A Comparative Study of the Diversity of Corticolous Lichens on *Cocos nucifera* L. (coconut) at Six (6) Line Path Villages in Berbice, Guyana

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Abstract
This study assessed the diversity, abundance, and community composition of lichens on 60 mature coconut palms (*Cocos nucifera* L.) across six neighboring villages in Corriverton, Berbice, Guyana, during the short-wet season of December 2025-January 2026. Quadrats (50×100 cm) were systematically placed on the trunk of each tree, and lichens were identified in situ and via laboratory analyses using morphological characteristics. A total of 5,876 individual lichens were recorded, representing 16 species across 11 families. Foliose and crustose growth forms dominated, with *Xanthoria parietina*, *Chrysothrix candelaris*, *Flavoparmelia caperta*, and *Lecanora spp*. being the most abundant. Species distribution exhibited moderate spatial heterogeneity, with some taxa (e.g.*, Graphis palmicola*, *Dirinaria picta*) restricted to specific sites, reflecting possible microhabitat and host-bark influences. Findings highlight the ecological significance of *C. nucifera* L. as a phorophyte supporting diverse and structurally complex corticolous lichen communities. This initial baseline assessment provides critical insights into host specificity, community assembly, and potential bioindicator applications for the possible use of lichens for monitoring environmental quality in coastal Guyanese ecosystems.

Keyword: *Cocos nucifera*, Corticolous Lichens, Host Specificity, Tropical Coastal Ecosystems, Species Diversity

1. Introduction
1.1 Lichens
Lichens are remarkably, evolutionarily successful symbiotic organisms that represent one of the most intricate and enduring forms of inter-kingdom biological association known in nature [6, 7, 12, 13, 14, 15, 16, 45, 51]. Traditionally defined as symbioses between a heterotrophic fungus (the mycobiont) and one or more photosynthetic partners (the photobionts, typically green algae or cyanobacteria), lichens form distinct composite organisms that are morphologically and physiologically unlike their constituent partners when grown separately [6, 7, 12, 13, 14, 15, 16, 23, 45, 51]. This unique dual or multipartite association enables lichens to thrive across virtually all terrestrial ecosystems, from tropical rainforests to polar deserts and barren rock surfaces, often colonizing habitats hostile to other life forms [12, 13, 14, 15, 16, 45, 51].

The classical conceptualization of lichen symbiosis highlights mutualistic nutrient exchange: photobionts provide photosynthates (fixed carbon) to the fungal partner, while the fungus offers physical protection, water retention, nutrient absorption from substrates, and structural support [6, 7, 14, 15, 16, 32, 45]. Recent studies, however, recognize this relationship as more complex than simple mutualism. Genomic and microbiome research has revealed additional microbial associates, including bacteria and secondary fungi, that contribute to physiological functions and add layers to the symbiotic interaction [15, 29, 40]. Furthermore, debates in the literature consider controlled parasitism or context-dependent interactions, reflecting intricate balances of benefits among partners [45].

Morphologically, lichens display extensive diversity, yet are traditionally categorized into three dominant growth forms; crustose (tightly attached to substrates), foliose (leaf-like thalli), and fruticose (shrubby or filamentous structures), with thallus architecture significantly influencing ecological roles and environmental interactions [12, 13, 14, 15, 16, 23]. These composite organisms colonize a wide variety of substrates, including rocks (saxicolous), soil (terricolous), and plant surfaces (corticolous), displaying remarkable ecological versatility and adaptability [45]. Among corticolous lichens, tree bark serves as a critical substrate influencing community composition through its physical and chemical properties, microhabitat availability, and host tree physiology [6, 12, 15. 26]. Across these diverse forms, many lichens synthesize distinctive secondary metabolites, which contribute to stress tolerance, competitive interactions, and deterrence of herbivory, and have garnered interest for potential biotechnological and pharmaceutical applications [14, 17, 51].

Ecologically, lichens perform key functions in terrestrial environments [14]. They are often among pioneer colonizers on bare substrates, facilitating soil formation and nutrient cycling by trapping dust, fixing atmospheric nitrogen (particularly in cyanobacteria-bearing lichens), and contributing to primary productivity in nutrient-limited systems [14, 15, 16, 23, 51]. Lichens' capacity to withstand extreme desiccation and temperature fluctuations underpins their success in harsh environments where most vascular plants cannot survive [14, 15, 51].

Lichens are also invaluable bioindicators of environmental quality [6, 7, 12, 13, 15, 16, 23, 59, 64]. Their sensitivity to atmospheric pollutants, particularly sulfur dioxide, nitrogen oxides, ozone, and heavy metals, has made them widely used in biomonitoring studies to assess air pollution gradients and ecosystem health [14, 23, 59, 64]. Lichens' ability to accumulate airborne contaminants in their thalli over long periods allows integration of temporal pollution exposure, permitting both qualitative and quantitative assessment of environmental stressors [14, 59, 64].

Despite their resilience and ecological importance, lichens face increasing threats from anthropogenic pressures including air pollution, land use change, habitat fragmentation, unsustainable harvesting, and climate change, which can alter species composition and reduce biodiversity in many regions [14, 15, 16, 32]. As a result, ongoing research efforts emphasize the need for comprehensive understanding of lichen biology, ecology, and conservation strategies.

1.2 Lichens on Woody Plant Hosts
The relationship between lichens and their host trees is not merely incidental; many lichen species exhibit host preferences or host specificity, where particular tree species support distinct lichen assemblages due to differences in bark texture, chemical compounds, bark pH, microclimatic exposure, and nutrient availability [6, 14, 15, 26]. Research on host specificity has shown that certain tree species within tropical and subtropical ecosystems may harbor diverse and unique lichen communities' relative to others, reflecting differential suitability as substrates [6, 7, 12, 13, 15].

Meliaceae hosts, for example *Swietenia mahagoni* (mahogany) are documented in host specificity studies as supporting rich corticolous lichen communities, often with higher species richness compared to other co-occurring hosts [6]. These trees, with relatively stable bark environments and complex microtopography, create niches that promote lichen colonization and persistence. In contrast, other host genera such as *Mangifera indica* (mango) may support lower lichen diversity, indicating variation in host suitability among woody plant species [6].

Beyond classical Meliaceae hosts, palm trees such as *Cocos nucifera* L., although belonging to the Arecaceae family, frequently play a significant ecological role in tropical coastal and agroforestry landscapes as substrates for corticolous lichens. *C. nucifera* is a monotypic and cosmopolitan palm species widely distributed throughout the tropics, known not only for its economic significance but also for its structural contribution to canopy and bark habitats [37]. The rigid, fibrous bark of coconut palms can provide a viable substrate for lichen establishment, particularly in humid tropical regions where moisture and light gradients favour epiphytic cryptogams. In studies conducted in Guyana by Bacchus & Da Silva (2021) [6], *C. nucifera* was observed to host a substantial portion of corticolous lichen communities, sometimes even exceeding the lichen species recorded on other studied hosts like *Mangifera indica,* underscoring its relevance as lichen substrate in urban and peri-urban ecosystems.

In coastal agroecosystems at No. 63 Benab, studies conducted by Bhagarathi *et al*. (2024a) [12] and Bhagarathi *et al.* (2024b) [13] have demonstrated that lichen communities exhibit pronounced host-plant specificity across woody plant species, including citrus trees such as *Citrus spp.* and other agriculturally important trees. Bhagarathi *et al*. (2024a) [12] documented that twelve lichen species (e.g. *Parmelia sulcata*, *Flavoparmelia soredians, Flavoparmelia caperta, Dirinaria applanate, Chrysothrix candelaris, Lecanoramuralis, Lecanora conizaeoide, Arthonia cinnabarina, Arthonia purinata, Candelaria concolor, Lepraria lobificans* and *Graphis elegans*) showed specificity toward four citrus host species sampled, indicating that particular bark substrates and microhabitats provided by these woody plants support distinct lichen assemblages. These results suggest that citrus trees contribute significantly

to regional lichen diversity by offering a range of physical and chemical bark environments that facilitate colonization and persistence of certain lichen taxa [12].

A study by Bhagarathi *et al*. (2024b) [13] recorded more than 52,000 individual lichens placed into 30 species across 23 genera at No. 63 Benab, and noted that *Cocos nucifera* exhibited the highest average number of lichens among sampled hosts, highlighting the importance of host identity and substrate suitability in structuring lichen communities on woody stems [13]. These findings reinforce broader ecological patterns observed in corticolous lichen research, wherein variation in bark texture, chemistry, and microclimatic exposure among tree species, including citrus hosts, influences species richness, community composition, and specificity of lichen assemblages [14, 15, 16].

In a complementary investigation focusing specifically on neem, Bhagarathi *et al*. (2026) [15] examined corticolous lichen diversity on *Azadirachta indica* (neem) as a host plant, across three contrasting sites in Berbice, Guyana, in order to evaluate community structure on this widely cultivated Meliaceae species. This study recorded 13 lichen species distributed among six families and eight genera, demonstrating that neem bark supports a moderately rich and structurally varied lichen assemblage. Diversity analyses using Shannon and Simpson indices indicated site-level variation in species richness and evenness, suggesting that microclimatic differences and localized environmental conditions influenced community composition. The relatively fissured and chemically distinctive bark of neem was observed to provide heterogeneous microhabitats conducive to colonization by crustose and foliose taxa. Bhagarathi *et al*. (2026) [15] concluded that *A. indica* functions as an ecologically significant phorophyte within coastal and peri-urban landscapes, contributing meaningfully to regional corticolous lichen diversity while exhibiting patterns of host-associated variation consistent with broader findings on bark texture, chemistry, and substrate stability in tropical systems.

