

อนุกรมวิธานเชิงตัวเลขของเฟิร์นบางชนิดในสกุล *Thelypteris* Schmidel sensu lato
ในประเทศไทย



นางสาวปานกมล ศรสุวรรณ

สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

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NUMERICAL TAXONOMY OF SOME FERN SPECIES IN THE GENUS
Thelypteris Schmidel sensu lato IN THAILAND



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จุฬาลงกรณ์มหาวิทยาลัย

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เฟิร์นสกุล *Thelypteris* Schmidel sensu lato เป็นสกุลขนาดใหญ่ของวงศ์ Thelypteridaceae มีสมาชิกเกือบ 1,000 ชนิด ส่วนใหญ่พบกระจายพันธุ์อยู่ในเขตร้อนและเขตกึ่งร้อนของโลก ปัจจุบันการจัดจำแนกเฟิร์นสกุลนี้โดยนักอนุกรมวิธานเฟิร์นยังคงมีความคิดเห็นที่แตกต่างกัน บางท่านได้จัดจำแนกเฟิร์นวงศ์นี้ไว้ในสกุล *Thelypteris* เพียงสกุลเดียว แต่ก็มีนักอนุกรมวิธานบางท่านเห็นว่าควรแยกเฟิร์นสกุลนี้ออกเป็นหลายสกุล หนังสือพรรณไม้ประเทศไทยรายงานเฟิร์นวงศ์นี้จำนวน 2 สกุล 51 ชนิด เฟิร์นวงศ์นี้พบทั่วไปในถิ่นอาศัยแบบต่าง ๆ ทั่วประเทศ ซึ่งถ้าจัดจำแนกตามระบบของ Holttum จะสามารถแยกออกได้เป็น 16 สกุล การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อให้เกิดความชัดเจนในการจัดจำแนกเฟิร์นสกุล *Thelypteris* s.l. โดยวิเคราะห์ข้อมูลจากพืชจำนวน 27 ชนิด รวม 518 ตัวอย่างด้วยเทคนิคการวิเคราะห์การจัดกลุ่ม และการวิเคราะห์การจัดจำแนก โดยใช้ลักษณะเชิงปริมาณ 21 ลักษณะ และลักษณะเชิงคุณภาพ 11 ลักษณะ ผลการวิเคราะห์การจัดกลุ่มโดยใช้เฉพาะลักษณะเชิงปริมาณพบว่าที่ค่าระยะห่างทางอนุกรมวิธาน 1.5 สามารถจำแนก *Thelypteris* s.l. ได้เป็น 3 กลุ่ม คือ *Thelypteris* s.s., *Macrothelypteris* และ *Pronephrium* และเมื่อวิเคราะห์การจัดกลุ่มโดยใช้ทั้งลักษณะเชิงปริมาณและลักษณะเชิงคุณภาพพบว่าได้ผลอย่างเดียวกัน ทำนองเดียวกันเมื่อนำไปวิเคราะห์โดยใช้เทคนิคการวิเคราะห์การจัดจำแนก พบว่า *Thelypteris* s.l. ประกอบด้วย 3 กลุ่มย่อย ลักษณะสำคัญที่ใช้ในจำแนกเฟิร์น 3 กลุ่ม/สกุล คือ ความกว้างของสเกล มุมระหว่างใบล่างสุดและแกนกลางใบ จำนวนของแอนนูลัสเซลล์ ความสูงของสปอร์ และเส้นผ่านศูนย์กลางของสปอร์ ผลจากการวิเคราะห์ลักษณะพื้นฐานวิทยาคครั้งนี้สนับสนุนการแยกเฟิร์นสกุล *Thelypteris* s.l. ออกเป็น 3 สกุล คือ *Thelypteris* s.s., *Macrothelypteris* และ *Pronephrium*

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PANKAMON SORNSUWAN: NUMERICAL TAXONOMY OF SOME FERN SPECIES IN THE GENUS *Thelypteris* Schmidel sensu lato THESIS ADVISOR: ASSOC. PROF. THAWEESAKDI BOONKERD, Ph.D.; THESIS CO-ADVISOR: TOSAK SEELANAN, Ph.D., 75 pp. ISBN 974-17-6817-6

Thelypteris Schmidel s.l. is one of the large genus of the Thelypteridaceae. It is comprised of about one thousand species, mostly occur in tropical and subtropical regions of the world. Up to now, *Thelypteris* s.l. cannot be clearly classified due to different generic concepts of pteridologists. Some authors, treated all species in a single genus, whilst the others segregated *Thelypteris* s.l. into many genera. In Thailand, *Thelypteris* s.l. is commonly found in various habitats throughout. Fifty one species were reported in Flora of Thailand and treated into two genera. In contrast, there were 16 genera according to Holttum's classification. In order to clarify this taxonomic inconsistency, 518 OTUs from 27 species were analysed using cluster and canonical discriminant analyses. The total of 21 quantitative and 11 qualitative characters were employed. In cluster analysis using only quantitative characters, the *Thelypteris* s.l. could be separated into three taxa: *Thelypteris* s.s., *Macrothelypteris* and *Pronephrium* at average taxonomic distance 1.50. The same result was obtained when both quantitative and qualitative characters were used. Likewise, canonical discriminant analysis suggested that there were three groups within the genus *Thelypteris* s.l. The three groups/genera can be distinguished on the basis of scale width, angle of basal pinnae to rachis, number of annulus cell, spore height and spore diameter. In all, the results from these morphometric analyses support the segregation of *Thelypteris* s.l. into three genera, viz. *Thelypteris* s.s., *Macrothelypteris* and *Pronephrium*.

Department.....Botany.....Student's signature.....

Field of study.....Botany.....Advisor's signature.....

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CONTENTS

	PAGE
Thai Abstract.....	iv
English Abstract	v
Acknowledgements	vi
Contents	vii
List of Scientific Names	viii
List of Tables	ix
List of Figures	x
List of Abbreviation.....	xv
Chapter 1 Introduction	1
Chapter 2 Literature Review	3
Chapter 3 Materials and Methods	14
Chapter 4 Results and Discussion	19
Chapter 5 Conclusion.....	71
References	72
Biography	75

สถาบันวิทยบริการ
จุฬาลงกรณ์มหาวิทยาลัย

LIST OF SCIENTIFIC NAMES

SPECIES	PAGE
<i>Meniscium proliferum</i> (Retz.) Sw.....	21
<i>Thelypteris arida</i> (D.Don) Morton.	22
<i>Thelypteris ciliata</i> (Wall. ex Benth.) Ching.	23
<i>Thelypteris confluens</i> (Thunb.) C.V. Morton	24
<i>Thelypteris crassifolia</i> (Blume) Ching.....	25
<i>Thelypteris crinipes</i> (Hook.) K. Iwats.....	26
<i>Thelypteris dentata</i> (Forssk.) St. John	26
<i>Thelypteris falciloba</i> (Hook.) Ching.....	28
<i>Thelypteris ferox</i> (Blume) Tagawa & K. Iwats.....	28
<i>Thelypteris flaccida</i> (Blume) Ching	29
<i>Thelypteris hirsutipes</i> (Clarke) Ching.....	30
<i>Thelypteris hirtisora</i> (C. Chr.) K. Iwats.....	31
<i>Thelypteris interrupta</i> (Willd.) K. Iwats.....	32
<i>Thelypteris larutensis</i> (Bedd.) Tagawa & K. Iwats.	33
<i>Thelypteris megaphylla</i> (Mett.) K. Iwats.....	34
<i>Thelypteris nudata</i> (Roxb.) Morton.	35
<i>Thelypteris polycarpa</i> (Blume) K. Iwats.	36
<i>Thelypteris repanda</i> (Fee) Tagawa & K. Iwats.	37
<i>Thelypteris siamensis</i> Tagawa & K. Iwats.	38
<i>Thelypteris singalanensis</i> (Baker) Ching.....	39
<i>Thelypteris sumatrana</i> (v.A.v.Ros.) K. Iwats.....	40
<i>Thelypteris terminans</i> (Hook.) Tagawa & K. Iwats.....	40
<i>Thelypteris torresiana</i> (Gaud.) Alston	41
<i>Thelypteris truncata</i> (Poir.) K. Iwats.	42
<i>Thelypteris viscosa</i> (Baker) Ching.....	43
<i>Thelypteris xylodes</i> (Kunze) Ching.....	44
<i>Thelypteris</i> sp.	45

LIST OF TABLES

TABLE	PAGE
3.1 Twenty one quantitative characters of fertile frond used in multivariate analyses of <i>Thelypteris</i> s. l. with their methods of scoring.....	16
3.2 Eleven qualitative characters of fertile frond used in multivariate analyses of <i>Thelypteris</i> s. l. with their methods of scoring	18
4.1 Twenty seven taxa of <i>Thelypteris</i> s.l. used in multivariate analyses.....	20
4.2 Pooled within canonical structure of 3 group/taxa according to the result of canonical discriminant analysis.	65
4.3 Summary of canonical discriminant function of 3 group/taxa (A-C) according to the result of canonical discriminant analysis.	66
4.4 F values, means and standard errors of 21 quantitative characters of the three genera	67



 สถาบันวิทยบริการ
 จุฬาลงกรณ์มหาวิทยาลัย

LIST OF FIGURES

FIGURE	PAGE
2.1 Dendrogram representatives of (a) single-linkage, (b) UPGMA-linkage, (c) complete-linkage clustering.	5
3.1 Measurement of characters listed in Table 3.1	17
4.1 <i>Meniscium proliferum</i> (Retz.) Sw. - habitat.....	46
4.2 <i>Meniscium proliferum</i> (Retz.) Sw.....	46
4.3 <i>Thelypteris arida</i> (D.Don) Morton - habitat	46
4.4 <i>Thelypteris ciliata</i> (Wall. ex Benth.) Ching - habitat	46
4.5 <i>Thelypteris ciliata</i> (Wall. ex Benth.) Ching - sori	46
4.6 <i>Thelypteris confluens</i> (Thunb.) C.V. Morton.	46
4.7 <i>Thelypteris crassifolia</i> (Blume) Ching.....	47
4.8 <i>Thelypteris crassifolia</i> (Blume) Ching - rhizome.	47
4.9 <i>Thelypteris crassifolia</i> (Blume) Ching - sori	47
4.10 <i>Thelypteris crinipes</i> (Hook.) K. Iwats. - habitat	47
4.11 <i>Thelypteris crinipes</i> (Hook.) K. Iwats. - sori	47
4.12 <i>Thelypteris dentata</i> (Forssk.) St. John - habitat	47
4.13 <i>Thelypteris dentata</i> (Forssk.) St. John - sori	47
4.14 <i>Thelypteris falciloba</i> (Hook.) Ching - habitat.....	48
4.15 <i>Thelypteris falciloba</i> (Hook.) Ching - sori.....	48
4.16 <i>Thelypteris ferox</i> (Blume) Tagawa & K. Iwats. - frond, rhizome.....	48
4.17 <i>Thelypteris ferox</i> (Blume) Tagawa & K. Iwats. - sori.....	48
4.18 <i>Thelypteris ferox</i> (Blume) Tagawa & K. Iwats.	48
4.19 <i>Thelypteris flaccida</i> (Blume) Ching - sori	48
4.20 <i>Thelypteris flaccida</i> (Blume) Ching - rhizome.	48
4.21 <i>Thelypteris flaccida</i> (Blume) Ching.....	49
4.22 <i>Thelypteris hirsutipes</i> (Clarke) Ching.....	49
4.23 <i>Thelypteris hirtisora</i> (C. Chr.) K. Iwats. - habitat	49
4.24 <i>Thelypteris hirtisora</i> (C. Chr.) K. Iwats. - sori	49
4.25 <i>Thelypteris interrupta</i> (Willd.) K. Iwats.- habitat.....	49
4.26 <i>Thelypteris interrupta</i> (Willd.) K. Iwats.- sori.....	49
4.27 <i>Thelypteris larutensis</i> (Bedd.) Tagawa & K. Iwats.	50

FIGURE	PAGE
4.28 <i>Thelypteris larutensis</i> (Bedd.) Tagawa & K. Iwats.- rhizome	50
4.29 <i>Thelypteris larutensis</i> (Bedd.) Tagawa & K. Iwats.- sori	50
4.30 <i>Thelypteris megaphylla</i> (Mett.) K. Iwats.	50
4.31 <i>Thelypteris nudata</i> (Roxb.) Morton - habitat	50
4.32 <i>Thelypteris nudata</i> (Roxb.) Morton - sori	50
4.33 <i>Thelypteris polycarpa</i> (Blume) K. Iwats.	51
4.34 <i>Thelypteris polycarpa</i> (Blume) K. Iwats.- habitat	51
4.35 <i>Thelypteris polycarpa</i> (Blume) K. Iwats.- sori	51
4.36 <i>Thelypteris repanda</i> (Fee) Tagawa & K. Iwats.	51
4.37 <i>Thelypteris repanda</i> (Fee) Tagawa & K. Iwats.- rhizome.....	51
4.38 <i>Thelypteris repanda</i> (Fee) Tagawa & K. Iwats.- sori.....	51
4.39 <i>Thelypteris siamensis</i> Tagawa & K. Iwats.	52
4.40 <i>Thelypteris siamensis</i> Tagawa & K. Iwats.- rhizome.....	52
4.41 <i>Thelypteris siamensis</i> Tagawa & K. Iwats.- sori.....	52
4.42 <i>Thelypteris singalanensis</i> (Baker) Ching.....	52
4.43 <i>Thelypteris singalanensis</i> (Baker) Ching - sori	52
4.44 <i>Thelypteris sumatrana</i> (v.A.v.Ros.) K. Iwats.- sori	52
4.45 <i>Thelypteris sumatrana</i> (v.A.v.Ros.) K. Iwats.- sori	52
4.46 <i>Thelypteris terminans</i> (Hook.) Tagawa & K. Iwats.- habitat.....	53
4.47 <i>Thelypteris terminans</i> (Hook.) Tagawa & K. Iwats.- sori	53
4.48 <i>Thelypteris torresiana</i> (Gaud.) Alston - habitat.....	53
4.49 <i>Thelypteris torresiana</i> (Gaud.) Alston - sori.....	53
4.50 <i>Thelypteris truncata</i> (Poir.) K. Iwats.- habitat	53
4.51 <i>Thelypteris truncata</i> (Poir.) K. Iwats.- sori.....	53
4.52 <i>Thelypteris truncata</i> (Poir.) K. Iwats.	53
4.53 <i>Thelypteris viscosa</i> (Baker) Ching.....	54
4.54 <i>Thelypteris viscosa</i> (Baker) Ching - rhizome	54
4.55 <i>Thelypteris viscosa</i> (Baker) Ching - sori	54
4.56 <i>Thelypteris xylodes</i> (Kunze) Ching - habitat	54
4.57 <i>Thelypteris xylodes</i> (Kunze) Ching - sori	54
4.58 <i>Thelypteris xylodes</i> (Kunze) Ching - rhizome	54

FIGURE	PAGE
4.59 <i>Thelypteris</i> sp.	55
4.60 <i>Thelypteris</i> sp.- sori.....	55
4.61 <i>Thelypteris</i> sp.- frond.....	55
4.62 UPGMA clustering of 518 OTUs based on 21 characters of <i>Thelypteris</i> s. l. in Thailand.....	60
4.63 UPGMA phenogram base on Gower's general similarity coefficient calculated between means of 21 quantitative and 11 qualitative morphological characters of the genus <i>Thelypteris</i> s. l. in Thailand Dashed line indicates 70% similarity phenon line, separating three clusters.	61
4.64 Ordination plot of 518 specimens from 27 taxa of <i>Thelypteris</i> s.l. in Thailand based on 21 quantitative characters	62
4.65 Means and Standard errors of the 5 important characters in separating the three proposed genera.	63

LIST OF ABBREVIATION

BCU	=	Herbarium at Department of Botany, Faculty of Science Chulalongkorn University, Bangkok, Thailand
BKF	=	Herbarium at Royal Forest Department, Bangkok, Thailand
CA	=	cluster analysis
CDA	=	canonical discriminant analysis
cm	=	centimeter
DIST	=	average taxonomic distance
E	=	Herbarium at Royal Botanic Garden, Edinburgh, Scotland
K	=	Herbarium at Royal Botanic Gardens, Kew, England
mm	=	millimeter
MVSP	=	Multivariate Statistics Package
NTSYS	=	numerical taxonomic system of multivariate statistical programs
OTU	=	Operational Taxonomic Unit
SE	=	Standard Error
SAHN	=	Sequential, Agglomerative, Hierarchical, and Non-overlapping
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

CHAPTER 1

INTRODUCTION

It has been estimated that there are probably about 10 million species of living organisms inhabiting the earth (Jones and Luchsinger, 1986). Up to now only a small fraction of animals, plants and micro-organisms have been described (Mayr and Ashlock, 1991). The larger part of the world plant diversity remains unsampled, unnamed and unclassified. This vast numbers of living plants must be named and arranged. Ideally, the arrangement should correspond as closely as possible to the natural relationships between organisms.

Likewise, plant taxonomists attempt to sort all the living plants into natural system as possible. They have to delimit each taxa through a selection of meaningful characters that will make a taxon whose members are similar to one another and unlike members of the other taxa.

In the past, little investigation had been made on this matter, plant taxonomists set too much values on certain characters which were applicable to define the status of species or higher taxonomic categories. However, the natural relationships among the species or the species group can only be established when the resemblance or difference of all characters are recognized.

Thelypteridaceae is one of the largest families of seedless vascular plants, comprising nearly a thousand species mostly in tropical and subtropical regions; less than 2% is found in the temperate. Diagnostic characters of the family Thelypteridaceae include possessing of two vascular bundles (meristele) through out the length of stipe (compared to many bundles in Dryopteroid ferns) and the presence of acicular hairs on many parts of frond. Spores are bilateral with a prominent perispore. Chromosome base numbers of Thelypteridaceae are ranged from 27 to 36 (Mickel and Beitel, 1988). In contrast, those of its related groups, i.e. Dryopteroids and Athyrioids, have 40 and 41 of their chromosome base numbers, respectively.

Up to now, the Thelypteridaceae can not be clearly classified, so that genera are included or excluded from this ferns family due to different concepts of various authors. The recent treatment concerning the circumscription and relationship of the Thelypteroid ferns are those given by Christensen (1938, cited in Smith, 1971), Copeland (1960, cited in Holttum, 1981), Ching (1963, cited in Holttum, 1981),

Morton (1963, cited in Smith, 1971), Iwatsuki (1964) and Holttum (1971). Some authors treated all species in to a single genus, i.e. *Thelypteris* Schmidel for example Morton (1963, cited in Smith, 1971), whilst the others segregated the genus *Thelypteris* s.l. into many genera, for example Christensen (1938, cited in Smith, 1971), Copeland (1960, cited in Holttum, 1981), Ching (1963, cited in Holttum, 1981), Iwatsuki (1964) and Holttum (1971).

The Thelypteridaceae is commonly found throughout Thailand. Fifty one species were reported and treated in two genera, *Thelypteris* and *Meniscium* (Tagawa and Iwatsuki, 1988), while Boonkerd and Polawatn (2000) proposed a segregation of *Thelypteris* s.l. into 14 genera. It can be seen that classification within the Thelypteridaceae so far is not clear and waiting for reinvesitigation.

Aim of the thesis

This thesis aims to explore some more information as a basis to treat *Thelypteris* Schmidel in Thailand by using numerical taxonomic techniques. Cluster analysis as well as discriminant analyses will be employed to analyse a data set of both quantitative and qualitative characters of some *Thelypteris*' species collecting from natural habitats throughout Thailand.

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CHAPTER 2

LITERATURE REVIEW

2.1 NUMERICAL TAXONOMY

2.1.1 OBJECTIVES AND PRINCIPLES OF NUMERICAL TAXONOMY

The main objective of numerical methods in taxonomy is to simplify and portray degrees of relationship or similarity among any groups of organisms. It utilizes many equally weighted characters and employs clustering and similar algorithms to yield objective grouping (Sneath and Sokal, 1973).

Sneath and Sokal (1973) summarized the following advantages of the numerical methods:

- (a) The ability of the methods to construct a system of classification using various characters from different sources together, such as morphology, physiology, anatomy, cytology, genetics, chemistry, ecology and paleobotany;
- (b) The ability of the methods to carry out efficiently by less highly skilled workers, since large portions of the taxonomic process are being done by a computer;
- (c) The ability of the methods to provide greater discrimination along the spectrum of taxonomic differences and to be more sensitive in delimiting taxa. Thus they should give better classifications and keys than can be obtained by conventional methods.

