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การศึกษาทบทวนพืชวงศ์ Lycopodiaceae ในภูมิภาคเอเชียตะวันออกเฉียงใต้

โดย

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FINAL REPORT

TAXONOMIC REVISION OF THE LYCOPODIACEAE IN SOUTHEAST ASIA

BY

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ชื่อโครงการวิจัย..การศึกษาทบทวนพืชวงศ์ Lycopodiaceae ในภูมิภาคเอเชียตะวันออกเฉียงใต้.....
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บทคัดย่อ

Lycopodiaceae sensu lato เป็นวงศ์ขนาดใหญ่วงศ์หนึ่งของพืชที่มีเนื้อเยื่อท่อลำเลียงมีจำนวนชนิดประมาณ 480 ชนิด นักพฤกษศาสตร์มีความเห็นที่แตกต่างกันในการจัดจำแนกวงศ์นี้กล่าวคือมีการจำแนกออกเป็น 1 สกุล (*Lycopodium* s.l.) ถึง 15 สกุล *Phylloglossum* Kunze. ซึ่งเดิมเคยจัดไว้ในวงศ์นี้ มักจะจัดไว้ในวงศ์ Phylloglossaceae เนื่องจากสกุลนี้มีลักษณะเฉพาะและพบเป็นพืชถิ่นเดียวของทวีปออสเตรเลีย ระบบหนึ่งที่เป็นที่ยอมรับกันมาก ได้จำแนกสมาชิกของวงศ์ Lycopodiaceae ที่พบในบริเวณอื่น ๆ ของโลกออกเป็น 3 สกุล คือ *Huperzia* Bernhardi, *Lycopodiella* Holub และ *Lycopodium* L. s. str. การศึกษาครั้งนี้มีวัตถุประสงค์ที่จะหาหลักฐานเพิ่มเติม ที่จะสนับสนุนการแยกวงศ์ Lycopodiaceae เป็น 1 หรือ มากกว่า 1 สกุล โดยศึกษาจากตัวอย่างพันธุ์ไม้แห้งจากพิพิธภัณฑ์พืชที่เก็บจากภูมิภาคเอเชียตะวันออกเฉียงใต้ จำนวน 409 ตัวอย่าง ซึ่งครอบคลุม 7 ชนิด และเป็นตัวแทนของ 3 สกุลข้างต้น โดยนำมาวิเคราะห์การจัดกลุ่มและการจัดจำแนก ผลการศึกษาพบว่าจากลักษณะเชิงปริมาณ 16 ลักษณะ ซึ่งสนับสนุนโดยลักษณะเชิงคุณภาพ 5 ลักษณะเมื่อวิเคราะห์การจัดกลุ่มสามารถแยกตัวอย่างที่ศึกษาออกเป็น 3 กลุ่มได้อย่างชัดเจน ซึ่งผลการแยกกลุ่มนี้ได้รับการยืนยันเมื่อนำมาวิเคราะห์การจัดจำแนกแบบต่าง ๆ โดยกำหนดกลุ่มจากผลการวิเคราะห์การจัดกลุ่มข้างต้น ซึ่งพบว่าลักษณะสัณฐานวิทยา 5 ลักษณะ ได้แก่ รูปร่างอับสปอร์ ระยะห่างระหว่างกลุ่มของใบบนกิ่ง ความหนาของใบ ความกว้างของอับสปอร์ และเส้นรอบวงของปลายกิ่งเป็นลักษณะสำคัญที่ใช้ในการแยกกลุ่ม 3 กลุ่มหรือสกุลจาก *Lycopodium* s.l.

จากการศึกษาเอกสารและตัวอย่างพันธุ์ไม้แห้ง ที่เก็บจากภูมิภาคเอเชียตะวันออกเฉียงใต้พบ สกุล *Huperzia* จำนวน 25 ชนิด สกุล *Lycopodiella* จำนวน 2 ชนิด และสกุล *Lycopodium* s. str. จำนวน 8 ชนิด สำหรับประเทศไทยจากการศึกษาครั้งนี้พบ สกุล *Huperzia* จำนวน 13 ชนิด สกุล *Lycopodiella* จำนวน 1 ชนิด และสกุล *Lycopodium* s. str. จำนวน 3 ชนิด ซึ่งเป็นชนิดที่พบเป็นครั้งแรกในประเทศไทยจำนวน 8 ชนิดใน 2 สกุล คือ *Huperzia cryptomerina* (Maxim.) Dixit, *H. dalhousiana* (Spring) Trevisan, *H. goebelii* (Nessel) Holub, *H. laxa* (C.Presl) Trevisan, *H. pulcherrima* (Hook. & Grev.) Pichi-Serm., *H. tetrasticha* (Kunze) Holub, *Lycopodium casuarinoides* Spring และ *L. complanatum* L.

Project Title ..Taxonomic Revision of the Lycopodiaceae in Southeast Asia….
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ABSTRACT

The Lycopodiaceae sensu lato is one of the large family of vascular plants comprising about 480 species. Treatment of the genera in this family is rather different among botanists ranging from a single genus, i.e. *Lycopodium* s.l. to 15 genera. *Phylloglossum* Kunze. is usually recognized as a distinct genus and family, Phylloglossaceae due to its unique characters and endemics to Australia. The most recognized classification segregated members of the Lycopodiaceae into three genera, namely *Huperzia* Bernhardi, *Lycopodiella* Holub, and *Lycopodium* L. s. str. The purpose of this study was to find additional evidences to support the separation of Lycopodiaceae from south-east Asian countries into one or more than one distinct genera. Four hundred and nine herbarium specimens (OTUs) from 7 species which represent the three segregated genera, were subjected to cluster analysis and discriminant analysis. Based on 16 quantitative characters and supported by 5 qualitative characters, cluster analysis strongly indicated the presence of three distinct groups within the studied specimens. This was accomplished by conducting a series of discriminant analyses using groups from the result of cluster analysis and the result was confirmed. It was found that 5 characters, i.e. sporangium shape, distance between two whorls, leaf thickness, width of sporangium, and diameter of apical shoot collectively supported the segregation of the 3 groups or genera from the *Lycopodium* s.l.

So far, 25 species of *Huperzia*, 2 species of *Lycopodiella* and 8 species of *Lycopodium* s. str. were recorded in South-East Asia, while Thailand has 13 species of *Huperzia*, 1 species of *Lycopodiella* and 3 species of *Lycopodium* s. str. The following 8 species:- *Huperzia cryptomerina* (Maxim.) Dixit, *H. dalhousiana* (Spring) Trevisan, *H. goebelii* (Nessel) Holub, *H. laxa* (C.Presl) Trevisan, *H. pulcherrima* (Hook. & Grev.) Pichi-Serm., *H. tetrasticha* (Kunze) Holub, *Lycopodium casuarinoides* Spring and *L. complanatum* L. are new records for Thailand.

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LIST OF ABBREVIATION

BCU	Kasin Suvatabandhu Herbarium, Department of Botany, Faculty of Science Chulalongkorn University, Bangkok, Thailand
BKF	Bangkok Forest Herbarium, Bangkok, Thailand
BK	Bangkok Herbarium, Bangkok, Thailand
BM	Cryptogamic Herbarium, Natural History British Museum, London, UK
CA	Cluster Analysis
CDA	Canonical Discriminant Analysis
cm	centimeter
DIST	average taxonomic distance
E	Herbarium, Royal Botanic Garden, Edinburgh, Scotland
K	Herbarium, Royal Botanic Gardens, Kew, England
L	Rijkherbarium, Leiden, The Netherlands
mm	millimeter
MVSP	Multivariate Statistics Package
NTSYS	Numerical Taxonomic System of Multivariate Statistical Programs
OTU	Operational Taxonomic Unit
P	Muséum National d'Histoire Naturelle, Paris, France
SAHN	Sequential, Agglomerative, Hierarchical, and Nonoverlapping
SE	Standard Error
SING	Herbarium, Singapore Botanic Gardens, Singapore
SPSS	Statistical Package for the Social Sciences
STAND	Standardize
s.s.	sensu stricto
s.l.	sensu lato
UPGMA	Unweighted Pair Group Method with Arithmetic Mean

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1. INTRODUCTION

1.1 General Morphology

The Lycopodiaceae Beauv. ex Mirb. are terrestrial, lithophytic, epiphytic or scandent homosporous, vascular plants. The free-living sporophytic plant body is consisting of a rhizome with adventitious roots, and an aerial portion. Horizontal stems, mainly protostelic, in some species becoming actino- or plectostelic, on substrate surface or subterranean, or forming stolons. Upright shoots simple or branched, usually conspicuously leafy at least at base. Lateral shoots present or absent, simple or branched, branching pattern dichotomous and sometimes pseudomonopodial. Upright and lateral shoots are rounded or flat in cross section. Microphylls on subterranean parts are flat, appressed, nonphotosynthetic, and scalelike; microphylls on aerial parts are appressed, ascending, or spreading, with one simple vein, needlelike to lanceolate or ovate, remote to dense and imbricate, homophyllous or heterophyllous, isophyllous or anisophyllous; spirally arranged or decussate or whorled. Sporophylls resembling the microphylls or modified, sometimes specialized and aggregated into distinct strobili. Eusporangia are found on the upper surface of the sporophylls, reniform to globose, thick-walled with numerous spores, either in unmodified shoot axes or in compact strobili. Strobili are sessile or stalked, upright, nodding, or pendant. Spores are of 1 kind, trilete, thick-walled with pitted to small-grooved, rugulate, or reticulate surfaces. The free-living gametophytes are monoecious, and are either irregularly lobed photosynthetic masses, or subterranean branching structures that lack chlorophyll and require a fungal symbiont. The multiflagellated sperm produced in an antheridium, travel through a film of water to reach the egg of an archegonium in order to initiate the zygote that may develop into the new sporophyte individual (Foster & Gifford, 1974; Øllgaard, 1990; Mabberley, 1997).

1.2 Taxonomic History of the Lycopodiaceae sensu lato

Linnaeus (1753) was the first taxonomist who studied this plant group and established the genus *Lycopodium* L., but he placed this genus with the Musci. Then Mirbel transferred this genus to the Lycopodiaceae (Lamarck, Monet and Mirbel, 1802). More than a hundred years later, Nessel (1939) studied this plant family and

subdivided a single large genus *Lycopodium* L. into two subgenera, i.e. *Urostachys* (Pritz.) Hert. and *Lycopodium* (L.) Hert. Then Herter (1949) purposed the Systema Lycopodiorum and Index Lycopodiorum which included detailed system of the taxonomic position of the species. However, several of his groups are rather unnatural (Øllgaard, 1987).

Previously, many authors attempted to reclassify the family into natural groups. For examples, Holub (1964, 1975), Pichi Sermolli (1977) and Ching (1981), they regarded *Lycopodium* s.l. as an assemblage of 4-12 genera. While Wilce (1972) studied morphology of spore, then recognized 12 sections within the genus *Lycopodium* s.l. and classified these sections into 3 subgenera. This outline of a system, with some modifications on taxonomic rank and circumscription has been generally accepted (Bruce 1976a, b, c, 1979a, b; Øllgaard, 1975, 1979). Cytotaxomically, Löve & Löve (1958) demonstrated that 4 basic numbers were presented; X=8, 11, 13 and 17. This finding underlined the phylogenetic importance of these cytotypes. They then separated *Lycopodium* s.l. into 4 genera. Likewise, Øllgaard (1987) reviewed the following important taxonomic characters in the Lycopodiaceae s.l.: branching patterns, cortex and stelar anatomy, distribution of mucilage cavities, leaf differentiation, morphology of sporophylls, sporangia, spores, gametophytes, chromosome numbers, and phytochemistry. Based on these characters, he divided the Lycopodiaceae into 4 genera, i.e. *Huperzia* (incl. *Phlegmariurus* Holub), *Phylloglossum*, *Lycopodium* sensu stricta (incl. *Diphasiastrum* Holub; *Diphasium* Rothm.; *Lycopodiastrum* Holub; *Pseudodiphasium* Holub; *Pseudolycopodium* Holub), and *Lycopodiella* (incl. *Lateristachys* Holub; *Palhinhaea* Vasc. & Franco; *Pseudolycopodiella* Holub).

The family has a worldwide distribution included about 480 species (Hassler and Swale, 2001), but up to now still have no general agreement on the classification. In China two families, i.e. the Lycopodiaceae s. str. and the Huperziaceae were recognized. The Lycopodiaceae s. str. includes 6 genera, i.e. *Lycopodium*, *Pseudolycopodiella*, *Lycopodiella*, *Palhinhaea*, *Diphasiastrum*, *Lycopodiastrum* while the Huperziaceae includes 2 genera namely, *Phlegmariurus*, and *Huperzia*, (Zhang & Kung, 2000ab). In Vietnam 14 species were reported and grouped into 3 genera, i.e. *Huperzia*, *Lycopodium* and *Lycopodiella* (Pham-Hoang, 1991). Likewise, 27 species were found in Malaysia and classified into the same above three genera (Paris & Latiff, 1997). In Thailand 9 species, were enumerated

within a single genus *Lycopodium* s.l., viz. *Lycopodium carinatum* Desv. *ex* Poiret, *L. cernuum* L., *L. clavatum* L., *L. hamiltonii* Sprengel, *L. nummulariifolium* Blume, *L. phlegmaria* L., *L. piscium* Blume, *L. serratum* Thunb. *ex* Murray, *L. squarrosum* G. Forster (Tagawa & Iwatsuki, 1979).

1.3 Previous Research Using Numerical Taxonomy

The applications of numerical and statistical methods to classify taxa of living plants is largely developed in the last seven decades. Historically, using quantitative methods in plant taxonomy was pioneered by Anderson in the 1930's (see Radford et al., 1974). The numerical techniques used at that time were simple but effective. A few carefully chosen characters were studied on relatively small numbers of plants from several populations. Today computers make similar sorts of comparisons possible for many characters using larger population sizes and studying many populations simultaneously. This ability to handle large sets of data is the main feature of numerical taxonomy. Since the late 1950's, Sokal, Sneath and their co-workers have actively promoted the employment of such techniques in a wide variety of organisms (Sneath, 1995).

Numerical studies have been performed on wide varieties of organisms and these approaches have shown to be useful in evaluating and refining the existing classification. In plants, numerical techniques have been employed widely and have been shown to have important impacts in solving problems of many taxonomic groups. Examples of publication on numerical taxonomy carried out on various plant groups are shown below.

Speer and Hilu (1999) carried out a multivariate morphometric study from 262 specimens of *Pteridium aquilinum* var. *latiusculum* and *P. aquilinum* var. *pseudocaudatum*. Numerical analysis based on 12 qualitative and quantitative characters did not result in recognizable grouping of samples on either a taxonomic, population, or geographic basis. However, when the whole qualitative characters were used in conjunction with some of the quantitative traits, the specimens grouped into two distinct clusters corresponding to the two recognized varieties. This morphometric study supported a taxonomic treatment at the variety level. Ohta and Takamiya (1999) performed the morphological investigations of the Japanese *Diplazium mettenianum* complex. An analysis of 374 plants utilizing 20 qualitative morphological characters showed that

the complex could be divided into five forms and statistical analysis of 16 quantitative morphological characters supported the distinction of five forms which were regarded as independent species, viz. *D. mettenianum, D. fauriei, D. deciduum* nom. nov., *D. griffithii*, and *D. hayatamae* sp. nov.

Two species of moonwort, *Botrychium* (Ophioglossaceae) in subgenus *Botrychium*, i.e. *Botrychium minganense* Victorin and *B. crenulatum* W.H. Wagner, can sometimes be confused in the field, even by experts, because of their reduced morphology. Swartz and Brunsfeld (2002) carried out morphometric analysis and RAPD markers from seven populations of *B. crenulatum* and 18 populations of *B. minganense*. Canonical variate analysis separated the samples into two species groups with 32% overlaps. UPGMA cluster analysis of RAPD profiles showed well-defined *B. minganense* and *B. crenulatum* clusters, but no distinct clusters within *B. minganense* that could be correlated with its morphological variability.

In 1956, Kitamura (see Whang et al., 2002) classified the *Ixeris chinensis* complex into three subspecies, namely *Ixeris chinensis* (Thunb.) Nakai subsp. *chinensis*, subsp. *strigosa* (H. Lév. et Vaniot) Kitamura, and subsp. *versicolor* (Fischer) Kitamura. However, Tzvelev (1964) transferred this complex into three different species of *Ixeridium*, viz. *Ixeridium chinensis* (Thumb.) Tzvelev, *I. strigosum* (H. Lév. et Vaniot) Tzvelev and *I. gramineum* (Fisch.) Tzvelev. Then, in 1992, Pak and Kawano (see Whang et al., 2002) re-classified the complex into two subspecies of one species and one different species in the same genus; *Ixeris chinensis* subsp. *chinensis* and subsp. *versicolor* and treated subsp. *strigosa* as a species, i.e. *I. strigosa* (H. Lév. et Vaniot) Pak et Kawawo. Recently, Whang et al. (2002) studied *Ixeris chinensis* complex using morphometric analysis, and concluded that this species complex should be separated into three taxa at subspecies level. So, their results supported Kitamura's classification of infraspecific taxa in the species complex.

Watson, Williams and Lance (1966) studied 24 genera of the angiosperm family Epacridaceae using two sorting methods in association with five different coefficients of similarity. They used 25 characters from various evidences such as floral morphology, vegetative morphology, pollen morphology and anatomy. They concluded that the various combinations of sorting methods and coefficients of similarity all indicated to the same general pattern of relationships among the genera.

The groups formed were robust and stable. They considered the groupings were "real" and had their basis in genetic relationships.

Forster and Liddle (1991) recognized five subspecies within *Hoya australis* complex using qualitative and quantitative characters of both vegetative and reproductive structures. *H. australis* subsp. *oramicola* was described and the new combinations *H. australis* subsp. *tenuipes* (*H. oligotricha* subsp. *tenuipes* K. Hill) and *H. australis* subsp. *rupicola* (*H. rupicola* K. Hill) were proposed. Chatrou (1997) used cluster analysis to reveal the patterns of macro-morphological variation in a species complex of *Malmea* (Annonaceae). Of 53 characters, 24 were important for clustering 238 herbarium specimens into 12 clusters. A new subspecies, *M. depressa* subsp. *abscondita*, was described. Moreover, *M. gaumeri* and *M. leiophylla* are suggested as synonym of *M. depressa*. While, cluster analysis and principal component analysis of 66 morphological characters from 103 populations of the *Lobelia cardinalis* complex failed to disclose groups of populations. The complex comprises a single species, *L. cardinalis,* and that this species should not be divided into infraspecific taxa (Thompson & Lammers, 1997). Likewise, 215 accessions of 30 taxa in the *Solanum brevicaule* complex and 42 accessions of six taxa outside the complex were determined using 53 morphological characters. Principal Component Analysis and Discriminant Analysis were used, but however, the outcomes were unable to support 30 taxa, suggesting a single variable complex (van den Berg et al, 1998).

Aldasoro et al. (1998) carried out a multivariate morphometric study from 127 herbarium specimens and nine populations of the genus *Sorbus*. The principal component, discriminant and cluster analysis of morphological and anatomical data were carried out. The result showed that twelve species could be easily recognized in the area. It was reported that *Simarouba amara* was frequently confused with two other continental species, *S. glauca* and *S. versicolor*. Cluster and Principal Component Analyses were applied to verify the distribution and variation of the diagnostic characters proposed in the preceding revision, i.e. anther size, stamen appendage, indument, leaflet surface, and venation features. *S. glauca* and *S. versicolor* were found to be morphologically closer than *S. amara*. Overlapping of characteristics in boundary populations of the three species was also found (Franceschinelli, Yamamoto & Shepherd, 1998).

Furthermore, intraspecific morphological variation was investigated in *Eriastrum densifolium*. To assess the five currently recognized subspecies vegetative and floral characters were analyzed at the species and population level by using cluster analysis. The herbarium specimens, field collections, and cultivated plants were used. The only exception was a group of plants distinguished from the remainder species by corolla-tube length. This group of individuals matches the circumscription of *E. densifolium* subsp. *sanctorum*. The other four recognized subspecies failed to form distinct morphological groups in all analyses (Brunell and Whitkus, 1998).

Hess and Stoynoff (1998) used cluster analysis and discriminant analysis examined vegetative and reproductive characters in *Quercus shumardii* var. *acerifolia* and comparing with *Q. shumardii, Q. buckleyi, Q. texana,* and the maple-leaf oak. Cluster analyses segregated maple-leaf oak from *Q. shumardii* and the other two recognized taxa. Based upon these numerical analyses and the evaluation of descriptive characters*, Q. acerifolia* was shown to be a distinct species. Nelson and Elisens (1999) performed cluster analysis, principal components analysis and canonical variance analysis based on 16 morphological characters from 33 populations represent all taxa and ploidy levels of the genus *Chelone*. This work recognized three diploid species without infraspecific taxa in this complex. Kephart et al. (1999) used principal component analysis and discriminant analysis to determine whether quantitative morphology could effectively distinguish varieties, population, and subpopulations of the polymorphic species, *Silene douglasii*. A phenetic analysis of 354 plants samples from 16 populations using vegetative characters (e.g., leaf width and pubescence) were the most effective characters to distinguish the var. *rupinae*, whereas reproductive characters (e.g. calyx width, petal dimensions) were more useful for var. *oraria* and var. *douglasii*.

The taxonomic status of *Asmeria*'s populations from the Horconera massif previously was miss identified or without a precise identification. Feliner, Aguilar and Rossello (2001) using principal component analysis and discriminant analysis examined on the basis of morphological and molecular data. A multivariate analysis indicated that the *Asmeria*'s populations could be distinguished morphologically and geographically close taxa. Furthermore, morphometric and molecular evidences warranted a taxonomic treatment of, a new species, *A. trianoi*. Petal pigment compositions were used as markers to study the relationship among seven wild tree

peony species of *Paeonia* section *Moutan* DC. from China. Principal component analysis and cluster analysis showed good agreement with a classification based on morphological characteristics of two subsections, i.e. *Vaginatae* F.C. Stern and subsection *Delavayanae* F.C. Stern. (Wang et al., 2001). Mikkelsen & Seberg (2001) used non-metric multidimensional scaling and principal component analysis to examine vegetative and reproductive characters of the *Bersama abyssinica* Fresen. complex (Melianthaceae) in East Africa. A new combination, *Bersama abyssinica* Fresen. ssp. *rosea* (Hoyle) Mikkelsen was proposed based on numerical analyses and the patterns observed in the field.