Several lichen species have been specifically documented from palm substrates, illustrating ecological examples of host association. For instance, the crustose lichen *Lecanora merrillii* was first described from material collected on the bark of *Cocos nucifera* in the Philippines, indicating the ability of certain lichen taxa to specialize on palms in coastal forests [60]. Similarly, *Pyrrhospora palmicola* was originally recorded from *C. nucifera* in the Seychelles, further illustrating the existence of palm-associated lichens in diverse biogeographic regions [3]. Species such as *Graphis palmicola* have been named for their palm-associated ecology, reflecting a pattern of lichen taxa evolving in close association with specific host tree types like coconut palms [41].

The study of lichens on *C. nucifera* and other woody hosts contributes importantly to our understanding of epiphytic biodiversity, host specificity, and ecosystem health in tropical landscapes. Because lichens respond sensitively to microenvironmental changes, including air quality and moisture regimes, their occurrences on particular hosts can also serve as bioindicators of environmental conditions [14, 15]. Recognizing the patterns of lichen distribution across hosts such as Meliaceae trees and palms like *C. nucifera* enhances both ecological theory and applied conservation, by linking substrate attributes with community structure and environmental gradients.

1.3 Lichens on *Cocos nucifera* L. Host

Cocos nucifera L., commonly known as the coconut palm, is a perennial monocotyledonous palm in the family Arecaceae that holds significant ecological, economic, and cultural importance across tropical and subtropical regions of the world. It is one of the most widely cultivated and naturalized palm species, occurring in more than 90 countries [11]. The species is well adapted to a variety of coastal and inland habitats, particularly sandy soils with high light availability and humidity, which facilitate its survival and growth beyond its putative origin in humid tropical forests of the Indo-Pacific [11].

As durable and long-lived woody hosts, coconut palms contribute substantially to local structural complexity in coastal ecosystems, serving as substrate for diverse communities of lichens, bryophytes, fungi, and other cryptogams [8]. The surface of the trunk of *C. nucifera* provide a range of microclimatic niches that vary in light exposure, moisture retention, and texture, which are known determinants of epiphytic colonization patterns [8].

Coconut palms play a vital role in coastal agriculture and local economies by providing food, oil, fibre, timber, and other value-added products, while simultaneously serving as perennial woody hosts that sustain diverse epiphytic lichen assemblages [12, 65]. In structurally complex rural and coastal landscapes, such trees enhance biodiversity and ecosystem functioning by supporting corticolous lichen communities that contribute to nutrient cycling, soil health, and associated ecological processes linked to sustainable agricultural systems [12, 58]. Importantly, the lichens found on coconut trunks function as sensitive bioindicators of air quality and environmental health, as their diversity and physiological condition reflect atmospheric pollution levels and broader anthropogenic disturbances in coastal agroecosystems [28, 59].

Research in Caribbean and tropical coastal settings has directly documented the role of *C. nucifera* as an effective host for epiphytic lichens. On Caye Caulker, Belize, at least 20 lichen species and a cyanobacterium were recorded growing as epiphytes on both shoreline and inland coconut palms, illustrating that coconut palm bark represents a viable substrate for lichen establishment and diversity in tropical littoral environments [8]. These findings indicate that the physical and chemical characteristics of coconut palm trunks are conducive to the establishment of lichen thalli and associated biota, and that such hosts can support cryptogamic assemblages similar to those found on other woody plant species.

Beyond bryophytes and lichens, *Cocos nucifera* has been shown to interact with a broader range of microbial and faunal symbionts and associates [24]. Studies of myxomycete assemblages on coconut palms in Brazil revealed that these hosts also provide microhabitats for diverse protistan communities, suggesting that the role of palms as ecological substrates extends across multicellular and unicellular groups [24]. Additionally, coconut root systems form associations with arbuscular mycorrhizal fungi, further demonstrating the integrative ecological relationships that *C. nucifera* maintains with other organisms throughout its life cycle.

Understanding *C. nucifera* as a host plan, is important not only for documenting biodiversity but also for interpreting ecosystem processes and community assembly in tropical landscapes, where palms represent dominant, long-lived woody plants. As substrate providers, coconut palms influence local epiphytic community structure and functional dynamics, offering a permanent and elevated host surface that integrates factors such as microclimate, bark properties,

and regional species pools. Consequently, examining *C. nucifera* host dynamics contributes to broader ecological insights into epiphyte distribution patterns, host specificity, and the role of woody plants in structuring cryptogamic biodiversity.

The general aim of this study was to identify and compare the diversity and abundance of lichens on *Cocos nucifera* L. at six neighboring villages in Corriverton, Berbice, Guyana. This study is important because it provides the first comparative baseline assessment of lichen diversity and abundance on *Cocos nucifera* L. in Berbice, Guyana, an area where there is a paucity of lichenological data. By examining spatial patterns of species composition and abundance across adjacent communities, the research helps to identify how subtle differences in land use, pollution exposure, vegetation management, and microhabitat conditions influence epiphytic lichen assemblages. The findings can therefore contribute to environmental monitoring, biodiversity conservation planning, and sustainable community development initiatives in coastal Guyana. Moreover, generating localized scientific data strengthens regional lichen research capacity and provides a reference framework for future ecological, taxonomic, and climate-related studies in Berbice and beyond.

2. Methodology
2.1 Study Location
This research was conducted along the East Coast of Berbice (Figure 1). The Line Path constituent comprises of six (6) neighboring villages. The six (6) sites are: Line Path 'A' village, Line Path 'B' village, Line Path 'C' village, Line Path 'D' village, Line Path 'E' and Line Path 'F' all found in the town of Corriverton (Figure 1).
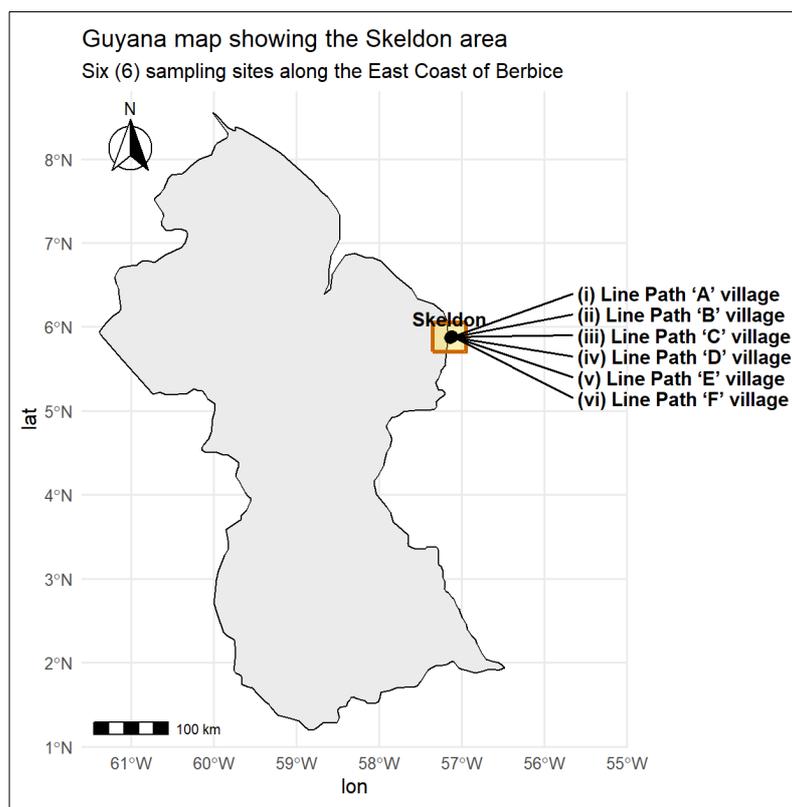

Fig 1: Map of Guyana showing the location of Skeldon, Corriverton, East Berbice Corentyne (Regions 6) and the six (6) sampling sites along the East Coast of Berbice: (i) Line Path 'A' village, (ii) Line Path 'B' village, (iii) Line Path 'C' village, (iv) Line Path 'D' village, (v) Line Path 'E' and (vi) Line Path 'F'

2.2 Experimental Design
The method utilized for this research was adopted from prior studies by Asta *et al*., 2002 [5]; Scheidegger *et al*., 2002 [54]; Bacchus & Da Silva, 2021 [6]; Bacchus & Da Silva, 2023 [7]; Bhagarathi *et al*., 2024a [12]; Bhagarathi *et al*., 2024b [13] and Bhagarathi *et al*. 2026 [15]. The experimental design utilized for this study is quantitative non-experimental. Purposive sampling was utilized in this study since only *Cocos nucifera* L. hosts trees were selected. The host plants were selected using the following criteria: (i) trees must be undamaged especially on the bark area and (ii) the trunk of the selected tree must be 50 cm girth or more [12, 13, 15].