Numerical taxonomy is actually an extension of Adansonian classification (Sneath and Sokal, 1973). It obtains principles in making classification established by Adanson (1727-1806). The followings are summary of Adanson's opinions on classification quote by Sneath and Sokal (1973):

- *The greater the content of information in the taxa of a classification and the more characters on which it is based, the better a given classification will be.*
- *Every character is of equal weight in creating natural taxa.*

- *Overall similarity between any two entities is a function of their individual similarities in each of the many characters in which they are being compared.*
- *Distinct taxa can be recognized because correlation of characters differs in the groups or organisms under study.*
- *Phylogenetic inferences can be made from the taxonomic structures of a group and from character correlation, given certain assumptions about evolutionary pathways and mechanisms.*
- *Taxonomy is viewed and practiced as an empirical (practical) science.*
- *Classifications are based on phenetic similarity.*

2.1.2 METHODS IN NUMERICAL TAXONOMY

Numerical taxonomy requires many steps in practice:

- 1) selection of taxa for study (those are usually called Operational Taxonomic Units or OTUs) which are simply the starting point units in numerical taxonomy; they might be individual organisms, populations, species, genera, etc;
- 2) selection of characters;
- 3) description and/or measurement of character states;
- 4) comparison of states to (a) determine a measure of overall similarity between each pair of OTUs, and (b) determine the taxonomic structure, i.e. the detection of possible groups and subgroups among all OTUs;
- 5) ranking of all OTUs into the categories of the taxonomic hierarchy.

2.1.3 THE NUMRICAL TECHNIQUES

2.1.3.1 Cluster Analysis (CA)

1) Steps of Cluster Analysis

Cluster analysis is a two-step process. In the first step, a symmetric matrix of similarity or dissimilarity among objects will be calculated. In the second step, a hierarchical grouping of these objects will be generated, and represented these in a cluster diagram, dendogram or phenogram. In each step, decisions must be made regarding the type of coefficient or clustering technique used; as such, there are a large number of ways a given data set may be analyzed.

2) Steps of Clustering Algorithms

In general, there are 5 specific steps in clustering:

1. Given a matrix of pairwise similarities/dissimilarities, find $\min(d_{ij})$;
2. Define the depth of a branch between those OTUs as either d_{ij} or $(d_{ij}/2)$;
3. Establish a new cluster containing OTUs i and j (i and j merged into a single OTU);
4. Define the distance from this cluster to all other OTUs/clusters by re-computing symmetric matrix with 1 less OTU;
5. Go back to step 1 and repeat.

This process is repeated until only one OTU remains. Alternative clustering methods differ primarily in how new distances will be defined in step 4. UPGMA clustering defines the distance of an OTU to a newly-established cluster as the arithmetic average of all component distances. Single linkage clustering uses the minimum distance among the component distances as the distance of an OTU from the new cluster, while complete linkage clustering uses the maximum of the component distances. Single and complete linkage represent extremes along a continuum, while UPGMA is in the middle.

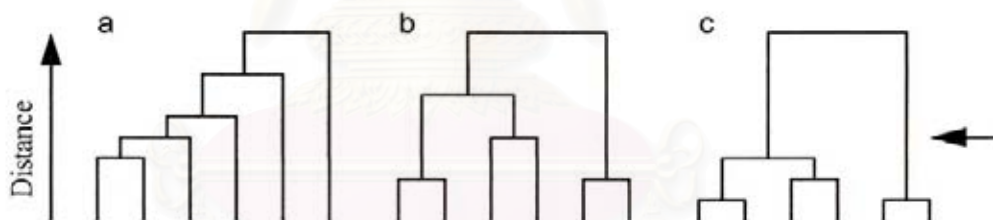


Figure 2.1 Dendrogram representative of (a) single-linkage, (b) UPGMA-linkage, (c) complete-linkage clustering.

3) Clustering

Once we have a symmetric matrix of similarity/dissimilarity between all pairs of OTUs, we can then group these into sets of similar objects. Most commonly-used clustering algorithm is sequential, agglomerative, hierarchical, and non-overlapping; this type of clustering is known as SAHN clustering. Clustering is very straightforward, and proceeds by iteratively grouping the most similar OTUs and then recalculating the similarities/dissimilarities among those that remain. In this way, we generate a direct solution that is based on local optima.

Two procedures are involved in every step in the clustering procedure: (1) joining of the most-similar OTUs to form clusters; and (2) re-computation of the similarity/dissimilarity between newly-established clusters and potential new members. New members are admitted to clusters in a pair-group manner, which generates a bifurcating tree (phenogram, dendrogram); alternatively, admission may be variable-group, which allows more than two OTUs at a node.

4) Dendrogram

A dendrogram is a diagrammatic illustration of relationships based on degree of similarity in which the OTUs are linked together at various levels of resemblance. It shows progressive inclusion of entity or groups of entities into larger groups so that the result is a set of hierarchically arranged groups within groups.

Groups are portrayed by stems. The inclusion of several groups into one group occurs at a node, and is depicted by a crossbar. The height at which each node occurs is known as its rank, and is based on a measure of resemblance.

The dendrogram is provided with a quantitative scale of the overall dissimilarity between groups. The most similar groups fuse first, followed by others fusing at successively lower levels of similarities. The degree of resemblance of the clusters and the extent to which they are distinct from other is displayed very clearly.

2.1.3.2 Canonical Discriminant Analysis (CDA)

The concepts of CDA can be described as following:

The differences between the groups can be established statistically by means of a test of the probability of the null hypothesis that all the groups of objects have the same centroid (multivariate mean). If there is only one measured variable, this is equivalent to the one-way analysis of variance for comparing two or more groups.

The relationships between the groups can be assessed visually by means of a scatter plot in which the positions of the individuals or the group means or both are plotted on axes known as canonical axes (discriminant functions) which depend on the original observations and are chosen by the analysis to best represent the differences between the groups.

Canonical discriminant analysis (CDA) is sometimes known simply as "canonical analysis".

1) Principles of Canonical Discriminant Analysis

This separation of groups (for two groups) is accomplished by finding a linear combination of the original variables for which the F value between groups is maximized.

In the cases of more than two groups, we get a set of canonical discriminant functions (canonical variates), or multiple axes that separate groups as sets of groups. Assuming that there are more variables than groups, there will be (m-1) canonical variates, where m is the number of groups. It is important to see the difference between Fisher discriminant functions and canonical discriminant functions: discriminant functions connect pairs of centroids, while canonical variates summarize the major axes of among-group variation.

Canonical discriminant functions fit the equation:-

$$Z_1 = a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \dots + a_{1n}x_n$$

where the a_{ij} values are coefficients derived from eigen analysis of the matrix between group variation, and the Z values are scores (coordinates) along the derived axis. If we bisect this axis, we can use the scores to assign individuals to groups at each end of the axis.

2) The step in Canonical Discriminant Analysis

1. Transform the variables so that the pooled within-class covariance matrix is an identity matrix.
2. Compute class means on the transformed variables.
3. Discriminant function is created from data. The values of the discriminant function should be differed as much as possible between the groups, or so that for the discriminant scores are a maximum.
4. Predicting or classifying new case using the discriminant function from step 3.

3) The Goal of Canonical Discriminant Analysis

1. To find the axis of greatest discrimination between groups identified a priori.
2. To test whether the means of those groups along that axis are significantly different.
3. To attempt to assign individual specimen to a group.

2.2 PREVIOUS WORKS USING NUMERICAL TAXONOMY

The use of numerical and statistical methods to classify taxa of living plant is largely developed from the last 55 years. Historically, the use of quantitative methods in plant taxonomy was pioneered by Anderson in the 1930's (Radford et al., 1974). The 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 advocated the employment of such techniques in a wide variety of organisms (Sneath, 1995).

Numerical studies have been performed on wide variety of organisms and these approaches have shown to be useful in evaluating and refining the existing classification.

A comprehensive list of publications on numerical taxonomy carried out on various organisms by various authors are sampled below.

In microbiology, this technique has been demonstrated to be an effective tool in identification and circumscription of difficult taxa such as *Streptomyces*, *Bacillus* and *Rhizobium* and help to clarify their taxonomy. For example, Goodfellow, Ferguson and Sanglier (1992) reviewed some of numerical taxonomic studies that have been done on *Streptomyces* which combine molecular, chemical and phenotypic data in delimiting taxa.

In the animal kingdom, numerical studies have been done spanning from invertebrate to vertebrate and the clustering obtained provides better understanding of the group studies. Studies have been done on a range of organisms such as in beetles (Biondi and Bologna, 1991) and tree-hoppers (Dietrich and Deitz, 1991).

In plants, 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.

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.

The taxonomic status of *Asmeria*'s populations from the Horconera massif previously misidentified or without an explicit identification. Feliner, Aguilar and Rosselló (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. trianai*.

Mikkelsen and 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.

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. subsection *Vaginatae* F.C. Stern and subsection *Delavayanae* F.C. Stern (Wang et al., 2001).

Kitamura (1956, cited in 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, cited in Whang et al., 2002)) transferred this complex into three different species of *Ixeridium*, viz. *Ixeridium chinensis* (Thunb.) Tzvelev, *I. strigosum* (H. Lév. et Vaniot) Tzvelev and *I. gramineum* (Fisch.) Tzvelev. Pak and Kawano (1992, cited in Whang et al., 2002)) re-classified the complex into two subspecies of one species and one different species in the same genus; *Ixeris shinensis* 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 (1956, cited in Whang et al., 2002) classification of infraspecific taxa in the species complex

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 performed separated the samples into two species groups with 32% overlap. 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.

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.

Lihová 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.

2.3 TAXONOMIC HISTORY OF *Thelypteris* sensu lato

Thelypteris sensu lato has been variously treated by pteridologists into genera, subgenera, or sections. Various systems have been proposed to arrange the species and genera in question, since new evidence is continuously being brought to bear upon the problems of classification.

The genus *Thelypteris* was firstly named by Schmidel in 1673; it has been conserved against *Thelypteris* Adanson (= *Pteris* L.) which may have been published earlier in the same year (cited in Holttum, 1981).

The diagnostic characters of the family Thelypteridaceae were not recognized until Christensen's study some tropical America species in 1913. In the 19th century there was much confusion in the use of generic names which were based mainly on soral characters (Iwatsuki, 1964).

The first New World species to be described within Thelypteroid group under study were from the island of Jamaica. In 1788, Swartz, one of the early collectors of Jamaican plants, characterized *Polypodium serra* Sw. (= *Thelypteris serra* (Sw.) R. St. John), *P. invisum* Sw. (= *Thelypteris invisum* (Sw.) Proctor), and *P. patens* Sw. (= *Thelypteris patens* (Sw.) Small ex R. St. John), citing the plates of Sloane, another early collector in Jamaica. In 1801, Swartz transferred these species and other species from *Polypodium* to his newly described genus *Aspidium* (Smith, 1981).

In 1801, Swartz published a genus *Lastrea*, and citing a few species; however, he did not refer to *Aspidium* or *Nephrodium*, though the species he cited should be placed in either (Holttum, 1981).

The genus *Lastrea* Bory, based on *Lastrea oreopteris* Bory (= *Thelypteris limbosperma* (All.) H. P. Fuchs) was taken up by Presl (1836, cited in Holttum, 1971), and many of the Thelypteroid ferns were included within its circumscription. Other generic names which have been applied at one time or another to members of Thelypteroid group are *Polystichum* Roth, *Cyclodium* C. Presl., and *Phegopteris* Fée.

In the late nineteenth century, the genus *Dryopteris* Adanson was resurrected and has been widely used since then in many classification schemes, such as floras, and manuals. In its broadest sense, *Dryopteris* included most of the pinnate-pinnatifid to decomposed ferns which possess dorsal sori covered by a reniform indusium.

In 1913, Christensen published a monograph of the fern *Dryopteris* sensu lato in the New World. He distinguished two groups within *Dryopteris* (Dryopteroid and Thelypteroid groups). The combination of these two fern groups mentioned by Christensen into a single genus *Dryopteris* is now regarded by most pteridologists as highly artificial, and in fact the Dryopteroid and Thelypteroid groups are often segregated into different families (Smith, 1971). Christensen (1938, cited in Holttum, 1981) himself later recognized *Thelypteris* as distinct from *Dryopteris* and even placed the two genera in different tribes. Morton (1963, cited in Smith, 1971) has also enumerated the important characters which distinguished *Dryopteris* from the Thelypteroid ferns.

Classification within *Thelypteris* has been the subject of divergent opinions. One extreme, that presented by Morton (1963, cited in Smith, 1971), placed all of the Thelypteroid ferns into a single genus *Thelypteris* Schmidel, typified by *Thelypteris palustris* Schott. In contrast, Ching (1963, cited in Holttum, 1981), placed the Thelypteroid ferns into three tribes and eighteen genera.

In 1963, Ching published a new classification system of Polypodiaceae s.l., in which he divided the Polypodiaceae into 33 families. The seventeenth of those is Thelypteridaceae comprising 18 genera in three tribes. This family was subdivided into three tribes distinguished by the difference of venation pattern (Iwatsuki, 1964).

Copeland (1947, cited in Iwatsuki, 1964) recognized nine genera of the family Thelypteridaceae including two major ones, *Lastrea* and *Cyclosorus*, which he distinguished on the basis of free simple veins or connivent at the sinus (*Lastrea*) versus veins of adjacent segments united below the sinus (*Cyclosorus*).

In his treatment ferns of Malaya, Holttum (1954, cited in Smith, 1971) made essentially the same distinction as Copeland did between the two groups of species,

but using the generic name *Thelypteris* instead of *Lastrea*. His first conclusion was that a division between *Thelypteris* and *Cyclosorus* base on free or united veins was not a natural one. He also concluded that the nature and distribution of glands and hairs provided important evidences which had never been well recorded.

Iwatsuki (1964) recognized three genera in the thelypteroid ferns. He segregated *Meniscium* (including *Goniopteris*) and *Stegnogramma* (including *Leptogramma* and *Dictyocline*) from the majority of the Thelypteroid ferns, of which he placed in *Thelypteris*. There were little convincing evidences given in his treatment to support such a division. Iwatsuki (1964) also subdivided the genus *Thelypteris* into fourteen subgenera and some subgenera were further subdivided into sections.

Holttum (1981) studied the ferns family thelypteridaceae in Malesian region. He recognized 22 genera, namely *Ampelopteris* Kunze, *Amphineuron* Holttum, *Chingia* Holttum, *Christella* L veill , *Coryphopteris* Holttum, *Cyclogramma* Tagawa, *Cyclosorus* Link, *Metathelypteris* (H. Ito) Ching, *Macrothelypteris* (H. Ito) Ching, *Mesophlebion* Holttum, *Nannothelypteris* Holttum, *Pneumatopteris* Nakai, *Parathelypteris* (H. Ito) Ching, *Phegopteris* F e, *Plesioneuron* Holttum, *Pronephrium* Presl, *Pseudocyclosorus* Ching, *Pseudophegopteris* Ching, *Sphaerostephanos* J. Sm., *Stegnogramma* Blume, *Thelypteris* Schmidel, *Trigonospora* Holttum. The results were published in Flora of Malesiana in 1981.

The pteridophytes of Thailand have recently been studied intensively in the course of the Flora of Thailand project. Tagawa and Iwatsuki have participated in this project and have enumerated some 620 species of pteridophytes of this country. Tagawa and Iwatsuki classified the family Thelypteridaceae into two genera (*Thelypteris* and *Meniscium*) which included 51 species. Fifty species were reported and treated in a single genus *Thelypteris*, while Boonkerd and Polawatn (2000) proposed segregation of *Thelypteris* s.l. into 14 genera namely *Amphineuron*, *Chingia*, *Christella*, *Coryphopteris*, *Cyclosorus*, *Metathelypteris*, *Macrothelypteris*, *Mesophlebion*, *Pneumatopteris*, *Pronephrium*, *Pseudophegopteris*, *Sphaerostephanos*, *Thelypteris*, *Trigonospora*. The results of Tagawa and Iwatsuki were published in 'Flora of Thailand' (1988). From the overall taxonomic history of the genus *Thelypteris*, it can be seen that up to now taxonomic status of the genus *Thelypteris* is still not clear and need to be clarified. In this thesis, attempts had been made to sort out taxonomic circumscription of *Thelypteris* by means of numerical taxonomy based on both quantitative as well as qualitative characters.

CHAPTER 3

MATERIALS AND METHODS

3.1 Specimen collections

The criterion used for OTUs selection was that these OTUs had to belong to any 16 genera according to Holttum's classification (1971, 1981). Therefore, at least 16 species would be collected in Thailand during field exploration.

Specimens of *Thelypteris* species were collected from known habitats noted in the **Flora of Thailand** (Tagawa and Iwatsuki, 1988). Due to the political crisis in the southernmost provinces of the country, specimen collections in Pattani, Yala and Narathiwat Provinces were not possible. So, voucher herbarium specimens deposited at Kew herbarium were used as a substitute.

Only complete specimens were collected and used for the analysis. The collected specimens were determined based on key to species in the Flora of Thailand, volume 3, part 3 (Tagawa and Iwatsuki, 1988). Then they were confirmed by comparing to the voucher specimen deposited at BCU, BKF and K (Herbarium abbreviations according to Holmgren and Holmgren (2005).

3.2 Character measurements

In total, 21 quantitative and 11 qualitative characters of the collected specimens were studied and selected for multivariate analyses (Table 3.1-3.2). Measurement of morphological characters was done on fertile fronds. 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.

3.3 Data analysis

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

In cluster analyses when only quantitative characters were used in cluster analyses, 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 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 was calculated and clustered by the group-average method as suggested by Gower (1971). For these proposes a statistic package, MVSP (Kovach Computing Services, MVSP Plus, version 3.1) was used.

Canonical discriminant analysis was performed with SPSS 11.0 for Windows (SPSS Inc., Chicago, IL, USA). Stepwise discriminant analysis was used to select a subset of characters that maximized differences among the groups determined by clusters analysis. Correct classification rates were used as indicators of separation among the groups.



