Eco. Env. & Cons. 30 (October Suppl. Issue) : 2024; pp. (S449-S459)
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ISSN 0971–765X

DOI No. http://doi.org/10.53550/EEC.2024.v30i06s.066

A comparative study on morpho-anatomical characters of eight *Huperzia* species from Arunachal Pradesh, India

M. Hossain[1], S. Sukul*[2] and V.K. Rawat[3]

[1]Shyamsundar College, Bardhaman Road Via Pahalanpur, Shyamsundar 713 424, W.B., India
[*2]Department of Botany, Visva-Bharati (A Central University), Santiniketan 731 235, W.B., India
[3]Arunachal Pradesh Regional Centre, Botanical Survey of India, Sankie View, Post Box No.-27, Itanagar 791 111, Arunachal Pradesh, India

(Received 8 June, 2023; Accepted 22 August, 2023)

ABSTRACT

Morphology and anatomy of eight species of *Huperzia* from Arunachal Pradesh was studied here. Following the PPG1 classification the genus *Huperzia* belongs to the subfamily Huperzioidae under the family Lycopodiaceae of the order Lycopsida which falls under the class Lycopodiopsida. The genus is a medium size evergreen plant with a vertical or ascending stem, with linear toelliptical leaves which are smooth-edged and spores are formed within the sporophylls. Scanning Electron Microscopic studies of the spores were also done. On the basis of all these observations keys to the species were prepared.

Key words: *Morpho-anatomy, Spore morphology, Huperzia, SEM study.*

Introduction

Huperzia Brenh. (*Sensu stricto*) is a genus of Lycophyte plants, commonly known as tassel ferns, or sometimes as the fir mosses or fir club mosses (Yumkham and Singh, 2011). This species has traditionally been included in the genus *Lycopodium* L. However, the trend in recent treatments has been to place them in a separategenus which possesses approximately 55 species having temperate, alpine, andarctic regions and tropical habitats (Holub, 1985; 1991 Zhang and Iwatsuki, 2013). In Korea and northeast China, four recognized taxa are included in the genus (Sun, 2007; Zhang and Iwatsuki, 2013), whereas eight taxa in Japan (Iwatsuki *et al.*, 1995), and five taxa in Far East Russia (Kharkevich, 2002). As many as 415 speciesare reported worldwide, from the tropics to the Artic and Sub - Antarctic zonesand from sea level to alpine environments (Singh and Singh, 2010). About 20 species and two varieties of tassel ferns are reported from India (Ghosh *et al.*, 2004). They are epiphytes found in moist forests and rainforests at high altitudes in and amongst mosses and other angiosperms epiphytes. Sometimes, it also grows in terrestrial and lithophyte conditions, including moist infertile soils in and around swamps and depressions (Yumkham and Singh, 2011).

The genus *Huperzia* is characterized by the stiffness of stems and sporangia at the axils of fertile leaves and the presence of gemma and gemmiferous branchlets (Boivin, 1950; Wagner and Beitel, 1992, 1993; Sun, 2007; Zhang and Iwatsuki, 2013). Tassel ferns are regarded as one of the most valued orna-

([1]Assistant Prof., *[2]Associate Prof., [3]Scientist E and Scientist-In-Charge)

mental species worldwide and have medicine and pharmaceutical product values that have already established in Chinese herbalism (Singh and Singh, 2010). It also shows anti-oxidant activity and treats contusions, strains, swellings, schizophrenia, and my asthenia gravis (Chang and But, 1987; College, 1985; Ma, 1997; Sun *et al.,* 1999).

Based on a specimen collected from Jilin Province of China, Ching (1981) described a new variety, *H. lucidula var. asiatica* Ching, that differentiated from *H. lucidula* by having more reflexed, darker green, comparatively smaller leaves than the latter. A new species, *Lycopodium javanicum* Sw. [= *Huperzia javanica* (Sw.) C. Yang] described by Swartz (1801) that possess lanceolate or obovate leaves with dichotomously branched stems. Later, Makino (1898) named the same as *L. serratum var. javanicum*. Likewise, Spring (1850) described *L. serratum var. longipetiolatum* Spring as a new variety with leaves whose petioles are narrowed down towards the base. Ching (1981) treated the same taxonas *L. serratum* Thunb., while Yang (1982) recognized it as adistinct species, *H. petiolate* (Spring) C. Yang, emphasizing that it has long petiolate leaves.

For the present study, plant specimens are collected inwild form from different places in Arunachal Pradesh, and the study is the first attempt in Arunachal Pradesh. Nothing has ever been published, written, ordocumented on different species of *Huperzia*.

Study Area

Arunachal Pradesh belongs to the Eastern Himalayan Ranges (26º 28' to 29º30, N and 91º 30' to 97º30' E) on the country's northeastern tip. Arunachal Pradesh occupies the most extensive area (83.743 sq. Km) in the northeastern region of India and consists of mountainous ranges sloping to the plains of Assam. The total human population of 8,64,558 (1991 census) lives in 3649 villages and small towns. The cattle population of the State is 9 lakhs (1991 census). As per the State of Forest Report, 1999 of Forest Survey of India, about 82% of the total geographical area of 83,740 sq. km., which is about 62% of the total geographical area and includes 10185.40 sq. km. of Reserve and Protected Forests which is about 12% of the area while the Protected Area Network covers an area of 9527.99 sq. km being 12% of the area and balance 38% is Unclassified Forest. The State contributes about 20% species of the country's total fauna. It possesses 4500 species of flowering plants and 400 species of pteridophytes, 23 species of conifers, 35 species of bamboos, 20 species of canes, 52 *Rhododendron* species and more than 500 species of orchids. It is considered one of the 12 mega-diversity "Hot Spots" in the world. The topographical and climatic conditions of the State favoured this luxuriant growth of forests which are home to myriad plant and animal forms, adding beauty to the landscape. Living in this incredible cradle of nature are the colourful and vibrant tribes of Arunachal Pradesh, for whom the forests and wildlife are of particular significance.

Materials and Methods

This study is based on herbarium specimens (Table 1) and personal collections from different parts of the study area of Arunachal Pradesh and about 13 herbarium specimens were collected and examined. Morphological characters were studied with the help of a light microscope, and measurements were made. Anatomical studies were limited to leaf morphology, stomata, stem morphology, stellar types, sporangium, and spores. Sporangia are collected from the dried specimen and spores are observed under (microscope name) for detail study followed by Devi, 1977 and Punt *et al.,* 2007 for palynological terminology.

