

VARIATIONS IN SPORE AND SPORANGIUM SURFACE STRUCTURE OF THE FERN-ALLIES LYCOPODIACEAE P. BEAUV. EX MIRBEL IN MALAYSIA

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Abstrak: Tiga puluh dua spesies, termasuk sebelas variasi daripada tiga genera dari famili Lycopodiaceae dijumpai di Malaysia telah dikaji morfologi sporanya dengan menggunakan mikroskop imbasan elektron. Genera yang berbeza menunjukkan morfologi spora dan corak pada permukaan spora dari pandangan distal yang berbeza. Jenis foveolat dan fosulat merupakan ciri khas corak pada permukaan spora dari pandangan distal bagi genus *Huperzia* manakala jenis retikulat adalah ciri genus *Lycopodium* dan jenis rugulat genus *Lycopodiella*. Satu kajian awal dinding sporangium telah dijalankan dan ianya bererti dari segi taksonomi.

Kata kunci: spora, dinding sporangium, SEM, mirip paku-pakis, Lycopodiaceae

Abstract: Thirty-two species, including eleven varieties from three genera of Lycopodiaceae found in Malaysia were examined for their spore's wall morphology using scanning electron microscopy. Different genera showed different spore morphologies and distal face ornamentation. Foveolate and fossulate types of distal face ornamentation were the characteristics of the genus *Huperzia*, while the reticulate types were characteristic of the genus *Lycopodium* and the rugulate type of the genus *Lycopodiella*. A preliminary study of the sporangium wall was also carried out in this study and is strongly taxonomically correlated.

Keywords: Spore, Sporangium Wall, SEM, Fern-Allies, Lycopodiaceae

INTRODUCTION

Fossils of fern-allies are known from as far back as the Silurian period (Piggott 1979). Fossils remain are found in rocks of the Paleozoic estimated to be at least 250 million years old (Correll 1956). They reached their greatest proliferation and development during the Carboniferous period (Correll 1956; Jones *et al.* 1984) in the Paleozoic era, which is around 300 million years ago (Piggott 1979).

Fern-allies, as a group, not only exhibit a tremendous range in habit but also in their habitat requirements (Correll 1956). The club mosses proper (Lycopodiaceae) is a large and widespread group (Jermy & Camus 1991). On the whole, most of these are terrestrial on mountains throughout the world or epiphytic in tropical areas and require abundant moisture and at least partial

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shade (Correll 1956). Some Lycopodiaceae are erect shrubby plants, or they may have a trailing or creeping habit, grow on rocks in full sun and often withstand extremely adverse condition (Correll 1956; Foster & Gifford 1959; Jermy & Camus, 1991; Øllgaard 1992).

The club mosses are small, vascular plants, basically dichotomously branching and reproduce sexually by spores. The sporophytes are small and herbaceous (Parihar 1973) consisting of true roots, an aerial stem and scale-like leaves called microphylls. These are small and spirally arranged on an elongated stem. The spores are of one size and generally borne singly in the axils of specialised leaves (sporophylls) that are often aggregated into cone-like strobili similar to or different in shape and size to sterile leaves. The sporophylls may be aggregated into definite strobili or in zones on the stem (Parihar 1973; Jermy & Camus 1991).

The Lycopodiaceae *sensu lato* is an ancient and probably monophyletic family without close living relatives and has a virtually cosmopolitan distribution (Øllgaard 1992). The estimated number of species ranges from approximately 300 to more than 400 around the world (Wikström and Kenrick 2001). The estimated number of species worldwide for both *Lycopodium* and *Lycopodiella* is about 40 (Wikström & Kenrick 2000b) and the estimated number of species of *Huperzia* is 300 (Wikström & Kenrick 2000a).

Lycopodiaceae spores are reproductive structures produced in the sporangia. Normal spores form in groups of four in most fern-allies. They have two basic shapes: subspherical to somewhat triangular in outline with 3-armed suture (trilete) (Lellinger 1985) for both recent and fossil spores (Wilce 1965). Trilete spores result when the four nuclei in a spore mother cell lie equidistant from one another in the form of a tetrahedron. The sutures form on the faces where the spores contact each other as they form (Lellinger 1985). In some species, however, spores are ornamented on both surfaces with a network of ridges termed *muri* (Wilce 1965).

The spores of *Lycopodium* germinate to produce a tiny, short-lived, peg-shaped gametophyte. Germination generally takes a considerable length of time and the percentage of germination is low (Whittier 1977; 1981; Whittier & Webster 1986). In some species, the spores germinate without delay, while still on the surface of the ground, but in others there may be a delay of many years (Sporne 1962). According to Whittier (1998), spores of the Lycopodiaceae need to be in the dark for a long time before they germinate and most species do not germinate until they have been in the dark for three months. The spores of Lycopodiaceae usually form an association with a fungus and some species have lost their photosynthetic capacity and rely on the fungus to provide the carbohydrate as food source.

For almost a century, no comprehensive studies were conducted on the family Lycopodiaceae in Malaysia. There is no up-to-date taxonomic revision on this family and there is a need to investigate the taxonomic status of the family. The last taxonomic work in Malaysia was made by Ridley in 1919. Realising Lycopodiaceae are not well known in Malaysia in terms of its taxonomy, a complete, extensive and detailed study was conducted to identify a set of proposed key characters to distinguish species of Lycopodiaceae. This paper

only highlights a part of the tools in taxonomic study of the family Lycopodiaceae in Malaysia.

Data from scanning electron microscope (SEM) studies supply an additional dimension to the nature and diversity of the major features of the wall (Tryon & Tryon 1982). The morphological characters of the spore such as size and ornamentation vary between species within the same genus and are important in delimiting genera and species in Lycopodiaceae. An investigation on the structure of the surface and wall of the spores of *Huperzia*, *Lycopodium* and *Lycopodiella* found in Malaysia was carried out to determine the variations found between the genera as well as variations within each genus. This investigation conducted as support and giving more information as it is providing good characters in delimiting species as well as genera besides the macro morphological characteristics.

MATERIALS AND METHODS

The spores and sporangia used for examination were obtained from the herbarium specimens or fresh materials collected from various localities in Malaysia (Appendix 1). Spores and sporangia were air-dried before being transferred onto aluminium stubs using double-sided tape and coated with gold. Observations were made using a Phillips XL 30 Scanning Electron Microscope at the microscope unit, Universiti Kebangsaan Malaysia.

