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## A new species of grass fern, *Schizaea erecta* (Schizaeaceae), from Dinagat Island, Mindanao, Philippines

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### Abstract

*Schizaea erecta* Amoroso & Coritico (Schizaeaceae) from Dinagat Island, Mindanao, Philippines, is here described. This species is distinguished from other species of *Schizaea* by its consistently erect sterile and fertile fronds, narrow laminae, opposite sorophore lobes, rhizomes covered with short appressed brown scales, and oblong sporangia with apical annulus and conspicuous long, white hairs. A taxonomic key to the species of Philippine Schizaeaceae is provided.

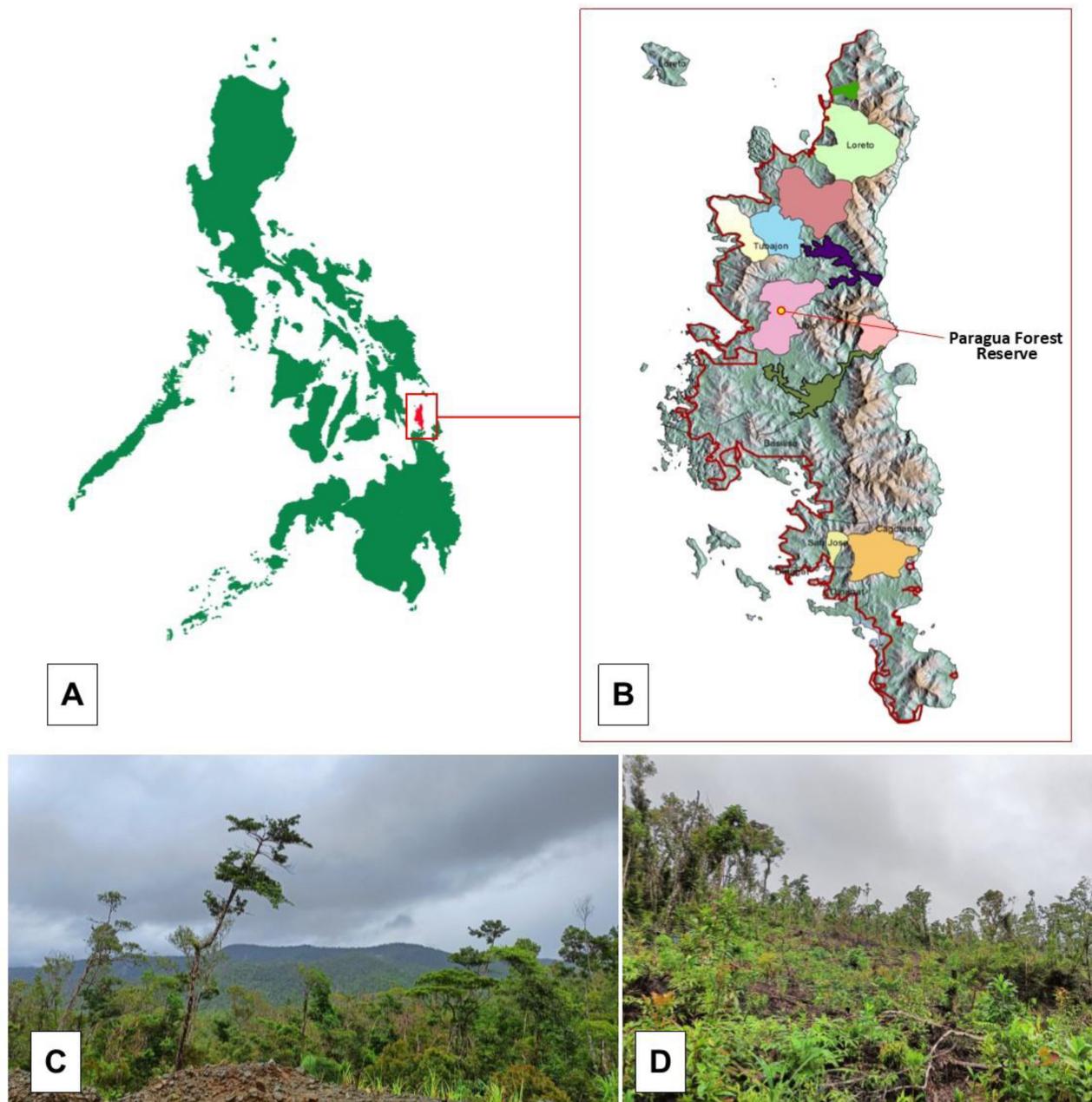
**Key words:** forest, morphology, pteridophytes, ultramafic soil

