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The moss flora of Saint Katherine Protectorate, South Sinai, with eight new records

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A total of 21 species of mosses were collected from Saint Katherine Protectorate after conservation; among these eight species represent new records, five for moss flora of Sinai and three for Egypt. Two species belong to ***Pohlia***, three each to ***Ptychostomum*** and ***Entosthodon***. Notes on climate, habitats, reproductive organs and fruiting of the examined species are given.

Key words**:** *Conservation, Moss flora, New records, Sinai, Saint Katherine Protectorate*.

Introduction

Saint Katherine Protectorate is an Egyptian national park in Saint Katherine region. It encloses most of the mountainous area of central South Sinai, including the country's highest mountain, Gebel Katherine (2641m, above sea level). It was declared as a protected area in 1988 by the Egyptian Authorities and was recognized by the IUCN due to its immense biological and cultural interest. It contains about 44% of Egypt's endemic flora, including mosses and a very high proportion of Egypt's endemic fauna. The Protectorate forms one element of a system of five protected areas, which collectively represent the diversity of marine coastal and terrestrial ecosystems and their contained biodiversity of South Sinai (Guenther *et al*., 2005).

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Saint Katherine is the coolest area in Sinai and Egypt as a whole owing to its high elevation. The low elevation wadis and surrounding borders of the Protectorate are warmer. Saint Katherine is characterized by arid climate. Most of the precipitation in Saint Katherine occurs during autumn, winter and spring. Considerable precipitation occurs of convective rains, which are very local in extent and irregular in occurrence (i.e. that in one year the rainfall may reach to 100 mm and in another it may be just 10 mm). Rainfall is sporadic but usually falls between October and May, major flash floods (due to heavy rainfall) can occur after torrential rain (Gilbert *et al.*, 2010).

Mosses represent an important element, which plays an essential role in ecosystem. In spite of the previous bryofloral exploration efforts, Egyptian conservation areas have not been explored enough. Till now only **five** out of **30** protectorate areas were explored bryofloristically namely, **Gebel Elba Natural protected Area** (Arnell 1963, Imam and Ghabbour 1972 & Abou Salama 2000), **Saint katherine National Park** (Abou Salama 2001), **Natural Siwa Protected Area** (Refai, 2001), **El-Wahat El-Bahreya** (Refai *et al*.,2002) and **El Omayed Protected Area** (El-Saadawi *et al*.,2013). Some protectorates were expected to have moss taxa but when visited by Abou Salama, one of the authors, i.e. (Saloga and Ghazal Islands, Wadi El Rayan in 1995) and (Wadi El-Gemal /Hamata in 2012) no mosses were detected. Moreover, during our first excursion to Saint Katherine and Abu Galum protectorates in **4/11/2009** to gather material for the present study, no mosses were found in Abu Galum Protectorate.

It is not surprising that this relatively small area of Southern Sinai, which is very rich in its flora of vascular plants, but its moss flora is generally scattered due to unsuitable dry conditions. As a result of identification difficulties, in some previous studies few species have been described as new while many other are not indeterminate (Abou-Salama, 1985 & 1991; Mansi, 1988). Therefore, further studies and explorations are needed for this protectorate. In addition, the impact of conservation on the Saint Katherine Protectorate bryoflora makes its study a necessity.

This study aims at updating our knowledge about the bryoflora of Saint Katherine protected area. Moreover, it will help in evaluation and development of this area as a protectorate regarding the bryoflora point of view, taking the conservation status (according to available data) of recorded species into consideration.

