Cyathea tenggerensis (Rosenst.) Domin from Ijen Geopark, Bondowoso and Banyuwangi, East Java

Fuad Bahrul Ulum*, *Mukhamad* Su'udi, *Edia Fitri* Dwinanti, *Rachel Oktavian* Fernanda and *Dwi* Setyati

Biology Department, Faculty of Mathematics and Science, Jember University, Indonesia

Abstract. *Cyathea contaminans* (Hook.) Copel. and *Cyathea orientalis* (Kunze) T. Moore, which flourish abundantly in the Erek-erek Geoforest ecotourism zone within Ijen Geopark, have long been regarded as ancient plant species. However, during a recent expedition to higher elevations, a tree fern with distinct morphological features, previously unreported, was discovered. The study, conducted in June 2024 within Ijen Geopark, encompassing the Bondowoso and Banyuwangi Regencies of East Java, involved the documentation and morphological observation of tree ferns at the site. The specimen identified was *Cyathea tenggerensis* (Rosenst.) Domin, a species distinguished by its unique characteristics, including dense golden-brown hairs enveloping throughout the stipe and costae, a height of up to 10 metres, and a trunk diameter significantly greater than that of *C. contaminans* and *C. orientalis*. As no prior records of this species exist within the conservation area, this study provides the first insight into its distribution. Furthermore, the research presents a detailed description of *C. tenggerensis* and identifies key morphological traits critical for accurate field identification. In light of these findings, we advocate for enhanced conservation measures to safeguard the long-term survival of tree ferns within their native habitat.

1 Introduction

Ijen Geopark, located in Bondowoso and Banyuwangi, Indonesia, is recognized for its geological, biological, and cultural diversity, with Ijen Crater as its prominent feature. Designated as a national geopark in 2018 and achieving UNESCO Global Geopark status in 2023, Ijen Geopark is home to the world's most acidic volcanic lake and a unique nighttime display of glowing blue sulfur flames, attracting substantial ecotourism interest. Encompassing 21 geosites, 6 biosites, and 9 cultural sites, the geopark aims to boost sustainable geotourism, particularly within Banyuwangi Regency [1, 2]. Research on Ijen's biodiversity has documented various aspects of its flora, fauna, and microbial diversity, highlighting the Erek-Erek Geoforest, a highland rainforest (1300-1400 meters above sea level) as a habitat for endemic species like *Arborophila orientalis* (gonggong partridge) [3,

* Corresponding author: fuad.fmipa@uenj.ac.id

4]. This highland forest also harbors a diverse assemblage of mosses, ferns, and flowering plants, essential for both ecological balance and educational tourism [1, 5]. Among its distinctive flora, the tree ferns of the genus *Cyathea* stand out, often reaching up to 10 meters in height and adding a prehistoric aesthetic to the landscape. Previous studies identified two prominent tree fern species here: *Cyathea contaminans*, the taller canopy species, and *C. orientalis*, which thrives in the understory [5, 6].

Tree ferns, as ancient members of the Cyatheaceae family, are iconic for their contribution to ancient forest landscapes. The Cyatheaceae family comprises around 600 species across tropical, subtropical, and temperate zones of the southern hemisphere, with Indonesia and the Malesian Archipelago as biodiversity hotspots, containing approximately 250 species endemic to the region [7, 8]. Historical accounts, such as Holttum's 1965 work, report about 15 species of tree ferns on Java [9], suggesting potential for a wider diversity of *Cyathea* species across the Ijen Geopark. Exploratory observations conducted in higher elevations of Ijen Geopark in June 2024 revealed a distinct morphological variation among tree ferns not previously reported in lower elevation zones like Erek-Erek Forest [6]. Notably, a characteristic feature was the dense, bright brown to golden scales covering the upper trunk, a trait that visually distinguishes these specimens. However, a number of tree ferns in this area were incorrectly labeled as *Cycas rumphii*, a gymnosperm with a palm-like appearance, reflecting common misidentifications due to limited local knowledge and similarities in arborescent growth.