2.3 Theoretical Framework
The theoretical framework (Figure 2) effectively organizes the research process for assessing lichen communities on *Cocos nucifera* L. along the East Coast of Berbice, Corriverton. It begins with the identification of key theoretical underpinnings, including lichen ecology, host tree specificity, and tropical coastal ecosystem dynamics, which guide the selection of variables and methodological approaches. The framework explicitly links the variables, host trees, lichen diversity, and environmental factors such as light exposure and microhabitat conditions, to the reviewed literature, providing clear justification for the chosen study design. This ensures that the research is grounded in ecological theory while highlighting the influence of host tree characteristics and environmental gradients on lichen colonization patterns.
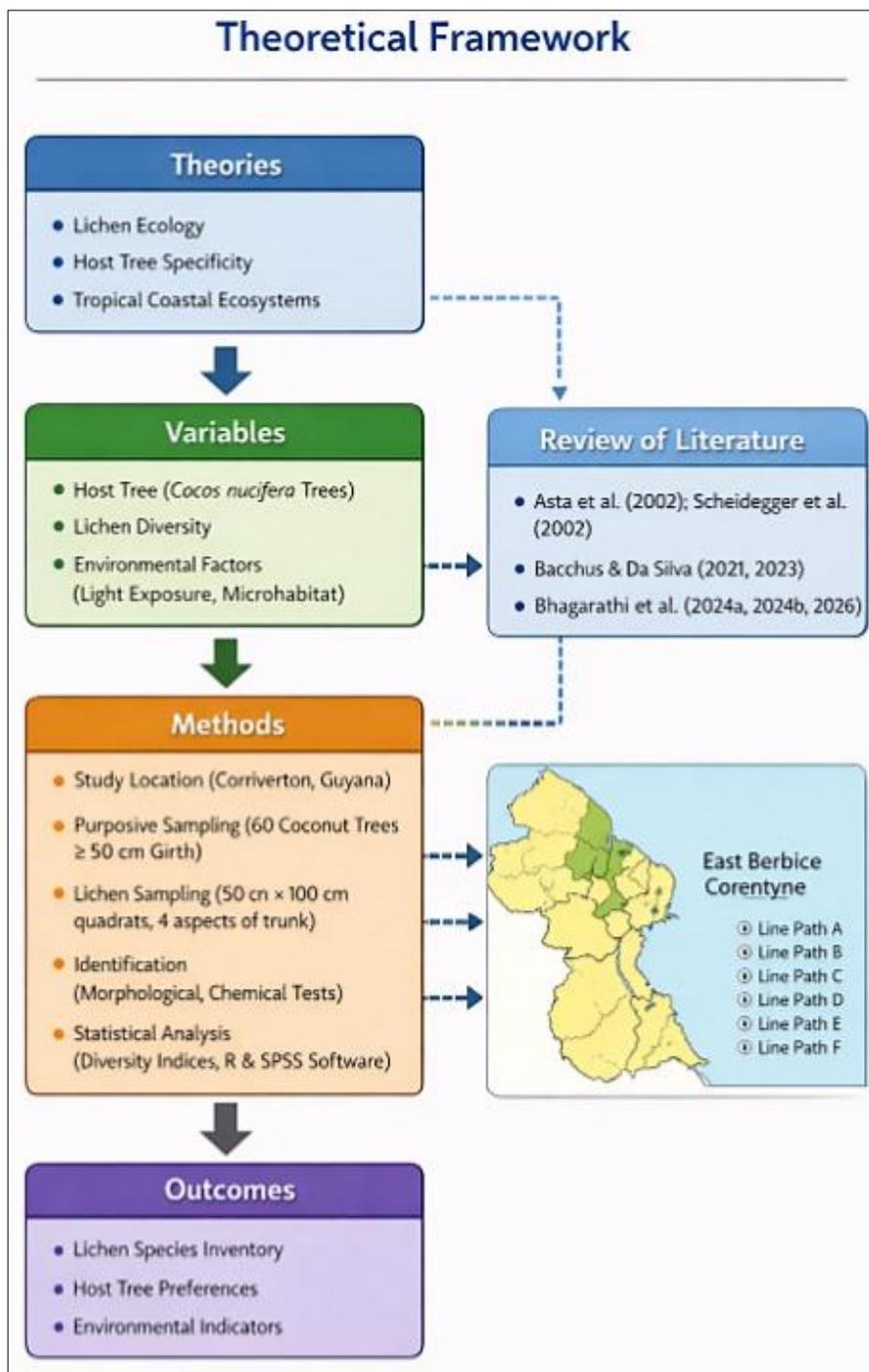
Fig 2: Theoretical Framework of the study

The framework (Figure 2) then transitions into the methods and outcomes stages, illustrating a systematic workflow from site selection through data collection, identification, and analysis. The inclusion of detailed methodological elements, such as purposive sampling of 60 coconut trees, quadrat placement on four trunk aspects, in situ and laboratory identification, and statistical analyses using diversity indices and software tools, emphasizes the study's rigor and replicability. The outcomes section demonstrates how the research aims to quantify lichen species inventories, host tree preferences, and environmental indicators, linking empirical observations back to the theoretical concepts. Overall, the flowchart provides a cohesive visual representation of the research design, effectively connecting ecological theory, methodological steps, and anticipated analytical outcomes in a publication-ready format.

2.4 Conceptual Framework
The conceptual framework (Figure 3) illustrates the stepwise methodology adopted for studying lichen communities on *Cocos nucifera* L. along the East Coast of Berbice, Corriverton. The framework begins with the study location, highlighting six specific sampling sites (Line Path A-F), which establishes the spatial context and ensures a structured approach to site selection. The subsequent experimental design stage emphasizes purposive sampling of mature coconut palms with a girth of ≥50 cm, reflecting careful host selection to control for variability in tree age, bark surface, and potential microhabitat heterogeneity. This stepwise depiction visually reinforces the rationale for the chosen non-experimental quantitative approach and demonstrates adherence to prior lichenological studies that underscore the importance of standardized host selection for meaningful ecological inference [6, 7, 12, 13, 15].
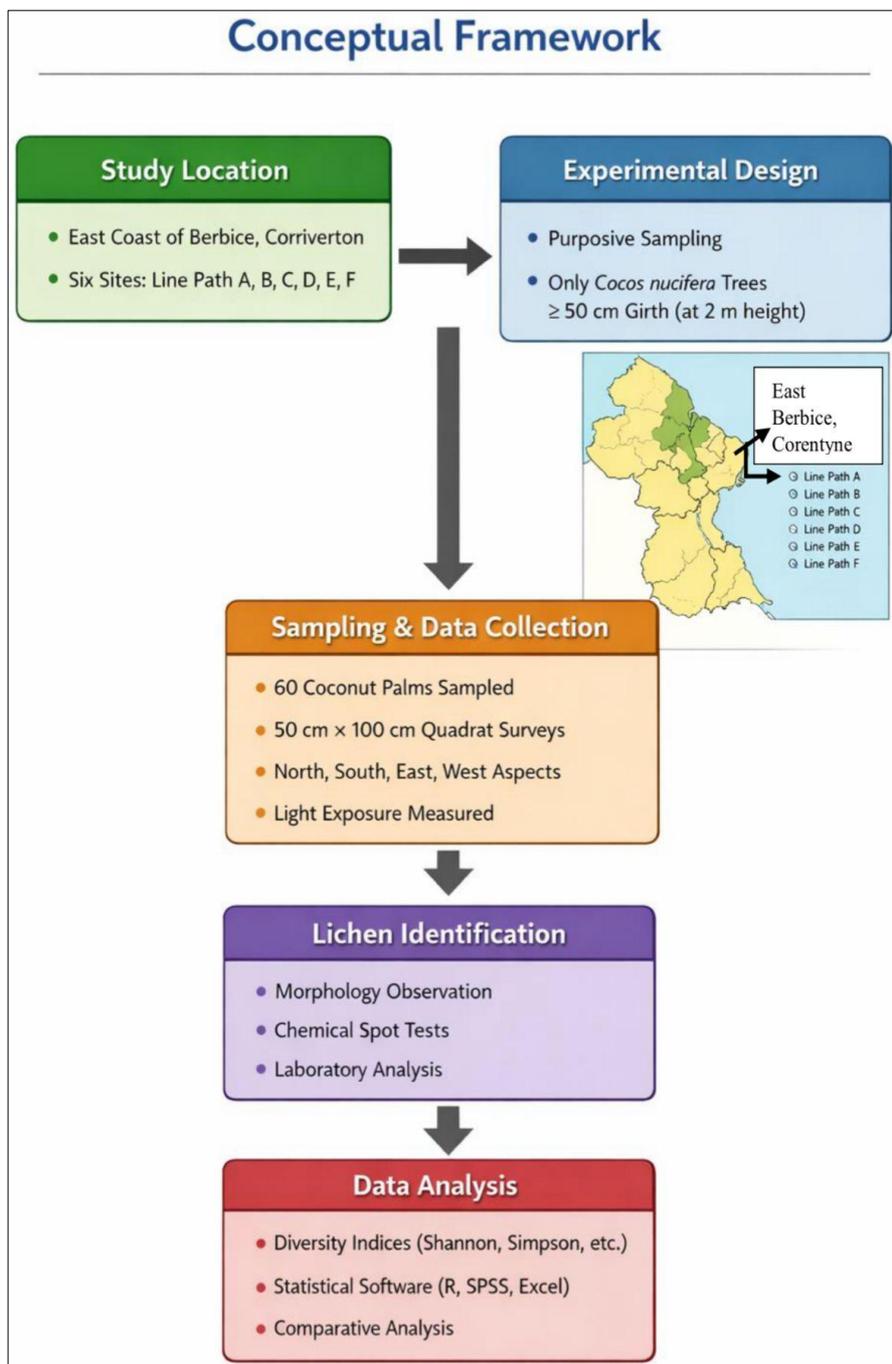
Fig 3: Conceptual Framework of the study

The framework (Figure 3) then progresses to sampling and data collection, detailing quadrat-based surveys with precise dimensions and standardized positioning across cardinal aspects of the trunk, alongside measurements of light exposure. This ensures uniformity in data acquisition and allows for accurate comparisons across individual trees and sites. The next stage, lichen identification, integrates both in situ morphological observations and laboratory-based chemical spot tests, reflecting a comprehensive taxonomic verification process. Finally, data analysis incorporates diversity indices and statistical software tools to quantify species richness, evenness, and community structure. Overall, the framework depicted on Figure 3 effectively communicates a logical and replicable research process, linking ecological context, host selection, field methodology, and analytical rigor, thereby providing a transparent foundation for interpreting lichen diversity and distribution patterns on coconut palms in tropical coastal ecosystems.