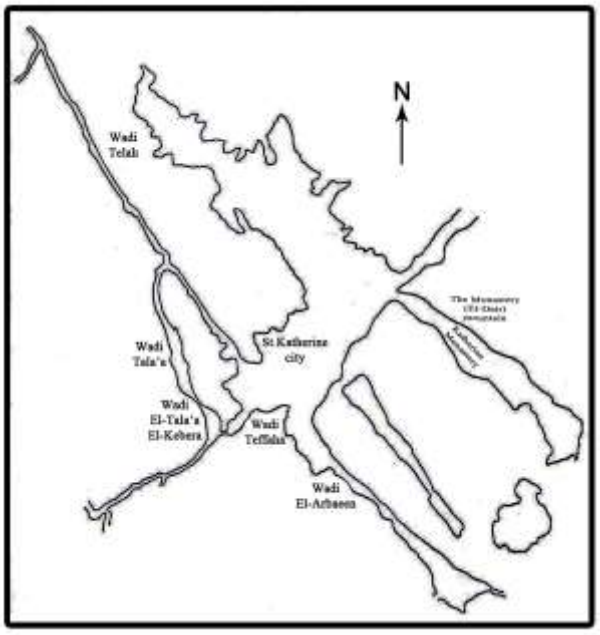
Study area and Materials

The Saint Katherine region (Map 1) is situated in the southern Sinai and is part of the upper Sinai massif (Danin, 1983). It is located between 33° 30′ to 34° 30′ E Longitude, and 28° 50′ to 29° 50′ N Latitude. Elevation ranges from 1300 to 2600 m. It extends over 4,250 km² of South Sinai, making it the largest protectorate in Egypt. It has a variety of landform types: **slopes, terraces, gorges, ridges, plains, and wadis** (Moustafa & Klopatek, 1995).

Five excursions were set out covering the period from November 2009 to July 2012. Seventy moss samples were collected from five wadis located in and around Saint Katherine city namely, Wadi El-Arbaeen, Wadi Teffaha, Wadi Tala'a, Wadi Telah and Wadi El- Tala'a El-Kebera (Map 2). Most gatherings were collected from relatively dry places and some others from moist places.

Specimens were examined, sectioned according to Abou Salama (1985) and Wilson (1990). The studied specimens were identified by being matched with the pre-identified Egyptian moss specimens from different phytogeographrical territories of Egypt. In addition, using moss floras of the different countries of the world. Adaptation to diverse habitats was taken into consideration in determining precise identification. Detailed information about all collected samples is available on herbarium packets kept at the Herbarium of the Suez Canal University (SCU-I, proposed abbreviation), Ismailia, Faculty of Science, Botany Department.

Map 1. Location of Saint Katherine area in southern Sinai**.**



Map 2. Detailed map of Saint Katherine Protectorate showing the sites of collection.

Results

The study of the seventy collected samples yielded 21 species. These species belong to nine genera, five families and four orders, as listed below.

Division: Bryophyta (Musci)
Class : Bryopsida
Order 1: Pottiales
Family: Pottiaceae Schimp.
Subfamily 1: Merceyoideae

Didymodon Hedw.
Didymodon fallax (Hedw.) R. H. Zander, Phytologia, 41: 28. 1978
Didymodon tophaceus (Brid.) Lisa, Elenco Muschi Torino, 31. 1837

Subfamily 2: Trichostomoideae

Eucladium Bruch & Schimp.
Eucladium verticillatum (Brid.) Bruch & Schimp. in Bruch *et al*., Bryol. Eur. 1: 93 (fasc. 33-36. Monogr. 3).1846

Subfamily 3: Pottioideae

Tortula Hedw.
Tortula brevissima Schiffn. Ann. Naturhist. Hofmus. 27: 481. 23-33. 481. 1913.
Tortula inermis (Brid.) Mont., Arch. Bot. (Paris) 1:136. 1832.
Weissia Hedw.
Weissia controversa Hedw., Sp. Musc. Frond. 67. 1801

Order 2: Grimmiales
Family: Grimmiaceae Arnold

Grimmia Hedw.
Grimmia anodon Bruch & Schimp. in Bruch *et al*., Bryol. Eur. 3: 110. 236 (fasc. 25--28 Mon. 8. 1).1845

Order 3: Funariales
Sub-order:Funariineae
Family: Funariaceae Schwäger.

Entosthodon Schwäger.
Entosthodon durieui Mont. Ann. Sci. Nat., Bot., sér. 3. 11: 33. 1849
**Entosthodon fascicularis* (Hedw.) Műll.Hal., Syn. Musc. Frond. 1: 120. 1848.
**Entosthodon muhlenbergii* (Turner) Fife, J. Hattori Bot. Lab. 58:

192. 1985.