### Introduction

The family Schizaeaceae (Schizaeales) represents about 0.4% of extant fern species diversity worldwide (PPG1, 2016). Its species differ from other ferns greatly in gross morphology, niche preferences, and life history (Ke *et al.*, 2022). They can be distinguished by their simplified shape, and unique annulus among ferns. Foliar characters are used to classify them into various groupings or genera (Reed, 1947), *viz.* *Actinostachys* Wallich (1828: 1), *Microschizaea* Reed (1947: 133), and *Schizaea* Smith (1793: 419); Hassler (2004–2023). There are about 35–40 species in the family, which are found throughout the tropical and south temperate regions of the world (PPG I, 2016; Smith *et al.*, 2006). Schizaeaceae has been found to comprise four major clades—*Microschizaea*, *Actinostachys*, *Schizaea pusilla* Pursh (1814: 657), and the remaining members of *Schizaea* (Ke *et al.*, 2022).

The Philippines is home to six species of grass ferns (Schizaeaceae) with four species of *Actinostachys* and two species of *Schizaea* (Barcelona *et al.*, 1996; Pelsner *et al.*, 2011; Amoroso *et al.*, 2021). Of these, two are endemic to the Philippines, specifically to Mt. Hamiguitan, Davao Oriental, namely, *A. minuta* Amoroso & Coritico (2020: 60) and *A. simplex* Amoroso & Coritico in Amoroso *et al.* (2021: 102). *Schizaea dichotoma* Linnaeus (1753: 1068) Smith (1793: 422) and *S. malaccana* Baker in Hooker & Baker (1868: 428) are distinguished within the family Schizaeaceae by having the sorophores attached pinnately to an elongate axis. *Schizaea dichotoma* is easily recognized by the dichotomously branching sterile portions of the frond, whereas *S. malaccana* has an unbranched sterile portion (Amoroso *et al.*, 2020). *Schizaea dichotoma* varies widely in morphology and cytology (Brownsey & Perrie, 2014), with various species sometimes segregated from it. Most segregates of this complex species are poorly characterized, and although collectively lumped into “*S. dichotoma*”, have been found to resolve as polyphyletic in the DNA sequence-based phylogeny of Ke *et al.* (2022).

During fieldwork in Paragua Forest, Dinagat Island, we collected an unusual individual of *Schizaea* growing in open areas near agricultural lands. After carefully examining these plants and comparing them to available type images, we conclude that they represent a species new to science. Here, we describe it with accompanying photographs, and present a key to the seven Philippine species of Schizaeaceae.



**FIGURE 1.** Study Site. **A.** Map of the Philippines. **B.** Map of Dinagat Island showing Paragua Forest Reserve (Source: DENR PENRO Dinagat Islands). **C, D.** Panoramic views of Paragua Forest Reserve.

## Materials and methods

Botanical exploration was conducted in Dinagat Island between 27 January and 3 February, 2023. During one of the surveys in Paragua Forest Reserve, Brgy. Mabini, Tubajon, a population of an undescribed species of *Schizaea* was observed. The type locality is situated at 10.29355°N, 125.58594°E, at 65 m elevation. It is 100 m from the national road and 200 m from Nadapa Watershed Area.

