Across all habitats, the rhizome of *A. quercifolia* is consistently described as fleshy, thick, woody, long-creeping, and branched, providing structural stability and nutrient storage (Fig. 3). However, scale coloration varies: epilithic forms often possess reddish-brown scales, while epiphytic and terrestrial types exhibit uniformly brown scales (Fig. 3A and 3C). The reddish hue in epilithic rhizomes may be an adaptation to increased sunlight exposure or a different composition of protective compounds aiding in water retention and desiccation resistance (Hidayat et. al., 2015).

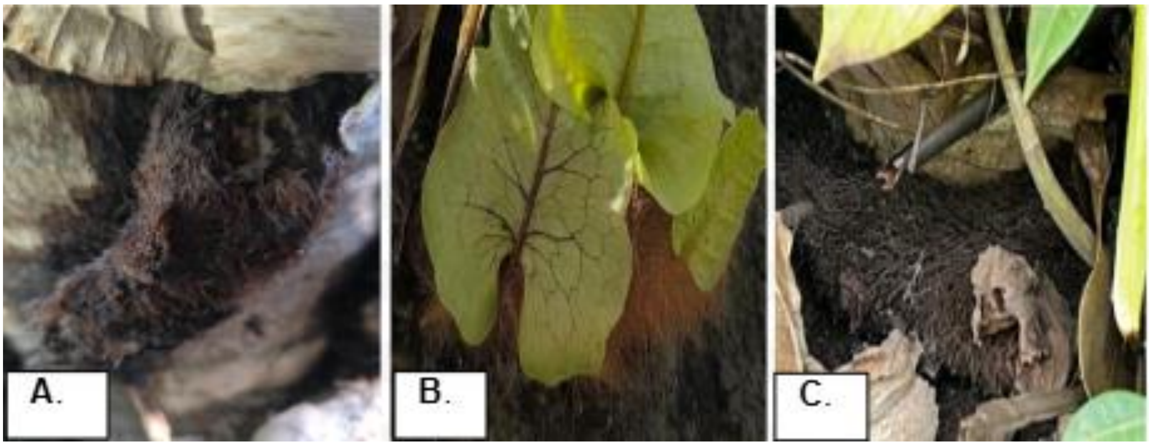

Figure 3. Rhizome of A. quercifolia in (A) Epiphytic, (B) Epilithic, and (C) Terrestrial

Frond dimorphism is a consistent trait among all habitat types, indicating a conserved reproductive strategy. In all cases, sterile fronds display a leathery, rough, and stiff texture with shallow lobes and an acute apex. These features suggest durability, important for capturing and retaining humus in canopy and forest floor environments.

Color transitions—from green when young to various shades of brown when mature—reflect age and exposure differences. Notably, epiphytic and epilithic fronds tend to become ashy brown (Fig. 4A and 4B), possibly due to increased exposure to air and light, while terrestrial forms turn more uniformly brown (Lubos & Amoroso, 2011). Fertile fronds in all habitats maintain a leathery texture and lobed morphology. However, the depth of lobing varies, with terrestrial individuals showing more deeply lobed fertile fronds, potentially enhancing photosynthetic efficiency in shaded, ground-level conditions. Epiphytic fertile fronds remain typically lobed, suited for elevated positions where light is more abundant (Costa et al., 2021).

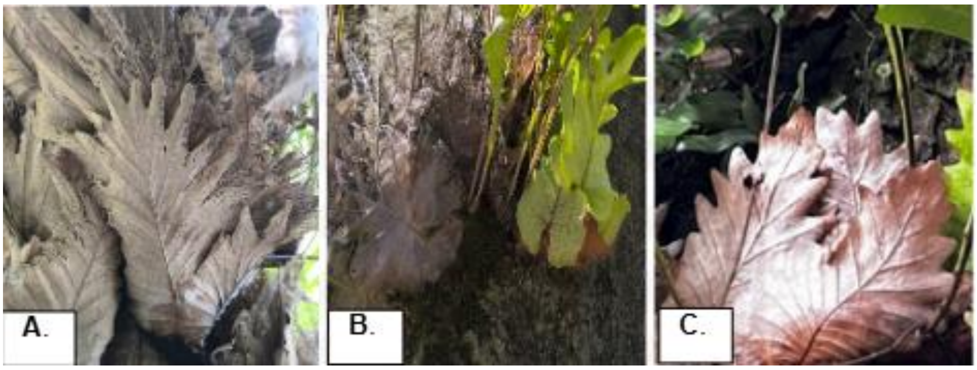

Figure 4. Sterile fronds of A. quercifolia in different habitats (A) Epiphytic, (B) Epilithic, and (C) Terrestrial.