**Entosthodon pulchellus* (H. Philib.) Bruguès, Orsis 15: 115 .2000

Note: *= New record to Sinai, **= New record to Egypt.

Order 4: Bryales

Family1: Bryaceae Schwäger.

Bryum Hedw.

Bryum argenteum Hedw., Sp. Musc. Frond. 181. 1801

Bryum funkii Schwägr., Sp. Musc. Frond. Suppl. 12: 89. pl. 69.1816

Bryum turbinatum (Hedw.) Turner, Muscol. Hibern. Spic.127.1804.

Ptychostomum Hornsch.

Ptychostomum imbricatulum (Müll. Hal.) D.T.Holyoak & N.Pedersen J. Bryol. 29: 120. 2007

***Ptychostomum pallens* (Sw.) J.R. Spence, Phytologia 87: 21. 2005

Ptychostomum pseudotriquetrum (Hedwig) J.R. Spence & H. P. Ramsay in Spence, Phytologia. 87: 23. 2005

***Ptychostomum rubens* (Mitt.) D. T. Holyoak & N. Pedersen. J. Bryol. 29: 120. 2007

**Ptychostomum torquescens* (Bruch & Schimp.) Ros & Mazimpaka, Cryptogamie, Bryologie, 34: 219. 2013.

Family 2: Mielichhoferaceae

Pohlia Hedw.

**Pohlia melanodon* (Brid.) A. J. Shaw, Bryologist. 84: 506.1981.

***Pohlia wahlenbergii* (F. Weber & D. Mohr) A. L. Andrews. Moss Fl. N. Amer. 2: 203.1935.

Data about localities, Number of pure and mixed gatherings, Herbarium specimen number (sample number is followed by the acronym **"YM"** where YM = Yasmin Mohamed – one of the authors of this paper), Microhabitat, sterility or fertility, any reproductive structure and distribution in phytogeographical territories in Egypt (for explanation of abbreviations see Map 3) are all given below.

Moss species of Saint Katherine Protectorate

1-*Didymodon fallax* (Hedw.) R. H. Zander, Phytologia, 41: 28. 1978

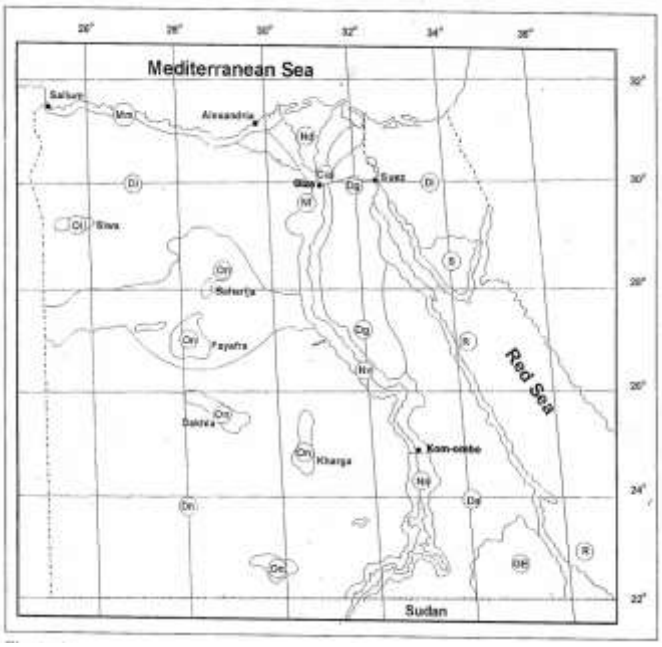
Collected from: Wadi Teffaha, Wadi Telah and Wadi El- Tala'a El-Kebera.

Mixed gatherings: YM 21b, YM30a, YM31b, YM51b, YM61b, YM62a

Microhabitat: below rocks, between rocks and inside rock crevices in shady and dry or wet places.
Fertility: Plants sterile
Distribution in Egypt: Mm, Nd, Nf, O, S.