The expansion of ecotourism infrastructure, including new electrical installations around the Ijen Crater, raises additional concerns about potential land-use conversion, posing a direct threat to indigenous flora by altering native vegetation. Given the ecological significance and tourism value of unique plant species, particularly tree ferns, this study aims to document and describe the tree ferns *Cyathea tenggerensis* (Rosenst.) Domin From Ijen Geopark. Additionally, a literature review was conducted to identify and assess conservation strategies to preserve these essential plant species within their natural habitats, safeguarding biodiversity amid growing ecotourism development.

2 Material and Methods

2.1 Fiel observation and collection

Specimens of *Cyathea tenggerensis* were observed by vegetation survey conducted in June 2024 in the Paltuding area, extending from the Kalipait waterfall to the ticketing area of Ijen Crater (located within Banyuwangi and Bondowoso Regencies). Observations and initial identifications were conducted through all tree fern species present on-site. A specimens displaying complete vegetative structures and mature, dark-colored sori were selected for collection. Collected vegetative structures included mature leaves with sori, and petioles. These samples were then analyzed in detail for species identification in the Botany Laboratory, Department of Biology, University of Jember [6].

2.2 Description and Identification

The identification process for *Cyathea* species was guided by established references, including Flora Malesiana, Series II: Pteridophyta [10] and Tree-Ferns of The Genus *Cyathea* in Java [9]. Morphological descriptions were made through direct field observations of live specimens, focusing on traits such as trunk height, trunk surface characteristics, leaf structure, crozier, scales, and spores. Additional features requiring magnification were examined in the laboratory using an Olympus SZ251 stereo microscope and a Nikon Eclipse L100LED MVR

binocular microscope. All images captured were processed with Inkscape 1.2 software. Spore characterization was performed in reference to several scientific sources to ensure accurate species identification [6].

2.3 Conservation review

The literature review draws upon prior assessments of progress and challenges in implementing the Global Strategy for Plant Conservation (GSPC). Relevant published articles on plant conservation and documented achievements in GSPC targets were compiled to illustrate national implementation efforts. These examples provide a basis for evaluating the strategies and outcomes across different regions, highlighting both advancements and areas for improvement in global plant conservation practices [11].

3 Results and Discussion

Cyathea tenggerensis (Rosenst.) Domin were observed in the Paltuding area of Ijen Geopark, at elevations between 1800–1900 m asl. Several stands near the ticketing area of Ijen Crater were miss labeled as *Cycas rumphii*, likely due to a misconception stemming from the arborescent growth form, which superficially resembles that of *Cycas* species. Conversely, previous plant inventories along the Ijen Crater hiking trail documented *Cyathea contaminans* (Hook.) Copel. [12], which may have been another case of misidentification due to shared morphological traits within the Cyatheaceae family. Further speciement identification with digital herbarium in GBIF with speciment identified as *C. tenggerensis* Herbarium ID L.1280243 (sample location Ijen 1650 asl) and L.1280234 indicated distict featured of sclae cover compared to our sample. We suggested that both herbarium were close related to *C. contaminans*. Our study provides a comprehensive specimen documentation and detailed description of *C. tenggerensis* within Ijen Geopark (Figure 1), clarifying its distinguishing characteristics. The diagnostic character of *C. tenggerensis* in [9] was scales on the lower surface of the costae are uniformly bullate and lack setae; long hairs are present on the lower surface of both costae and costules but are restricted to the apices of the pinnules might related to the *C. contamians*. Based on the scale feature, the sample of *C. tenggerensis* from Ijen Geoprak was displayed scales with marginal hairs and bear shorter scales at the base, and this caharacter related to the key feature of genus Alsophila [13].
Cyathea tenggerensis (Rosenst.) Domin, Accepted name (POWO): *Sphaeropteris tenggerensis* (Rosenst.) R.M.Tryon, Synonim: *Alsophila tenggerensis* Rosenst.