Fresh material was collected for morpho-anatomical comparison with *Schizaea dichotoma* and *ex-situ* propagation in the CMU Fernery. Initial taxonomic descriptions and photo-documentation of key plant structures were done *in situ*

at the type locality. For identification we used herbarium specimens from JSTOR (plants.jstor.org), Co's Digital Flora of the Philippines (www.philippineplants.org) and relevant literature (Holtum, 1959; Barcelona *et al.*, 1996; Sofiyante *et al.*, 2019).

Morphological characters of fresh specimens were carefully examined with a stereomicroscope. For anatomical study, the free-hand technique was employed. Cross sections of the rhizome, stipe and lamina were examined to evaluate anatomical characteristics for taxonomic use, and clearing technique was done to determine the stomatal type and distribution of stomata. The sections were examined under the microscope and photographed for morpho-anatomical documentation.

## Taxonomy

### *Schizaea erecta* Amoroso & Coritico, *sp. nov.* (Figs. 2–4)

Type:—PHILIPPINES. Dinagat Island: Municipality of Tubajon, Paragua Forest, 10.29355°N, 125.58594°E, 65 m, 30 January 2023, *V.B. Amoroso with F.P. Coritico & M.M. Guiang. 3003* (holotype PNH!, isotypes CMUH!, BRIT!).

**Diagnosis:**—*Schizaea erecta* resembles *S. dichotoma* in having hairy rhizomes, dimorphic fronds, stipes with a t-shaped xylem strand, laminae fan-shaped and branching dichotomously, stomata hypocytic, sorophores pinnately arranged in 2 rows, and sporangia with long non-glandular hairs, but differs by having a rhizome with short-appressed brown hairs (vs. long, coarse brown hairs), the stipe longer and up to 26.6 cm long with a narrow groove (vs. up to 20 cm long and deeply grooved), fronds 3–5 times branching dichotomously (vs. 6–8 times branching), narrower (8–14 cm long by 2.0–4.5 cm wide), and consistently erect fronds (vs. 15 cm long by 17 cm wide, not erect), sorophores up to 39 per stipe with 12–16 lobes alternately arranged (vs. up to 34 with 5–10 lobes oppositely arranged), and sporangia oblong with long white hairs (vs. reniform with brown hairs).