2-*Didymodon tophaceus* (Brid.) Lisa, Elenco Muschi Torino, 31. 1837

Collected from: Wadi Telah.
Mixed gatherings: Ym26a, Ym28b, Ym32a.
Microhabitat: On rocks, between rocks and between rocks and land, in shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: Cai, Dg, Mm,Nd,Nf,Nn,Nv,O,S.



Map 3. Phytogeographical territories in Egypt (After Täckholm, 1974; El- Hadidi & Fayed 1994/95; El-Hadidi, 2000). **Cai**: Cairo area; **Da**: Arabian Desert; **Dg**: Galala Desert; **Di**: Isthmic Desert; **Dl**: Libyan Desert; **Dn**: Nubian Desert; **GE**: Gebel Elba; **Mm**: Western Mediterranean coastal land (Mareotic sector); **Nd**: Nile Delta; **Nf**: Nile Faiyum; **Nn**: Nile Nubia, from Kom-Ombo southwards to Egyptian boundaries with the Sudan including the areas now inundated by the waters of Lake Naser since 1965; **Nv**: Nile Valley, from Cairo-Giza to Kom-Ombo; **On**: Oases of the Nubian Desert; **Ol**: Oases of the Libyan Desert; **R**: Red Sea costal plains; **S**: Southern Sinai massive (Sinai proper i.e. relatively high mountains, south of Isthmic desert).

3-*Eucladium verticillatum* (Brid.) Bruch & Schimp. in Bruch *et al*., Bryol. Eur. 1: 93 (fasc. 33-36. Monogr. 3).1846

Collected from: Wadi Tala'a,Wadi Telah and Wadi El-Tala'a El-Kebera

Pure gatherings: YM63.

Mixed gatherings: YM22a, YM23a, YM25c,

Microhabitat: Common, inside wet rock crevices and on semi shaded granite soil, between rocks and land, below rocks and between rocks in shady and wet place.

Fertility: Plants sterile

Distribution in Egypt: Cai, S.

4-*Tortula brevissima* Schiffn. Ann. Naturhist. Hofmus. 27: 481. 23-33. 481. 1913.

Collected from: Wadi El-Arbaeen.

Mixed gatherings: YM19b.

Microhabitat: Below rocks in shady and dry place

Fertility: Plants sterile

Distribution in Egypt: Mm,S.

5-*Tortula inermis* (Brid.) Mont., Arch. Bot. (Paris) 1:136. 1832.

Collected from: Wadi El-Arbaeen, Wadi Teffaha and Wadi El-Tala'a El-Kebera.

Pure gatherings: YM8, YM9, YM52, YM53.

Mixed gatherings: YM3a, YM6b, YM10b, YM19a, YM20b, YM21a, YM33b, YM37b, YM46b, YM61a, YM68a.

Microhabitat: Between rocks and land, below rocks, between rocks and within rock crevices in shady and dry place.

Fertility: Plants fruiting, sporophyte rare, archegonia, antheridia and rhizoidal gemmae are present.

Distribution in Egypt: S.

6-*Weissia controversa* Hedw., Sp. Musc. Frond. 67. 1801

Collected from: Wadi Telah

Mixed gatherings: YM31e.

Microhabitat: Below rocks and between rocks in shady and wet place.

Fertility: Plants fruiting, sporophyte, archegonia and antheridia present

Distribution in Egypt: S.

7-*Grimmia anodon* Bruch & Schimp. in Bruch et al., Bryol. Eur. 3: 110. 236 (fasc. 25-28 Mon. 8. 1).1845.

Collected from: Wadi El- Arbaeen, Wadi Teffaha, Wadi El-Tala'a El-Kebera and Wadi Tala'a

Pure gatherings: YM4, YM5, YM7, YM11, YM12, YM13, YM14, YM15, YM16, YM17, YM18, YM34, YM35, YM36, YM38, YM39, YM40, YM41, YM42, YM43, YM44, YM45, YM47, YM48, YM49, YM50, YM59, YM60, YM64, YM65, YM66, YM67, YM69, YM70, YM71, YM72.
Mixed gatherings: YM6a, YM10a, YM20a, YM33a, YM37a, YM46a, YM51a, YM62b, YM68b.
Microhabitat: below rocks and on their sides, between rocks and land, on rocks, between rocks, inside rock crevices and within rock crevices in shady and dry place.
Fertility: Plants sterile
Distribution in Egypt: S.