2.5 Sampling and Data Collection
Sampling was done during the short wet season period in Guyana during the month of December of 2025 and January 2026. Purposive sampling was the method used to select *Cocus nucifera* L.(coconut) palms across multiple sites. A total of sixty (60) coconut palms were sampled in this study. Ten (10) trees were sampled were sampled from each of the Line Path villages, Corriverton.
Healthy, fully mature trees were selected for sampling. Only undamaged, free-standing individuals with a girth ≥ 50 cm, measured at 2 m above ground level, were included to ensure that exclusively mature trees were sampled [6, 7, 12, 13, 15, 54].
Sun exposure was quantified by measuring the amount of incident light reaching the trunk surface, taking into account shading effects from surrounding vegetation and nearby structures [6, 7, 12, 13, 15, 35].
A total of sixty (60) sampling quadrats were established across the six (6) sites, one for each host plant that was

sampled. Lichen surveys were conducted using twine quadrats measuring 50 cm × 100 cm. On each host tree, quadrats were positioned on the north, south, east, and west aspects of the trunk at a standardized height of 5 ft (≈1.5 m) above ground level [6, 7, 12, 13, 15, 33]. Sampling was carried out within each quadrat on the trunk surface, as well as on soil and any rocks present within the quadrat area. The basal portion of the trunk was excluded to minimize variability among trees and to avoid microhabitat heterogeneity associated with the trunk base [6, 7, 12, 13, 15, 35].

All lichen species present and their frequencies within each 50 cm × 100 cm quadrat were recorded on a standardized lichen survey datasheet developed for this study. The surface cover of each target lichen species was estimated to the nearest cm² and subsequently expressed as a percentage of the sampled trunk area [6, 7, 12, 13, 15].

2.6 Lichen Identification
Preliminary identification of lichen specimens was conducted *in situ* based on detailed morphological observations of the thalli and apothecia using a hand lens. Specimens were identified at minimum to the genus level, and to species level where diagnostic characters permitted [12, 13, 15].

Taxonomic identification was supported by standard lichenological literature suggested by prior studies conducted by Bhagarathi *et al*., 2024a [12]; Bhagarathi *et al*., 2024b [13]; Bhagarathi *et al*. 2026 [15], including Mosses and Lichens: A Popular Guide to the Identification and Study of Our Commoner Mosses and Lichens, Their Uses, and Methods of Preserving, A Reference Notebook: Identifying Mixed Hardwood Forest Lichens, and Collector's Handy Book: Algae, Fungi, Diatoms, Lichens, Desmids and Mosses. Additional dichotomous keys and field guides consulted included Lichens: Two Lives, Field-Oriented Keys to the Florida Lichens, Heathland Lichens, and Lichen Identification Guide (2015).

Standard chemical spot tests were performed by carefully removing a portion of the cortex with a sterile scalpel to expose the medulla, followed by the application of appropriate reagents using a pipette. Resulting color reactions were observed and recorded under magnification to aid in species identification [12, 13, 15, 33]. Specimens that could not be reliably identified in the field were collected and transported to the laboratory for further examination. Following identification, all observations and measurements were systematically compiled and tabulated on standardized lichen datasheets used throughout the field survey [12, 13, 15].

2.7 Data Analysis
Diversity indices are quantitative measures that describe community structure by integrating both species richness (the number of species) and the relative distribution of individuals among species (evenness). Diversity values increase with greater species richness and more equitable abundance distributions, reaching a maximum when all species are equally abundant for a given number of taxa [12, 13, 15, 50]. In this study, species diversity was assessed based on the number of species present and their proportional representation within the community. To facilitate comparative analyses, Menhinick's richness index, Simpson's diversity index, Shannon-Wiener diversity index, and Pielou's evenness index were calculated [12, 13, 15, 33].

Data obtained from the study were subjected to statistical analysis using R software (version 4.2.2; R Studio interface), IBM Statistical Package for the Social Sciences (SPSS) version 23, and Microsoft Excel 2016. Descriptive and inferential analyses were performed as appropriate, and relevant charts, tables, and graphical visualizations were generated using the same software platforms to facilitate data comparison and interpretation.

3. Result and Discussion
3.1 Species / Distribution of Corticolous Lichens
This study recorded a total of 11 lichen families, comprising 13 genera and 16 species, distributed across the six sampling sites (Table 1). The data indicate a moderately rich corticolous lichen assemblage with both widely distributed taxa and site-restricted representatives. Overall, family-level richness was relatively consistent among sites, although certain families exhibited restricted occurrence patterns, suggesting microhabitat differentiation and possible environmental filtering.

Parmeliaceae was the most consistently represented family, with 2 genera and 3 species recorded at all six sites (Table 1). The uniform presence of this family indicates its ecological adaptability and tolerance to the prevailing coastal environmental conditions. Members of Parmeliaceae are typically foliose lichens known for their resilience to fluctuating humidity and light regimes, which may explain their widespread occurrence across all study locations [14, 16].

Similarly, Lecanoraceae (1 genus, 2 species) showed complete distribution across all sites (Table 1), reinforcing its ecological amplitude and competitive ability on bark substrates [14]. The constant presence of these taxa suggests that bark characteristics (e.g., pH, texture, moisture retention) across sites were sufficiently similar to support their establishment.

Families such as Teloschistaceae, Cladoniaceae, Chrysotrichaceae, and Stereocaulaceae each recorded 1 genus and 1 species consistently across all six sites (Table 1). Their uniform distribution may indicate broad ecological tolerance and effective dispersal mechanisms. In tropical coastal systems, such lichens often demonstrate physiological plasticity that enables survival under high irradiance and intermittent moisture availability [14, 16].

In contrast, Monoblastiaceae, Collemataceae, and Graphidaceae displayed restricted and patchy distributions (Table 1). Monoblastiaceae was recorded only at Sites 2, 4, and 5; Collemataceae occurred at Sites 1, 4, and 6; while Graphidaceae was found exclusively at Site 3 (Table 1). These localized occurrences may reflect microclimatic variation, subtle differences in bark chemistry, or varying levels of anthropogenic disturbance among sites [14, 16]. Graphidaceae, for instance, is often associated with relatively stable, humid microhabitats, and its restriction to a single site may indicate localized environmental suitability [12, 13].

Caliciaceae and Candelariaceae demonstrated intermediate distribution patterns. Caliciaceae (1 genus, 2 species) was present at all sites but exhibited slight variation in species richness, suggesting differential species establishment or survival across sites (Table 1). Candelariaceae (2 genera, 2 species) showed reduced richness at Sites 4 and 5, which may reflect local environmental constraints or competitive interactions [12, 13].

From a community structure perspective, Sites 1, 2, 3, and 6 supported relatively higher and more stable family representation compared to Sites 4 and 5, where certain families were absent. However, no site exhibited extreme reduction in overall family diversity, indicating that corticolous lichen communities are broadly distributed across the study area.

Table 1: Number of genera and species at each site

#	Family	Total # of Gen.	Total # Of SP.	SITE # 1		SITE # 2		SITE # 3		SITE # 4		SITE # 5		SITE # 6	
				# OF GEN.	# OF SP.	# OF GEN.	# OF SP.	# OF GEN.	# OF SP.	# OF GEN.	# OF SP.	# OF GEN.	# OF SP.	# OF GEN.	# OF SP.
1	Parmeliaceae	2	3	2	3	2	3	2	3	2	3	2	3	2	3
2	Caliciaceae	1	2	1	1	1	2	1	2	1	2	1	1	1	1
3	Candelariaceae	2	2	2	2	2	2	2	2	1	1	1	1	2	2
4	Teloschistaceae	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	Cladoniaceae	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	Chrysotrichaceae	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	Monoblastiaceae	1	1	0	0	1	1	0	0	1	1	1	1	0	0
8	Collemataceae	1	1	1	1	0	0	0	0	1	1	0	0	1	1
9	Lecanoraceae	1	2	1	2	1	2	1	2	1	2	1	2	1	2
10	Stereocaulaceae	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	Graphidaceae	1	1	0	0	0	0	1	1	0	0	0	0	0	0

The observed distribution patterns suggest that while the general coastal environment provides suitable conditions for a core assemblage of corticolous lichens, fine-scale ecological factors likely influence species turnover at individual sites [15]. Variations in tree age, bark morphology, canopy cover, moisture exposure, and anthropogenic influences may contribute to these differences [14, 16]. The dominance of widely distributed families alongside a subset of restricted taxa highlights a balance between ecological generalists and habitat-sensitive species within the community.

Overall, the findings demonstrate that corticolous lichen diversity within the study area is structured by both broad environmental tolerance and localized ecological conditions. The consistent representation of several families across all sites suggests environmental stability, whereas the patchy occurrence of others underscores the importance of microhabitat heterogeneity in shaping lichen distribution patterns.