RESULTS AND DISCUSSION

Spore Surface and Shape

Table 1 summarizes the spore characteristics observed in species of Lycopodiaceae. Spores in Lycopodiaceae are tetrads (Plate 1) of the trilete type, with a triradiate aperture in all species but both trilete and monolete are found in *Lycopodiella cernua* var. *crassifolium* (Plate 2). The monolete spores are also found in *Huperzia* spp. according to Jones and Blackmore (1988). The tetrad spores in most species of the genus *Huperzia* are subglobose in shape except for all the terrestrial *Huperzia* as in *H. australiana*, *H. beccarii* (Plate 3), *H. serrata* and *H. goliathensis*. Trilete spores are regarded as the primitive type because they occur earlier in the fossil record (Chaloner 1970; 1976; Gensel 1980)

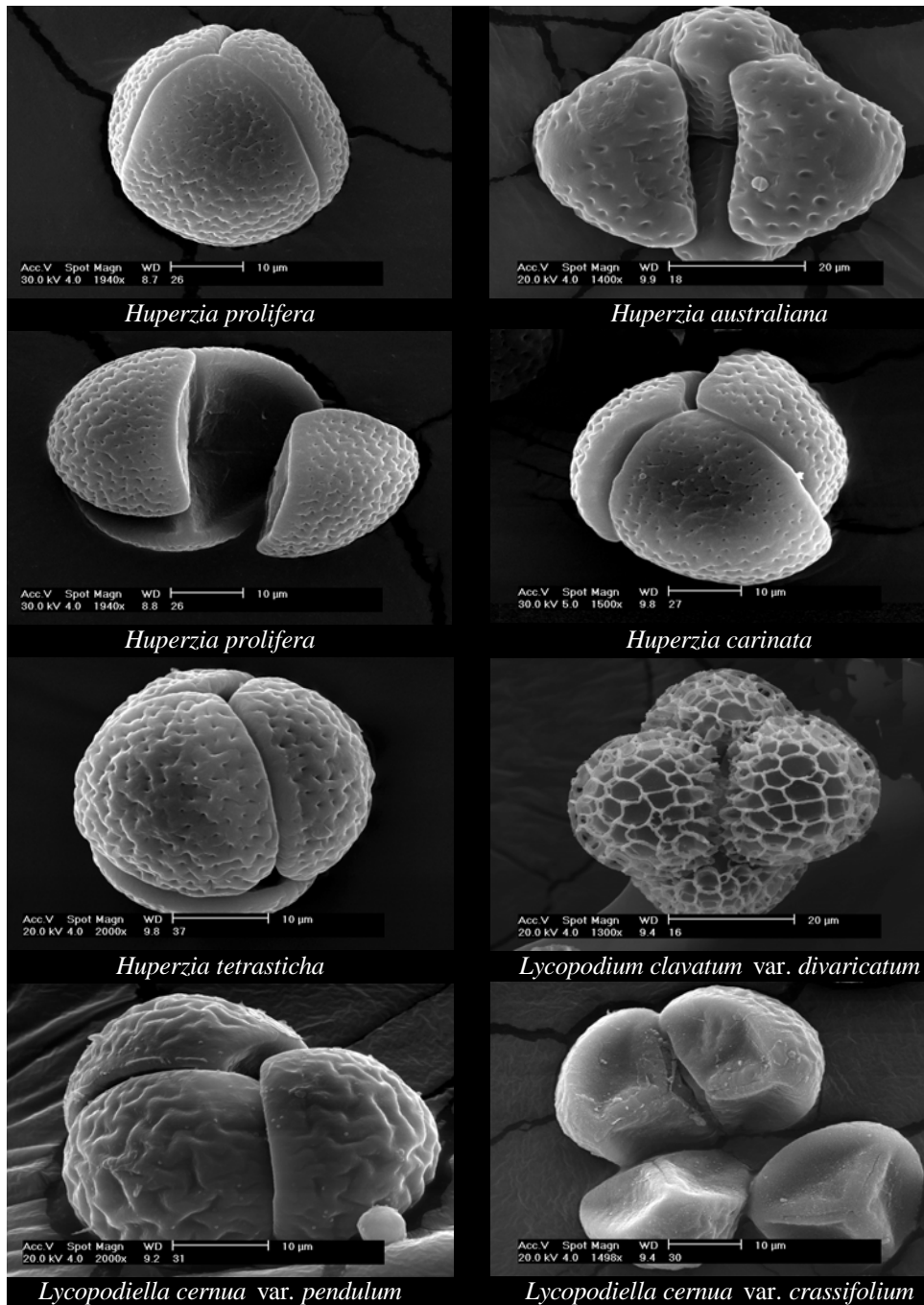


Plate 1: Spores of Lycopodiaceae in tetrad association.

