

PRELIMINARY CHECKLIST OF EPIPHYTIC TERRESTRIAL ALGAE ON TREE TRUNKS OF SRI GADING EDUCATIONAL FOREST AND UiTM PAHANG JENGA CAMPUS, PENINSULAR MALAYSIA

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Abstract

Epiphytic terrestrial algae are chlorophyll-bearing organisms that grow on tree trunks, with some species frequently occurring in symbiosis with fungi, ferns, and lichens. They primarily belong to three distinct evolutionary lineages: Cyanobacteria, Chlorophyta, and Streptophyta. The diversity of epiphytic terrestrial algae in Jengka, Pahang, remains poorly characterized in the existing literature. Therefore, this study aims to enhance the understanding of epiphytic algae species diversity and contribute to maintaining records of these species for future reference. The study identified epiphytic terrestrial algae species and examined their abundance on the tree trunks of Sri Gading Educational Forest and UiTM Pahang, Jengka Campus. Scraping blades were used to collect algal samples from randomly selected tree trunks at the study sites. Samples from each tree were subsequently placed in a tube containing a 70% ethanol solution. Species identification was conducted using standard taxonomic literature and the world's algal database, while species diversity was analysed using PAST software. Nine species across three genera were recorded from sites, including four species from Sri Gading Educational Forest and six species from the campus. The family Trentepohliaceae was the most dominant, with *Trentepohlia arborum* being the most common species. The diversity index indicates that terrestrial algae species on the Jengka Campus were comparatively more abundant than those in the Sri Gading Educational Forest. *Trentepohlia* sp. often exhibits high sensitivity to airborne pollutants and typically thrives only in habitats with low pollution, indicating that air quality at the study sites was comparatively good.

Keywords: Air quality indicator, epiphytic terrestrial algae, Jengka, species diversity, Trentepohliaceae

Introduction

Algae are significant colonizers of uninhabited terrestrial and aquatic environments globally (Alwi *et al.*, 2015). They are often classified as aquatic organisms, resulting in the infrequent recognition of terrestrial algae (Alwi *et al.*, 2015; Ismail *et al.*, 2016). While several algal taxa

persist under terrestrial and aerial conditions, most thrive in aquatic habitats (Saber *et al.*, 2022). In general, terrestrial algae, notably filamentous Trentepohliales, dominate subaerial communities in tropical habitats, whereas coccoid green algae from the Chlorococcales constitute the majority of bark algae in temperate environments (Ambika & Krishnamurthy, 2018). These organisms are termed "terrestrial algae" because they do not require free water for survival but can efficiently extract atmospheric moisture (Alwi *et al.*, 2015). Hoffmann (1989) indicated that epiphytic algae are often located on tree bark (epiphloeic algae) or on the leaves of higher plants (epiphyllic algae). In some cases, free-living epiphytic algal species also participate in lichen communities (Tschermak-Woess, 1978). Common species that colonize tree bark or wooden pilings include *Pleurococcus* and *Cystococcus* (Fritsch, 1992).

Epiphytic terrestrial algae may absorb atmospheric contaminants (Ismail *et al.*, 2016). Packer (2009) stated that algae are recognized for their substantial capacity to absorb carbon dioxide, which supports cellular growth. *Trebouxia* sp. may serve as a biomarker for detecting increases in CO₂ concentration over medium- to long-term periods (Ismail *et al.*, 2017). The substantial amounts of organic carbon produced by algae may be subsequently metabolized by other species and used as a nutritional source (Ismail, 2012).

In contrast to terrestrial algae, phycologists have primarily concentrated their research on marine and freshwater algae, resulting in an incomplete understanding of the diversity and ecological processes associated with terrestrial algae (Alwi *et al.*, 2015). Numerous studies address algal growth in aquatic environments, as shown by Veluchamy and Palaniswamy (2020), who examined marine algal species and their significance for pharmaceutical, medicinal, and scientific applications. The lack of data on terrestrial algae has contributed to increasing challenges in understanding the diversity and distribution of these species. This is because terrestrial algae remain comparatively understudied relative to aquatic algae.

This study aims to identify and analyse the diversity of terrestrial algal species in Jengka, Pahang. This research provides a preliminary taxonomic record of epiphytic terrestrial algae in the Jengka region, establishing an important baseline for monitoring local air quality and understanding the ecological roles of these organisms within tropical forest ecosystems.