Table 1. Locality and voucher specimen of the sampled specimen in the present study:

Species names	Location	Voucher
Huperzia arunachalensis (D.D.Pant & P.S.Pandey) Fraser-Jenk.	Mayedie Pass	-
Huperziahamiltonii (Spring ex Hook. & Grev.) T.Sen & U.Sen	Dampa Tiger Reseve	14820
Huperziaherteriana (Kumm.) T.Sen & U.Sen	Tawang	
Huperzia phlegmaria (L.) Rothm.	Goseng Village	20707
Huperzia pulcherrima (Wall. ex Hook. & Grev.) Pic.Serm.	Mahao Lake	-
Huperzia squarrosa (G.Forst.) Trevis.	Raga to Zero	17118
Huperzia javanica (Sw.) C.Y.Yang	IT road	20369
Huperzia bucahwangensis Ching	Tayalicampon Kamin-Hapoli road	-

Results and Discussions

Huperzia Bernh., in Schrader, J. Bot. 1800(2): 126. 1801.

Lectotype (Rothmaler, Feddes Rep. 54: 59. 1944): *Huperzia selago* (L.) Bernh. ex Schrank and Mart. (as *Lycopodium selago* L.).

Taxonomic treatment: Although many *Huperzia* species were transferred to *Phlegmariurus* by Ching, and thence in the Flora of China (2013), there is no consistent or significant morphological separation between the two and molecular differences in the absence of morphological divergence cannot be of much taxonomic significance or value. L.B. Zhang and Iwatsuki (Flora of China 2-3. 2013) attempted to separate them by smaller size, an erect and terrestrial versus pendent and epiphytic habit and other such insignificant differences, which clearly break down even in the Chinese species. Only *Huperzia* is recognised here, as in most literature.

1. *Huperzia arunachalensis* (D.D. Pant and P.S. Pandey) Fraser-Jenk., in Fraser-Jenkins, Kandel and Pariyar, Ferns Fern-Allies Nepal: 45. 2015 (12.4.2015), non Mazumdar and Mukhopadhyay (Bionature (Bhopal) 34(2): 33-35. 2016 ("2014")).

Holotype: From N.E. India, Arunachal Pradesh, *Lycopodium arunachalensis*, Sewak Pass, Lohit Division, about 5700 ft.-6200 ft. a.s.l., *P.S. Pandey* 2101-2103, in 1978. "All three numbers taken off a single [c]lump, P.S. Pandey, Holotype", a single sheet, Herb. Feroze Gandhi College, Rae Bareli [ex. herb. Allahabad Univ.].

Lycopodium arunachalense D.D.Pant and P.S. Pandey, PhytaMonogr. 3: 11-13, t. 3A, pl. 1A. 1985 (as "arunachalensis").

Lycopodium sahnii D.D. Pant and P.S. Pandey, Phyta Monogr. 3: 16, t. 10A. 1985.

Description: [Fig. 1]. Stem slender, leaf bases covering the stem. T. S. of stem shows single layered epidermis followed by homogeneous parenchymatous cortex that limited inner side with single layered endodermis. Pericycle followed by endodermis and single layered, stele actinostele, exarch. Leaves arise on the stem at the very beginning of the soil surface. Microphylls lanceolate (3-4mm x 0.5mm), entire, acute, spirally arranged, sessile broad base, very densely arranged, stomata anomocytic, Stomatal Index 7.30 (Table 2). Leaves are arranged compactly to form a crown-like structure at the stem tip of the stem. Sporophylls are restricted in numbers in between 6-9 nodes below a certain distance from the apical vegetative leaves. Sporangium reinform, with a short stalk, yellowish in color, arises at the adaxial base of leaf.1mm in diameter.Spores globose, trilete, granulose.

Habit: Terrestrial, herbaceous grass-like.

Habitat: Amidst mosses on the rock surface

Distribution: Arunachal Pradesh, Sikkim, West Bengal [Asia: Bhutan, China, Nepal, Tibet].

Taxonomic treatments: Fraser-Jenkins, Kandel and Pariyar (2015) erroneously described the upper sporophylls as usually having very small teeth. This species is similar in size to *H. erubescens*(Brack.) Holub (syn.: *H. somae*(Hayata) Ching, *H. rubricaulis* ["*rubicaulis*"] S.K.Wu and X.Cheng, non (Alderw.) Holub) from China (Yunnan), Japan, Taiwan, the Philippines and Hawai'i), which is a further species distinct from *H. arunachalensis* in its narrower leaves and even smaller stature. *H. rubricaulis* was erroneously synonymised within *H. arunachalensis* by

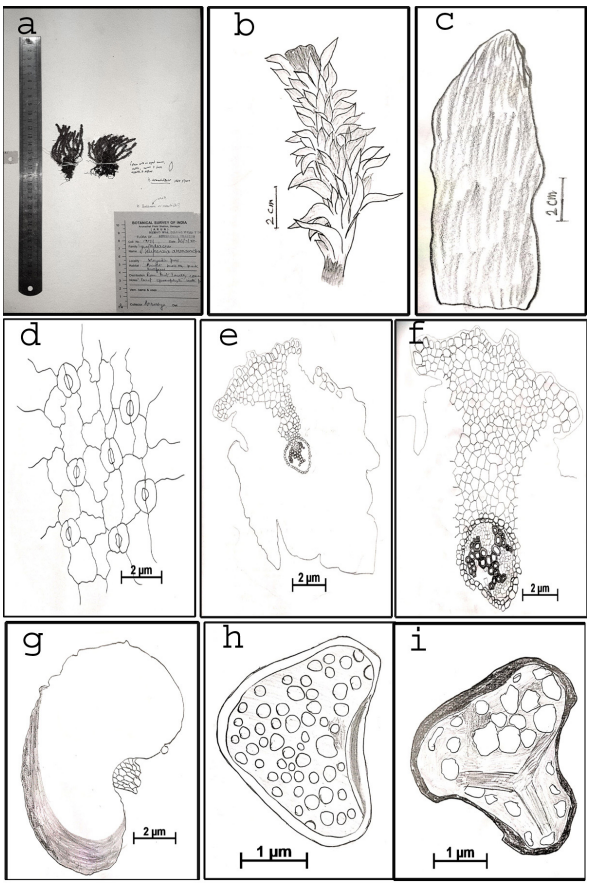

Fig. 1. a. habit; b. habit sketch; c. vegetative leaf; d. stomata; e& f. T. S. of; g. sporangium h. spore distal view;i. spore proximal view.