8-*Entosthodon durieui* Mont. Ann. Sci. Nat., Bot., sér. 3. 11: 33. 1849

Collected from: Wadi Telah
Pure gatherings: Ym24
Mixed gatherings: YM28f.
Microhabitat: Below rocks, between rocks and inside rock crevices in shady and wet place.
Fertility: Plants fruiting, sporophyte rare, archegonia, antheridia and rhizoidal gemmae present.
Distribution in Egypt: Cai, GE, S.

9-*Entosthodon fascicularis* (Hedw.) Műll.Hal., Syn. Musc. Frond. 1: 120. 1848.

Collected from: Wadi Tala'a
Mixed gatherings: YM23c.
Microhabitat: Below rocks - shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: Cai, Di.

10-*Entosthodon muhlenbergii* (Turner) Fife, J. Hattori Bot. Lab. 58: 192. 1985.

Collected from: Wadi Telah
Mixed gatherings: YM25b, YM31a.
Microhabitat: Below rocks in shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: Cai, GE.

11-*Entosthodon pulchellus* (H. Philib.) Bruguès, Orsis 15: 115 .2000.

Collected from: Wadi Telah
Mixed gatherings: Ym27f, YM30b

Microhabitat: Below rocks and between rocks in shady and wet place.
Fertility: Plants fruiting, sporophyte, archegonia and antheridia present
Distribution in Egypt: Di, GE.

12-*Bryum argenteum* Hedw., Sp. Musc. Frond. 181. 1801.
Collected from: Wadi Telah and Wadi El- Arbaeen.
Mixed gatherings: YM3b, YM28h, YM29aC.
Microhabitat: Between rocks and land and within rock crevices in dry and wet place.
Fertility: Plants sterile have numerous rhizoidal gemmae and also have axillary gemmae.
Distribution in Egypt: Cai , Di, Mm, S.

13-*Bryum funkii* Schwägr., Sp. Musc. Frond. Suppl. 12: 89. pl. 69.1816.
Collected from: Wadi Telah
Mixed gatherings: YM28d.
Microhabitat: Between rocks in shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: Di, Dg, S.

14-*Bryum turbinatum* (Hedw.) Turner, Muscol. Hibern. Spic.127.1804.
Collected from: Wadi Telah
Mixed gatherings: YM27c, YM28a YM32b.
Microhabitat: Between rocks and land, below rocks and between rocks in shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: O, S.

15-*Ptychostomum imbricatulum* (Müll. Hal.) D.T.Holyoak & N.Pedersen J. Bryol. 29:120. 2007.
Collected from: Wadi Telah
Mixed gatherings: YM25e, YM28g, YM29c C, YM31c.
Microhabitat: Below and between rocks, within rock crevices, between rocks and land in shady and wet place and Found grow on water (mosses used algae act as substrate).
Fertility: Plants sterile, rhizoidal gemmae present.
Distribution in Egypt: Cai, Di,Mm,Nd,S.

16-*Ptychostomum pallens* (Sw.) J.R. Spence, Phytologia 87: 21. 2005. (Figure 1).
Collected from: Wadi Telah
Mixed gatherings: YM27d, YM29cD, YM31d.