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Table 3.1 Twenty one quantitative characters of fertile frond used in multivariate analyses of *Thelypteris* s. l. with their methods of scoring

No.	Character	Details of measurements and counts
1.	scale width (mm)	width of scale at base of stipe
2.	scale length (mm)	length of scale at base of stipe
3.	stipe length (mm)	length of stipe
4.	rachis length (cm)	length of rachis
5.	basal pinnae width (cm)	width of basal pinnae
6.	basal pinnae length (cm)	length of basal pinnae
7.	angle of basal pinnae to rachis	-
8.	number of pinnae/frond	-
9.	distance between the pair of the largest pinnae (cm)	-
10.	lateral pinnae width (cm)	width of the largest lateral pinnae
11.	lateral pinnae length (cm)	length of the largest lateral pinnae
12.	pinnae lobe depth (mm)	perpendicular distance between margin and base of lobe
13.	number of sori per lobe	number of sori per lobe of the largest lateral pinnae
14.	lateral vein length (cm)	length of lateral vein of the largest lateral pinnae
15.	pair number of lateral veins/ pinnae	-
16.	sporangium width (mm)	the longest distance measured from side to side of sporangium at the equatorial axis
17.	sporangium length (mm)	the longest distance measured from base to top of sporangium (without stalk)
18.	number of annulus cell	number of annulus cell/ sporangium
19.	stalk length (mm)	length of sporangium stalk
20.	spore height (mm)	height of spore from lateral view
21.	spore diameter (mm)	diameter of spore from lateral view

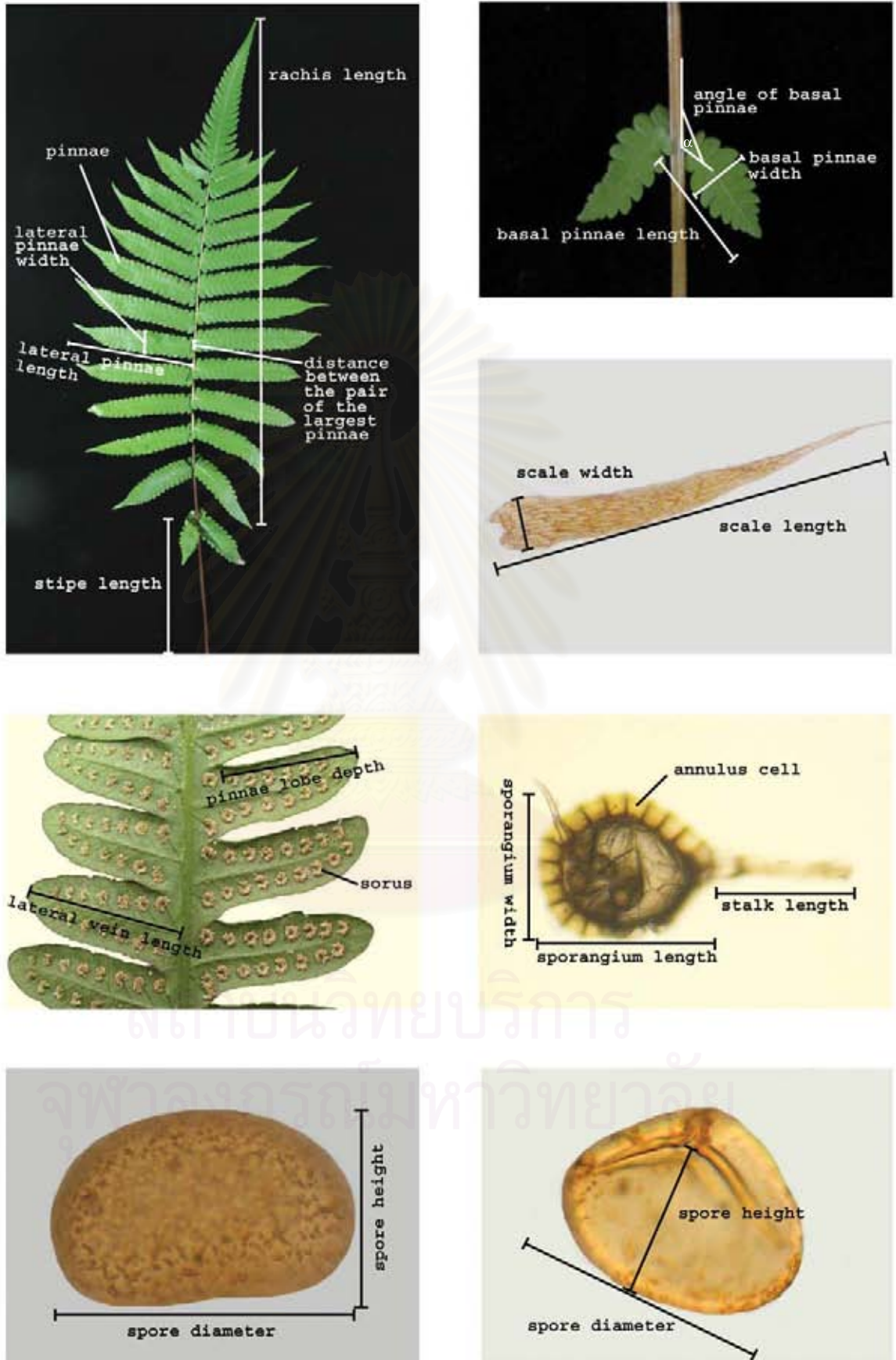


Figure 3.1 Measurement of characters listed in Table 3.1

Table 3.2 Eleven qualitative characters of fertile frond used in multivariate analyses of *Thelypteris* s. l. with their methods of scoring

No.	Character	Character description
1.	form of rhizome	erect (1), suberect (2), short creeping (3), long creeping (4)
2.	many buds on rachis	absent (0), present (1)
3.	basal pinnae	not or slightly reduced (1), extremely reduced (2), suddenly reduced to form butterfly shaped auricles (3)
4.	form of frond	one pinnate (1), bipinnate-tripinnatifid (2)
5.	upper-surface of costae	not grooved (0), grooved (1)
6.	margin of pinnae	subentire (1), pinnae lobed less than half way to costae (2), pinnae lobed to a half way towards costae (3), pinnae always deeply lobed (4)
7.	venation pattern	vein free (1), vein anastomosing (2), vein in several pairs all anastomosing and joining to form zigzag composite vein alternating with the costules (3)
8.	sori	exindusiate (0), indusiate (1)
9.	acicular hairs or glandular hairs on sporangium	absent (0), present (1)
10.	acicular hairs or glandular hairs on sporangium stalk	absent (0), present (1)
11.	spore type	monolete (1), trilete (2)

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Specimen collections

A total of 518 specimens were included in the overall analyses. Of these, four hundreds and eight specimens which represented sixteen species of *Thelypteris* s.l. in Thailand were gathered from their natural habitats during July 2003 to October 2004. Voucher specimens from this collection were deposited at BCU and BKF. Another one hundred and ten specimens of a different eleven taxa were herbarium specimens deposited at K. The specimens were determined to species of the *Thelypteris* s.l. in Thailand. The determination results together with a related genera and species according to Holttum (1971, 1981) were showed in Table 4.1. It is noteworthy that a putative new species of *Thelypteris* (Fig. 4.59-4.61) was found at Khao Luang National Park, Nakhon Si Thammarat Province. This species is somewhat similar to *Thelypteris ciliata*, but they differ in shape and apex of lateral pinnae. Its spore characters matched the typical characters of the genus *Trigonospora* (Holttum, 1971). According to the type specimens deposited as K, this species may be a new species. However, further investigations need to be carried out to verify this finding.

Table 4.1 Twenty seven taxa of *Thelypteris* s.l. used in multivariate analyses

No.	Botanical Name (Tagawa & Iwatsuki, 1988)	Corresponding taxa after Holttum (1971 and 1981)
1.	<i>Meniscium proliferum</i> (Retz.) Sw.	<i>Ampelopteris prolifera</i> (Retz.) Copel.
2.	<i>Thelypteris arida</i> (D. Don) Morton	<i>Christella arida</i> (D. Don) Holttum
3.	<i>Thelypteris ciliata</i> (Wall. ex Benth.) Ching	<i>Trigonospora ciliata</i> (Benth.) Holttum
4.	<i>Thelypteris confluens</i> (Thunb.) C. V. Morton	<i>Thelypteris confluens</i> (Thunb.) Morton
5.	<i>Thelypteris crassifolia</i> (Blume) Ching	<i>Mesophlebion crassifolium</i> (Blume) Holttum
6.	<i>Thelypteris crinipes</i> (Hook.) K. Iwats.	<i>Christella crinipes</i> (Hook.) Holttum, B. Nayar & Kaur
7.	<i>Thelypteris dentata</i> (Forssk.) St. John	<i>Christella dentata</i> (Forsskal) Brownsey & Jermy
8.	<i>Thelypteris falciloba</i> (Hook.) Ching	<i>Pseudocyclosorus falcilobus</i> (Hook.) Ching
9.	<i>Thelypteris ferox</i> (Blume) Tagawa & K. Iwats.	<i>Chingia ferox</i> (Blume) Holttum
10.	<i>Thelypteri flaccida</i> (Blume) Ching	<i>Metathelypteris flaccida</i> (Blume) Ching
11.	<i>Thelypteris hirsutipes</i> (Clarke) Ching	<i>Coryphopteris hirsutipes</i> (Clarke) Holttum
12.	<i>Thelypteris hirtisora</i> (C. Chr.) K. Iwats.	<i>Sphaerostephanos hirtisorus</i> (C. Chr.) Holttum
13.	<i>Thelypteris interrupta</i> (Willd.) K. Iwats.	<i>Cyclosorus interruptus</i> (Willd.) H. Ito
14.	<i>Thelypteris larutensis</i> (Bedd.) Tagawa & K. Iwats.	<i>Sphaerostephanos larutensis</i> (Bedd.) C. Chr.
15.	<i>Thelypteris megaphylla</i> (Mett.) K. Iwats.	<i>Sphaerostephanos penniger</i> (Hook.) Holttum
16.	<i>Thelypteris nudata</i> (Roxb.) Morton	<i>Pronephrium nudatum</i> (Roxb.) Holttum
17.	<i>Thelypteris polycarpa</i> (Blume) K. Iwats.	<i>Sphaerostephanos polycarpus</i> (Blume) Copel.
18.	<i>Thelypteris repanda</i> (Fee) Tagawa & K. Iwats.	<i>Pronephrium repandum</i> (Fée) Holttum
19.	<i>Thelypteris siamensis</i> Tagawa & K. Iwats.	<i>Christella siamensis</i> (Tagawa & K. Iwats.) Holttum
20.	<i>Thelypteris singalanensis</i> (Baker) Ching	<i>Metathelypteris singalanensis</i> (Baker) Ching
21.	<i>Thelypteris sumatrana</i> (v.A.v.Ros.) K. Iwats.	<i>Pseudophegopteris sumatrana</i> Holttum
22.	<i>Thelypteris terminans</i> (Hook.) Tagawa & K. Iwats.	<i>Amphineuron terminans</i> (Hook.) Holttum
23.	<i>Thelypteris torresiana</i> (Gaud.) Alston	<i>Macrothelypteris torresiana</i> (Gaud.) Ching
24.	<i>Thelypteris truncata</i> (Poir.) K. Iwats.	<i>Pneumatopteris truncata</i> (Poiret) Holttum
25.	<i>Thelypteris viscosa</i> (Baker) Ching	<i>Coryphopteris viscosa</i> (Baker) Holttum
26.	<i>Thelypteris xylodes</i> (Kunze) Ching	<i>Pseudocyclosorus xylodes</i> (Kunze) Ching
27.	<i>Thelypteris</i> sp.	<i>Trigonospora</i> sp.

The followers below are detailed descriptions, of the 27 studied species.

THELYPTERIDACEAE

Ching ex Pic. Serm., *Webbia* 24: 709. 1970; Holttum in *Fl. Mal. II.* 1: 331. 1981; Kuo, *Fl. Taiwan Vol. 1.* 2nd ed.: 401. 1980.

Rhizome erect, short-creeping or long-creeping; scales usually thin, not peltate. Stipes not articulated to stem, containing two vascular bundles at base and uniting into a U-shaped bundle in the upper part. Fronds usually pinnate with crenate or lobed pinnae, upper surfaces of costae grooved or not, if grooved, not open to admit groove of rachis; lowest pinnae without enlarged basiscopic basal pinnules; hairs normally unicellular; veins free in deeply lobed pinnae, or basal veins in adjacent lobes anastomosing to form an excurrent vein, which may be joined by other veins, terminating at the base of a sinus-membrane. Sori borne on abaxial surface of veins, indusiate or not; indusia reniform, glabrous or bearing hairs and/or glands.

1. *Meniscium proliferum* (Retz.) Sw., *Syn. Fil.*: 19, 206. 1806; K. Iwats., *J. Jap. Bot.* 38: 315. 1963; Tagawa et K. Iwats., *Fl. Thail.* 3(3): 435. 1988.— *Hemionitis prolifera* Retz., *Obs Bot.* 6: 36. 1791.— *Polypodium proliferum* (Retz.) Roxb., *Wall., List no.* 312. 1828.— *Goniopteris prolifera* (Retz.) Fee, *Cr. Vasc. Br.* 1: 105. 1869; Bedd., *Handb.*: 296. f. 153. 1883.— *Dryopteris prolifera* (Retz.) C. Chr., *Index Fil.* 286. 1905.— *Cyclosorus proliferus* (Retz.) Tard. ex Tard. et C. Chr., *Notul. Syst.* 7: 76. 1938; in *Fl. Gen. I.-C.* 7(2): 389. 1941.— *Ampelopteris prolifera* (Retz.) Copel., *Gen. Fil.*: 144. 1947; Holttum, *Rev. Fl. Malaya* 2: 299. 1955; *Dansk Bot. Ark.* 23: 233. 1965; in *Fl. Mal. II.* 1: 387. f. 7 d-f. 1981; Kuo, *Fl. Taiwan Vol. 1.* 2nd ed.: 402. 1980. — *Thelypteris prolifera* (Retz.) Reed, *Phytologia* 17: 306. 1968.

Rhizome creeping, about 4 mm diam.; scales ovate-subtriangular, brown, hairy. **Stipe** up to 59.9 cm long, hairy, scaly at base. **Frond** oblong-lanceolate; rachis proliferous, bearing a tuft of fronds and rooting at several places, with simple or bifurcate hairs; lateral pinnae about 39 pairs, shortly stalked, linear-lanceolate, moderately acute to acute at apex, truncate at base, very shallowly incised, 9.9 by 1.6 cm; lobes rectangular, oblique, truncate at apex, herbaceous, dark olive-green when

dry; veins pinnate, main veins about 36 pairs, uniting to form a goniopteroid venation. **Sori** oblong or elongate along united veinlets, naked; sporangia glabrous. (Figure 4.1-4.2)

T h a i l a n d.— NORTHERN: Chiang Rai, Chiang Mai; EASTERN: Chaiyaphum, Udon Thani; CENTRAL: Saraburi; SOUTH-WESTERN: Kanchanaburi.

D i s t r i b u t i o n.— Tropics and subtropics throughout the Old World (type from S. India).

E c o l o g y.— On moist banks near streams usually in open places or in light shade at low to medium altitudes.

S p e c i m e n s e x a m i n e d.— P. Sornsuwan 015 [BCU].

2. *Thelypteris arida* (D. Don) Morton, Amer. Fern J. 49: 113. 1959; K. Iwats., J. Jap. Bot. 38: 314. 1963; Tagawa et K. Iwats., Fl. Thail. 3(3): 431.1988.— *Aspidium aridum* D. Don, Prod. Fl. Nepal.: 4. 1825.— *Nephrodium aridum* (D. Don) J. Smith in Hook., J. Bot. 4: 188. 1841.— *Cyclosorus aridus* (D. Don) Ching, Bull. Fan Mem. Inst. Biol. 8: 194. 1938; Holttum, Rev. Fl. Malaya 2: 259. f. 146. 1955.— *Christella arida* (D. Don) Holttum in Nayar & Kaur, Comp. Bedd. Handb.: 206. 1974; Kew Bull. 31: 320. 1976; in Fl. Mal. II. 1: 555. f. 1i. 1981; Kuo, Fl. Taiwan Vol. 1. 2nd ed.: 404. 1980.

Rhizome long-creeping, about 3 mm diam.; scales pale brown, membranous, caducous, up to 2.48 by 0.79 mm. **Stipe** about 32.1 cm long, scaly as well as hairy near base, bearing reduced pinnae on upper part. **Fron**d oblong-lanceolate, gradually narrowing downwards, acute at apex; rachis densely hairy throughout; lower pinnae gradually narrowing downwards to mere auricles, middle pinnae larger, sessile, patent, linear-lanceolate, gradually narrowing towards long-acuminate apex, more or less auricled at base, up to 11 by 1.3 cm, lobed $\frac{1}{3}$ way to costa; segments oblong-subdeltoid, acute to aciculate at apex, entire; chartaceous to coriaceous, pubescent on lower surface; veins pinnate, about 3 lower pairs uniting with those of the opposite groups, hairy as well as yellow-glandular. **Sori** medial; indusia small, thin, hairy, usually immersed among sporangia at maturity. (Figure 4.3)

T h a i l a n d.— NORTHERN: Chiang Rai, Chiang Mai, Tak;
PENINSULAR: Satun, Yala.

D i s t r i b u t i o n.— Himalaya (type) to W. Malesia, north to N. Vietnam,
Hong Kong and Taiwan.

E c o l o g y.— On clayey ground or in grassy fields in some open places at
medium altitudes.

S p e c i m e n s e x a m i n e d.— O. Vannasri 50, 53 [BCU]; P.
Ratchata 211, 339 [BCU]; T. Boonkerd 608, 609 [BCU]; Blume s.n. (type) [K]; E.
Smith 1099 [K].

3. *Thelypteris ciliata* (Wall.) Ching, Bull. Fan Mem. Inst. Biol. 6: 289. 1936; Tagawa
et K. Iwats., Fl. Thail. 3(3): 401. 1988; Holttum, Rev. Fl. Malaya 2: 250. f. 142. 1955.
— *Aspidium ciliatum* Wall., List n.: 351. 1823.— *Lastrea ciliata* Hook., Kew J. Bot.
9: 335. 1857.— *Nephrodium calcaratum* var. *ciliatum* Baker, Syn. Fil. 494. 1874.—
Nephrodium ciliatum Clarke, Trans. Linn. Soc. Lond. II. Bot. 1(8): 514. 1880.—
Lastrea calcarata Moore var. *ciliate* (Benth.) Bedd., Handb.: 235. f. 121. 1883. —
Dryopteris calcarata (Blume) O. Ktze. var. *ciliata* C. Chr., Index Fil.: 256. 1905.—
Dryopteris pseudocalcarata C. Chr., Ind. Fil. Suppl. III: 95. 1934.— *Trigonospora*
ciliata (Benth.) Holttum, Blumea 19: 29. 1971; Reinwardtia 8: 507. 1974; in Fl. Mal.
II. 1: 375. f. 5, c-e. 1981.

Rhizome erect, bearing closely tufted fronds and a dense mat of tough black
roots. **Stipe** of fertile fronds to 19.2 cm long, more or less clothed, like the rachis, with
soft spreading pale hairs about 1 mm long; scales on young circinate fronds small,
broad, dark, early deciduous. **Frond** to about 38.8 by 8.9 cm; free pinnae about 14
pairs, the lowest usually deflexed but not reduced, the middle pinnae spreading or
somewhat oblique, the upper often very oblique, all sessile; the acuminate apical
lamina deeply lobed; middle pinnae to about 4.43 cm long and 1.06 cm wide, the fertile
slightly narrower than the sterile, base unequal, broadly cuneate to truncate on the
acroscopic side, the lowest segment elongated into an auricle, rounded on the
basiscopic side apex sub-acuminate, the sides cut about half-way towards the rachis
into oblique subfalcate blunt lobes about 3 mm wide; veins in each lobe 5 pairs,
simple, the lowest anterior vein of a group running to the sinus. **Sori** rather large,

occupying most of the surface of fertile pinnae; indusia large, persistent, ciliate; hairs on costae above very short, appressed, rest of upper surface glabrous; costae below bearing numerous spreading pale hairs about 1 mm long, similar hairs scattered on costules. (Figure 4.4-4.5)

T h a i l a n d.— NORTHERN: Chiang Rai, Chiang Mai, Tak, Phitsanulok, Phrae; NORTH-EASTERN: Phetchabun, Loei; SOUTH-EASTERN: Chanthaburi; PENINSULAR: Nakhon Si Thammarat, Yala.

D i s t r i b u t i o n.— Nepal to W. Malesia, north to Hong Kong (type).

E c o l o g y.— Usually on muddy stream-beds in dense forests at 500 – 1700 m alt.

S p e c i m e n s e x a m i n e d.— P. Sornsuwan 027, 028, 029, 030 [BCU]; B. Hansen, G. Seidenfaden and T. Smitinand 11257 [E]; Jain 25 (type) [K]; Plernchit 236 [K].

4. *Thelypteris confluens* (Thunb.) Morton., Contr. U.S. Nat. Herb. 38: 71. 1967; Holttum In Fl. Mal. II. 1: 377. f. 5, g-h. 1981; Tagawa et K. Iwats., Fl Thail. 3(3): 401.1988.— *Pteris confluens* Thunb., Prodr. Pl. Cap.: 171. 1800.— *Nephrodium squamulosum* Hook. f., Fl. N. Z. 2: 39. 1854.— *Thelypteris squamulosa* (Hook. f.) Ching, Bull. Fan Mem. Inst. Biol. 6: 5, 329. 1936.

Rhizome long-creeping, with distant fronds; scales oblong with long tails, sparsely hairy at margin, 2.27 by 1.34 mm, pale brown. **Stipe** stramineous with dark base, about 52.6 cm long. **Fron**d oblong-lanceolate, acute at apex, up to 84.1 by 12.6 cm, pinnate; lateral pinnae lanceolate, acute at apex, shortly stalked, pinnatisect, up to 6.33 by 0.9 cm; segments oblong, oblique, moderately acute at apex; rachis and costa scaly underneath with broad pale brown membranous scales; veins pinnate, veinlets forked or simple, reaching the margin of lobes. **Sori** dorsal on veinlets, round, sometimes adhering to the next at maturity; indusia round-reniform, hairy at margin. (Figure 4.6)

T h a i l a n d.— NORTHERN: Chiang Mai.

D i s t r i b u t i o n.— Africa (type), S. India, Burma, Laos, Sumatra, New Guinea, and New Zealand.

E c o l o g y.— In swamps in rather open places at about 1000 m alt.

S p e c i m e n s e x a m i n e d.— Unknown s.n. (type) [K]; V. S. Manickam and S. J. 170 [K]; Th. Sorensen, K. Larsen and B. Hansen 2727, 2851 [K].

5. *Thelypteris crassifolia* (Blume) Ching, Bull. Fan Mem. Inst. Biol. 6: 285. 1936; Holttum, Rev. Fl. Malaya 2: 246. 1955; Tagawa et K. Iwats., Fl Thail. 3(3): 403. 1988.— *Aspidium crassifolium* Blume, En. Pl. Jav.: 158. 1828.— *Lastrea crassifolia* (Blume) Moore, Ind. Fil.: 89. 1858.— *Mesophlebion crassifolium* (Blume) Holttum, Blumea 19: 30. 1971; 22: 232. 1975.— *Mesophlebion motleyanum* (Hook.) Holttum in Nayar & Kaur, Comp. Bedd. Handb.: 209. 1975; in Fl. Mal. II. 1: 381. 1981.— *Nephrodium motleyanum* Hook., Syn. Fil.: 266. 1867.