Stipe and rachis coloration also varies across habitats and may indicate adaptations to differing light intensities and nutrient levels. In epiphytic and epilithic forms, the stipe often shows a gradient from brown or green on the upper (adaxial) surface to darker shades like black or brown on the lower (abaxial) side. This dual coloring could serve protective or thermoregulatory functions. The rachis often transitions from brown to green or appears brownish-black in both epiphytic and epilithic forms. In contrast, terrestrial specimens sometimes show fully green rachises, which may be associated with lower light environments and the need for greater photosynthetic contribution from supporting structures (Hidayat et al., 2015; National Parks Board Singapore, n.d.)

Variations of Quantitative Characters

Table 1. Descriptive results of variations in morphological characteristics among different habitats.

Morphological Characteristics	Location	Mean	SD
Fertile Frond Length	EPI	79.40	16.01
	EPL	19.60	5.18
	TER	68.40	5.13
Fertile Frond Width	EPI	36.60	11.44
	EPL	13.60	2.07
	TER	40.60	1.34
Sterile Frond Length	EPI	17.40	4.10
	EPL	9.80	1.10
	TER	21.20	1.48
Sterile Frond Width	EPI	14.40	2.30

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	EPL	6.80	1.48
	TER	10.20	1.30
Stipe Length	EPI	22.80	1.10
	EPL	13.00	5.24
	TER	21.00	2.55
Rachis Length	EPI	56.00	14.95
	EPL	4.80	1.92
	TER	42.60	4.04

Table 1 shows the statistical variation of morphological characteristics among different habitat conditions; it was assessed using descriptive statistics, revealing significant differences in frond dimensions and structural components. Fertile frond length and width varied notably across locations, with the epiphytic (EPI) *Aglaomorpha quercifolia* displaying the greatest mean values (79.40 cm and 36.60 cm, respectively), while the epilithic (EPL) habitat exhibited the lowest values (19.60 cm and 13.60 cm, respectively).

Similar trends were observed in sterile frond dimensions, where EPI specimens showed markedly larger measurements compared to those from EPL and terrestrial (TER) habitats. These findings align with the study of Lubos and Amoroso (2011), which reported that *A. quercifolia*, being primarily epiphytic, typically possesses large sterile fronds ranging from 20–30 cm in length and 15–25.5 cm in width, supporting the idea that epiphytic forms develop more robust frond structures.

Moreover, stipe and rachis lengths also demonstrated substantial variation, particularly in rachis length, where EPI specimens recorded the highest mean (56.00 cm), while EPL specimens had the lowest (4.80 cm). These findings suggest that habitat conditions significantly influence morphological traits—likely as a result of environmental factors such as nutrient availability, substrate stability, and light exposure.

Extent of Morphological Variations to the Different Habitats

The variation in qualitative and quantitative characters among *A. quercifolia* populations in different habitats reflects intraspecific variability, which is defined as the differences occurring between various individuals of the same species, recognized through morphological characteristics (Dumont, 2018).

Table 2. MANOVA test across Location (Pillai's Trace)

Variable	F-value	p-value	Verbal Interpretation
Location	57.1	< 0.001	Significant

Sig. at p-value < 0.05

Table 3. Univariate test in all living condition of *A. quercifolia*

Dependent Variable	Sum of Squares	df	Mean Square	F	p-value
Fertile Frond Length	10130.8	2	5065.4	49.1	< .001
Fertile Frond Width	2123.3	2	1061.67	23.3	< .001

Sterile Frond Length	336.9	2	168.47	25	< .001
Sterile Frond Width	144.9	2	72.47	23.6	< .001
Stipe Length	272.1	2	136.07	11.6	0.002
Rachis Length	7049.7	2	3524.87	43.4	< .001

Sig. at p-value < 0.05

The extent of morphological variations of *A. quercifolia* across different habitats was evaluated using MANOVA, with Pillai's Trace indicating a significant overall effect of location on morphological traits ($F = 57.1$, $p < 0.001$) (Table 2). Univariate tests further confirmed significant differences for all measured attributes shown in table 3, with fertile frond length ($F = 49.1$, $p < 0.001$) and rachis length ($F = 43.4$, $p < 0.001$) showing the greatest variation among locations. Similarly, fertile frond width, sterile frond dimensions, and stipe length exhibited statistically significant differences ($p < 0.05$). However, stipe length ($F=11.6$, $p = 0.002$) statistically showed a lower variation among locations.