Fraser-Jenkins, Kandel and Pariyar (2015). Both species are generally similar to *H. ceylanica*, but are consistently smaller and have entire leaves. *H. arunachalensis* is also distinct in its deflexed leaves. It was misplaced under the name *H. vorwerkii* (Nessel) Holub, a synonym of *H. ceylanica*, by Mazumdar (Phytotaxa 226(1): 99-100. 2015) without seeing either the type or protologue of *H. arunachalensis*. A recent request for a decision concerning the very evident homonymy of the misspelt "*H. rubicaulis*", the name referring to the pink stem, by Chen, Hai and Zhang (Taxon 65(5): 1184-1185. 2016) with *H. rubricaulis* did not mention the present correction of the synonymisation of "*H. rubicaulis*" already informed in advance to L.B. Zhang by CRFJ, which renders the issue of minimal significance.

2. *Huperzia hamiltonii* (Spreng.) Trevis., Atti Soc. Ital. Sci. Nat. 17: 248. 1874.

Holotype: From Nepal, [Kathmandu District], Narainhetty, *F. Buchanan* [*Hamilton*], 28.12.1802, BM).

Lycopodium obtusifolium Buch.-Ham. ex D.Don, Prodr. Fl. Nepal. 18-19. 1824, non Sw. 1806.
Lycopodium hamiltonii Spreng., Linnaeus Syst. Veg., ed. 16, 5: 129, 428. 1828, nom. nov. for *L. obtusifolium* Buch.-Ham. ex D.Don.
Urostachys hamiltonii (Spreng.) Herter ex Nessel, Die Bärlappgew. 68. 1939.
Phlegmariurus hamiltonii (Spreng.) Á.Löve and D.Löve, Taxon 26(2-3): 324-326. 1977.
Huperzia hamiltonii (Spreng.) T.Sen&U.Sen, Fern Gaz. 11(6): 419.1978, isonym.
Phlegmariurus hamiltonii (Spreng.) L.B.Zhang, Fl. Reipubl. Pop. Sin. 6(3): 42. 2004, isonym.
Lycopodium aloifolium Wall. ex Grev. and Hook., Bot. Misc. 2: 367. 1831.
Huperzia aloifolia (Wall. ex Grev. and Hook.) Trevis., Atti Soc. Ital. Sci. Nat. 17: 248. 1874.
Urostachysaloifolius (Wall. ex Grev. and Hook.) Herter ex Nessel, Die Bärlappgew. 70: 1939.
Phlegmariurus aloifolius (Wall. ex Grev. and Hook.) A.R.Field and Bostock, Phyto Keys 20: 36. 2013.
Lycopodium empetrifolium Dalzell, J. Bot. Brit. For. 4: 113. 1852.
Lycopodium hamiltonii Spreng. var. *petiolatum* C.B. Clarke, Trans. Linn. Soc. Lond., 2 Bot., 1: 590, 593. 1880 (as "petiolata").
Lycopodium petiolatum (C.B.Clarke) Baker, Handb. Fern-Allies 9. 1887.
Urostachys hamiltonii var. *petiolatus* (C.B.Clarke) Herter ex Nessel, Die Bärlappgew. 68. 1939.
Huperzia petiolata (C.B.Clarke) R.D.Dixit, J. Bombay Nat. Hist. Soc. 77(3): 541. 1981 ("1980").
Phlegmariurus hamiltonii var. *petiolatus* (C.B.Clarke) Ching, Act. Bot. Yunnan. 4(2): 126-127. 1982.
Phlegmariurus petiolatus (C.B.Clarke) H.S. Kung and L.B. Zhang, Act. Phytotax. Sin. 37(1): 45. 1999.
Urostachyspetiolatus Herter ex Nessel, Die Bärlappgew. 196. 1939 (non *L. hamiltonii* var. *petiolatum* C.B.Clarke).

Description: (Fig. 2). Stemslender dichotomously forked. T. S. of stem shows single layered epidermis followed by homogeneous parenchymatous cortex that limited inner side with single layered endodermis followed by single layered pericycle. Stele fragmented, exarch. Leavesentire (10-15 mm x 3-4mm), oblanceolate, with a short petiole-like structure, acute, sporophylls are arises from the branching of the stem. Stomata anomocytic type, Stomatal Index-7.35 (Table 2). Sporangium sessile, kidney shaped. Spores are globose, trilete granulose.

Habitat: Epiphytes

Habit: Terrestrial, epiphytic

Distribution: Arunachal Pradesh, Assam State, Chhattisgarh, Goa, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Sikkim, Tamil Nadu, Uttarakhand, West Bengal [Asia: Bhutan, China, Myanmar, Nepal, Sri Lanka, Thailand, Tibet, Vietnam].

Taxonomic Treatments: Although the S. Indian *H.*

Table 2. Stomatal Index of the species studied:

Specimen name	Stmatal index
Huperzia arunachalensis(D.D.Pant & P.S.Pandey) Fraser-Jenk.	7.30
Huperziahamiltonii (Spring ex Hook. & Grev.) T.Sen & U.Sen	7.35
Huperziaherteriana (Kumm.) T.Sen & U.Sen	5.51
Huperzia phlegmaria (L.) Rothm.	10.30
Huperzia pulcherrima (Wall. Ex Hook. & Grev.) Pic.Serm.	2.14
Huperzia squarrosa (G.Forst.) Trevis.	9.5
Huperzia bucahwangensis Ching	4.31

aloifolia and the Himalayan *H. petiolata* both appear slightly distinct from *H. hamiltonii* in different ways, and have sometimes been treated as separate species (including by Fraser-Jenkins 2008, corrected by Fraser-Jenkins, Kandel and Pariyar 2015), they both widely and completely merge into it morphologically, often with two forms on the same plant. They are apparently conspecific growth forms of *H. hamiltonii* in contrast to their treatment in the Flora of China 2-3 (2013). Both represent narrower-leaved forms of the species, the latter obviously so. The conspecificity of "*H. aloifolia*"was supported in a detailed studyby Shrestha and Zhang (Indian Fern J. 31(1-2): 154-161. 2014).