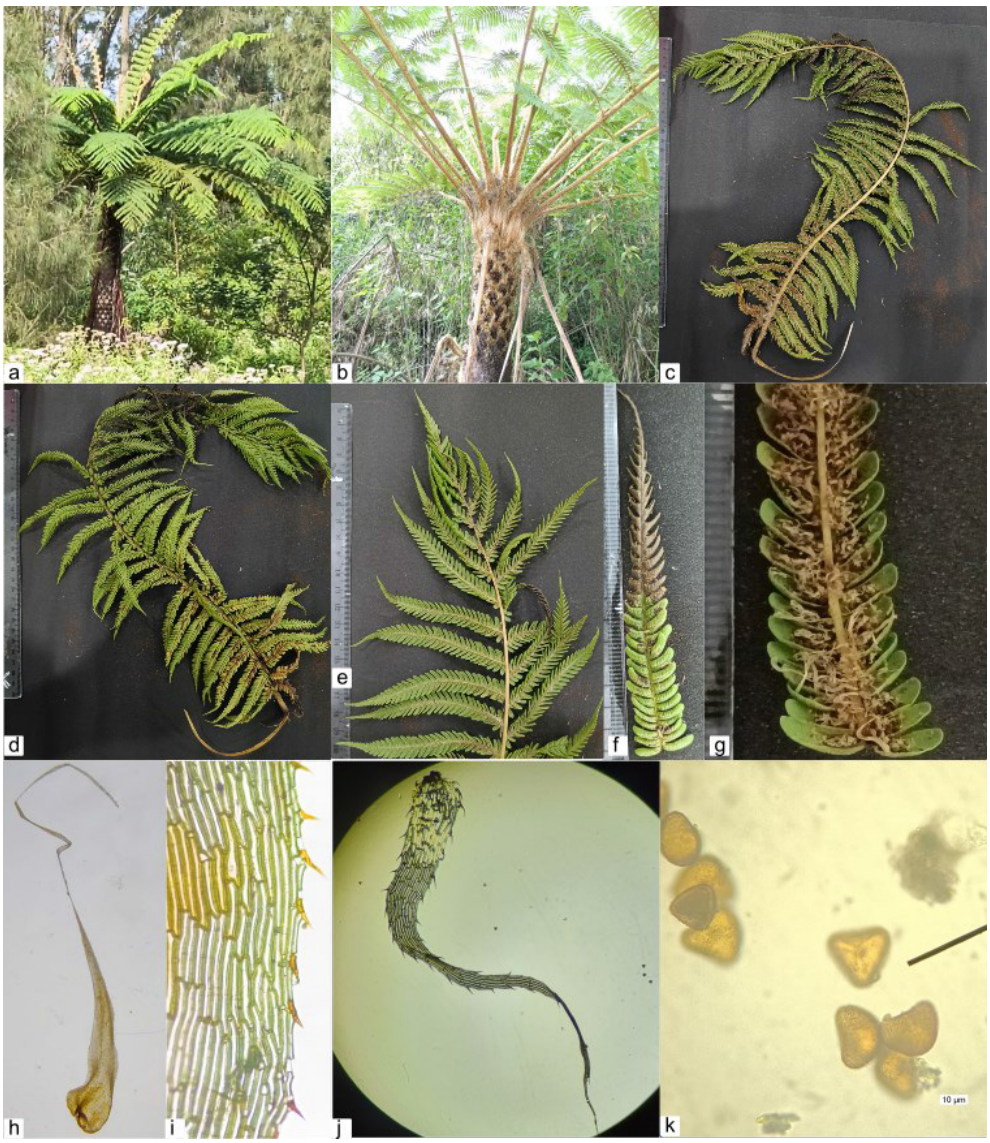

Fig. 1. *Cyathea tenggerensis* (Rosenst.) Domin: a) Aroborescent growth; b) Tunk and stipe coveren by dense bright scales; c) Fertil Pinna (abaixal); d) Pinna (adaxial); e) Terminal pinna (abaxial); f) Pinnule (adaxial); Fertil pinnule with sory and dense scale (abaxial); h) Stipe scale; i) Scale cell shape and margin with setae; j) Pinnule scale with setae at the margin; k) Trillete spores.

