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***Encalypta raptocarpa* Schwägrichen and
Schistidium rivulare (Bridel) Podpera new
moss species from South Sinai, Egypt**

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Encalypta raptocarpa Schwägrichen and *Schistidium rivulare* (Bridel) Podpera new moss species from South Sinai, Egypt

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South Sinai is the richest phytogeographical territory with mosses in Egypt, as it contains nearly half the number of recorded moss taxa. The topographic and climatic gradients of mountains and wadis develop unique microhabitats for plant biodiversity. These have led to the exceptional bryoflora of South Sinai where 36 moss taxa are restricted in it. Here, we propose a further investigation of the moss flora of South Sinai from the mountain near Saint Katherine Monastery and the surrounding road to the area of Shaq El-louzah. Nineteen taxa were recorded from the area under study. Two of them were new records to the moss flora of Egypt (*Encalypta raptocarpa* Schwägrichen and *Schistidium rivulare* (Bridel) Podpera). This increases the number of mosses known from Egypt to 201 taxa and from South Sinai to 97. The new recorded species are described and illustrated, with details on the collection sites and habitats. Additional notes are also given on their world distributions, along with some floristic remarks.

Keywords: Mosses, *Encalypta*, *Schistidium*, Biodiversity, Saint Katherine Protectorate

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Graphical Abstract

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***Encalypta raptocarpa* and *Schistidium rivulare*
new moss species from South Sinai, Egypt**

Study Area:
Saint Katherine Mountain and surrounding area,
South Sinai, Egypt.

Nineteen samples were collected from the four sites,
The samples were separated into **44** specimens and **19** species

Site 3: The Road to Farsh El-louza
Habitat: Sunny, dry location; on sand and between rocks
Taxa: *Bryum argenteum*
Didymodon umbrosus
Gemmabryum ruderales
Gymnostomum mosis
Molendoa handelii
Ptychostomum turbinatum

Site 1: The road of Saint Katherine mountain, near Saint Katherine Monastery
Habitat: Below large rocks, on sand, shaded place.
Taxon: *Grimmia anodon*

Site 2: Farsh Elijah & Byzantine Dam
Habitat: *Shaded and humid location; inside the well on the wall.
*Shaded and dry location between the rocks
Taxa: *Didymodon Australasiae*
Didymodon umbrosus
Grimmia crinite
Gymnostomum calcareum

Site 4: Farsh El-louza
Habitat: Shaded, slightly wet location; on rocks inside mountain crevices
Taxa: **Encalypta raptocarpa*
**Schistidium rivulare*
Bryum argenteum
Didymodon umbrosus
Encalypta vulgaris
Entosthodon sp.
Fissidens crispus
Gemmabryum dichotomum
Gemmabryum ruderales
Gymnostomum viridulum
Imbricobryum gemmiparum
Microbryum starckeianum
Molendoa handelii
Ptychostomum turbinatum

INTRODUCTION

The Sinai Peninsula, situated in the Irano-Turanian phytogeographical region of the Middle East, is recognized as a plant diversity hotspot, particularly within the Saint Katherine protectorate. This region harbors 44% of Egypt's indigenous plant species, including mosses, and a significant proportion of the country's endemic fauna (Ibrahim et al., 2013).

Despite being the coldest phytogeographical region in Egypt, it falls within the country's arid belt. The Sinai Peninsula encompasses two phytogeographical territories: a) the Isthmic Desert (DI) in the northern Mediterranean coastal plains and its internal desert; and b) South Sinai (S) in the south, characterized by its highly elevated mountains. The topography of South Sinai fosters the development of numerous microhabitats, each with unique environmental

conditions that support its distinct flora (Khedr, 2021). Most microhabitats are characterized by stony terrain where soil depth does not exceed one centimeter, promoting moss growth with minimal competition from higher plants (Khedr, 2021). Mosses thrive on rock surfaces, within rock crevices, beneath overhanging boulders, and on fine granite soil. Occasionally, they spread over extensive areas, forming substantial coverings. Certain mosses also flourish in small freshwater ponds formed by snowmelt and rainwater accumulation (Abou Salama, 1991).