The "*H. petiolata*" form, which is perhaps predominant in Meghalaya, was synonymised by Fraser-Jenkins (2008). It has often been confused and misreported as the Chinese and Japanese species, *H. fordii* (Baker) R.D.Dixit, which does not occur

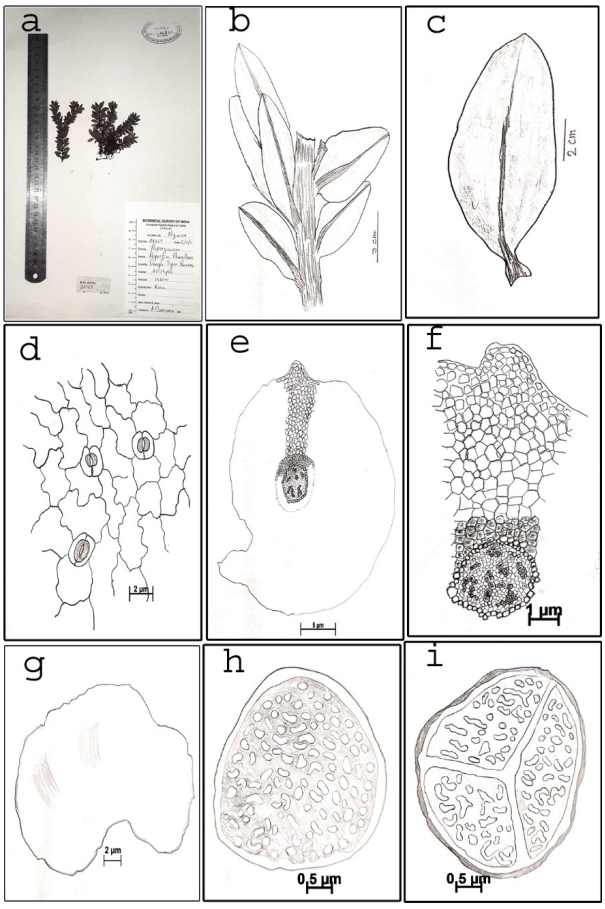

Fig. 2. a. Habit; b. Habit sketch; c. microphyll; d. stomata; e & f. T. S. of stem; g. sporangium; h. spore distal view;i. spore proximal view.

in India or the Indo-Himalaya, despite its report in the *Flora of China* 2-3 (2013), which was based on the erroneous report by Dixit (1987) from Sikkim. Mazumdar (Webbia 70(2): 289-291. 2015) continued to follow Fraser-Jenkins' (2008) erroneous separation of *H. aloifolia* and lectotypified it less appropriately from a specimen in BM instead of the one in Hooker's herbarium at K, but fortunately referring to the same taxon.

3. *Huperzia herteriana* (Kümmerle) T. Sen and U. Sen, Fern Gaz. 11(6): 415-417, t. 1, f. k-r. 1978 (as "herterana").

Holotype: From N.C. India, Sikkim, reg. temp., 10,000 ft., *J.D. Hooker* 374, P; isotype K.

Lycopodium sikkimense Herter, in Engler, Bot. Jahrb. Syst. 43(1): 42-43. 1909, non Müll.Hal. 1861.

*Urostachyssikkimensis*Herter ex Nessel, Die Bärlapgew. 52, t. 7, f. 1. 1939.

Lycopodium herterianum Kümmerle, Magyar Bot. Lapok 26: 99. 1928 (as "herteranum"), nom. nov. for *L. sikkimense* Herter.

Urostachysherterianus (Kümmerle) Herter, Estud. Bot. Reg. Uruguay 20: 64. 1949.

Huperzia herteriana (Kümmerle) T. Sen & U. Sen, Fern Gaz. 11(6): 415-417, f. 1, k-r. 1978 (as "herterana").

Urostachysthwaitesii Herter ex Nessel, Die Bärlappgew. 52. 1939, nom. nud.

Huperzia kamaensis Ching & S.K.Wu, Act. Bot. Yunnan. 3(3): 300. 1981.

Huperzia kamaensis Ching & S.K.Wu, in Wu, Flora Xizangica 1: 9. 1983, isonym.

Description: (Fig. 3). Root Creeping, stemslender, round in outline, erect, dichotomously branched and a dichotomy arises at a certain point of the stem. Stem diameter 2-3 mm. T. S. of stem shows single layered epidermis followed by thick-walled hypodermis; upper cortex made up of thick-walled parenchymatous cells without intercellular spaces that followed by thin-walled angular parenchymatous inner cortex. Endodermis single layered and pericycle layer absent. Stele exarch, star shaped. Leaves are lanceolate, entire, and sessile, with two leaves at each node and arranged in an opposite decussate manner, vegetative leaves are slightly larger in size (10-11mm x 1-3mm) than fertile leaves (5-8mm x 1mm), and leaves are slightly broader at the middle than base and apex. At the apical portion of the stem, leaves are arranged in a rosette structure. Stomata anomocytic type and stomatal Index is 5.51 (Table 2). Sporangium kidney-shaped, short stalked,

present at the base of each sporophyll. Sporophylls are present at a certain length of the stem not up to the apical tip of the stem. Sporophylls are restricted to 6-9 nodes in fertile branches.Spores trilete, tetrahedral with sinuous margin, fine granulose.

Habit: Plant terrestrial, herbaceous grass-like.

Habitat: On soil and also on trees along with mosses.

Distribution: Arunachal Pradesh, Manipur, Sikkim, West Bengal[Asia: Bhutan, China, Myanmar, Nepal, Tibet]. A report from Uttarakhand was in error for *H. hamiltonii*.

4. *Huperzia phlegmaria* (L.) Rothm., Feddes Repert. Spec. Nov. Regni Veg. 54: 62. 1944.

Syntypes: from South India and Sri Lanka, "Habitat in Malabaria, Zeylona" Dillenius, Hist. Musc. t. 61, f. 5 (1741).

Lycopodium phlegmaria L., Sp. Pl. 2: 1101. 1753.

Lepidotis phlegmaria (L.) P.Beauv., Prodr. Aethéogam. 109. 1805.

Urostachysphlegmarius (L.) Herter ex Nessel, Die Bärlappgew. 215. 1939.

Phlegmariurus phlegmaria (L.) Holub, Preslia 36(1): 21. 1964.

Phlegmariurus phlegmaria (L.) U.Sen & T.Sen, Fern Gaz. 11(6): 421, f. 4a-j. 1978, isonym.

Huperzia phlegmaria (L.) Panigrahi, Higher Plants Indian Subcont, add. ser. Indian J. Forest. 7, 4: 109. 1993, isonym.

Lycopodium filiforme Wall. ex Roxb., in Griffith, Calcutta J. Nat. Hist. 4: 473. 1844, non Sw.

Description: (Fig.4). Sten slender, dichotomously branched, reproductive branches produce vegetative branches on the tip later on. T. S. of stem shows single layered epidermis followed by thick-walled parenchymatous upper cortex without intercellular spaces that followed by thin-walled angular parenchymatous inner cortex. Endodermis single layered and pericycle layer absent. Stele exarch, protostele, xylem strand broken up. Leaflanceolate, alternate, acute, truncate base, present throughout the stem, short petiolate. Stomata anomocytic, Stomatal Index 10.3 (Table 2). There is a distinct differentiation in vegetative and fertile leaves, Vegetative leaves much broader than fertile leaf. Sporangium adaxial, at the base of the fertile leaf, kidney shaped, stalked. Spore globose, trilete granulose.

