TAXONOMIC REVISION OF FERN GENUS *Diplazium* Sw. (WOODSIACEAE) IN THAILAND

Mr. Puttamon Pongkai

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science Program in Botany

Department of Botany

Faculty of Science

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การทบทวนอนุกรมวิธานเฟิร์นสกุล *Diplazium* Sw. (WOODSIACEAE) ในประเทศไทย

นายพุทธมน ผ่องกาย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาพฤกษศาสตร์ ภาควิชาพฤกษศาสตร์
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Thesis Title	TAXONOMIC REVISION OF FERN GENUS *Diplazium* Sw. (WOODSIACEAE) IN THAILAND
By	Mr. Puttamon Pongkai
Field of Study	Botany
Thesis Advisor	Professor Thaweesakdi Boonkerd, Ph.D.

Accepted by the Faculty of Science, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

…….. Dean of the Faculty of Science
(Professor Supot Hannongbua, Dr.rer.nat.)

THESIS COMMITTEE

…….. Chairman
(Assistant Professor Chumpol Khunwasi, Ph.D.)

…….. Thesis Advisor
(Professor Thaweesakdi Boonkerd, Ph.D.)

…….. Examiner
(Assistant Professor Rossarin Pollawatn, Ph.D.)

…….. External Examiner
(Somran Suddee, Ph.D.)

พุทธมน ผ่องกาย : การทบทวนอนุกรมวิธานเฟิร์นสกุล *Diplazium* Sw. ในประเทศไทย. (TAXONOMIC REVISION OF FERN GENUS *Diplazium* Sw. IN THAILAND) อ. ที่ปรึกษาวิทยานิพนธ์หลัก : ศ. ดร. ทวีศักดิ์ บุญเกิด, 150 หน้า.

รายงานล่าสุดของบัญชีรายชื่อเฟิร์นสกุล *Diplazium* ที่พบในประเทศไทยในหนังสือ พรรณพฤกษชาติประเทศไทย ฉบับที่ 3 พบจำนวน 29 ชนิด และเมื่อเร็ว ๆ นี้ได้มีรายงานการพบ *Diplazium* ชนิดที่พบครั้งแรกในประเทศไทยเพิ่มเติม แต่รูปวิธานที่ใช้ในการระบุชนิดในหนังสือพรรณพฤกษชาติประเทศไทย ปัจจุบันยังไม่ได้แก้ไขเพิ่มเติมชนิดที่พบใหม่เหล่านี้ นอกจากนี้ยังพบว่ารูปวิธานที่ใช้ในการระบุชนิดสามารถทำได้ยาก เนื่องจากการใช้ลักษณะของพืชที่ไม่เฉพาะเจาะจง จึงจำเป็นต้องศึกษาทบทวนบัญชีรายชื่อของสกุล *Diplazium* ที่พบในประเทศไทยใหม่ การวิจัยครั้งนี้เน้นศึกษาลักษณะสัณฐานวิทยา กายวิภาคศาสตร์ และเรณูวิทยาของ *Diplazium* แต่ละชนิด เพื่อนำข้อมูลไปประกอบในการระบุชื่อวิทยาศาสตร์ในระดับชนิดและจัดทำรูปวิธานจำแนกชนิดใหม่ต่อไป

การศึกษาครั้งนี้ได้ศึกษาลักษณะทางสัณฐานวิทยา 7 ลักษณะ และลักษณะทางกายวิภาคศาสตร์ 2 ลักษณะโดยใช้ทั้งตัวอย่างสด และตัวอย่างจาก พิพิธภัณฑ์พืชต่าง ๆ พบว่าลักษณะของเหง้า สิ่งปกคลุม ก้านใบ แผ่นใบ และลักษณะกายวิภาคศาสตร์ของก้านใบ รวมกันมีประโยชน์ในการศึกษาอนุกรมวิธานของ *Diplazium* โดยลักษณะที่มีความสำคัญคือ สัณฐานวิทยาของเกล็ดและรูปร่างของมัดท่อลำเลียงที่ก้านใบตอนบน จากการศึกษาเรณูวิทยาของ *Diplazium* จำนวน 31 ชนิด โดยใช้กล้องจุลทรรศน์แบบใช้แสง และกล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด พบว่า *Diplazium* ทุกชนิดมีสปอร์เป็นรูปไต มีรอยเชื่อมเดียวขนาด 30-68 X 20-50 ไมโครเมตร สามารถแบ่งกลุ่มสปอร์ตามลักษณะลวดลายของผนังสปอร์ในชั้น perispore ได้ 8 แบบคือ baculate, echinate, pustulate, reticulate, rugate, rugate-retate, regulate และ smooth ซึ่งลักษณะที่เห็นได้ด้วยกล้องจุลทรรศน์เหล่านี้สามารถใช้ในการจำแนกชนิดได้

การศึกษาครั้งนี้สรุปได้ว่ามี *Diplazium* ชนิดที่เป็นของไทยจำนวน 31 ชนิดโดย 3 ชนิดคือ *D. griffithii* T. Moore, *D. lobatum* (Tagawa) Tagawa และ *D. pallidum* (Blume) T. Moore เป็นชนิดที่พบครั้งแรกในประเทศไทย ในที่นี้ *D. simplicivenium* Holttum ถูกจัดให้เป็นชื่อพ้องของ *D. dilatatum* Blume แต่ *D. petilotii* Tardieu ไม่ได้รวมอยู่ในบัญชีรายชื่อครั้งนี้ ได้จัดทำรูปวิธานพร้อมคำบรรยายลักษณะ วาดภาพลายเส้น และข้อมูลการกระจายพันธุ์ของแต่ละชนิด

ภาควิชา พฤกษศาสตร์ ลายมือชื่อนิสิต .....

สาขาวิชา พฤกษศาสตร์ ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก .....

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PUTTAMON PONGKAI : TAXONOMIC REVISION OF FERN GENUS *Diplazum* Sw. IN THAILAND. ADVISOR : PROF. THAWEESAKDI BOONKERD, Ph.D., 150 pp.

The most up-to-date account of *Diplazium* in Thailand, including 29 species, is in Flora of Thailand, vol. III. Recently, some new recorded species were reported. However, the key to the species in the Flora of Thailand did not include these new records. Moreover, it is difficult to determine the species using this key, due mainly to the ambiguity of the key characters. The account of the Thai *Diplazium*, therefore, is needed to be re-examined. This research was designed to explore additional data for species determination and key construction by examining the morphological, anatomical and palynological characters of the available species.

In this study, 7 morphological and 2 anatomical characters of the Thai *Diplazium* were examined. Both fresh plants and herbarium specimens were used. It was found that growth form of rhizome, indumenta, stipe and lamina characters together with anatomy of stipes are collectively useful in *Diplazium* taxonomy with special reference to scales morphology and shape of vascular bundle of upper portion of stipes. A palynological study of 31 species was undertaken using light and scanning electron microscopy. All studied species have monolete spores, which are bilateral, kidney-shaped, 30-68 by 20-50 μm and bearing perispore. The spores sculpture can be divided into 8 types: baculate, echinate, pustulate, reticulate, rugate, rugate-retate, rugulate and smooth types. These microscopic characters can be used to identify different species.

Thirty one species of Thai *Diplazium* are enumerated and discussed. Three of them, namely *D. griffithii* T. Moore, *D. lobatum* (Tagawa) Tagawa and *D. pallidum* (Blume) T. Moore are new records for the Thai Flora. *Diplazium simplicivenium* Holttum was treated here as a synonym of *D. dilatatum* Blume, while *D. petilotii* Tardieu is excluded from this account. Key to the species together with descriptions, line drawings and distribution of each species are provided.

Department : Botany Student's Signature .....

Field of Study : Botany Advisor's Signature .....

Academic Year : 2011

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CHAPTER I

INTRODUCTION

Diplazium Sw. is a genus of ferns in the family Woodsiaceae. It includes about 400 species worldwide (Lellinger, 1985), usually grows naturally in the dense forests. *Diplazium* has a wide distribution in the warmer parts of the world, scarcely and only locally extending into temperate areas. It usually occurs from the lowlands to the mountainous areas in the tropics (Kramer and Kato, 1990). In Thailand, it can be found throughout the country, especially in the peninsular Thailand (Boonkerd & Pollawatn, 2000).

The fern species in the genus *Diplazium* are medium to large in size. They have both radial and dorsiventral construction, and are usually covered with dense scales on the rhizome. The scales are ovate, subdeltoid to linear lanceolate in shape, they are brown to black with margin that may be entire or toothed. The stipes are dark at base and usually grooved on the upper portion. Fronds are vary in from, from simple, pinnate to bipinnate compound leaves. The sori are indusiate and usually stretch out on both sides of the vein (diplazoid), that may be straight or slightly curved (Lellinger, 1985).

So far, the taxonomic boundaries of the genus *Diplazium* are still uncertain and in great need of revision and emending. For example, not yet fully grown plant may be fertile (produce spores), so it is difficult to assign to a species. Up to now, the natural subdivision of the genus has not been given (Kramer and Kato, 1990).

The last updated account of *Diplazium* was in the pteridophyte flora of Thailand which included 29 species (Tagawa & Iwatsuki, 1988). In addition, Boonkerd et al. (2004) had added a new recorded species, i.e. *D. procumbens* Holttum to the *Diplazium*

account. Previously, key to species of the genus *Diplazium* in the pteridophyte flora of Thailand did not included these new recorded species. In addition, it is hard to determine the species using this key due mainly to the use of continuous, overlapping, quantitative characters. So, the account of the Thai *Diplazium* is needed to be revised.

Aim of the thesis

This thesis aims to provide additional data for species determination by exploring the morphological, anatomical and palynological characters of the available species of the fern genus *Diplazium* Sw. in Thailand and construct a key to species based on these characters.

CHAPTER II

MORPHOLOGICAL AND ANATOMICAL STUDY

2.1 Introduction

Plant morphology is a field of study dealing with the external and gross internal structure of plant organ (Simpson, 2010). Generally, taxonomic study still rely largely on morphological and anatomical data. These data has shown great taxonomic significance and were used in classification of both major and minor categories (Jones and Luchsinger, 1987).