The bryoflora of South Sinai has been extensively studied over the years. Decaisne (1834) was the first to report mosses from the mountains of Saint Katherine, followed by Lorentz (1867), Hart (1891), Renauld & Cardot (1894), Geheeb (1903), Kneucker (1903), Geheeb (1904), Imam & Ghabbour (1972), Bilewsky (1974), Abou-Salama (1985), Mansi (1988), Abou-Salama (1991, 2001), Shabbara (2007), El-Saadawi et al. (2013), and Ibrahim et al. (2013). These works were compiled and revised by El-Saadawi et al. (2015), who identified 95 moss taxa in the region. South Sinai boasts unique records, including 36 taxa found exclusively in this area. Additionally, the orders Encalyptales and Grimmiales are restricted to this territory in Egypt. However, the full extent of moss diversity remains underexplored due to the arid conditions and the challenges of accessing some microhabitats. This study aims to reinvestigate the bryoflora in the South Sinai territory, considering the impacts of climate change, species shifts, adaptation, and potential extinction.

Study Area

South Sinai is a triangular plateau located at the southern end of the Sinai Peninsula. Its northern base stretches from the well of Taba on the Gulf of Aqaba in the east to Ras Masala on the Gulf of Suez in the west, with its sides extending along the Gulfs of Aqaba and Suez until they converge at Ras Mohammed in the south¹. Covering a total area of 31,272 km², it is characterized by a complex system of altitudes, reaching up to 2,642 meters above sea level, and rugged igneous and metamorphic mountains dissected by deep wadis (Figure 1).

The climate here exhibits a wide range of temperatures between summer and winter, with an average annual rainfall of 57 mm. However, the climate varies in the high mountains of the Saint Katherine area, which receives approximately 100 mm of rainfall and snow annually (Ayyad et al., 2000).

Temperature ranges and annual precipitation vary significantly between the lowlands and the mountain tops, where altitude effects overshadow those of latitude. For instance, the mean monthly temperature at the mountain peaks ranges from -1 to 2°C in winter to 17–19°C in summer, whereas temperatures in the lowlands are much higher, like those in Cairo (Said, 1990; Abou-Salama, 2001).

MATERIAL AND METHODS

During an excursion to the mountains of South Sinai on April 10–11, 2021, nineteen samples were collected from four sites by the first author (Fig. 1, Table 1). Most samples contained mixed taxa, which were subsequently separated into 45 specimens after examination. The specimens were analyzed using a Novex Holland Model RZT (Netherlands) stereo microscope and an Olympus CX23 (Japan) light microscope. Identification was conducted by comparing the specimens with authenticated Egyptian moss samples at the Bryophyta section of the Cairo Ain Shams herbarium (CAIA Botany Department, Faculty of Science, Ain Shams University), which had been identified and/or revised by both foreign and Egyptian bryologists. Additional comparisons were made with available flora books, published revisions, and unpublished theses in the lab. After identification, the specimens were preserved in CAIA. Detailed information is provided on the specimens' envelopes at the herbarium. The herbarium number (H.No.) includes the location (S for South Sinai) and the serial number of taxa from the same region, ranging from CAIA-S-324 to CAIA-S-342.

Names of identified taxa were validated through the Tropicos database (Tropicos, 2024). Newly recorded taxa were photographed and described. Distribution of the reported taxa in the phytogeographical territories of Egypt was based on El-Saadawi et al. (2015).

The global distribution of the identified taxa was determined using data from the Global Biodiversity Information Facility (GBIF) (GBIF, 2024). This distribution is reported based on the phytogeographical regions of mosses worldwide, as outlined in the Index Muscorum by Crosby & Bauer (1983).

RESULTS AND DISCUSSION

The investigation of the 19 samples revealed that they can be separated into 44 herbarium specimens belonging to six families, 13 genera, and 19 species.