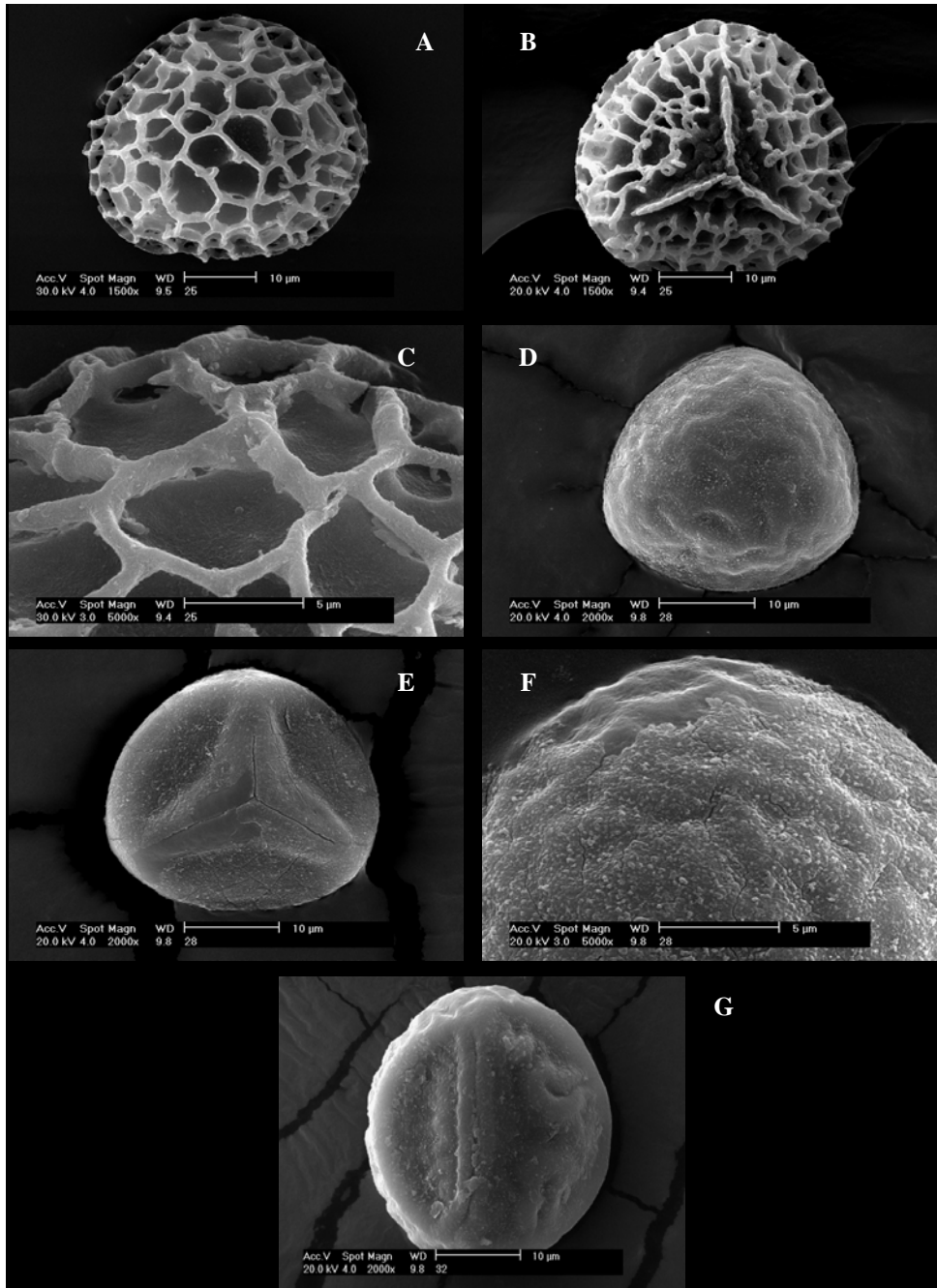


Plate 2: Spores of Lycopodiaceae from polar view. A, B, C: *Lycopodium casuarinoides*; D, E, F: *Lycopodiella cernua*; G: *Lycopodiella cernua* var. *crassifolium*. A & D are distal faces; B, E, G are proximal faces; C & F are detail of surface of distal faces.

Four distinct spore surface types in Lycopodiaceae were recognized from this study. The foveolate and fossulate types were the characteristic of the genus *Huperzia*, while the reticulate types were the characteristic of the genus *Lycopodium* and the rugulate type of the genus *Lycopodiella*. Differences in the spore surfaces are related to the type and time of gametophyte development (Øllgaard 1985; 1987). The same result also observed in Lycopodiaceae by Tryon and Lugardon (1990) and Bidin *et al.* (2002). Based on morphology observation, genus *Huperzia* and *Lycopodiella* have sessile strobilus while stalked in branchlet systems in *Lycopodium*. Moreover, in *Huperzia* and *Lycopodiella*, strobili of various length and thickness are borne at the apex of the branches and are diagnostic for the genera. Genus *Huperzia* mostly found as epiphyte on tree trunk or branches but some species are terrestrial erect or lithophytic. *Lycopodiella cernua* is a creeper but sometimes the branches are climbing while genus *Lycopodium* is a creeper except for *L. casuarinoides* and *L. volubile*, which are climbing.

The foveolate or fossulate surface of *Huperzia* was very consistent. Among the *Huperzia* spp. the proximal faces were smooth except in *H. australiana* (Plate 3) and *H. goliathensis*, which are foveolate. The distal face was fossulate in *H. dalhousiana* (Plate 5) and *H. verticillata* (Plate 4), foveolate-fossulate in *H. phlegmarioides* (Plate 5) while in the rest of the species studied it was foveolate. The spore shape in *Huperzia* varied from subtriangular to subglobose. The terrestrial *Huperzia* spores had truncate lobes with concave areas between them similar to those from the *Selago* group (Tryon & Lugardon 1990) as in *H. australiana* and *H. beccarii* (Plate 3), *H. goliathensis* and *H. serrata*. These terrestrial erect *Huperzia* were found at altitude 700 m and above except for *H. australiana* which was observed only at 1800 m at Mount Kinabalu, Sabah. All these terrestrial *Huperzia* also formed bulbils at the apex but the amount of bulbils depending on the species and ecology.

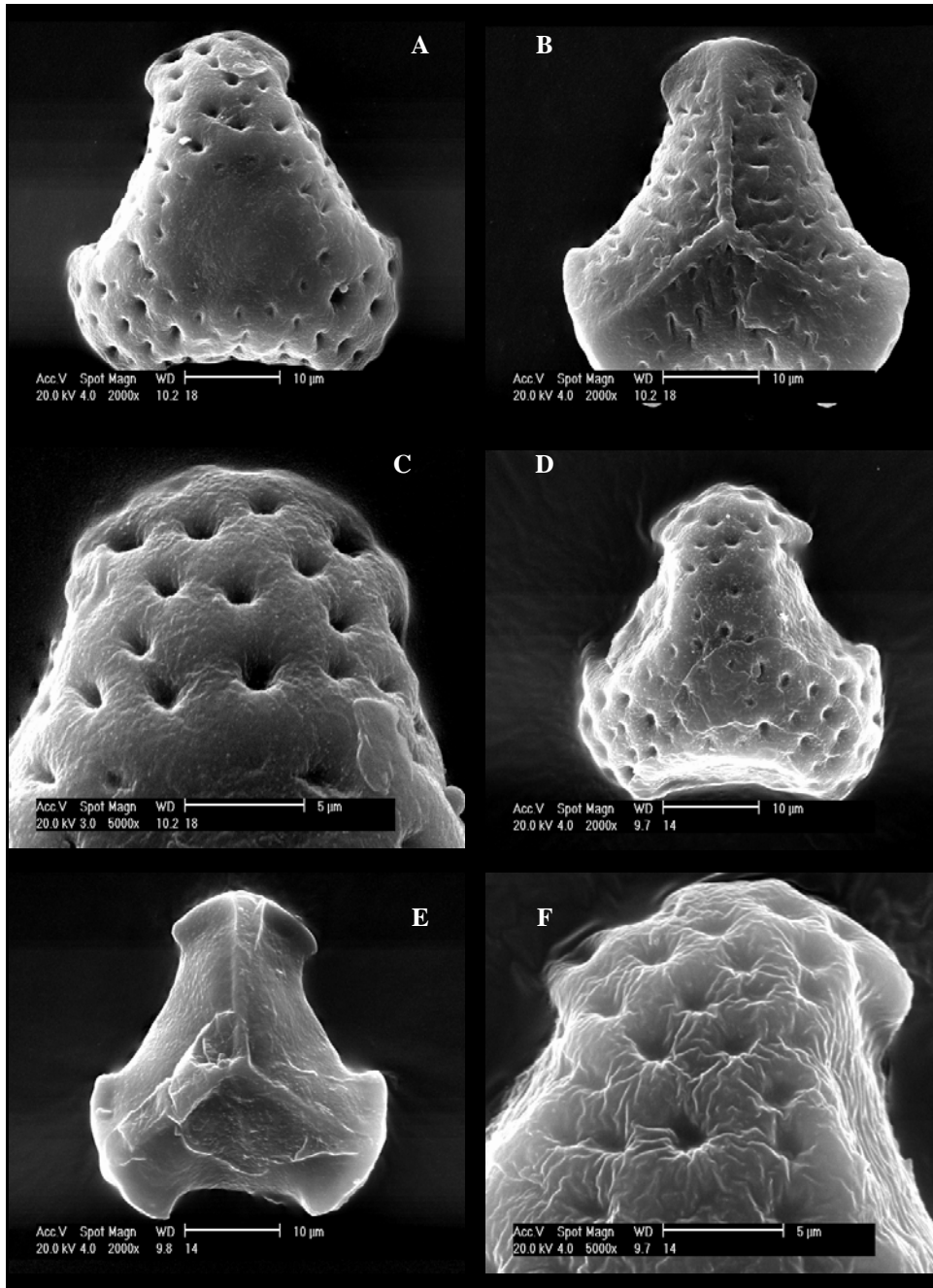


Plate 3: Spores of Lycopodiaceae from polar view. A, B, C: *Huperzia australiana*; D, E, F: *Huperzia beccarii*. A & D are distal faces; B & E are proximal faces; C & F are detail of surface of distal faces.