Hernández, Terrazas and Angeles (2006) studied rhizome and foliar anatomy of the Mexican *Dryopteris* species by compared with other species in Dryopteridaceae and the other fern families. The result showed that some anatomical characters can be used in species determination, i.e. the presence of crystals on the periphery of rhizome which found only in *D. rossii* C. Chr. and *D. maxonii* Underw. & C. Chr. or having more layers of sclerenchyma and meristeles on the stipe which found only in *D. wallichiana* (Spreng.) Hyl.

Murtaza et al. (2008) studied morphology, anatomy and spores morphology of *Schizaea dichotoma* (L.) Smith compared with *Lygodium japonicum* (Thunb.) Sw. in Pakistan. It was suggested that *Schizaea dichotoma* is more primitive than the *Lygodium japonicum* (Thunb.) Sw. and the other members of the Schizaeaceae due to ramification of the rachis, the presence of protostele and convex-plane spores.

Adedeji and Jewoola (2008) studied leaf epidermal characters of 12 species of the family Asteraceae. Four stomatal types are observed, i.e. anomocytic, brachyparacytic, anisocytic and diacytic. The result showed that *Vernonia cinerea* Linn. can be separated from *V. amygdalina* Del. by the presence of anisocytic stomatal types.

While *Emilia praetermissa* Milne-Redhead can be splited from *E. coccinea* (Sims) G. Don by the presence of brachyparacytic stomatal type. It was also found that *Agaratum conyzoides* L. and *Synedrella nodiflora* (L.) Gaertn. are the only two species with occasional diacytic stomatal types.

Srinual (2009) investigated anatomy of the family Dipterocarpaceae in Thailand which included stomatal structure of leaves. Six stomatal types are observed, i.e. anomocytic, actinocytic, cyclocytic, hexacytic, paracytic and tetracytic. The result showed that the stomatal features are useful for species determination, especially at the species level. For example, *Vatica odorata* (Griff.) Symington and *V. harmandiana* Pierre are rather similar in their general morphological characters. However, these two species are different in having stomatal types. *Vatica harmandiana* has both cyclocytic and actinocytic stomata, whereas, *V. odorata* has only cyclocytic stomata.

Ohta and Takamiya (1999) investigated morphology, cytology and taxonomy of the Japanese *Diplazium mettenianum* complex. Twenty qualitative morphological characters of 374 plants were analyzed. They concluded that the complex should be divided into five forms. Likewise, statistical analysis of 16 quantitative morphological characters also supported the segregation of five forms which were regarded as independent species, viz. *D. mettenianum*, *D. fauriei*, *D. deciduum* nom. nov., *D. griffithii* and *D. hayatamae* sp. nov.

2.2 Materials and Methods

2.2.1 Plant materials

Fresh and dry herbarium specimens of 31 *Diplazium* species found in Thailand were used in morphological studies and 27 species (Table 2.1) were used in anatomical studies.

Table 2.1 Twenty seven species of the *Diplazium* species used in anatomical studies.

No.	Scientific name	Collector number (Herbarium)
1.	*D. bantamense* Blume	P. Pongkai 32 (BCU)
2.	*D. conterminum* Christ	P. Pongkai 15 (BCU)
3.	*D. cordifolium* Blume	P. Pongkai 37 (BCU)
4.	*D. crenato-serratum* (Blume) T. Moore	P. Pongkai 27 (BCU)
5.	*D. dilatatum* Blume	P. Pongkai 13 (BCU)
6.	*D. donianum* (Mett.) Tardieu	Y. Yuyen 43 (BCU)
7.	*D. esculentum* (Retz.) Sw.	O. Neamsuvan 103 (BCU)
8.	*D. griffithii* T. Moore	T. Boonkerd 492, 1330 (BCU)
9.	*D. heterophlebium* (Mett. ex Baker) Diels	E. Hennipman 3432 (BKF)
10.	*D. leptophyllum* Christ	T. Shimizu & M. Hutoh T10210 (BKF)
11.	*D. lobatum* (Tagawa) Tagawa	Pteridophyte trip 72; W.R. 29 (BCU)
12.	*D. malaccense* C. Presl	J. Middleton et.al. 138168 (BKF)
13.	*D. megaphyllum* (Baker) Christ	E. Hennipman et.al. 3064 (BKF)
14.	*D. mettenianum* (Miq.) C. Chr.	P. Pongkai 20, 23 (BCU)
15.	*D. muricatum* (Mett.) Alderw.	P. Pongkai 12 (BCU)
16.	*D. pallidum* (Blume) T. Moore	E. Hennipman 3998 (BKF)
17.	*D. petrii* Tardieu	P. Pongkai 68, 69 (BCU)
18.	*D. proliferum* (Larmarck) Kaulf.	Charn Apasutaya 121a, 121b (BCU)
19.	*D. riparium* Holttum	P. Pongkai 45, 48 (BCU)
20.	*D. siamense* C. Chr.	P. Pongkai 9, 16 (BCU)
21.	*D. sorzogonense* (C. Presl) C. Presl	P. Pongkai 30, 49 (BCU)
22.	*D. subintegrum* Holttum	P. Pongkai 35 (BCU)
23.	*D. subserratum* Blume	G. Murata et.al. 49576 (BKF)
24.	*D. subsinuatum* (Wall. ex Hook. & Grev.) Tagawa	A. Sathapattayanon 576 (BCU)
25.	*D. sylvaticum* (Bory) Sw.	P. Pongkai 18, 19 (BCU)
26.	*D. tomentosum* Blume	P. Pongkai 31,38 (BCU)
27.	*D. xiphophyllum* (Baker) C. Chr.	D. J. Middleton et.al. 1682 (BKF)

2.2.2. Morphological study

The specimens were examined from both vegetative and reproductive characters using a stereomicroscope or a light microscope. The characters included types of rhizome, shape of fronds, venation patterns, shape of sori and scale morphology, i.e. shape of scales, scale colour, scale margin, etc.

2.2.3. Anatomical study

Transverse sections of upper portion of stipes, varying in thickness from 10-15 μm were cut using Automatic MT-3 microtome (Toyozumi Dengenkiki co., Ltd.) without embedding in paraffin. Samples of stipes from dried herbarium specimens were boiled in water until they were soft or sank, then they were transferred to cold water before cutting. Subsequently, the sections were stained with 1% safranin O solution for 5-10 minutes and temporarily mounted using nail varnish and observed under a light microscope and a stereomicroscope.

Epidermal study of leaves were focused on stomatal types. The epidermal peels were prepared by applying nail varnish to an approximate 1 cm^2 surface area on abaxial surface of frond. Let it dry, then used a pair of fine forceps to lift the replica of the epidermis off the frond and placed it on a microscope slide. Placed a cover glass over the peel and sealed with a drop of nail varnish. The epidermal peels were then observed using a light microscope. The terminology of stomatal types are according to Sen and De (1992).

2.2.4 Microphotography

All microphotographs were taken using a Nikon Eclipse E200 microscope fitted with an Nikon Digital sight DS-Fi1 digital camera.

2.3 Results

2.3.1 Gross morphology of *Diplazium*

Rhizome

Generally, rhizome of *Diplazium* can be divided into 2 types, i.e. creeping or upright rhizome. They usually vary in sizes, sometimes forming a small trunk. Rhizome is generally protected with scales, especially near apex, some species has wiry roots. From this study the creeping rhizome are found in 9 species, i.e. *D. conterminum*, *D. donianum*, *D. griffithii*, *D. leptophyllum, D. lobatum*, *D. mettenianum*, *D. petrii*, *D. procumbens* and *D. subsinuatum*. In contrast, the upright rhizome are found in 22 species, i.e. *D. bantamense*, *D. cordifolium*, *D. crenato-serratum*, *D. dilatatum*, *D. esculentum*, *D. heterophlebium*, *D. malaccense*, *D. megaphyllum*, *D. muricatum*, *D. pallidum*, *D. polypodioides*, *D. prescottianum*, *D. proliferum, D. riparium*, *D. siamense*, *D. sorzogonense*, *D. subintegrum*, *D. subserratum*, *D. sylvaticum*, *D. taiwanense, D. tomentosum* and *D. xiphophyllum* (Table 2.2).

Scale

Scales have a wide range of forms from subtriangular to linear. Their colour are light brown to nearly black, concolorous or having black margin (Figure 2.2, 2.3). The concolorous scales are found in 20 species, i.e. *D. crenato-serratum*, *D. heterophlebium*, *D. leptophyllum*, *D. lobatum*, *D. malaccense*, *D. mettenianum*, *D. muricatum*, *D. pallidum*, *D. petri*, *D. prescottianum*, *D. procumbens*, *D. proliferum*, *D. riparium*, *D. subintegrum*, *D. subserratum*, *D. subsinuatum*, *D. sylvaticum*, *D. taiwanense*, *D. tomentosum* and *D. xiphophyllum*. The scales having black margin are found in 11 species, i.e. *D. bantamense, D. conterminum, D. cordifolium, D. dilatatum, D. donianum, D. esculentum, D. griffithii, D. megaphyllum, D. polypodioides, D. siamense* and *D. sorzogonense.* The margin of the scales may be entire or toothed. The

entire scales are found in 11 species, i.e. *D. cordifolium*, *D. heterophlebium*, *D. leptophyllum*, *D. malaccense*, *D. pallidum*, *D. prescottianum*, *D. riparium*, *D. subintegrum*, *D. subsinuatum*, *D. tomentosum* and *D. xiphophyllum*. The toothed scales are found in 20 species, i.e. *D. bantamense*, *D. conterminum*, *D. crenato-serratum*, *D. dilatatum*, *D. donianum*, *D. esculentum*, *D. griffithii*, *D. lobatum*, *D. megaphyllum*, *D. mettenianum*, *D. muricatum*, *D. petrii*, *D. polypodioides*, *D. procumbens*, *D. proliferum*, *D. siamense*, *D. sorzogonense*, *D. subserratum*, *D. sylvaticum* and *D. taiwanense*. The teeth at margin of scales are always composed of two cells which may be separated at their tips. Some species, i.e. *D. riparium* and *D. subintegrum* have glandular cells at margin (Figure 2.1).