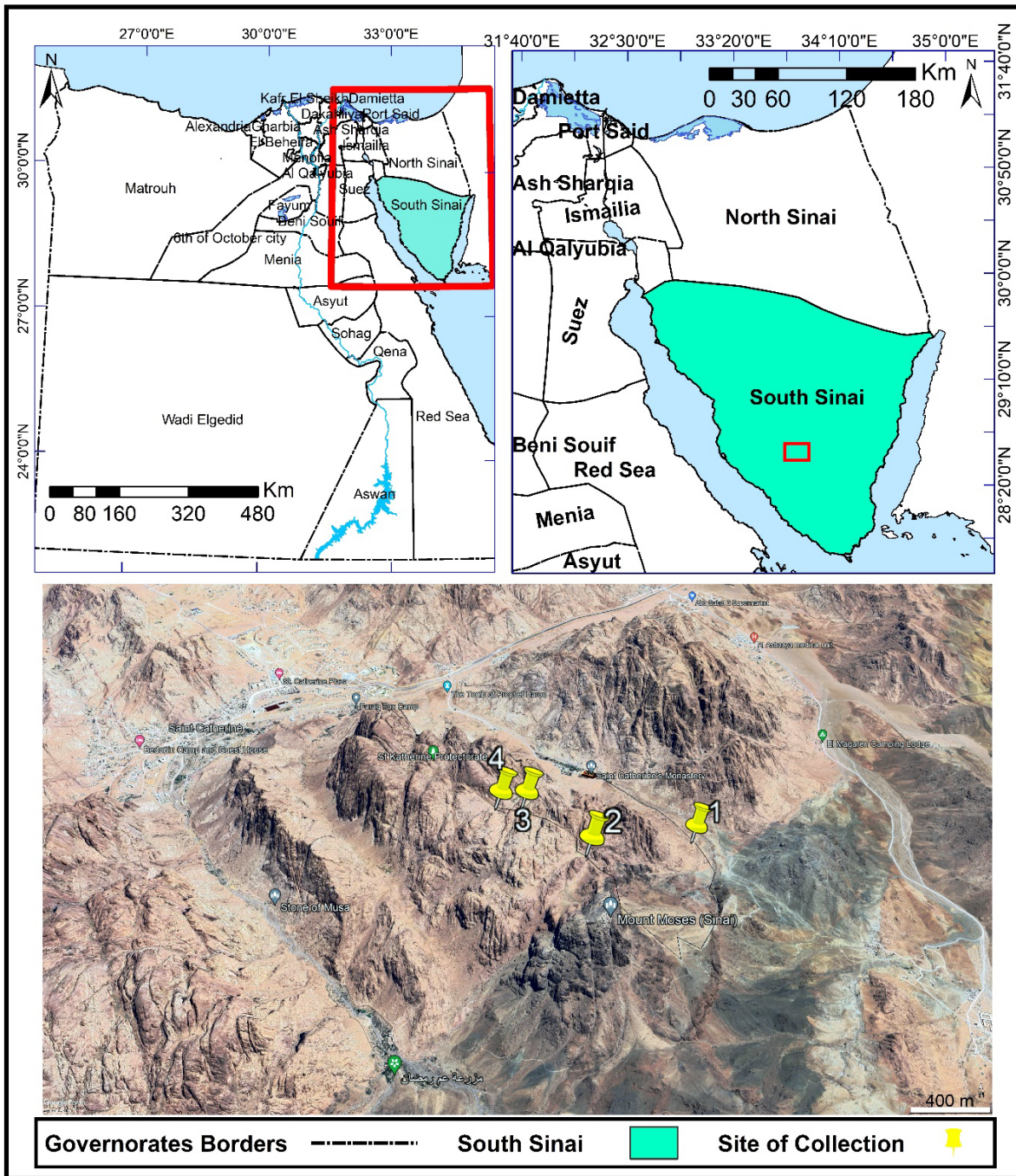


Figure 1. Maps show the relation between the four sites of collection in Saint Katherine Mountain and surrounding areas in South Sinai and Egypt.

This study has added two new records to the bryoflora of the South Sinai territory and Egypt. Consequently, the number of fully recorded taxa in the South Sinai territory has increased from 95 to 97, and in Egypt from 199 to 201 (El-Saadawi et al., 2015; Hassan et al., 2017; El-Sakaty et al., 2018; Khalil & Farag, 2018; Taha, 2020; Abou-Salama et al., 2021;

Lashin et al., 2022; Isaac et al., 2024). The 19 recorded species from the road of Saint Katherine Monastery and Shaq El-lozah are listed below, along with their distribution in other phytogeographical territories in Egypt and in the world. Species new to Egypt are marked with an asterisk (*) and are provided with descriptions and illustrations.

Table 1. Data of collection sites, habitats, and coordinates, as well as the number of samples and specimens from each site and the Herbarium Number (H. No) of specimens.