Table 4. Extent of Morphological Characteristics in Different Locations Using Post-hoc Analysis.

	Comparison		**Mean Difference**	**p-value**	**Verbal Interpretation**
	Location A	**Location B**			
Fertile Frond Length	EPI	EPL	59.8	0.001	Significant
	EPI	TER	11.0	0.384	Not Sig.
	EPL	TER	-48.8	<0.001	Significant
Fertile Frond Width	EPI	EPL	23.0	0.022	Significant
	EPI	TER	-4.00	0.735	Not Sig.
	EPL	TER	-27.00	<0.001	Significant
Sterile Frond Length	EPI	EPL	7.60	0.027	Significant
	EPI	TER	-3.80	0.219	Not Sig.
	EPL	TER	-11.40	<0.001	Significant
Sterile Frond Width	EPI	EPL	7.60	0.001	Significant
	EPI	TER	4.20	0.026	Significant
	EPL	TER	-3.40	0.012	Significant

Stipe Length	EPI	EPL	9.80	0.028	Significant
	EPI	TER	1.80	0.382	Not Sig.
	EPL	TER	-8.00	0.052	Significant
Rachis Length	EPI	EPL	51.2	0.003	Significant
	EPI	TER	13.4	0.231	Not Sig.
	EPL	TER	-37.8	<0.001	Significant
Sig. at p-value < 0.05					

Table 4 shows that the epiphytic and epilithic samples, as well as the terrestrial and epilithic samples of *A. quercifolia*, exhibit significant differences, suggesting that these habitats contribute to distinct variations in morphological characteristics. However, the epiphytic and terrestrial samples do not show a significant difference in most morphological traits, except for the width of the sterile fronds, which has a mean difference of 4.20.

Based on the investigation, in terms of fertile frond length, the epiphytic and terrestrial specimens are significantly taller and larger compared to the epilithic specimens. Although the epiphytic and terrestrial samples have almost identical measurements, the epiphytic specimens are considered the tallest among the three populations, with a mean difference of 11.0. This suggests that epiphytic and terrestrial specimens of *A. quercifolia* are well-adapted to its habit as an epiphyte, growing on tree trunks. Epiphytic plants are able to survive on trees due to structures and mechanisms that make them withstand extreme environmental conditions such as low water supply that can also result to nutrient limitation (Ainuddin & Nur Najwa, 2009; Zotz & Hietz, 2001).

The post hoc analysis for sterile frond length (Table 4) showed significant differences between EPI and EPL (7.60, $p = 0.027$) and EPL and TER (-11.40, $p < 0.001$), indicating that habitat conditions significantly influence frond length. However, the comparison between EPI and TER (-3.80, $p = 0.219$) was not statistically significant, suggesting that these two locations exhibit similar sterile frond lengths. In the case of *A. quercifolia*, their sterile nest fronds play an important role in the survival of the species in epiphytic and terrestrial habitats as they contribute to the enhancement of nutrient acquisition of the species. These structures trap leaf litter and water to buffer the plant from drought and nutrient scarcity and inconsistency (Schmidt & Zotz, 2001). According to Janssen and Schneider (2005), *A. quercifolia* possesses humus-collecting foliar structures as an adaptation to its epiphytic life form. *A. quercifolia* demonstrates notable morphological adaptations that support efficient nutrient absorption in both its epiphytic and terrestrial forms. In particular, epiphytic individuals possess specialized humus-collecting structures that allow the fern to trap and utilize organic debris from the surrounding canopy, enhancing nutrient uptake in nutrient-poor arboreal environments. Terrestrial forms, on the other hand, benefit from direct access to soil nutrients (Hidayat et. al., 2015). In general, ferns typically grow in cool, moist, and shady environments. In this study, most of the epiphytic and terrestrial specimens were observed in densely shaded areas, which allowed them to trap more fallen leaves and sticks. These materials eventually decompose into humus, enhancing nutrient uptake. These observations might also influence the morphological characteristics associated with epilithic living conditions that has a bigger mean difference value compared to epiphytic and terrestrial living conditions. The epilithic specimens that were observed in this study were found in less shaded areas, which may have affected the amount of humus collected. This could have led to insufficient nutrient availability, resulting in stunted growth and altered morphological characteristics. Epilithic ferns, which grow on rock surfaces, often face challenges such as limited soil and nutrient availability. Research indicates that these ferns exhibit specific adaptations at various structural levels to cope with their environment. Their morphological and physiological traits are influenced by factors like light intensity and nutrient scarcity, affecting their overall growth and development (Shamrov, 2015). As a result, nutrient acquisition is more efficient in epiphytic and terrestrial habitats than in epilithic conditions