3.1 Decription

The trunk tall reach 10 m and thickened at the base by a dense network of adventitious roots, revealing leaf scars in upper part. Stipe over 60 cm long, warty with persistent basal scales. The scales, up to 45 × 2.5–3.5 mm, are a shiny, firm golden brown and bear setae. The pinnae reach 50 cm long, pinnules size approximately 110 × 16 mm. Pinnules sessile and nearly lobed to the costa, with 1–2 basal segments mostly free and costules spaced 2.5–3 mm apart. The lamina segments firm, with reflexed edges when dry and a likely glaucous underside, with 10–12 pairs of veins. Sori exindusiate, situated closer to the costule than the lamina

edge, and possess pale paraphyses. The pinna rachis densely warty on its underside, carrying residual pale scales up to 7 mm with setae. The costae adorned with bullate pale brown scales with marginal hairs and bear shorter scales at the base, while the costules exhibit similar scales with occasional short hairs.

3.2 Field identification

The tree ferns *C. tenggerensis*, *C. contaminans*, and *C. orientalis* observed in Ijen Geopark displayed unique morphological characteristics that aid in their identification. *C. tenggerensis* reaches heights of up to 10 meters and has a larger trunk diameter than *C. contaminans*, with a dense covering of scales on the upper trunk and visible leaf scars, while the lower trunk is covered with adventitious roots. *C. contaminans* can grow over 10 meters tall, with a medium-sized trunk that has dense scales primarily at the stipe base and persistent adventitious roots. In contrast, *C. orientalis* has a smaller trunk diameter, lacks dense scaling, and shows no leaf scars; instead, withered petioles hang and remain attached to the hollow trunk surface. In terms of stipe characteristics, *C. tenggerensis* features a yellow stipe with dense scales and non-rigid spines, distinguishing it from *C. contaminans*, which has a green stipe that turns violet with age and bears sharp, rigid spines with white scales limited to the base. The stipe of *C. orientalis* lacks rigid spines. Reproductive structures further differentiate these species: both *C. tenggerensis* and *C. contaminans* lack an indusium, while *C. orientalis* has a cup-shaped indusium covering two-thirds of the sori. All three species share trilete spores with a central depression. Ecologically, *C. tenggerensis* is found in open and understory areas above 1800 meters asl, whereas *C. contaminans* prefers similar habitats below 1700 meters asl. *C. orientalis* primarily occupies understory regions and is often intermixed with the other two species. This combination of morphological and ecological distinctions highlights the diversity within the *Cyathea* genus in high-elevation forest ecosystems. Morphological features between three *Cyathea* species of Ijen Geopark is displayed in Table 1.

Table 1. Diagnostic comparison character of *C. tenggerensis, C. Contaminans,* and *C. orientalis*.

Character	*C. tenggerensis*	*C. contaminans*	*C. orientalis*
Tree heigh	Reach 10 meter	> 10 meter	< 10 meter
Trunk	Bigger diameter than C. contaminans, high dense of scale cover the upper part and leaf scar at upper part of the trunk, lower trunk covered by adventitious root	Medium size in diameter, lower dense scale cover the basal of stipe, leaf scar at upper part of the trunk, lower trunk covered by adventitious root and persistent	Smller diameter size, not covered by dense scale, no leaf scar, the with withered petioles hanging and attached to the stem surface, hollow surface
Stipe	Yellow, coverted with dense scale, spine not rigid and not sharp	Green when young but violet when old, many Sharp and rigid spines, covered with white scale only at the base	spines are non-rigid
Sorus	No indusium	No indusium	Indusium in cup shape covered 2/3 area
Spore	Trilete spores with a central depression	Trilete spores with a central depression	Trilete spores with a central depression