Site	Name of Site	Habitat	Latitude	Longitude	Alt (a.s.l.)	No. of Samples (Specimens)	H. No
1	The road of Saint Katherine Mountain, near Saint Katherine Monastery	Below large rocks, on sand, shaded place	28.5486	33.9819	1670	3 (3)	CAIA-S-324-326
2	Farsh Elijah and Byzantine Dam	Shaded and humid location; Inside the well on the wall.	28.5444	33.9749	2030	1 (1)	CAIA-S-327
		Shaded and dry location Between the rocks	28.5447	33.9751		1 (3)	CAIA-S-328 (a, b, c)
3	The Road to Shaq El-lozah	Sunny, dry location; on sand and between rocks	28.5482	33.9709	1995	5 (12)	CAIA-S-329-333
4	Shaq El-lozah	Shaded, slightly wet location; on rocks inside mountain crevices	28.548	33.97	2020	9 (26)	CAIA-S-334-342

List of recorded taxa**I. Bryaceae****A. *Bryum* Hedw.****1. *Bryum argenteum* Hedw.**

Collection sites (No. of Specimens): 3 (5), 4 (1).
H. No.: CAIA-S-329-a/ CAIA-S-330-a/ CAIA-S-331-a/ CAIA-S-332-a/ CAIA-S-333-a/ CAIA-S-340-a/ CAIA-S-341-a.

Bulbils were present.

Distribution: In Egypt; Cai (Cairo), Dg (Galala Desert), Di (Isthmic Desert), S (Sinai), O (Oasis), and Mm (Mariotic sector). In the world: Cosmopolitan.

B. *Imbribryum* N. Pedersen**2. *Imbribryum gemmparum* (De Not.) J.R. Spence**

Collection sites (No. of Specimens): 4 (1). H. No.: CAIA-S-334-c. Bulbils were abundant.

Distribution: In Egypt; Nf (Nile Fayoum), Cai, S, O, and Mm. In the world: Afr1 (N. Africa, Madeira, Azores, Canary Islands), Afr2 (Central Africa, St. Helena Islands), Am1 (N. America, Greenland, Aleutian Islands, Bermudez), As2 (China, Mongolia, Japan, Korea, Formosa), As5 (Asiatic part of the Middle east, including Cyprus), Eur (Europe).

C. *Gemmabryum* J.R. Spence and H.P. Ramsay**3. *Gemmabryum dichotomum* (Hedw.) J.R. Spence and H.P. Ramsay**

Collection sites (No. of Specimens): 4 (1). H. No.: CAIA-S-339-b.

Bulbils were abundant.

Distribution: In Egypt; Nv (Nile Valley), Nd (Nile Delta), Nf, Cai, Dg, Di, S, O, and Mm. In the world: Cosmopolitan.

4. *G. ruderale* (Crundw. and Nyholm) J.R. Spence

Collection sites (No. of Specimens): 3 (3), 4 (2).
H. No.: CAIA-S-330-b/ CAIA-S-331-b/ CAIA-S-332-b/ CAIA-S-334-a/ CAIA-S-341-b.

Rhizoidal and basal axile gemma were observed.

Distribution: In Egypt; S. In the world: Afr1, Afr4 (S. Africa, Kergulen Islands), Am1, As (Asia), Austr2 (New Zealand), Eur.

D. *Ptychostomum* Hornsch.**5. *Ptychostomum turbinatum* (Hedw.) J.R. Spence**

Collection sites (No. of Specimens): 3 (1), 4 (1).
H. No.: CAIA-S-333-b/ CAIA-S-337-a

Distribution: In Egypt; S, O, and Mm. In the world: Afr1, Afr2, Afr4, Am1, Am4 (Am.4-Venezuela, Colombia, Peru, Bolivia, Ecuador, Galapagos Islands), Am6 (Chile, Argentina, Uruguay, Falkland Islands, Continent of Antarctica), As1 (N. Asia including Sakhalin), As2, As5, Eur.

II. Encalyptaceae**E. *Encalypta* Hedw.****6. **Encalypta raptocarpa* Schwägrichen (Fig2)**

Collection sites (No. of Specimens): 4 (1). H. No.: CAIA-S-337-b

Sporophyte present

Distribution: **New record to Egypt.** In the world: Afr1, Afr2, Am1, Am2 (Central America), Am4, Am6, As1, As2, As5, Austr2, Eur.