However, the post hoc results for both stipe and rachis length follow a similar trend. The analysis for stipe length (Table 4) showed significant differences between EPI and EPL (9.80, $p = 0.028$), and between EPL and TER (-8.00, $p = 0.052$), indicating notable variations in stipe length across these habitats. In contrast, the comparison between EPI and TER (1.80, $p = 0.382$) was not statistically significant, suggesting that stipe lengths in these two habitats are relatively similar.

Similarly, the post hoc analysis for rachis length revealed significant differences between EPI and EPL (51.2, $p = 0.003$), and between EPL and TER (-37.8, $p < 0.001$), highlighting substantial variation. However, the comparison between EPI and TER (13.4, $p = 0.231$) was not statistically significant, indicating that rachis lengths in these two habitats are also comparable.

These findings underscore the influence of environmental factors on rachis and stipe development, with EPL exhibiting the most distinct differences compared to the other habitats.

Based on the observations, the epiphytic population has a higher number of individuals than the epilithic and terrestrial populations. They are found growing abundantly on trunks of huge trees, with some fertile fronds hanging on the side of the trunk or branches. Thus, *A. quercifolia* is adapted to epilithic and terrestrial habitats, they are much more well adapted to their epiphytic habitat, as observed in their large fronds and their wide occurrence as an epiphyte.

CONCLUSION

The findings of the study lead to several important conclusions regarding the morphology of *Aglaomorpha quercifolia* across different habitats. First, the specimens collected from various environments displayed morphological similarities, particularly in structures such as the rhizome, sterile frond, fertile frond, and stipe, confirming that they all belong to the same species. However, despite these similarities, both quantitative and qualitative differences were evident. Quantitative variations included differences in the length and width of sterile and fertile fronds, as well as in stipe and rachis length, while qualitative variations were observed in the texture of fertile fronds and in the coloration of sterile fronds and rachises. Statistical analyses further revealed significant differences in frond dimensions and structural components across habitats. For instance, epiphytic specimens exhibited the largest fertile fronds, with mean lengths and widths of 79.40 cm and 36.60 cm, respectively, whereas epilithic specimens displayed the smallest, measuring only 19.60 cm and 13.60 cm. Similarly, the epilithic population had the shortest and narrowest sterile and fertile fronds, ranging from 8–11 cm and 5–9 cm for sterile fronds, and 14–26 cm and 11–16 cm for fertile fronds. Overall, morphological variation was significantly influenced by habitat, with fertile frond length and rachis length showing the greatest differences, while stipe length displayed comparatively lower variation. These findings suggest that *A. quercifolia* is better adapted to epiphytic conditions, as evidenced by its larger frond size and wide distribution in this habitat.

RECOMMENDATIONS

Based on the results of this study, several recommendations are proposed to further enhance the understanding of *Aglaomorpha quercifolia* and its morphological variation across habitats. First, a more extensive morphological investigation of the species is recommended to provide a stronger and more comprehensive basis for assessing variation. Additionally, anatomical and physiological studies should be conducted to gain deeper insights into the species' adaptability to different environmental conditions. Expanding the sampling area is also advised, as this would yield a broader and more accurate representation of morphological variation. Continuous measurement of microclimatic parameters, such as temperature, humidity, light intensity, and canopy cover, using dataloggers is suggested to establish clearer correlations between specific environmental conditions and morphological adaptations. Finally, comprehensive analyses of soil and humus content—including pH, organic matter, nutrient levels (particularly nitrogen and phosphorus), and moisture retention—should be carried out to better understand how substrate quality influences the morphological traits of *A. quercifolia*.

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