Microhabitat: Below and between rocks in shady and wet place and found grow on water.
Fertility: Plants sterile.
Distribution in Egypt: New recorded to Egypt.
17-*Ptychostomum pseudotriquetrum* (Hedwig) J.R. Spence & H. P. Ramsay in Spence, Phytologia. 87: 23. 2005.
Collected from: Wadi Telah, Wadi El- Tala'a El- Kebera and Wadi Tala'a
Pure gatherings: YM54, YM56, YM57, YM58.
Mixed gatherings: YM22b, YM23b, YM25a, YM26b, YM29aB, YM29b, YM55a
Microhabitat: Below rocks, on rocks, between rocks and land, within rock crevices, Permanent water and between rocks in shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: S.
18-*Ptychostomum rubens* (Mitt.) D. T. Holyoak & N. Pedersen. J. Bryol. 29: 120. 2007. (Figure 2).
Collected from: Wadi Telah
Mixed gatherings: YM25d, YM27a, YM28e, YM 29cB.
Microhabitat: Below and between rocks in shady and wet place.
Fertility: Plants sterile, rhizoidal gemmae present.
Distribution in Egypt: New recorded to Egypt.
19-*Ptychostomum torquescens* (Bruch & Schimp.) Ros & Mazimpaka, Cryptogamie, Bryologie, 34: 219. 2013.
Collected from: Wadi Telah and Wadi El- Tala'a El- Kebera.
Mixed gatherings: YM29aA, YM29cA, YM55b.
Microhabitat: Permanent water, between rocks and within rock crevices in shady and wet place and also found growing on water.
Fertility: Plants sterile
Distribution in Egypt: Dg
20- *Pohlia melanodon* (Brid.) A. J. Shaw, Bryologist. 84: 506.1981
Collected from: Wadi Telah.
Mixed gatherings: YM27e.
Microhabitat: Below and between rocks in shady and wet place.
Fertility: Plants sterile
Distribution in Egypt: Mm

21-*Pohlia wahlenbergii* (F. Weber & D. Mohr) A. L. Andrews. Moss Fl. N. Amer. 2: 203.1935. (Figure 3).
Collected from: Wadi Telah.
Mixed gatherings: YM27b, YM28c, YM32c.
Microhabitat: Between rocks and land, below and between rocks in shady and wet place.
Fertility: Plants sterile.
Distribution in Egypt: New recorded to Egypt.

Discussion

The largest family, in Saint Katherine Protectorate is ***Bryaceae*** (38.2%) being represented by eight species within two genera. ***Pottiaceae*** was come second (28.5%), being represented by six species in four genera. Out of the nine reported genera the largest were: ***Ptychostomum*** (5 species), ***Entosthodon*** (4 species), ***Bryum*** (3 species), followed by ***Didymodon, Tortula*** and ***Pohlia*** (2 species each), while three genera; ***Eucladium, Grimmia*** **and** ***Weissia*** were represented by one species each.

Grimmia anodon had the highest percentage of occurrence of all recorded species in the study area, followed by ***Tortula inermis***. Wadi Telah is characterized by high diversity due to the presence of 17 species out of 21 recorded species, followed by Wadi El-Tala'a Elkebera (6 species). This shows that wadi Telah represents the main center of diversity of the moss bryoflora in the mountainous region in South Sinai, which is the richest of the studied wadis by water.

No species were found as pure samples and five species were found in pure and mixed samples representing the most common element of the flora. 16 species were recorded only in mixed samples and includes rare and common species.

Only four out of 21 studied species were fruiting. These are: ***Tortula inermis, Weissia controversa, Entosthodon durieui*** and ***Entosthodon pulchellus***. The only species having axillary gemmae was ***Bryum argenteum*** and five species carried rhizoidal gemmae namely; ***Tortula inermis, Entosthodon durieui, Bryum argenteum, Ptychostomum rubens*** **and** ***Ptychostomum imbricatulum***.

The floral similarity is largest between species of the study area and the Cairo region (Cai). There are seven species common to both areas, followed by Western Mediterranean coastal land (Mm) (sharing six species). On the other hand, elements of similarity between the moss floras of the other parts

of Egypt (Nile Faiyum, Nile Valley, Isthmic Desert and Gebel Elba) and that of Sinai are quite few (El-Saadawi *et al*., 2003).

There are more elements of similarity between the species recorded in this study and the bryoflora of some neighboring countries. Spain, Greece and Sicily have the largest of shared species (21). Followed by Canary Islands and Serbia sharing 20 species. Corsica, Morocco and Slovenia sharing 19 species. On the other hand, the least similarity was Andorra sharing with 6 species. (Ros *et al*., 2013).