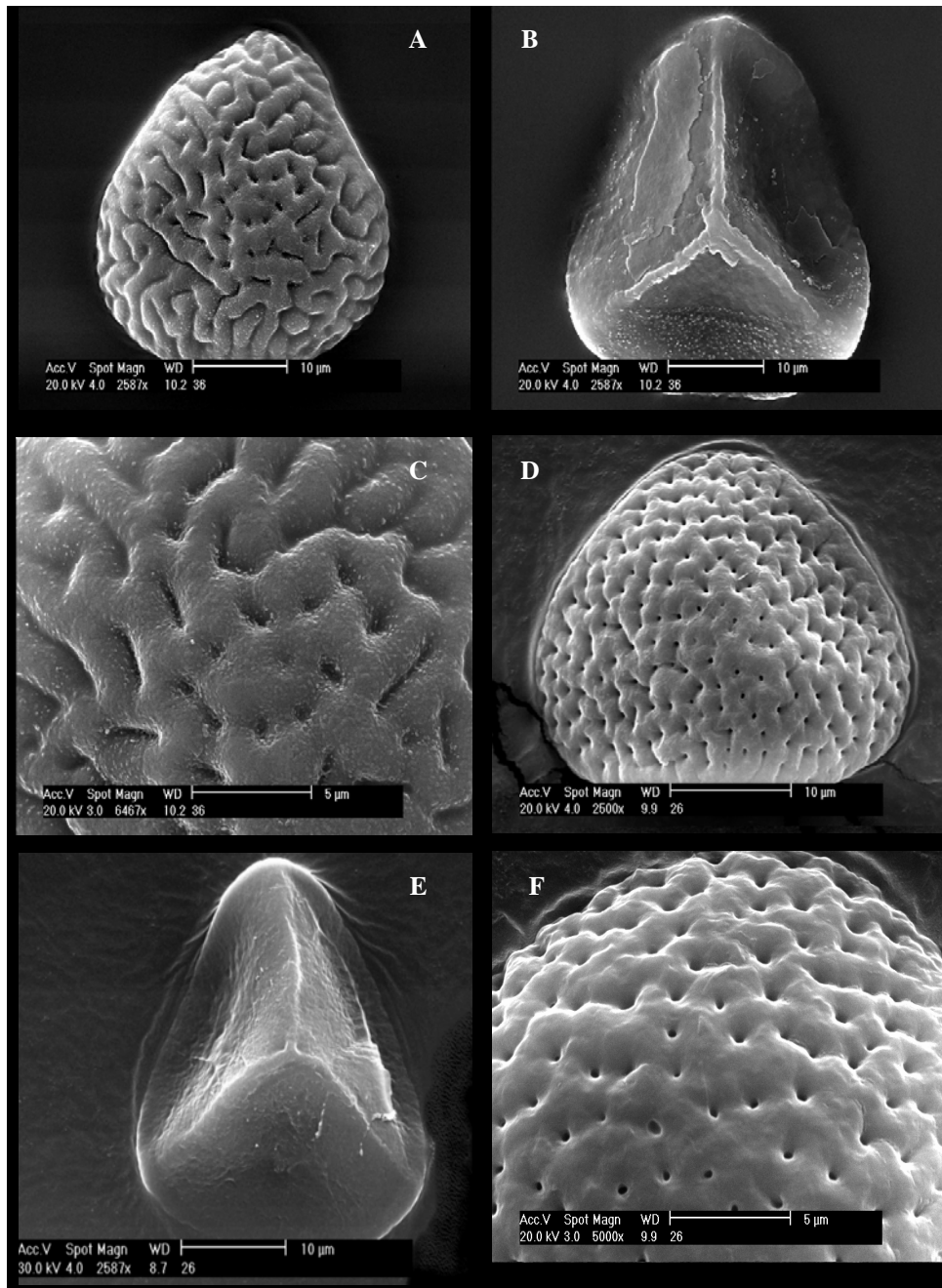


Plate 4: Spores of Lycopodiaceae from polar view. A, B, C: *Huperzia verticillata*; D, E, F: *Huperzia prolifera*. A & D are distal faces; B & E are proximal faces; C & F are detail of surface of distal faces