Morphometric study characters among *Acacia aroma*, *A. macracantha*, *A. caven*, and *A. furcatispina* were studied with morphometric techniques by Casiva et al. (2002). They used a correlation between species for morphometric analysis to obtain a phenogram that represented phenetic similarities among species. The results of cluster and principal component analyses agree with those obtained from molecular data. It was found that *Acacia aroma* and *A. macracantha* had the highest similarity, while *A. furcatispina* is the most differentiated species.

Lihova et al. (2004) used morphometric analysis and amplified fragment length polymorphism (AFLP) to re-evaluate subspecific status of tetraploid *Cardamine amara* subsp. *olotensis* from Catalonia and to resolve the taxonomic position of central Italian populations usually placed within *C. amara* and/or *C. rephanifolia* s.l. Morphometric result showed Catalonian and Italian populations to be similar to each other, but distinct from other *C. amara*.

In Thailand, some biosystematic studies were carried out using numerical techniques. For example, Boonkerd, Saengmanee and Baum (2002) studied *Bauhinia pottsii* G. Don in Thailand. Twenty four qualitative and forty nine quantitative morphological characters were examined in 200 specimens using cluster analysis and canonical discriminant analysis to determine the taxonomic relationship among the four varieties. The morphometric study supported a taxonomic treatment at the variety level. *Cassia* L. sensu lato, a large heterogeneous genus of flowering plants, occurs naturally in the tropics around the world. Recent works based on floral morphology supported a division of this genus into three genera, namely *Cassia* L. s. str., *Chamaecrista* Moench and *Senna* Miller. In order to investigate this new classification, 508 specimens of 18 taxa of the genus *Cassia* s.l. grown in Thailand

were analysed using cluster analysis and canonical discriminant analysis (Boonkerd, Pechsri and Baum, 2005). The total 32 vegetative and reproductive morphological characters were employed in these analyses. In cluster analysis, *Cassia* s.l. can be separated into four groups, respectively viz. *Chamaecrista, Senna alata, Senna* and *Cassia* s.str. From canonical discriminant analyses using the four-cluster grouping as a priori groups, it can be concluded that *Cassia* s. str., *Senna*, and *Chamaecrista* are distinct taxa. The three most important characters that separate the three genera are filament length, fruit length, and ovary stalk length. These quantitative characters, together with some qualitative characters, were useful in constructing an identification key to these genera.

Although restricted to material from South-East Asia and the understanding of its Flora, the present research aimed to find additional evidence to support the segregation of *Lycopodium* s. str., *Huperzia* and *Lycopodiella* from *Lycopodium* s.l. as suggested by Øllgaard (1987) by using morphometric analyses.

1.3 Objectives

1.3.1 To survey and explore some additional species of the Lycopodiaceae s.l. in Thailand.

1.3.2 To revise the classification of the Lycopodiaceae s.l. by exploring the morphometric relationship among the three genera, i.e. *Huperzia, Lycopodium* s. str. and *Lycopodiella* in South-East Asia.

2. MATERIALS AND METHODS

2.1 *Plant materials*

Plant materials used in this research were based solely on the existing herbarium specimens from the main herbaria in Thailand, Singapore and Europe. To update the enumeration of Thai Lycopodiaceae, additional specimens of *Lycopodium* s.l. species were collected from protected areas throughout Thailand, especially from the areas close to the borders of neighbouring countries. However, due to the political crisis in the southernmost provinces of the country, specimen collections in Pattani, Yala and Narathiwat Provinces were cancelled. The collected specimens were determined based on key to species in the Flora of Thailand, volume 3, part 1 (Tagawa and Iwatsuki, 1979). Then they were confirmed by comparing to the voucher specimens deposited at BCU, BK, BKF, BM, K, L, P, QBG and SING (Herbarium abbreviations according to Holmgren and Holmgren 2005). The voucher specimens from this study have been deposited at BCU.

2.2 *Data collection and numerical analysis*

2.2.1 Qualitative characters

Basic statistics of 8 qualitative characters, i.e. mean, standard deviation and variance (Table 2.1) were analyzed using SPSS 11.0 for Windows. Subsequently, some discriminating characters were used together with quantitative characters in cluster and canonical discriminant analyses.

Table 2.1 Eight qualitative characters of fertile branch used in multivariate analyses of *Lycopodium* s. l. with their methods of scoring.

No.	Character	Character description
1.	growth habit	erect=1, ascending=2, recurved=3, pendulous=4
2.	leaf differentiation	homophyllous=1, heterophyllous=2, gradually heterophyllous=3
3.	vein prominence	hardly visible=1, visible=2
4.	margin shape	teeth=1, rugulate=2, smooth=3
5.	leaf surface	smooth=1, papilate=2
6.	stomate distribution	thinly disperse=1, densely disperse=2

No.	Character	Character description
7.	shape of epidermal cells	irregular shape=1, rectangular shape=2
8.	sporangium shape	Reniform-caudate=1, long reniform =2

2.2.2 Quantitative characters

2.2.2.1 Character measurement

Measurement of morphological characters was carried out on fertile branches. For each specimen, 16 vegetative and reproductive morphological characters were measured or counted (Table 2.2). The measurement of macroscopic character was carried out using a standard ruler or a digital caliper. Whereas the microscopic character was measured with the aid of the light microscope equipped with 10X lens coupled to micrometer disc and 10X or 40X objectives.

Table 2.2 Sixteen quantitative characters of *Lycopodium* s.l. used in morphometric analyses.

NO.	Characters with their methods of scoring
1.	Diameter of main stem in cm
2.	Diameter of lateral branch in cm
3.	Diameter of apical shoot in cm
4.	Width of microphyll in cm
5.	Length of microphyll in cm
6.	Distance from apex to the widest portion of microphyll in mm
7.	Length of fertile branches in cm
8.	Length of strobilus in cm
9.	Width of strobilus in cm
10.	Length of sporophyll in mm
11.	Width of sporophyll in mm
12.	Length of sporangium in mm
13.	Width of sporangium in mm
14.	Distance between two whorl
15.	Leaf thickness in mm
16.	Number of leaves in a whorl

2.2.2.2 Data analysis

Cluster analysis (CA) and canonical discriminant analysis (CDA) were performed to determine the pattern of grouping of 409 specimens (OTUs).

In cluster analyses when only quantitative characters were used the original data matrix was first standardized (STAND) and the resultant matrix was used to produce the distance matrix based on average taxonomic distance (DIST). Then, cluster analysis was conducted using the unweighted pair-group method arithmetic (UPGMA) in SAHN. These procedures are available in NTSYS-pc version 2.11S (Exeter Software © 2002 by Applied Biostatistics, Inc.).

When mixed characters, i.e. quantitative and qualitative morphological characters were measured altogether, Gower similarity coefficient will be calculated without data transformation and clustered by the UPGMA method as suggested by Gower (1971). For these proposes a statistic package, MVSP (Kovach Computing Services, MVSP Plus, version 3.1) was used.

Stepwise discriminant analysis was used to select a subset of characters that maximized differences among the groups determined by cluster analysis. A classification criterion was generated in a subsequent discriminant analysis, estimated for error rates and crossvalidated.

Canonical discriminant analysis was performed with SPSS 11.0 for Windows (SPSS Inc., Chicago, IL, USA) to characterize mean differences among the groups suggested by cluster analyses, to acquire insight into group differences and to estimate character weights from correlations between canonical variables and original variables. A priori results from cluster analysis were used for the group criteria.

To summarize the range of variation between and within groups on each character, univariate analysis was performed. Boxplots of the most important characters were carried out using SPSS 11.0 for Windows.

2.3 Taxonomic revision of the Lycopodiaceae in South-East Asia

The results obtained from cluster and canonical discriminant analyses were used to revise the classification of the Lycopodiaceae in South-East Asia and constructed the key to genera and to species.

2.4 Enumeration of the Lycopodiaceae in Thailand

Thai *Lycopodium* s.l. from the existing herbarium specimens and additional collected specimens were determined to species. Classification of the Thai plants are based on taxonomic revision of the Lycopodiaceae in South-East Asia. Some new record taxa were described. Keys to genera and to species were constructed.

3. RESULTS AND DISCUSSIONS

3.1 Plant materials

Due to many incomplete specimens deposited at the main herbaria in Europe. Morphometric analyses were focused on voucher herbarium specimens of 7 species of *Lycopodium* s.l. (Table 3.1) deposited at K, L, and P. They are corresponding to 3 genera in South-East Asia according to Index of the Lycopodiaceae (Øllgaard, 1989). Five species, namely *L. carinatum, L. phlegmaria, L. nummulariifolium, L. serratum,* and *L. squarrosum* are representatives of the genus *Huperzia*, while only one species of *L. cernuum* and *L. clavatum* are representatives of the genera *Lycopodiella* and *Lycopodium* s. str., respectively. These 7 species are commonly found in South-East Asian countries (Tagawa & Iwatsuki, 1979; Paris & Latiff, 1997; Alston, 1951; Pham-Hoang, 1991).

Table 3.1 Seven species of *Lycopodium* s.l. used in morphometric analyses.

NO.	*Lycopodium* s.l.	Corresponding Taxa according to Øllgaard (1989)
1.	*L. carinatum* Desv.	*Huperzia carinata* (Poiret) Trevisan
2.	*L. phlegmaria* L.	*Huperzia phlegmaria* (L.) Rothm.
3.	*L. nummulariifolium* Blume	*Huperzia nummulariifolia* (Blume) Chambers
4.	*L. serratum* Thunb.	*Huperzia serrata* (Thunb. *ex* Murray) Trevisan
5.	*L. squarrosum* Forst.	*Huperzia squarrosa* (G. Forster) Trevisan
6.	*L. cernuum* L.	*Lycopodiella cernua* (L.) Pichi-Serm.
7.	*L. clavatum* L.	*Lycopodium clavatum* L.

3.2 *Data collection and numerical analysis*

Eight qualitative characters of *Lycopodium* s.l. were examined and scored. It can be seen that *L. squarrosum* has a variable growth habit, while the others are quite uniform in this character. This species has both upright and drooping branches. *L. serratum* and *L. squarrosum* also have variation in leaf differentiation. Heterophyllous leaves were observed in some studied specimens of these two species. Leaf margin was studied and found that only *L. serratum* has a teethed margin, while the others have entire margin. Some variations in stomatal distribution were observed in *L. carinatum, L. nummulariifolium* and *L. clavatum*. It was found that vein

Table 3.2 Eight qualitative characters of fertile plant of *Lycopodium* s. l. with their methods of scoring.

No.	*Lycopodium* s.l.	growth habit* erect=1 ascending=2 recurved=3 pendulous=4	leaf differentiation* homophyllous=1 heterophyllous=2 gradually heterophyllous=3	vein prominence hardly visible=1 visible=2	margin shape* teeth=1 rugulate=2 entire=3	leaf surface smooth=1 papilate=2	stomatal distribution* thinly disperse=1 densely disperse=2	shape of epidermal cells irregular shape=1 rectangular shape=2	sporangium shape* reniform-cordate=1 reniform =2
1.	*L. carinatum* Desv.	4	3	2	3	1	1, 2	1	1
2.	*L. phlegmaria* L.	4	2	2	3	1	2	1	1
3.	*L. nummulariifolium* Blume.	4	2	2	3	1	1, 2	1	1
4.	*L. serratum* Thunb.	1	1, 3	2	1	1	2	1	2
5.	*L. squarrosum* Forst.	2, 3, 4	2, 3	2	3	1	2	1	1
6.	*L. cernuum* L.	1	2	1	3	1	2	1	2
7.	*L. clavatum* L.	1	2	1	3	1	1, 2	1	2

Note: Qualitative character with superscript asterisk * denotes character used in cluster and canonical discriminant analyses

prominence, leaf surface and shape of epidermal cells are uniform in all seven species and within each species. These non variable characters were discarded from numerical analyses. So, five out of eight qualitative characters were included in cluster and canonical discriminant analyses.

3.2.1 Cluster analysis

In cluster analysis, two similarity (or distance) coefficient matrices were produced. The first matrix was the average taxonomic distance derived from 16 quantitative characters and the second one was the Gower's similarity coefficient matrix derived from 16 quantitative characters (Table 2.2) and five qualitative characters. (Table 3.2).

The results of the first cluster analysis using the average taxonomic distance matrix was failed to group the 409 specimens of *Lycopodium* s.l. into the previous recognized genera. However, when the Gower's similarity coefficient matrix was calculated using the 70% similarity phenon line as a reference (Sneath and Sokal, 1973), three main groups/genera could be distinguished in the UPGMA phenogram (Figure 3.1), i.e. *H* 1-5, *L* 1 and *L* 2.

All OTUs in group *H* 1-5 were members of the genus *Huperzia*. On close examination of a dendrogram in Fig. 3.1 it appears that two subclusters could be established within the *Huperzia* group. Subcluster 1 comprised of *H. serrata*. The other cluster contained the rest 4 species, *H. nummulariifolia*, *H. phlegmaria*, *H. squarrosa*, and *H. carinata*, respectively. Group *L* 1 is solely *Lycopodiella cernua*. The third groups is composed of all OTUs of *Lycopodium clavatum* (*L* 2).

This study was based on plant materials collected from various habitats in South-East Asia (see appendix) and they tended to differ in plant dimension. Unlike the flowering plants (For example, Boonkerd et al., 2005; Hess and Stoynoff, 1998) the quantitative characters of these Lycopods alone can not place individual specimens into previous recognized taxa in cluster analysis. Their plasticity of characters in response to the physical environments are probably due to their simple morphology (Øllgaard, 1992).

In all, the results of cluster analyses supported the recognition of the three genera, i.e. *Huperzia*, *Lycopodiella* and *Lycopodium* as was suggested by Øllgaard (1987). He used a combination of characters to distinguish the three mentioned

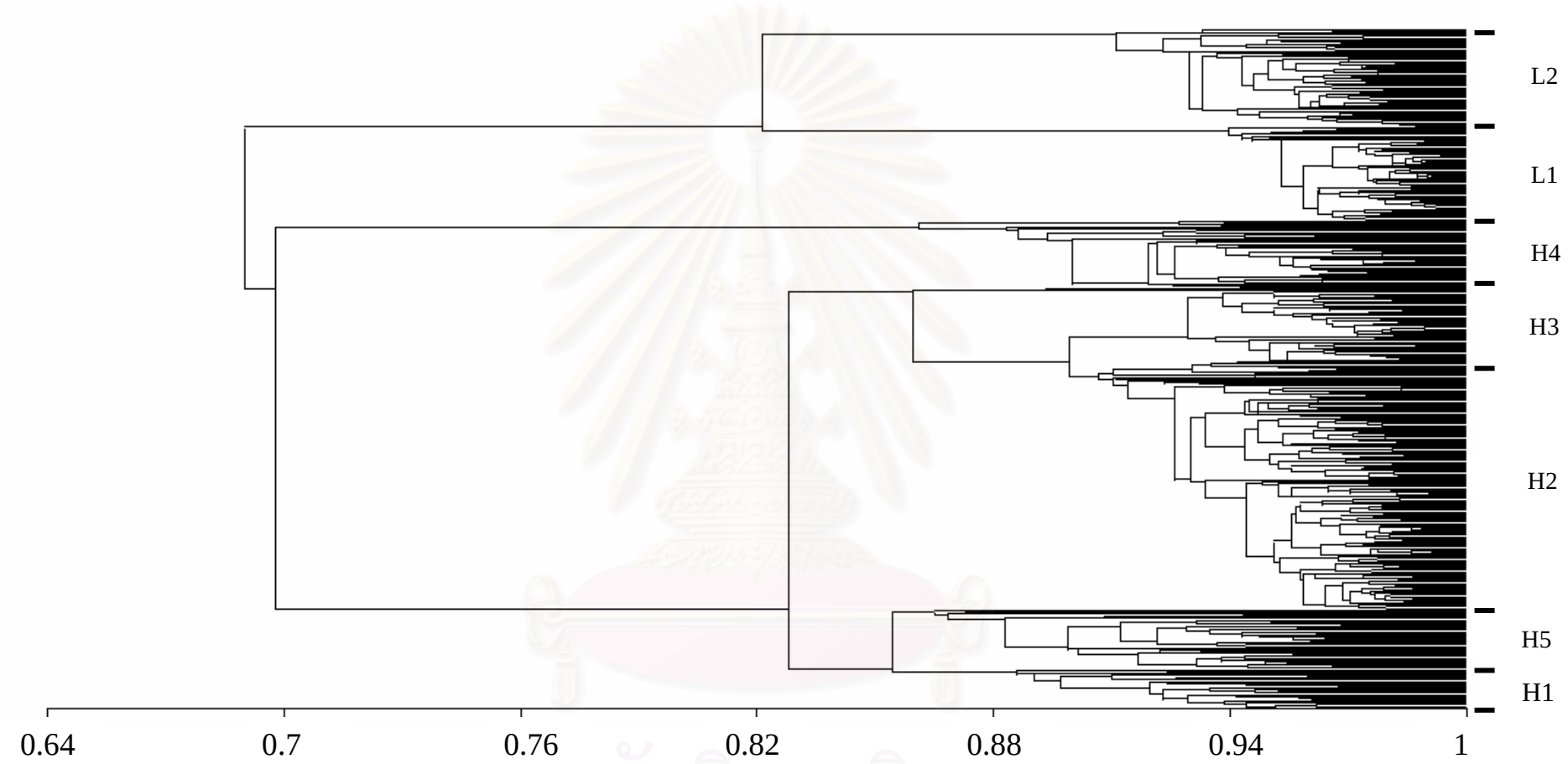

Figure 3.1 UPGMA clustering of 409 OUT's based on 16 quantitative characters and 5 qualitative characters (H1, *Huperzia carinata;* H2, *H. phlegmaria*; H3, *H. nummulariifolia;* H4, *H. serrata;* H5, *H. squarrosa;* L1, *Lycopodiella cernua;* L2 *Lycopodium clavatum*)

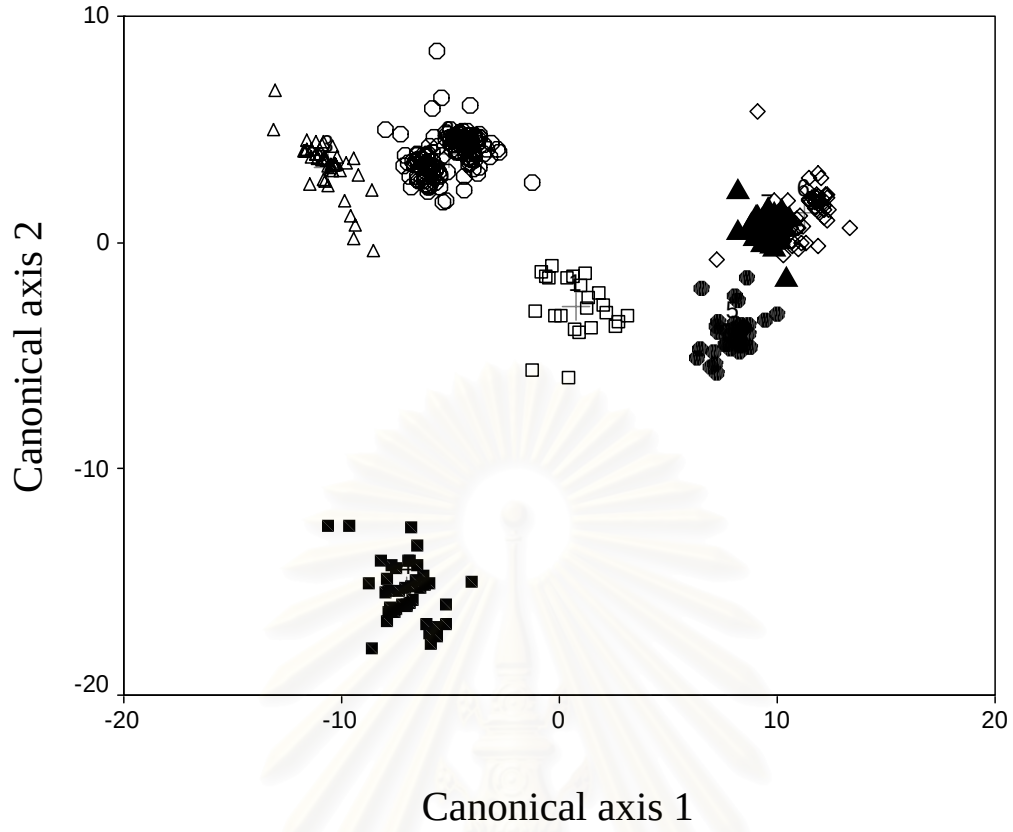

Figure 3.2 Canonical plot of 409 specimens from the seven species of *Lycopodium* s.l. obtained by canonical discriminant analysis □ *H. carinata*, ○ *H. phlegmaria*, △ *H. nummulariifolia* ■ *H. serrata* ● *H. squarosa*, ◇ *Lycopodiella cernua*, ▲ *Lycopodium clavatum*

genera, for example branching patterns, cortex and stellar anatomy, distribution of mucilage cavities, leaf differentiation, morphology of sporophylls, sporangia, spores, and gametophytes, chromosome numbers, and phytochemistry (Øllgaard, 1987).

3.2.2 Canonical discriminant analysis

3.2.2.1 Grouping of the seven species.

The canonical plot on the two canonical axes (Fig. 3.2) shows that the seven species of *Lycopodium* s.l. are separated into 2 groups on canonical axis 1. Group I is composed of 4 species of *Huperzia*, namely *H. carinata, H. phlegmaria*, *H. nummulariifolia* and *H. serrata*; whereas group II consists of *H. squarrosa, Lycopodiella cernua* and *Lycopodium clavatum*.

The nature of the groups differences is shown by the pooled within canonical structure (Table 3.3). Canonical variable 1 is 99.2% correlated with the 21 characters and the variance explained by it is 58.6%. It is most highly associated with character 16 (number of leaves in a whorl). Canonical variable 2 explains 98.5% of the total variance. This axis is most highly associated with character 14 (distance between two whorls). The three characters; 1 (diameter of main stem), 2 (diameter of lateral branch in cm) and 8 (length of strobilus) were not selected by stepwise discriminant analysis to be used in further canonical discrininant analysis (Table 3.3)

Based on the results of cluster analysis together with canonical discriminant analyses it is reasonable to segregate the seven species of *Lycopodium* s.l. into more than a single genera as was treated by Tagawa & Iwatsuki (1979). As can be seen from Fig. 3.2, the phenetic gaps between groups are larger than those within groups. So, the three-segregated genera was used as a priori group in further canonical discrininant analysis.