Description: Gametophyte yellowish to light-green plant, 0.8-1.0 cm high, central strand absent. Leaves incurved to crisped when dry, erect-patent to spreading when moist, 2.2-2.7 mm long, lanceolate to lingulate spathulate, obtuse and apiculate; margins plane, papillose-crenulate; costa reddish, percurrent not narrowing in upper part, papillose on abaxial side above up to 200 µm wide at mid leaf; basal cells rectangular 10-20 x 40 µm (w x L), thin-walled, hyaline, mid-leaf cells isodiametric, strongly papillose, obscure, 10–12 µm wide.

Specialized asexual reproduction organs are not present. Sporophyte lateral. Setae orange to dark red up to 2.5 mm. Long; capsules cylindrical, brown, ribbed, up to 4 mm long, deeply furrowed when dry and empty; peristome rudimentary and pale fragile; spores sparsely papillose, 50: 55 µm in size, proximal surface with radial ridges, minutely granular, distal surface with prominent papillae; calyptra entire or erose at base, papillose towards apex. This species is distinguished from *E. intermedia* Jur. by the dark colour of the ribs in the capsule and a longer seta. Also different from *E. vulgaris* by ellipsoid ribbed capsules, and wide toward the base.

7. *E. vulgaris* Hedw.

Collection sites (No. of Specimens): 4 (1). H. No.: CAIA-S-337-e/ CAIA-S-342-a

Sporophyte present.

Distribution: In Egypt; S. In the world: Afr1, Afr4, Am1, Am2, Am3 (West Indian Islands (Antilles, Greater and lesser Bahamas)), Am4, As1, As5, Austr1 (Australia, Tasmania), Austr2, Eur.

III. Fissidentaceae

F. *Fissidens* Hedw.

8. *Fissidens crispus*

Collection sites (No. of Specimens): 4 (1). H. No.: CAIA-S-340-c

Distribution: In Egypt; Nv, Cai, S and Mm. In the world: Afr (Africa), Am (America), As2, As3 (India, Pakistan, Bangladesh, Ceylon, Burma, Siam, Indo-China), As4 (Indonesia, Malaya, Philippine Islands, New Guinea), As5, Austr1, Eur.

IV. Funariaceae

G. *Entosthodon* Schwägr.

9. *Entosthodon* sp.

Collection sites (No. of Specimens): 4 (2). H.

No.: CAIA-S-331-c/ CAIA-S-342-b

Distribution: In Egypt: Nn (Nile Nubia), Nv, Nd, Nf, Cai, Dg, Di, S, O and Mm. In the world: Cosmopolitan.

V. Grimmiaceae

H. *Grimmia* Hedw.

10. *Grimmia anodon* Bruch and Schimp.

Collection sites (No. of Specimens): 1 (3). H.

No.: CAIA-S-324-327

Distribution: in Egypt; S. In the world: Afr1, Am1, Am2, Am4, Am6, As1, As2, As5, Austr1, Austr2, Eur.

11. *G. crinite* Brid.

Collection sites (No. of Specimens): 2 (1). H.

No.: CAIA-S-328-c

Distribution: In Egypt; S. In the world: Afr1, As1, Eur.

I. *Schistidium* Bruch & Schimp.

12. * *Schistidium rivulare* (Bridel) Podpera (Fig. 3)

Collection sites (No. of Specimens): 4 (4). H.

No.: CAIA-S-337-c/ CAIA-S-338-b/ CAIA-S-339-a/ CAIA-S-340-b.

Sporophyte present

Distribution: **New record to Egypt.** In the world: Afr1, Am1, Am2, Am4, Am6, As1, As2, As5, Austr1, Austr2, Eur.

Description: Plants dark green, olivaceous to brownish green, tufts or mats, up to 1.5-4 cm high. Stems 1.2 – 3.6 cm long, ± pentagonal in cross-section, with central strand, sclerodermis clearly differentiated. Leaves erect, often curved towards stem to slightly contorted when dry, erect to spreading when moist, ovate-lanceolate to ovate-triangular, 1.8 - 2.5 mm long, 0.6 - 0.8 mm wide, keeled to slightly concave; apex acute to slightly obtuse, sometimes ending in a series of pellucid cells, lack a hair point; margins usually recurved to past mid leaf, sometimes to near apex, rarely plane, slightly denticulate to smooth, 1- or 2-stratose, often in more than one row; costa ending below apex to percurrent, in cross-section epidermis differentiated ventrally and dorsally surrounded median stereid band;