Figure 2.1 Scales of *Diplazium*. A: toothed and black-margined scale of *D. conterminum*; B: toothed and concolorous scale of *D. crenato-serratum*; C: entire and concolorous scale of *D. subintegrum* and D: entire and black-margined scale of *D. cordifolium*.

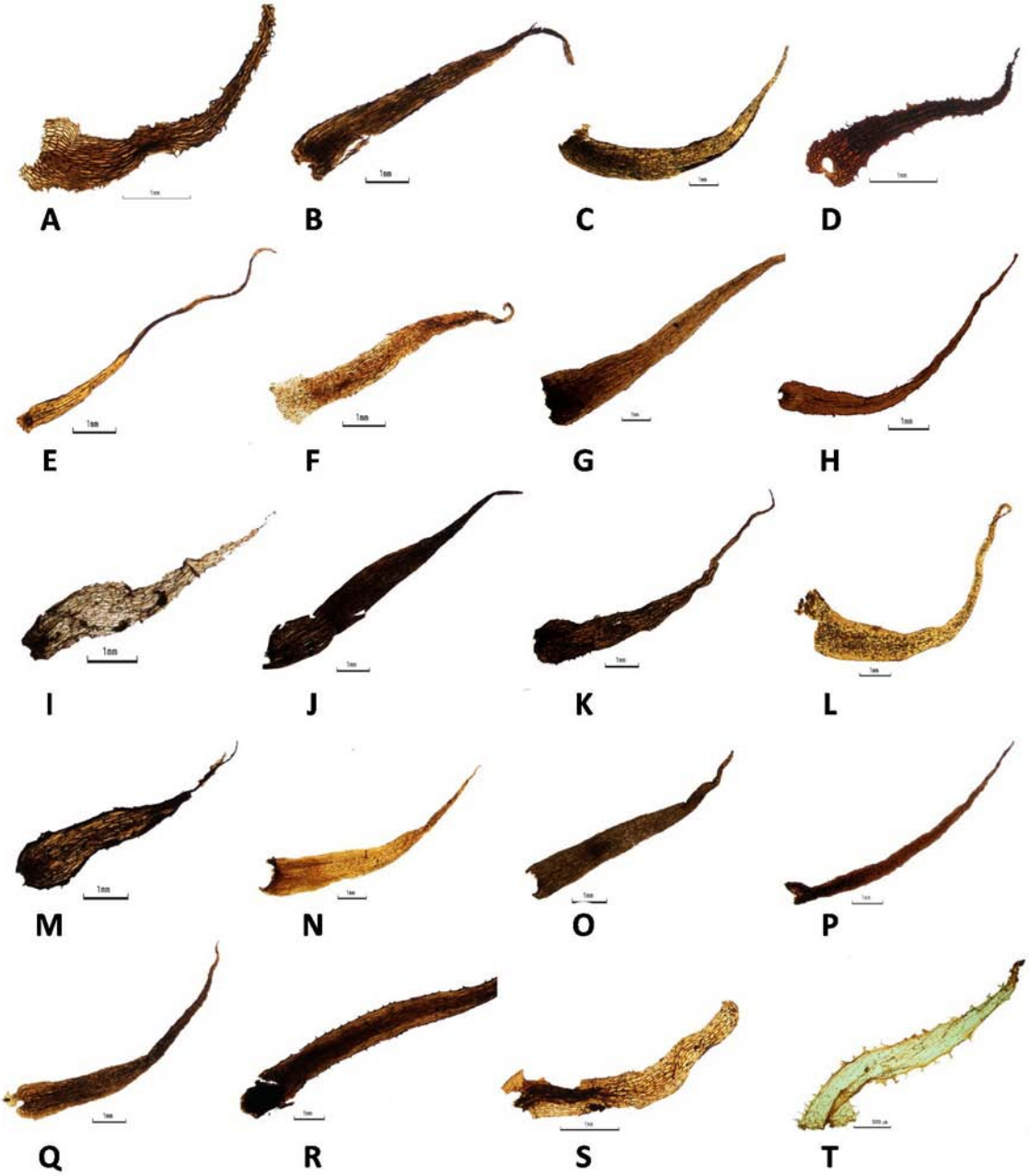

Figure 2.2 Scales of *Diplazium*. A: *D. bantamense*; B: *D. conterminum*; C: *D. cordifolium*; D: *D. crenato-serratum*; E: *D. dilatatum*; F: *D. donianum*; G: *D. esculentum*; H: *D. griffithii*; I: *D. heterophlebium*; J: *D. leptophyllum*; K: *D. lobatum*; L: *D. malaccense*; M: *D. megaphyllum*; N: *D. mettenianum*; O: *D. muricatum*; P: *D. pallidum*; Q: *D. petrii*; R: *D. polypodioides*; S: *D. procumbens* and T: *D. proliferum*

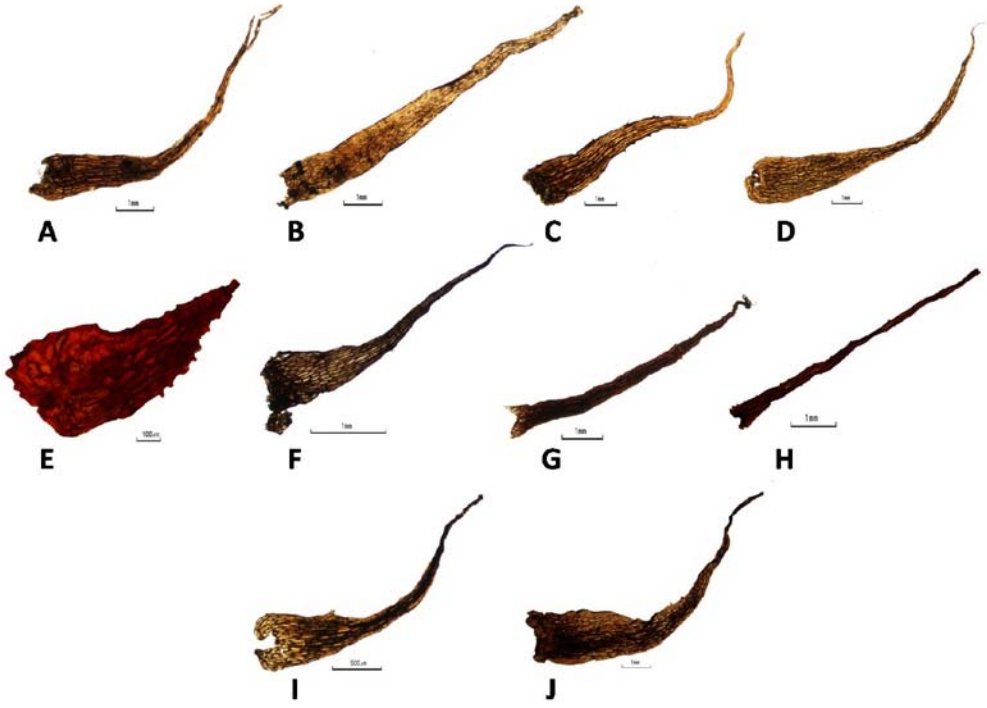

Figure 2.3 Scales of *Diplazium*. A: *D. riparium*; B: *D. siamense*; C: *D. sorzogonense*; D: *D. subintegrum*; E: *D. subserratum*; F: *D. subsinuatum*; G: *D. sylvaticum*; H: *D. taiwanense*; I: *D. tomentosum* and J: *D. xiphophyllum*

Stipe

Stipes of the studied species have a longitudinal groove on adaxial surface. Generally, they are stramineous to brown. The surface of stipes are normally glabrous, except in *D. polypodioides* which having prickly surface due to scars of fallen scales. The lower portion of stipes usually bearing the same types of scales that cover the rhizome.

Frond

Fronds are monomorphic in all studied species, they vary in shape and size. Laminae are either a simple or unipinnate or bipinnate. The simple fronds are found in 3

species, namely *D. cordifolium*, *D. subserratum* and *D. subsinuatum*. The unipinnate fronds are found in 19 species, namely *D. bantamense*, *D. crenato-serratum*, *D. donianum*, *D. heterophlebium*, *D. lobatum*, *D. malaccense*, *D. megaphyllum*, *D. mettenianum*, *D. pallidum*, *D. petrii*, *D. prescottianum*, *D. proliferum*, *D. riparium*, *D. siamense*, *D. sorzogonense*, *D. subintegrum*, *D. sylvaticum*, *D. tomentosum* and *D. xiphophyllum*. The bipinnate fronds are found in 9 species, namely *D. conterminum*, *D. dilatatum*, *D. esculentum*, *D. griffithii, D. leptophyllum*, *D. muricatum*, *D. polypodioides*, *D. procumbens* and *D. taiwanense*.

Venation

The venation patterns of the studied *Diplazium* species are of two types, i.e. free and anastomosing veins. The free veins are observed in 25 species, i.e. *D. bantamense*, *D. conterminum*, *D. crenato-serratum*, *D. dilatatum*, *D. donianum*, *D. griffithii*, *D. leptophyllum*, *D. lobatum*, *D. malaccense*, *D. megaphyllum*, *D. mettenianum*, *D. muricatum*, *D. pallidum*, *D. petrii*, *D. polypodioides*, *D. prescottianum*, *D. procumbens*, *D. siamense*, *D. sorzogonense*, *D. subintegrum*, *D. subserratum*, *D. subsinuatum*, *D. sylvaticum*, *D. taiwanense* and *D. tomentosum*. While the anastomosing veins are presented in 6 species, i.e. *D. cordifolium*, *D. esculentum*, *D. heterophlebium*, *D. proliferum*, *D. riparium* and *D. xiphophyllum*.

Sori

Sori of the 31 *Diplazium* species are elongate along both sides of veinlets (diplazoid) or only on acroscopic side, they are covered with thin indusia. The shape of sori are usaually linear but 2 species, namely *D. conterminum* and *D. muricatum* have oblong sori.

Table 2.2 Morphological characters of *Diplazium*.