Table 2: Species frequency distributed over each study site & overall total of each site

Family	Species	Thallus	Reproduction	Site # 1 *	Site # 2 *	Site # 3 *	Site # 4 *	Site # 5 *	Site # 6 *	Total at the 6 Sites *
Parmeliaceae	*Flavoparmelia soredians*	Foliose	Soredia	104	84	126	64	54	118	550
	Flavoparmelia caperta	Foliose	Soredia	136	84	153	91	53	71	588
	Melanohalea exasperatula	Foliose	Isidia	28	13	22	7	17	4	91
Caliciaceae	*Dirinaria applanata*	Foliose	Pycnidia	71	53	44	29	65	54	316
	Dirinaria picta #	Foliose	Soredia	0	18	24	11	0	0	53
Candelariaceae	*Candelaria concolor*	Foliose	Isidia	57	49	68	0	0	37	211
	Candelariella reflexa	Crustose	Soredia	66	41	56	61	64	37	325
Teloschistaceae	*Xanthoria parietina*	Foliose	Apothecia	127	119	155	148	141	136	826
Cladoniaceae	*Gymnoderma lineare*	Fruticose	Apothecia	16	28	37	31	21	32	165
Chrysotrichaceae	*Chrysothrix candelaris*	Crustose-leprose	Soredia	134	186	97	161	86	147	811
Monoblastiaceae	*Anisomeridium biforme*	Crustose	Pcynidia	0	24	0	81	73	0	178
Collemataceae	*Collema furfuraceum*	Foliose	Isidia	41	0	0	64	0	34	139
Lecanoraceae	*Lecanora muralis*	Crustose	Apothecia	109	112	97	91	101	87	597
	Lecanora conizaeoide	Crustose	Apothecia	98	138	101	84	116	76	613
Stereocaulaceae	*Lepraria lobificans*	Crustose-leprose	Soredia	78	41	58	72	47	63	359
Graphidaceae	*Graphis palmicola* #	Crustose	Apothecia	0	0	54	0	0	0	54
	Total			1065	990	1092	995	838	896	5876

Site # 1 *: Line Path 'A', Site # 2 *: Line Path 'B', Site # 3 *: Line Path 'C', Site # 4 *: Line Path 'D', Site # 5 *: Line Path 'E' and Site # 6 *: Line Path 'F'

#: Possible Species Identified for the first time based on Morphological Characterization

A total of 5,876 individual corticolous lichen thalli were recorded across the six sampling sites (Line Path 'A' - 'F'), representing 16 species distributed among 11 families (Table 2). Species abundance varied both spatially and taxonomically, reflecting differences in ecological tolerance, reproductive strategy, and possible microenvironmental heterogeneity among sites [14, 15, 16].

Among the recorded taxa, *Xanthoria parietina* (Teloschistaceae) was the most abundant species, with a total of 826 individuals (Table 2). Its consistently high frequency across all six sites (127-155 individuals per site) indicates strong ecological plasticity and effective sexual reproduction via apothecia. The widespread dominance of this species suggests tolerance to variable light exposure and possibly nutrient-enriched bark substrates, characteristics often associated with anthropogenically influenced or open coastal environments.

Similarly, *Chrysothrix candelaris* (Chrysotrichaceae) exhibited very high abundance (811 individuals), particularly at Sites 2 and 4 (Table 2). Its crustose-leprose thallus and soredial reproduction likely enhance rapid colonization and vegetative dispersal, contributing to its dominance. The abundance of this species suggests favorable bark texture and moisture retention across several sites.

Within Parmeliaceae, *Flavoparmelia caperta* (588 individuals) and *Flavoparmelia soredians* (550 individuals) were highly abundant and consistently distributed across all six sites (Table 2). Both species reproduce primarily via soredia, indicating that vegetative propagation plays a significant role in maintaining population stability and spatial persistence. In contrast, *Melanohalea exasperatula* (91 individuals), which reproduces by isidia, showed comparatively lower abundance and more uneven distribution (Table 2) suggesting either competitive exclusion or more specific microhabitat requirements.

Crustose species within Lecanoraceae were also prominent. *Lecanora conizaeoide* (613 individuals) and *Lecanora muralis* (597 individuals) were consistently recorded across all sites, demonstrating strong adaptability to bark substrates (Table 2). Their apothecial reproduction may facilitate long-distance dispersal, explaining their broad distribution and stable population sizes.

Site 3 (Line Path 'C') recorded the highest total abundance of 1,092 individuals, followed closely by Site 1 (Line Path 'A') recording 1,065 individuals. These sites likely provide optimal microclimatic conditions such as moderate humidity, adequate light exposure, and suitable bark characteristics that favor lichen colonization and persistence. Conversely, Site 5 (838 individuals) recorded the lowest abundance, suggesting relatively less favorable conditions, possibly due to increased disturbance, shading, or differences in bark physicochemical properties. Although total abundance varied, dominant species such as *Xanthoria parietina*, *Chrysothrix candelaris*, and both *Lecanora* species maintained substantial representation at all sites, indicating a stable core community structure across the landscape.

Analysis of reproductive modes reveals that species reproducing vegetatively (soredia and isidia) contributed significantly to total abundance. Soredial species such as *Flavoparmelia caperta*, *F. soredians*, *Chrysothrix candelaris*, *Candelariella reflexa*, and *Lepraria lobificans* collectively accounted for a large proportion of total individuals. Vegetative reproduction likely enhances rapid colonization of bark surfaces and local persistence in dynamic coastal conditions.

Sexually reproducing species via apothecia (e.g., *Xanthoria parietina*, *Lecanora muralis*, *L. conizaeoide*, *Gymnoderma lineare*) were also abundant, suggesting that spore-based dispersal is effective within the study area. The coexistence of both reproductive strategies indicates a balanced community structure where local expansion (vegetative propagation) and broader dispersal (sexual reproduction) operate simultaneously.

Certain taxa displayed restricted distribution patterns. *Graphis palmicola* (Graphidaceae) was recorded exclusively at Site 3 (54 individuals), suggesting site-specific microhabitat suitability, possibly linked to localized humidity or bark stability. Similarly, *Dirinaria picta* (Caliciaceae) was absent from Sites 1, 5, and 6, while *Anisomeridium biforme* (Monoblastiaceae) was confined to Sites 2, 4, and 5. Such patchy occurrences may indicate sensitivity to environmental gradients or subtle differences in host tree characteristics.

Foliose lichens dominated numerically, particularly within Parmeliaceae and Teloschistaceae, reflecting favorable conditions for larger thallus development. Crustose and crustose-leprose forms (e.g., *Chrysothrix candelaris*, *Lecanora spp.*, *Lepraria lobificans*) were also well represented, highlighting the structural diversity of the corticolous community. The single fruticose species, *Gymnoderma lineare* (165 individuals), showed moderate abundance across all sites, suggesting tolerance but limited competitive dominance.

The corticolous lichen community across the six Line Path sites demonstrates a structured yet stable assemblage characterized by: (i) A dominant core group of ecologically tolerant and widely distributed species. (ii) Significant contributions from both vegetative and sexual reproductive strategies. (iii) Moderate spatial heterogeneity reflected in site-specific taxa and abundance variation.

Overall, the distribution patterns indicate that while the coastal environment supports a broadly similar lichen community across sites, localized ecological factors influence species frequency and relative abundance. The dominance of physiologically resilient species suggests environmental stability with subtle microhabitat variation shaping community composition at finer spatial scales.

A comprehensive study across the Mediterranean basin examined host preferences of epiphytic lichens on 72 tree species and found that a significant proportion (>30% locally; ~25% regionally) of lichen species exhibited preference for particular phorophyte hosts (i.e., host bias), despite lichens obtaining most nutrients from the atmosphere rather than substrates. This result aligns with observations in the current research where several taxa demonstrated non-uniform distribution (e.g., *Graphis palmicola* restricted to Site 3, and *Dirinaria picta* occurring at specific sites), suggesting substrate characteristics influence community composition [4].

A regional study in the tropical dry forests of the Atlántico Department, Colombia, documented spatial turnover in corticolous lichen assemblages across four locations. A total of 135 taxa showed significant differences in community composition between sites, which were strongly associated with habitat heterogeneity and environmental gradients. Similar to the current study, species richness and composition varied between sampling localities, underscoring the influence of site-specific conditions on lichen diversity patterns [26].

In Ibagué, Colombia, a study of corticolous lichens across urban and peri-urban environments recorded 29 taxa across 13 families. Species abundance and coverage differed between zones, and community composition varied with phorophyte species and environmental conditions, highlighting how local ecological gradients alter lichen assemblage structure. These findings echo the differential frequency patterns and relative abundances observed across your sample sites, demonstrating how environmental context (e.g., urban versus natural) shapes lichen communities [44].

Research on epiphytic corticolous lichens along an altitudinal gradient in Xinjiang, China revealed variation in species richness and community composition tied to elevation and associated microclimates. Species composition and diversity peaked at mid-altitudes and declined toward upper and lower elevations. This gradient effect parallels spatial heterogeneity in your study, where Site 3 and Site 1 recorded higher total abundance and taxa representation relative to other sites, suggesting environmental gradients influence lichen distribution patterns [1].

In the central mountains of Sri Lanka, corticolous lichen diversity varied significantly with vegetation type, disturbance regime, and canopy structure. Indicator species analyses showed that distinct lichen taxa were associated with undisturbed versus disturbed plots, which aligns with your results showing site-specific occurrences of certain species (e.g., *Graphis palmicola*, *Anisomeridium biforme*) likely influenced by local environmental conditions or human impact. These patterns support the idea that habitat structure and disturbance gradients are critical determinants of corticolous lichen diversity [62].