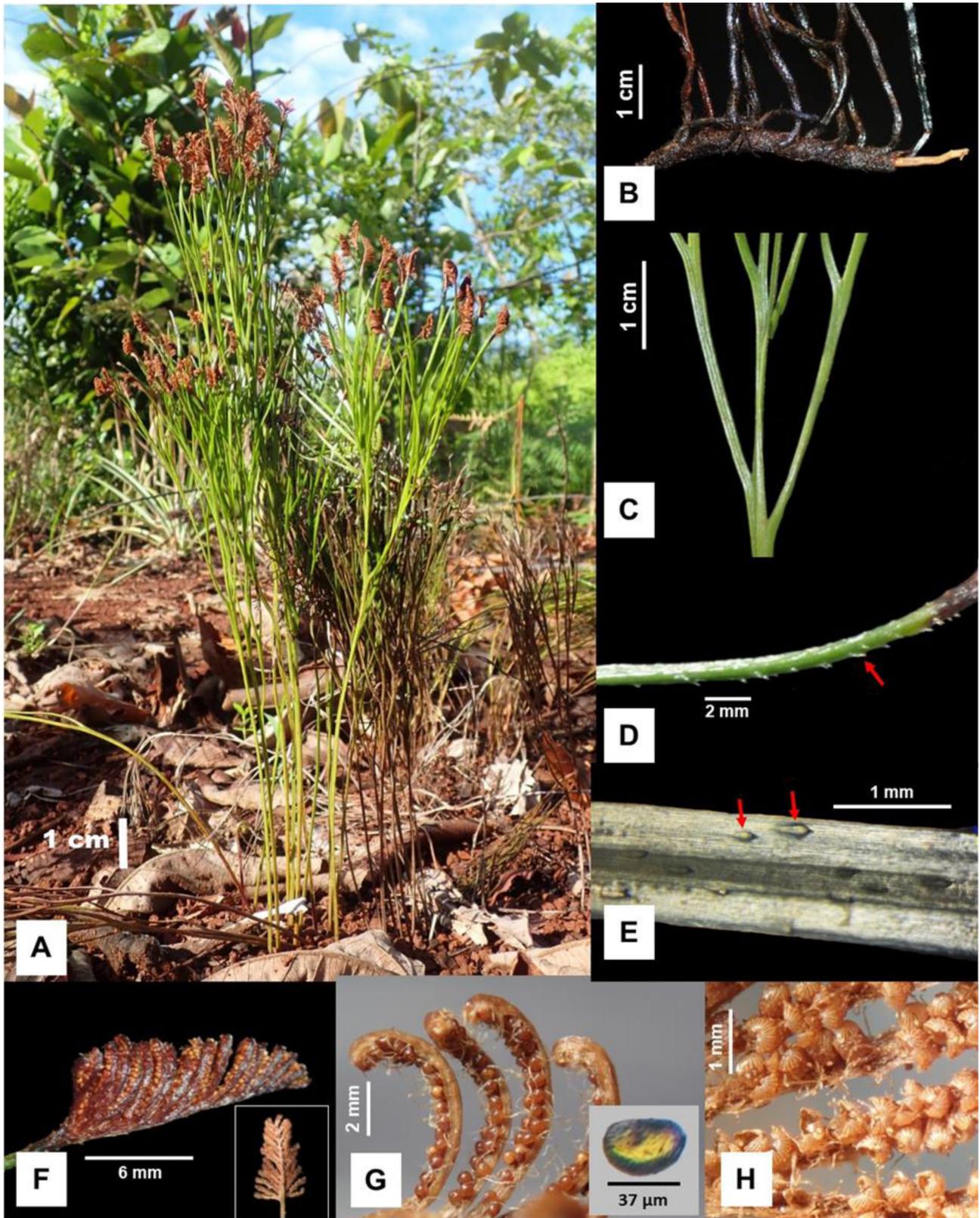
**Description:**—Terrestrial, 30–50 cm long. *Rhizomes* short creeping, 1.5–5.0 cm below ground, 0.3 mm thick, covered with persistent shiny brown appressed hairs 1–2 mm long. *Fronds* dimorphic, crowded, irregularly branched; *sterile fronds*: erect, stipes distinct, 18.5–26.6 cm long, base partly buried in ground, blackish and becoming light green in upper portion, slightly winged at middle to distinctly winged at apex, with shallow groove and scattered short hairs; laminae fan-shaped, 9–15 cm long and each axis 1 mm wide, whole laminae 2–4 cm wide, costae distinct, branching dichotomously 3–5 times; *fertile fronds* erect, stipes 11–27 cm long, tetragonal in transection and distinctly winged in upper portion; lamina fan-shaped, 8–14 × 2.0–4.5 cm, branching dichotomously 3–5 times, basal branch slightly flattened, 1–2 mm wide, distal branch up to 0.5 mm wide with scattered small projections (bases of glandular hairs). *Sorophores* born distally of each branch of frond, 5–12 mm long, 24–39 per stipe, bearing 12–16 pairs of lobes, pinnately arranged in 2 rows and opposite in arrangement. *Sporangia* in two rows associated with long white non-glandular hairs, with opposite to alternate arrangement, loosely arranged at base and tightly packed in upper part, oblong with short stout stalk, brown, annulus apical, opening by a vertical slit. *Spores* monolete and reniform, 37 µm in diameter.