3.2.2..2 The three segregated genera.

Univariate F values of the 21 characters used in canonical discriminant analysis as well as their pooled within canonical structure of the three segregated genera are shown in Table 3.3. Fifteen out of twenty one characters were used in this analysis (Table 3.3). Canonical variable 1 (axis 1) is 99% correlated with these characters and the variance explained by it is 97.6% (Table 3.4). It is most highly associated with the following two characters (Table 3.3), viz. 21 (sporangium shape), and 14 (distance between two whorls) in descending order of the absolute values of the correlation (Table 3.3). A high canonical correlation indicates a strong relationship between the specific linear combination of variables (Baum and Bailey, 1984). This axis is most important for separating *Huperzia*, *Lycopodium* and *Lycopodiella*. The variance explained by canonical variable 2 is 2.4% of the total. This axis is most highly associated with 13 characters: 15 (leaf thickness), 13 (width of sporangium), 3 (diameter of apical shoot), 20 (stomate distribution), 7 (length of fertile branches), 9 (width of strobilus), 10 (length of sporophyll), 4 (width of microphyll), 16 (number of leaves in a whorl), 6 (distance from apex to the widest portion of microphyll), 8 (length of strobilus), 5 (length of microphyll), and 18 (leaf differentiation) in a corresponding manner.

Table 3.3 Sixteen quantitative and five qualitative characters, in the study of *Lycopodium* s.l. Univariate F values of the different character used in the canonical discriminant analysis and pooled within canonical structure using (I) 7 species grouping, and (II) 3 segregated genera grouping

No.	Characters	(I)				(II)			
		F-value	AXIS 1	AXIS 2	AXIS 3	F-value	AXIS 1	AXIS 2	Sig.
1.	Diameter of main stem in cm	25.34	-0.07	-0.04	0.13	9.07	-0.03	0.09	0.000
2.	Diameter of lateral branch in cm	30.73	-0.05	-0.05	0.14	14.02	-0.03	0.10	0.000
3.	Diameter of apical shoot in cm[ab]	89.72	0.05	-0.11	0.38	72.13	-0.01	**0.27**	0.000
4.	Width of microphyll in cm[ab]	676.71	-0.38	0.08	0.03	585.18	-0.12	**-0.15**	0.000
5.	Length of microphyll in cm[ab]	249.71	-0.14	-0.20	0.33	249.71	-0.08	**0.09**	0.000
6.	Distance from apex to the widest portion of microphyll in mm[ab]	120.42	-0.08	-0.09	0.33	225.95	-0.07	**0.12**	0.000
7.	Length of fertile branches in cm[ab]	34.68	0.03	-0.04	0.25	37.53	-0.00	**0.20**	0.000
8.	Length of strobilus in cm[b]	29.77	0.05	-0.01	0.26	70.46	-0.04	**0.11**	0.000
9.	Width of strobilus in cm[ab]	157.32	0.11	-0.17	0.26	52.68	0.02	**0.20**	0.000
10.	Length of sporophyll in mm[ab]	444.94	0.11	-0.37	0.42	36.30	0.00	**0.19**	0.000
11.	Width of sporophyll in mm[a]	55.91	0.02	-0.09	0.24	36.26	-0.04	0.17	0.000
12.	Length of sporangium in mm[a]	99.42	-0.06	-0.08	**0.44**	262.73	-0.02	0.32	0.000
13.	Width of sporangium in mm[ab]	139.76	-0.03	-0.15	**0.48**	194.95	-0.04	**0.36**	0.000
14.	Distance between two whorls in mm [ab]	1884.23	-0.43	**0.68**	0.26	43.24	**-0.03**	**0.00**	0.000
15.	Leaf thickness in mm[ab]	294.99	-0.20	-0.05	-0.20	483.76	-0.09	-0.41	0.000
16.	Number of leaves in a whorl[ab]	2450.36	**0.65**	0.51	0.01	241.96	0.07	**0.13**	0.000
17.	Growth habit	-	-	-	-	244.50	-0.16	0.10	0.000
18.	Leaf differentiation[ab]	135.47	0.06	0.05	0.24	1.77	-0.01	**-0.01**	0.000
19.	Leaf margin	-	-	-	-	9.25	-0.16	0.10	0.171
20.	Stomate distribution[ab]	148.29	-0.07	-0.05	0.40	189.21	-0.06	**0.20**	0.000
21.	Sporangium shape[ab]	-	-	-	-	1028.92	**0.16**	-0.10	0.000

Note Character followed by superscript alphabet indicates character entered in stepwise discriminant analysis and subsequently used in canonical discriminant Analysis:- [a]: (I) and (II); [b]: (II); Bold numbers on axis 1-3 denotes largest absolute correlation between each character and any discriminant function

Table 3.4 Summary of canonical discriminant function of *Lycopodium* s.l.

Seven species groupings

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	63.60	58.6	58.6	0.992
2	33.31	30.7	89.3	0.985
3	4.94	4.6	93.8	0.912
4	3.88	3.6	97.4	0.892
5	2.03	1.9	99.3	0.818
6	0.80	0.7	100	0.666

Three segregated genera groupings

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	181.92	97.6	97.6	0.99
2	4.44	2.4	100.0	0.90

The F values (Table 3.3) very nearly reflect the association with canonical Axis 1 because of its high correlation and high amount of variance explained. According to stepwise discriminant analysis 6 variables, viz. 1 (diameter of main stem), 2 (diameter of lateral branch), 11 (width of sporophyll in mm),12 (length of sporangium in mm),17 (growth habit) and 19 (leaf margin) were not selected for further use in canonical discriminant analysis (Table 3.3).

The canonical plot on the two canonical axes (Figure 3.3) shows that the three genera are distinct. The 409 OTUs (samples) of *Lycopodium* s.l. (Table 3.1) separated into three groups on canonical axis 1. Group 1, the largest group, is composed of 5 species of *Huperzia*. Group 2 is composed of a single species, *Lycopodiella cernua*. Group 3 is composed of *Lycopodium clavatum*. It can be seen that, among the three groups, group 1 and 3 were rather heterogeneous, while group 2 was less variable. It can be concluded that cluster analyses and canonical discriminant analyses do support the separation of *Lycopodium* s.l. in South-East Asia into 3 genera, i.e. *Huperzia*, *Lycopodiella* and *Lycopodium* s. str. based on both quantitative and qualitative characters.

Table 3.5 shows means and standard deviation of 16 quantitative characters of *Huperzia*, *Lycopodiella* and *Lycopodium* s. str. Boxplots of the four most important

Table 3.5 Means and standard deviation of 16 quantitative and 5 qualitative characters of the three segregated genera from *Lycopodium* s. l.

Character	**Genera**					
	Huperzia		*Lycopodiella*		*Lycopodium* s. str.	
	mean	± SD	mean	± SD	mean	± SD
1.	2.50	1.23	2.69	0.66	2.89	0.60
2.	1.52	0.74	1.46	0.47	1.94	0.47
3.	0.83	0.41	0.50	0.19	1.36	0.43
4.	3.59	1.56	0.48	0.13	0.68	0.15
5.	11.77	6.04	3.40	0.73	7.02	1.26
6.	8.97	3.13	3.38	0.72	6.53	1.26
7.	63.85	61.60	24.45	14.78	116.40	42.42
8.	89.86	79.94	10.24	4.5	44.67	15.79
9.	2.00	1.99	1.89	0.33	3.34	0.56
10.	3.34	3.80	1.73	0.65	5.11	0.96
11.	1.26	0.61	1.01	0.32	1.65	0.32
12.	0.94	0.21	0.45	0.00	0.95	0.22
13.	1.17	0.33	0.59	0.12	1.49	0.39
14.	3.77	1.55	1.87	0.21	2.45	0.13
15.	0.17	0.00	0.11	0.00	0.08	0.00
16.	3.22	1.45	9.05	1.13	8.00	0.00
17.	3.58	1.04	1.00	0.00	2.00	0.00
18.	2.09	0.56	2.00	0.00	2.00	0.00
19.	2.72	0.69	3.00	0.00	3.00	0.00
20.	1.88	0.32	1.00	0.00	1.79	0.40
21.	1.13	0.34	3.00	0.00	2.00	0.00

characters that segregate these three genera are presented in Figure 3.4. It can be seen that sporangium shape (21) and distance between two whorls (14) are the most important qualitative and quantitative characters, respectively.

3.2.3 Classificatory discriminant analysis

Fifteen of the twenty one quantitative and qualitative characters (Table 3.3) were determined by stepwise discriminant analysis to be important for discriminating between the three segregated genera. The resulting linear discriminant function classified 100% of the 409 specimens correctly when using the suite of the first two important characters for canonical axis 1-2 based on 40, 37 and 3 observations for each segregated genus. Because of these, the linear discriminant function (Table 3.6) can be used for identification of specimens of *Lycopodium* s.l. To use the discriminant function in Table 3.6 for generic identification, multiply each character score by its coefficient in each column. Calculate the total for each column, the column with the highest total is a genus to which the specimen belongs. Though this method of identification is different from traditional keys, it can be used in a complementary manner.

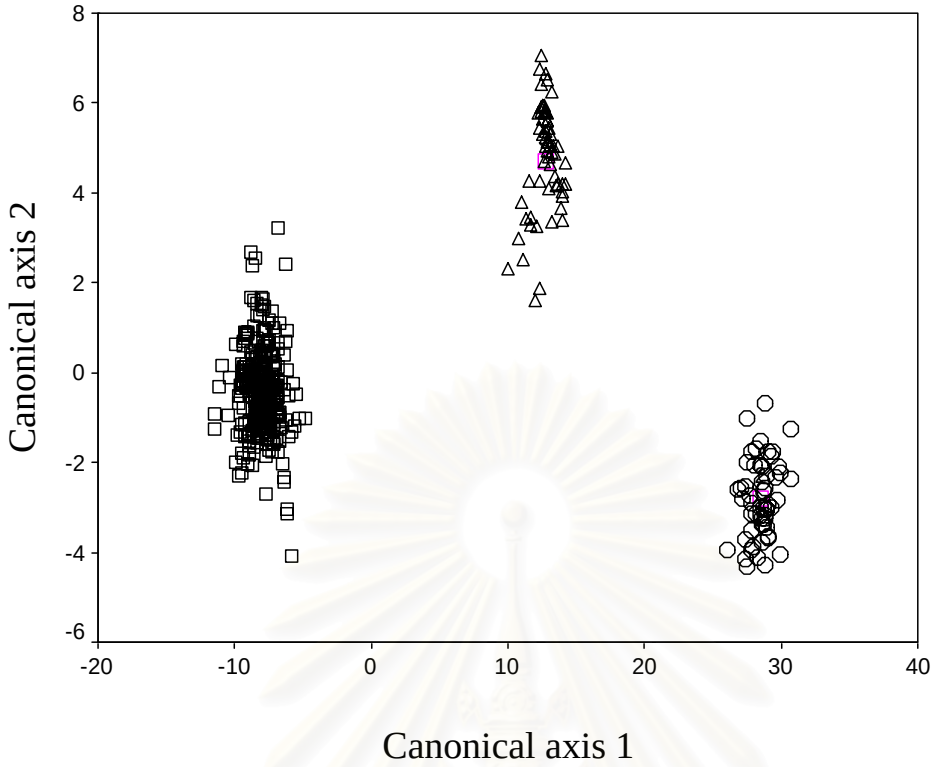

Figure 3.3 Canonical plot of 409 specimens from the seven species of *Lycopodium* s.l. obtained by canonical discriminant analysis
□ *Huperzia*, ○ *Lycopodiella*, △ *Lycopodium* s. str.

Two techniques of morphometric analysis were used to investigate the taxonomic status of 7 species in the genus *Lycopodium* s.l. in South-East Asia. We conclude that the results from the numerical taxonomic study as well as the comparison of qualitative characters of *Lycopodium* s.l. provide justification for the recognition of the three genera of Lycopodiaceae, namely *Huperzia*, *Lycopodiella* and *Lycopodium* s. str. This result, although based on 7 species only, is in agreement with (Øllgaard, 1987) who used characteristic of branching patterns, cortex and stellar anatomy, distribution of mucilage cavities, leaf differentiation, morphology of sporophylls, sporangia, spores, and gametophytes, chromosome numbers, and phytochemistry. From the overall result of the analyses it can be seen that *Huperzia* and *Lycopodium* s. str. are rather heterogeneous genera, whereas *Lycopodiella* is rather a homogeneous genus. This finding is also in agreement with (Øllgaard, 1989) who subdivided the genus *Huperzia* into 22 groups due to the most diverse in habitat, growth habit and morphology. According to him, *H. serrata* is belonged to the *Huperzia selago* group. *H. carinata* and *H. squarrosa* are member of the

Huperzia carinata group and the *Huperzia squarrosa* group, respectively. While *H. phlegmaria* and *H. nummulariifolia* are in the same group, the *Huperzia phlegmaria* group, but in different subgroup. These two species are grouped next together which reflect the close relationship (Figure 3.1).

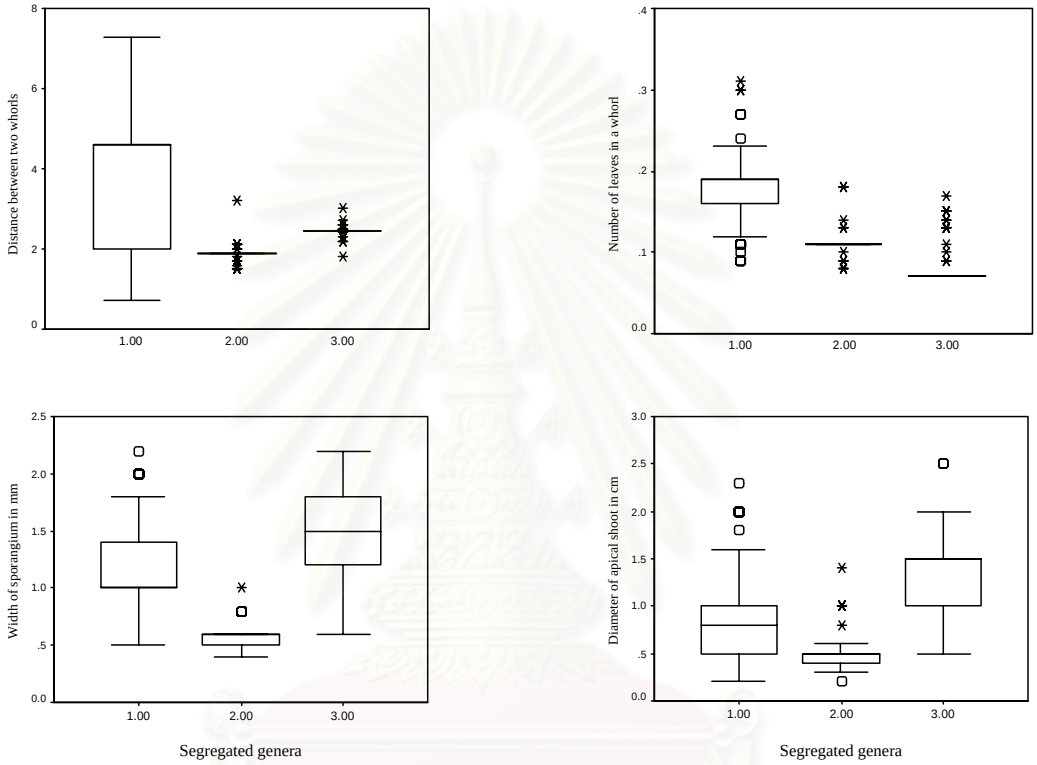

Figure 3.4 Boxplots of the four most important quantitative characters of the three segregated genera of *Lycopodium* s.l.
(1 *Huperzia*, 2 *Lycopodiella*, 3 *Lycopodium* s.str.)

The present findings reveal a close relationship between *Lycopodiella* and *Lycopodium* s. str. (Figs. 3.1-3.2). They are terrestrial, usually found in the fully exposed mountainous areas. Due to rather small number of complete herbarium specimens. Only one species in each genus can be used in this study. Thus the taxonomic status of the genus *Lycopodiella* and *Lycopodium* s. str. could benefit from a multivariate morphometric approach based on worldwide material that is beyond the scope of this study.

Table 3.6 To identify a specimen to one of the three genera, multiply each character score by its coefficient in each column; compute the total for each column; the column with the highest total is the genus to which the specimen belongs.

Character	*Huperzia*	*Lycopodiella*	*Lycopodium* s.str.
3. Diameter of apical shoot in cm	-12.055	-9.527	-6.875
4. Width of microphyll in cm	13.763	9.331	4.685
5. Length of microphyll in cm	-48.370	-249.005	-155.343
6. Distance from apex to the widest portion of microphyll in mm	58.504	201.678	137.736
7. Length of fertile branches in cm	9.463	15.199	14.813
8. Length of strobilus in cm	-1.518	-6.857	-5.722
9. Width of strobilus in cm	19.983	42.222	31.609
10. Length of sporophyll in mm	16.816	10.968	22.322
13. Width of sporangium in mm	-14.085	-22.365	-7.327
14. Distance between two whorl	180.425	321.115	284.508
15. Leaf thickness in mm	-144.818	-227.916	-211.520
16. Number of leaves in a whorl	151.771	321.283	253.300
18. Leaf differentiation	42.713	69.666	48.365
20. Stomate distribution	19.063	-24.259	3.593
21. Sporangium shape	444.909	998.167	756.212
(Constant)	-671.001	-2267.801	-1501.426

3.3 *Taxonomic revision of the Lycopodiaceae in South-East Asia*

The results of cluster and canonical discriminant analyses provided justification for the recognition of the three genera of Lycopodiaceae in South-East Asia. In most cases they can be distinguished morphologically by their sporangium shape, distance between two whorls, sporangium width, number of leaves in a whorl etc. The following is a simplified key to the segregated genera of *Lycopodium* s.l. (data from 7 species) using both quantitative and qualitative characters (Tables 3.2-3.3) based on the output obtained from DELTA (Dallwitz et al., 1993).

Key to the genera

1a	Distance between two whorls more than 2.2 mm; sporangium width more than 0.8 mm……...	2
1b	Distance between two whorls less than 2.2 mm; sporangium width less than 0.8 mm……	2. *Lycopodiella*
2a	Vein visible; terrestrial, epiphytic or epilithic plants in shady places……..	1. *Huperzia*
2b	Vein hardy visible; terrestrial plants, usually occur in fully exposed areas…….....	3. *Lycopodium* s. str.

From taxonomic literatures, there are at least 35 species within three genera of the Lycopodiaceae in South-East Asia (Table 3.7). Malaysia has about 25 species and probably the highest number of species in the region. While there is no data available from Myanmar and Indonesia at time of data collections. Iwatsuki & Tagawa (1979) enumerated 9 species of the *Lycopodium* s.l. from Thailand based on the existing herbarium specimens and some of their collections. The present study lists 8 new records for Thailand based on extensive specimen collection from the last 25 years. It is expected that some more new records can be collected in peninsular Thailand, especially in Hala-Bala forests, Yala and Narathiwat Provinces. Due to the social unrest in these areas we can not collect more species. However, specimen collections at Khao Nan National Park in Nakhon Si Thammarat Province, a species of *Huperzia laxa* was reported. Geographically speaking this species is a member of malesian elements. Khao Nan National Park is probable to be the northernmost station of this species.

In Vietnam there are about 14 species of *Lycopodium* s.l., 4 species, viz. *Huperzia cancellata*, *H. salvinioides*, *H. subdisticha*, and *Lycopodium obovalifolium* namely are indigenous to Indochina region (Pham-Hoang, 1991). It is expected to discover some of these Indochinese species in North-East Thailand, but no additional

species was found at the time of the excursion. Extensive specimen collections at Phu Luang Wildlife Sanctuary in Loei Province and Khao Soi Dao National Park in Chanthaburi Province are needed to gain some more species from Indochina region.

Table 3.7 Checklists of *Huperzia*, *Lycopodium* s. str. and *Lycopodiella* in South East Asia

No.	Scientific Name	Thailand[1]	Malaysia[2]	Vietnam[3]	Indochina[4]
1.	*Huperzia australiana* (Herter) Holub		✓		
2.	*Huperzia cancellata* (Spring) Trevisan			✓	✓
3.	*Huperzia carinata* (Desv. ex Poiret) Trevisan	✓	✓	✓	✓
4.	*Huperzia chinensis* (Christ) Ching			✓	✓
5.	*Huperzia coralia* (Spring) Holub		✓		
6.	*Huperzia* aff. *ceylanica* (Spring) Trevisan		✓		
7.	*Huperzia cryptomerina* (Maxim.) Dixit	✓			
8.	*Huperzia dalhousiana* (Spring) Trevisan	✓	✓		
9.	*Huperzia goebelii* (Nessel) Holub	✓			
10.	*Huperzia hamiltonii* (Sprengel) Trevisan	✓		✓	✓
11.	*Huperzia hippuris* (Desv. ex Poiret) Trevisan		✓		
12.	*Huperzia horizontalis* (Herter ex Nessel) Holub		✓		
13.	*Huperzia laxa* (C.Presl) Trevisan	✓	✓		
14.	*Huperzia nummulariifolia* (Blume) Chambers	✓	✓		
15.	*Huperzia phlegmaria* (L.) Rothm.	✓	✓	✓	✓
16.	*Huperzia phlegmarioides* (Gaudich.) Rothm.		✓		
17.	*Huperzia phyllantha* (Hook. & Arnott) Holub		✓		
18.	*Huperzia pinifolia* Trevisan	✓	✓		
19.	*Huperzia pulcherrima* (Hook. & Grev.) Pichi-Serm.	✓			
20.	*Huperzia salvinioides* (Herter) Holub			✓	✓
21.	*Huperzia serrata* (Thunb. ex Murray) Trevisan	✓	✓	✓	✓
22.	*Huperzia squarrosa* (G.Forster) Trevisan	✓	✓	✓	✓
23.	*Huperzia subdisticha* Mak.			✓	
24.	*Huperzia tetrasticha* (Kunze) Holub	✓	✓		
25.	*Huperzia verticillata* (L.f.) Trevisan		✓		
26.	*Lycopodiella caroliniana* (L.) Pichi-Serm.		✓		
27.	*Lycopodiella cernua* (L.) Pichi-	✓	✓	✓	✓

No.	Scientific Name	Thailand[1]	Malaysia[2]	Vietnam[3]	Indochina[4]
	Serm.				
28.	*Lycopodium casuarinoides* Spring	✓	✓	✓	✓
29.	*Lycopodium clavatum* L.	✓	✓	✓	✓
30.	*Lycopodium complanatum* L.	✓		✓	✓
31.	*Lycopodium obovalifolium* Bonap.			✓	✓
32.	*Lycopodium platyrhizoma* Wilce		✓		
33.	*Lycopodium scariosum* G. Forst.		✓		
34.	*Lycopodium volubile* G. Forst.		✓		
35.	*Lycopodium wightianum* Wall. ex Grev. & Hook.		✓		
	Total species in each country	17	25	14	13

[1] result from this study; [2] Paris & Latiff (1997); [3] Pham-Hoang (1991); [4] Alston (1951)

3.4 Enumeration of the Lycopodiaceae in Thailand

The existing herbarium specimens of *Lycopodium* s.l. from Thailand deposited at BCU, BK, BKF, BM, K, L, P, QBG and SING as well as additional collections and type specimens of each species were studied. It was found that 17 species are indigenous to Thailand (Table 3.7). Eight of these species are new records and one species is a new determination.