Materials and Methods

Sample collection

The sample collection procedure was conducted at two primary sites: Universiti Teknologi MARA (UiTM) Pahang Branch, Jengka Campus, and Sri Gading Educational Forest, where trees were randomly selected at each location to ensure a diverse representation of algal communities (Figure 1). Trees that typically host terrestrial algae on their bark are characterized by high surface roughness, moisture retention, and specific chemical properties. Rough-textured bark is more conducive to algal growth than smooth-textured bark because its deep fissures and crevices provide a stable microhabitat that traps humidity and protects the algae from environmental stressors such as UV radiation and desiccation (Freudenthal *et al.*, 2024). Tree size is a critical driver of community assembly (Dreyling *et al.*, 2024), with larger, older trees providing a more stable and long-lived substrate for the formation of complex microbial biofilms (Freudenthal *et al.*, 2024).

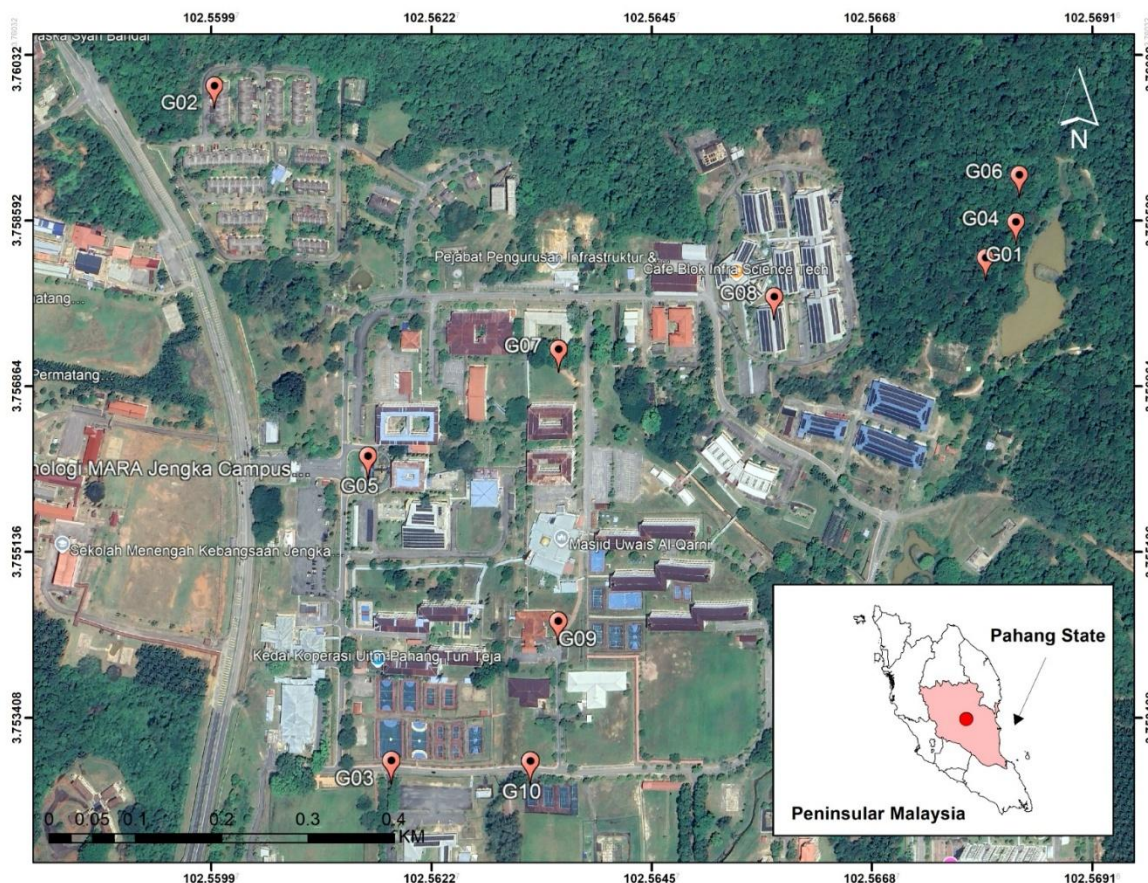


Figure 1 Primary study sites: UiTM Pahang, Jengka Campus (G02, G03, G05, G07, G08, G09, G10) and Sri Gading Educational Forest (G01, G04, G06)

During the collection process, the terrestrial algal layer was carefully scraped from the bark of selected trees, targeting different bark textures to capture a range of algal species. Each sample was immediately placed in a specimen container containing 70% ethanol to preserve it for subsequent analysis. Each container was labelled with the collection date, geographical coordinates, and a description of the sample colour to ensure accurate organization. The labelled containers were then placed in zip-lock bags to protect them during transport to the laboratory. In the laboratory, the samples were analysed to identify species and assess species richness, contributing to an improved understanding of the diversity and ecological roles of terrestrial algae in the study areas.