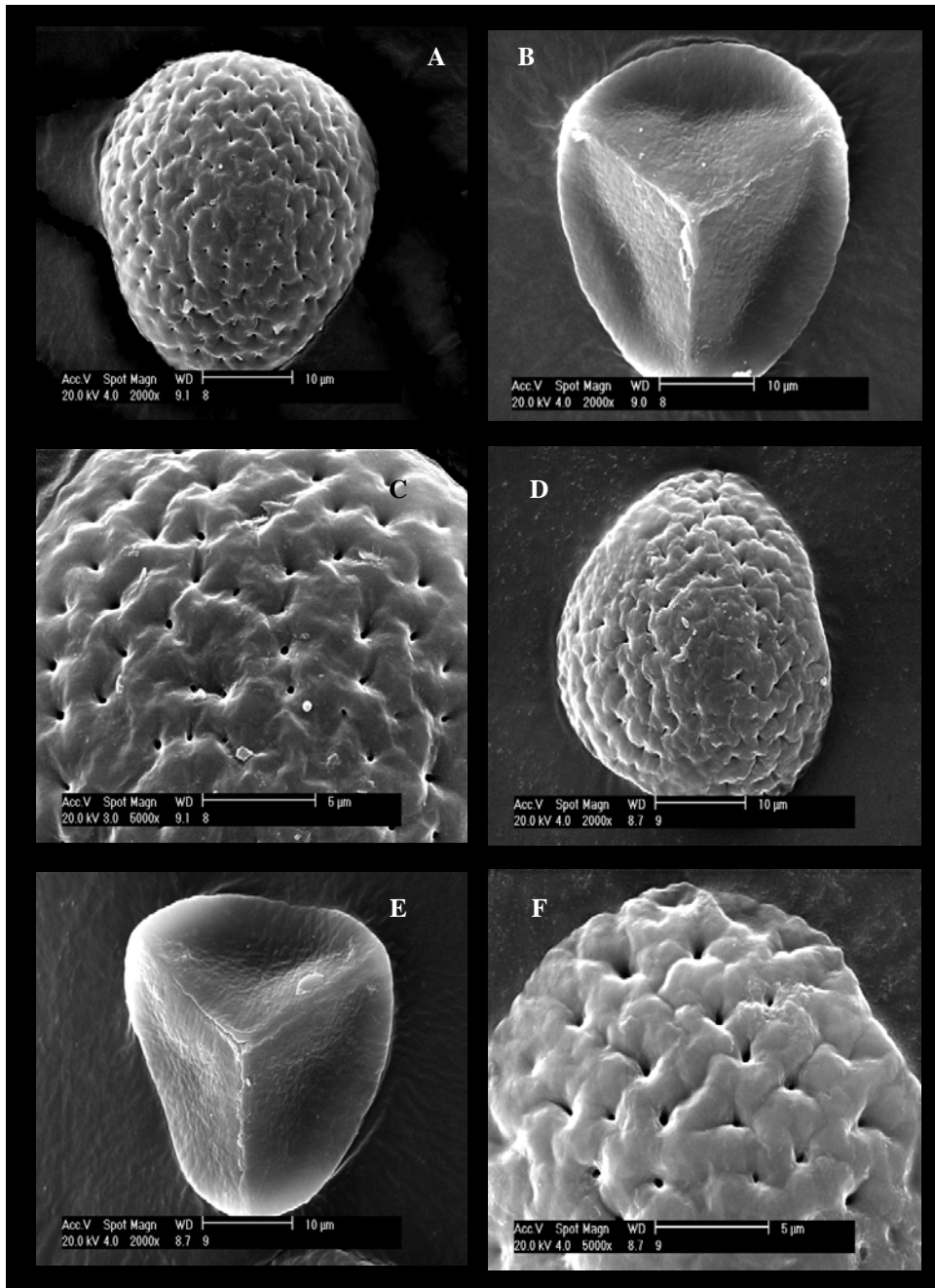


Plate 5: Spores of Lycopodiaceae from polar view. A, B, C: *Huperzia phlegmarioides*; D, E, F: *Huperzia dalhousiana*. A & D are distal faces; B & E are proximal faces; C & F are detail of surface of distal faces.

In *Lycopodium*, all species observed had reticulation on both proximal and distal faces. The reticulate type of ornamentation on the distal face was similar to those of the subgenus *Lycopodium* (Tryon & Tryon 1982). According to Tryon and Lugardon (1990), the reticulate elements were largely composed of lamellate exospore elaborated in the centripetal direction (towards the inside). The perispore formed the outer surface and was often the characteristic contour of the spores.

Lycopodiella and its four varieties showed no difference in terms of its distal and proximal face ornamentation. The distal face had rugulate surface and the proximal face is granular. The rugulate type of ornamentation in *Lycopodiella cernua* spores was reported to be characteristic of the genus (Tryon & Lugardon 1990). The spore shapes were spheroidal with a distinct equatorial flange.

Spore Size

The spore size reported here was based on the measurement of the longest axis, excluding the perispore, which was taken on the equatorial dimension illustrated by Erdtman (1965) and applied by Erdtman (1969; 1972) and Tryon and Lugardon (1990). The size of the spores in Lycopodiaceae ranged from 20.5–37.0 μm with spores of *Lycopodium clavatum* being the smallest and *Lycopodium* spp. the largest (Table 1). The spores of *Huperzia* ranged from 24.0–38.0 μm and the largest was *H. phlegmaria* var. *laxum*. In *Lycopodium*, the sizes ranged from 20.5–38.0 μm while among the *Lycopodiella*, *La. cernua* var. *crassifolium* was the largest (27.5–29.5 μm). The spore sizes reported here could be used for identification of species and varieties. Rusea (1993) and Bidin (1996) used spore size as one of the tools for classification and identification of *Tectaria* and *Adiantum*, respectively.

Table 1: Spore characteristics of Lycopodiaceae

SPECIES	CHARACTERS		
	Equatorial diameter (µm)	Distal face ornamentation	Proximal face ornamentation
<i>Huperzia australiana</i> (Herter) Holub	32.0 - 36.0	Foveolate	Foveolate
<i>H. beccarii</i> (Alderw.) Holub	29.0 - 31.5	Foveolate	Smooth
<i>H. goliathensis</i> (Alderw.) Holub	29.5 - 33.5	Foveolate	Foveolate
<i>H. serrata</i> (Thunb. ex Murray) Trevisan	30.5 - 34.0	Foveolate	Smooth
<i>H. carinata</i> (Desv. ex Poiret) Trevisan	25.0 - 31.0	Foveolate	Smooth
<i>H. dalhousiana</i> (Spring) Trevisan	29.0 - 32.0	Fossulate	Smooth
<i>H. nummulariifolia</i> (Bl.) Cham., Jer. & Crab.	27.5 - 31.0	Foveolate	Smooth
<i>H. phlegmaria</i> (L.) Rothm.	25.0 - 27.0	Foveolate	Smooth
<i>H. phlegmaria</i> var. <i>brachystachyum</i> Rosenb.	28.5 - 34.0	Foveolate	Smooth
<i>H. phlegmaria</i> var. <i>filiforme</i> Alderw.	24.0 - 29.5	Foveolate	Smooth
<i>H. phlegmaria</i> var. <i>latifolium</i> Alderw.	27.0 - 31.0	Foveolate	Smooth
<i>H. phlegmaria</i> var. <i>laxum</i> Blume	32.0 - 37.0	Foveolate	Smooth
<i>H. phlegmaria</i> var. <i>longifolium</i> Spring	27.5 - 31.0	Foveolate	Smooth
<i>H. phlegmaria</i> var. <i>ovatum</i> Alderw.	28.5 - 35.0	Foveolate	Smooth
<i>H. phlegmarioides</i> (Gaudich.) Rothm.	29.5 - 32.0	Foveolate - Fossulate	Smooth
<i>H. phyllantha</i> (Hook. & Arnott) Holub	27.0 - 30.0	Foveolate	Smooth
<i>H. pinifolia</i> Trevisan	24.0 - 29.0	Foveolate	Smooth
<i>H. prolifera</i> (Blume) Trevisan	26.0 - 32.0	Foveolate	Smooth
<i>H. squarrosa</i> (G. Forster) Trevisan	27.5 - 32.0	Foveolate	Smooth
<i>H. tetrasticha</i> (Kunze) Holub	25.0 - 29.5	Foveolate	Smooth
<i>H. verticillata</i> (L. f) Trevisan	29.0 - 34.0	Fossulate	Smooth
<i>Lycopodium casuarinoides</i> Spring	24.0 - 35.0	Reticulate	Reticulate
<i>L. clavatum</i> (L.) P. Beauv.	20.5 - 25.5	Reticulate	Reticulate
<i>L. clavatum</i> var. <i>divaricatum</i> Rac.	22.0 - 26.0	Reticulate	Reticulate
<i>L. platyrhizoma</i> Wilce	22.5 - 26.0	Reticulate	Reticulate
<i>Lycopodium</i> sp.	31.5 - 38.0	Reticulate	Reticulate
<i>L. volubile</i> G. Forster	27.5 - 33.0	Reticulate	Reticulate
<i>Lycopodiella cernua</i> (L.) Pichi-Serm.	26.0 - 29.0	Regulate	Granular
<i>La. cernua</i> var. <i>capillaceum</i> Spring	24.0 - 26.5	Regulate	Granular
<i>La. cernua</i> var. <i>crassifolium</i> Spring	27.5 - 29.5	Regulate	Granular
<i>La. cernua</i> var. <i>pendulum</i> Baker	21.5 - 26.0	Regulate	Granular
<i>La. cernua</i> var. <i>salakense</i> Alderw.	25.0 - 27.5	Regulate	Granular