**Etymology:**—The specific epithet refers to the erect fronds of the species.

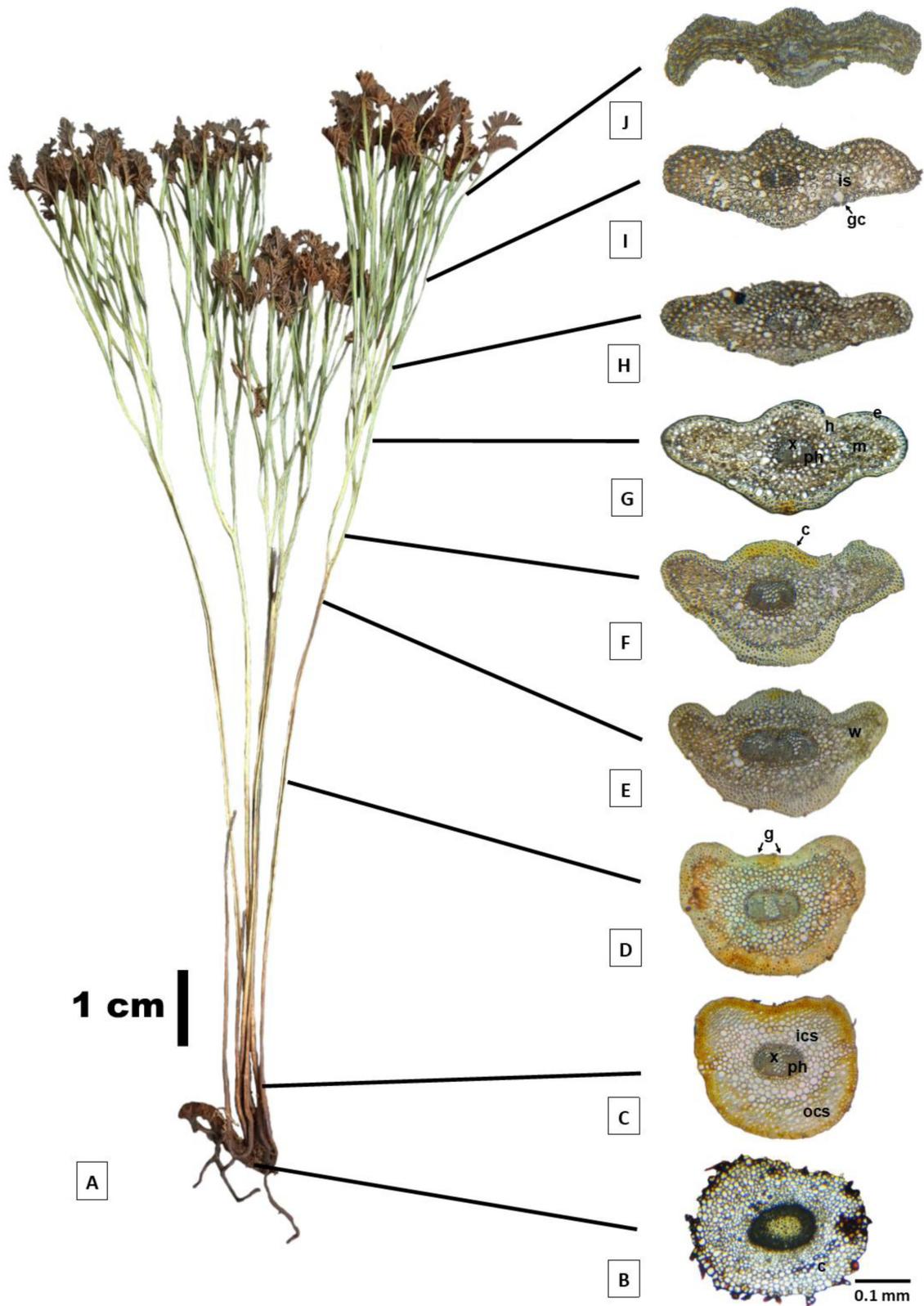
**Suggested common name:**—Dinagat grass fern.

**Distribution and habitat:**—*Schizaea erecta* is known only from open habitat at 65 m elevation. It grows as a terrestrial plant in colonies with rhizomes growing below the ground in ultramafic soil associated with plants such as *Dicranopteris linearis* (Burman 1768: 235) Underwood (1907: 250), *Imperata cylindrica* (Linnaeus 1759: 878) Palisot de Beauvois (1812: 165), *Piper* sp., *Pteridium aquilinum* (Linnaeus 1753: 1075) Kuhn in Decken (1879: 11), *Pteris cretica* Linnaeus (1767: 130), and *Smilax* sp. (Figure 5).