Microscopic observations

The samples were examined immediately after collection. However, if issues arose and preservation was required, the samples were chilled at approximately 1-4°C to prevent post-sampling growth. A light microscope at 400x magnification was used to facilitate identification and algal cell counting. Images of algae were captured using the built-in camera of the Dino-Eye connected to the light microscope. Micromorphological features, including thallus structure, overall shape, gametangial shape, presence of sporangia, and reproductive cells, were examined and documented. Specimens were identified based on microalgal morphology, following Millow and Salleh (2006) and the World Algal Database (Guiry & Guiry, 2023).

Statistical analysis

The richness and evenness of terrestrial algae species were determined through the Shannon-Wiener Index and Simpson's Index by using PAST software.

Results and Discussion

Total collection of terrestrial algae

All samples in the study areas were classified within the Phylum Chlorophyta, as shown in Table 1 below. Nine species were recorded across both sites, with Jengka Campus exhibiting higher species diversity (six species) than Sri Gading Educational Forest (four species). *Trentepohlia arborum* was the most abundant species and the only taxon present at both locations (N=4). Additional species included *T. aurea* (N=3), *T. abietina* (N=3), *Rosenvingiella radicans* (N=3), *T. prolifera* (N=2), *T. umbrina* (N=2), and *T. diffracta* (N=2). By contrast, the least common species were *Printzina lagenifera* and *T. rigidula*, each represented by a single individual. Images of all nine species under 400x magnifications are shown in Figure 2.

Table 1 List of algae species collected from UiTM Jengka and Sri Gading Educational Forest. Note: SGEF = Sri Gading Educational Forest; UPJC = UiTM Pahang Jengka Campus; presence of species is denoted with '+' and absence of species as '-'

Family	Species	Site		Count
		UPJC	SGEF	
Prasiolaceae	<i>Rosenvingiella radicans</i>	-	+	3 (15.8%)
Trentepohliaceae	<i>Printzina lagenifera</i>	+	-	1 (5.3%)
	<i>Trentepohlia abietina</i>	-	+	3 (15.8%)
	<i>Trentepohlia arborum</i>	+	+	4 (21.1%)
	<i>Trentepohlia aurea</i>	+	-	3 (15.8%)
	<i>Trentepohlia diffracta</i>	-	+	2 (10.5%)
	<i>Trentepohlia prolifera</i>	+	-	2 (10.5%)
	<i>Trentepohlia rigidula</i>	+	-	1 (5.3%)
	<i>Trentepohlia umbrina</i>	+	-	2 (10.5%)