3.2 Possible First Time Record of Lichen Species in Guyana based on Morphological Characterization and Available Literature

Recent lichenological investigations conducted in Guyana by van den Boom & Sipman, (2016) [61], Bacchus & Da Silva (2021) [6], Bacchus & Da Silva (2023) [7], Bhagarathi *et al*. (2024a) [12], Bhagarathi *et al*. (2024b) [13] and Bhagarathi *et*

al. (2026) [15] have primarily focused on general floristic inventories and broad ecological assessments, with limited emphasis on host-specific corticolous assemblages and never recorded the occurrence of *Graphis palmicola* (Graphidaceae) nor *Dirinaria picta* (Caliciaceae). Reviews of available national literature by Bhagarathi *et al*. (2022) [16] and Bhagarathi (*et al*.) 2023 [14], documented checklists which indicates that neither *G. palmicola* nor *D. picta* had been previously reported within the territorial boundaries of Guyana. Earlier studies conducted in Guyana by Hekking & Sipman (1988) [30], Sipman, (1991) [56], Sipman & Aptroot (1992) [57], Lücking (1998) [39] and Cáceres & Lücking (2004) [21] concentrated largely on common and widespread taxa, particularly within Parmeliaceae and Lecanoraceae, and did not record the occurrence of these two species on any phorophyte.
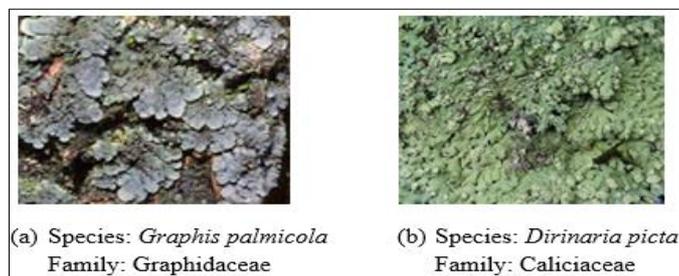

(a) Species: *Graphis palmicola*
Family: Graphidaceae

(b) Species: *Dirinaria picta*
Family: Caliciaceae

Fig 4: Possible New Records of Lichen Species for Guyana based on Observed Morphological Features

The investigation of corticolous lichens on *Cocos nucifera* L. represents possibly the first confirmed documentation of *G. palmicola* and *D. picta* for Guyana (Figure 4). Their detection underscores the importance of host-targeted and site-specific surveys in revealing overlooked components of tropical lichen biodiversity. These new national records contribute significantly to the baseline lichen flora of Guyana and highlight the likelihood that additional undocumented taxa remain within coastal and agroecosystem habitats, warranting further systematic exploration.

The species *Graphis palmicola* was formally described from specimens collected on a coconut tree (*Cocos nucifera* L.) in the Nicobar Islands, where the species epithet itself derives from the Latin palma ("palm") and cola ("dwelling"), indicating its ecological association with palm hosts in coastal forest environments [41]. This original description represents a clear example of a lichen species preferentially colonizing palm bark surfaces in tropical coastal settings. Similarly, *Dirinaria picta*, a foliose lichen in the family Caliciaceae, has been documented growing epiphytically on the trunk of oil palm (*Elaeis guineensis*), demonstrating its ability to colonize palm hosts in West Africa and providing insight into the species' ecological breadth on palm substrates [2].

These records from geographically distinct regions (Indian Ocean islands and African oil palm plantations) highlight the ecological plasticity of both taxa in utilizing palm phorophytes as suitable substrates, and provide valuable comparative points for this study that is reporting these species on *Cocos nucifera* L. in what may be considered new records for Guyana.

Table 3: Comparison of Diversity data at the six (6) sites

Site (Line Path)	Shannon Diversity Index (H′)	Simpson Diversity Index (SDI) (1-D)	Specie Richness (SR)	Specie Evenness (SDI/LN[SR]) (J′)
# 1 (A)	2.435	0.892	13	0.949
# 2 (B)	2.512	0.907	14	0.952
# 3 (C)	2.474	0.900	14	0.938
# 4 (D)	2.486	0.902	14	0.942
# 5 (E)	2.318	0.879	12	0.932
#6 (F)	2.407	0.889	13	0.938

The assessment of corticolous lichen communities across the six study sites (Line Path A-F) revealed moderate to high levels of species diversity, evenness, and richness. Diversity indices, including the Shannon Diversity Index (H′) and Simpson Diversity Index (SDI), were calculated to quantify species heterogeneity and dominance patterns, while species richness (SR) and species evenness (J′) provided complementary insight into community structure.

3.3 Estimated Species Diversity
The Shannon Diversity Index values ranged from 2.318 at Site 5 (Line Path 'E') to 2.512 at Site 2 (Line Path 'B'). This index accounts for both species richness and the proportional abundance of each species, thus reflecting the uncertainty in predicting the species identity of a randomly selected individual from the community. The highest H′ value 2.512 at Site 2 (Line Path 'B') indicates the greatest diversity, likely resulting from both a relatively high number of species (14) and balanced abundances among dominant and subordinate taxa. In contrast, Site 5 (Line Path 'E') had the lowest H′ (2.318), corresponding with the lowest species richness (12 species), suggesting comparatively reduced heterogeneity and a slightly higher dominance of certain taxa. The Simpson Diversity Index (1-D), which emphasizes the probability that two randomly selected individuals belong to different species, ranged from 0.879 at Site 5 to 0.907 at Site 2. The high SDI values (>0.87 at all sites) indicate low dominance and high coexistence among species, implying that no single species overwhelmingly dominates the corticolous lichen assemblage. This pattern is consistent with the observed frequency data, where several foliose and crustose taxa (*Xanthoria parietina*, *Flavoparmelia caperta*, *Chrysothrix candelaris*) were abundant but did not exclude other species.

3.4 Estimated Species Richness
Species richness varied from 12 species at Site 5 (Line Path 'E' to 14 species at Sites 2 (Line Path 'B'), 3 (Line Path 'C'),

and 4 (Line Path 'D'), reflecting the total number of species present at each site. Sites with higher species richness (e.g., Line Paths B, C, and D) coincided with higher Shannon and Simpson indices, indicating that both richness and abundance distribution contribute to overall diversity. Conversely, lower richness at Site 5 (Line Path 'E') aligns with slightly reduced diversity indices, suggesting that fewer species in combination with minor variations in relative abundances can influence diversity metrics.

3.5 Estimated Species Evenness

Species evenness (J'), calculated as H' / ln(SR), measures the distribution of individuals among species and indicates how equitably abundance is shared. Evenness values were generally high, ranging from 0.932 at Site 5 (Line Path 'E') to 0.952 at Site 2 (Line Path 'B'), indicating that lichen individuals were relatively evenly distributed among species at all sites. High evenness demonstrates that no single species disproportionately dominates the community,

supporting the observation that both foliose and crustose taxa co-occur in substantial numbers without competitive exclusion.

Overall, the corticolous lichen communities on *Cocos nucifera* L. at the six Line Path sites exhibit moderate to high diversity, richness, and evenness. Site 2 (Line Path B) consistently recorded the highest Shannon and Simpson indices as well as the highest evenness (J' = 0.952), indicating an optimally structured community with both high species number and equitable abundance distribution. Site 5 (Line Path E), while slightly lower in all indices, still maintains relatively high diversity (H' = 2.318; SDI = 0.879; J' = 0.932), suggesting that even sites with fewer species sustain well-balanced communities. The combination of diversity indices, species richness, and evenness reflects stable, heterogeneously structured corticolous lichen assemblages across the study area, with localized variations likely influenced by microhabitat conditions, phorophyte characteristics, and site-specific environmental factors.

3.6 Site and Host Plant Specificity of Lichens

Table 4: Site Specificity of Corticolous Lichens towards *Cocos nucifera* L. as host plant

Lichen Family	Lichen Species	Site # 1	Site # 2	Site # 3	Site # 4	Site # 5	Site # 6
Parmeliaceae	*Flavoparmelia soredians*	✔	✔	✔	✔	✔	✔
	Flavoparmelia caperta	✔	✔	✔	✔	✔	✔
	Melanohalea exasperatula	✔	✔	✔	✔	✔	✔
Caliciaceae	*Dirinaria applanata*	✔	✔	✔	✔	✔	✔
	Dirinaria picta #	X	✔	✔	✔	X	X
Candelariaceae	*Candelaria concolor*	✔	✔	✔	X	X	✔
	Candelariella reflexa	✔	✔	✔	✔	✔	✔
Teloschistaceae	*Xanthoria parietina*	✔	✔	✔	✔	✔	✔
Cladoniaceae	*Gymnoderma lineare*	✔	✔	✔	✔	✔	✔
Chrysotrichaceae	*Chrysothrix candelaris*	✔	✔	✔	✔	✔	✔
Monoblastiaceae	*Anisomeridium biforme*	X	✔	X	✔	✔	X
Collemataceae	*Collema furfuraceum*	✔	X	X	✔	X	✔
Lecanoraceae	*Lecanora muralis*	✔	✔	✔	✔	✔	✔
	Lecanora conizaeoide	✔	✔	✔	✔	✔	✔
Stereocaulaceae	*Lepraria lobificans*	✔	✔	✔	✔	✔	✔
Graphidaceae	*Graphis palmicola* #	X	X	✔	X	X	X

✔-Lichen Species Present at Site, X-Lichen Species Absent at Site
#: Possible Species Reported for the first time from Guyana based on Observed Morphological Characterization

The analysis of corticolous lichen distribution across the six Line Path sites demonstrates notable patterns of site and host plant specificity, highlighting both ubiquitous and site-restricted taxa on *Cocos nucifera* L. as a phorophyte. The majority of the 16 species recorded exhibited broad site occurrence, with several taxa present at all six sampling locations.