**Conservation Status:**—Dinagat Island was identified as a critical terrestrial conservation priority in the Philippines (Ong *et al.*, 2002). Logging, mining, and land conversion threaten the entire island (Haribon, 2004). *Schizaea erecta* is known only within the Paragua forest, Municipality of Tubajon, with an estimated number of 30 individuals growing in just one open area near agricultural land. The habitat is prone to land conversion because of nearby residential areas. Thus, we recommend listing the species as critically endangered based on its restricted population with ≤ 50 mature individuals and the extent of occurrence estimated to be ≤ 10 km<sup>2</sup> (IUCN Standards and Petition Committee 2019).



**FIGURE 2.** *Schizaea erecta*. **A.** Habit showing erect axis. **B.** Short-creeping rhizome. **C.** Dichotomous branching of lamina. **D.** Distal branch showing scattered projections of glandular hairs. **E.** Bases of glandular hairs. **F.** Sorophore. **G.** Lobes of sorophore showing the 2 rows of oblong sporangia with long white non-glandular hairs, and spore (inset). **H.** Dehiscence of sporangia showing vertical slit and long, white, non-glandular hairs.



**FIGURE 3.** *Schizaea erecta*. Habit (A) and anatomy (B–J): **A.** Habit. **B.** Rhizome (c—cortex). **C.** Basal Stipe (ocs—outer cortical sclerenchyma, ics—inner cortical sclerenchyma, x—xylem, ph—phloem). **D.** Middle stipe (g—groove). **E.** Apical stipe (w—wing). **F.** Lamina (1st branch) (c—costa). **G.** Lamina (2nd branch) (m—mesophyll, e—epidermis, h—hypodermis, x—xylem, ph—phloem). **H.** Lamina (3rd branch). **I.** Lamina (4th branch) (gc—guard cells, is—intercellular spaces). **J.** Lamina (5th branch).

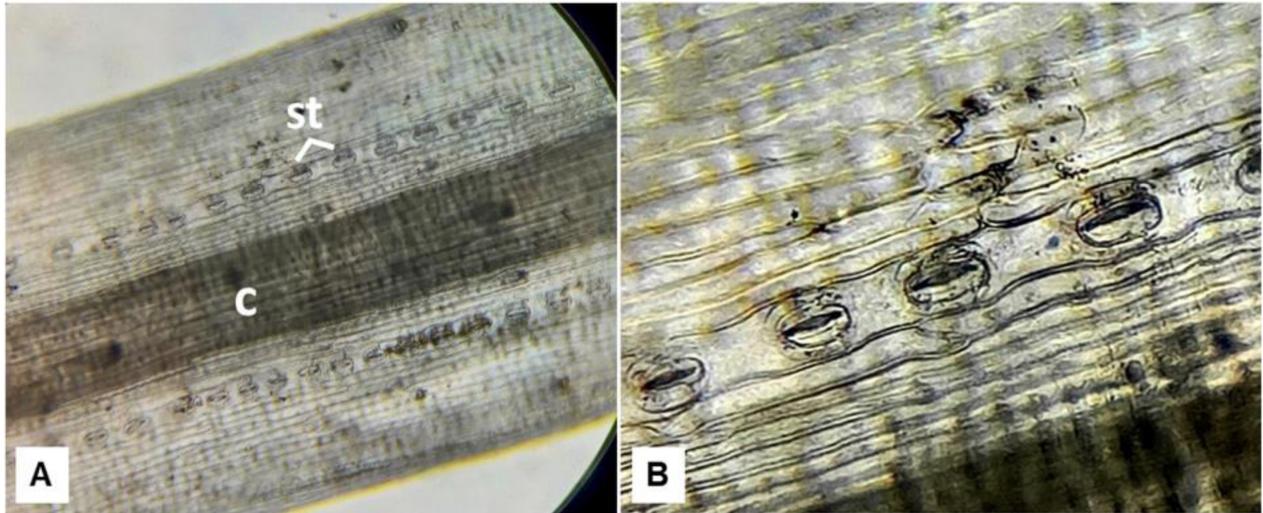


FIGURE 4. *Schizaea erecta*. A. Single row of stomata on each side the of costa. B. Hypocytic stomata (c—costa; st—stomata).