Table 3.8 Seventeen indigenous species of *Lycopodium* s.l. from Thailand.

NO.	*Lycopodium* s.l.	Remark
1.	*Huperzia carinata* (Desv. ex Poiret) Trevisan	-
2.	*Huperzia cryptomerina* (Maxim.) Dixit	New record
3.	*Huperzia dalhousiana* (Spring) Trevisan	New record
4.	*Huperzia goebelii* (Nessel) Holub	New record
5.	*Huperzia hamiltonii* (Sprengel) Trevisan	-
6.	*Huperzia laxa* (C.Presl) Trevisan	New record
7.	*Huperzia nummulariifolia* (Blume) Chambers	-
8.	*Huperzia phlegmaria* (L.) Rothm.	-
9.	*Huperzia pinifolia* Trevisan	New determination
10.	*Huperzia pulcherrima* (Hook. & Grev.) Pichi-Serm.	New record
11.	*Huperzia serrata* (Thunb. ex Murray) Trevisan	-
12.	*Huperzia squarrosa* (G.Forster) Trevisan	-
13.	*Huperzia tetrasticha* (Kunze) Holub	New record
14.	*Lycopodiella cernua* (L.) Pichi-Serm.	-
15.	*Lycopodium casuarinoides* Spring	New record
16.	*Lycopodium clavatum* L.	-
17.	*Lycopodium complanatum* L.	New record

LYCOPODIACEAE

Lycopodiaceae Beauv. ex Mirb.; Hist. Nat. Veg. (Lam. & Mirb.) 4: 293 (1802). *Huperziaceae* Rothm.; Fedde Repert. 66: 236 (1962) [nom. nov.].--*Urostachyaceae* Rothm.; Fedde Repert. 54: 58 (1944) [nom. illeg.].—*Phylloglossaceae* Kze.; Bot. Zeit. 1: 722 (1843).

The following enumeration of Thai species follows the classification of Øllgaard (1987, 1989) and the result from this phenetic study. According to that classification, there are three genera occur in Thailand, viz. *Huperzia*, *Lycopodium* s.str., and *Lycopodiella*.

Key to the genera

1a	Epiphytic or epilithic plants; branches isotomous, strobilus distinct or indistinct …….	1. *Huperzia*
1b	Terrestrial plants ……	2
2a	Strobilus distinct……..	3
3a	Strobili erect, sessile or pedunculate	2. *Lycopodium* s.str
3b	Strobili pendent and sessile, or erect with simple branches; Sporophylls green and leaf-like ……..	3. *Lycopodiella*
2b	Strobilus indistinct; branches isotomous ……	1. *Huperzia*

HUPERZIA BERNHARDI

Sporophytes terrestrial or epiphytic, isotomously branched throughout. Growth habit pendent to recurved, erect, or ascending. Branches all similar, or in some terrestrial species differentiated into prostrate, sometimes subterranean and aerial branched. Trophophylls and sporophylls conform, gradually dimorphic or in some species sharply dimorphic. Sporangia axillary, reniform with a short slender stalk, isovalvate, with thickened, lignified, sinuate side walls in epidermal cells. Spores foveolate-fossulate.

Cosmopolitan, with perhaps 300 species, by far the largest of the three genera, with approximately 25 species in South-East Asian countries and about 13 species in Thailand (Fig. 3.5).

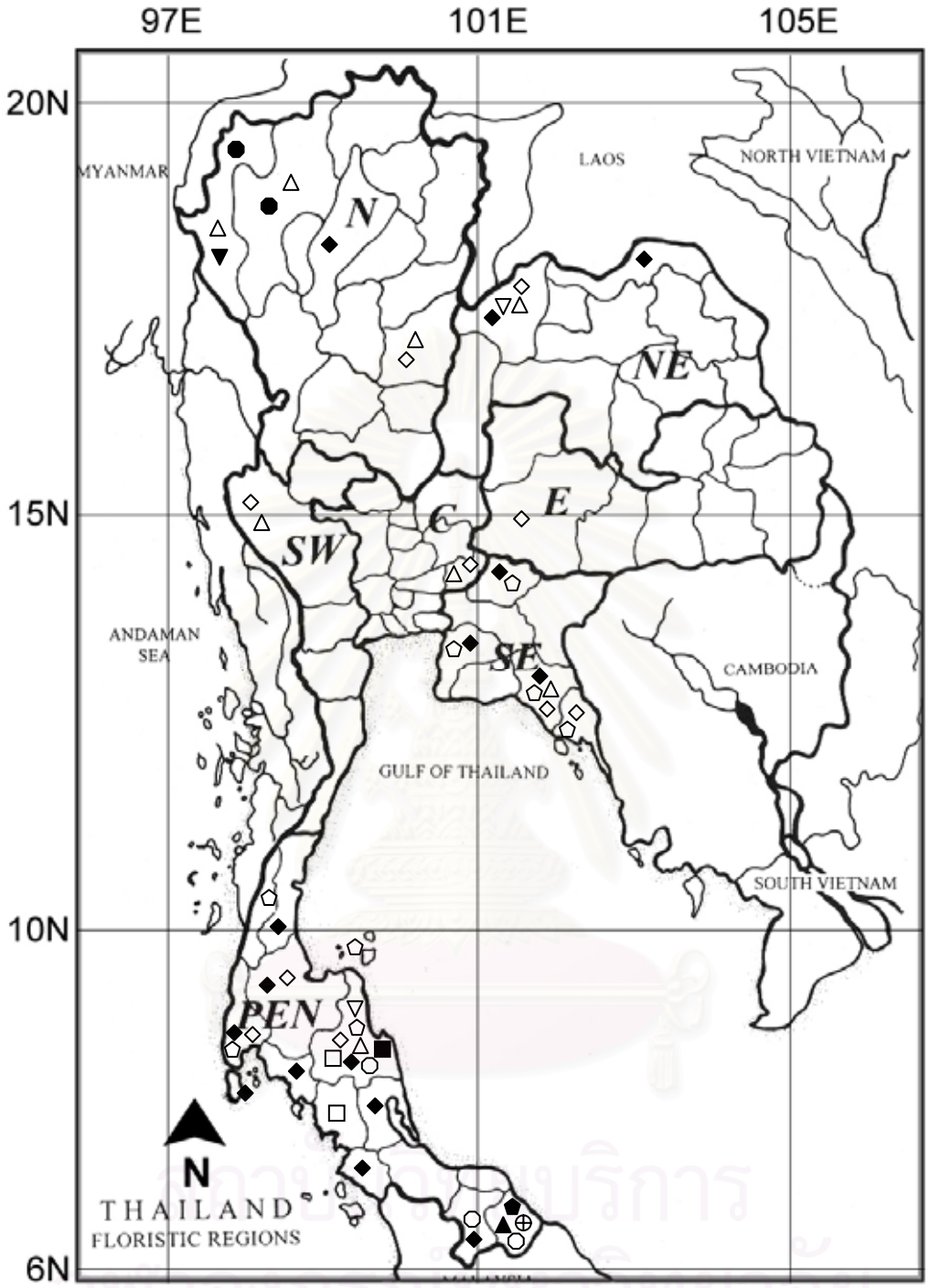

Figure 3.5 Distribution map of *Huperzia* in Thailand

⬠ *H. carinata*, ▼ *H. cryptomerina*, ▲ *H. dalhousiana*, ⊕ *H. goebelii*, △ *H. hamiltonii*, ■ *H. laxa*, ○ *H. nummulariifolium*, ◆ *H. phlegmaria*, □ *H. pinifolium*, ● *H. pulcherrima*, ▽ *H. serrata*, ◇ *H. squarrosa*, ⬟ *H. tetrasticha*

Key to the species

1a	Sporophylls and vegetative leaves more or less nearly the same size……..	2
1b	Sporophylls noticeably reduced in size in comparison with vegetative leaves……..	3
2a	Terrestrial plant in shady places, on humus rich ground; stem erect, leaves narrowly lanceolate, serrate at margin….	11. *H. serrata*
2b	Epiphytic or lithophytic plants in shady or opened places; stem usually pendulous or ascending, leaves entire……..	4
4a	Plants restricted to the northern provinces……	5
4b	Plants otherwise……	6
5a	Vegetative leaves coriaceous, narrowly laceolate to ovate-lanceolate, midrib distinct, 1.5-2.0 mm in width……..	2. *H. cryptomerina*
5b	Vegetative leaves chartaceous, linear, midrib usually indistinct, less than 1 mm in width……..	10. *H. pulcherrima*
6a	Vegetative leaves appressed, overlapped; sporophylls fully covered sporangia…….	7
6b	Vegetative leaves patent, not overlapped; sporophylls usually not covered sporangia……..	8
7a	Stem and leaves terrete in appearance; vegetative leaves and sporophylls slightly appressed……..	1. *H. carinata*
7b	Stem and leaves quadrangular in appearance; vegetative leaves and sporophylls strongly appressed……..	13. *H. tetrasticha*
8a	Main stem 1-2 mm in diameter; leaves elliptic-oblong, 3-5 mm broad, chartaceous to slightly succulent in texture…..	5. *H. hamiltonii*
8b	Main stem 3-5 mm or more in diameter; leaves linear-lanceolate, 1-2 mm broad, coriaceous in texture……..	12. *H. squarrosa*
3a	Vegetative leaves ovate-elliptic, appressed, arranged in 2 rows; Sporophyll usually not covered the whole sporangia when mature…….	7. *H. nummulariifolia*
3b	Vegetative leaves linear to lanceolate, patent, spirally arranged……	9
9a	Vegetative leaves and sporophyll coriaceous in texture, sporophyll ovate, acuminate, usually covered the whole sporangia……..	3. *H. dalhousiana*
9b	Vegetative leaves and sporophyll chartaceous in texture…	10
10a	Vegetative leaves linear, midrib indistinct; sporophyll ovate to laceolate, appressed……	6. *H. laxa*
10b	Vegetative leaves narrowly lanceolate to ovate-lanceolate..	11
11a	Fertile branches repeated 2-4 times dichotomously forked, bearing 4-8 strobili at apex of a sterile branch……..	8. *H. phlegmaria*
11b	Fertile branches usually forked once, bearing 2 strobili at apex of a sterile branch…….	12
12a	Sporophyll usually appressed at base and slightly patent at apex, ovate, apex acuminate…….	4. *H. goebelii*
12b	Sporophyll usually patent, the same shape as vegetative leaves but much reduced in size……	9. *H. pinifolia*

1. Huperzia carinata (Desv. *ex* Poiret) Trevisan, Atti Soc. Ital. Sci. Nat. 17: 247. 1874.—*Huperzia struthioloides* (C. Presl) Rothm.; Feddes Repert. 54: 61 (1944).—*Lycopodium acrostachyum* Hook. & Grev.; Icon. filic. 2: t. 181 (1831).—*Lycopodium carinatum* Desv. ex Poiret; Encycl. suppl. 3: 555 (1813 [1814]).—*Lycopodium carinatum* var. *minus* Tagawa (1964).—*Lycopodium cumingii* Loddiges (Salomon 1883: 224). —*Lycopodium pendulum* Roxb.; Calcutta J. Nat. Hist. 4. 472 (1844).—*Lycopodium struthioloides* C. Presl; Reliq. haenk. 1: 82 (1825). —*Lycopodium urostachyum* Wall. ex Ridley; J. Straits Branch Roy. Asiat. Soc. 80: 142. 1919. —*Phlegmariurus carinatus* (Poiret) Ching; Acta Bot. Yunnanica 4: 120 (1982). —- *Selaginella struthioloides* (C. Presl) L. Underw.; Bull. Torrey Bot. Club 25: 132 (1898). —*Urostachys carinatus* (Poiret) Herter; Bot. Arch. 3: 115 (1923). — *Urostachys struthioloides* (C. Presl) Herter ex Nessel; Bärlappgewächse 170 (1939). —Type: Indes orientales, aux îles Séchelles (? or New Ireland) ["Isle Praslin"] (P-Juss. 639, BM photo!).

Stems 50 cm or more long, slender, about 0.7 cm in diameter including leaves, pendulous, one to three times dichotomously forked. *Leaves* narrowly lanceolate, apex subulate, base attenuate, sessile, about 1.25 x 0.13 cm, chartaceous in texture, margins entire, appressed and revolute, midrib indistinct. *Strobilus* indistinct. *Sporophylls* about the same size as microphyll, oblong subdeltoid, to 5 mm long, 1.5 mm broad.

Specimen examined.— Hansen & T. Smitinand-11968 (BKF); W.T. Tsang-27272, W.T. Tsang-29892, Taurier-1985, D.C. Collius-138 (K)

Thailand.—SOUTH-EASTERN: Chon Buri (Si Racha, Hup Bon Hills), Chanthaburi (Khao Soi Dao, Taruang), Trat (Koh Chang); PENINSULAR: Ranong (Khao Thalu, Muang Laen, Thung Kha), Surat Thani (Koh Samui), Phangnga, Nakhon Si Thammarat (Khao Luang).

Distribution. — South China, South Ryukyus, Taiwan, Indochina, Malesia and Polynesia.

Ecology.— Epiphyte on mossy-tree trunk in shady places and humid areas.

Vernacular. —Hang nu (หางหนู), Hang pia check (หางเปียเจ็ก), Soi nari (สร้อยนารี) (South-Eastern).

2. Huperzia cryptomerina (Maxim.) Dixit, J. Bombay Nat. Hist. Soc. 77 (3): 541. 1981.—*Lycopodium cryptomerinum* Maxim.—*Phlegmariurus cryptomerianus* (Maxim.) Ching*;* Acta Phytotaxonomica Sinica 37(1): 51 (1999).—*Urostachys cryptomerianus* (Maxim.) Herter ex Nessel*;* Die Bärlappgewächse 70 (1939). —Syntypes: Kyushu, Japan (LE).

Stems 10-30 cm, robust, thick, 2-3 cm in diameter including leaves, pendulous, one to three times dichotomously forked. *Leaves* narrowly lanceolate to ovate-lanceolate, 15-18 x 1.5-2 mm, leathery in texture, margins entire and revolute, midrib distinct. *Strobilus* indistinct. *Sporophylls* about the same size as microphyll.

Specimen examined.—O. Thaithong s.n. (BCU).

Thailand.— NORTHERN: Chiang Mai (Huai Nam Dung).

Distribution.— Korea, Japan, Taiwan, India

Ecology.— Epiphyte on mossy-tree trunk.

Notes. —This species is rather rare, known only from one collection.

3. Huperzia dalhousiana (Spring) Trevisan, Atti Soc. Ital. Sci. Nat. 17: 247. 1874. —*Huperzia caudifolia* (Alderw.) Holub; Folia Geobot. Phytotax. 20: 71 (1985).—*Huperzia clarae* (Bailey) Holub; Folia Geobot. Phytotax. 20: 71 (1985).—
Lycopodium caudifolium Alderw.; Bull. Jard. Bot. Buitenzorg, ser. 2, 1: 14 (1911).—
Lycopodium clarae Bailey; Queensl. Dept. Agric., Brisbane, Bull. 21 (Bot. Bull. 7): 69 (1893).— *Lycopodium dalhousianum* Spring; Mém. Acad. Roy. Sci. Belg. 24 [Mon. Lyc. 2]: 25 (1849]).—*Urostachys caudifolius* (Alderw.) Herter ex Nessel; Bärlappgewächse 185 (1939).—*Urostachys clarae* (Bailey) Herter ex Nessel; Bärlappgewächse 185 (1939).—*Urostachys dalhousianus* (Spring) Herter ex Nessel; Bärlappgewächse 185 (1939). Type: Lady Dalhousie 36, from the island of Pinang (K!, holotype; BONN-Nessel, isotype (Adelbert MS)).

Stems 50-70 cm, robust, thick, 5-6 cm in diameter including leaves, pendulous, one to two times dichotomously forked. *Leaves* linear to linear-triangular, 10-20 x 1.75-3.25 mm, lateral ones spreading, pale-green to brownish at age, leathery in texture, margins entire and revolute, midrib distinct. *Strobilus* 6-18 cm x 5-7 m, terminal on the branchlets, simple to twice forked. *Sporophylls* ovate, acuminate, usually covering the whole sporangium.

Specimen examined.—T.Boonkerd & R. Pollawatn 341 (BCU); W. Norris s.n. (K); J.H. Corner s.n.; Singapore Field No. 34641 (K).

Thailand.— PENNINSULAR: Yala (Khao Budo).

Distribution : NE-Queensland, peninsular Malaysia (Penang Isl., Pahang, Melaka), Borneo.

Ecology.— Epiphyte on mossy-tree trunk.

4. Huperzia goebelii (Nessel) Holub; Folia Geobot. Phytotax. 20: 73 (1985).—
Urostachys goebelii Nessel; Repert. Spec. Nov. Regni Veg. 36: 188, t. 175 (1934) —*Huperzia heroldii* (Nessel) Holub; Folia Geobot. Phytotax. 20: 73 (1985). —-*Urostachys heroldii* Nessel; Revista Sudamer. Bot. 6: 167, t. 14, f. 69 (1940). —Syn type : *Urostachys goeblii* Nessel , Haniff 10225 from Kelantan (BM!)

Stems 80-100 cm, slender, 0.6-1.5 cm in diameter including leaves, pendulous, two to four times dichotomously forked. *Leaves* ovate-lanceolate, 0.6-1.6 cm x 2.2 mm, patent,

light green to light brown at age, glossy, texture paperaceous, margins entire and revolute, midrib distinct. *Strobilus* 3-6.2 cm x 0.1.-0.2 cm, terminal on the branchlets, twice or more forked. *Sporophylls* ovate, apex short acuminate, usually not covering the whole mature sporangium.

Specimen examined—T. Boonkerd & R. Pollawatn 352 (BCU); Haniff 10225 (BM).

Thailand.—SOUTH-EASTERN: Trat (Koh Chang); PENNINSULAR: Yala (Khao Budo).

Distribution.— Sumatra, Borneo.

Ecology.— Epiphyte on mossy-tree trunk.

5. Huperzia hamiltonii (Spreng.) Trevis.; Atti Soc. Ital. Sci. Nat. 17: 248 (1874).— *Huperzia hamiltonii* (Spreng.) T. Sen & U. Sen; Fern Gazette 11(6): 419-420, f. 2, bb-hh (1978) [nom. illeg., non Huperzia hamiltonii (Spreng.) Trevis. (1874).— *Lycopodium hamiltonii* Sprengel; Syst. veg. 5: 429 (index) (1828).—*Lycopodium obtusifolium* Buch.-Ham. ex D. Don; Prodromus Florae Nepalensis 18-19 (1825) [nom. illeg., non Lycopodium obtusifolium Sw. (1806).—*Phlegmariurus hamiltonii* (Spreng.) Á. Löve & D. Löve; Taxon 26(2-3): 324 (1977).—*Urostachys hamiltonii* (Spreng.) Herter ex Nessel; Die Bärlappgewächse 68 (1939).

Stems 15-35 cm or more long, 1.0-2.0 mm in diameter without leaves, pendulous, one to three times dichotomously forked. *Leaves* narrowly lanceolate, elliptic to ovate, apex acute to rounded, narrowing towards sessile base, patent, about 0.6-1.5 cm x 0.2-0.6 cm, chartaceous to slightly succulent in texture, margins entire, midrib more or less distinct on lower surface. *Strobilus* indistinct to slightly distinct. *Sporophylls* usually smaller than the microphylls or much reduced, oblong to subdeltoid, 2-7 mm long, 1.5 mm broad.

Specimen examined—B. Hansen et al. 10916, C.F. van Beusekom & C. Phengkhlai 982, E. Hennipman 3865, 3943, G. Murata et al. T15954, J.F. Maxwell 94-1012, K. Iwatsuki et al. T8376, K. Iwatsuki & N. Fukuoka T7155, T7490, M. Tagawa et al. T. 3032, Phoenchit Suvarnakoses 597, R. Geesink et al. 8013, T. Smitinand 5468, 17192, 90-88 (BKF); T. Boonkerd & R. Pollawatn 61 (BCU).

Thailand.—NORTHERN: Chiang Mai (Doi Chiang Dao, Khun Mae Lan, Khun Kong San, Doi Suthep, Doi Inthanon), Mae Hong Son (Doi Khun Huay Pong), Phitsanulok (Phu Miang); NORTH-EASTERN: Loei (Phu Luang, Phu Rua, Phu Kra Dung); CENTRAL: Nakhon Nayok (Khao Yai, Khao Kiew); SOUTH-EASTERN: Chanthaburi (Khao Soi Dao), Trat (Koh Chang); SOUTH-WESTERN: Kanchanaburi (Sisawat, Thong Pha Phum); PENINSULAR: Ranong (Khao Thalu, Muang Laen, Thung Kha), Surat Thani (Koh Samui), Phangnga, Nakhon Si Thammarat (Khao Luang).