Spore Apertures

The aperture is the most conspicuous feature of the spores (Tryon & Lugardon 1990). Apertures were usually the thinner parts of the spore-coat, which directly or indirectly, permit the living contents within the spores to come out, wholly or in part, when the spores germinate (Erdtman 1969). The aperture was defined as openings (Harris & Harris 1994) and the tetrad mark (Kremp 1965) was found mainly at the proximal face of the spores in Lycopodiaceae. It consisted of a projecting fold that in section appeared as a prominent ridge enveloping a narrow slit (Tryon & Lugardon 1990). The aperture in Lycopodiaceae was trilete in shape and was radially symmetrical with various sizes and shapes. Among the genera, *Lycopodium* has the most prominent aperture.

Sporangium Wall

Studies related to variations of the sporangium wall structure were few and not popular in Malaysia. Three species were studied, namely *Huperzia phlegmaria*, *Lycopodium clavatum* and *Lycopodiella cernua*.

According to Øllgaard (1975), the sporangium wall in Lycopodiaceae consists of two to several cell layers. Based on the observation of the sporangium wall (Plate 6), various patterns among the three species were observed. In *H. phlegmaria*, the sinuses were very shallow. This species was characterized by sinuate walls, which were thickened and lignified. In *L. clavatum*, the sporangium wall was conspicuously sinuate, lignified and thickened and similar to those of the *L. clavatum* group of species (Øllgaard 1975). The thickenings appeared Z-shaped or curled in *L. clavatum*. In *La. cernua*, the wall had buttress-like, semiannular or parallel half-ring lignified thickenings (Plate 6). The half-ring fork often forms an irregular, thickened plate on the wall. The sporangium walls of this species thus are strikingly different from the other two species.

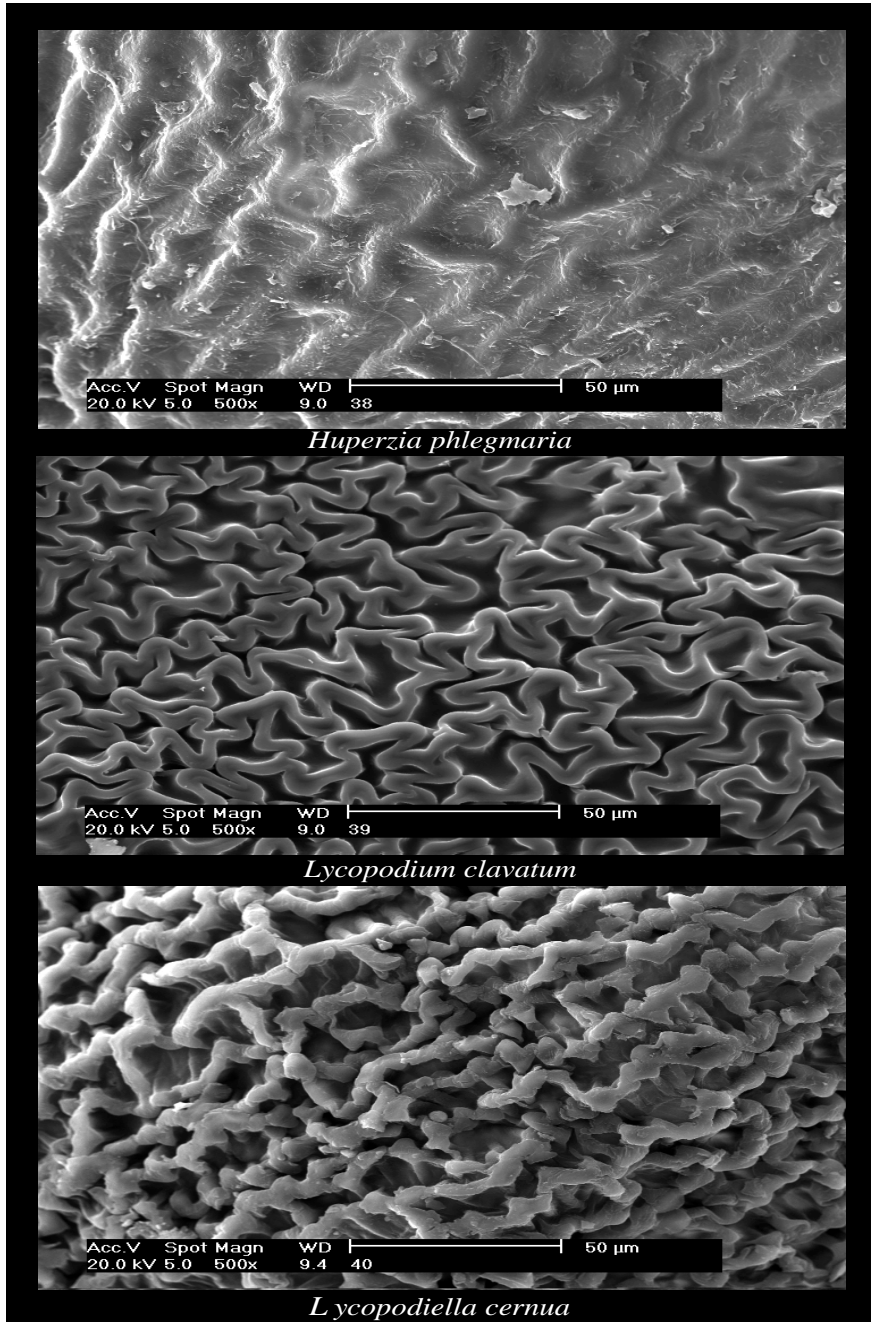


Plate 6: Sporangium walls of selected species of Lycopodiaceae

CONCLUSION

The spore morphology was useful for genus and species identification, and classification of Lycopodiaceae. All the spores in different genera have different spores in morphological type and shape based on distal and proximal face ornamentations. The spore size could also be used in the identification of species and some varieties. The distinct character observed in *H. australiana* and *H. goliathensis* was their foveolate surface at distal and proximal face ornamentations and both species are terrestrial erect at higher altitude with high humidity. Fossulate distal surface can be found in epiphytic *H. dalhousiana* with lanceolate leaves and *H. verticillata* with subcapillary leaves while foveolate-fossulate distal surface was distinctly observed in epiphytic *H. phlegmarioides*. Spore morphology was therefore useful for species and especially genus identification. Results obtained from this study support the classification made using macro morphological study, which was conducted at the same time. This additional information and observation give clearer picture in delimiting species and genera of the family Lycopodiaceae in Malaysia.