Habit : Epiphyti

Distribution: Andaman and Nicobar Islands, Arunachal Pradesh, Assam State, Karnataka, Kerala, Meghalaya, Nagaland, Sikkim, Tamil Nadu, Tripura, West Bengal [Asia: Bangladesh, Bhutan, Cambodia, China, Japan, Laos, Malaysia, Myanmar, Nepal,Sri Lanka, Thailand, Tibet, Vietnam; Pacific Islands; Africa; Australasia: Australia].

5. *Huperzia pulcherrima* (Wall. ex Hook. and Grev.) Pic.Serm., Webbia 24(2): 719. 1970.

Lectotype (Mazumdar, Webbia 70(2): 289-291. 2015): from Nepal, *N. Wallich* [Num. List no.] 115, Herbarium Hookerianum, K.

Lycopodium pulcherrimum Wall. ex Hook. & Grev., Icon. Fil. 1(2): 38, t. 79. 1827.

*Lycopodium setaceum*Buch.-Ham. ex D.Don var. *pulcherrimum*(Wall. ex Hook. and Grev.) C.B.Clarke, Trans. Linn. Soc. Lond., 2 Bot., 1: 590. 1880.

Urostachyspulcherrimus (Wall. ex Hook. and Grev.) Herter ex Nessel, Die Bärlappgew. 72, t. 11, f. 9. 1939.

Phlegmariuruspulcherrimus (Wall. ex Hook. and Grev.) Á.Löve and D.Löve, Taxon 26(2-3): 324. 1977.

Huperzia pulcherrima(Wall. ex Hook. and Grev.) T.Sen and U.Sen, Fern Gaz. 11(6): 417. 1978, isonym.

*Lycopodium setaceum*Buch.-Ham. ex D.Don, Prodr. Flor. Nepal. 18. 1824, non Lam. 1789.

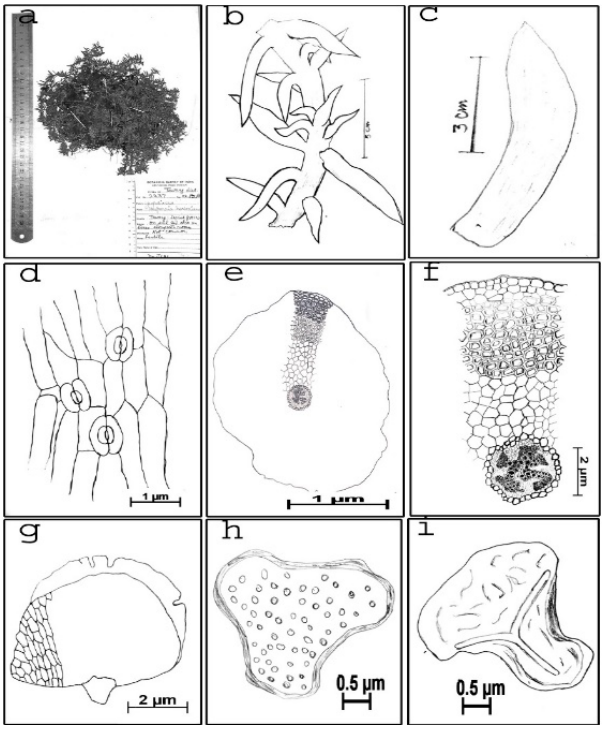

Fig. 3. a. Habit; b. Habit sketch; c. microphyll; d. stomata; e & f. T. S. of stem; g. sporangium; h. spore distal view;i. spore proximal view.

Huperzia setacea Trevis., Atti Soc. Ital. Sci. Nat. 17: 248. 1874.

Urostachyssetaceus (Trevis.) Herter ex Nessel, Arch. Bot. São Paulo 1: 408. 1927.

Huperzia setacea (Trevis.) Rothm., Feddes Repert. Spec. Nov. Regn. Veg. 54: 61. 1961, isonym.

Lycopodium subulifolium Wall. ex Hook. and Grev., Icon. Fil. t. 49. 1831.

Huperzia subulifolia (Wall. ex Hook. and Grev.) Trevis., Atti. Soc. Ital. Sci. Nat. 17: 248. 1875.

Urostachyssubulifolius (Wall. ex Hook. and Grev.) Herter, Estud. Bot. Reg. Uruguay 20: 84. 1949.

Huperzia subulifolia (Wall. ex Hook. and Grev.) T.Sen & U.Sen, Fern Gaz. 11(6): 417. 1978, isonym.

Huperzia subulifolia (Wall. ex Hook. and Grev.) Mandal & U. Sen, Biol. Mem. 3(2): 197. 1979 ("1978"), isonym.

Phlegmariurussubulifolius (Wall. ex Hook. and Grev.) S.R. Ghosh, in Ghosh *et al.*, Pterid. Fl. E. India 66. 2004 (as "subulifolia").

?*Huperziasubulifolia* (Wall. ex Hook. and Grev.) Trevis. var. *assamica* Mandal and U. Sen, Biol. Mem. 3(2): 225. 1979 ("1978"). (type not seen).

Description: (Fig.5). Roots densely arise at the lower or basal portion of the stem, profusely branched. Stemslender, dichotomously branched, leaves densely cover the whole plant. T. S. of stem shows single layered epidermis followed by thick-walled parenchymatous upper cortex without intercellular spaces that followed by thin-walled angular parenchymatous inner cortex. Endodermis single layered and pericycle layer absent. Stele exarch, protostele, xylem strand broken up.Leaveslinear (9-12mm x 0.5mm) entire, acute, arranged spirally, sessile, leaf-base broad, densely arranged. Stomata anomocytic sparsely distributed. Stomal Index 2.14 (Table 2). Sporophylls are the same as vegetative leaves, arise certain portion of the stem not to the entire body of the stem. Sporangium develops at the base of the