Figure 3.6 *Huperzia carinata* a: an epiphytic plant in it natural habitat at Khao Soi Dao, Chanthaburi Province; b: a cultivated plant; c: sporophylls

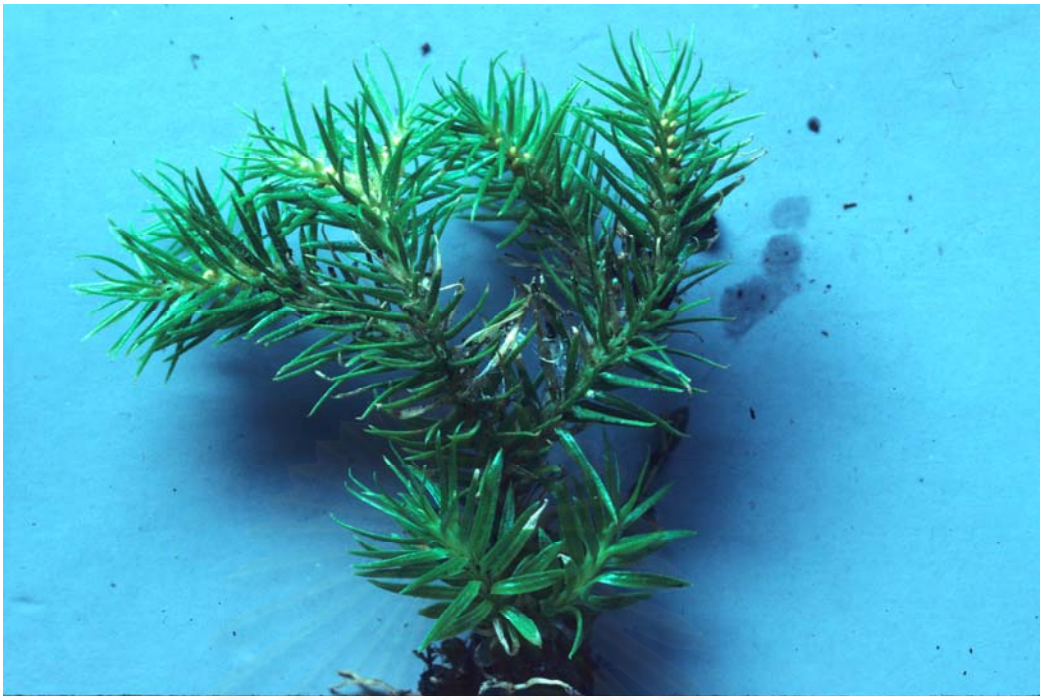

Figure 3.7 *Huperzia cryptomerina*, an epiphytic plant from Huai Nam Dung National Park, Chiang Mai Province (Photograph courtesy of Associate Professor Dr. Obchant Thaithong).

Distribution. —Nepal, India (throughout, in hilly regions), Myanmar, Sri Lanka, Indochina, Malesia, Taiwan.

Ecology.— Epiphyte on mossy-tree trunk in shady places and humid areas.

Notes. —This is a heterogeneous species and has a tendency to be a complex species. Some plants from Khao Luang (Nakhon Si Thammarat) and Khao Kiew (Khao Yai National Park) have distinct strobili similar to *H. phlegmaria*, but usually have some patent sporophylls. While some plants from the north have rather broad leaves. In all, three forms occur in Thailand (Figs. 3.10 a-f).

6. Huperzia laxa (C. Presl) Trevisan, Atti Soc. Ital. Sci. Nat. 17: 247. 1874. — Type: Haenke s. n., from Luzon, Philippines (K!, isotype). —*Lycopodium laxum* C. Presl

Stems 20-45 cm, pendulous, slender, 0.8-1.6 mm in diameter including leaves, 1-2 times dichotomously branched. *Leaves* linear, 8-12 x 0.6-1.00 mm; patent, thin but firm in texture; margins entire, revolute; midrib normally indistinct, light green to green in colour, glossy. *Strobilus* slightly distinct. *Sporophylls* ovate, apex long acuminate. *Sporangia* in the axils of leaves, reniform.

Specimen examined—KNP 020 (BCU); W.M.A. Brooke s.n. (BM); J. Sinclair & Kiah bin Salleh 40419 (E).

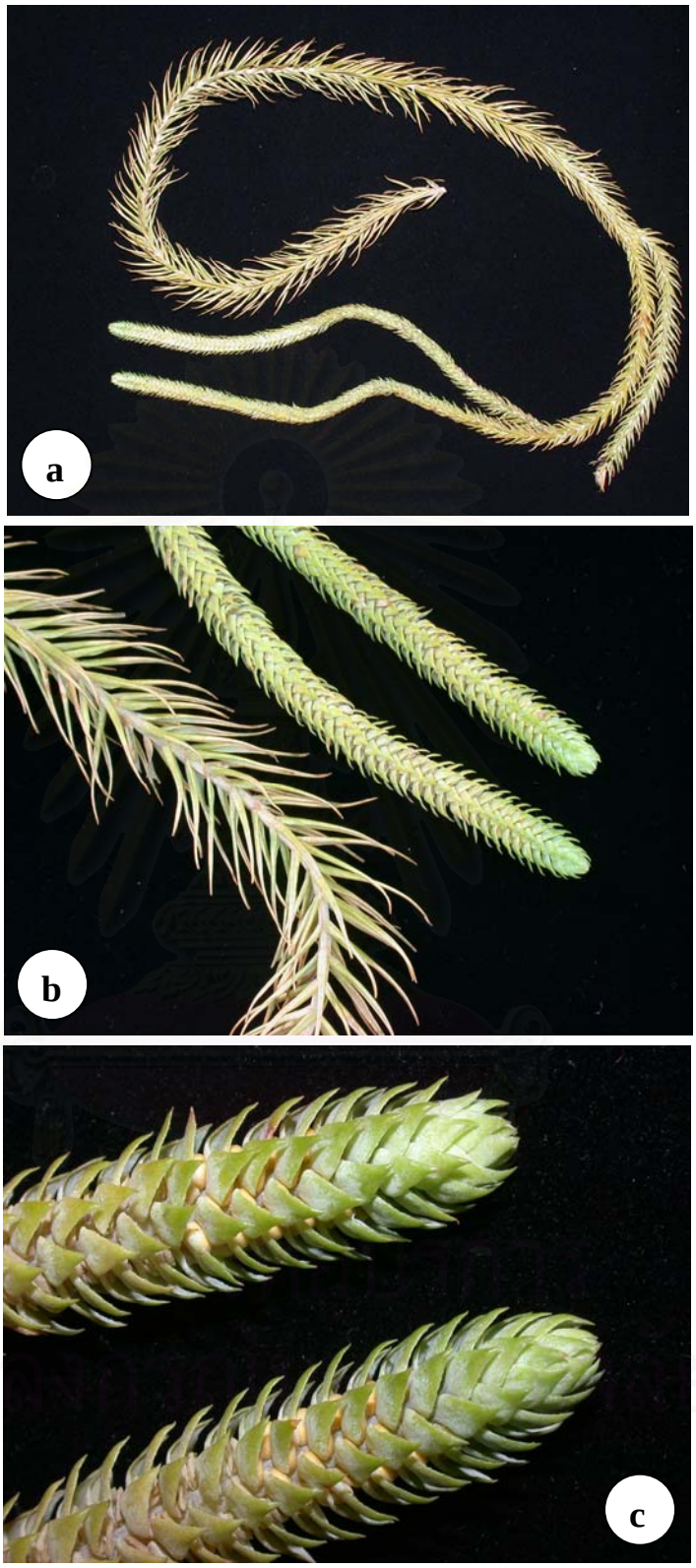

Figure 3.8 *Huperzia dalhousiana* a-b: a branch with strobili; c: part of strobili showing sporophylls and sporangia

Figure 3.9 *Huperzia goebelii* a: branches showing strobili;
b: sporophylls and sporangia

a

b

Figure 3.10 *Huperzia hamiltonii* a: an epiphyte on mossy tree-trunk at Thong Pha Phum National Park, Kanchanaburi Province; b: sporophylls and sporangia

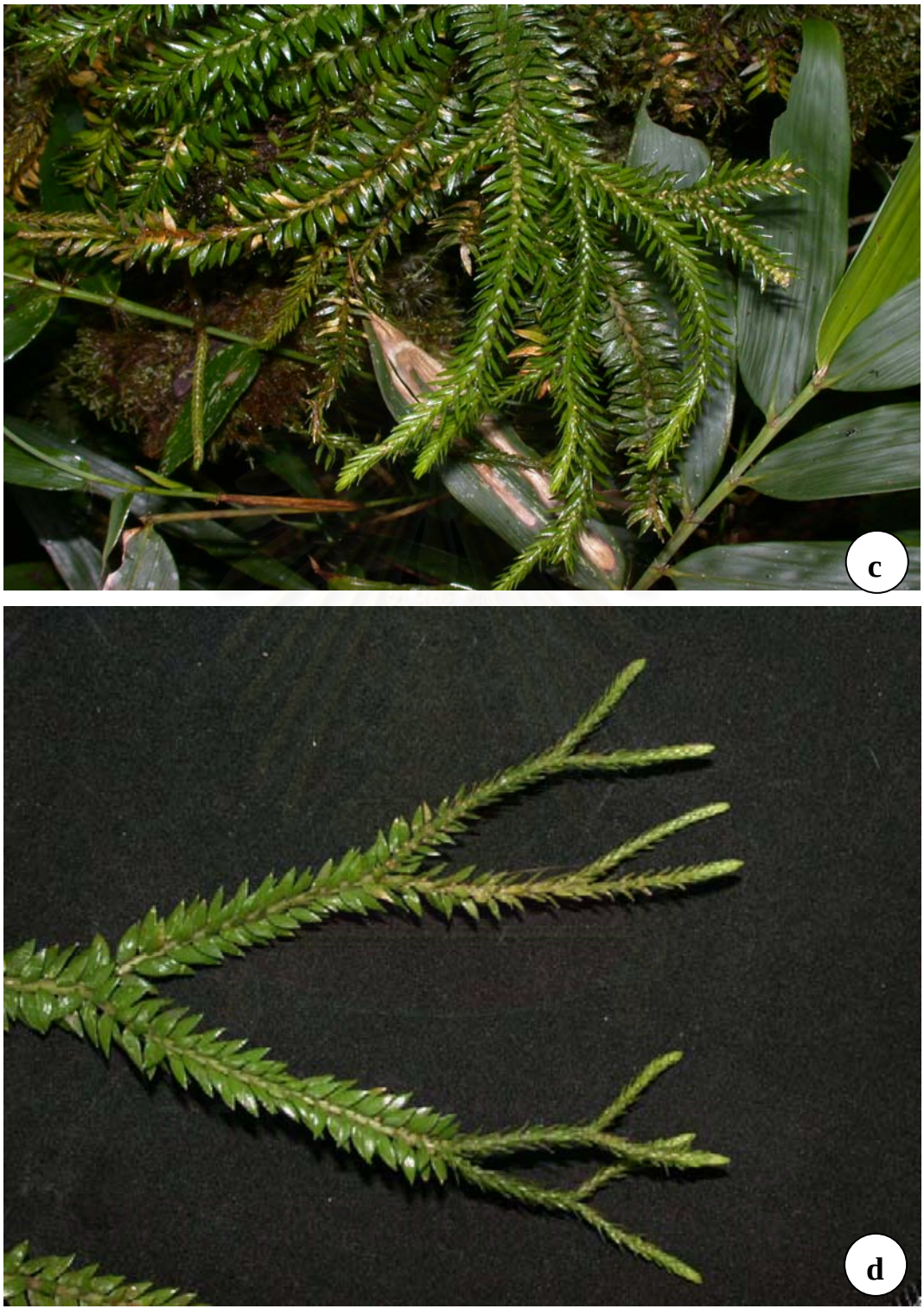

Figure 3.10 (continued) c: *Huperzia hamiltonii* grow on mossy tree-trunk at Khao Luang National Park, Nakhon Si Thammarat Province; d: sporophylls at terminal Branches reduced in size

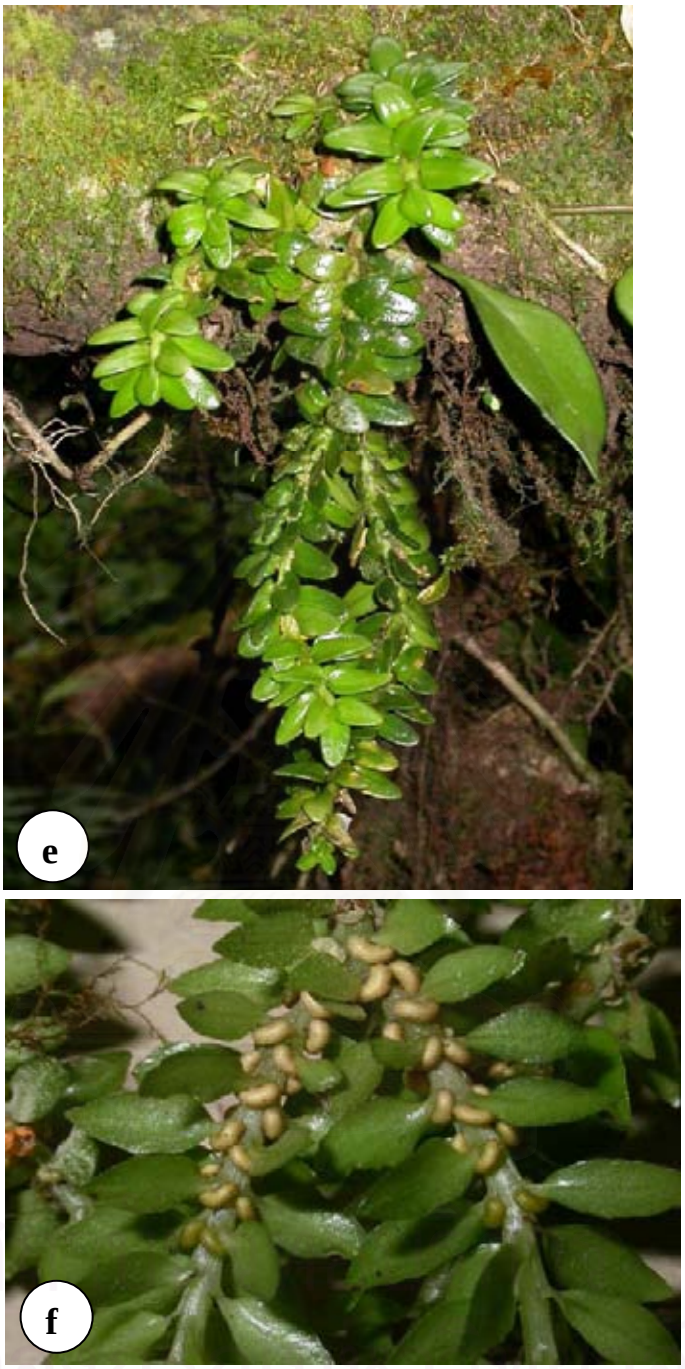

Figure 3.10 (continued) e: *Huperzia hamiltonii* grow on mossy tree trunk at Doi Inthanon National Park, Chiang Mai Province; f: sporophylls and sporangia

Figure 3.11 *Huperzia laxa* a: an epiphytic plant at Khao Nan National Park; b: a portion of fertile branch showing sporophylls and sporangia.

Thailand.— PENINSULAR: Nakhon Si Thammarat (Khao Nan).

Distribution.— Malesia.

Ecology.— Epiphyte on mossy tree-trunk in evergreen forest at low altitudes.

7. Huperzia nummulariifolia (Blume) Chambers, Jermy & Crabbe, Brit. Fern Gaz. 10: 176. 1971.—*Lycopodium nummulariifolium* Blume; Enum. pl. Javae 2: 263 (1828).—*Phlegmariurus nummulariifolius* (Blume) Ching; Acta Bot. Yunnanica 3: 298 (1981).—*Urostachys nummulariifolius* (Blume) Herter; Philipp. Sci. 22: 182 (1923).—*Lycopodium rotundifolium* Roxb.; Calcutta J. Nat. Hist. 4: 473 (1844). —Type: Blume s.n. (L!), Sallak, Java (L 0057363, (Adelbert MS), 908.342-266!).

Stems 60 cm or more long, 1.0-1.5 mm in diameter without leaves, pendulous, one to three times dichotomously forked. *Leaves* ovate to suborbicular, apex rounded to acute, base rounded, ascending, about 0.6-1.5 cm x 0.2-0.6 cm, chartaceous to fleshy in texture, margins entire, midrib distinct on both surfaces. *Strobilus* distinct, abruptly slender at the apex of vegetative branches. *Sporophylls* usually smaller than the microphylls or much reduced, appressed, ovate with acute apex, to 1 mm long, 1.0 mm broad, usually not covering the whole sporangium when mature.

Specimen examined.— B. Sangkhachand & B. Nimanong-1289 (BKF); A.G. Piggot-2305, A.C. Maingay-M.D.-2289, David W. Lee-UL 61A, P.C. Boyce-393 (K); W.J.J.O. de Wilde-18188 (L)

Thailand.—PENINSULAR: Nakhon Si Thammarat (Khao Luang, Promlok), Narathiwat (Waeng), Yala (Betong, Khao Kalakhiri).

Distribution. —Peninsular Malaysia (Kedah, Penang Isl., Kelantan, Pahang, Jahor), Java, Sumatra, Nicobars, Fiji (Viti Levu, Ovalau, Taveuni).

Ecology.— Epiphyte on mossy-tree trunk in shady places and humid areas.

Vernacular. —Raya klet hoi (ระย้าเกล็ดหอย) (Peninsular)

8. Huperzia phlegmaria (L.) Rothm., Feddes Repert. 54: 62. 1944.—*Lycopodium phlegmaria var. marchionicum* E. Br. (1931).—*Huperzia edanoi* (Copel.) Holub; Folia Geobot. Phytotax. 20: 72 (1985).—*Huperzia harmsii* (Nessel) Holub; Folia Geobot. Phytotax. 20: 73 (1985).—*Lepidotis phlegmaria* (L.) P. Beauv.; Prodr. aethéogam. 109 (1805).—*Lycopodium edanoi* Copel.; Philipp. J. Sci. 46: 209 (1931).— Lycopodium filiforme Roxb.; Calcutta J. Nat. Hist. 4: 473. 1844 [non Sw. 1800.—*Lycopodium phlegmaria* L.; Sp. pl. 1101 (1753).—Lycopodium phlegmaria var. longibracteatum Domin (1913).—*Phlegmariurus phlegmaria* (L.) Holub; Preslia 36(1): 21 (1964).—*Phlegmariurus phlegmaria* (L.) Sen & Sen; Fern Gaz. 11 (6): 421. f. 4 a (1978).—*Urostachys edanoi* (Copel.) Nessel; ärlappgewächse 230 (1939).—
Urostachys harmsii Herter ex Nessel; [Bärlappgewächse 223.1939 [nom. inval.], Revista Sudamer. Bot. 6: 166 (1940).—*Urostachys phlegmaria* (L.) Herter ex Nessel; DieBärlappgewächse 215 (1939). — Type: Uncertain; in Malabaria, Zeylona. Several

collateral references are cited. Dill., Hist. Musc. t. 61, f. 5 A, B, C. 1741, is eligible as lectotype.

Stems 80 cm or more long, 1.3-9.0 mm in diameter without leaves, pendulous, one to three times dichotomously forked. *Leaves* narrowly lanceolate to oblong-lanceolate, apex acuminate, base rounded to truncate, patent, about 0.5-1.6 cm x 0.15-0.6 cm, texture coriaceous, light green to yellowish green glossy, margins entire, midrib distinct on both surfaces. *Strobilus* distinct at apex of vegetative branches, 1.2 mm in diameter, 5.5-12.5 cm long. *Sporophylls* very much smaller than the microphylls, ovate to subdeltoid, appressed, about 1 mm long, 1 mm broad, usually not fully covered the whole sporangium when mature.

Specimen examined.— B. Hansen & T. Smitinand 12019, Ch. Charoenphol et al.-3857, B. Sangkhachard-175, T. Smitinand-696 (BKF); I.H. Burkill & R.E. Holttum-8788, H.R. Ridley (K)

Thailand.—NORTHERN: Chiang Rai (Khun Khon), Lampang; NORTH-EASTERN: Loei (Phu Luang, Phu Kra Dung), Nong Khai; SOUTH-EASTERN: Prachiburi (Khao Yai), Chon Buri (Hup Bon Hills), Chanthaburi (Khao Soi Dao); SOUTH-WESTERN: Kanchanaburi (Thong Pha Phum); PENINSULAR: Chumphon (Thasan), Surat Thani (Song Phi Nong), Phangnga (Khao Thong Lang), Krabi (Ko Pu, Nai Sa, Nai Chong), Phuket, Nakhon Si Thammarat (Khao Luang), Phatthalung (Khao Soi Dao, Khao Pok), Satun (Thung Nui, Tarutao), Yala (Betong).

Distribution.—India (West Bengal, Sikkim, Assam, Arunachal Pradesh, Kerala), Andamans, Nicobars, peninsular Malaysia, Borneo (Mt. Kinabalu, etc.), Malesia, Sri Lanka, Taiwan, Japan, Ryukyu Isl., China, Queensland, Christmas Isl. (Austr.), Sumatra, Philippines, Palawan, Palau Isl. (Babeldoab, Koror, Malakal), Tonga (Late Isl., 'Eua), Western Samoa (Aleipata Isl., Savaii, Upolu), Niue, Cook Isl. (Rarotonga), American Samoa (Manua Isl., Tutuila, Ta'u), Society Isl. (Tahiti), Marquesas Isl. (Nuku Hiva, Fatu Hiva), Principe Isl., Sao Tomé, Uganda, Tanzania, Malawi, Guinea, Liberia, Cameroun, Equatorial Guinea, Principe Isl., Gabon, ?Zaire, Bioko Isl. (Fernando Poo).

Ecology.—Epiphyte on mossy-tree trunk in shady places and humid areas at medium and high altitudes.

Vernacular. —Chong nang khli (ช้องนางคลี่) (South-western); klet nakkharat (เกล็ดนาคราช) (North-eastern); raya (ระย้า) (Peninsular); yom doi (ยมโดย) (Central).

9. Huperzia pinifolia Trevisan, Atti Soc. Ital. Sci. Nat. 17: 247. 1874, as a *nom. nov.* for *Lycopodium pinifolium* Blume, *non* Kaulf.—*Urostachys pinifolius* (Blume) Herter; Bot. Arch. 3: 16 (1923). —*Lycopodium piscium* (Herter) Tag. & Iwatsuki, Acta Phytotax. Geobot. 22: 103. 1967;—*Urostachys piscium* Herter, Index Lyc. 75 (1949). —Type: Blume s.n., Javae Sylvis Arborum (L 908.343.178!).