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Claysius Kongoi et al.

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Appendix 1. Specimens used in Spore and Sporangium Morphology study

Huperzia australiana

PAHANG: Cameron Highlands, G. Brinchang, *Ab. Samad, UKMB 00122*, 13. 8. 1970 (UKMB). **SABAH:** Ranau, Mt. Kinabalu, *Takashi Sato, Joseph Gasia, Benedict Paulus, UKMB 1381*, 24–26. 10. 1981 (UKMB, SNP); Near RTM, *Claysius Kongoi, CK 59*, 24. 5. 2002 (UPM).

H. beccarii

SABAH: Kinabalu Park, Sayat-sayat, 6500 ft., *Takashi Sato, 199*, 21. 2. 1981 (SNP); Mt. Kinabalu, along the trail to Panar Laban, 2100-2600 m, *Claysius Kongoi, CK 76*, 24. 5. 2002 (UPM).

H. carinata

PAHANG: Jeram Besu, *Claysius Kongoi, CK 24*, 21. 10. 2001 (UPM). **SARAWAK:** Kuching, Bengoh, G. Timurang Tengah limestone, *Claysius Kongoi, CK 42*, 9. 4. 2002 (UPM); G. Serad limestone, *Claysius Kongoi, CK 110*, 5. 4. 2002 (UPM).

H. dalhousiana

SABAH: Ranau, Kinabalu Park, *John H. Beaman, Reed S. Beaman & T. Lawrence Mellichamp, 7931*, 18. 12. 1983 (UKMB, SNP); Mountain Garden, 1600 m, *Claysius Kongoi, CK 50*, 23. 5. 2002 (UPM).

H. goliathensis

PAHANG: Cameron Highlands, *Kasim Rejab, s.n.*, 20. 12. 1970 (UKMB); G. Brinchang, 5900 ft., *Abd. Samad, UKMB 00143*, 13. 8. 1970 (UKMB). **SABAH:** Ranau, Kinabalu Park, Trail to Panar Laban, 2500 m, *Claysius Kongoi, CK 62*, 24. 5. 2002 (UPM).

H. nummulariifolia

PERAK: Taiping, Bukit Larut, *Claysius Kongoi, CK 29*, 20. 3. 2002 (UPM). **SABAH:** Lahad Datu, Danum Valley, Sg. Sabaran, 220 m, *R. Jaman & A. Bidin, RJ 2772*, 7. 6. 1989 (UKMB). **SARAWAK:** Padawan, G. Timurang limestone, *Claysius Kongoi, CK 34*, 8. 4. 2002 (UPM).

H. phlegmaria

SABAH: Kota Belud, Minodtuhan Trail, 1500 m, *R. Jaman, RJ 4068*, 7. 6. 1992 (UKMB). **SARAWAK:** Padawan, G. Timurang limestone, *Claysius Kongoi, CK 35*,

Claysius Kongoi et al.

8. 4. 2002 (UPM); Bengoh, G. Timungan limestone, *Claysius Kongoi*, CK 86, 6. 4. 2002 (UPM).

H. phlegmaria var. brachystachyum

PAHANG: Cameron Highlands, on the way down from Tanah Rata to the North-South highway, *Claysius Kongoi*, CK 91, 12. 1. 2002 (UPM). **SABAH:** Lahad Datu, near Sg. Segama, *Peter J. Edwards* 2079, 20. 2. 1986 (UKMB, SAN, SAR).

H. phlegmaria var. filiforme

PAHANG: Taman Negara, Sg. Kenyam, *Mohd. Itam*, AB 1668, 19. 10. 1982 (UKMB). **PERAK:** Taiping, B. Larut, *Claysius Kongoi*, CK 47, CK 90, 20. 3. 2002 (UPM).

H. phlegmaria var. latifolium

PAHANG: Cameron Highlands, *A. Samat*, s.n, 20. 12. 1970 (UKMB). **SABAH:** Ranau, Kinabalu Park, near Conservation office, *Claysius Kongoi*, CK 52, 23. 5. 2002 (UPM).

H. phlegmaria var. laxum

PAHANG: Cameron Highlands, *Zuriati*, s. n, 20. 12. 1970 (UKMB); *A. Latiff*, *A. Zainudin & Sani Miran*, ALM 945, 12. 9. 1985 (UKMB); Sam Poh Temple's Trail, *Claysius Kongoi*, CK 7, 1. 12. 2001; CK 93, 12. 1, 2002 (UPM). **JOHOR:** Endau, Labis F. R, Bukit Temambong, 690 m, *G. W. H. Davidson* 43, 13. 2. 1986 (UPM).

H. phlegmaria var. longifolium

PAHANG: Jeram Besu, *Claysius Kongoi*, CK 25, 21. 10. 2001 (UPM). **KEDAH:** G. Jerai, *Evans & Gordon*, s. n, Jun 1921 (SING).

H. phlegmaria var. ovatum

PAHANG: Cameron Highlands, G. Brinchang, *Willis R. Littke*, s. n, 3. 4. 1974 (UKMB); Near MARDI, *Claysius Kongoi*, CK 97, 12. 1. 2002 (UPM). **SABAH:** Ranau, Kinabalu Park, *Claysius Kongoi*, CK 53, 23. 5. 2002 (UPM).

H. phlegmarioides

PERAK: G. Hijau, *J. Sinclair & Kiah*, 38730, 14. 9. 1949 (SING). **PULAU PINANG:** *Mucker 15509*, 22. 9. 1924 (SING). **PERLIS:** B. Pelarit, *Claysius Kongoi*, CK 118, 31. 10. 2002 (UPM).

H. phyllantha

PAHANG: Central Pahang, South of Kuala Lompat Krau Game Reserve, *T. C. Whitmore, FRI 3565*, 16. 4. 1967 (SING, KEP). **KELANTAN:** Gua Musang, *Razali Jaman, RJ 1995*, 9. 10. 1985 (UKMB).

H. pinifolia

PAHANG: Cameron Highlands, B. Ruil, *Claysius Kongoi*, CK 102, 20. 7. 2002 (UPM). **SABAH:** Lahad Datu, Danum Valley, *Sukup Akin, Zainal Awang & Sani Gorudin, SA 2627*, 5. 5. 1992 (UKMB).