Rhizome short-creeping, up to 1 cm diam.; scales linear-lanceolate, up to 7.03 by 0.49 mm, brown, hairy. **Stipe** stramineous with dark base, about 63.3 cm long in soriferous fronds. **Fron**d oblong, attenuate at apex, up to 107 by 16.6 cm, narrower in soriferous fronds; lowest pinnae usually deflexed, lower pinnae distinctly stalked, narrowly oblong with acuminate apex and broadly cuneate base, up to 14.6 by 2.7 cm in sterile ones, up to 2.5 cm wide in soriferous ones, lobed to $\frac{2}{3}$ way towards costa; upper pinnae sessile, smaller, ascending; segments oblong, oblique to falcate, round at apex, entire, up to 13 by 7 mm; chartaceous to coriaceous, deep green, verrucose on lower surface; veins pinnate, veinlets simple, basal posterior ones springing directly from costa running to sinus between segments. **Sori** medial, 7 mm diam.; indusia persistent, hairy. (Figure 4.7-4.9)

Thailand.— PENINSULAR: Surat Thani, Nakhon Si Thammarat, Narathiwat, Satun.

Distribution.— W. Malesia (type from Java).

E c o l o g y.— On humus-rich mountain slopes in dense evergreen forests at about 1400 m alt.

S p e c i m e n s e x a m i n e d.— P. Sornsuwan 035 [BCU]; Blume s.n. (type) [K]; B. E. G. and M. Allen 3480 [K]; B. S. Parris 6624, 10604 [K]; K. Iwatsuki, M. Kato, G. Murata and Y. P. Moge B-2496 [K]; M. Kato, K. Ueda, M.

Okamoto, H. Akiyama, B. Sunarno and U. W. Mahjar C- 5063 [K]; S. P. Lim LSP1809 [K].

6. *Thelypteris crinipes* (Hook.) K. Iwats., J. Jap. Bot. 38: 315. 1963; Tagawa et K. Iwats., Fl. Thail. 3(3): 430. 1988.— *Nephrodium crinipes* Hook., Sp. Fil. 4: 71. 1862.— *Cyclosorus crinipes* (Hook.) Ching, Bull. Fan Mem. Inst. Biol. 8: 179. 1938.— *Christella crinipes* (Hook.) Holttum in Nayar & Kaur, Comp. Bedd. Handb.: 208. 1974; Kew Bull. 31: 326. 1976.

Rhizome erect; scales linear-lanceolate with long-tailed apex, up to 10.59 by 0.7 mm, brown, glabrous. **Stipe** 36.6 cm long, with reduced pinnae on upper part, densely scaly throughout. **Fronde** oblong-lanceolate with acute apex, up to 120.6 by 30.18 cm; rachis scaly throughout; several lower pinnae distinctly reduced and immersed among scales, lower normal pinnae straight, ascending, linear, gradually narrowing towards long-acuminate apex, up to 2 by 1.5 cm, lobed half-way to costa; segments oblong, oblique, acute at apex; chartaceous, green to deep green, pubescent on undersurface; costa pubescent; veins pinnate, basal pairs of veinlets uniting with those of the adjacent group to form connivent veinlets, the others running to the margin of segments, hairy. **Sori** medial or nearer to margin, round; indusia round-reniform, densely hairy. (Figure 4.10-4.11)

T h a i l a n d.— **NORTHERN:** Chiang Rai, Chiang Mai, Mae Hong Son, Lamphun, Lampang, Tak; **SOUTH-WESTERN:** Uthai Thani.

D i s t r i b u t i o n.— Himalaya (type) and S.W. China.

E c o l o g y.— On sandy ground along streams in deciduous or evergreen forests at low to medium altitudes.

S p e c i m e n s e x a m i n e d.— P. Sornsuvan 038 [BCU]; C. F. van Beusekom and T. Santisuk 2890 [K]; E. Hennipman 3059 [K]; E. Smith 1098 [K]; M. Tagawa, H. Koyama and M. Hutoh T.10515 [K].

7. *Thelypteris dentata* (Forssk.) St. John, Amer. Fern J. 26: 44. 1966; Tagawa et K. Iwats., Fl. Thail. 3(3): 427. 1988.— *Polypodium dentatum* Forssk., Fl. Aegypt.-Arab.

185. 1775.— *Cyclosorus dentatus* (Fossk.) Ching, Bull. Fan Mem. Inst Biol. 8: 206 1938.— *Christella dentata* (Forssk.) Holttum, J.S. African Bot. 40(2): 143. 1974; Kuo, Fl. Taiwan Vol. 1. 2nd ed.: 404. 1980.— *Cyclosorus subpubescens* auct. Non (Blume) Ching; Holttum, Rev. Fl. Malaya 2: 273. f. 157. 1955.

Rhizome short, erect, ascending, or shortly creeping, with a tuft of fronds; scales narrow, about 8 by 1.5 mm, pale brown, hairy. **Stipe** about 70.5 cm long, bearing reduced pinnae on upper portion, scaly at base, hair throughout. **Fron**d narrowly oblong, acute at apex, gradually narrowing downwards, up to 72.5 by 42 cm; lateral pinnae about at apex, gradually narrowing downwards, up to 72.5 by 42 cm; lateral pinnae about 20 pairs, patent to ascending, sessile, linear-lanceolate, more or less auricled at base, gradually narrowing towards long-acuminate apex, up to 23.5 by 2 cm, lobed 1/3 to 2/3 way casta; lower pinnae gradually becoming smaller downwards but rarely reduced to mere auricles; segment oblong-subdeltoid, oblique, rounded at apex, entire; herbaceous to softly papyraceous, yellow-green to green, densely pubescent on both surfaces; basal veinlets and basal second anterior ones uniting below callous-membrane. Sori medial, round; indusia large, densely hairy. (Figure 4.12-4.13)

Thailand.— NORTHERN: Chiang Rai, Chiang Mai, Mae Hong Son, Lamphun, Lampang, Phae, Tak, Phitsanulo; NORTH-EASTERN: Phetchabun, Loei, Khon Kaen; CENTRAL: Nakhon Nayok, Saraburi, Bangkok; SOUTH-EASTERN: Prachin Buri, Chanthaburi, Trat; SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Surat Thani, Nakhon Si Thammarat, Phangnga, Trang, Satun.

D i s t r i b u t i o n .— Pantropic (type from Arabia).

E c o l o g y .— Terrestrial on rather dry ground slopes in remnants of the forest in mine area, about 500-800 m alt.

S p e c i m e n s e x a m i n e d .— P. Somsuwan 010, 011, 012 [BCU]; A. Sathapattayanon 228, 258 [BCU]; O. Vannasri 65, 66 [BCU]; T. Boonkerd 669, 687, 704 [BCU]; Y. Yuyen 5 [BCU]; C. Niyomdham et al 1477 [BKF]; M. Matsuoka 184 [BKF]; T. Shimizu 8700 [BKF]; Winit 990 [BKF]; T. Smitinand and H. Sleumer 1018 [E]; E. Smith 3031 [K]; K. Larsen, T. Santisuk and E. Warncke 3244 [K]; T. Shimizu, K. Iwatsuki, N. Fukuoka, M. Hutoh, D. Chaiglom and A. Nalampoon T.11364 [K].

8. *Thelypteris falciloba* (Hook.) Ching, Bull. Fan Mem. Inst. Biol. 6: 298. 1936; Tagawa et K. Iwats., Fl. Thail. 3(3): 422. 1988.— *Lastrea falciloba* Hook., J. Bot. 9: 337. 1857.— *Aspidium falcilobum* (Hook.) Benth., Fl. Hongkong: 445. 1861.— *Nephrodium falcilobum* (Hook.) Hook., Spec. Fil. 4: 108. 1862. — *Pseudocyclosorus falcilobus* (Hook.) Ching, Acta Phytotax. Sinica 8: 324. 1963.— *Nephrodium calcaratum* sensu Baker, Syn. Fil. 264. 1867.— *Dryopteris calcarata* sensu v.A.v.R., Handb. Mal. Ferns: 185. 1908.

Rhizome erect, stout, stipes tufted, 8-12 cm long; scales elongated, up to 4 by 2 mm, pale brown, thin and appressed, hairy at margin. **Stipe** up to 19.0 cm long, with reduced pinnae nearly to base. **Fronde** oblong-lanceolate, acute at apex, up to 53.6 by 20.4 cm; lower pinnae reduced to more auricles, middle pinnae linear-lanceolate, gradually narrowing towards long-acuminate apex, cuneate at sessile base, up to 10.2 by 1.1 cm, deeply lobed nearly towards costa; segments falcate, oblique, forming angle of 35–45 between costa and costule, acute at apex, entire and often involute; softly chartaceous, green, pubescent on under surface; vernation free, 26 pairs of main vein, veins pinnate, veinlets simple, hairy, basal anterior ones running to callous-membrane in sinus between segments. **Sori** round, medial; indusia persistent, glandular; no glands or hairs present on the body of sporangium, a short 2-3 celled hair with swollen end-cell present on the stalk of sporangia; spores monolets, bilateral, light brown. (Figure 4.14-4.15)

Thailand.— NORTHERN: Chiang Rai, Chiang Mai.

Distribution.— Assam, Upper Burma, SW. & S. China (type from Hong Kong), and Vietnam.

Ecology.— Terrestrial near streams in shade at medium altitudes.

Specimens examined.— P. Sornsuvan 014 [BCU]; T. Boonkerd 1299 [BCU]; J. F. Maxwell 93-261 [E]; B. Hansen, G. Seidenfaden and T. Smitinand 10956 [K]; J. F. Maxwell 93-201 [K]; Winit 975 [K].

9. *Thelypteris ferox* (Blume) Tagawa & K. Iwats., Acta Phytotax. Geobot. 23: 54. 1968; Fl. Thail. 3(3): 403. 1988.— *Aspidium ferox* Blume, En. Pl. Jav.: 153. 1828.— *Nephrodium ferox* (Blume) Moore, Ind. Fil.: 91. 1858; Bedd., Handb.: 279. 1883.—

Cyclosorus ferox (Blume) Ching, Bull. Fan Mem. Inst. Biol. 8: 167. 1938; Holttum, Rev. Fl. Malaya 2: 265. f. 151. 1955.— *Chingia ferox* (Blume) Holttum, Blumea 19: 31. 1971.— *Chingia pseudoferox* Holttum, Kalikasan 3: 24. 1974.— *Thelypteris paleata* auct. non (Copel.) Holttum: Tagawa & K. Iwats., Acta Phytotax. Geobot. 23: 53. 1968.

Rhizome erect; scales narrow, about 3.5 by 2 mm, hairy, brown. **Fron**d gigantic; rachis glabrous or sparsely scaly with linear hairy scales; middle lateral pinnae linear, up to 33.3 by 2.1 cm, gradually narrowing towards long-acuminate apex, narrowing a little towards truncate base, lobed to ¼ way towards costa; segments oblong-subdeltoid, moderately acute at apex, entire; papyraceous to thinly chartaceous, firm, glabrous; veins pinnate, the lowest meeting with concurrent veinlets, lower several pairs uniting at long callous membrane below sinus. **Sori** strictly costular, round, usually confluent along costules at maturity; indusia brown, thin, small but persistent, hairy, glandular at margin. (Figure 4.16-4.18)

Thailand.— PENINSULAR: Yala.

Distribution.— Malesia (type from Java).

Ecology.— Terrestrial in forests along streams at 60 – 500 m alt.

Specimens examined.— Wallich 298 (type) [K]; E. Smith 2675 [K]; B. S. Parris 11069 [K]; M. Kato, K. Ueda and Z. Fanani C-13267 [K]; M. Kato, B. Sunarno, and H. Akiyama C-2986 [K]; M. Kato, K. Ueda, M. Okamoto, H. Akiyama B. Sunarno and U. W. Mahjar 6895 [K]; K. Iwatsuki, M. Kato, K. Ueda and U. W. Mahjar A-349 [K].

10. *Thelypteris flaccida* (Blume) Ching, Bull. Fan Mem. Inst. Biol. 6: 336. 1936; Tagawa et K. Iwats., Fl. Thail. 3(3): 399. 1988.— *Aspidium flaccidum* Blume, En. Pl. Jav.: 161. 1828.— *Lastrea flaccida* (Blume) Moore, Ind. Fil.: 92. 1858; Bedd., Handb.: 244. f. 125. 1883.— *Metathelypteris flaccida* (Blume) Ching, Acta Phytotax. Sin. 8: 306. 1963; Holttum in Fl. Mal. II. 1: 351.f.3, e-f. 1981.

Rhizome erect; scales narrow, thin and usually crisped, up to 5 by 0.8 mm, brown, hairy on dorsal surface and at margin. **Stipe** tufted, numerous, up to 19.5 cm

long, stramineous to pale castaneous, scaly on basal portion, hairy throughout. **Fron**d oblong-lanceolate, up to 46.8 by 13.42 cm; pinnae about 5 cm apart, falcate, basal one or two smaller, all sessile, middle larger ones lanceolate, acuminate at apex, up to 6.7 by 1.9 cm; costa hairy throughout, winged; pinnules patent, narrowly oblong, rounded at apex, decurrent at base towards the wings of costa, deeply lobed to $\frac{2}{3}$ way towards costule, up to 10 by 5 mm; lobes oblong to subdeltoid, moderately acute at apex, serrate; papyraceous, green; veins pinnate, veinlets usually forked, not reaching the very margin of lobes; hairs all unicellular, simple, patent or sometimes hooked on laminar surface. **Sori** dorsal on veinlets, medial; indusia caducous, small, pale brown, hairy. (Figure 4.19-4.21)

Thailand.— NORTH-EASTERN: Phetchabun.

Distribution.— Ceylon, India, SW. China N. Vietnam, and Java (type).

Ecology.— On half-shaded, humus-rich banks of new road at about 1200 m alt.; Only once collected from Phu Miang, Phetchaboon TAGAWA et al. 11698 (BKF, K, KYO).

Specimens examined.— Blume s.n. (type) [K]; R. E. Holttum 211 [K]; R. E. Holttum, U. Sen and Party T76, L4, L13 [K]; T. Shimizu, K. Iwatsuki, N. Fukuoka, M. Hutoh, D. Chaiglom and A. Nalampoon T.11698 [K]; V. S. Manicham and K. M. Matthew 34266 [K].

11. *Thelypteris hirsutipes* (C. B. Clarke) Ching, Bull. Fan Mem. Inst. Biol. 6: 314. 1936; Tagawa et K. Iwats., Fl. Thail. 3(3): 406. 1988.— *Lastrea hirsutipes* (C. B. Clarke) Bedd., Handb. Suppl.: 52. 1892.— *Coryphopteris hirsutipes* (C. B. Clarke) Holttum In Nayar & Kaur, Comp. Bedd., Handb.: 203. 1974; Blumea 23: 27. 1976; in Fl. Mal. II. 1: 359. f. 4, c. 1981.

Rhizome short-creeping, with close fronds; scales sparse, small, up to 2.01 by 0.51 mm, bright brown, hairy. **Stipe** stramineous to castaneous, dark and densely hairy at base; hairs pale, patent, up to 2 mm long, multicellular. **Fron**d oblong, acute at apex, up to 67 by 14.1 cm; lower one or two pinnae reflexed, middle pinnae sessile, patent, acute to acuminate at apex, up to 7.1 by 1.3 cm, deeply lobed nearly to costa; segments oblong, rounded to obtuse at apex, softly papyraceous, green, hairy; veins

pinnate, veinlets simple, all reaching the margin of segments, hairy as well as glandular. **Sori** medial or subcostular, large, up to 1 mm diam.; indusia round-reniform, persistent, hairy. (Figure 4.22)

T h a i l a n d.— NORTH-EASTERN: Loei; PENINSULAR: Nakhon Si Thammarat.

D i s t r i b u t i o n.— E. Himalaya (type) to SW. China and W. Malesia.

E c o l o g y.— On mountain slopes in evergreen forests at medium elevations, 1100 – 1600 m alt.

S p e c i m e n s e x a m i n e d.— K. Iwatsuki, H. Koyama, M. Hutoh and A. Chintayungkun T.14582 [K]; M. Tagawa, K. Iwatsuki and N. Fukuoka T.4791 [K].

12. *Thelypteris hirtisora* (C. Chr.) K. Iwats., J. Jap. Bot. 38: 314. 1963; Tagawa et K. Iwats., Fl. Thail. 3(3): 418. 1988.— *Dryopteris hirtisora* C. Chr., Contr. U.S. Nat. Herb. 26: 277, 330. 1931.— *Cyclosorus hirtisorus* (C. Chr.) Ching, Bull. Fan Mem. Inst. Biol. 8: 221. 1938.— *Cyclosorus validus* auct. non (H. Christ) Tardieu: Tardieu et C. Chr. in Fl. Gén. I.-C. 7(2): 398. 1941, p.p.— *Cyclosorus acuminatus* auct. non (Houtt.) Nakai ex H. Ito: Holttum, Dansk Bot. Ark. 20: 22. 1961.

Rhizome long-creeping, about 5.38 mm diam.; scales up to 8.81 by 1.43 mm, brown, hairy. **Stipe** 35.5 cm long, scaly at base, hirsute throughout. **Fronde** oblong or subrectangular with a long terminal pinna, up to 84.8 by 37 cm; lower pinnae hardly reduced, or lower one or two pairs slightly reduced and deflexed, larger pinnae patent to slightly ascending, about 11 pairs, nearly straightly, shortly stalked, linear, gradually narrowing to long-acuminate apex, round to broadly cuneate at base, up to 18.5 by 1.9 cm, lobed more than 1/3 way towards costa; segments subdeltoid, oblique, acute at apex; softly papyraceous, hirsute on surface, more than 2 pairs of lower veinlets truly anastomosing below callous-sinus. **Sori** medial, round; indusia rather small, hairy, persistent but usually under sporangia in matured sori; sporangia setose. (Figure 4.23-4.24)

T h a i l a n d .— NORTHERN: Chiang Rai, Chiang Mai, Tak; NORTH-EASTERN: Phetchabun, Loei; SOUTH-WESTERN: Kanchanaburi.

D i s t r i b u t i o n .— SW. China, Upper Myanmar (type) and Indochina.

E c o l o g y.— Terrestrial on rather dry slopes in light shade in natural forests, about 900-1000 m alt.

S p e c i m e n s e x a m i n e d.— P. Sornsuvan 013 [BCU]; A. Sathapattayanon 257, 327, 330 [BCU]; O. Vannasri 73 [BCU]; P. Ratchata 124 [BCU]; Y. Yuyen 203 [BCU]; H. Koyama 40129 [BKF]; T. Shimizu et al. 23673 [BKF]; S. Mitsuta et al 50378 [BKF]; J. F. Maxwell 91-206 [E]; E. Hennipman 3337 [K]; M. Tagawa, K. Iwatsuki, H. Koyama and A. Chintayungkun T.8587 [K]; T. Shimizu, K. Iwatsuki, N. Fukuoka and A. Chintayungkun T.11366 [K]; Th. Sorensen, K. Larsen and B. Hansen 1596 [K].

13. *Thelypteris interrupta* (Willd.) K. Iwats., J. Jap. Bot. 38: 314. 1963, nom. tant.; Tagawa et K. Iwats., Fl. Thail. 3(3): 400. 1988.— *Pteris interrupta* Willd., Phytogr. 1: 13. t. 10. 1794.— *Cyclosorus gongylodes* (Schkuhr) Link, Hort. Berol. 2: 128. 1833; Holttum, Rev. Fl. Malaya 2: 261. f. 148. 1955.— *Dryopteris gongylodes* (Schkuhr) O. Ktze., Rev. Gen. Pl. 2: 811. 1891.— *Cyclosorus interruptus* (Willd.) H. Ito, Bot. Mag. Tokyo 51: 714. 1937, nom. tant.; Holttum, in Fl. Mal. II. 1: 386. f. 1, r, 7, a-c.1981.— *Aspidium goggilodus* Schkuhr, Kr. Gew. 1: 193. t. 33 C. 1809.— *Thelypteris goggilodus* (Schkuhr) Small, Ferns SE. States: 248, 475. 1938.