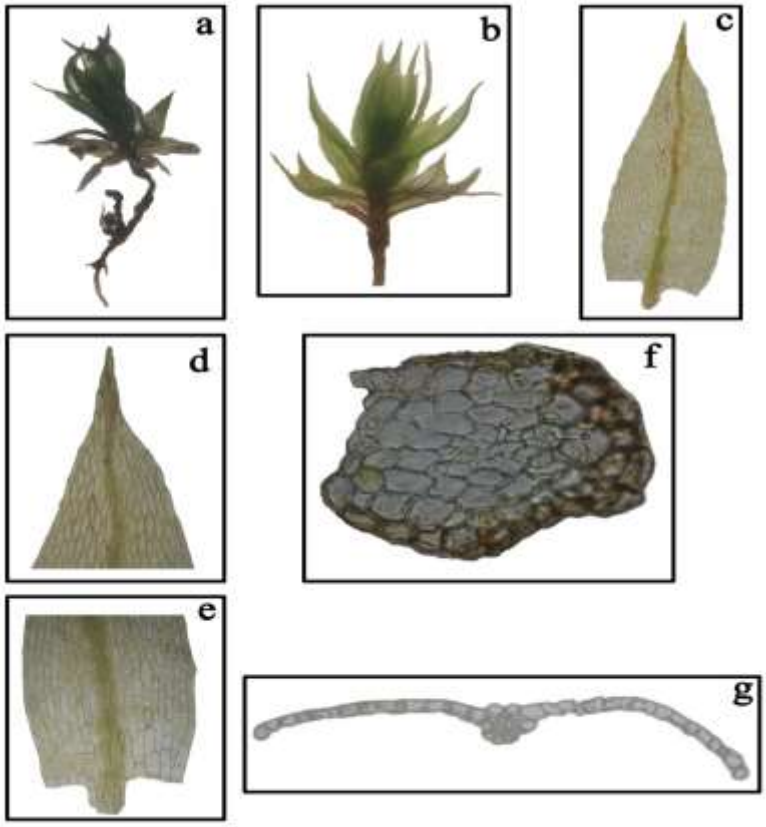


Figure 1. a. Dry Plant (x16), b. Wet Plant (x16), c. Leaf (x40), d. Leaf Apex (x63), e. Leaf Base (x60), f. T.S of Stem and g. T.S of Leaf.