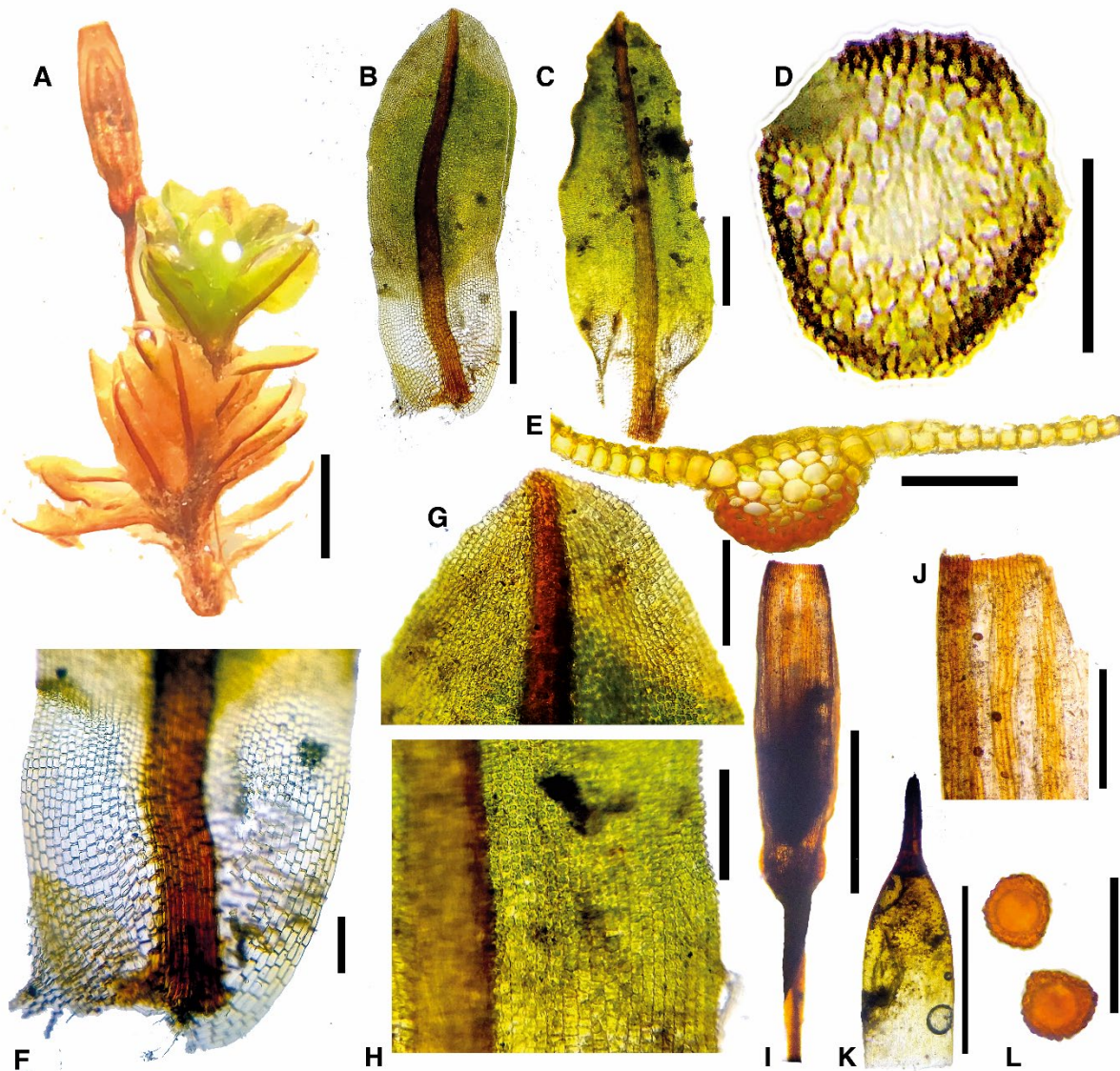


Figure 2. *Encalypta raptocarpa*. A) Fruiting gametophyte (2 mm); B & C) Leaves (500 µm); D) Cross-section of stem (100 µm); E) Cross-section of leaf (200 µm); F) Leaf base (200 µm); G) Leaf apex (200 µm); H) Middle laminal cells (200 µm); I) Capsule (2 mm); J) Dark ribs of capsule wall (500 µm); K) Calyptra (2 mm); L) Spores (100 µm).