No.	Species	Rhizome	Scales margin	Scales shape	Scales color	Stipes surface	Larminar shape	Venation	Sori shape
1.	*D. bantamense* Blume	erect	toothed	narrowly lanceolate	black margin	glabrous	imparipinnate	free	linear
2.	*D. conterminum* Christ	creeping	toothed	linear long tail	black margin	glabrous	bipinnate	free	oblong
3.	*D. cordifolium* Blume	erect	entire	narrowly lanceolate	black margin	glabrous	simple	anastomosing	linear
4.	*D. crenato-serratum* (Blume) T. Moore	erect	toothed	narrowly lanceolate	concolorous	glabrous	unipinnate	free	linear
5.	*D. dilatatum* Blume	erect	toothed	linear long tail	black margin	glabrous	bipinnate	free	linear
6.	D. donianum (Mett.) Tardieu	creeping	toothed	narrowly lanceolate	black margin	glabrous	imparipinnate	free	linear
7.	*D. esculentum* (Retz.) Sw.	erect	toothed	linear long tail	black margin	glabrous	bipinnate	anastomosing	linear
8.	*D. griffithii* T. Moore	creeping	toothed	narrowly lanceolate	black margin	glabrous	bipinnate	free	linear
9.	*D. heterophlebium* (Mett. ex Baker) Diels	erect	entire	ovate long tail	concolorous	glabrous	unipinnate	anastomosing	linear
10.	*D. leptophyllum* Christ	creeping	entire	linear long tail	concolorous	glabrous	bipinnate	free	linear
11.	*D. lobatum* (Tagawa) Tagawa	creeping	toothed	narrowly lanceolate	concolorous	glabrous	imparipinnate	free	linear
12.	*D. malaccense* C. Presl	erect	entire	linaer long tail	concolorous	glabrous	unipinnate	free	linear
13.	*D. megaphyllum* (Baker) Christ	erect	toothed	lanceolate	black margin	glabrous	imparipinnate	free	linear
14.	*D. mettenianum* (Miq.) C. Chr.	creeping	toothed	narrowly lanceolate	concolorous	glabrous	unipinnate	free	linear
15.	*D. muricatum* (Mett.) Alderw.	erect	toothed	linear long tail	concolorous	glabrous	bipinnate	free	oblong
16.	*D. pallidum* (Blume) T. Moore	erect	entire	linear long tail	concolorous	glabrous	imparipinnate	free	linear
17.	*D. petrii* Tardieu	creeping	toothed	linear long tail	concolorous	glabrous	unipinnate	free	linear
18.	*D. polypodioides* Blume	erect	toothed	linear long tail	black margin	prickly	bipinnate	free	linear

Table 2.2 Morphological characters of *Diplazium*. (Continued)

No.	Species	Rhizome	Scales margin	Scales shape	Scales color	Stipes surface	Larminar shape	Venation	Sori
19	*D. prescottianum* (Wall. ex Hook.) T. Moore	erect	entire	narrowly lanceolate	concolorous	glabrous	unipinnate	free	linear
20.	*D. procumbens* Holttum	creeping	toothed	narrowly lanceolate	concolorous	glabrous	bipinnate	free	linear
21.	*D. proliferum* (Lam.) Kaulf.	erect	toothed	narrowly lanceolate	concolorous	glabrous	imparipinnate	anastomosing	linear
22.	*D. riparium* Holttum	erect	entire	narrowly lanceolate	concolorous	glabrous	imparipinnate	anastomosing	linear
23.	*D. siamense* C. Chr.	erect	toothed	linear long tail	black margin	glabrous	unipinnate	free	linear
24.	*D. sorzogonense* (C. Presl) C. Presl	erect	toothed	narrowly lanceolate	black margin	glabrous	unipinnate	free	linear
25.	*D. subintegrum* Holttum	erect	entire	lanceolate long tail	concolorous	glabrous	imparipinnate	free	linear
26.	*D. subserratum* Blume	erect	toothed	subtriangular	concolorous	glabrous	simple	free	linear
27.	*D. subsinuatum* (Wall. ex Hook. & Grev.) Tagawa	creeping	entire	narrowly lanceolate	concolorous	glabrous	simple	free	linear
28.	*D. sylvaticum* (Bory) Sw.	erect	toothed	linear long tail	concolorous	glabrous	unipinnate	free	linear
29.	*D. taiwanense* Tagawa	ascending	toothed	linear long tail	concolorous	glabrous	bipinnate	free	linear
30.	*D. tomentosum* Blume	erect	entire	lanceolate long tail	concolorous	glabrous	unipinnate	free	linear
31.	*D. xiphophyllum* (Baker) C. Chr.	erect	entire	lanceolate long tail	concolorous	glabrous	imparipinnate	anastomosing	linear

2.3.2 Anatomy of stipes

Studying the x-section of stipes of the *Diplazium* species revealed that there are several layers of schlerenchyma below the epidermis and the vascular strand are observed near the center of the stipe. The vascular strands are concentric, it is defined as amphicribal vascular bundle (Dickison, 2000), which consists of a central strip of xylem surrounded by phloem. The vascular bundle is embedded within ground parenchymatous tissue.

The vascular structure of stipes of the *Diplazium* in this study shows a variable forms and they can be classified into 4 groups, i.e. U-shaped, V-shaped, W-shaped and two-vascular-bundles groups (Figures 2.4-2.8; Table 2.3).

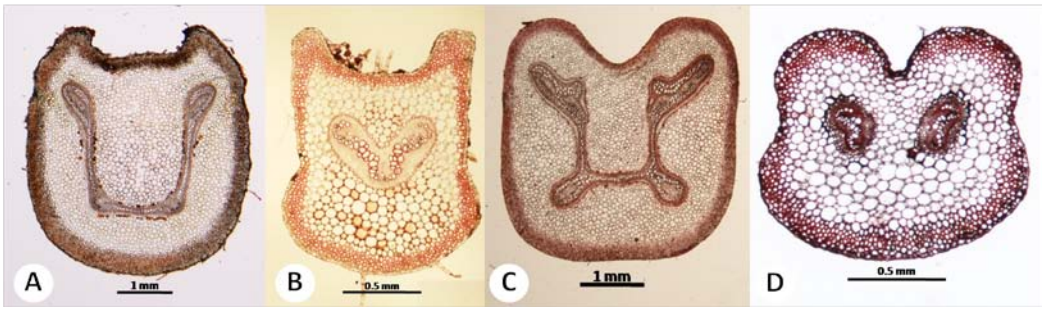

Figure 2.4 Stipes anatomy of the *Diplazium*. A: U-shaped group; B: V-shaped group; C: W-shaped group and D: two-vascular-bundles group.

Group 1. U-shaped group

There are 17 species having U-shaped vascular bundle, i.e. *D. bantamense*, *D. conterminum*, *D. dilatatum*, *D. donianum*, *D. griffithii*, *D. heterophlebium*, *D. leptophyllum*, *D. lobatum*, *D. malaccense*, *D. megaphyllum*, *D. mettenianum*, *D. muricatum*, *D. pallidum*, *D. siamense*, *D. sorzogonense*, *D. subintegrum* and *D. xiphophyllum*.

Group 2. V-shaped group

Six species, namely *D. cordifolium*, *D. crenato-serratum*, *D. petrii*, *D. riparium*, *D. sylvaticum* and *D. tomentosum* are belonged to this group.

Group 3. W-shaped group

Diplazium esculentum is the only species having W-shaped vascular strand.

Group 4. Two-vascular-bundles group

Diplazium subserratum and *D. subsinuatum* are the 2 species obtaining two separated vascular bundles at upper portion of stipe.

Table 2.3 Stomatal type and shape of vascular bundle. A: polocytic type; B: copolocytic type; U: U-shaped group; V: V-shaped group; W: W-shaped group; TWO: two vascular bundles group.

No.	Species	stomatal type	shape of vascular bundle
1.	*D. bantamense* Blume	A, B	U
2.	*D. conterminum* Christ	A, B	U
3.	*D. cordifolium* Blume	A, B	V
4.	*D. crenato-serratum* (Blume) T. Moore	A, B	V
5.	*D. dilatatum* Blume	A, B	U
6.	*D. donianum* (Mett.) Tardieu	A, B	U
7.	*D. esculentum* (Retz.) Sw.	A, B	W
8.	*D. griffithii* T. Moore	A, B	U
9.	*D. heterophlebium* (Mett. ex Baker) Diels	A, B	U
10.	*D. lobatum* (Tagawa) Tagawa	A, B	U
11.	*D. malaccense* C. Presl	A, B	U
12.	*D. megaphyllum* (Baker) Christ	A, B	U
13.	*D. mettenianum* (Miq.) C. Chr.	A, B	U
14.	*D. muricatum* (Mett.) Alderw.	A, B	U
15.	*D. pallidum* (Blume) T. Moore	A, B	U
16.	*D. petrii* Tardieu	A, B	U
17.	*D. polypodioides* Blume	A, B	U
18.	*D. proliferum* (Lam.) Kaulf.	A, B	-
19.	*D. riparium* Holttum	A, B	V
20.	*D. siamense* C. Chr.	A, B	U
21.	*D. sorzogonense* (C.Presl) C. Presl	A, B	U
22.	*D. subintegrum* Holttum	A, B	U
23.	*D. subserratum* Blume	A, B	TWO
24.	*D. subsinuatum* (Wall. ex Hook. & Grev.) Tagawa	A, B	TWO
25.	*D. sylvaticum* (Bory) Sw.	A, B	V
26.	*D. tomentosum* Blume	A, B	V
27.	*D. xiphophyllum* (Baker) C. Chr.	A, B	U