Similar to *Huperzia hamiltonii*, but having much reduced sporophylls in both width and length.

Specimen examined—E. Hennipman 3865 (BKF).

Figure 3.12 *Huperzia nummulariifolia* a-b: epiphytic plants with strobili; c: microphylls; d: part of a strobilus showing sporophylls and sporangia

Figure 3.13 *Huperzia phlegmaria* a: epiphytic plants in it natural habitat at Heaw Narok Waterfall, Khao Yai National Park; b: isotomous branches; c: microphylls and strobili; d: shoot apex of strobili showing sporophylls and sporangia

Figure 3.14 *Huperzia pinifolia* a-b: epiphytic plants with strobili

Thailand.— PENINSULAR: Nakhon Si Thammarat (Khao Luang National Park).

Distribution. —Borneo (Mt. Kinabalu, etc.).

Ecology.— Epiphyte on mossy-tree trunk in Hill evergreen forest at 1,740 m.

Notes.—Tagawa & Iwatsuki (1965) recognized *Lycopodium pinifolium* Blume based on specimens collected from Phuket, but in the Flora of Thailand, volume 3, part 1 they enumerated a species, *L. piscium* instead. It's dubious that *Lycopodium*

pinifolium Blume or *Huperzia pinifolia* Trevisan naturally occurs in Thailand. All the specimens determined as *L. piscium* collected from Khao Luang National Park, Nakhon Si Thammarat are matched with the voucher specimen of *H. hamiltonii* (Spreng.) Trevis.. Only one specimen (E. Hennipman 3865, BKF) determined as *H. hamiltonii*, from Khao Luang National Park is matched with the type specimen of *Huperzia pinifolia* Trevisan form B deposited at L. It is worth investigating the relationship between *Huperzia pinifolia* Trevis. and *H. hamiltonii* and to reconsider the status of *Huperzia pinifolia* in the Flora of Thailand.

10. Huperzia pulcherrima (Hook.& Grev.) Pichi-Serm., Webbia 24: 719. 1970. —— *Huperzia pulcherrima* (Wall. ex Hook. & Grev.) Sen & Sen; Fern Gaz. 11 (6): 419. f 2 i-r (1978).—*Huperzia setacea* Trevis.; Atti Soc. Ital. Sci. Nat. 17: 248 (1874).—*Huperzia taiwanensis* (Ching) Holub; Folia Geobot. Phytotax. 20(1): 77 (1985).—*Lycopodium pulcherrimum* Wall. ex Hook. & Grev.; Icones Filicum 1(2): t. 38 (1827).—*Lycopodium setaceum* Buch.-Ham. ex D. Don; Prodromus Florae Nepalensis 18(1825) [nom. illeg., non *Lycopodium setaceum* Lam. (1789).—*Phlegmariurus pulcherrimus* (Hook. & Grev.) Löve & Löve; Taxon 26: 324 (1977).—*Phlegmariurus taiwanensis* Ching; Acta Bot. Yunnanica 4: 124 (1982 [nom.superfl. for *Lycopodium pulcherrimum* Hook. & Grev. by reference to Hayata(1914: 132).—*Urostachys amphorae* Herter; Index Lyc. 51 (1949 [nom. superfl. for *Urostachys pulcherrimus* (Hook. & Grev.) Nessel).—*Urostachys pulcherrimus* (Hook. & Grev.) Herter ex Nessel; Bärlappgewächse 72 (1939).— *Urostachys setaceus* (Hamilt. ex D. Don) Herter ex Nessel; Arch. Bot. SaoPaulo 1: 408. 1927 [Bärlappgewächse 141 (19399). Type: Wallich s.n., from Nepal (BM!, K!).

Stems 10-25 cm long, pendulous, slender, 1-1.5 cm in diameter including leaves, 1-3 times dichotomously branched near base. *Leaves* linear, 10-14 x 0.7-1.0 mm, subremote, erect to patent, flexuose to tortuose at maturity, not much decurrent at base, thin but firm in texture, margins wavy, involute, midrib normally indistinct, rarely feeble midrib observed in the basal part, yellowish-green to green in colour. *Strobilus* indistinct. *Sporophylls* similar to vegetative leaves. *Sporangia* reniform, in the axils of leaves starting above the middle to apex.

Specimen examined—P. Suksathan 1758-1, 2360 (QBG); Wallich 1821 (K); D.G., R.J.D. Mc Beath, H.J. Noltie & M.F. Watson 965; C.B. Clarke s.n. (E).

Thailand.—NORTHERN: Chiang Mai (Doi Inthanon, Huai Nam Dung).

Distribution.—India (NW-Himalayas, E-India), Sri Lanka, Nepal, Bhutan, China, Taiwan, Japan.

Ecology.—Epiphytes on mossy-tree trunk or lithophytes in hill evergreen forest between 1,670-2,000 m altitude.

Figure 3.15 *Huperzia pulcherrima* a: an epiphytic plant from Mae Ya Pai; b: branches with sporophylls and sporangia.

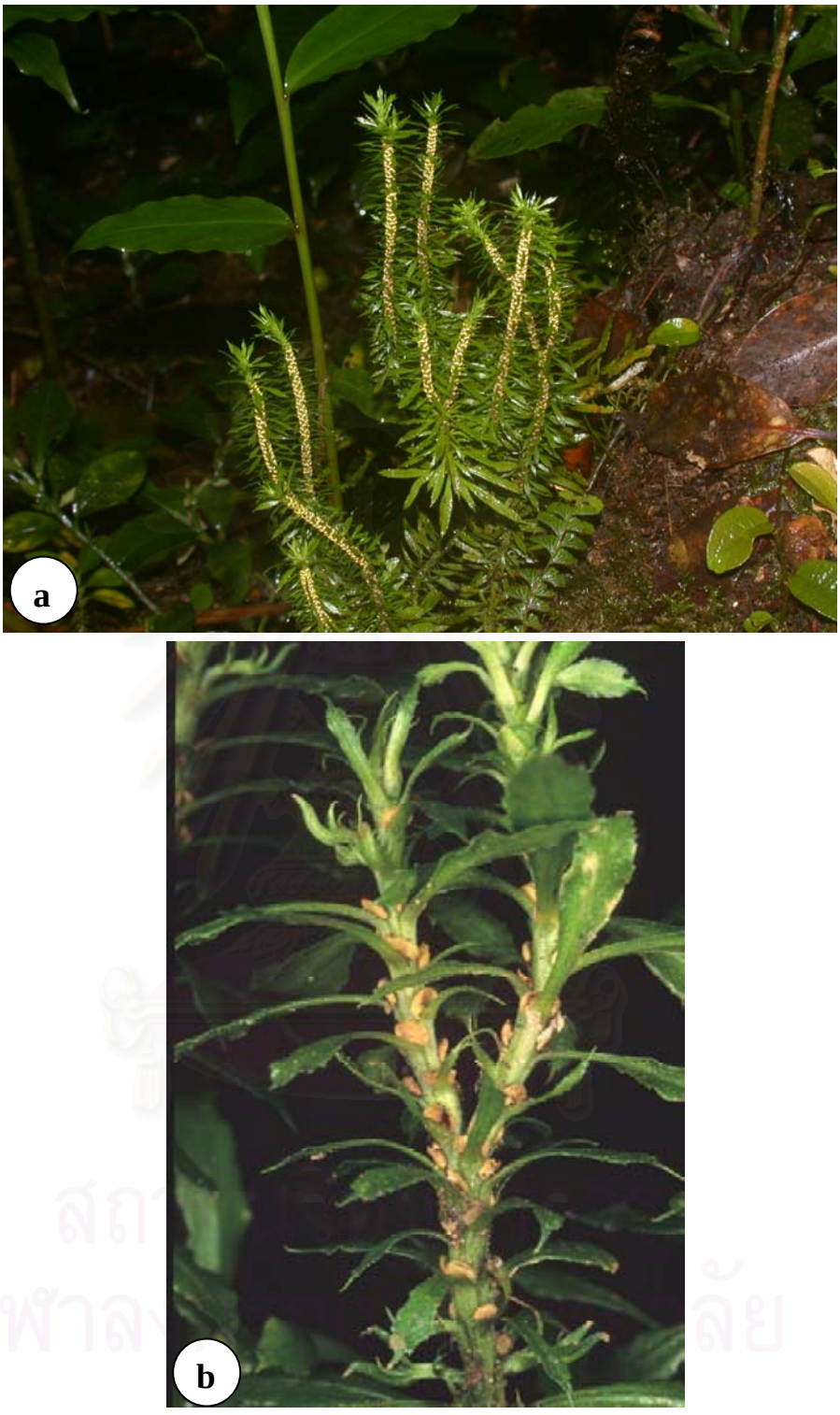

Figure 3.16 *Huperzia serrata* a: terrestrial plants from Khao Luang National Park, Nakhon Si Thammarat Province; b: fertile branches showing sporophylls and sporangia

Figure 3.17 *Huperzia squarrosa* a: lithophytic plants from Phu Hin Rong Kla National Park, Phisanulok Province; b: fertile branches showing sporophylls and sporangia

11. Huperzia serrata (Thunb. *ex* Murray) Trevisan, Atti Soc. Ital. Sci. Nat. 17: 248. 1874.— *Huperzia selago* (L.) Bernh. ex Schrank & C. Mart. ssp. *serrata* (Thunb.) A. & D. Löve—*Huperzia serrata* (Thunb.) Rothm.; Feddes Repert. 54 (1): 59 (1944).-- *Huperzia serrata f. longipetiolata* (Spring) Ching; Acta Botanica Yunnanica 3(3): 294 (1981).— *Huperzia shangsiensis* (Chun Y. Yang) Holub; Folia Geobot. Phytotax. 26(1): 92 (1991).— *Lycopodium serratum* Thunb. ex Murray; Systemat Vegetabilium. Editio decima quarta 944 (1784), also Thunb., Fl. Jap. 341, t. 38 (1784).—*Lycopodium serratum var. javanicum* (Sw.) Makino; Botanical Magazine12(131): 13 (1898).—*Lycopodium serratum var. longipetiolatum* Spring; Monogr. Lycop. 2: 18 (1850).— *Lycopodium serratum var. myriophyllifolium* Hayata; Icones plantarum formosanarum nec non & contributiones ad floram formosanam. 4: 133 (1914).—
Lycopodium serratum var. thunbergii Makino; Botanical Magazine 12(131): 12 (1898).— *Phlegmariurus shangsiensis* Chun Y. Yang; Acta Phytotaxonomica Sinica 22(1): 87-88, f. 1 (1984).—*Plananthus serratus* (Thunb. ex Murray) P. Beauv.; Prod. aethéogam. 100, 111 (1805).—*Urostachys* javanicus (Sw.) Herter; Index Lyc. 66 (1949).—*Urostachys myriophyllifolius* (Hayata) Herter; Estudios Botánicos en la Región Uruguaya 20: 71 (1949).—*Urostachys serratus* (Thunb. ex Murray) Herter; Bot. Arch. 3: 13 (1923).— *Urostachys serratus* (Thunb. ex Murray) Herter var. sachalinensis Nessel; Repert. Spec. Nov. Regni Veg. 36: 179, t. 171. 1934.— *Urostachys serratus* var. *japonica-neotropicus* Herter ex Nessel (1940).—*Urostachys sachalinensis* (Nessel) Herter; Index Lyc. 80. 1949.—*Lycopodium sargassifolium* Liebm.; Overs. Kongel. Danske Vidensk. Selsk. Forh. Medlemmers Arbeider 1847: 41.—Type: Thunberg s.n., from Japan (UPS-Thunb. 25333B, holotype).

Stems ascending with several erect branches, 8-20 cm tall, slender, 1-1.5 cm in diameter including leaves, 1-3 times dichotomously branched. *Leaves* elliptic to oblanceolate, 1.5-2.5 x 0.3-0.5 cm, patent, thin but firm in texture, deep green, margins irregularly serrate, midrib normally distinct. *Strobilus* indistinct. *Sporophylls* lanceolate, usually below apex of vegetative branches. *Sporangia* reniform, in the axils of sporophylls.

Specimen examined.— M. Tagawa et al.T-1508, T. Smitinand-4945, T. Smitinand-1266, T. Smitinand-9454, E. Hennipman-3864 (BKF); J. & M.S. Clemens-27758, Dostae-5192, B.S. Parris-11429 (K); A.H.G. Alston 12851 (L)

Thailand.—NORTH-EASTERN: Loei (Phu Luang, Phu Kradung); PENINSULAR: Nakhon Si Thammrat (Khao Luang).

Distribution.—India (West Bengal, Sikkim, Arunachal Pradesh, Assam, Meghalaya, Manipur, Tamil Nadu), Nepal, Burma, Sri Lanka, NE-Thailand, peninsular Thailand, Fiji (Viti Levu), Western Samoa (Savaii), peninsular Malaysia (Pahang), Borneo (Mt. Kinabalu, etc.), E-Siberia, Taiwan, Cuba, Hispaniola (Haiti), Mexico (Hidalgo, Oaxaca), Fujian, Guangdong, Guangxi, Guizhou, Hainan, Heilongjiang, Hubei, Hunan, Jiangxi, Jilin, Liaoning, Shaanxi, Sichuan, Japan, Ryukyu Isl., Korea, Vietnam, Hawaii (Kauai, Oahu, Molokai, Lanai, Hawaii Isl.), New Caledonia, NE-Queensland.

Ecology.—Terrestrials on humus-rich ground in hill evergreen forest above 1,000 m altitude.

12. Huperzia squarrosa (C.Forster) Trevisan; Atti Soc. Ital. Sci. Nat. 17: 247 (1874).—*Huperzia cunninghamioides* (Hayata) Holub; Folia Geobot. Phytotax. 20(1): 72 (1985). —*Huperzia epiceifolia* (Desv. ex Poiret) Trevisan; Atti Soc. Ital. Sci.Nat. 17: 248 (1874).—*Huperzia lecomteana* (Nessel) Holub; Folia Geobot. Phytotax. 20: 74 (1985).—*Huperzia squarrosa* (G. Forst.) Rothm.; Repert. Spec. Nov. Regn. Veg. 54: 62 (1944).—*Lycopodium cunninghamioides* Hayata; Icones plantarum formosanarum nec non & contributiones ad floram formosanam. 4: 131 (1914).—*Lycopodium epiceifolium* Desv. ex Poiret; Encycl. suppl. 3: 559 (1813[1814]). —*Lycopodium forsteri* Poiret; Encycl. suppl. 3: 545 (1813 [1814]).—*Lycopodium gnidioides* Blanco; Fl. Filip. 824. 1837, ed. 2.569. 1845, ed. 3 (3): 239 (1879).—*Lycopodium madagascariense* Desv.; [nom. inval. (Spring 1842: 34).—*Lycopodium pseudo-squarrosum* Pampan.; Bull. R. Soc. Tosc. Orticult. 111,13: 99, t. 2 (1908).—*Lycopodium squarrosum* G. Forster; Fl. ins. austr. 479 (1786).—*Phlegmariurus cunninghamioides* (Hayata) Ching; Acta Botanica Yunnanica 4(2): 125 (1982).—*Phlegmariurus squarrosus* (G. Forster) Löve & Löve; Taxon 26: 324 (1977).—*Plananthus squarrosa* (Sw.) P. Beauv.; Prodr. Aetheog. 112 (1805).—*Urostachys cunninghamioides* (Hayata) Herter ex Nessel; Die Bärlappgewächse 206 (1939).—*Urostachys epiceaefolius* (Desv.) Herter ex Nessel; Die Bärlappgewächse 202 (1939).—*Urostachys epiceaefolius* var. *acutifolius* (Desv.) Herter ex Nessel; DieBärlappgewächse 292 (1939). —*Urostachys epiceifolius* (Poiret) Herter ex Nessel; Bärlappgewächse 202 (1939).—*Urostachys lecomteanus* Nessel; Repert. Spec. Nov. Regni Veg. 36: 1871 t.174 (1934).—*Urostachys madagascariensis* (Desv. ex Nessel) Herter; Estudios Botánicos en la Región Uruguaya 20: 68 (1949), Alt. title: IndexLycopodiarum 68 (1949).—*Urostachys madagascariensis* (Nessel) Herter; Index Lyc. 68 (1949).—*Urostachys squarrosus* (G. Forst.) Herter; Botanisches Archiv 3: 14 (1923).—*Urostachys squarrosus* (G. Forster) Herter var. prolifer (Blume) Nessel f. madagascariensis Nessel.—*Urostachys squarrosus* var. *proliferus* (Blume) Herter ex Nessel; Bärlappgewächse 200 (1939). —Type: G. Forster, from Otaheiti [Tahiti] (P!), (Spring 1842: 53); (BM-herb. G. Forster (Adelbert MS)).

Stems 15-60 cm or more long, about 3.0-5.0 mm in diameter without leaves, pendulous or ascending, one to three times dichotomously forked. *Leaves* linear lanceolate, apex acuminate, patent, 1.0-1.5 cm x 0.1-0.2 cm, coriaceous in texture, margins entire, midrib more or less distinct on both surfaces. *Strobilus* indistinct. *Sporophylls* usually smaller than the microphylls, at the apex of vegetative branches, narrowly oblong to linear; sporangia reniform.

Specimen examined.— T. Smitinand-729 (BKF); H.C. Robinson et al.-6070, D.J. Collins-482, J.H. Beaman-9050 (K); M. Poilane 1952 (P); E. Hennipman-5250 (L)

Thailand.—NORTHERN: Phitsanulok (Phu Miang, Phu Hin Rong Kla); NORTH-EASTERN: Loei (Phu Luang, Phu Rua, Phu Kra Dung); CENTRAL:

Nakhon Nayok (Khao Yai, Khao Kiew); SOUTH-EASTERN: Chanthaburi (Phriew), Trat (Dan Chumphon); SOUTH-WESTERN: Kanchanaburi (Klang Dong, Song Tho, Thong Pha Phum); PENINSULAR: Surat Thani (Ban Kop Kaep), Phangnga (Bang To), Nakhon Si Thammarat (Khiri wong, Khao Luang).

Distribution. —India (West Bengal, Sikkim, Meghalaya, Assam, Kerala), Nepal, Burma, Bangladesh, Sri Lanka, Malesia, Philippines, peninsular Malaysia (Kedah, Kelantan, Perak, Pahang), Borneo (Mt. Kinabalu, etc.), Java, Thailand (widespread), China, Taiwan, Japan, NE-Queensland, Madagascar, Mauritius, Réunion, Seychelles, Palau Isl. (Babeldaob), Micronesia (Pohnpei, Kosrae), Tonga (Late Isl., Tafahi), New Caledonia, Society Isl. (Tahiti), Cook Isl. (Rarotonga), American Samoa (Manua Isl., Tutuila, Ta'u, Olosega), Western Samoa (Savaii, Upolu), Austral Isl. (Rapa Iti, Tubuai).

Ecology.—Epiphyte on mossy-tree trunk or in rock crevices in shady or slightly exposed places above 1,200 m altitudes.

Vernacular.—Chong nang khli (ช้องนางคลี่) (Northern); hang khang (หางค่าง) (Peninsular).

13. Huperzia tetrasticha (Kunze) Holub, Folia Geobot. Phytotax. 20: 77. 1985. — *Lycopodium tetrastichum* Kunze; Bot. Zeit. (Berlin) 6: 99 (1848).—*Lycopodium sarasinorum* Christ; Verh. Naturf. Ges. Basel 11: 34, t. 2o f. 11-12 (1894).—*Urostachys sarasinorum* (Christ) Herter ex Nessel; Bärlappgewächse 182 (1939).—*Urostachys tetrastichus* (Kunze) Herter ex Nessel; Bärlappgewächse 183 (1939, by reference to Alderw (1915a: 35)).—Type: Zollinger 2460 (L 0057313), from Java (G, HBG, L!).

Stems 35-40 cm long, pendulous, slender, 4-5 mm in diameter including leaves, 2-3 times dichotomously branched, main stem and branches 4-angled. *Leaves* linear, 6-8 x 0.7-1 mm, dense, appressed, thin but firm in texture, margins entire, midrib distinct, base ovate, apex short acuminate, light green to dark green in colour. *Strobilus* slightly distinct, about 3 mm in diameter. *Sporophylls* usually smaller than the microphylls, appressed. *Sporangia* in the axils of sporophyll, starting from base to the middle of sporophyll, usually covered the whole sporangia when mature.

Specimen examined—T. Boonkerd & R. Pollawatn 221 (BCU); W.J.J.O. de Wilde and B.E.E. de Wilde-Duyfjes 12139, W.J. Lutjeharms 7411, S.H. Koorders, Kds. 18455, Hew Wee-lek 691, M. Kato, K. Ueda, M. Okamoto, H. Akiyama, B. Sunarno and U.W. Mahjar No. C. 6265 (L); Unesco Limestone Expedition 1962 No. 632 (SING).

Thailand.— PENNINSULAR: Narathiwat (Budo ranges), Yala (Sukirin).

Distribution.—Indonesia, peninsular Malaysia (Kelantan, Pahang, Negeri Sembilan), Sulawesi, Philippines.

Ecology.—Epiphyte on mossy tree-branches in tropical rain forest at 600-800 above mean sea levels. It usually grows in cluster about 50-100 branches, some branches in humid areas may reach 1 m long.