upper laminal cells irregular, angular, isodiametric or short-rectangular, thick wall, (6.0) 10.0 - 12.5 µm long, 5.0 - 8.0 µm wide; basal laminal cells quadrate, short to long rectangular, thin wall, 20 - 30 µm long, 4.0 - 6.0 (10) µm wide, smooth, with thin walls. Seta short, up to 0.4 mm long; Sexual condition autoicous. Capsule red-brown to slightly black, short-cylindric to cupulate, 0.8 - 1.2 mm; exothecial cells isodiametric, usually irregularly angular, or elongate, sometimes

rounded, irregularly thickened or thick-walled; rim usually darker than capsule wall; stomata present; peristome squarrose-recurved, to slightly revolute, 300-520 µm, dark red, densely papillose, usually weakly perforated. Spores 15 - 20 µm, granulose.

This species is distinguished from *S. agassizii* Sull and Lesq. by bistratose leaf lamina and from *S. apocarpum* by sub-globose capsule and no distinguished hair point

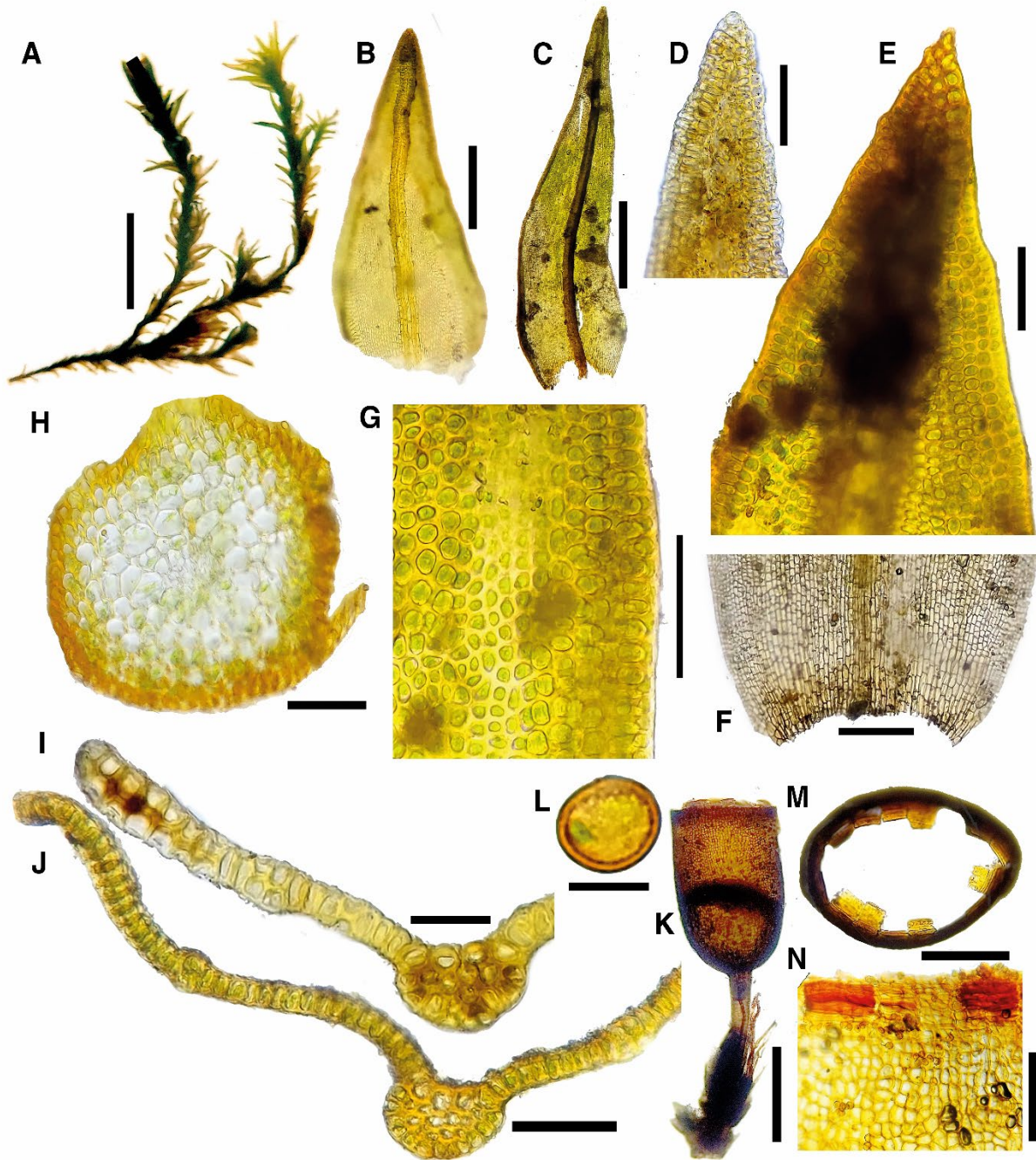


Figure 3. *Schistidium rivulare*. A) Fruiting gametophyte (500 µm); B & C) Leaves (500 µm); D) Leaf apex slightly-obtuse (100 µm); E) Leaf apex-acute (100 µm); F) Leaf base (100 µm); G) Middle laminal cells (100 µm); H) Cross-section of stem (100 µm); I) Cross-section of leaf at apex (100 µm); J) Cross-section of leaf below middle (100 µm); K) Capsule (200 µm); L) Spore (20 µm); M) Capsule mouth showing incurved peristome teeth (200 µm); N) Magnified part of capsule wall showing exothecial cells (100 µm).

VI. Pottiaceae

J. Didymodon Hedw.

13. *Didymodon umbrosus* (Müll.Hal.) R.H. Zander
Collection sites (No. of Specimens): 2 (1), 3 (1),
4 (1). H. No.: CAIA-S-328-b/ CAIA-S-333-b/
CAIA-S-335-a

Distribution: In Egypt; S. In the world: Afr1,
Afr2, Afr4, Am1, Am2, Am4, Am6, Eur.

14. *D. australasiae* (Hook. and Grev.) R.H. Zander
Collection sites (No. of Specimens): 2 (1). H.
No.: CAIA-S-328-a

Distribution: In Egypt; Dg, Di, and S. In the world: Afr1, Afr2, Afr4, Am1, Am2, Am4, Am5 (Brazil, Paraguay, Guinea, Trinidad), Am6, As2, As5, Austr1, Austr2, Eur.