Rhizome long-creeping, up to 4 mm diam., usually dark and naked; scales caducous, subdeltoid, pale brown, thin, up to 17.37 by 0.94 mm, glabrous. **Stipe** up to 77.2 cm long, stramineous with dark base, glabrous. **Fronde** oblong-lanceolate, acute at apex, basal pinnae hardly reduced, up to 136 by 90.2 cm; middle larger pinnae sessile, linear-lanceolate, gradually narrowing towards acute apex, rounded at base, up to 15.1 by 1.2 cm, lobed to ¼ way towards costa; costa hairy, bearing scales sparsely; segments oblong- subdeltoid with aciculate apex; papyraceous to thinly chartaceous, pubescent on under surface; veins pinnate, usually 1.5 pairs of basal veinlets uniting with those of the adjacent groups, hairy as well as glandular. **Sori** confined to segments, usually confluent at maturity; indusia hairy, caducous. (Figure 4.25-4.26)

T h a i l a n d.— NORTHERN: Phayao, Lampang; CENTRAL: Krung Thep; SOUTH-WESTERN: Prachuap Khiri Khan; PENINSULAR: Surat Thani, Nakhon Si Thammarat, Phatthalung, Songkhla, Krabi, Phuket, Yala.

D i s t r i b u t i o n.— Pantropic (type from India).

E c o l o g y.— On grassy banks along streams or in open marshy places at low altitudes.

V e r n a c u l a r.— Kut yang, kut mon (Northern); phak kut chang (South-eastern).

S p e c i m e n s e x a m i n e d.— P. Sornsuvan 036 [BCU]; Ch. Charoenphol, K. Larsen and E. Warncke 4559, 5042 [E]; H. T. 301 (type) [K]; E. Smith 1854 [K]; H. Kunstler 126 [K].

14. *Thelypteris larutensis* (Bedd.) Tagawa & K. Iwats., Acta Phytotax. Geobot. 23: 53. 1968; Tagawa et K. Iwats., Fl. Thail. 3(3): 417. 1988.— *Nephrodium larutense* Bedd., Handb. Suppl.: 73. 1892.— *Sphaerostephanos larutensis* (Bedd.) C. Chr., Ind. Fil. Suppl. 33: 172. 1934; Holttum in Fl. Mal. II. 1: 489. f. 12 d-e. 1981.— *Cyclosorus larutense* (Bedd.) Ching, Bull. Fan Mem. Inst. Biol. 10: 245. 1941; Holttum, Rev. Fl. Malaya 2: 284. f. 165. 1955.

Rhizome short; scales narrow, up to 7.87 by 0.97 mm, hairy. **Stipe** up to 11.7 cm long, hairy throughout, scaly near base, bearing reduced pinnae. **Fronde** oblong-lanceolate, with a distinct terminal pinna; middle lateral pinnae narrowly lanceolate, gradually narrowing towards long-acuminate apex, subtruncate to broadly cuneate at sessile base, up to 14.6 by 2.2 cm, lobed to ¼ way towards costa; segments oblique, round to obtuse at apex, papyraceous, pubescent on both surfaces; rachis and costa hairy, hairs setose, multicellular; veins pinnate, veinlets 38 pairs, several basal pairs uniting to form a long excurrent vein, hairy, glandular on under surface; veins in several pairs and all anastomosing, free excurrent veins rare, the lateral secondary veins unite regularly in pairs to form a series of angular areoles with an excurrent tertiary veinlet pointing away from the midrib; lower surface pustular, variously hairy, uppersurface has hairs on the costa only. **Sori** medial, oblong, hardly confluent at maturity; indusia oblong, persistent, up to 1.7 by 0.7 mm, bearing round, red, sessile glands and setose hairs; sporangium stalk with glandular hairs, no acicular hairs

present on the wall of the capsule, annulus quite conspicuous of 14 cells; spores monolet, bilateral. (Figure 4.27-4.29)

T h a i l a n d.— PENINSULAR: Yala.

D i s t r i b u t i o n.— Malaya (type) and Borneo.

E c o l o g y.— In shade at low altitudes.

S p e c i m e n s e x a m i n e d.— King 2398 (type) [K]; A. G. Piggott 2954, 2961 [K]; R. E. Holttum s.n. [K].

15. *Thelypteris megaphylla* (Mett.) K. Iwats., Mem. Coll. Sci. Univ. Kyoto B. 31: 34. 1964; Tagawa et K. Iwats., Fl. Thail. 3(3): 417. 1988.— *Aspidium megaphyllum* Mett., Ann. Mus. Lugd. Bat. 1: 233. 1864.— *Cyclosorus megaphyllus* (Mett.) Ching, Bull. Fan Mem. Inst. Biol. 8: 225. 1938; Holttum, Rev. Fl. Malaya 2: 268. f. 154. 1955.— *Cyclosorus euphlebius* auct. non Ching; Holttum, Dansk Bot. Ark. 23: 232. 1965.— *Sphaerostephanos penniger* (Hook.) Holttum in Nayar & Kaur, Comp. Bedd.: 209. 1974; in Fl. Mal. II. 1: 461. f. 1 a-h. 1981.— *Nephrodium pennigerum* Hook., Spec. Fil. 4 : 82, t. 24B. 1862.

Rhizome short, massive; scales linear-lanceolate with long tails, about 10.86 by 0.78 mm, dark brown, hairy at margin as well as on dorsal surface. **Stipe** stramineous, hairy throughout, bearing small reduced pinnae on upper portion, about 11.58 cm long. **Fron**d up to 168.8 by 60 cm; rachis densely setose hairy; lower pinnae suddenly reduced to form butterfly-shaped auricles, middle pinnae larger, ascending, linear-lanceolate, widest at middle portion, rather suddenly narrowing towards acute apex, narrowing towards base, cuneate to subtruncate at basiscopic and truncate to auricles at acroscopic bases, sessile, up to 29.1 by 3.8 cm, lobed to $\frac{1}{4}$ way towards costa; segments oblong-subdeltoid, oblique, round to moderately acute at apex, entire; papyraceous to chartaceous, green, covered with round yellow glands on both surfaces; veins pinnate, veinlets, several lower pairs anastomosing, pubescent. **Sori** medial; indusia round reniform to horse-shoe-shaped, sometimes confluent, pubescent. (Figure 4.30)

T h a i l a n d.— SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Nakhon Si Thammarat, Trang, Yala.

D i s t r i b u t i o n.— Malesia (type from Java).

E c o l o g y.— On moist slopes in dense evergreen forests at low altitudes.

S p e c i m e n s e x a m i n e d.— P. Sornsuan 031, 032 [BCU]; Blume s.n. (type) [K]; E. Smith 1864, 683 [K]; G. H. Addison 37172 [K]; K. Iwatsuki, G. Murata, J. Dransfield and D. Saerudin S.722 [K].

16. *Thelypteris nudata* (Roxb.) Morton, Contr. U.S. Nat. Herb. 38: 352. 1974; Tagawa et K. Iwats., Fl. Thail. 3(3): 411. 1988.— *Polypodium nudatum* Roxb., Calc. J. Nat. Hist. 4: 491. 1844.— *Polypodium multilineatum* Wall. ex Hook., Sp. Fil. 5: 11. 1863.— *Goniopteris multilineata* (Wall.) Bedd., Ferns Br. India t. 231. 1867.— *Nephrodium moulmeinense* Bedd., Ferns Br. Ind. Suppl.: 18. 1876.— *Nephrodium multilineatum* (Wall. ex Hook.) Bedd., Handb. Suppl.: 80. 1892.— *Dryopteris moulmeinense* (Bedd.) C. Chr., Ind. Fil.: 278. 1905.— *Abacopteris multilineata* (Wall. ex Hook.) Ching, Bull. Fan Mem. Inst. Biol. 8: 253. 1938; Holttum, Rev. Fl. Malaya 2: 297. 1955.— *Cyclosorus multilineatus* (Wall. ex Hook.) Tardieu et C. Chr. in Fl. Gén. I.-C. 7(2): 358. 1941.— *Thelypteris multilineata* (Wall. ex Hook.) Morton, Amer. Fern J. 49: 113. 1959.— *Dryopteris urophyllum* auct. non (Mett.) C. Chr.: Bonap., Not. Pterid. 14: 49. 1923.— *Nephrodium urophyllum* auct. non (Mett.) Keys.: Smith, E. J. Siam Soc. Nat. Hist. Suppl. 8: 5. 1929.— *Pronephium nudatum* (Roxb.) Holttum, Blumea 20: 111. 1972.

Rhizome creeping, about 5 mm diam., rhizome surface bears papillate, capped hairs mixed with the acicular ones, the acicular hairs have transverse septum near the base, beside these, glandular hairs with a short slender stalk and having a thin-walled, balloon-shaped terminal cell are borne on the rhizome surface, some of the glandular hairs branched and each branch terminating in a globular cell; scales caducous, dark brown, ovate-lanceolate, terminated by a glandular cell which is balloon-like; hairy. **Stipe** firm erect, slightly swollen and scaly at base, fortherest glabrous, about 71.4 cm long, bears sparse, unicellular acicular hairs on the surface. **Fronde** oblong, up to 220.2 by 57 cm; lateral pinnae lanceolate, sessile, ascending, gradually narrowing towards long-acuminate apex, rounded to narrowly cuneate at base, subentire or crenate, 10-12

pais, up to 28.5 by 4.5 cm; terminal pinna like lateral ones, rounded to subtruncate at base; marginal lobes acute at apex, with cartilaginous margin; chartaceous, green, verrucose on lower surface; venation meniscioid. **Sori** rather close to excurrent veinlets or medial in two rows between costules; indusia setose. (Figure 4.29-4.30)

T h a i l a n d.— NORTHERN: Chiang Rai, Chiang Mai, Mae Hong Son, Lampang, Tak, Nan, Phitsanulok, Phrae; CENTRAL: Nakhon Nayok; SOUTH-EASTERN: Chanthaburi, Trat; SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Surat Thani, Nakhon Si Thammarat, Phangnga, Yala.

D i s t r i b u t i o n.— Himalaya (type), Myanmar, China and N. Vietnam.

E c o l o g y.— Terrestrial on rather dry ground near stream in light shade in remnants of the forest in mine area, about 600-900 m alt.

V e r n a c u l a r.— Kut daeng (South-eastern).

S p e c i m e n s e x a m i n e d.— P. Sornsuwan 005 [BCU]; A. Sathapattayanon 043, 102, 113, 116 [BCU]; P. Ratchata 20 [BCU]; T. Boonkerd 502, 743, 762 [BCU]; J. F. Maxwell 97-417 [BKF]; K. Iwatsuki et al 7320 [BKF]; Winit 996 [BKF]; J. F. Maxwell 92-181 [E]; A. F. G. Kerr. 10339 [K]; B. Hansen, G. Seidenfaden and T. Smitinand 11331 [K]; Th Sorensen, K. Larsen and B. Hansen 2949 [K].

17. *Thelypteris polycarpa* (Blume) K. Iwats., Mem. Coll. Sci. Univ. Kyoto B. 31: 32. 1964; Tagawa et K. Iwats., Fl. Thail. 3(3): 416. 1988.— *Aspidium polycarpum* Blume, Pl. Jav.: 156. 1828.— *Nephrodium polycarpum* (Blume) Keys., Pol. Cyath. Hb. Bung.: 7. 1873.— *Cyclosorus polycarpus* (Blume) Holttum, Rev. Fl. Malaya 2: 283. f. 164. 1955.— *Mesochlaena polycarpa* (Blume) Bedd., Ferns Br. Ind. Suppl.: 13. 1876.— *Sphaerostephanos polycarpus* (Blume) Copel., Univ. Calif. Publ. Bot. 16: 60. 1929; Holttum, Blumea 19: 40. 1971; Kalikasan 4: 56. 1975; in Fl. Mal. II. 1: 448. f. 12 a-c. 1981.

Rhizome massive, erect; scales narrow, up to 12.81 by 1.33 mm, hairy at margin as well as on dorsal surface, concolorous brown. **Stipe** about 19.6 cm long, 2 cm diam., hairy, bearing reduced pinnae nearly to base. **Fronde** about 219.6 by 58.5 cm, oblong-lanceolate; lower pinnae suddenly reduced to butterfly-like projections and to mere auricles, middle pinnae nearly straight, ascending or patent, linear, up to

29.3 by 1.8 cm, lobed to a half-way toward costa; segments oblong, oblique, rounded at apex, entire; chartaceous, green; rachis and costa pubescent; veins pinnate, main veins 63 pairs, veinlets simple, lower 2.5 pairs usually uniting below sinus, hirsute on both surfaces, ending in hydathodes just inside the margin. **Sori** medial, elongate along veinlets, up to 1.5 by 0.2 mm, confluent at maturity; indusia oblong, dark, hairy. (Figure 4.33-4.35)

T h a i l a n d.— SOUTH-EASTERN: Chanthaburi; PENINSULAR: Surat Thani, Phangnga, Nakhon Si Thammarat, Trang, Satun, Narathiwat, Yala.

D i s t r i b u t i o n.— Malesia (type from Java).

E c o l o g y.— On rather dry ground by paths in open places at low altitudes.

S p e c i m e n s e x a m i n e d.— P. Sornsuvan 002; [BCU]; Ch. Charoenphol, K. Larsen and E. Warncke 3477 [E]; Unknown s.n. (type) [K]; E. Smith 1866, 1840 [K]; T. Boonkerd 1170 [K].

18. *Thelypteris repanda* (Fee) Tagawa & K. Iwats., Acta Phytotax. Geobot. 26: 170. 1975; Tagawa et K. Iwats., Fl. Thail. 3(3): 413. 1988.— *Polypodium urophyllum* Wall. List n. 299. 1823.— *Goniopteris repanda* Fee, Gen. Fil.: 251. 1852.— *Phegopteris urophylla* Mett., Pheg. Aspid.: 26. 1858.— *Polypodium urophyllum* (Mett.) Wall. ex Hook., Sp. Fil. 5: 9.1863.— *Nephrodium urophyllum* (Mett.) Keys., Pol. Cyath. Hb. Bung.: 49. 1873.— *Cyclosorus urophyllus* (Mett.) Trad. ex Trad. & C. Chr., Not. Syst. 7: 77. 1938.— *Abacopteris urophylla* (Mett.) Ching, Bull. Fan Mem. Inst. Biol. 8: 251. 1938; Holttum, Rev. Fl. Malaya 2: 296. f. 172. 1955.— *Thelypteris urophylla* (Mett.) K. Iwats. in Tagawa & K. Iwats., Southeast As. St. 3(3): 81. 1965.— *Pronephrium repandum* (Fee) Holttum, Blumea 20: 108. 1972; in Fl. Mal. II. 1: 353. f. 1 n, 16 i-j. 1981.

Rhizome creeping, about 1 cm diam.; scales narrow, up to 5.92 by 1.25 mm, dark brown to blackish, hairy at margin as well as on dorsal surface. **Stipe** closely arranged, tufted, stout erect mainly glabrescent, smooth, to 79.1 cm long, brownish with dark scaly at base; scales lanceolate, linear, brown. **Lamina** oblong to obovate, to about 133.6 cm long having 5 pairs of lateral pinnae an apical pinnae; lateral pinnae situated at a distance of 4-7 cm from each other, upper sessile where as the lowest

shortly stalked; pinnae to 25.3 cm long, 4.4 cm wide, basal pinnae sometimes reduced, lower ones shortly stalked, oblong-lanceolate, cuspidate at apex, cuneate at base, up to 24.6 by 3.96 cm, irregularly undulate at margin; terminal pinna longer, broader; texture thin but firm, drying greenish or brownish-green; the upper surface finely verrucose, glabrous, the lower surface copiously hairy, hairs short erect; rachis, costae and costules copiously hairy below with quite short spreading hairs; papyraceous, firm, yellowish-green to green, verrucose; venation meniscioid, vein several pairs all anastomosing with veins of adjacent groups excepting the three terminal veins on the basioscopic side of a costule, which pass to the free cartilaginous edge of the lamina; excurrent vein-lets free, or joining with the next pair of veins above. **Sori** in two medial to subcostular rows, exindusiate; sporangia with several setose hairs. (Figure 4.36-4.38)

T h a i l a n d.— SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Chumphon, Surat Thani, Phuket, Nakhon Si Thammarat, Trang, Satun, Yala.

D i s t r i b u t i o n.— Burma, N. Vietnam, Malaya (type), Sumatra, Borneo (var. *nitida*), W. Java, Celebes (var. *nitida*) and Philippines (var. *nitida*).

E c o l o g y.— On humus-rich mountain slopes in dense evergreen forests at low to medium altitudes.

S p e c i m e n s e x a m i n e d.— K. Lukchant 18 [BCU]; H. T. 299 (type) [K]; E. Smith 2473, 3003 [K]; P. L. 129 [K].

19. *Thelypteris siamensis* Tagawa & K. Iwats., Acta Phytotax. Geobot. 22: 101. f. 5. 1967; Tagawa et K. Iwats., Fl. Thail. 3(3): 426. 1988.— *Christella siamensis* (Tagawa & K. Iwats.) Holttum, Kew Bull. 31: 332. 1976.

Rhizome erect; scales linear-lanceolate with long tails, about 6.80 by 0.86 mm, sparsely hairy at margin. **Stipe** densely scaly at base, hirsute throughout, up to 34 cm long. **Fronde** oblong-lanceolate, acute at apex, up to 79.9 by 20 cm; a few lower pinnae slightly reduced, deflexed, auricled at acroscopic base, middle larger ones falcate, sessile, linear-lanceolate, long-acuminate at apex, broadly cuneate to truncate at base, up to 10 by 1.2 cm, lobed to $\frac{2}{3}$ way to costa; segments oblong, oblique, rounded to moderately acute at apex, entire, papyraceous, hairy on surface; basal veinlets uniting

to form goniopteroid venation. **Sori** medial to supramedial; indusia round-reniform, persistent, densely hirsute. (Figure 4.39-4.41)

T h a i l a n d.— NORTH-EASTERN: Phetchabun, Loei (Phu Luang, type).

D i s t r i b u t i o n.— Endemic.

E c o l o g y.— On humus-rich mountain slopes in evergreen forests at 1200 – 1400 m alt.

S p e c i m e n s e x a m i n e d.— P. Sornsuwan 037 [BCU]; P. Ratchata 277 [BCU]; J. F. Maxwell 90-161 [E]; E. Smith 2724, 2726 [K]; T. Shimizu, K. Iwatsuki, N. Fukuoka, M. Hutoh, D. Chaiglom and A. Nalampoon T.11373, T.11399 [K]; T. Smitinand 6000, 6002 [K].

20. *Thelypteris singalanensis* (Baker) Ching, Bull. Fan Mem. Inst Biol. 6: 334. 1936; Tardieu et C. Chr. in Fl. Gén. I.-C. 7(2): 365. 1941; Holttum, Rev. Fl. Malaya 2: 243. f. 138. 1955; Tagawa et K. Iwats., Fl. Thail. 3(3): 399. 1988.— *Nephrodium singalanense* Baker, J. Bot. 18: 212. 1880.— *Lastrea singalanense* (Baker) Bedd., Handb. Suppl.: 54. 1892.— *Dryopteris singalanense* (Baker) C. Chr., Ind. Fil. 293. 1905.— *Metathelypteris singalanensis* (Baker) Ching var. *singalanensis*, Acta Phytotax. Sinica 8: 306. 1963; Holttum in Fl. Mal. II. 1: 352. f. 3, g. 1981.

Rhizome short, erect; scales very sparse, linear, up to 7.68 by 1.94 mm, dark brown. **Stipe** stramineous, up to 48.7 cm long, scaly and hairy at base when young, glabrescent upwards. **Fronde** about 97.1 by 17.8 cm; pinnae sessile, linear-lanceolate, caudate-acuminate at apex, up to 8.9 by 1.8 cm; lower surface of rachis, costae, costules and veins bearing copious very short capitate hairs, some capitate hairs also on surface between veins; pinnules narrowly oblong, patent to falcate, entire, rounded to moderately acute at apex; softly papyraceous to papyraceous, green; veins pinnate, veinlets simple, forked, or triforked, glabrous. **Sori** dorsal on veinlets, in a medial row between costules and margin of pinnules; indusia thin, glabrous. (Figure 4.42-4.43)

T h a i l a n d.— NORTHERN: Phitsanulok; SOUTH-WESTERN: Kanchanaburi; PENINSULAR: Nakhon Si Thammarat.

D i s t r i b u t i o n.— Vietnam, Malesia, Sumatra (type), Borneo and W. Java.

E c o l o g y.— Terrestrial on wet mountain slopes in light shade in remnant of the forest in mine area, at 890 m alt.

S p e c i m e n s e x a m i n e d.— A. Sathapattayanon 097 [BCU]; M. Tagawa, K. Iwatski and N. Fukuoka 2019 [BKF]; E. Smith 903 [BKF]; H. Koyama et al. 33231 [BKF]; J. Sinclair 6004 [E]; P. T. O. MA 37 [K].