H. prolifera

PAHANG: Cameron Highlands, G. Brinchang, *A. Samat, UKMB 00151*, 25. 9. 1971 (UKMB); Sam Poh Temple's Trail, *Claysius Kongoi*, CK 11, 1. 12. 2001 (UPM). **PERAK:** Taiping, Bukit Larut, *Claysius Kongoi*, CK 77, 24. 5. 2002 (UPM).

H. serrata

PAHANG: Fraser's Hill, 2nd year student 1973/ 1974, *UKMB 03590*, 1. 7. 1973 (UKMB); Cameron highlands, Trail to G. Purdah, *A. Latiff, A. Zainudin & Sani Miran, UKMB 00145*, 12. 9. 1985 (UKMB); Parit fall, *Claysius Kongoi*, CK 1, 16. 9. 2001 (UPM). **SABAH:** Ranau, Kinabalu Park, Liwagu trail, *Claysius Kongoi*, CK 51, 23. 5. 2002 (UPM).

H. squarrosa

SABAH: Ranau, steep slopes and cliffs on SW side of Lohan River, *John H. Beaman, R. S. Beaman, John T. Atwood, Teofila E. Beaman, Libby Besse & Pamla Decker, 9050*, 24. 3. 1984 (UKMB, SNP). **SARAWAK:** Kuching, Bengoh, G. Timungan, *Claysius Kongoi*, CK 31, 6. 4. 2002 (UPM).

H. tetrasticha

Claysius Kongoi et al.

SABAH: Ranau, Kg. Kiau, *Claysius Kongoi*, CK 112, 24. 5. 2002 (UPM).
SARAWAK: Mt. Murad, 1700 m, *H. P Nootboom & P. Chai*, 1934, 28. 8. 2001 (SAR); Padawan, G. Timurang limestone, *Claysius Kongoi*, CK 37, 8. 4. 2002 (UPM).

H. verticillata

SABAH: Ranau, Pinosuk Plateau, near the Mentaki River, *John H. Beaman, Teofila E. Beaman & Eric A. Christenson*, 10789, 28. 7. 1984 (UKMB, SNP); *John H. Beaman, John T. Atwood, Reed S. Beaman, Libby Besse & Pamla Decker*, 9026, 22. 3. 1984 (UKMB, SNP).

Lycopodium casuarinoides

PAHANG: Cameron Highlands, Sam Poh Temple's Trail, *Claysius Kongoi*, CK 8, CK 9, 1. 12. 2001 (UPM). **SABAH:** Ranau, Kinabalu Park, *Takashi Sato*, 2159, 24-26. 9. 1981 (UKMB, SNP, SAN); Near RTM, 3000 m, *Claysius Kongoi*, CK 66, 24. 5. 2002 (UPM).

L. clavatum

PAHANG: Cameron Highlands, G. Brinchang, M. Kasim, UKMB 02353, 17. 11. 73 (UKMB); S. Anthony, S. A. 16, 13. 5. 1976 (UPM); Near Telekom station, *Claysius Kongoi*, CK 105, 24. 2. 2002 (UPM). **SABAH:** Ranau, Kinabalu Park, Bundu Tuhan view trail, 1600 m, *Claysius Kongoi*, CK 48, 23. 5. 2002 (UPM).

L. clavatum var. divaricatum

PAHANG: Genting Highlands, *A. Latiff, A. Zainudin & Sani Miran*, AIM 918, 12. 9. 1985 (UKMB); Near Telekom station, *Claysius Kongoi*, CK 106, 12. 10. 2001; CK 104, 24. 02. 2002 (UPM). **KEDAH:** G. Jerai, *A. Samad*, UKMB 03647, 13. 8. 1970 (UKMB).

L. platyrhizoma

PAHANG: Cameron Highlands, Sam Poh Temple's Trail, *Claysius Kongoi*, CK 81, 20. 7. 2002 (UPM). **SABAH:** Ranau, Kinabalu Park, Power station, *Takashi Sato, Ahmad Zainudin, Jumaat Hj. Adam, A. K. Falaludin*, UKMS 32, 15. 3. 1981 (UKMB, SNP).

L. volubile

SABAH: Ranau, Kinabalu Park, Track to Mt. Kinabalu, 2306 m, *Shafie Ahmad, s. n.*, May 1973 (UKMB, SNP); *Prof Rao et al.*, 3, 13. 6. 1976 (SING); Trail from Power Station-Layang-layang, 7000 ft., *Lee, Aban & Dewol*, 69967, 12. 9. 1983 (SNP, SAN).

Lycopodiella cernua

PAHANG: Cameron Highlands, G. Jasar, *Claysius Kongoi*, CK 83, 20. 7. 2002 (UPM); Genting Highlands, *Zai & Yaacob, s.n.*, 7. 12. 1981 (UKMB). **SELANGOR:** Gombak Bt. 20, *Kamarudin M. Salleh, KMS 243, KMS 244*, 10. 12. 1981 (UKMB).

La. cernua* var. *capillaceum

PAHANG: Fraser's Hill, *Mohd. Sarif Abd. Manap, s.n.*, 17. 12. 1981 (UKMB). **PERAK:** Pulau Saga, *Lagani Sahid & Sani Miran, LS 96*, 22. 7. 1990 (UKMB). **SABAH:** Ranau, Kinabalu Park, near Conservation office, 1600 m, *Claysius Kongoi, CK 63*, 24. 5. 2002 (UPM).

La. cernua* var. *crassifolium

PAHANG: Genting Sempah, *Mohd. Kasim Rejab, s. n.*, July 1981 (UKMB). **PERAK:** Pulau Rumbia, *Lagani Sahid & Sani Miran, LS 77*, 21. 7. 1990 (UKMB); Taiping, Bukit Larut, *Claysius Kongoi, CK 99*, 20. 3. 2002 (UPM).

La. cernua* var. *pendulum

PAHANG: Genting Highlands, Jalan Telekom, 1790 m, *Claysius Kongoi, CK 2*, 12. 10. 2001; *CK 21*, 24. 02. 2002 (UPM). **TERENGGANU:** Bukit Besi Dungun, *1st year student, UKMB 01463*, 19. 2. 1973 (UKMB). **NEGERI SEMBILAN:** Jeram Toi, *Rozi Puteh Ismail, RPI 66*, 13. 12. 1981 (UKMB).

La. cernua* var. *salakense

PAHANG: Genting Highlands, *Amran b. Samek, AMF 001*, 7. 12. 1981 (UKMB). **PERAK:** Taiping, Bukit Larut, *Claysius Kongoi, CK 27*, 20. 3. 2002 (UPM). **SABAH:** Ranau, Kinabalu Park, Bundu Tuhan view trail, *Claysius Kongoi, CK 49*, 23. 5. 2002 (UPM).