K. *Gymnostomum* Nees & Hornsch.

15. *Gymnostomum calcareum* Nees and Hornsch.
Collection sites (No. of Specimens): 2 (1). H. No.: CAIA-S-327
Distribution: In Egypt; Nv, Nd, Nf, Dg, S, GE (Gebel Elba), and Mm. In the world: Afr1-3, Am1, Am2, Am4-6, As1, As2, As5, Austr1, Austr2, Eur.

16. *G. mosis* (Lorentz) Jur. and Milde

Collection sites (No. of Specimens): 3 (1). H. No.: CAIA-S-329-c.
Distribution: In Egypt; Di, and S. In the world: Afr1, As5, Eur.

17. *G. viridulum* Brid.

Collection sites (No. of Specimens): 4 (3). H. No.: CAIA-S-336/CAIA-S-337-d/CAIA-S-338-a.
Distribution: In Egypt; Nv, Cai, Dg, Di, S, and Mm. In the world: Afr1, Am1, As5, Eur.

L. *Microbryum* Schimp.

18. *Microbryum starckeanum* (Hedw.) R.H. Zander
Collection sites (No. of Specimens): 4 (1). H. No.: CAIA-S-335-b.
Sporophyte present.
Distribution: In Egypt; Cai, Di, S, and Mm. In the world: Afr1, Afr4, Am1, Am2, Am4, As1, As5, Austr1, Austr2, Eur.

M. *Molendoo* Lindb.

19. *Molendoo handelii* (Schiffn.) Brinda and R.H. Zander
Collection sites (No. of Specimens): 3 (1), 4 (1). H. No.: CAIA-S-329-b/ CAIA-S-334-b.
Archegonium present.
Distribution: In Egypt; Nv, and S. In the world: Afr1, Am1, Am4, As3, As5, Eur.

CONCLUSION

The Sinai Mountains are home to diverse species, which remain largely undiscovered. Here, two new species were identified and added as a new record to South Sinai and Egypt. Furthermore, based on current naming, the generic names of five species have been changed. It is worth noting that the genus *Molendoo* Lindb has been firstly reported in Egypt as a synonymous to *Anoetangium* Schwägr.

Disclosure statement

No potential conflict of interest was reported by the authors.

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NOTES ON CONTRIBUTORS

All authors contributed equally to the study, samples preparation, photography and identification. The first author collected the samples from the study area. All authors read, revised, and approved the final manuscript.

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