Vernacular.—Soi nang krong Leiam (สร้อยนางกรองเหลี่ยม) (Bangkok)

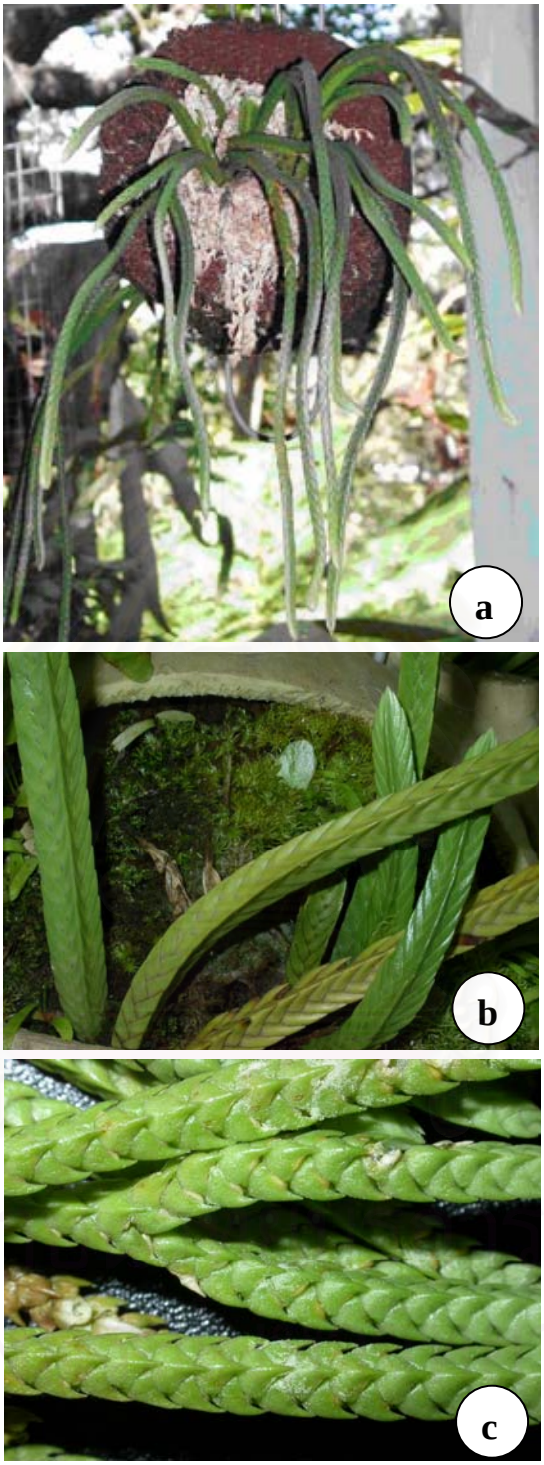

Figure 3.18 *Huperzia tetrasticha* a: an epiphytic plant (cultivated); b: microphylls densely arranged on quadrangular-shaped stem and branch; c: sporophylls and sporangia

LYCOPODIELLA HOLUB

Sporophyte terrestrial with anisotomous branching throughout, either with prostrate, creeping vegetative shoots producing dorsally arising, erect, strobilus-bearing branches, or with arching-looping runner-shoots producing dorsally arising, highly ramified, usually treelike shoot systems that terminate in usually nodding branchlets with pendent strobili. Shoot isophyllous or anisophyllous. Leaves with or without veinal mucilage canals. Sporophylls subpeltate, with a median basiscopic wing, or with coalescent basal membranes which almost enclose the sporangia, basal mucilage canals present. Sporangia reniform, on the sporophyll base, or axillary, strongly anisovalvate, or isovalvate. Spores rugate.

The genus occurs in tropical regions of the world or in moist temperate areas with the majority in the Americas. It comprises about 40 species, two species are found in South-East Asia. Only one species occurs in Thailand (Fig. 3.19).

Lycopodiella cernua (L.) Pichi-Serm.—*Lycopodium cernuum* L., Sp. Pl. 1103. 1753. *Lepidotis cernua* (L.) P. Beauv.; *Palhinhaea cernua* (L.) Carv. Vasc. & Franco.—Type: Linnaean Herb. 1257.13 (LINN, lectotype), designated by W. T. Stearn (1979: notula in LINN); see also note by Proctor (1985: 29).

Main stem creeping and erect; main erect stems to more than 50 cm tall, bearing many branches densely covered with leaves on upper portions, 3-4 mm in diameter; lateral branches 3-5 mm in diameter, densely covered with leaves, usually about 10 cm long. *Leaves* linear, apex pointed, 3-5 mm X 0.5 mm, margin entire, patent and recurved in upper portion, texture soft, light green to yellowish green. *Strobilus* distinct at apex of vegetative branches, pendulous, 5-10 cm long, about 3 mm in diameter. *Sporophylls* ovoid, apex acuminate, base broadly ovate, pale yellowish, margin ciliate.

Specimen examined.— T. Smitinand-1835, C. Phengkhlai et al.-4078 (BKF); A.F.G. Kerr-13591, Gen Murata et al.-T17054, D.J. Collins-2359 (K); M. Poilane-375 (P); C. Holstvoogd-196 (L)

Thailand.—NORTHERN: Chiang Rai (Doi Tung, Kiu Thap Yang, Mae Lao, Doi Phacho, Khun Khon), Chiang Mai (Doi Chiang Dao, Mae Rim, Doi Suthep, Doi Inthanon), Phitsanulok (Thung Salaeng Luang, Phu Hin Rong Kla), Tak (Doi Musoe); NORTH-EASTERN: Loei (Phu Luang, Phu Rua, Phu Kra Dung), Nong khai (Phu Wua); CENTRAL: Nakhon Nayok (Khao Yai, Khao Kiew); SOUTH-EASTERN: Trat (Ko Chang); SOUTH-WESTERN: Kanchanaburi (Wang Ka, Thong Pha Phum), Prachuap Khiri Khan (Sam

Roi Yod); PENINSULAR: Chumphon (Bang Son), Ranong, Surat Thani (Ban Don), Satun (Tarutao), Nakhon Si Thammarat (Khao Luang, Thung Song, Ron Phibun), Trang (Khao Chong, Thale Song Hong, Sam Roi Yot), Songkhla (Saba Yoi), Narathiwat (Bacho, Waeng), Yala (Gunong Ina, Ban To, Padang Besar).

Distribution. —Widespread in tropics and subtropics of the world.

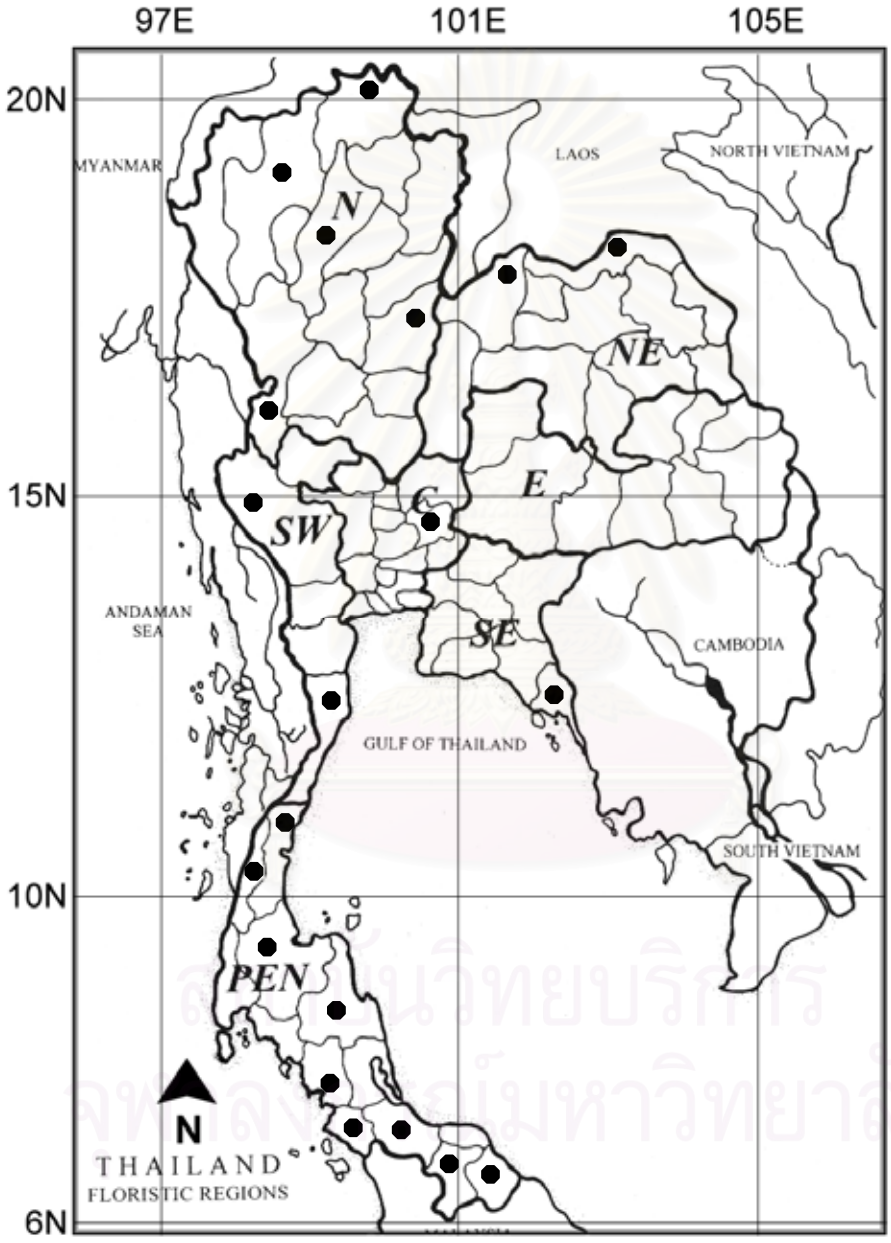

Figure 3.19 Distribution map of *Lycopodiella cernua* (●) in Thailand

Figure 3.20 *Lycopodiella cernua* a-b: terrestrial plants in their natural exposed Habitats, Phu Luang Wildlife Sanctuary, Loei Province; c: branches showing pendent strobili with pale yellowish sporophylls.

Ecology.—Terrestrial, usually in fully exposed mountain slopes. It is common in disturbed areas from near sea level to 2,200 m altitudes.

Vernacular.—Kud khon (กูดขน) (Northern); ya kan phiang (หญ้าก้านเพียง), yaeng yae (แหยงแย้) (North-eastern); slap (สลาบ), dok hin (ดอกหิน) (South-eastern); rangkai (รังไก่), ruai kai (รวยไก่), sam roi yot (สามร้อยยอด)(Peninsular).

LYCOPODIUM L.

Sporophytes terrestrial, anisotomously branched, with elongate, indeterminate, subterranean, creeping, or scandent main stems. Branchlet leaves uniform or strongly anisophyllous. Sporophylls ephemeral, dying after sporangium dehiscence, gathered in specialized, compact strobili. Strobili erect, simple or forked, sessile or borne on simple or forked peduncles. Sporophyll peltate, or subpeltate with a thin, basal, decurrent wing, with or without a basal mucilage cavity. Sporangia attached to the sporophyll base, reniform, with a short thick stalk, isovalvate or slightly anisovalvate. Spores reticulate.

A cosmopolitan genus of approximately 40 species, with about 8 species in South-East Asia and 3 species in Thailand (Fig. 3.21).

Key to the species

1a Plants with creeping and erect stem, fertile and sterile branches of upright stem erect; strobili erect or ascending…… 2.

1b Scandents on mountain ridges; fertile and sterile branches pendulous, strobili pendulous or ascending, borne singly at the tip of ultimate fertile branches……. 1. *L. casuarinoides*

2a Ultimate branches usually terete; vegetative leaves patent, apex with long point……... 2. *L. clavatum*

2b Ultimate branches usually flattened; vegetative leaves appressed, apex acuminate……. 3. *L. complanatum*

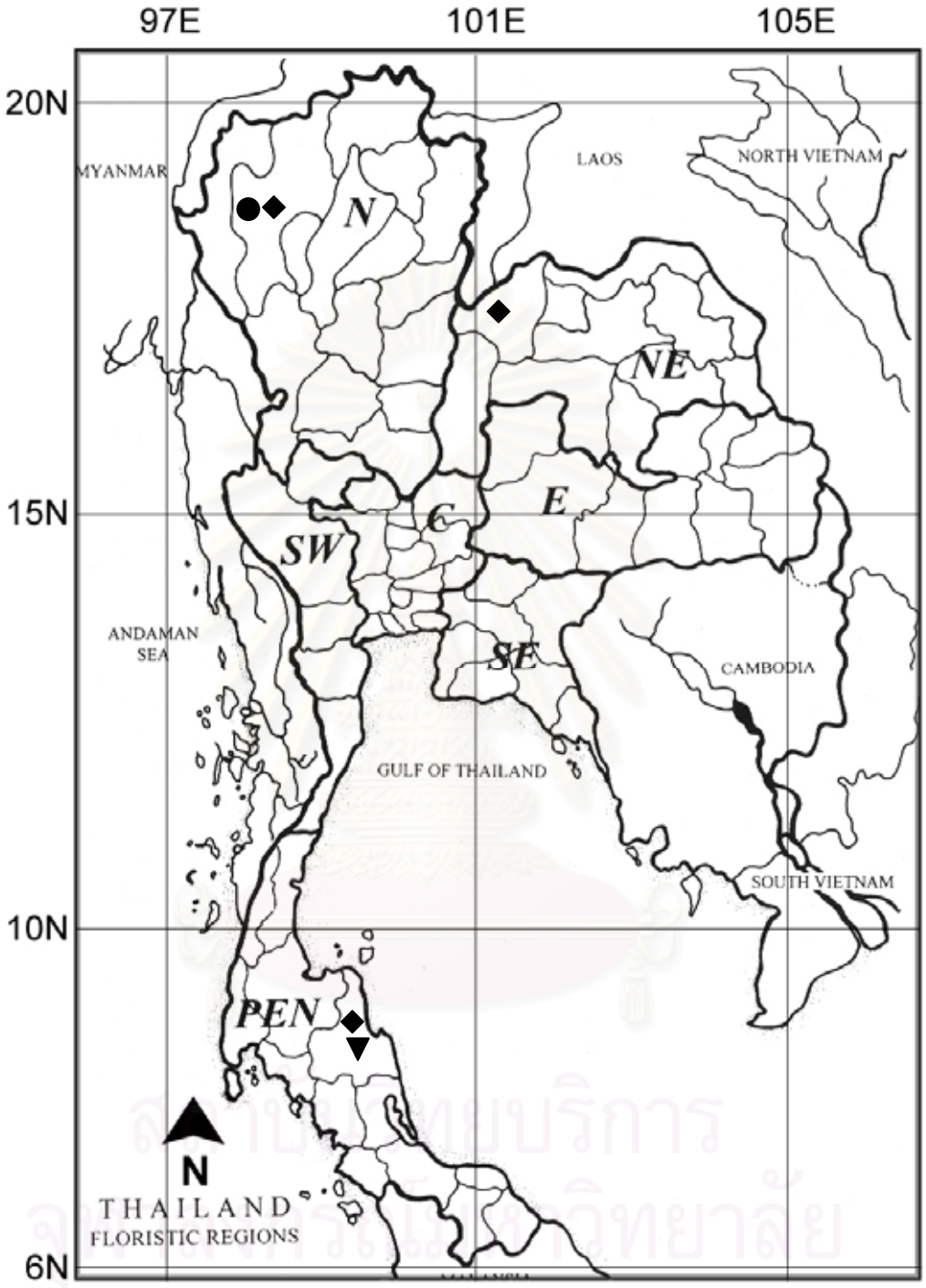

Figure 3.21 Distribution map of *Lycopodium* s.str. in Thailand

▼ *L. casuarinoides*, ◆ *L. clavatum*, ● *L. complanatum*

1. Lycopodium casuarinoides Spring, Bull. Acad. Roy. Sci. Belg. 8: 521. 1841.—*Lepidotis casuarinoides* (Spring) Rothm.; *Lycopodiastrum casuarinoides* (Spring) Dixit.—Type: Cuming 2346, "Philippines" [Malacca, Mt. Ophir (Adelbert MS)] (BM!, G-Deless., K!, L!, P!, UPS, isotypes).

Stems scandent, thin to thick, stiff, dark straminaceous to red, branched, branches remote, copiously compound, ultimate branchlets 10-25 cm long, about 4 mm in diameter, pendulous. *Leaves* variable, scattered on the stem, decurrent and peltate near the base, green to reddish; of the branchlets more variable, decurrent with only a minute, persistent, free blade possessing a long, subulate, hyaline, deciduous or persistent entire apex, sometimes closer with long aristate, free blade upto 3.0 mm long. *Strobilus* 2.5-7.5 cm x 3-4 mm, cylindrical, panicled on the special branchlets. *Sporophylls* broadly ovate, ascending, apex cuspidate-acuminate, margins scariose; sporangia reniform.

Specimen examined.—C. Thorat 158 (BCU); H.C. Robinson s.n., J.S. Wapou 5886, Kep. 78596, T. Shimizu, K. Iwatsuki, N. Fukuoka & M. Hutoh M 13527, H.H. Bartlett 7489, C.G.G. J. van Steenis 3687, 8359; Ilias Paie S 33032; Ilias Paie S 33032 (K).

Thailand.— PENINSULAR: Nakhon Si Thammarat (Khao Luang).

Distribution.— India, Bhutan, Myanmar, China, Malesiana.

Ecology.— Terrestrial on mountain ridge, in fully exposed areas**.**

2. Lycopodium clavatum L., Sp. Pl. 1101. 1753—*Lepidotis clavata* (L.) P. Beauv. — Type: In Europae Sylvis Muscosis. Uncertain; LINN 1257.2 was not in LINN until after 1755 (Jackson, 1912). Several collateral references cited in the protologue.

Main stems prostrate, widely creeping on ground surface, subterranean, irregularly branching, 3-4 mm in diameter; aerial stems ascending to erect, branches anisotomous, 2-3 times, bearing dense leaves. *Leaves* patent, spirally arranged, linear to linear-lanceolate, apex acuminate, 4-6 mm long x 0.5-1 mm broad, margin entire, midrib hardly visible, coriaceous in texture, green to yellowish green. *Strobilus* distinct, upright, on the erect stalk, stalks 7-15 cm long; 2.5-8.5 cm long, 3-4 mm in diameter. *Sporophylls* oblong-ovate, apex acuminate, margin dentate to scariose, about 2.5 mm long and 1.5 mm broad, yellow; sporangia reniform.

Specimen examined.—T.Boonkerd & R. Pollawatn 382 (BCU); Ch. Charoenphol, K. Larsen & E. Warncke 4743 (E); T. Sato et al. 100 (SING)

Thailand.—NORTHERN: Chiang Mai (Doi Inthanon); NORTH-EASTERN: Loei (Phu Kra Dung); PENINSULAR: Nakhon Si Thammarat (Khao Luang).

Distribution.—Cosmopolitan.

Ecology.—Terrestrial on wet ground on hill slopes, grasslands or roadsides, in fully exposed areas**,** above 1,200 m altitudes.

Vernacular.**—**Kut khon (กูดขน) (Northern); sam roi yot (สามร้อยยอด) (Peninsular).

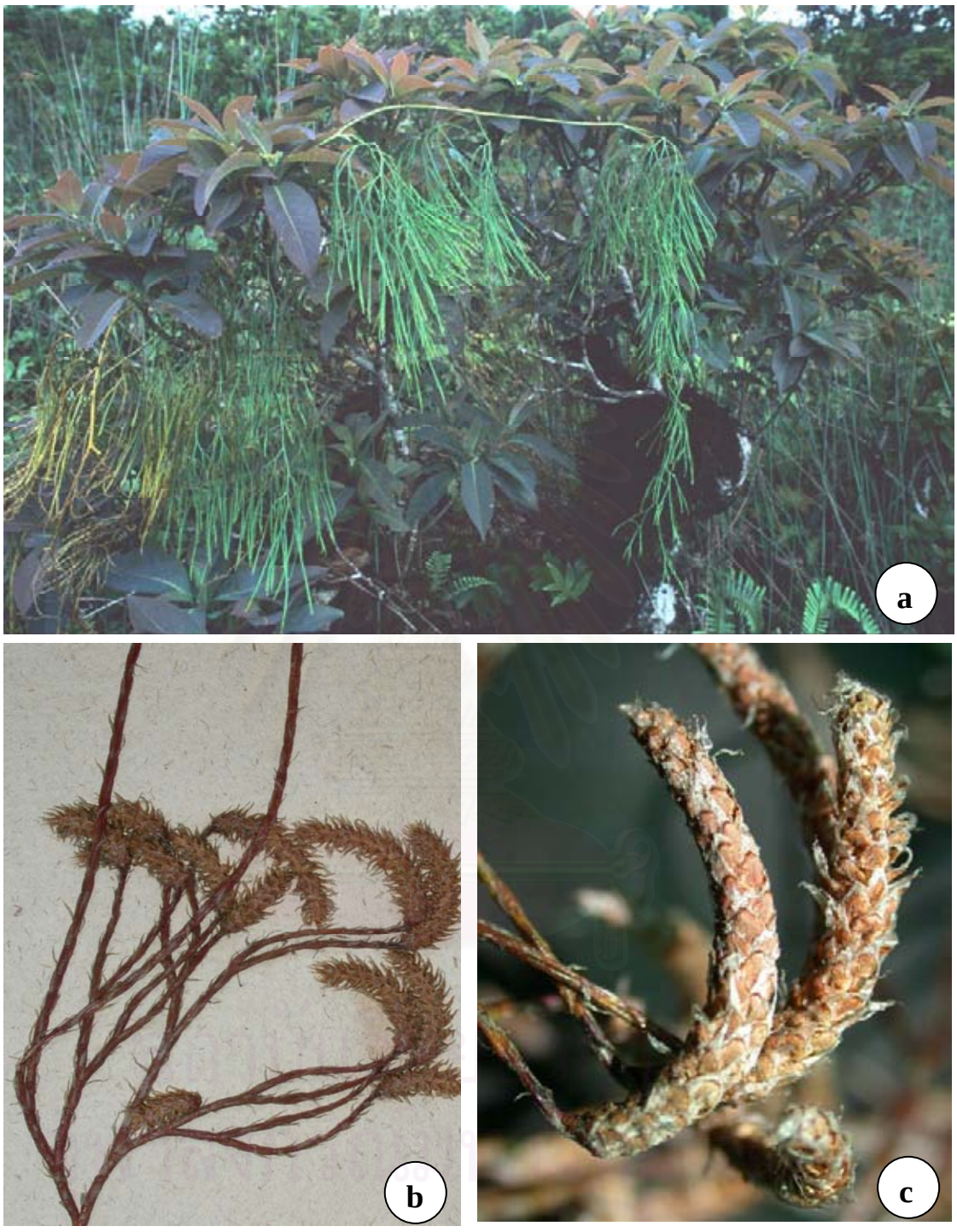

Figure 3.22 *Lycopodium casuarinoides* a: a scandent at the summit of Khao Luang National Park, Nakhon Si Thammarat Province; b-c: branches showing strobili.

Figure 3.23 *Lycopodium clavatum* a : branches showing upright strobili; b: terrestrial plants in their natural habitat at Doi Inthanon National Park, Chiang Mai Province.