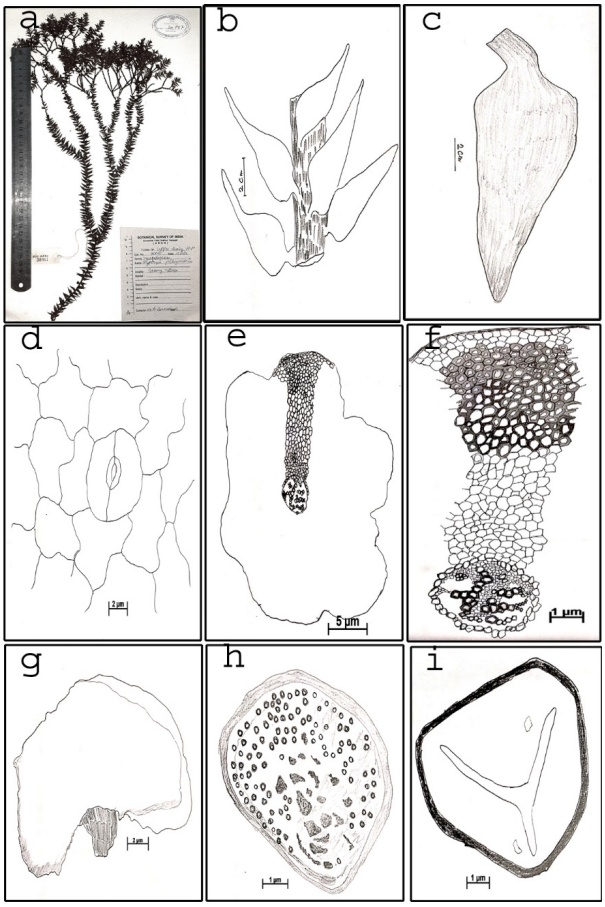

Fig. 4. a. Habit; b. Habit sketch; c. microphyll; d. stomata; e & f. T. S. of stem; g. sporangium; h. spore distal view;i. spore proximal view.

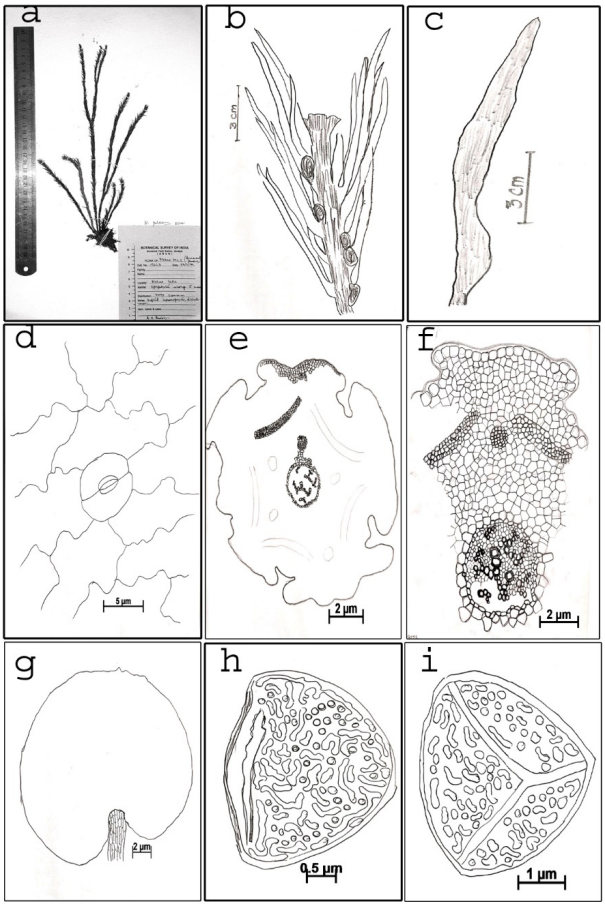

Fig. 5. a. Habit; b. Habit sketch; c. microphyll; d. stomata; e & f. T. S. of stem; g. sporangium; h. spore distal view;i. spore proximal view.

sporophylls, arises on dichotomize branches. Spores triangular with rounded edges, trilete, regulate.

Habitat: Epiphytic along with mosses

Distribution: Arunachal Pradesh, Himachal Pradesh, Manipur, Meghalaya, Sikkim, Uttarakhand, West Bengal [Asia: Bhutan, China, Myanmar, Nepal, Sri Lanka, Tibet].

Taxonomic treatments:*H. subulifolia* and *H. pulcherrima* have traditionally been treated as separate species, but appear to be merely individual forms due to growth habit, the former having longer, pendent branches and being epiphytic. *H. subulifolia*is the commoner C. and E. Indo-Himalayan and Chinese form, from Uttarakhand eastwards to Meghalaya, Myanmar, Tibet and China, though overlooked in the Flora of China (2013). The records of *H. pulcherrima* in PE from east China are *H. cryptomerina*, but *H. pulcherrima* (*H. subulifolia*form) occurs in Yunnan (det. C.R. Fraser-Jenkins). The type of *H.pulcherrima* belongs to the same form as the longer, narrow-leaved, epiphytic and pendent plant redescribed as *L. subulifolia*.

6. *Huperzia squarrosa* (G.Forst.) Trevis., Atti Soc. Crittog. Ital. 17: 247. 1875.

Type: from Tahiti: "Otahaiti, *J.* &*G. Forster*", BM, P.

*Lycopodium squarrosum*G.Forst., Fl. Ins. Austr 86. 1786.

Plananthussquarrosus (G.Forst.) P.Beauv., Prodr. Fam. Aethéogam. 112. 1805.

Huperzia squarrosa(G.Forst.) Trevis., Atti Soc. Ital. Sci. Nat. 17: 247. 1874.

Urostachyssquarrosus (G.Forst.) Herter, Bot. Archiv 3: 14. 1923.

Huperzia squarrosa(G.Forst.) Rothm., Feddes Rep. Spec. Nov. Regn. Veg. 54(1): 62. 1944, isonym.

Phlegmariurussquarrosus (G.Forst.) Á.Löve&D.Löve, Taxon 26(2-3): 324. 1977.

*Lycopodium ulicifolium*Vent. ex Sw., Syn. Fil. 177. 1806.

Phlegmariurusulicifolius(Vent. ex Sw.) S.R.Ghosh, in Ghosh et al., Pterid. Fl. E. India 1: 64. 2004.

*Lycopodium hookeri*Wall. ex Hook. & Grev., Icon. Fil. t. 183. 1831.

*Lycopodium lohitense*D.D.Pant&P.S.Pandey, PhytaMonogr. 3: 26, 29, t. 13A. 1985 (as "lohitensis").

Description: (Fig. 6). Stem erect, slender, covers with dense leaves, dichotomously branched, the fertile branch dichotomizes further. T. S. of stem shows single layered epidermis followed by 2-3 layered hypodermis. The outer cortex thick-walled parenchymatous without intercellular spaces that followed by thin-walled angular parenchymatous inner cortex. Endodermis single layered followed by many layered pericycle. Stele plectostele type, xylem exarch.Leaves (20mm x 1.5mm) lanceolate acute, margins toothed,sessile, broad base morphologically different from fertile leaves (5-7mm x 1mm) that are comparatively smaller in size. Stomata anomocytic type and Stomatal Index 9.5 (Table 2). Leaves are spirally arranged. Sporophylls are arise from the dichotomizes of the stem extended up to the tip.Sporangium arises at the base of the sporophylls. A single sporangium arises at each base of the sporophyll. Sporophylls broad base completely covers the sporangium. Sporangium is kidney or tosome globe in shape.Spore trilete, regulate.