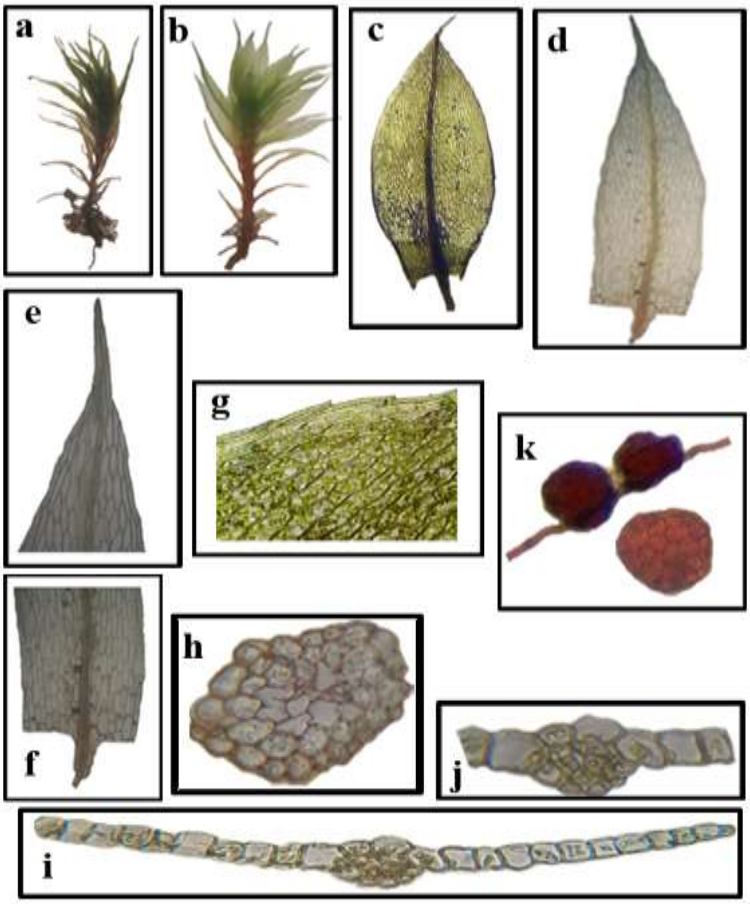


Figure 2. a. Dry Plant (x3), b. Wet Plant (x4), c. Leaf (x30), d. Another Leaf (x30), e. Leaf Apex (x40), f. Leaf Base (x40), g. Marginal cells of leaf (x400), h. T.S of Stem, i.T.S of Leaf, j. Magnified part of T.S of Leaf showing costa and k. Rhizoidal Gemmae (x9).

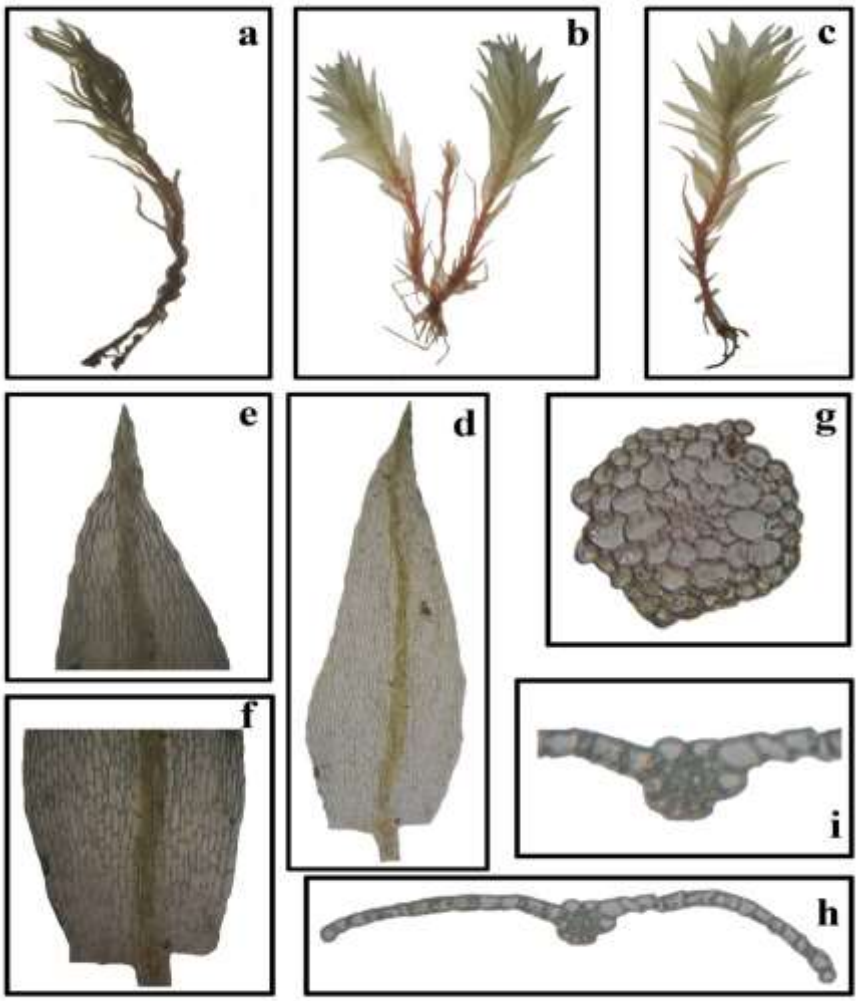


Figure 3. a. Dry Plant (x7), b. Wet Branched Plant (x5), c. Wet branched Plant (x6), d. Leaf (x34), e. Leaf Apex (x63), f. Leaf Base (x75), g. T.S of Stem, h. T.S of Leaf and j. Magnified part of T.S of Leaf showing costa.

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