Species such as *Flavoparmelia soredians*, *Flavoparmelia caperta*, *Melanohalea exasperatula* (Parmeliaceae), *Dirinaria applanata* (Caliciaceae), *Candelariella reflexa* (Candelariaceae), *Xanthoria parietina* (Teloschistaceae), *Gymnoderma lineare* (Cladoniaceae), *Chrysothrix candelaris* (Chrysotrichaceae), *Lecanora muralis*, *Lecanora conizaeoide* (Lecanoraceae), and *Lepraria lobificans* (Stereocaulaceae) were consistently observed at all six sites. Their ubiquitous presence indicates low host specificity and high ecological plasticity, suggesting that these taxa are well-adapted to the bark microenvironment of coconut palms in coastal Guyana. These species likely possess traits, such as versatile reproductive strategies (soredia, isidia, or apothecia) and tolerance to variable microclimatic conditions, that facilitate

widespread colonization and persistence across spatially distinct sites [12, 13].

In contrast, certain species displayed restricted occurrence, indicating higher site specificity and potential sensitivity to localized environmental factors. Notably, *Dirinaria picta* (Caliciaceae) was recorded for the first time in Guyana and was absent from Sites 1, 5 and 6. Similarly, *Graphis palmicola* (Graphidaceae), also a new national record, was detected only at Site 3. These restricted distributions suggest that these taxa may require specific microhabitat conditions, such as optimal humidity, light exposure, or bark chemistry, which are not uniformly available across all sampling locations [14, 16]. The detection of these species exclusively at certain sites reinforces the notion that targeted host-specific surveys are critical for uncovering previously undocumented lichens in the region.

Other taxa, including *Candelaria concolor* (Candelariaceae), *Anisomeridium biforme* (Monoblastiaceae), and *Collema furfuraceum* (Collemataceae), exhibited intermediate site specificity, occurring at selected subsets of sites. Their partial distribution likely reflects a combination of

environmental filtering, competitive interactions, and differences in substrate suitability.

The high prevalence of generalist species alongside a subset of restricted taxa indicates a nested community structure on *Cocos nucifera* L., with a stable core assemblage of widely distributed lichens and additional specialized taxa sensitive to microenvironmental variation. The presence new records (*D. picta* and *G. palmicola*) further underscores the importance of host-targeted surveys in revealing previously overlooked components of Guyana's lichen flora.

Overall, these patterns of site and host specificity suggest that while coconut palms provide a broadly suitable habitat for corticolous lichens, localized ecological conditions, such as bark texture, moisture retention, and exposure to sunlight, play a critical role in shaping species composition, distribution, and diversity at fine spatial scales [16]. This information provides a foundation for further ecological and biogeographical studies on host-specific lichen assemblages in the Guiana Shield.

This study did not assess potential determinants of host specificity, including bark pH, water content, permeability, degree of shading, and exudation of tree sap [21]. Additionally, given that lichen species often exhibit vertical stratification along the tree trunk, the examination of only a limited section of the trunk may have contributed to the observed lower species richness [34].

3.7 Lichen Diversity in the Neotropics

The Neotropical region, encompassing tropical America from southern Mexico through Central America and South America, including the Caribbean, is recognized as a global hotspot for lichen biodiversity, with exceptionally high species richness, ecological complexity, and endemism relative to many other biogeographical regions. Systematic reviews estimate that at least 427 lichen species from 58 families have been recorded across 12 Neotropical countries, illustrating both taxonomic breadth and geographic dispersal of lichens in the region [16].

Foliicolous, corticolous, and crustose lichens are widespread across diverse habitats of the Neotropics, from lowland rainforests to tropical dry forests and montane cloud forests, reflecting the adaptability of lichen symbioses to contrasting microclimatic conditions and substrate types [16, 26]. For example, analysis of corticolous communities in Colombian tropical dry forests revealed 135 lichen taxa across multiple sites, with significant species turnover among sites and numerous records of undescribed species, underscoring both the high diversity and the taxonomic novelty present in Neotropical lichen floras [26].

Lichen diversity in the Neotropics is shaped by a combination of biogeographical history, habitat heterogeneity, and environmental gradients. Molecular phylogenetic studies on tropical genera such as *Coccocarpia* suggest that lichen diversification in the tropics may involve complex evolutionary histories with deep lineage divergence and possible cryptic diversity, pointing toward potential species richness far exceeding current taxonomic estimates [22]. Many lichen genera common in the Neotropics, such as *Calopadia* (foliicolous crustose lichens) and others, have centers of diversity in tropical regions, reinforcing the idea that evolutionary processes in these climates have promoted diversification [16]. Foliicolous lichen surveys in Guyana have documented hundreds of species, demonstrating that trees and leaves in humid Neotropical forests support diverse lichen assemblages with low endemism at regional scales,

but strong representation across Neotropical lowland to submontane gradients [39].

This diversity is influenced by microhabitat features such as moisture regimes, light gradients, and substrate chemistry, as well as anthropogenic factors such as land use and forest disturbance, which can alter community structure and reduce species richness where natural habitat complexity is lost [16, 26]. Overall, the Neotropical lichen biota embodies both immense diversity and significant knowledge gaps, suggesting that continued taxonomic exploration and integrative molecular research will be essential for documenting and conserving this rich yet understudied component of tropical biodiversity.

3.8 Role of Lichens in Agriculture

Lichens collectively perform ecological functions with potential significance for agricultural systems. One of the most salient ecological services provided by lichens is nitrogen fixation, which is mediated by cyanobacteria-containing lichen taxa. Cyanobacterial photobionts possess nitrogen-fixing capabilities that convert atmospheric N_2 into ammonia or nitrate, thereby enriching nutrient-poor substrates with biologically available nitrogen [38]. In natural ecosystems, this nitrogen enrichment contributes to soil fertility and promotes plant growth when lichens decay and release fixed nitrogen into the soil matrix. Such natural processes offer conceptual parallels for sustainable agriculture, particularly in low-input or organic systems where synthetic nitrogen fertilizers may be reduced in favor of biologically mediated nutrient inputs [38].

In addition to nutrient cycling, lichens contribute to soil structure and microbial dynamics, which are critical determinants of soil health in agricultural contexts. Research indicates that lichen cover and species composition can influence soil physico-chemical properties, including pH, moisture content, and nutrient availability, through species-specific effects on soil enzyme activity and microbial community composition [9]. These modulatory effects enhance soil quality by promoting beneficial microbial processes that support plant nutrient uptake and resilience to stress.

Moreover, lichen tissues and associated bacteria have shown biocontrol and plant growth-promoting potentials; for example, bacteria isolated from lichens, such as *Bacillus licheniformis*, have been demonstrated to produce indole-3-acetic acid (IAA), solubilize phosphates, produce siderophores, and suppress pathogenic fungi, thereby enhancing crop growth and health [31].

Complementing microbial contributions, certain lichen secondary metabolites exhibit antimicrobial properties against plant pathogens, suggesting potential for eco-friendly biopesticide development [48]. Collectively, these ecological functions underscore the multifaceted role of lichens in agricultural landscapes, from nutrient enrichment and soil health maintenance to potential biofertilizer and biocontrol applications, offering promising directions for sustainable agriculture research and practice.

3.9 Lichen Diversity in Agro Ecosystems

Lichen communities in agro-ecosystems are shaped by a suite of ecological, environmental, and anthropogenic factors, often resulting in distinct patterns of species richness and functional composition relative to natural habitats. Agricultural landscapes typically exhibit lower overall lichen species richness compared to undisturbed forests, largely due to land-use conversion and habitat fragmentation that reduce

substrate continuity and microhabitat heterogeneity essential for many lichen taxa [58, 65]. Studies examining lichen diversity along gradients from forest to farmland indicate a consistent decline in rare and specialized lichen species with increasing agricultural intensity, while more generalist or nutrient-tolerant taxa become relatively more prevalent in open rural areas [58].

This shift is frequently linked to land use intensity, substrate availability, and microclimatic changes associated with crop fields, hedgerows, and managed grasslands, which often lack the structural complexity and stable bark surfaces provided by mature trees in forested environments [53]. Additionally, agricultural practices may increase localized nutrient inputs (e.g., nitrogen deposition from fertilizers), further favoring nutrient-tolerant lichens at the expense of oligotrophic species that are indicators of high habitat quality and environmental stability [53].

Within human-modified landscapes, spatial configuration and management regimes play a crucial role in shaping lichen diversity patterns. Agroecosystems that retain patches of woody vegetation, riparian buffers, and field margins can support higher lichen species richness by providing microhabitats analogous to natural ecosystems, promoting both corticolous and epiphytic communities [58]. For example, research in Guyana's coastal agroecosystems demonstrated substantial lichen diversity on mature tree hosts within rural and peri-agricultural settings, including a high number of species records and first-time regional records, underscoring the capacity of structurally complex agroecosystems to sustain lichen biota when heterogeneous habitats persist [12].

However, the overall literature also highlights that lichen diversity is sensitive to anthropogenic disturbance gradients, such that intensification of agriculture, removal of woody vegetation, and landscape simplification tend to homogenize lichen communities and reduce the occurrence of sensitive or specialist species [58, 65]. Consequently, enhancing structural diversity within agroecosystems, through practices such as maintaining tree cover, hedgerows, and diversified crop mosaics, may be key to conserving lichen diversity and the associated ecological functions these symbiotic organisms provide, including nutrient cycling and bioindicator services.