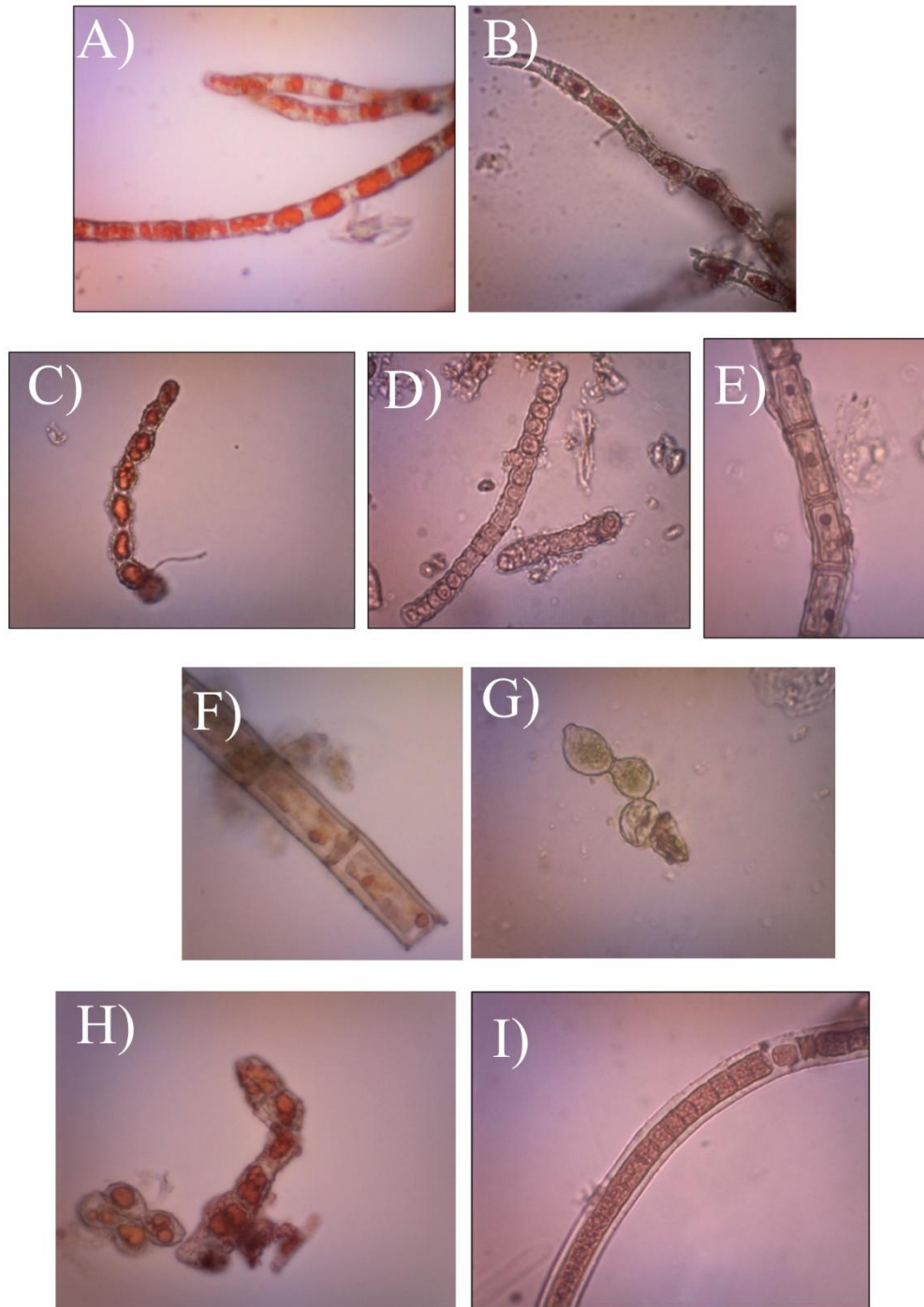


Figure 2 Images of species collected (400x magnifications): A) *Trentepohlia aurea*, B) *Trentepohlia prolifera*, C) *Trentepohlia umbrina*, D) *Trentepohlia diffracta*, E) *Trentepohlia arborum*, F) *Trentepohlia abietina*, G) *Trentepohlia rigidula*, H) *Printzina lagenifera*, and I) *Rosenvingiella radicans*.

Species diversity

Trentepohliales (Phylum Chlorophyta) were the dominant and most abundant algae on tree bark, consistent with the results of Neustupa and Skaloud (2008). Rindi *et al.* (2010) reported

that Trentepohliales are widely recorded as the most diverse and predominant group in humid tropical climates, and are therefore among the most common green algae in terrestrial environments.

The Shannon-Weiner Diversity Index indicates that the richness of algal species in UiTM Jengka exceeds that of the Sri Gading Educational Forest, a finding that is consistent with the results derived from Simpson's Diversity Index (Table 2). Although both values are very high, this result should not be interpreted solely as evidence of high diversity among terrestrial algae, given the low sampling intensity.

Table 2 Diversity values for each location

Location	UiTM Jengka	Sri Gading Educational Forest
Shannon-Weiner Diversity Index	1.80	0.99
Simpson's Diversity Index	0.89	0.73

The number of algal species is related to bark roughness, pH, and light intensity (Ismail *et al.*, 2016). Neustupa and Škaloud (2008) reported a significant positive association between algal abundance and bark roughness. Consequently, the diversity and composition of Trentepohliales are expanding due to the availability of open, unshaded microhabitats. Maltsev *et al.* (2020) confirmed that low crown density in trees promoted the development of light-dependent and often drought-resistant cyanobacterial species, which is relevant to the geographical context of Sri Gading Educational Forest. As crown density and shading increase, the abundance of cyanobacteria within algal communities decreases. Furthermore, bark pH significantly influences algal density. Research indicates that elevated bark pH may promote epiphytic communities, whereas decreased bark pH can facilitate their dispersal (Alwi *et al.*, 2015).

Razli *et al.* (2020) suggested that the distribution of terrestrial algae is influenced by variation in their tolerance to environmental pollutants. The growth of microalgae may be constrained in highly polluted environments. Ismail *et al.* (2019) reported that *Trentepohlia* sp. can only thrive in environments with minimal pollution, as this species exhibits increased vulnerability to contaminants. Compared to the species located at UiTM Jengka, most samples were collected in proximity to the campus main road, where pollution levels were elevated due to automotive fuel combustion and human activities. According to Ng *et al.* (2011), human movement significantly affected algal abundance.