FIGURE 5. Habit and habitat of *Schizaea erecta*.

**Discussion:**—*Schizaea erecta* is most similar to *S. dichotoma*, based upon descriptions of Holttum (1959) and Sofiyanti *et al.* (2019), and examination of JSTOR type images and Co’s Digital Flora of the Philippines (Table 1). The species share nearly the same height and the presence of hairs on their rhizomes. Their fronds are dimorphic with fan-shaped lamina which branch dichotomously, they both have hypocytic stomata, and they both possess two rows of sorophores. However, the new species differs from *S. dichotoma* in having rhizome hairs 1.0–2.3 mm long (vs. 2–3 mm) (Figure 2B); sterile fronds branching dichotomously 4–5 times (vs. 6–8 times) (Figure 2C). Further, the frond is consistently erect whereas that of *S. dichotoma* is not erect (Figure 2A). The sorophore of *S. erecta* has 12–16 pairs of

lobes whereas *S. dichotoma* has 5–10 pairs. The sporangia of *S. erecta* are oblong whereas *S. dichotoma* has reniform sporangia (Figure 2G, H).

**TABLE 1.** Comparison of the morphological characters differentiating *Schizaea dichotoma* and *Schizaea erecta*.

Characters	<i>S. dichotoma</i> (Sofiyanti & Fitmawati, 2019)	<i>S. dichotoma</i> (Holttum, 1959)	<i>Schizaea erecta</i>
Height (cm)	ca. 35–45	No data	30–50
Rhizome	Short	Creeping, 3–6 cm below surface of ground	Short creeping, 0.3 mm thick, 1.5–5 cm below the surface of ground
Rhizome hairs	Present	Present, coarse shiny brown, 2–3 mm long	Present, shiny brown, appressed, 1–2 mm long, covering entire rhizome
<b>Sterile frond</b>			
Length of stipes (cm)	ca. 15–20	No data	18.5–26.6
Wing of stipes	Not winged	No data	Slightly winged at the middle to distinctly winged at the apex
Size of lamina (cm)	ca. 15 × 17	No data	9–15 × 2–4
Branching of lamina	Dichotomously 6–8 times	No data	Dichotomously 4–5 times
<b>Fertile frond</b>			
Length of stipes (cm)	Up to 20	15–30 (extremes 10–50)	11–27
Winged stipe	Narrowly present	Narrowly winged towards apex	Distinctly winged towards apex with two grooves
Lamina orientation	Not erect	No data	Erect
Size of lamina	Up to 35 cm long	10–20 cm long & wide	8–14 cm long & 2–4.5 cm wide
Branching of lamina	Dichotomously 6–8 times	Dichotomously 2–8 times	Dichotomously 3–5 times
Basal branches	No data	Like stipe	Slightly flattened, 1–1.5 mm wide
Distal branches	No data	Wings gradually wider, 1.5 mm wide, lacking prominent costa on lower surface	Flattened, up to 0.5 mm wide, costa slightly prominent
<b>Sorophore</b>			
Length of sorophores	No data	Occupying the distal 3–5 mm of each branch of frond	Occupying the distal 5–12 mm long of each branch of frond
No. of sorophores	Up to 34 per stipe	No data	24–39 per stipe
<b>Lobes of Sorophore</b>			
No. of lobe pairs	7	5–10	12–16
Arrangement of lobes	Pinnate, alternate	No data	Opposite
<b>Sporangia</b>			
Stalk	No data	No data	Short stout stalk
Shape and color	Reniform	No data	Oblong, brown
Annulus position	No data	No data	Apical annulus
Arrangement	No data	No data	Opposite to alternate, loosely arranged at the base and tightly packed in upper parts
Hairs	No data	Long, brown hairs	Conspicuous long-white hairs