21. *Thelypteris sumatrana* (v.A.v.Ros.) K. Iwats., Acta Phytotax. Geobot. 22: 101. 1976; Tagawa et K. Iwats., Fl. Thail. 3(3): 429. 1988.— *Dryopteris sumatrana* v.A.v.Ros., Handb.: 227. 1908.— *Cyclosorus sumatranus* (v.A.v.Ros.) Ching, Bull. Fan Mem. Inst. Biol. 10: 249. 1941; Holttum, Rev. Fl. Malaya 2: 275. f. 158. 1955.— *Pseudophegoteris sumatrana* Holttum, Blumea 17: 22. 1969.

Rhizome erect; **Stipe** 43.5 cm long, reddish. **Fronde** 115.8 cm long; lower pinnae distinctly reduced; largest pinnae 30.3 cm long; pinnules on basiscopic side longer than on acroscopic; largest pinnules 7.5×1.7 cm acuminate, partly adnate at base to pinna-rachis, lobed $\frac{3}{4}$ towards costae, lobes subentire with rounded apices, costules 3-6 mm apart, veins mostly forked; lower surface of rachis, costae and costules glabrous. **Sori** above the fork on a vein, sometimes on both branches, almost globose; sporangia not setiferous. (Figure 4.44-4.45)

T h a i l a n d.— CENTRAL: Saraburi; SOUTH-WESTERN: Kanchanaburi, Prachin Buri; PENINSULAR: Surat Thani, Chumphon, Nakhon Si Thammarat, Satun.

D i s t r i b u t i o n.— Indochina to W. Malesia, (type from Sumatra).

E c o l o g y.— Open place by small stream.

S p e c i m e n s e x a m i n e d.— R. E. Holttum 26211 (type) [K]; B. S. Parris and J. P. Croxall 8211 [K].

22. *Thelypteris terminans* (Hook.) Tagawa & K. Iwats., Acta Phytotax. Geobot. 26: 169. 1975. Tagawa et K. Iwats., Fl. Thail. 3(3): 432. 1988.— *Nephrodium terminans* Hook., Sp. Fil. 4: 73. 1862.— *Amphineuron terminans* (Hook.) Holttum, Amer. Fern J. 63: 82. 1973; Blumea 23: 207. 1977; in Fl. Mal. II. 1: 545. f. 19 a. 1981.— *Nephrodium pteroides* auct. non (Retz.) J. Smith: Bedd., Handb.: 269. 1883.—

Dryopteris pteroides auct. non (Retz.) O. Ktze.: C. Chr., Contr. U.S. Nat. Herb. 26: 184. 1931.— *Cyclosorus interruptus* auct. non (Willd.) H. Ito: Ching, Bull. Fan Mem. Inst. Biol. 8: 184. 1938; Holttum, Rev. Fl. Malaya 2: 262. f. 149. 1955.— *Thelypteris interrupta* auct. non (Willd.) K. Iwats.: Tagawa & K. Iwats., Southeast As. St. 3(3): 79. 1965.— *Cyclosorus extensus* extensus auct. non (Blume) Ching: Holttum, Dansk Bot. Ark. 20: 23. 1961.

Rhizome long-creeping, about 1 cm diam.; scales narrow, brown, up to 6.44 by 0.77 mm, hairy. **Stipe** 62.9 cm long, stramineous with dark scaly base, pubescent. **Fron**d oblong-lanceolate, acute at apex, 129 by about 529 cm; lateral pinnae 15 pairs, basal pinnae not or little reduced, patent to ascending, lower ones linear, straight, gradually narrowing towards long-acuminate apex, cuneate and shortly stalked at base, up to 20.3 by 1.8 cm, lobed to half-way to costa; segments oblong, oblique, round to moderately acute at apex; entire, papyraceous, green; veins pinnate, veinlets simple, hairy, basal 1-1.5 pairs uniting with those of the next group below sinus. **Sori** confined to upper part of segments, often hollowed; indusia persistent, hairy. (Figure 4.46-4.47)

Thailand.— Common all over the country.

Distribution.— Tropics of Asia (type from Burma) to Australia (Queensland).

Ecology.— Common on rather dry mountain slopes in forests at low or medium altitudes up to 1200 m alt.

Specimens examined.— P. Sornsuvan 007, 008, 009; [BCU]; E. Smith 962, 3006 [K].

23. *Thelypteris torresiana* (Gaud.) Alston, Lilloa 30: 111. 1960; K. Iwats., J. Jap. Bot. 38: 314. 1963; Tagawa et K. Iwats., Fl. Thail. 3(3): 398. 1988.— *Polystichum torresianum* Gaud. in Freyc., Voy. Bot.: 333. 1817.— *Macrothelypteris torresiana* (Gaud.) Ching, Acta Phytotax. Sin. 8: 310. 1963; Holttum, Blumea 17: 27. 1969; in Fl. Mal. II. 1: 348. f. 2, h-j. 1981; Kuo, Fl. Taiwan Vol. 1. 2nd ed.: 417. 1980.— *Aspidium setigerum* auct. non (Blume) Kuhn: Christ, Bot. Tidsskr. 24: 108. 1901; C. Chr., Bot. Tidsskr. 32: 342. 1916.

Rhizome suberect; scales narrow, brown, up to 9.8 by 0.79 cm, hairy on dorsal surface as well as margin, the base often a few cells thick. **Stipe** up to 42.8 cm long, about 1 cm diam. near base, sometimes spinose in lower part. **Fron**d oblong to oblong-ovate, tripinnate, up to 102.6 by 40 cm; pinnae oblong, acuminate at apex, up to 19.5 by 7.42 cm; ultimate segments oblong, oblique, rounded to moderately acute at apex, lobed to $\frac{3}{4}$ way towards midrib; lobes oblong to subdeltoid, entire, sometimes involute; rachis terete, glabrous; pinna-rachis hairy on upper surface, costules winged throughout, hairy; veins and surfaces hairy with unicellular or multicellular hair; texture herbaceous to softly papyraceous, green but often brownish when dried. **Sori** round, usually close to midrib of ultimate segments; indusia small, often covered by mature sporangia, round-reniform, hairy. (Figure 4.48-4.49)

T h a i l a n d.— **NORTHERN:** Chiang Rai, Chiang Mai, Lampang, Lamphum, Tak; **CENTRAL:** Nakhon Nayok; **SOUTH-EASTERN:** Trat; **SOUTH-WESTERN:** Kanchanaburi; **PENINSULAR:** Chumphon, Surat Thani, Nakhom Si Thammarat, Satun, Yala.

D i s t r i b u t i o n.— Mascarene Islands, throughout tropical Asia (type from Mariana Islands), Polynesia, Hawaii, north to Japan and south to Australia; also naturalized in the New World.

E c o l o g y.— On sunny slopes along roads at edge of forests at low to medium altitudes.

S p e c i m e n s e x a m i n e d.— P. Sornsuan 003, 004 [BCU]; P. Ratchata 237 [BCU]; Y. Yuyen 14 [BCU]; Cuming 1 (type) [K]; E. Smith 1107 [K].

23. *Thelypteris truncata* (Poir.) K. Iwats., Coll. Sci. Univ. Kyoto B. 31: 33. 1964; Tagawa et K. Iwats., Fl. Thail. 3(3): 420. 1988.— *Polypodium truncatum* Poir. In Lamk., Enc. 5: 534. 1804.— *Nephrodium truncatum* (Poir.) Presl, Tent. Pterid.: 81. 1836.— *Cyclosorus truncatus* (Poir.) Tard. ex Tard. & C. Chr., Notul. Syst. 7: 78. 1938; Holttum, Rev. Fl. Malaya 2: 266. f. 152. 1955.— *Pneumatopteris truncata* (Poir.) Holttum, Blumea 21: 314. 1973; in Fl. Mal. II. 1: 429. f. 11 d-f. 1981; Kuo, Fl. Taiwan Vol. 1. 2nd ed.: 455. 1980.

Rhizome erect; scales brown, thin, up to 3.3 by 0.93 mm, consisting of large cells, hairy. **Stipe** up to 7.71 cm long, pale, dark and scaly at base, pubescent, bearing

reduced pinnae in upper part. **Fron**d oblong-lanceolate, up to 153.4 cm or more long, 48.9 cm wide; lower pinnae suddenly reduced to mere auricles, middle pinnae larger, straight, ascending, up to 24.5 by 2.0 cm, lobed to $\frac{1}{3}$ way towards costa, gradually narrowing towards long-acuminate apex, broadly cuneate at sessile base, nearly parallel at margin; segments obtuse at apex, minutely dentate; papyraceous, green, verrucose on lower surface, glabrous; veins pinnate, a few pairs of basal veinlets anastomosing, free ones ending in teeth at margin of segments. **Sori** medial; indusia pale, glabrous, persistent. (Figure 4.50-4.52)

T h a i l a n d.— **NORTHERN:** Chiang Rai, Chiang Mai, Mae Hong Son, Lamphun, Tak, Phrae, Phitsanulok; **NORTH-EASTERN:** Loei; **SOUTH-EASTERN:** Chanthaburi; **PENINSULAR:** Krabi, Surat, Thani, Nakhon Si Thammarat, Trang, Yala.

D i s t r i b u t i o n.— Sri Lanka, S. India, Himalaya to S. China, Burma, Indochina, Ryukyu Is., Taiwan, W. Malesia to Philippines. Sometimes all the local species are considered to be conspecific with this, and the area is then widely extended. Type was said to come from Brasil, but it is considered to be a specimen from Asia.

E c o l o g y.— On wet ground usually along streams in light or deep shade at low to medium altitudes up to 1500 m alt.

V e r n a c u l a r.— Kut kan daeng (Northern).

S p e c i m e n s e x a m i n e d.— P. Sornsuan 040 [BCU]; P. Ratchata 8, 133, 138, 218 [BCU]; Y. Yuyen 101 [BCU]; Blume s.n. (type) [K]; E. Smith 3044 [K]; M. Tagawa, K. Iwatsuki, H. Koyama and A. Chintayungkun T.860 [K].

25. *Thelypteris viscosa* (Baker) Ching, Bull. Fan Mem. Inst. Biol. 6: 315. 1936; Holttum, Rev. Fl. Malaya 2: 252. 1955; Tagawa et K. Iwats., Fl. Thail. 3(3): 404. 1988.— *Nephrodium viscosum* Baker, Syn. Fil.: 264. 1867.— *Lastrea viscosa* (Baker) J. Smith ex Bedd., Ferns Br. Ind.: t. 334. 1870.— *Nephrodium gymnopoda* Baker, Trans. Linn. Soc. II. Bot. 4: 252. 1894.— *Coryphopteris viscosa* (Baker) Holttum, Blumea 19: 33. 1971.— *Coryphopteris gymnopoda* (Baker) Holttum, Blumea 23: 29. 1976; in Fl. Mal. II. 1: 360. 1981.

Rhizome erect, often more than 10 cm tall above ground; scales linear-lanceolate, up to 3.05 by 0.38 mm, brown with irregularly toothed paler margin. **Stipe** dark brown to castaneous, pubescent, scaly on lower portion, up to 13.4 cm long. **Fron**d narrowly oblong, acute at apex, up to 46.28 by 10.2 cm; lower pinnae deflexed, middle pinnae patent or ascending, nearly straight, sessile, lanceolate, acute at apex, truncate at base, up to 5.1 by 0.99 cm, deeply lobed nearly to costa; costa brown, hairy throughout; segments oblong, patent to oblique or falcate, rounded at apex, crenate at margin, up to 10 by 4 mm; papyraceous, deep green in living plants, brownish when dry; veins pinnate, veinlets simple, hairy. **Sori** medial; indusia round-reniform or horse-shoe-shaped, or sometimes elongate to form athyroid sori, glandular. (Figure 4.53-4.55)

Thailand.— PENINSULAR: Surat Thani, Nakhon Si Thammarat.

Distribution.— Malesia (type), Sumatra, Borneo and Philippines.

Ecology.— On clayey ridge in dense evergreen forests at about 1100–750 m alt., near summit of mountains.

Specimens examined.— Cuming 401 (type) [K]; A. G. Piggott 1897 [K]; C. G. Atthew s.n. [K].

26. *Thelypteris xylodes* (Kunze) Ching, Bull. Fan Mem. Inst. Biol. 6: 296. 1936; Tagawa et K. Iwats., Fl. Thail. 3(3): 421. 1988.— *Aspidium xylodes* Kuntze, Linnaea 24: 283. 1851.— *Pseudocyclosorus xylodes* (Kunze) Ching, Acta Phytotax. Sin. 8: 324 1963; Holttum, in Fl. Mal. II.1: 413. f. 10 d–e. 1981.

Rhizome short, ascending to suberect; scales small, caducous, up to 2.61 by 0.77 mm, brown, hairy. **Stipe** up to 3.4 cm long, variable in size, bearing auricles of reduced pinnae nearly to the base. **Fron**d oblong-lanceolate, acute to acuminate at apex, 79.5 by 23.6 cm, variable in size; lower pinnae suddenly reduced to auricles, lowest normal pinna often reduced and deflexed, middle pinnae linear-lanceolate, gradually narrowing towards long-acuminate apex, broadly cuneate at sessile base, deeply lobed to $\frac{3}{4}$ way to costa; segments narrowly oblong, oblique, acute at apex, entire or crenate; chartaceous, deep green; veins pinnate, veinlets simple, basal ones

running to callous-membrane in sinus between segments. **Sori** round, medial to costular; indusia persistent, glabrous. (Figure 4.56-4.58)

T h a i l a n d .— NORTHERN: Chiang Rai, Chiang Mai, Phitsanulok.

D i s t r i b u t i o n .— Sri Lanka, S. India (type), Himalaya, S. & SW. China and Vietnam.

E c o l o g y .— On wet sandy ground or stream-beds in light shade at medium altitudes.

S p e c i m e n s e x a m i n e d .— P. Sornsuwan 041 [BCU]; Unknown s.n. (type) [K]; P.W. Mackinon. s.n. [K].

27. *Thelypteris* sp.

Rhizome short, erect; scales up to 3 by 1.5 mm, membranous, appressed, brown, hairy. **Stipe** stramineous to greyish, hairy throughout, about 25.4 cm long. **Fron**d oblong-lanceolate, acute at apex, 42.8 by 8 cm; lowest pinnae shortened, deflexed, pinnae of lower 1/3 largest, patent, sessile, linear-lanceolate, caudately acuminate at apex, broadly cuneate at base, often auricled; rachis and costa densely hirsute; segments falcate, oblique, rounded at apex, subentire, hairy at margin; chartaceous or thicker, deep green; veins pinnate, veinlets simple, basal anterior ones running to sinus, hairy. **Sori** subcostular, often confluent at maturity; indusia hairy. (Figure 4.59-4.61)

T h a i l a n d .— PENINSULAR: Nakhon Si Thammarat.

E c o l o g y .— Terrestrial on wet mountain slopes in light shade in remnant of the forest in mine area, at 890 m alt.

S p e c i m e n s e x a m i n e d .— P. Sornsuwan 016, 017, 018, 019, 020, 021, 022, 023, 024, 025, 026 [BCU].



Fig.4.1 *Meniscium proliferum* (Retz.) Sw.
- habitat



Fig.4.2 *Meniscium proliferum* (Retz.) Sw.



Fig.4.3 *Thelypteris arida* (D.Don) Morton
- habitat



Fig.4.4 *Thelypteris ciliata* (Wall. ex Benth.)
Ching - habitat



Fig.4.5 *Thelypteris ciliata* (Wall. ex Benth.)
Ching - sori



Fig.4.6 *Thelypteris confluens* (Thunb.) C.V.
Morton



Fig.4.7 *Thelypteris crassifolia* (Blume) Ching



Fig.4.8 *Thelypteris crassifolia* (Blume) Ching
- rhizome



Fig.4.9 *Thelypteris crassifolia* (Blume) Ching
- sori



Fig.4.10 *Thelypteris crinipes* (Hook.) K. Iwats.
- habitat



Fig.4.11 *Thelypteris crinipes* (Hook.) K. Iwats.
- sori



Fig.4.12 *Thelypteris dentata* (Forssk.)
St. John - habitat



Fig.4.13 *Thelypteris dentata* (Forssk.)
St. John - sori



Fig.4.14 *Thelypteris falciloba* (Hook.) Ching - habitat



Fig.4.15 *Thelypteris falciloba* (Hook.) Ching - sori



Fig.4.16 *Thelypteris ferox* (Blume) Tagawa & K. Iwats. - frond, rhizome



Fig.4.17 *Thelypteris ferox* (Blume) Tagawa & K. Iwats. - sori



Fig.4.18 *Thelypteris ferox* (Blume) Tagawa & K. Iwats.



Fig.4.19 *Thelypteris flaccida* (Blume) Ching - sori



Fig.4.20 *Thelypteris flaccida* (Blume) Ching - rhizome



Fig.4.21 *Thelypteris flaccida* (Blume) Ching



Fig.4.22 *Thelypteris hirsutipes* (Clarke) Ching



Fig.4.23 *Thelypteris hirtisora* (C. Chr.) K. Iwats. - habitat



Fig.4.24 *Thelypteris hirtisora* (C. Chr.) K. Iwats. - sori



Fig.4.25 *Thelypteris interrupta* (Willd.) K. Iwats. - habitat



Fig.4.26 *Thelypteris interrupta* (Willd.) K. Iwats. - sori



Fig.4.27 *Thelypteris larutensis* (Bedd.) Tagawa & K. Iwats.



Fig.4.28 *Thelypteris larutensis* (Bedd.) Tagawa & K. Iwats. - rhizome



Fig.4.29 *Thelypteris larutensis* (Bedd.) Tagawa & K. Iwats. - sori



Fig.4.30 *Thelypteris megaphylla* (Mett.) K. Iwats.



Fig.4.31 *Thelypteris nudata* (Roxb.) Morton - habitat



Fig.4.32 *Thelypteris nudata* (Roxb.) Morton - sori



Fig.4.33 *Thelypteris polycarpa* (Blume)
K. Iwats.



Fig.4.34 *Thelypteris polycarpa* (Blume)
K. Iwats. - habitat

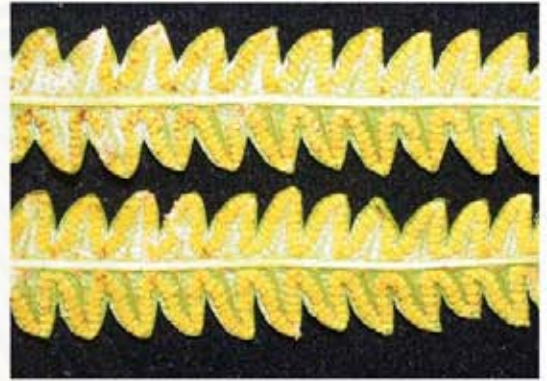


Fig.4.35 *Thelypteris polycarpa* (Blume)
K. Iwats. - sori



Fig.4.36 *Thelypteris repanda* (Fee) Tagawa &
K. Iwats.



Fig.4.37 *Thelypteris repanda* (Fee) Tagawa &
K. Iwats. - rhizome

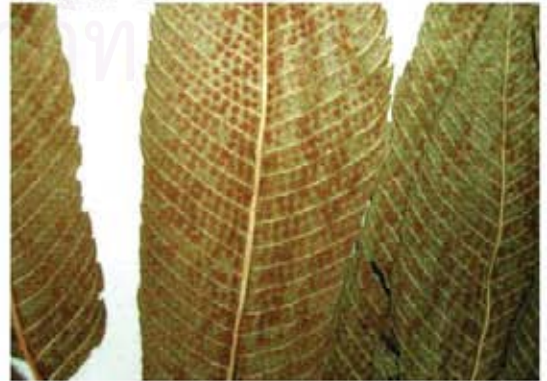


Fig.4.38 *Thelypteris repanda* (Fee) Tagawa &
K. Iwats. - sori



Fig.4.39 *Thelypteris siamensis* Tagawa & K. Iwats.