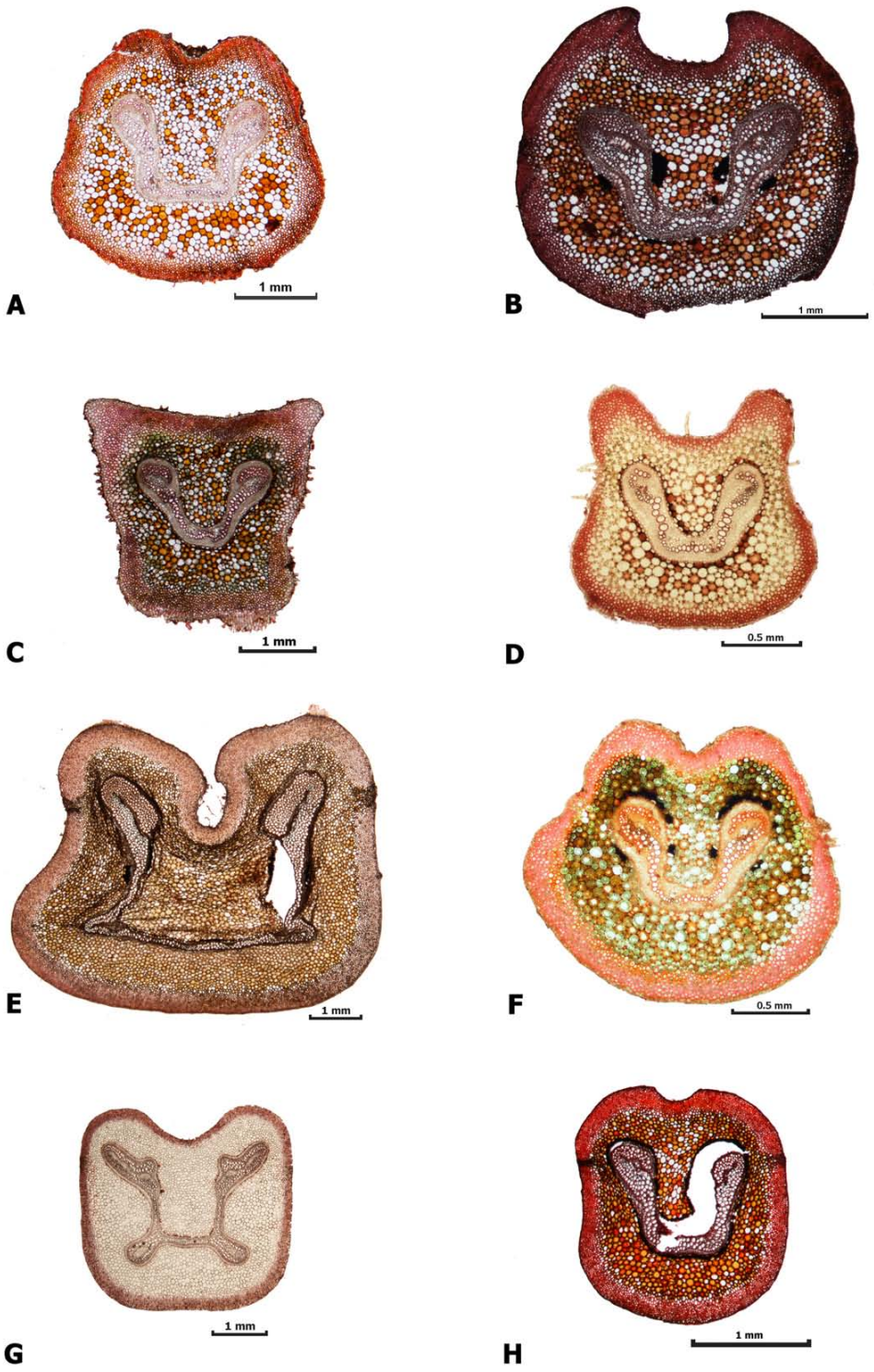

Figure 2.5 X-section of stipes of *Diplazium*. A: *D. bantamense*; B: *D. conterminum*; C: *D. cordifolium*; D: *D. crenato-serratum*; E: *D. dilatatum*; F: *D. donianum*; G: *D. esculentum* and H: *D. griffithii*.

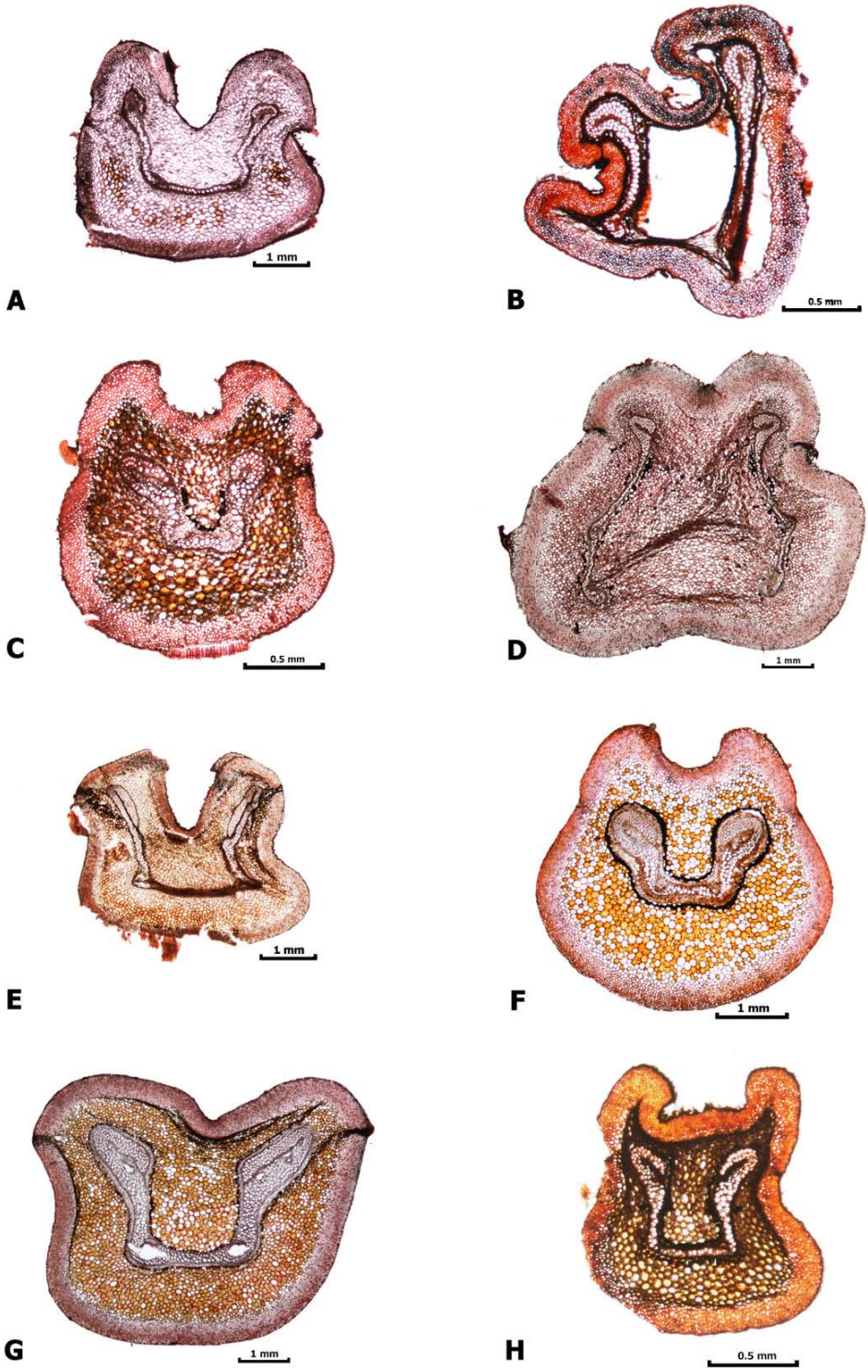

Figure 2.6 X-section of stipes of *Diplazium*. A: *D. heterophlebium*; B: *D. lobatum*; C: *D. malaccense*; D: *D. megaphyllum*; E: *D. mettenianum*; F: *D. muricatum*; G: *D. pallidum* and H: *D. petrii*.

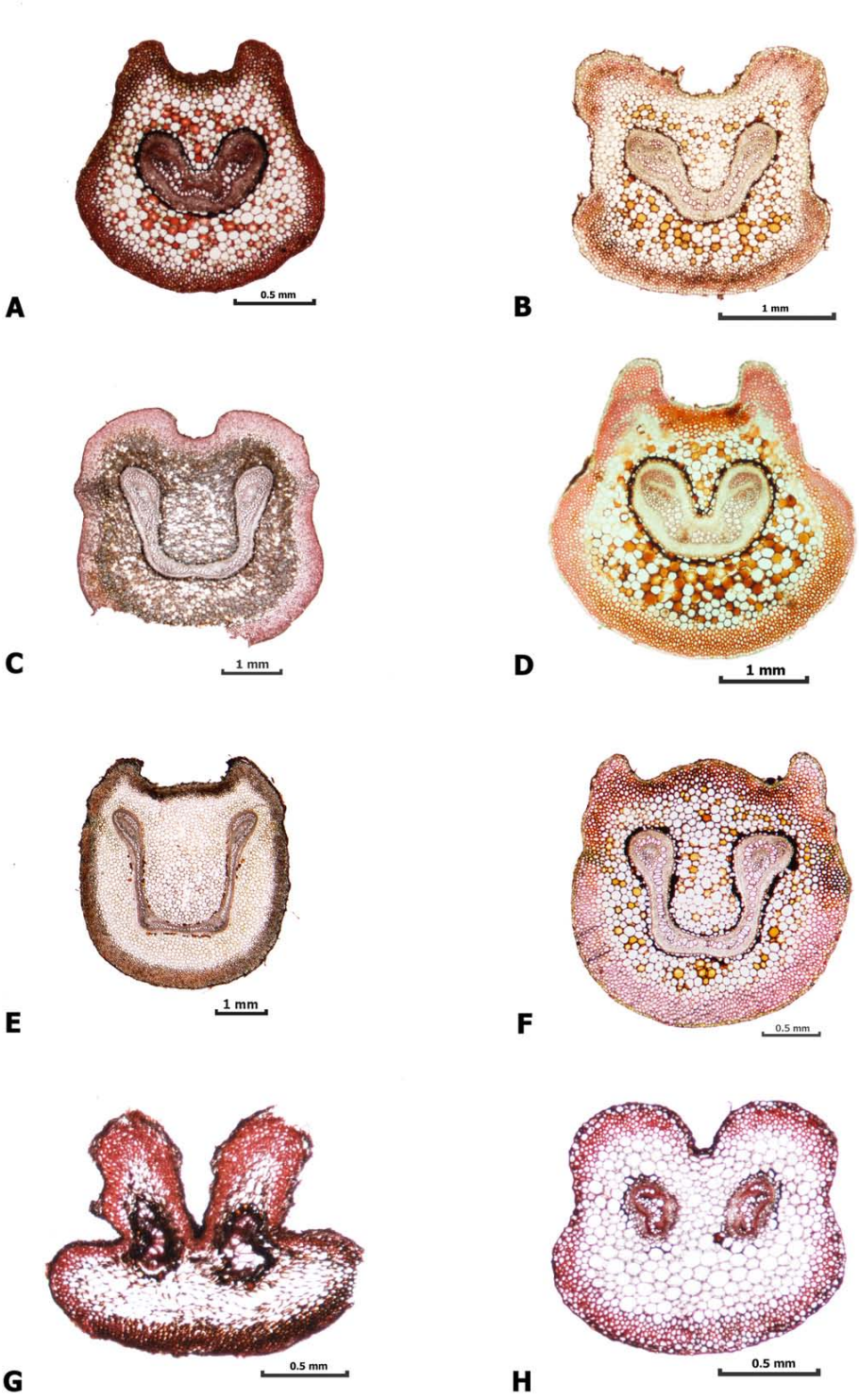

Figure 2.7 X-section of stipes of *Diplazium*. A: *D. polypodioides*; B: *D. riparium*; C: *D. siamense*; D: *D. sylvaticum*; E: *D. sorzogonense*; F: *D. subintegrum*; G: *D. subserratum* and H: *D. subsinuatum*.