Ke *et al.* (2022) and Brownsey & Perrie (2014) stated that the *S. dichotoma* complex exhibits wide morphological and cytological variation. However, most members of this complex are poorly characterized and have been collectively lumped into “*S. dichotoma*”, which was found to be polyphyletic in the phylogeny of Ke *et al.* (2022). Although our new species was not included in this phylogeny, we reckon that it is morphologically so distinct that it merits treatment as a separate species, especially in anticipation of further splitting in this group. With the recognition of this new species, there are now 21 species of *Schizaea* worldwide (PPG I, 2016) and three in the Philippines.

The salient anatomical features of *Schizaea erecta* include the following: the rhizome is almost circular with appressed hairs as outgrowths of the epidermal cells. The cortex is mainly composed of parenchyma cells. The stele is a haplostele with the phloem surrounding the xylem tissue (Figure 3B). The stipe shape changes from tetragonous at the base with indistinct costa and concave with narrow groove at the middle and somewhat flattened in the upper stipe with two distinct grooves and wings. The cortex becomes complex, being composed of the outer cortical sclerenchyma and the inner cortical parenchyma cells with the stele becoming actinostele and with a T-shaped xylem strand (Figure 3C–E). The lamina is flattened at the lower axis with distinct costa and incurved at the apical axis. The outer wall of the smaller epidermal cells is thickened and inwardly with large hypodermal cells. The vascular bundle is surrounded by a layer of large endodermis and a single layer of pericycle as also reported by Sofiyanti *et al.* (2019). Moreover, both surfaces of the costa have large sclerenchyma cells to protect the inner undifferentiated mesophyll from drying as the plants are found in open area. The guard cells protrude on the abaxial surface of the epidermis and connect to the large intercellular spaces.

The anatomy of *Schizaea erecta* differs from that of *S. dichotoma* in the rhizomes for having larger outer cortical cells and smaller inner cortical cells (vs. smaller outer cortical cells and larger inner cortical cells), vascular bundles surrounded by ring-like sclerenchymatous cell layers (vs. star-shaped sclerenchymatous cell layers), numerous metaxylem (vs. 4 metaxylem); stipe tetragonous at the base and flattened in the upper stipe with narrow groove (vs. M-shaped and deeply grooved); lamina narrowly grooved (vs. deeply grooved), and guard cells protruding from the abaxial surface (vs. guard cells sunken).

### Key to the genera and species of grass ferns (Schizaeaceae) in the Philippines

1. Sorophores pinnately arranged or comb-like (*Schizaea*).....2
- Sorophores digitate (*Actinostachys*).....4
2. Fronds unbranched .....*Schizaea malaccana*
- Fronds repeatedly dichotomously branched.....3
3. Laminae arching; segments  $\geq 2$  mm wide.....*Schizaea dichotoma*
- Laminae consistently erect; segments  $< 2$  mm wide.....*Schizaea erecta*
4. Laminae  $\geq 2$  mm wide; stipes indistinct.....5
- Laminae  $< 2$  mm wide; stipes distinct.....6
5. Laminae (sterile portion)  $\leq 5$  mm wide; stomata in one row on each side of costa; sporangia in four rows on the sorophores .....*Actinostachys digitata*
- Laminae (sterile portion)  $\leq 2.5$  mm wide; stomata in two rows on each side of costa; sporangia in two rows on the sorophores .....*Actinostachys inopinata*
6. Epiphytic; sorophores  $< 6$  mm long, 1 to 4.....*Actinostachys minuta*
- Terrestrial; sorophores  $\geq 6$  mm long, 1.....*Actinostachys simplex*

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