Fig.4.40 *Thelypteris siamensis* Tagawa & K. Iwats. - rhizome

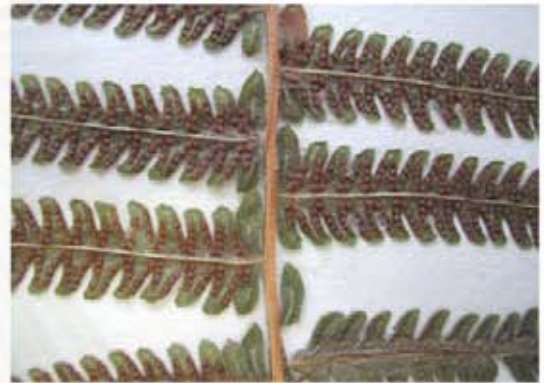


Fig.4.41 *Thelypteris siamensis* Tagawa & K. Iwats. - sori



Fig.4.42 *Thelypteris singalanensis* (Baker) Ching



Fig.4.43 *Thelypteris singalanensis* (Baker) Ching .- sori



Fig.4.44 *Thelypteris sumatrana* (v.A.v.Ros.) K. Iwats. - sori

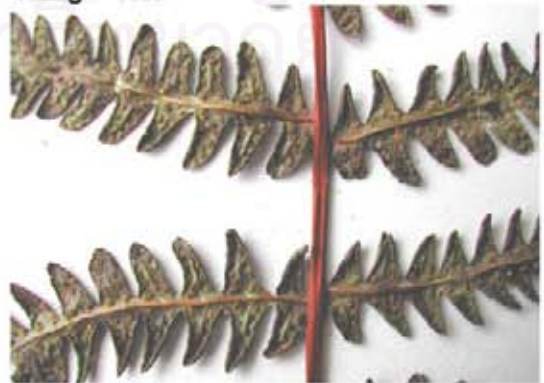


Fig.4.45 *Thelypteris sumatrana* (v.A.v.Ros.) K. Iwats. - sori



Fig.4.46 *Thelypteris terminans* (Hook.)
Tagawa & K. Iwats. - habitat



Fig.4.47 *Thelypteris terminans* (Hook.)
Tagawa & K. Iwats. - sori



Fig.4.50 *Thelypteris truncata* (Poir.) K. Iwats.
- habitat



Fig.4.48 *Thelypteris torresiana* (Gaud.) Alston
- habitat



Fig.4.49 *Thelypteris torresiana* (Gaud.) Alston
- sori



Fig.4.51 *Thelypteris truncata* (Poir.) K. Iwats.
- sori



Fig.4.52 *Thelypteris truncata* (Poir.) K. Iwats.



Fig.4.53 *Thelypteris viscosa* (Baker) Ching



Fig.4.54 *Thelypteris viscosa* (Baker) Ching - rhizome



Fig.4.55 *Thelypteris viscosa* (Baker) Ching - sori



Fig.4.56 *Thelypteris xylodes* (Kunze) Ching - habitat



Fig.4.57 *Thelypteris xylodes* (Kunze) Ching - sori



Fig.4.58 *Thelypteris xylodes* (Kunze) Ching - rhizome



Fig.4.59 *Thelypteris* sp.

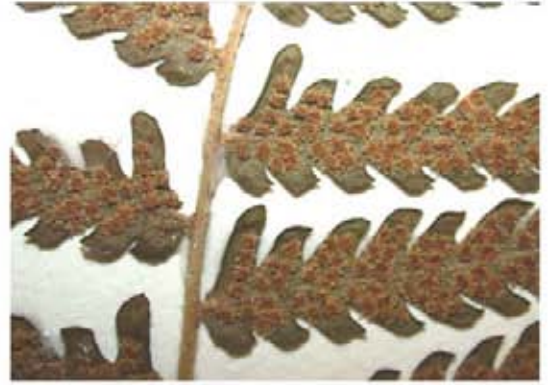


Fig.4.60 *Thelypteris* sp. - sori



Fig.4.61 *Thelypteris* sp. - frond

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4.2 Numerical taxonomy studies

In this present study, two multivariate techniques:- cluster and canonical discriminant analyses were used to analyse quantitative and qualitative characters of *Thelypteris* s.l.

4.2.1 Cluster analysis

In cluster analysis, two similarity (or distance) coefficient matrices were produced. The first matrix was the average taxonomic distance derived from 21 quantitative characters and the second one was the Gower's similarity coefficient matrix derived from 21 quantitative characters and 11 qualitative characters.

The results of the first cluster analysis using the average taxonomic distance matrix was showed in Figure 4.62. The dendrogram split the 518 specimens into three groups (Group A-C) at the 1.50 of average taxonomic distance. The first group (A) consisted of twenty three species (*Meniscium proliferum*, *Thelypteris arida*, *T. ciliata*, *T. confluens*, *T. classifolia*, *T. crinipes*, *T. dentata*, *T. falciloba*, *T. ferox*, *T. flaccida*, *T. hirsutipes*, *T. hirtisora*, *T. interrupta*, *T. larutensis*, *T. megaphylla*, *T. polycarpa*, *T. siamensis*, *T. singalanensis*, *T. terminans*, *T. truncata*, *T. viscosa*, *T. xyloides*, *T. sp.*). The second group (B) comprised of two taxa, namely *T. torresiana* and *T. sumatrana*. Whilst the third group (C) included two species: *T. nudata* and *T. repanda*.

Similar results were obtained when both quantitative and qualitative characters were used. The dendrogram derived from the second cluster analysis was showed in Figure 4.63. Using the 70% similarity phenon line as a reference (Sneath and Sokal 1973), three main groups could be distinguished in the UPGMA phenogram. Members of the three groups (Group A-C) were the same as those of the three groups obtained from the first cluster analysis.

In group A, there were 13 genera according to Holttum's classification (1971, 1981). They are *Ampelopteris*, *Amphineuron*, *Chingia*, *Christella*, *Coryphopteris*, *Cyclosorus*, *Metathelypteris*, *Mesophlebion*, *Pneumatopteris*, *Pseudocyclosorus*, *Sphaerostephanos*, *Thelypteris* and *Trigonospora*. He used a combination of characters to distinguish the 13 mentioned genera. In contrast, according to Tagawa and Iwatsuki (1988), 23 species of group A were subdivided into two genera (Table 4.1). Of these 22 species were *Thelypteris* and one species was *Meniscium*. They used a proliferous character of rachis to separate *Meniscium* from *Thelypteris*.

In the light of both cluster analyses, it is evident that the group A should be sorted only into one genus/taxon, preferably grouped into the genus *Thelypteris* since the type genus “*Thelypteris*” is in this cluster and this taxon has higher priority than the others.

On close examination of a dendrogram in Fig. 4.63 it appears that two subclusters could be established. Subcluster 1 comprised of *T. prolifera*, corresponding to *Ampelopteris* sensu Holttum or *Meniscium* sensu Tagawa and Iwatsuki. It is noteworthy that both authors used the same characters to classify this taxon, i.e. proliferous character on rachis. The other cluster contained the rest 12 genera as mentioned earlier.

Two taxa in group B were corresponding to *Pseudophegopteris* and *Macrothelypteris* in Holttum’s classification (1971). Holttum recognized these two genera based on characters of scales on fronds and spore morphology. However, Pichi Sermolli (1970, cited in Holttum, 1971) recognized only one genus, and transferred all species of *Pseudophegopteris* to *Macrothelypteris*. Unification of these two genera was based on bi-pinnate fronds. It is evident that the results of cluster analyses from this study support Pichi Sermolli’s classification.

All OTUs in group C were members of the genus *Pronephrium* sensu Holttum based on venation pattern. Holttum (1971) used venation pattern as an important character to separate the genus *Pronephrium* from the other genera in his classification. He noted that when pinnae lobes are not deep, veins from adjacent costules joined to form an excurrent straight or zigzag vein. These united veins run to the translucent membrane at the base of a sinus between two lobes (Holttum, 1971). It can be seen that the results of cluster analyses clearly supports the separation of the genus *Pronephrium* from the majority of *Thelypteris* s.l.

In all, the results of cluster analyses supported the recognition of the three genera, i.e. *Thelypteris*, *Macrothelypteris* and *Pronephrium*.

4.2.2 Canonical discriminant analysis

In canonical discriminant analysis, 21 characters were evaluated by stepwise discriminant analysis to determine which characters are important in discriminating among these three groups as suggested by cluster analyses. The following 19 out of 21 characters, 1, 2, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21 were selected as important characters that gave the best separation of the groups (Table 4.2).

In addition, the specimens were correctly classified into respective group (A, B, or C) with 100% accuracy. These classification rates are extremely high considering the existing variations among the three groups. The results were the same when original group (27 taxa) were used as a priori in canonical discriminant analysis, i.e. yielding 3 groups in an ordination plot (Fig. 4.64).

The ordination plot of the 518 OTUs was presented on the two canonical axes (Figure 4.64). It can be seen that group B is clearly separated from group A and C on canonical axis 1. Likewise, group C is evidently separated from group A and B on canonical axis 2). So the three groups appear distinct. Canonical variable 1 (axis 1) is most highly influenced by five characters (Table 4.2), viz. scale width (1), angle of basal pinnae to rachis (7), number of annulus cell (18), spore height (20) and spore diameter (21). The canonical correlation of the first canonical discriminant function is 98% with all the variables and the variance explained by it is 77% (Table 4.3). Thus, these two axes are effective for separating the three morphological groups of the genus *Thelypteris* s.l. in Thailand.

From the ordination plot in Fig. 4.64, it can be seen that, among the three groups, group B was rather heterogeneous, while group C and group A were less variable in descending order of variations.

It can be concluded that cluster analyses and canonical discriminant analyses from this study do not support a separation of *Thelypteris* s.l. in Thailand into neither two genera as proposed by Tagawa and Iwatsuki (1988), nor 16 genera (Table 4.1) according to Holttum's classification (1971 and 1981). In contrast, the results from this study do support the separation of *Thelypteris* s.l. in Thailand into 3 genera, i.e. *Thelypteris*, *Macrothelypteris* and *Pronephrium* based on both quantitative and qualitative characters.

4.2.3 Important characters

Univariate analysis of 21 quantitative characters was performed (Table 4.4). It can be seen that there were statistical significant differences ($P < 0.05$) in all characters among the three proposed genera, viz. *Thelypteris*, *Macrothelypteris* and *Pronephrium*. The F-values (Table 4.4) indicate by their magnitude the relative order of importance of the characters in general. It is clear that the F-values almost reflect the association of characters with canonical axis 1 because of its high correlation and high variance explained. Basic statistics of the three proposed were also summarized

in Table 4.4. It can be concluded that the vegetative characters of *Thelypteris* and *Pronephrium* were generally larger than *Macrothelypteris*. In contrast, the reproductive characters of *Macrothelypteris* were bigger than *Thelypteris* and *Pronephrium*. In general, the means of the most important characters were significantly different, especially the five most important characters for axis 1 as can be seen from Fig. 4.65.



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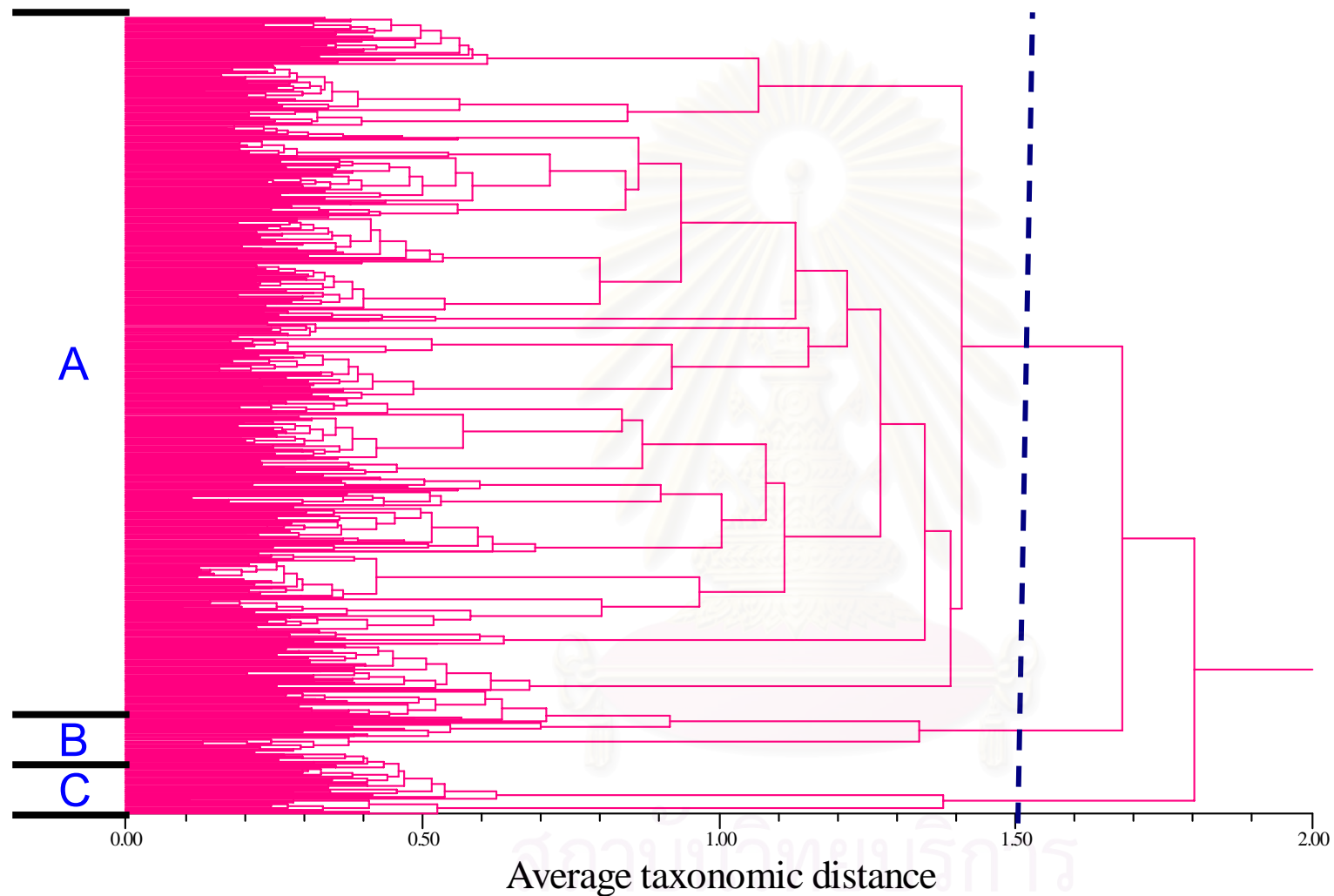


Figure 4.62 UPGMA clustering of 518 OTUs based on 21 characters of *Thelypteris* s. l. in Thailand. **A:** *Meniscium proliferum*, *Thelypteris polycarpa*, *T. larutensis*, *T. hirtisora*, *T. megaphylla*, *T. singalanensis*, *T. flaccida*, *T. confluens*, *T. falciloba*, *T. xyloides*, *T. ciliata*, *T. interrupta*, *T. classifolia*, *T. ferox*, *T. viscosa*, *T. hirsutipes*, *T. arida*, *T. siamensis*, *T. dentata*, *T. crinipes*, *T. truncata*, *T. terminans* and *T. sp.* **B:** *T. torresiana* and *T. sumatrana* **C:** *T. nudata* and *T. repanda*

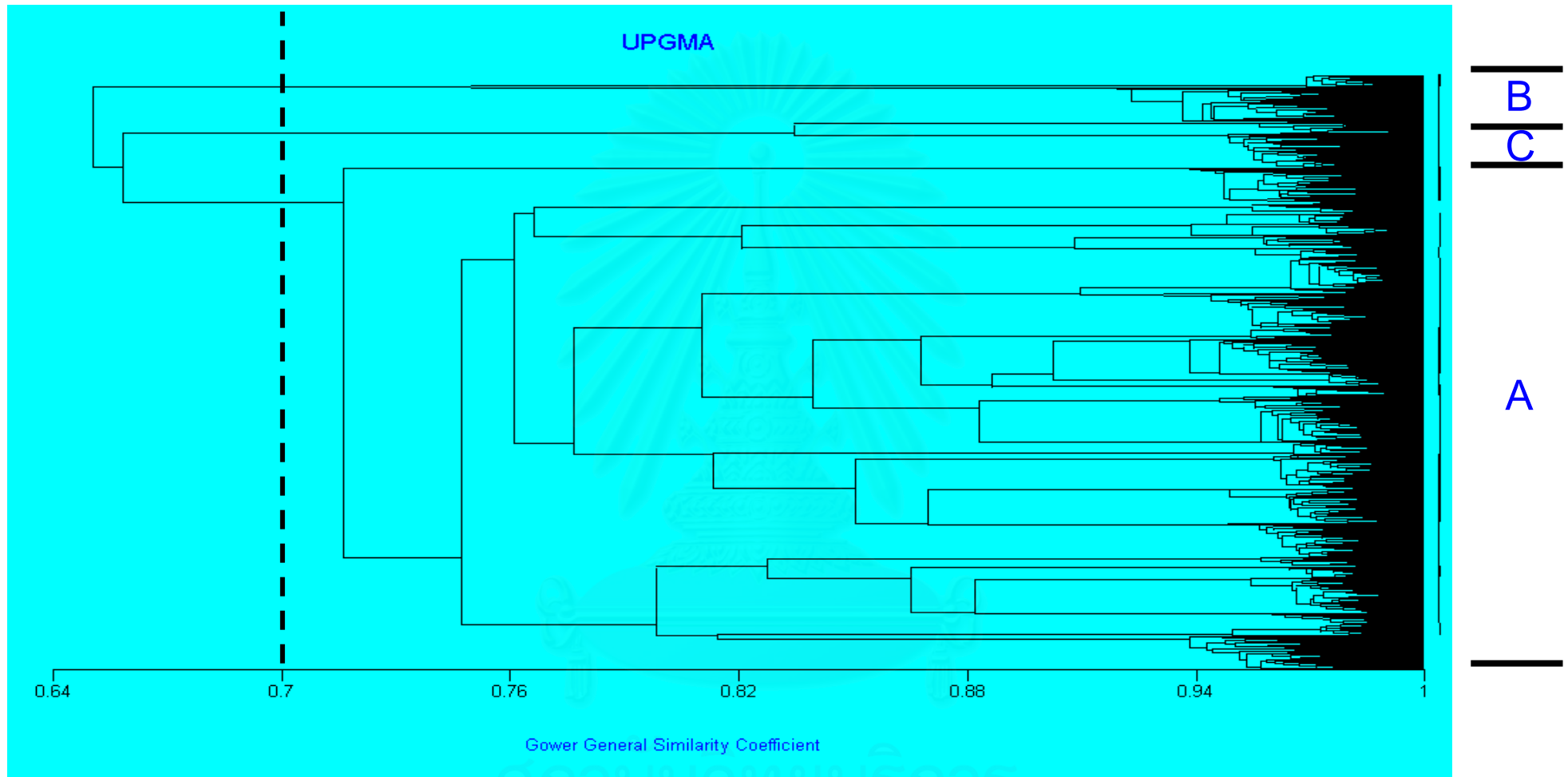
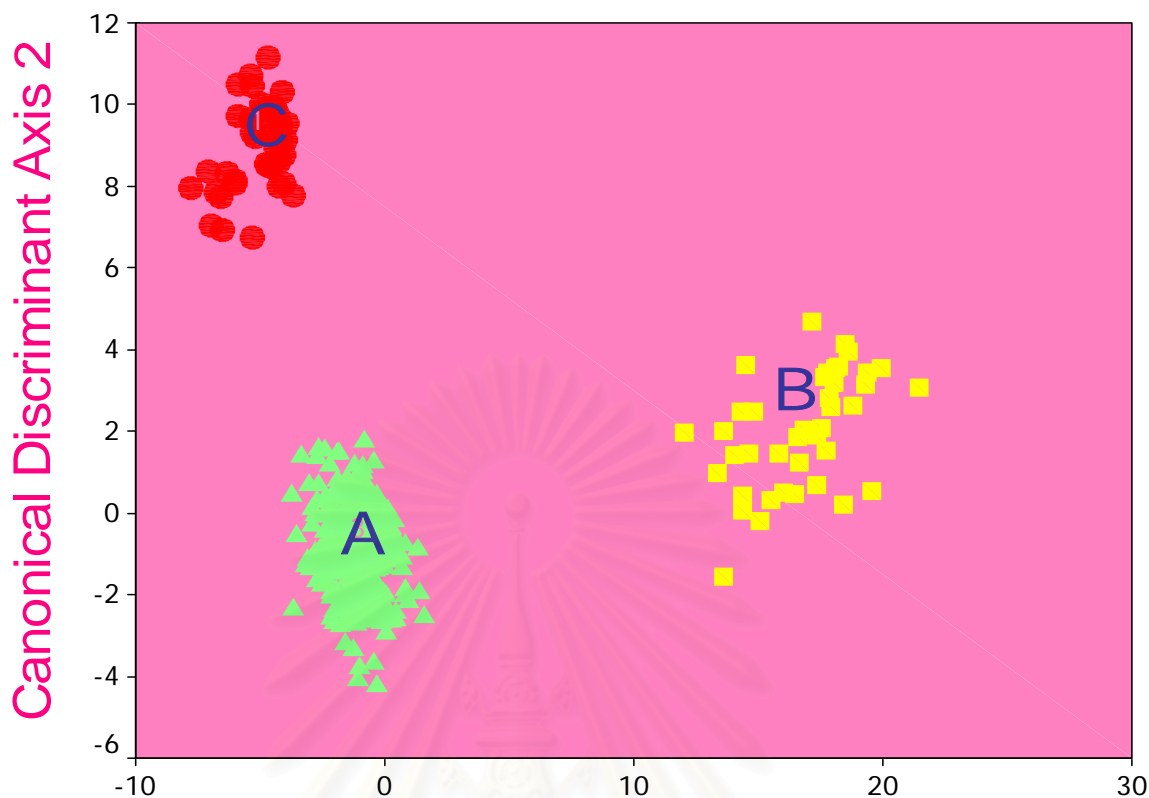