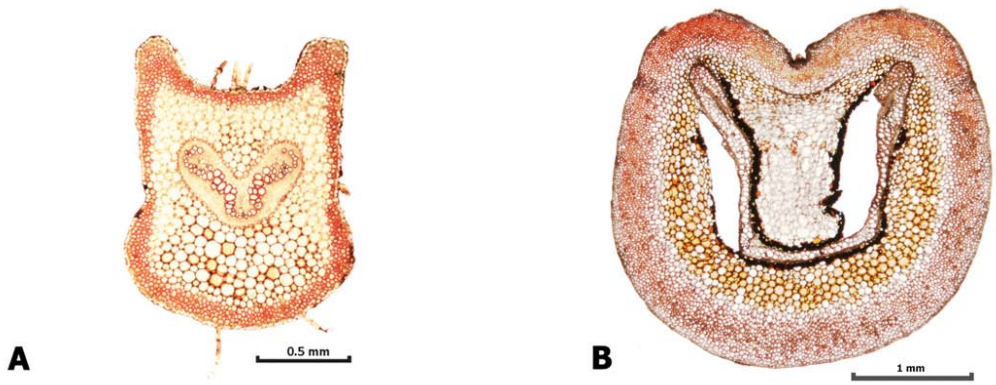

Figure 2.8 X-section of stipes of *Diplazium*. A: *D. tomentosum* and B: *D. xiphophyllum*.

3.2.3 Epidermal study

- Distribution of stomata

All the studied species have stomata only on abaxial surface (hypostomatous).

- Stomatal type

All of the studied species have two stomatal types, i.e. polocytic and copolocytic, on each lamina (Table 2.3; Figure 2.10-12).

The polocytic type: guard cells are surrounded by a single U-shape or horseshoe-shape of subsidiary cell (Figure 2.9 A).

The copolocytic type: guard cells are surrounded by U-shape or horseshoe-shape of subsidiary cells and subsidiary cells are surrounded by U-shape of epidermal cell (Figure 2.9 B).

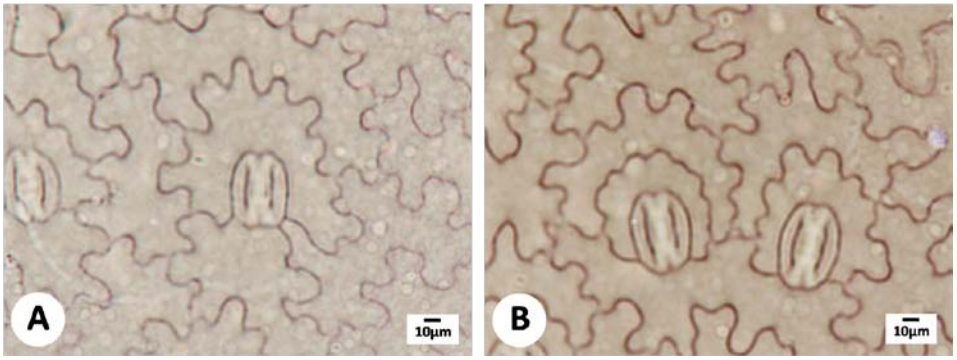

Figure 2.9 Stomatal type of the Thai *Diplazium*; A: polocytic, B: copolocytic.

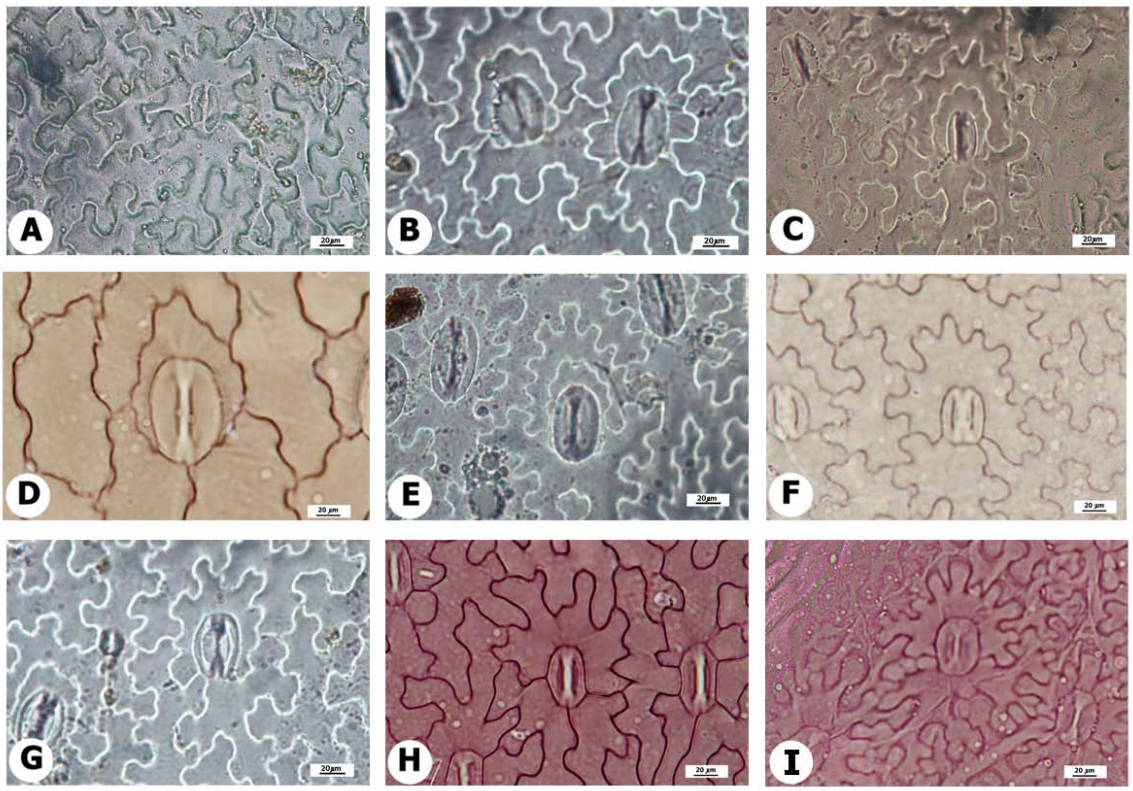

Figure 2.10 Stomatal structure of *Diplazium*. A: *D. proliferum*; B: *D. bantamense*; C: *D. conterminum*; D: *D. cordifolium*; E: *D. crenato-serratum*; F: *D. dilatatum*; G: *D. donianum*; H: *D. esculentum* and I: *D. griffithii*.

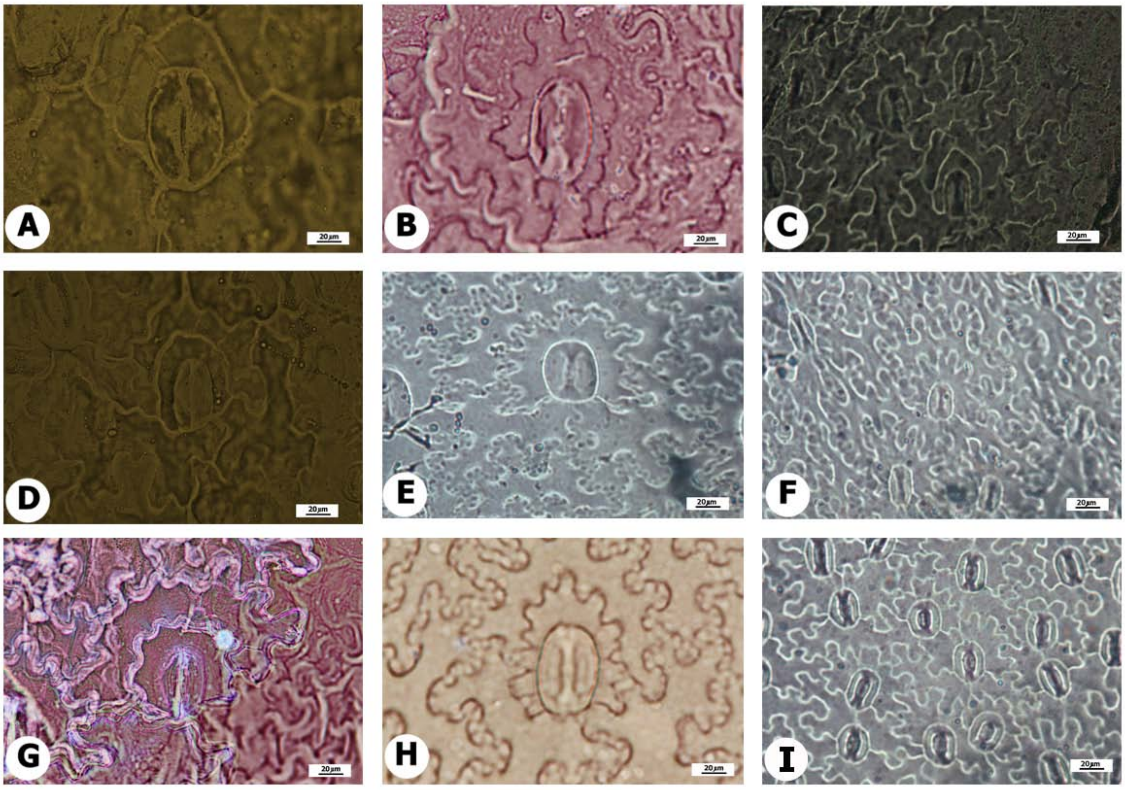

Figure 2.11 Stomatal structure of *Diplazium*. A: *D. heterophlebium*; B: *D. lobatum*; C: *D. malaccense*; D: *D. megaphyllum*; E: *D. mettenianum*; F: *D. muricatum*; G: *D. pallidum*; H: *D. petrii* and I: *D. polypodioides*.