Terrestrial algae exhibit a complex relationship with air quality, often showing increased abundance in response to certain pollutants that act as fertilizers. Research indicates that elevated levels of carbon dioxide (CO₂) and nitrogenous gases (such as NO_x and NH₃) significantly stimulate algal growth; for example, algae in polluted urban environments can reach densities more than three times higher than those in unpolluted areas due to their high absorption capacity and ability to fix CO₂ efficiently (Meyer *et al.*, 2010). Furthermore, atmospheric pollutants can alter bark pH, often increasing alkalinity or neutralizing natural acidity, which favours the proliferation of dominant green algal species such as *Apatococcus* and *Desmococcus* (Štifterová & Neustupa, 2015).

According to Ismail *et al.* (2015), who conducted a study comparing less polluted and contaminated environments, the polluted environment exhibited a significantly higher algal density. Carbon limitation has been recognized as a constraint on algal production; therefore, carbon scarcity may lead to reduced growth under severe conditions (Brown, 1996). In addition to carbon, algae require a nitrogen supply (Ismail *et al.*, 2015), as nitrogen supports algal

metabolic processes. Similar to carbon, insufficient nitrogen levels may also inhibit algal cell growth. In contaminated areas, carbon and nitrogen concentrations exceed those in non-polluted environments, thereby influencing the development of epiphytic terrestrial algae (Aresta, 2003; Cardon et al., 2008; Ismail et al., 2015). Jengka Campus is exposed to vehicular emissions, including motorbikes, vehicles, and buses that emit carbon monoxide, whereas Sri Gading Educational Forest is less affected.

The prominent presence of *Trentepohlia* sp. on campus may be attributed to its requirement for minimal pollutant inputs, as this species exhibits heightened sensitivity to pollution (Ismail et al., 2019; Razli et al., 2020). Ismail et al. (2019) found that the growth of *Trentepohlia* sp. occurred only in areas with comparatively low pollution levels. The high frequency of *Trentepohlia* sp. recorded in this study suggests that the research locations experience lower levels of air pollution. Nevertheless, further research on the effects of air pollution on terrestrial algal diversity in Jengka is necessary to confirm this inference. Meanwhile, *R. radicans* is an algal species that favours high humidity, as well as protection from extreme temperature and light exposure (Menéndez et al., 2006). Consequently, the species was particularly abundant and readily observed at the entrance of the Sri Gading Educational Forest.

Given their high sensitivity to atmospheric composition and rapid reproductive cycles, epiphytic terrestrial algae can serve as effective, low-cost bioindicators for monitoring local changes in air quality (Štifterová & Neustupa, 2015; Freudenthal et al., 2024). Because these non-vascular organisms lack a protective cuticle and rely directly on the atmosphere for nutrients and moisture, they exhibit measurable responses to fluctuations in carbon dioxide and nitrogenous pollutants, including visible shifts in cell density, chlorophyll production, and colour changes (often transitioning from vibrant green to yellowish tints) (Singh & Singh, 2014). The increased abundance and colonization of epiphytic terrestrial algae on tree bark can be readily observed and quantified as a proxy for increasing urban pollution levels.

Nevertheless, the findings from this study constitute a benchmark record of the diversity of terrestrial epiphytic algae in Jengka, Pahang, and this information will be essential for future research to determine whether these organisms can function as bioindicators of air pollution.

Conclusion

In conclusion, nine species from two families and three genera were identified at both locations, including four species from Sri Gading Educational Forest and six species from Jengka Campus. *Trentepohlia arborum* exhibited the highest diversity and was the most abundant species at both locations. Many areas of Sri Gading Educational Forest remain unexplored, and it is anticipated that additional species may be identified in the future. Consequently, further research on terrestrial algae should be conducted more intensively to document a wider range of terrestrial algal species. Moreover, algal identification should be supplemented with molecular analyses, since molecular taxonomy could strengthen morphological identification procedures. Further research is recommended to identify the parameters influencing algal cell populations, including bark pH, atmospheric moisture content, and relative humidity.

Ethics Statement

The research does not require research ethics approval.

Authors Contribution

Original draft preparation: Saffiee, N.S., Abdul Rahman, N.A.S.; Editing: Roslan, S.N.L.; Analysis: Ismail, N. A., Mohd Izam, N. A., Razali, N. B.; Analysis, review, editing: Farinordin, F.A.

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Conflict of interest

The author(s) confirm that the article content has no conflicts of interest.

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