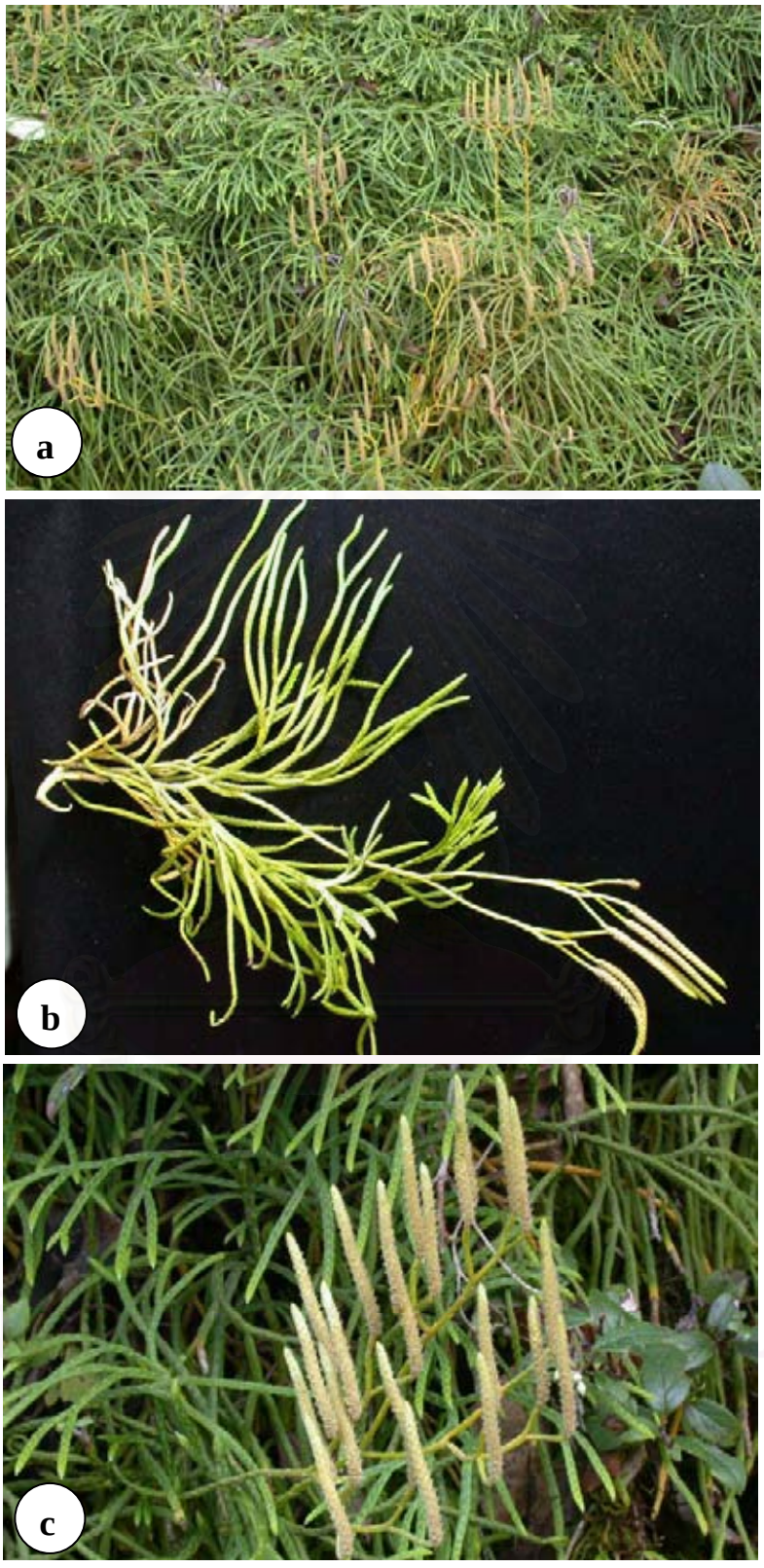

Figure 3.24 *Lycopodium complanatum* a : terrestrial plants in natural habitat at Doi Inthanon National Park, Chiang Mai Province; b: a plant with fertile branches; c: fertile branches with strobili.

3. Lycopodium complanatum L., Sp. Pl. 1104. 1753.—*Diphasiastrum complanatum* (L.) Holub; *Diphasium complanatum* (L.) Rothm.; *Lepidotis complanata* (L.) P. Beauv.; *Stachygynandrum complanatum* (L.) C. Presl.— Type: Apparently none extant (Wilce 1961: 96-97; 1965: 134-135); the designation of LINN 1257.20 by H. P. Fuchs (1954, notula in LINN) is dubious.

Main stem long creeping, usually on ground surface, several times dichotomously branched, upright branches erect, terete; scales linear-lanceolate on both prostrate stem and erect stem. *Leaves* 4-whorled, partially adnate and arranged in three parallel plains (dorsal, lateral and ventral) and are dimorphous or trimorphous, opposite and decussate, rarely in some species is monomorphous, and spirally arranged in 5-6 vertical rows. *Strobilus* distinct from the sterile branches, terminal, 1.5-3.0 cm long, on upright stalks. *Sporophylls* deltoid, apex acuminate, margins entire-undulate; sporangia reniform. *Spores* with reticulate exine.

Specimen examined.—T.Boonkerd & R. Pollawatn 387 (BCU); Gustav Mann. s.n. (E)

Thailand.— NORTHERN: Chiang Mai (Doi Inthanon).

Distribution.— Cosmopolitan in northern temperate regions and alpine regions in the tropics.

Ecology.—Terrestrial on mountain slope, dry ground to marshy places, usually in open areas above 2,300 m altitude.

CONCLUSION

In the present study, 409 specimens (OTUs) from 7 species of *Lycopodium* s.l. in South-East Asia were subjected to cluster analyses and canonical discriminant analyses. Based on 16 quantitative characters and supported by 5 qualitative characters, cluster analyses strongly indicate the presence of three distinct groups, i.e. *Huperzia*, *Lycopodiella* and *Lycopodium* s. str. The 3 groups were subsequently evaluated by canonical discriminant analyses. It was found that 5 characters, i.e. sporangium shape, distance between two whorls, leaf thickness, width of sporangium, and diameter of apical shoot collectively supported the segregation of 3 groups or genera from the *Lycopodium* s.l.

So far, 25 species of *Huperzia*, 2 species of *Lycopodiella* and 8 species of *Lycopodium* s. str. were recorded in South-East Asia, while Thailand has 13 species of *Huperzia*, 1 species of *Lycopodiella* and 3 species of *Lycopodium* s. str.

Lycopodiella cernua is the most common species, since it is one of a sun-loving plant, so it occurs both in exposed natural habitats and exposed areas due to man-made disturbance. While *Huperzia cryptomerina* is probably the rarest species as it is known only from a single collection from Huai Nam Dung National Park, Chiang Mai Province and never been seen from the last decade. De Vol (1975) and Ohwi (1984) also reported that *H. cryptomerina* is a rare species in Taiwan and Japan, respectively. So far, some species confined to southernmost provinces such as *Huperzia dalhousiana, H. laxa,* and *H. tetrasticha* are also rarely found. But these species also occur in Malaysia and probably in the other countries of Malesiana region. To know the exact status of rarity in Thailand need to have additional explorations. However, it seems to be impossible to do so at present, since the southernmost areas are still unsafe for any activities due to unrest.

Huperzia hamiltonii is probably the most variable species due to its wide distribution and has a tendency to be a complex species. Three forms or probably ecotypes are reported here. The general form occurs throughout the country, has narrow lanceolate vegetative leaves and sporophylls (Figs 3.10 a-b). The second form confined to Khao Luang National Park, has narrow lanceolate vegetative leaves and much reduced in size of sprophylls (Figs 3.10 c-d). The third form restricted to the high altitudes of mountains in northern Thailand. This form has broad and glossy surface in both vegetative leaves and sporophylls which are coriaceous in texture (Figs 3.10 e-f). The variations of sterile and fertile leaves of this species is worth investigating.

Regarding to natural habitats, Khao Luang National Parks is the most important site for extensive explorations as the park and the surrounding areas are rich in members of the Lycopodiaceae. This protected area houses eleven out of seventeen species in Thailand, viz. *Huperzia carinata*, *H. hamiltonii*, *H. laxa*, *H. nummulariifolia*, *H. phlegmaria*, *H. pinifolia*, *H. serrata*, *H. squarrosa*, *Lycopodiella cernua*, *Lycopodium clavatum*, and *L. casuarinoides.* Khao Luang is the only natural site of *L. casuarinoides*, the scandent *Lycopodium*. This species distributes from India, China through Malay Peninsula. At Khao Luang and the other natural habitats, *L. casuarinoides* usually occupies the primary forest of the mountain ridges or the summit of the mountains. Geographically speaking, *L. casuarinoides* should be found in the high mountains of the northern provinces. Its absence from the northern districts is probably due to the clearance of its natural habitats. As we have already known that the mountains in the north have been disturbed by human activity for a long time.

Some *Huperzia* species have commercial values, it is widely cultivated as an ornamental plants in a hanging basket. It is one of an expensive plant owing to the high demands, but only small numbers can be supplied due to the difficulty in propagations and their growth rate is rather slow. So far, ornamental species, such as *H. carinata*, *H. phlegmaria*, and *H. nummulariifolia* are rarely found in the wild. Since many plants were removed from their natural habitats and offered for sale in local markets and other countries. A new technique to propagate these species is really needed to protect these species from over gathering, eventually extirpating these species from their natural habitats.

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Appendix

Collector Numbers

Huperzia carinata
K: W.T. Tsang-27272, B. Hansen & T. Smitinand-11968, Singapore Field No. 3827, W.T. Tsang-29892, Taurier-1985, D.C. Collius-138, C. Boden Kloss-14557, Reccari-7/65, Zippelius s.n., Hayocp-2341, Hayocp-2343, Sinor Saut-3414, Othman Ismawi-S. 42305, B.E.G. Moleswort-Allen-3166, Coll. Hative-60, Thoi-Lobb-1857, Kadia-A608, Kadia-A608 , J. van Borssum Waalkes-3296, C.B. Robinson-1973
P: M. Poilane 3281**,** R.C. McGregor 10780
L: S.H. Koorders 21193 B, W.J.J.O. de Wilde 12114

Huperzia phlegmaria
K: R.H. Yapp-432, J.W. Anderson-22/10/1912, K.M. Kochmmen-M.1, I.H. Burkill & R.E. Holttum-8788, J.H. Burkill-3512, I. Ilippauce-7589, K.H. Yapp-178, D.F.A. Hirvey rec. viii-1886, Dr. King's-2436, FRI-27039, Dr. King's-2470, Lelecutis-1363, B.S. Paris 10917, ABD. Samat & B. Abdullah-5087, M.E.D. Poore-0526, J.W. Purseglove-4166, G.P. Lewis 93, G.P. Lewis 81, M.R. Henderson-21950, Dr. King's-3023, H3966/59-50, H.C. Robinson 6325, Kiah-32091, Md. Hauiff & Nur-10237, H.R. Ridley 7813, H.C. Robinson 1913, University of Malaya-5087, H3966/59-60, H.C. Robinson & C.B. Kloss-6002, R.H. Yapp-431, Patrick Selvaraj-99689, Slayman-3016, M. Noor & Samsuri-MN. 24, B. Hansen & T. Smitinand 12019, R.H. Yapp-844, Ch. Charoenphol et al.-3857, M. Poilane-1878, M. Poilane-5988, D.J. Collins-481, T. Smitinand-696, W.T. Tsang-27270, D.J. Collins-139, Singapore Field No.3826, B. Sangkhachard-175, W. Hancock-1892, O. Beccari-11/79, C. Boden-Kloss-11447, Johanis P. Mogea-459, Korthals s.n., P. Buwalda-6400, C.G. Matthew-H3966/59-71, P. Buwalda-7598, W.J. Lutjeharms-4757, J.A. Lorzing-15130, J.A. Lorzing-13395, J. Dransfield-3394, C.G. Matthew-H2015/14, W.J.J.O. de Wilde-19078, J. Dransfield-3393, Rahmat Si Boeea-9502, Korthals s.n., A.D.E. Elmer-21903, M.S. Clemens-11271, J. & M.S. Clemens-26404, Kadir-A607, E.C. & L.B. Abbe et al.-9930, E.F. de Vogel-5130, E.F. de Vogel-5434, Anta-1199, Bunnamaijer-937, Kostermans & Anta-396, Kostermans & Anta-571, Anta 1286, Bequcert-228, J. Dransfield-4257, P. Buwalda-2991, Junghuhn-263, V. Schiffner-1893/94, Junghuhn-201, Ernst-26, Kunio Iwatsuki-B432, H. Zollinger-862.3, V. Schiffner-1893/94, Junghuhn-294A, Bahh & Drink-6610, H.N. Ridley-H3966/59/80, H.N. Ridley-H3966/59/81, H.N. Ridley-H3966/59/82, H.N. Ridley-H3966/59/83, V. Schiffner-P22, Raciborski-13, Korthals s.n., Junghuhn-265, Junghuhn-264, D.A. Powell-221, D.A. Powell-301, D.A. Powell-320, Kostermans-18120, IBOET-516, H.O. Forbes-2416, A.C. Church-678, A. Kostermans-21420, H.J. Lam-3170, C. Hose-723, C. Hose-723, P.S. Ashton-S. 19057, J. & M.S. Clemens-20421, Othman Ismawi-S. 42319, J. & M.S. Clemens-21027, A.D.E. Elmer?, H.N. Ridley H3966/59-148, Burbidje-H/3966/59-28, B.L. Burtt & P.J.B. Woods-2342, J.W. Purseglove & M.-P. 4826, Bojeng bin Sitam-S. 23219, Sibat ak. Luang-23219, J.W. Purseglove & M.-P. 4513, P.W. Richards-H3966/59/78, G.H. Shl.-346-H3966/59-74, Peter Sie-S. 35547, Axel. D. Poulsen-148, H. Beaman-10019, H. Beaman-8381, H. Beaman-10469, H. Beaman-9942, Amin G. et al.-San 94669, Amin G. et al.-San 94583, F. Krispinus-89858, Dewol S. & Petrus S.-San 89583, Dewol S. & Kodoh T.-San 89344, M. Tamura & M. Hotto-557, M. Tamura & M. Hotto-617/1, M. Tamura & M. Hotto-617/2, Peter J. Edwards-2079, P.F. Cockburn-85024, Aban Gibot-78647, G. Shea & Aban-77157, Dewol & Abd. Karim-San 77571, J. Ampuria-41532, Anudah-275, H.N. Ridley-

H3966/59/86, D. Darnaedi-2029, D. Darnaedi-2049, V. Balgooy-3214, P.J. Eyma s.n., K. Iwatsuki et al.-C81
P: M. Poilane 4255, M. Buysman 2068
L: N.A.P. Franken & M.C. Roos 339, R.D. Hoogland 5020

Huperzia nummularifolia,
K: A.G. Piggot-2305, J.S. Gamble-July 1925, Flora of Kelantan Md. Nur. 12108, Kiah-Singapore Field-31750, Bukit Basan-D.T. 125, Hook. et al. s.n., A.C. Maingay-M.D. -2289, Flora of Penang-1004, Malaypeninsula-8064, Flora of Kelantan Md. Nur. 12108, Flora of Malay Peninsula-693, Malayan Peninsula-Sir W. Norris, Flora of Penang (vis) 1915, West Hill Penang -1915, Sidex bin Kiah-S. 283, B. Sangkhachand & B. Nimanong-1289, G.P. Lewis-99, David W. Lee-UL 61A, W.J. Lutjeharms-3874, W.J.J.O. de Wilde-18188, Bunnemeyu-1976, C. Boden-Kloss-10581, J.P. Mogea-4158, Heryocp-2287, G.D. Haviland-Mar. 1894, G.K. Sus-353, P.W. Richards-1169, Herb. Hookerianum-294, B.O.O.F.-420, P.W. Richards-1229, J.A.R. Anderson-12819, B.L. Burtt & P.J.B. Woods-2300, M. Jacobs-5167, Ilias Paie-S. 12129, Paul Chai-S. 36481, P.C. Boyce-393, W. Meijer-41019, Leonardo Co-3180, Dr. A. Rant-784
P: M.G. Bamler 54, Zollinger I. 55
L: W.J.J.O. de Wilde 14846, Blume s.n.

Huperzia serrata
K: Dosyae-5188, M. Tagawa et al.T-1508, T. Smitinand-4945, T. Smitinand-1266, T. Smitinand-9454, E. Hennipman-3864, Lyhe-24, Y. Laumonier-TBF. 30, Y. Laumonier-YL198, A. Ernst-896, W.J.J.O. de Wilde 15193, W.J.J.O. de Wilde 18632, G. Argent et al.-NGS 1046, Dostae-5286, Dostae-5288, L.R. Lanjouw-92, Dostae-5295, Dostae-5194, Dostae-5287, Dostae-5187, Dostae-5196, Dostae-5195, J.H. Beaman-8210, J.H. Beaman-8803, W.L. Chew et al.-593, J. & M.S. Clemens-27758, Dostae-5192, R.W. Richards-2434, B.S. Parris-11429, B.S. Parris-11561, J. & M.S. Clemens-29065, J. & M.S. Clemens-32957, W.L. Chew & E.J.H. Corner-4301, E.F. de Vogel-5144, P.J. Eyma-471, V. Balgooy-3256, B.S. Parris-11210
P: M. Evrard 1920, Koenicke 12280
L: E.F. de Vogel 8362, A.H.G. Alston 12851

Huperzia squarosa
K: Dr. King's-3150, R.H. Yapp-485, M^{d} Nur 12032, Singapore Botanic Garden-17/11/1911, H.C. Robinson et al.-6070, Singapore field note-11223, Dan H. Nicolson-1646, D.J. Collins-482, T. Smitinand-729, W.T. Tsang-27116, Eug. Poilane-1952, O. Beccari-479, Y. Laumonier-TFB 4315, C. Boden-Kloss 14540, K. Iwatsuki-S. 577, Raap-466, T.P. Mousset-122, R.B. le Mardi-122, Raciborski-10/11/1920, J. & M.S. Clemens-32184, J.H. Beaman-9050, G. Kesus-350, W. Meijer-635, Susjah-274, W.L. Chew et al.-1889, J. & M.S. Clemens s.n., J.H. Beaman-10796, P.J. Eyma-3874, P.J. Eyma-3764, P.J. Eyma-1068, Lee Joncheere-1731, E. Hennipman-5942
P: M. Poilane 1952, H.N. Whitford 798
L: W.J.J.O. de Wilde 12022, E. Hennipman-5250

Lycopodiella cernua,
K: V.L. Yurung-40, H.C. Robinson & C.B. Kloss-6029, H.J.-130, N.H.-14150, Bogen-3, Hardial & Samsuri-254, E. Soepadmo & Mahmud-1107, L.B. & E.C. Abbe et al.-9027, Univ. of Malaya-8022, P.-4214, B.S. Parris-10883, B.S. Parris-10927, B.S. Parris-10928, R. Melville-4799, J.R. Flenley-39, Mohd. Shah-Ms. 1447, P.J. Edwards & B.S. Parris-17/85,

J.R. Flenley-24, Abdul Hamid-36036, H.N. Ridley-H3166/59-445, R.H. Yapp-487, V. Schiffner-H3966/59-403, A.G. Piggot-2346, Singapore field note-7990, R.H. Yapp-31, C.C. Hosseus-510, C. Phengkhlai-430, A.F.G. Kerr-13591, Gen Murata et al.-T17054, D.J. Collins-2359, B. Sangachand & T. Smitinand-248, T. Smitinand-1835, D. Chianglom s.n., C. Phengkhlai et al.-4078, C.F. van Beusekom et al.-4491, F. Floto-7460, Th. Sorensen et al.-731, F. Floto-7387, Th. Sorensen et al.-449, L.B. & E.C. Abbe & T. Smitinand-9421, M. Poilane-2125, W.T. Tsang-27453, M. le Dr. Thorel-279, W.T. Tsang-29979, W.T. Tsang-30522, W.T. Tsang-29513, W.T. Tsang-29247, W.T. Tsang-26974, W.T. Tsang-30209, C.G.G.J. van Steenis-8457, C.G. Matthew-3/01/13
P: M. Poilane-375, F. Evrard 976
L: C. Holstvoogd-196, A. Zainal & Arbainsyah 1810

Lycopodium clavatum
K: B.S. Parris & P.J. Edwards-18/85, Fri-27130, R.E. Holttum-11203, J. Sinclair-9954, Chew Wee-Lek-11203, R.E. Holttum-31386, T. Shimizu et al.-M13420, ABD. Samat & B. Abdullah-2053, K. Banfield-H/3966/59-41, Hardial & Samsuri-252, H.B.G. Garrett-321(1), H.B.G. Garrett-321(2), K. Bonchuai & T. Smitinand-1450, T. Smitinand & E.C. Abbe-6412, T. Smitinand & I. Alsterlund-6691, T. Smitinand-2334, P. Suvanakoses-576, Ch. charoenphol et al.-4743, Y. Laumonier-6634, D. Darnaedi-137, Bunn Emeyer-5150, W. Hancock-1892, C.G. Matthew-H3966/59-42, K. Iwatsuki et al.-S. 1161, K. Iwatsuki et al.-S. 1440, J.C. Whitehead & J.R. Flenley-236, O. Beccari-278, A. Ernst-500, De Voogd-April, 1941, V. Schiffner-P. 10, Herb. Hookerianum-290, W. Meijer-1720, Purch-275, J. & M.S. Clemens-30377, Raciborskt s.n., Main-359, Bruce E. Weber-23/03/1966, B.S. Parris-11292, B.S. Parris-11603, J. Sinclair, Kadim-9139, Saikkeh Lantoh-San 82754, Aban Gibot-San 79577, John H. Beaman-9964, D.A. Simpson, R. Casserly-89/223, J. & M.S. Clemens-28532, J. & M.S. Clemens-51629, R.E. Holttum-25455, B. Molesworth Allen-3264, Bruce E. Weber-54729, W.L. Chew et al.-725, Aban Gobot-San 74129, J. & M.S. Clemens-29003, Bunnemeyer-12262, B.S. Parris-11187
P: M. Poilane 12579, M. Fleischer s.n.
L: T. Shimizu et al. 13421, C.G.G.J. van Steenis-10637