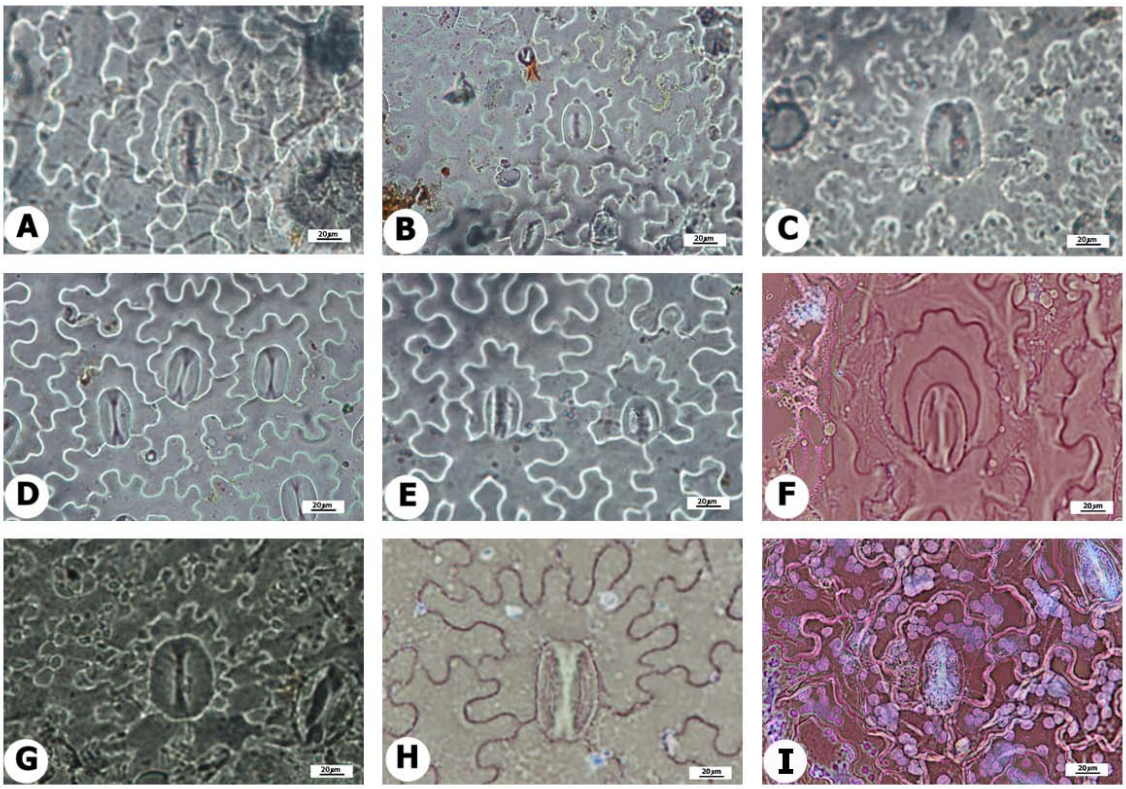

Figure 2.12 Stomatal structure of *Diplazium*. A: *D. riparium*; B: *D. siamense*; C: *D. sylvaticum*; D: *D. sorzogonense*; E: *D. subintegrum*; F: *D. subserratum*; G: *D. subsinuatum*; H: *D. tomentosum* and I: *D. xiphophyllum*.

2.4 Discussion and Conclusion

2.4.1 Gross morphology

All of morphological characters of the *Diplazium* species in this study can be used for species determination as well as for the key constructions. For example, *D. polypodioides* and *D. muricatum* are difficult to distinguish in the field, they have erect rhizome and bipinnate frond. It is found form this study that *D. polypodioides* has prickly stipes while *D. muricatum* has glabrous stipe. Previously, Holttum (1940) pointed out the important of scales in species determination. The *Diplazium* usually have scales covering on the young part of rhizome and lower portion of stipes. Sometimes they can be found on the costa, but usually smaller in size than the one on the rhizome or stipes.

It was found from this study that scales of the *Diplazium* species can be divided into 4 types, i.e. toothed and black-margined scale, toothed and concolorous scale, entire and concolorous scale and entire and black margin scale which are important characters and can be used for species determination.

2.4.2 Anatomy of stipes

In general, the *Diplazium* species have two vascular strands at lower portion of stipes. They are extending upward alongside to the lamina base. It was found from this study that the two strands may combine together forming a single V, U or W shaped vascular strand as can be seen from the cross-section (Fig. 2.4). However, some species may have two free vascular strands throughout their stipe length. The results of the present study corresponded with the study of Ogura (1927) who studied leaf of *Diplazium esculentum* (Retz.) Sw., Bir (1969) who studied *Diplazium latifolium* and Kato (1977) who studied anatomy of *Athyrium* and allied genera (including *Diplazium*) of Japan. The result of these three studies are the same which showed that *Diplazium* have the U or V-shape vascular bundle in the stipes. However, it is the first report from this study that there occur a W-shaped vascular strand and two free vascular-bundles in the upper portion of stipes in the genus *Diplazium*.

Smith (1976) studied morphology of *Diplazium* and *Asplenium*. He noted that the vascular structure of stipes in these two genera are different. *Diplazium* has U or V-shape, but *Asplenium* has X-shaped in cross-section. It can be concluded that the anatomy of stipes are useful characters in species determination of the *Diplazium* species.

2.4.3 Epidermal study

All of the *Diplazium* species in this study have stomata only on abaxial surface. This result corresponded with Cotthem (1970) who studied 6 species of *Diplazium*, i.e. *D. cordifolium Blume*, *D. dilatatum* Blume, *D. latisquamatum* Holttum, *D. montanum* van Aldrew., *D. simplicivenium* Holttum and *D. thelypteroides* (Michx) C. Presl. So it can be concluded that *Diplazium* are hypostomatous species which is the most common feature in vascular plant (Simpson, 2010).

The stomatal types of the *Diplazium* species in this study corresponded with Sen and De (1992) who studies structure and ontogeny of stomata in ferns which included 3 species of *Diplazium*, i.e. *D. esculentum* (Retz.) Sw., *D. polypodioides* Blume and *D. proliferum* (Lam.) Kaulf. These 3 species have both polocytic and copolocytic stomata. It was found from this study that the stomatal types of *Diplazium* are not specific in each species, two stomatal types can be observed in the same species and the other group of ferns, for example *Microsorum punctatum* (L.) Copel. Complex which was studied by Petchsri (2007). He studied epidermal character of this fern group. The results showed that *Microsorum punctatum* and its related species have both polocytic and copolocytic stomata. Moreover, these two stomatal types can be observed in the other fern families.

Sen and De (1992) study structure and ontogeny of stomata in 22 families of ferns. The result showed that the polocytic and copolocytic stomata are found in 16 families, for example Adiantaceae, Aspleniaceae, Blechnaceae, Davalliaceae and Polypodiaceae, etc. It is also found in Cyatheaceae, Denstaedtiaceae, Dicksoniaceae and Pteridaceae (Thurston, 1969). So, stomatal types in ferns are not suitable character to be used in species determination. In contrast, in certain flowering plant genera, for example *Vernonia* (Asteraceae) (Adedeji and Jewoola, 2008), *Vatica* (Dipterocapaceae) (Srinual, 2009), stomatal types are good taxonomic character.

CHAPTER III

PALYNOLOGICAL STUDY

3.1 Introduction

Palynology is the study of pollen and spores (Hyde and Williams, 1944). Spores and pollens have a number of morphological and ultrastructural features. These palynological features have provided a set of characters that are important for inferring polygenetic relationship of plant. In addition, the features of spores and pollens can often be used to indentify a particular plant taxon (Simpson, 2010).

Pteridophyte spores have actually been an object of study for over a century, but many of the earlier papers are overlooked or ignored (Erdtman, 1971; Warren and Wagner, 1974). The development of the compound microscope in the mid-17th century and the scanning electron microscope (SEM) in 1942, promoted pollen and spore morphological studies, especially at the species level (Devi, 1977; Bogner, 2007). It has played an important role in the studies of fern classification and phylogeny (Liu et al, 2000).

3.2 Spore morphological works on *Diplazium*

Devi (1977) explored spore morphology of 11 Indian ferns species, i.e. *D. asperum* Blume, *D. bantanense* Blume, *D. bellum* C.B. Clarke, *D. dilatitum* Blume, *D. esculentum* (Retz.) Sw., *D. japonicum* (Thubg.) Bedd., *D. hachijoense* Nakai, *D. nipponicum* Tagawa, *D. okudairai* Makino, *D. polypodioides* Blume and *D. wichurae* Mett. using only light miscoscope. It was found that the spores of *Diplazium* are monolete, bilateral and plano-convex in lateral view. Perine is often smooth or sometime absent. Tryon and Lugardon (1990) used SEM for studying spores of 32 species of

Diplazium from herbarium specimens mainly deposited in the Harvard University Herbarium and the other herbaria in Europe. They found that spores are monolete and having 32-55 μm in size. Spore shape is ellipsoidal and surface usually wing-like folds. Ohta and Takamiya (1999) used spore morphology characters that observed by using SEM to distinquish *Diplazium griffithii* from other species in the *Diplazium mettenianum* complex. By the surface ornamentation of perispores was low rugate. Rugae were discontinuous, while they were continuous in the other species.