Habitat: Epiphytes

Distribution: Andaman & Nicobar Islands,

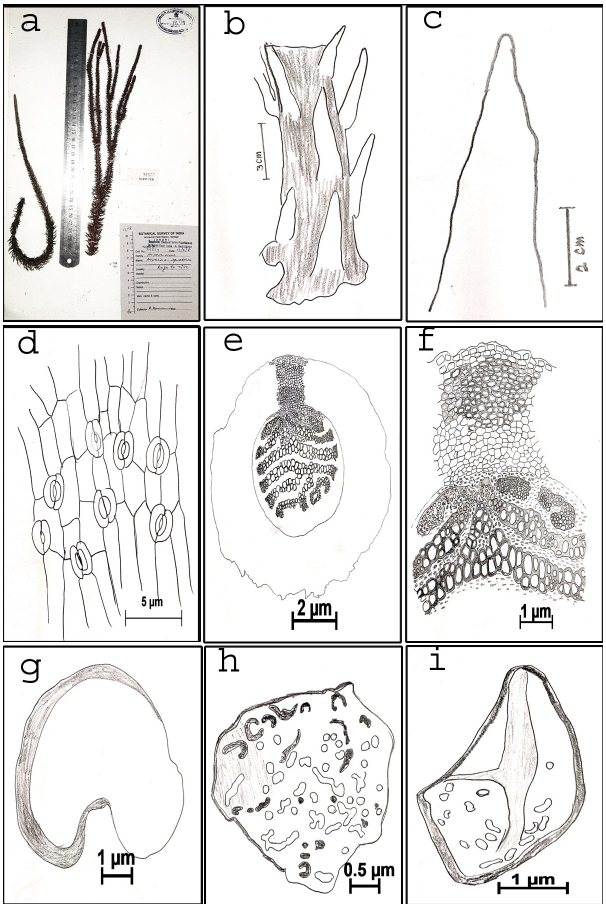

Fig. 6. a. Habit; b. Habit sketch; c. microphyll; d. stomata; e & f. T. S. of stem; g. sporangium; h. spore distal view;i. spore proximal view.

Arunachal Pradesh, Assam State, Kerala, Meghalaya, Manipur, Meghalaya, Mizoram, Myanmar, Nagaland, Odisha, Sikkim, Tripura, West Bengal [Asia: Bangladesh, Bhutan, Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Taiwan, Thailand, Tibet; Australasia: Australia; Pacific Islands; Africa: Madagascar, Mascarenes, Seychelles].

Taxonomic treatments: Ghosh *et al.* (2004) treated this species in India as if a separate species, *H. ulicifolia*, making a new combination. But during the monsoon Indian plants have similarly squarrose, exserted leaves at 90° or sometimes a little more to the stem as in S.E. Asian and Pacific Island plants, though closing somewhat during the dry season. While some slight genetic differences are only to be expected to occur geographically between the Himalaya and Pacific Isles, this does not imply they are separate species and there is no acceptable morphological basis for separating them. Mazumdar's (Webbia 70(2): 289-291. 2015) citation of others' work on such findings in Australia did not justify his treating the two as different species. The morphology of Indian plants was described by him incorrectly while also overlooking Dixit's (1987) previous lectotypification of *L. ulicifolium* from the same Ventenat specimen in Swartz' herbarium (at S), originating not from India, but S.E. Asia, most probably Indonesia.

7. *Huperzia javanica* (Sw.) C.Y.Yang, Bull. Acad. Military Med. Sci. 13(5): 368. 1989.

Type: from Indonesia, Java, *C.P. Thunberg*,UPS.

Lycopodium javanicum Sw.,in Schrader J. Bot. 1800(2): 114. 1801 (as "iauanicum").

Lycopodium serratum var. *javanicum* (Sw.) Makino, Bot. Mag., Tokyo 12: 13. 1898.

Urostachysjavanicus (Sw.) Herter, Estud. Bot. Reg. Uruguay 20: 66. 1949.

Huperzia javanica(Sw.) Fraser-Jenk., Taxon. Revis.

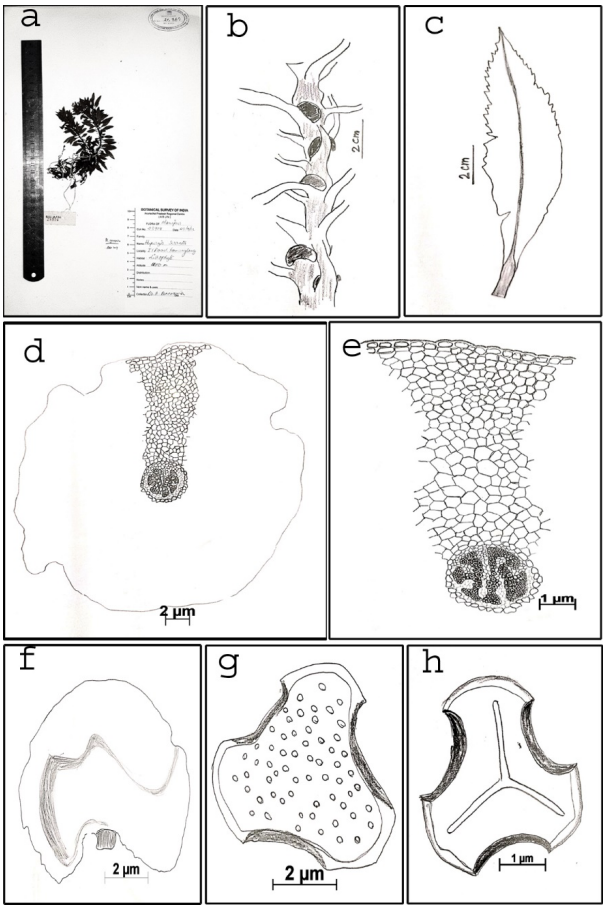

Fig. 7. a. Habit; b. Habit sketch; c. microphyll; d&e. T. S. of stem; f. sporangium;g. spore distal view;h. spore proximal view.