3.10 Lichens on Agricultural Crop Plants
Lichens, as complex symbiotic associations, colonize a wide array of substrates in terrestrial ecosystems, including rocks, soil, woody plants, and agricultural landscapes [65]. Traditional lichenology has often focused on forest and natural systems, but there is an increasing recognition that agricultural landscapes also provide viable substrates and microhabitats for lichen colonization and persistence [65].

The presence and diversity of lichens on crop plants and within agricultural fields are influenced by a combination of host plant properties, management practices, microclimate, and anthropogenic impacts such as agrochemical application and habitat modification [28, 65]. Agricultural trees such as citrus and coconut palms, and perennial crops with substantial bark or stem surfaces, can therefore serve as important biological platforms for epiphytic lichens in rural settings.

Research on lichen host specificity in agroecosystems demonstrates that lichen taxa can exhibit differential occurrence and diversity among crop hosts, depending on the physical and chemical characteristics of plant substrates and the surrounding environment. In Guyana, for example, studies of lichen communities on citrus trees revealed that certain species exhibited host specificity, with some lichens more frequently associated with particular crop hosts, suggesting that bark texture, microhabitat availability, and microclimatic conditions influence community assembly [12]. Similarly, coconut palms (*Cocos nucifera* L.) in coastal rural systems have been found to support diverse lichen assemblages, illustrating that woody agricultural plants with persistent stems can sustain significant epiphytic cryptogam diversity, comparable to what is observed on trees in natural forests. These findings align with broader observations from other crop-dominated landscapes, where lichens and other cryptogams such as bryophytes occur on farm trees and plantation crops, acting as bioindicators of microenvironmental quality and ecosystem condition [28, 65].

Agricultural practices can significantly affect the occurrence and composition of lichen communities. The application of fertilizers, herbicides, and other agrochemicals may alter local air and substrate chemistry, with potential consequences for lichens due to their sensitivity to atmospheric deposition and chemical pollutants [28]. Further, lichens have been widely used as bioindicators of environmental contamination, including agricultural pollution, because they accumulate metals and agrochemical residues in their thalli, making them effective sentinels of ecosystem health [28].

In rural agricultural landscapes such as the polish countryside, lichen diversity in agroecosystems has been shaped by anthropogenic impacts, weather patterns, and land-use intensity, with some species becoming threatened or declining under increasing disturbance and chemical exposure [65]. Thus, the study of lichens on agricultural crop plants not only contributes to understanding host plant associations and biodiversity patterns but also provides insight into the broader ecological effects of farming practices on cryptogamic organisms.

Overall, the integration of lichens into agricultural ecological research highlights the value of these organisms as biotic indicators of environmental quality, components of crop-associated biodiversity, and informants of anthropogenic influence in agroecosystems. More systematic assessment of lichen communities on crops, especially perennial woody hosts in both tropical and temperate agricultural landscapes, is needed to advance our understanding of how agricultural production influences epiphytic symbiotic systems. Such research also has practical implications, as it can inform sustainable land management practices that conserve biodiversity while maintaining productive landscapes.

3.11 Ecological Impact of Lichens
Lichens represent one of the most ecologically important symbiotic associations in terrestrial ecosystems due to their roles in nutrient cycling, ecosystem structure, and biological monitoring. As composite organisms, lichens are capable of colonizing extreme and nutrient-poor environments where few other organisms can persist [55, 59]. One of their primary ecological functions is in biogeochemical cycling: lichens contribute to the weathering of rocks and the formation of soil through the release of organic acids, mechanical disruption, and capture of atmospheric particles, processes that initiate soil development and facilitate plant succession on bare substrates [55, 59]. Moreover, cyanolichens, those with cyanobacterial photobionts, can fix atmospheric nitrogen, directly increasing nitrogen availability in oligotrophic ecosystems and influencing nutrient dynamics at community and landscape scales [10, 43, 55].

Beyond nutrient inputs, lichens also influence ecosystem complexity and biodiversity. Their thalli create microhabitats and structural heterogeneity on substrates such as tree bark, rocks, and soil surfaces, supporting diverse communities of invertebrates, microorganisms, and other cryptogams [55, 59]. Epiphytic lichens, in particular, contribute to nutrient redistribution by intercepting rainwater and atmospheric deposition, and by trapping minerals that eventually leach into the soil, enhancing local nutrient pools [18, 19, 49]. In forested ecosystems, dense lichen mats may increase habitat complexity critical for micro- and macrofauna, including arthropods, mollusks, and nesting materials for birds, thereby linking lichen presence to broader trophic interactions and energy flow [55, 59].

Lichens are also established biological indicators of environmental change due to their high sensitivity to air quality and climate variables. Because lichens lack protective structures such as roots and a cuticle, they absorb atmospheric water and nutrients across the entire thallus surface, making them especially responsive to atmospheric pollutants, including sulfur dioxide, nitrogen oxides, ozone, and heavy metals [59, 64]. The composition, abundance, and health of lichen communities thus reflect local and regional air quality, allowing scientists and land managers to use lichens as practical biomonitoring tools to assess environmental stressors and habitat integrity [46, 59]. In riparian and forest landscapes, changes in lichen species richness and functional traits correspond to land-use intensity and habitat disturbance, reinforcing their utility in ecological assessments and conservation planning [25, 35].

Overall, lichens are critical contributors to ecosystem functioning and environmental monitoring. Their roles in nutrient cycling, soil formation, habitat provisioning, and sensitivity to environmental stress underscore their importance in both natural and managed ecosystems. Recognition of lichens' ecological significance has motivated their integration into biodiversity and air quality monitoring programs worldwide, where they serve as cost-effective and biologically meaningful indicators of ecosystem health and environmental change.

4. Conclusions

This study documented 16 lichen species across 11 families and 13 genera from 60 sampled *Cocos nucifera* L. trees, indicating a moderately rich corticolous lichen assemblage in the coastal landscape of Berbice. Parmeliaceae, Lecanoraceae, and Teloschistaceae were consistently represented across all six sampling sites, reflecting ecological resilience and adaptability to the prevailing coastal environmental conditions.

Xanthoria parietina, *Chrysothrix candelaris*, *Flavoparmelia caperta*, and *Flavoparmelia soredians* dominated numerically, illustrating strong ecological plasticity. The prevalence of both vegetatively reproducing species (via soredia and isidia) and sexually reproducing species (via apothecia) suggests that the lichen community maintains stability through a combination of local colonization and broader dispersal strategies.

While most lichen species were broadly distributed, certain taxa displayed restricted distributions. For instance, *Graphis palmicola* occurred exclusively at Site 3, and *Dirinaria picta* and *Anisomeridium biforme* were patchily distributed across other sites. These patterns indicate the influence of microhabitat heterogeneity, including localized differences in bark texture, moisture retention, light exposure, and possibly anthropogenic impacts.

The study confirms that *Cocos nucifera* L. serves as an effective and ecologically significant phorophyte in tropical coastal ecosystems. Its fibrous bark, structural complexity, and longevity provide suitable microhabitats for a diversity of corticolous lichens, supporting both generalist and habitat-sensitive species.

The presence and abundance of lichens with varying tolerance to environmental stressors highlight their potential as bioindicators of air quality, microclimatic variation, and ecosystem health. The patchy distribution of sensitive taxa underscores the relevance of site-specific environmental conditions in influencing lichen community composition.

5. Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Expanded Sampling: Future studies should include a larger number of *C. nucifera* L. trees across additional sites, encompassing both urban and rural gradients, to better capture variability in lichen diversity and host specificity.
2. Full Trunk Assessment: Lichen surveys should consider all vertical strata of the tree trunk, including the basal portions, to account for species that may preferentially colonize specific trunk levels and to provide a more comprehensive inventory.
3. Environmental Parameter Analysis: Investigations should measure bark pH, moisture content, texture, shading, and sap exudates to determine their influence on lichen colonization, abundance, and host specificity, providing mechanistic insights into community assembly.
4. Longitudinal Monitoring: Repeated surveys across different seasons and years could assess temporal dynamics in lichen communities, capturing the effects of seasonal moisture availability, precipitation, and anthropogenic impacts on species distribution.
5. Conservation and Bioindicator Applications: Given the presence of both generalist and sensitive lichen species, coconut palms could serve as practical platforms for monitoring environmental health. Policymakers and ecologists should consider lichens as bioindicators of ecological integrity in coastal and urban landscapes.
6. Public Awareness and Integration: Local communities and agricultural institutions should be educated about the ecological role of lichens and the importance of conserving host trees like coconut to maintain epiphytic biodiversity and ecosystem services.

By implementing these recommendations, future research and conservation efforts can enhance understanding of lichen ecology on *C. nucifera* L., contribute to biodiversity monitoring, and inform sustainable management strategies for coastal ecosystems in Guyana and comparable tropical regions.

6. Compliance with Ethical Standards
1. Acknowledgment

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2. Declaration of competing interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

3. Disclosure of conflict of interest
The authors certify that this submission is original work and is not under review at any other publication. The authors hereby declare that this manuscript does not have any conflict of interest.

4. Statement of informed consent
The authors declare that informed consent was obtained from all individual participants included in the study. All work utilized in this study was fully cited and referenced so authors of prior researches are given their due credentials for their work.

5. Data Availability
Data will be made available on request.

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