Figure 4.63 UPGMA phenogram base on Gower's general similarity coefficient calculated between means of 21 quantitative and 11 qualitative morphological characters of the genus *Thelypteris* s. l. in Thailand. Dashed line indicates 70% similarity phenon line, separating three clusters **A**: *Meniscium proliferum*, *Thelypteris polycarpa*, *T. larutensis*, *T. hirtisora*, *T. megaphylla*, *T. singalanensis*, *T. flaccida*, *T. confluens*, *T. falciloba*, *T. xylodes*, *T. ciliata*, *T. interrupta*, *T. classifolia*, *T. ferox*, *T. viscosa*, *T. hirsutipes*, *T. arida*, *T. siamensis*, *T. dentata*, *T. crinipes*, *T. truncata*, *T. terminans* and *T. sp.* **B**: *T. torresiana* and *T. sumatrana* **C**: *T. nudata* and *T. repanda*



Canonical Discriminant Axis 1

Figure 4.64 Ordination plot of 518 specimens from 27 taxa of *Thelypteris* s.l. in Thailand based on 21 quantitative characters. **A:** *Meniscium proliferum*, *Thelypteris polycarpa*, *T. larutensis*, *T. hirtisora*, *T. megaphylla*, *T. singalanensis*, *T. flaccida*, *T. confluens*, *T. falciloba*, *T. xylodes*, *T. ciliata*, *T. interrupta*, *T. classifolia*, *T. ferox*, *T. viscosa*, *T. hirsutipes*, *T. arida*, *T. siamensis*, *T. dentata*, *T. crinipes*, *T. truncata*, *T. terminans* and *T. sp.*, **B:** *T. torresiana* and *T. sumatrana*, **C:** *T. nudata* and *T. repanda*

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Figure 4.65 Means and Standard errors of the 5 important characters in separating the three proposed genera. (1, *Thelypteris*; 2, *Macrothelypteris*; and 3, *Pronephrium*)

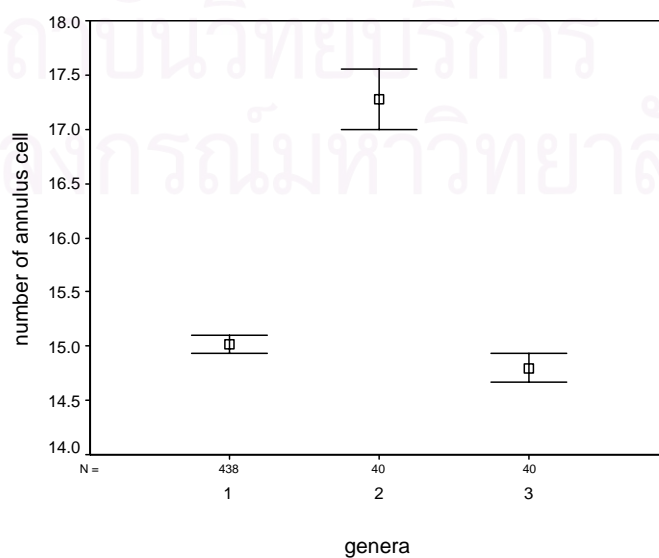
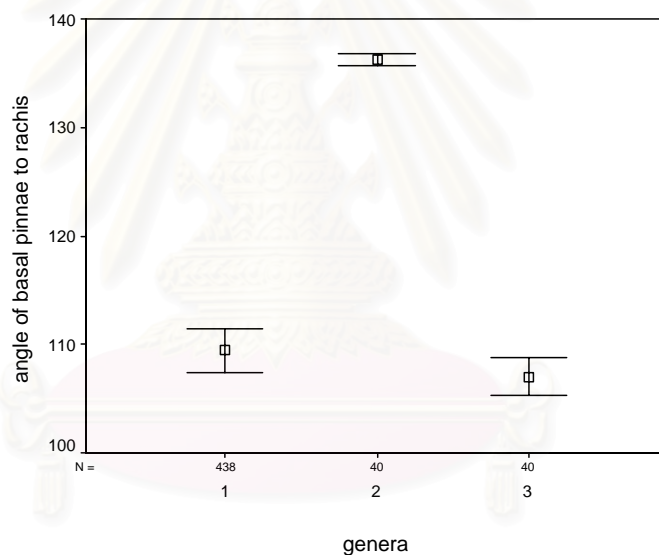
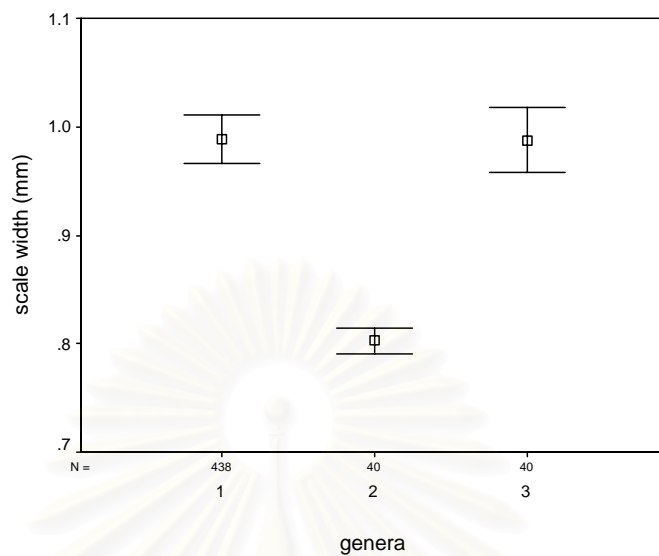
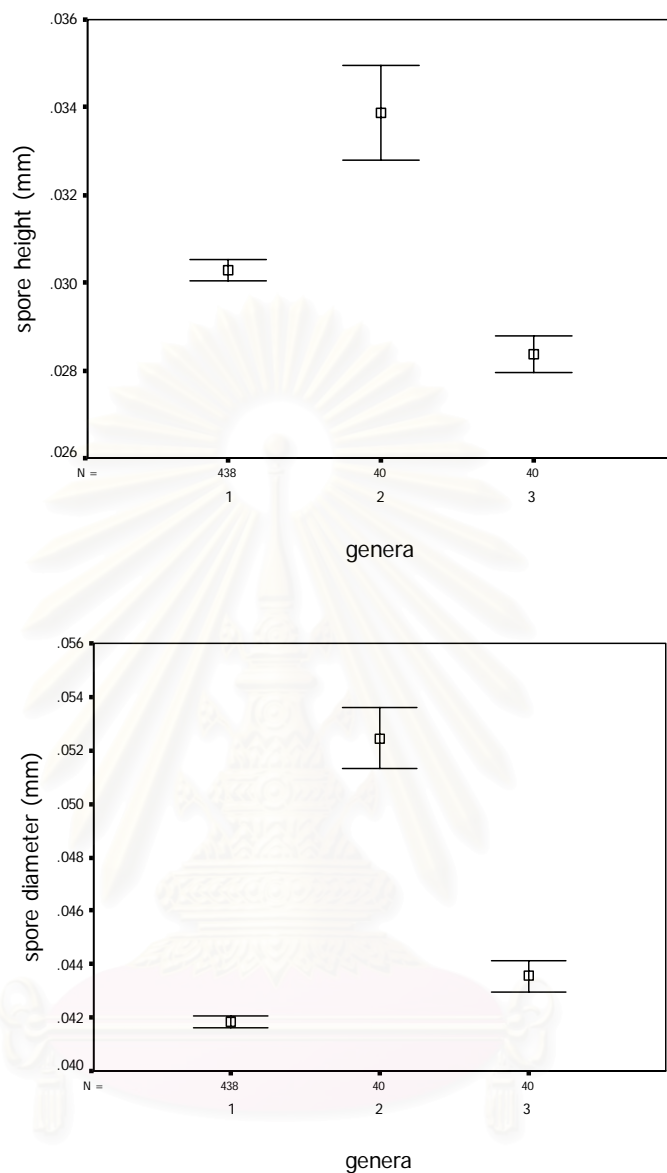


Figure 4.65 (continued)



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Table 4.2 Pooled within canonical structure of 3 groups/taxa (A-C) according to the result of canonical discriminant analysis.

Character	Axis 1	Axis 2
1. scale width	-0.018*	0.004
2. scale length	0.022	0.053*
3. stipe length ^a	-0.026	0.165*
4. rachis length	-0.020	0.081*
5. basal pinnae width	0.306	0.448*
6. basal pinnae length	0.064	0.243*
7. angle of basal pinnae to rachis	0.038*	0.020
8. number of pinnae/frond ^a	-0.003	-0.106*
9. distance between the pair of the largest pinnae	0.015	0.190*
10. lateral pinnae width	0.269	0.428*
11. lateral pinnae length	0.025	0.154*
12. pinnae lobe depth	0.081	-0.171*
13. number of sori per lobe	-0.156	0.232*
14. lateral vein length	-0.086	0.349*
15. pair number of lateral veins/ pinnae	-0.114	0.228*
16. sporangium width	0.067	-0.187*
17. sporangium length	0.050	-0.210*
18. number of annulus cell	0.075*	0.019
19. stalk length	0.004	-0.094*
20. spore height	0.042*	-0.020
21. spore diameter	0.099*	0.076

* Largest absolute correlation between each variable and any discriminant function

a This variable not used in the analysis

Table 4.3 Summary of canonical discriminant function of 3 groups/taxa (A-C) according to the result of canonical discriminant analysis.

Function	Eigenvalue	% of Variance	Cumulative %	Canon. Corre.	Wilk's lamda	Chi-square	Sig.
1	24.72	77	77	0.98	0.005	2719.508	0.000
2	7.39	23	100	0.93	0.119	1076.395	0.000



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Table 4.4 F values, means and standard errors of 21 quantitative characters of the three genera

No.	Character	F-value	Sign.	<i>Thelypteris</i>		<i>Macrothelypteris</i>		<i>Pronephrium</i>	
				mean	± SE	mean	± SE	mean	± SE
1	scale width	3.406	0.034	0.989	0.022	0.802	0.012	0.987	0.029
2	scale length	4.653	0.010	7.122	0.220	8.938	0.288	8.463	0.341
3	stipe length	64.369	0.000	34.694	1.052	42.962	2.127	73.290	1.419
4	rachis length	12.643	0.000	78.026	3.116	62.292	1.407	125.337	8.030
5	basal pinnae width	1389.034	0.000	1.209	0.025	8.205	0.379	3.647	0.071
6	basal pinnae length	180.645	0.000	6.951	0.340	21.170	0.974	24.115	0.473
7	angle of basal pinnae to rachis	9.105	0.000	109.431	41.786	136.250	0.557	107.000	1.761
8	number of pinnae/frond	11.214	0.000	53.324	1.871	34.900	1.275	30.250	1.915
9	distance between the pair of the largest pinnae	73.811	0.000	1.120	0.040	2.129	0.327	2.915	0.135
10	lateral pinnae width	1086.859	0.000	1.683	0.035	8.402	0.348	4.455	0.065
11	lateral pinnae length	50.752	0.000	14.984	0.430	22.202	0.890	27.727	0.601
12	pinnae lobe depth	78.586	0.000	4.015	0.086	5.597	0.095	1.051	0.032
13	number of sori per lobe	358.855	0.000	10.774	0.241	3.175	0.607	30.700	0.782
14	lateral vein length	373.739	0.000	0.861	0.017	0.700	0.018	2.416	0.059
15	pair number of lateral veins/ pinnae	241.801	0.000	35.641	0.766	17.325	0.430	84.775	0.844
16	sporangium width	80.274	0.000	0.192	0.001	0.213	0.001	0.130	0.008
17	sporangium length	74.180	0.000	0.243	0.002	0.253	0.001	0.155	0.012
18	number of annulus cell	37.463	0.000	15.016	0.078	17.275	0.277	14.800	0.130
19	stalk length	17.531	0.000	0.189	0.003	0.175	0.011	0.121	0.007
20	spore height	13.198	0.000	0.030	0.000	0.033	0.001	0.028	0.000
21	spore diameter	81.385	0.000	0.041	0.000	0.052	0.001	0.043	0.000

4.3 Taxonomic implication

Thelypteris s.l. is a large and complex genus composing about 1,000 species and being a single genus in the family Thelypteridaceae (Vasudeva and Bir, 1993), since its separation from the dryopteroid ferns about 60 years ago. Although generally recognized as a natural monophyletic group, there are still some difference in opinions among pteridologists on generic circumscription. Morton (1963, cited in Smith, 1971) placed all species in a single genus *Thelypteris* Schmidel; while Holttum (1971, 1981) recalled 25 genera in the Old World alone. Likewise, Pichi Sermolli (1970, cited in Holttum, 1971) mainly followed Holttum's classification, and accepted 32 genera in the Thelypteridaceae worldwide. Also, Boonkerd and Polawatn (2000) proposed a segregation of *Thelypteris* s.l. in Thailand into 14 genera namely *Amphineuron*, *Chingia*, *Christella*, *Coryphopteris*, *Cyclosorus*, *Metathelypteris*, *Macrothelypteris*, *Mesophlebion*, *Pneumatopteris*, *Pronephrium*, *Pseudophegopteris*, *Sphaerostephanos*, *Thelypteris* and *Trigonospora*. In contrast, Iwatsuki (1964) recognized three genera in the *Thelypteris* s.l.

According to the results of cluster analyses and canonical discriminant analyses from this study, 27 species of the genus *Thelypteris* s.l. were subdivided into three distinct taxa, probably as three genera, viz. *Thelypteris*, *Pronephrium* and *Macrothelypteris*. Corresponding results were presented by Smith and Cranfill (2002), they recognized 5 genera, namely *Macrothelypteris*, *Pseudophegopteris*, *Phegopteris*, *Thelypteris* s.s. and *Cyclosorus* sensu Smith based on data from four chloroplast genes (*rps4* gene + *rbcL* gene + *trnS* spacer, + *trnL* spacer; 2600 base pairs) of specimens from 23 genera according to Holttum's classification. They note that their sampling was as yet insufficient to favor one classification over another. It is pertinent to note that the present analysis suggested that recognition of an intermediate number of genera may be the most suitable for classification in Thelypteridaceae.

In Thailand, Tagawa and Iwatsuki (1988) classified the family Thelypteridaceae into two genera, i.e. *Thelypteris* and *Meniscium* which included 51 species. They were 50 species of *Thelypteris* s.l. and 1 species of *Meniscium*, i.e. *M. proliferum*. Twenty one species from this study, namely *Thelypteris polycarpa*, *T. larutensis*, *T. hirtisora*, *T. megaphylla*, *T. singalanensis*, *T. flaccida*, *T. confluens*, *T. falciloba*, *T. xylodes*, *T. ciliata*, *T. interrupta*, *T. classifolia*, *T. ferox*, *T. viscosa*, *T. hirsutipes*, *T. arida*, *T. siamensis*, *T. dentata*, *T. crinipes*, *T. truncata* and, *T. terminans* were grouped together and were placed in the genus *Thelypteris* s.s. It can be seen that 21 species were part of

the 50 species of the *Thelypteris* s.l. (Tagawa and Iwatsuki, 1988). However, *Meniscium proliferum* was also included in the genus *Thelypteris* s.s from the result of this study.

Of great interest to the present analysis is the genus *Macrothelypteris*. The important quantitative characters that separated the genus *Macrothelypteris* from the genus *Thelypteris* s.s. were scale width, angle of basal pinnae to rachis, number of annulus cell and size of spore (Figure 4.64). However, two qualitative characters, i.e. frond-form and venation pattern tend to be more important for separating *Thelypteris*, *Pronephrium* and *Macrothelypteris* since these two characters are easily notice in the field. Frond-form and venation pattern are important characters of the generic circumscription in the genus *Macrothelypteris* as mentioned in Holttum (1971) in his revision of the family Thelypteridaceae. He noted that most of the species in the genus *Macrothelypteris* and *Pseudophegopteris* have bi-pinnate frond and should not be used alone as a diagnostic character in key construction. However, Pichi Sermolli (1970, cited in Holttum, 1971) placed all species of *Pseudophegopteris* in the single genus *Macrothelypteris*, characterized by plants with bi-pinnate fronds. The results of cluster analysis and canonical discriminant analysis from this study support the recognition of combining *Macrothelypteris* spp. and *Pseudophegopteris* spp. into one taxon the single genus, *Macrothelypteris*, as was pointed out by Pichi Sermolli (1970, cited in Holttum, 1971). Other evidence supporting this merging came from chromosomal information which Ching (1963, cited in Iwatsuki, 1963) reported that both *Macrothelypteris* and *Pseudophegopteris* had the same base chromosome number, $x=31$.

The venation pattern of the genus *Pronephrium* (Holttum, 1971) was also important character of the generic circumscription in this genus. The results of numerical taxonomy studies also support the separation of the genus *Pronephrium* from the majority of *Thelypteris* s.l. The generic arrangement of Holttum (1971) for the genus *Pronephrium* was adopted here.

When considering characters that Holttum (1971) used in his “Studies in the family Thelypteridaceae III. A new system of genera in the old world” to classify 16 genera of *Thelypteris* s.l., it is clear that these characters may not contain much information. For example, the presence of acicular or glandular hairs of sporangia was always a diagnostic character of the genus *Christella*. However, this character was not supported the separation of members in the genus *Christella* from other as 4 taxa of *Christella* include in these analyses were not clustered together in cluster analyses.

The present results on multivariate analyses of morphological characters suggest a reduction of the thirteen taxa:- *Ampelopteris*, *Amphineuron*, *Chingia*, *Christella*, *Coryphopteris*, *Cyclosorus*, *Metathelypteris*, *Mesophlebion*, *Pneumatopteris*, *Pseudocyclosorus*, *Sphaerostephanos*, *Thelypteris* and *Trigonospora* to the single genus *Thelypteris*.

Some quantitative characters were described in the genera description in Holttum's (1971) classification, i.e. lamina length, lobe depth and pair of vein per lobe. In the present study, 21 quantitative characters have been used. Five characters were the important characters to segregate *Thelypteris* s.l into three genera.

The numerical approach also succeeded in resolving some aspects of the ambiguous nature of the genus, especially those caused by phenotypic variations. Based on quantitative characters and supported by qualitative characters, the multivariate analyses strongly indicate the presence of three distinct morphotypes. From the results of numerical taxonomy studies, I recognized three genera in the Thelypteroid ferns in Thailand. I segregated *Pronephrium* and *Macrothelypteris* (including *Pseudophegopteris*) from the majority of the Thelypteroid ferns, which I placed in *Thelypteris*.

In conclusion, the taxonomic status of genera in the family Thelypteridaceae still remain to be investigated on a worldwide basis.

CHAPTER 5

CONCLUSION

In the present study, 518 specimens (OTUs) from 27 species of *Thelypteris* s.l. in Thailand were subjected to cluster analyses and canonical discriminant analyses. Based on 21 quantitative characters and supported by 11 qualitative characters, cluster analyses strongly indicate the presence of three distinct groups, i.e. *Thelypteris* s.s., *Macrothelypteris* and *Pronephrium*. The 3 groups were subsequently evaluated by canonical discriminant analyses. It was found that 5 characters, i.e. scale width, angle of basal pinnae to rachis, number of annulus cell, spore width and spore length collectively supported the segregation of 3 groups or genera from the *Thelypteris* s.l.

The following is an identification key of the segregated genera from the *Thelypteris* s.l. in Thailand.

- 1a Number of annulus cell equal or more than 17..... **1. *Macrothelypteris***
- 1b Number of annulus cell less than 17..... 2.
 - 2a Spore diameter less than 0.43 mm long..... **2. *Thelypteris***
 - 2b Spore diameter equal or more than 0.43 mm long..... **3. *Pronephrium***

It's worth noting that the putative new species of *Thelypteris* was found during field collection in the south of Thailand. Based on its spore characteristics, this taxon would be classified to *Trigonospora* of Holttum (1971). After comparing to the type specimens deposited at Kew herbarium, this species tends to be new to science. Further investigation need be carried out to verify this finding. However, in the present study this species was included in *Thelypteris*. Hence, this new species will be described as a species novum of *Thelypteris* from Thailand.

In all, numerical taxonomy can re-examine the principles of taxonomy, especially the proposed classification. This computerized processing techniques prove to be useful in classification of *Thelypteris* s.l. in Thailand.

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BIOGRAPHY

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