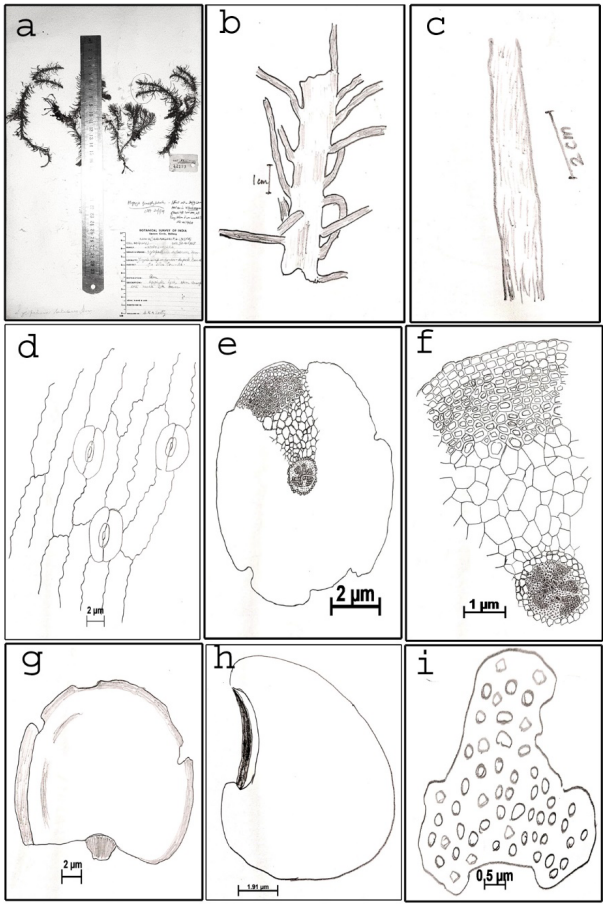

Fig. 8. a. Habit; b. Habit sketch; c. microphyll; d. stomata; e & f. T. S. of stem; g. sporangium; h. spore distal view;i. spore proximal view.

Indian Subcontinental Pteridophytes 220. 2008, isonym.
Huperzia indica S.R. Ghosh, Pterid. Fl. E. India 51-53, Fig. 7. 2004, nom. inval. herbarium not stated.

Description: (Fig.7). Stemslender, branched, dichotomy starts at the very beginning, just above the soil surface, and leaves are clothed throughout. T. S. of stem shows single layered epidermis followed homogeneous cortex made up of thin-walled angular parenchymatous cells without any intercellular spaces. Endodermis single layered followed by single layered pericycle. Stele actinostele but xylem broken up and exarch. Leaves lanceolate (25-30 mm x 4-5mm.), margin serrate, apex acuminate, and leaf margins at the base fuse together to form a long petiole-like structure. Sporophylls arise on second dichotomy of stem branches. Sporangium kidney shaped with a very short stalk. Arises at the adaxial side of the leaf. Spores trilete, tetrahedral, granulose.
Habitat: Lithophytes and terrestrial

Distribution: Arunachal Pradesh,Assam State, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tamil Nadu, West Bengal [Asia: Bhutan, China, Indonesia, Malaysia, Myanmar, Philippines, Sri Lanka, Thailand, Tibet].

Taxonomic treatment: Close to and usually treated as a synonym of *H. serrata*, but differs rather consistently in its longer leaves with less toothed bases and is a more subtropical, S.E. Asian species of the complex. *H. indica* S.R. Ghosh is a poorly developed, exposed plant of this species.

8. Huperzia bucahwangensis Ching, Act. Bot. Yunnan. 3(3): 301. 1981.
Holotype: from China, N.W. Yunnan, Taron - Taru Divide, Valley of Bucahwang, upon back of tree, 2400 m., *T.T. Yü* 20132, 4.9.1938, PE.
Huperzia kingdonwardiana Fraser-Jenk., Indian J. Forestry 38(4): 1-2, t. 1 a, b. 2015.
Stem: Slender, dichotomously branched, covers with densely placed leaves near to the soil surface up to the tip.
Description: (Fig.8). Stem: Slender, dichotomously branched, covers with densely placed leaves near to the soil surface up to the tip. T. S. of stem shows single layered epidermis followed homogeneous cortex made up of thin-walled angular parenchymatous cells without any intercellular spaces. Endodermis single layered followed by single layered pericycle. Stele actinostele xylem exarch. Leaveslinear or needle-like (8-15 mm x 0.5-0.8 mm), entire, alternate, densely arranged. Stomata anomocytic type and Stomatal Index 4.31(Table 2). Sporophylls form at the branching point of the stem which does not reach up to the tip. Sporangium kidney shaped with very short stalk, yellowish and arises onadaxial side of leaf.Spores trilete, granulose.

Habitat: Epiphytic, on the tree trunk

Distribution: Arunachal Pradesh [Asia: Myanmar, Tibet].

Taxonomic treatment: Previously reported from India by Dixit (1987) and thence in the Flora of China (2013), sub *Phlegmariurus*, as *H. cryptomerina* (Maxim.) R.D. Dixit (repeated as Ching ex H.S. Kung and L.B. Zhang (Flora of China 2013) in error. This species was then reported by Fraser-Jenkins and Benniamin (2010) as the closely related *H. quasipolytrichoides* (Hayata) Ching, from Taiwan, but was redetermined by Fraser-Jenkins at the BM in 2012 as a new species, *H. kingdonwardiana*, in prep., being obviously more robust and with longer, narrower, often more deflected leaves than *H. quasipolytrichoides*. However, Fraser-Jenkins subsequently studied the type of *H. bucahwangensis* in PE in 2.2016 and immediately identified it as being conspecific, thus placing *H. kingdonwardiana* into its synonymy.

Key to the species

1a. Trophophylls lanceolate……..2
1b. Trophophylls not lanceolate……3
2a. Trophophylls entire, spores triangular in shape----------5
2b. Trophophylls dentate, spores sub-triangular in shape……..…***H. javanica*** **(1)**
5a. Stele starshaped……6
5b. Stele not star shaped……7
6a. Trophophylls arranged spirally…… ***H. arunachalensis*** **(2)**
6b. Trophophylls opposite decussate…….…… ***H. herteriana*** **(3)**
7a. Stele plecto-stele type.…… ***H. squarrosa*** **(4)**
7b. Stele dissected protostele.…….…. ***H. phlegmaria*** **(5)**
3a. Trophophylls obovate..…….…. ***H. hemiltonii*** **(6)**
3b. Trophophylls linear, margin entire…… 4
4a. stele star shaped; spores semi-circular…….... ***H. bucahwangensis*** **(7)**
4b. Stele dissected protostele, spores triangular……..…. ***H. pulcherima*** **(8)**

Acknowledgements

The authors are grateful to the Head, UGC-DRS-SAP & DST-FIST sponsored Department of Botany, Visva-Bharati, Santiniketan for providing laboratory facility to conduct the work. The authors are also sincerely thankful to the Scientist in Charge, APRC, BSI for proving herbarium facility to fulfil this work.

Conflict of Interest

The authors fully agree that there is no conflict of works for the present study.

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