Habitat Location	Apen area and understory at area Above 1800 asl	Apen area and understory Below 1700 asl	Understory, mix with *C. contaminans* and *C. tenggeriensis*

3.3 Conservation Importance and Vulnerability

The significant presence of *C. tenggerensis* in Paltuding underscores its ecological value as a vital species within its habitat; however, its restricted distribution and habitat specificity make it susceptible to threats from human activities. Misidentification, such as labeling *C. tenggerensis* as *Cycas rumphii*, points to a need for enhanced taxonomic knowledge and ongoing monitoring to prevent exploitation and habitat degradation. The tree ferns' role in supporting forest structure and biodiversity highlights the importance of safeguarding *Cyathea* species as a means of maintaining ecosystem stability [7, 8].

Environmental protection is crucial to sustaining Indonesia's geoparks, which face significant risks from over-tourism, including environmental degradation, littering, and erosion that detract from their natural and visual appeal. While tourism offers economic benefits, increased visitor numbers—particularly in areas close to urban centers—have introduced challenges such as traffic congestion, diminished air quality, and ecosystem disruption [14]. The establishment of local communities within these tourist areas further heightens the risk of biodiversity loss, as human activities intensify pressure on native habitats. However, local community involvement in tourism remains limited due to operational (e.g., information gaps and lack of accountability), structural (e.g., funding and policy restrictions), and cultural barriers (e.g., mistrust and power imbalances), all of which hinder meaningful engagement in sustainable practices. Addressing these challenges through transparent governance and inclusive planning could foster enhanced community involvement in ecotourism, promoting sustainable tourism development [15, 16].

While ecotourism brings economic benefits, it can lead to direct disturbances such as trampling, erosion, and habitat loss which disrupt the regeneration cycles of *Cyathea* species [7, 16, 17]. Annual destruction of young ferns in high-traffic areas impacts population recovery and threatens the long-term survival of these species. Addressing this requires community engagement and tourist education on the ecological roles and conservation needs of tree ferns [16, 17, 18]. Awareness programs that communicate the risks of overharvesting and educate on sustainable interactions can help mitigate these impacts.

To address these challenges, a multi-faceted approach is suggested. Conservation actions should include habitat protection measures, such as limiting access to sensitive areas and promoting alternative ecotourism routes. Ex-situ conservation efforts, including spore propagation and nursery cultivation, could bolster populations under pressure. Additionally, community involvement in sustainable harvesting practices and conservation programs could foster local stewardship, reducing illegal collection. Controlled ecotourism that minimizes direct interference and manages visitor impact zones is recommended to support population stability and recovery [16].

The adaptability of *Cyathea* species to varied forest environments highlights their potential role in forest restoration. Fast-growing and tolerant of open habitats, many tree ferns can aid in stabilizing soil, creating microclimates, and restoring degraded landscapes [7, 8]. Given that tree ferns often take 5–20 years to reach reproductive maturity, efforts to combat unsustainable harvesting are crucial, particularly in economically pressured regions where tree ferns are exploited for food, construction, and ornamental uses [8]. In summary, conservation strategies for *Cyathea* should encompass habitat protection, community education, and sustainable management within ecotourism areas. Through such measures, the ecological and cultural value of *Cyathea* can be preserved, contributing to ecosystem resilience and biodiversity conservation in tropical forest environments.

5 Conclusion

The identification of *Cyathea tenggerensis* in Ijen Geopark contributes to the botanical knowledge of East Java, adding a previously undocumented species to the region's flora. This discovery underscores the need for ongoing botanical surveys, particularly in ecotourism areas where species may be overlooked or misidentified. Conservation efforts for *C. tenggerensis* are critical to ensure its survival, given its ecological role and vulnerability to environmental and anthropogenic pressures. Enhanced monitoring and public awareness can help protect this species and the broader biodiversity within the Geopark.

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