Lui, Kuo and Lui (2000) studies Spores of fern Genera Athyrioids in Taiwan by using the scanning electron microscope (SEM). The spores of fifty-six were examined. The result of this work showed the number of *Diplazium* species are 21 species, some of its also found in Thailand can be divided in to 6 type, i.e. baculate type, echinate type, reticulate type, rugate-retate type, postulate type and bacillate-retate type.

3.2 Materials and Methods

3.2.1 Plant materials

Spores were collected from the presented herbarium specimens that deposited in Professor Kasin Suvathabhandhu Herbarium (BCU) and the forest Herbarium (BKF) (Table 3.1). Additional collections of *Diplazium*'s specimens were gathered from their natural habitats throughout Thailand.

3.2.2 Methods

Unacetolysed spores were examined by scanning electron Microscope (SEM), model JEOL JSM-5410 LV and the light microscope, model Olympus CH30. Then the SEM micrographs were taken with 1,500 to 3,500 magnification at 15 kV and the light micrographs were taken from Olympus CH30.

The spore morphological observations were focused on shape, size and wall ornamentation. The size of spores were measured on both equatorial (E) and polar (P) view. The terminology of spore ornamentation followed Punt (2007) and Tryon and Lugardon (1990).

Table 3.1 The specimens of *Diplazium* for palynological study.

SPECIES	SPECIMENS (HERBARIUM)
Diplazium bantamense Blume	P. Pongkai 32, 33 (BCU); Taam, Y.W. 1030 (BKF)
Diplazium conterminum Christ	P. Pongkai 15 (BCU); T. Shimizu et al. T11603 (BKF)
Diplazium cordifolium Blume	P. Pongkai 34, 37 (BCU); E. Hennipman 3815 (BKF)
Diplazium crenato-serratum (Blume) T. Moore	P. Pongkai 27, 40, 46 (BCU); K. larsen 1783 (BKF)
Diplazium dilatatum Blume	P. Pongkai 13,14 (BCU); T. Boonkerd 1245 (BCU); M. Takawa T8608 (BKF)
Diplazium donianum (Mett.) Tardieu	P. Pongkai 21, 22 (BCU); TBK, YSM and CSB 248 (BCU); Y. Yuyen 43 (BCU)
Diplazium esculentum (Retz.) Sw.	O. Neamsuvan 103 (BCU); O. Ratana 25 (BCU)
Diplazium griffithii T. Moore	T. Boonkerd 492, 1330 (BCU); E. Hennipman 3041 (BKF)
Diplazium heterophlebium (Mett. ex Baker) Diels	C. Phengklai et al. 10522 (BKF); E. Hennipman 3432 (BKF)
Diplazium leptophyllum Christ	J. F. Maxwell 93-771, 98-1444 (BKF); T. Shimizu and M. Hutoh 10210 (BKF)
Diplazium lobatum (Tagawa) Tagawa	Pteridophyte trip 72 (BCU); W.R. 29 (BCU)
Diplazium malaccense C.Presl	J. Middleton et.al. 138168 (BKF)
Diplazium megaphyllum (Baker) Christ	E. Hennipman et.al. 3064 (BKF)
Diplazium mettenianum (Miq.) C. Chr.	P. Pongkai 20, 23 (BCU); E. Hennipman 3691 (BKF)
Diplazium muricatum (Mett.) Alderw.	P. Pongkai 12 (BCU); CC. & CH. 329 (BKF)
Diplazium pallidum (Blume) T. Moore	E. Hennipman 3998 (BKF); Kai Larsen, T. Smitinand & E. Warncke 312 (BKF)

Table 3.1 The specimens of *Diplazium* for palynological study. (Continued)

SPECIES	SPECIMENS (HERBARIUM)
Diplazium petrii Tardieu	P. Pongkai 68, 69 (BCU); K. Iwastsuki et.al. T8387 (BKF)
Diplazium polypodioides Blume	P. Pongkai 5 (BCU); T. Vougthavone 153 (BKF)
Diplazium prescottianum (Wall. ex Hook.) T .Moore	Kai Larsen, T. Smitinand & W. Warncke 312 (BKF)
Diplazium procumbens Holttum	D. J. Middleton et.al. 1762 (BKF)
Diplazium proliferum (Lam.) Kaulf.	Charn Apasutaya 121a, 121b (BCU); H. Cuming 303 (BKF)
Diplazium riparium Holttum	P. Pongkai 45, 48 (BCU); T. Seelanan 3 (BCU)
Diplazium siamense C. Chr.	P. Pongkai 16 (BCU); K. Iwatsuki 4462 (BKF)
Diplazium sorzogonense (C. Presl) C. Presl	P. Pongkai 30 (BCU); D.J. Middleton et.al. 1429 (BKF)
Diplazium subintegrum Holttum	P. Pongkai 35 (BCU)
Diplazium subserratum Blume	G. Murata et.al. 49576 (BKF)
Diplazium subsinuatum (Wall. ex Hook. & Grev.) Tagawa	A. Sathapattayanon 576 (BCU); G. Murata et al. T49576 (BKF)
Diplazium sylvaticum (Bory) Sw.	P. Pongkai 18, 19 (BCU)
Diplazium taiwanense Tagawa	D. J. Middleton et al. 3772 (BKF)
Diplazium tomentosum Blume	P. Pongkai 31,38 (BCU); T. Boonkerd 330 (BCU)
Diplazium xiphophyllum (Baker) C. Chr.	D. J. Middleton et.al. 1682 (BKF); T. Smitinand 1003 (BKF)

3.3 Result

Spores morphology of 31 species of *Diplazium* in Thailand has been investigated by using the light microscope and the scanning electron Microscope (SEM). The result of this study shows that the spores of *Diplazium* are monolete, bilateral, kidney shape, 30-68 by 20-50 µm, concavo-convex to plano-convex and perispore is present in all species. (Table 3.3; Figure 3.1-3.4)

The spores ornamentation of 31 species of *Diplazium* can be divided in to 8 types base on their ornamentation. (Table 3.2)

1. Baculate type

Perispore includes the apex of baculate process, scattered around the spores. There is only one species, i.e. *D. subsinuatum*.

2. Echinate type

Perispore appears to be composed of dense several short spines, which united at the apex. There is only one species, i.e. *D. leptophyllum*.

3. Pustulate type

Perispore has scattered pustules around the spores. There is only one species, i.e. *Diplazium esculentum*.

4. Reticulate type

Perispore has many wing-like folds, the border of folds are sharp or fimbriate and are irregularly connected giving the appearance of a network. There are 3 species, i.e. *D. cordifolium, D. donianum* and *D. siamense*.

5. Rugate type

The surface of perispore is irregularly rugate. There is only one species, i.e. *D. subserratum*.

6. Rugate-Retate type

Perispore has rather low folds or ridges, ridges are smooth. This type is the largest one, there are 19 species namely, *D. bantamense*, *D. dilatatum, D. griffithii*, *D. heterophlebium*, *D. lobatum*, *D. malaccense*, *D. megaphyllum*, *D. mettenianum*, *D. muricatum*, *D. polypodioides*, *D. procumbens*, *D. proliferum, D. riparium*, *D. sorzogonense*, *D. subintegrum*, *D. sylvaticum*, *D. taiwanense*, *D. tomentosum,* and *D. xiphophyllum*.

7. Rugulate type

Perispore has low folds, sometimes having fimbriate surface, arranged in an irregular pattern. There are 4 species belong to this type, i.e. *D. conterminum*, *D. crenato-serratum*, *D. petrii* and *D. prescottianum*.

8. Smooth type

Perispore is smooth, There is only one species, i.e. *D. pallidum*.

3.4 Discussion and Conclusion

The spore of *Diplazium* 31 species are monolete, bilateral and the preispore present in all species which corresponded to the study by Tryon and Lugardon (1991). They reported the present of perispore of *Diplazium* 32 species. These characters indicate that the fern genus *Diplazium* are more derivative than other ferns, that having trilete and absent of perispore (Warren and Wagner, 1974; Devi, 1977).

Diplazium dilatatum and *D. polypodioides* have perispore with low folds or ridges, ridges are smooth. This result is corresponded to the study by Devi (1977). However, he reported the absent of perispore in *D. bantamense* and *D. esculentum*. But this study found the existence of perispore in *D. bantamense*, which belong to rugate-retate type. Likewise, spores of *D. esculentum* also bearing perispore which is belonged to pustulate type. The differences of Devi (1977) and the present study are

more or less from the spore preparation, because Devi (1977) treated spores with acetolysis method and the perispore may be vanished.

In comparison with a previous study by Lui (2000), 10 studied species of *Diplazium* (Table 3.2) are common with this study. Five species namely, *D. subsinuatum*, *D. esculentum*, *D. dilatatum*, *D. megaphyllum* and *D. mettenianum* have perispores which corresponds to this study. But Lui (2000) reported the presence of echinate type in *D. conterminum* and *D. taiwanense*, and the rugate-retate type in *D. donianum* and *D. petrii*. While the reticulate type was found in *D. lobatum*. His result is different from this study, which *D. conterminum* and *D. petrii* have perispore in rugulate type; while the perispore of *D. lobatum* and *D. taiwanense* are rugate-retate type and *D. donianum* has reticulate type of perispore. The difference of these two studies probably due to difference in identification of specimens.

Table 3.2 Comparison of spore ornamentation types by Lui, 2000 and this study.

SPECIES	ORNAMENTATION TYPE	
	This study	Lui, 2000
Diplazium conterminum Christ	rugulate	echinate
Diplazium dilatatum Blume	rugate-retate	rugate-retate
Diplazium donianum (Mett.) Tardieu	reticulate	rugate-retate
Diplazium esculentum (Retz.) Sw.	pustulate	pustulate
Diplazium lobatum (Tagawa) Tagawa	rugate-retate	reticulate
Diplazium megaphyllum (Baker) Christ	rugate-retate	rugate-retate
Diplazium mettenianum (Miq.) C.Chr.	rugate-retate	rugate-retate
Diplazium petri Tardieu	rugulate	rugate-retate
Diplazium subsinuatum (Wall. ex Hook. & Grev.) Tagawa	baculate	baculate
Diplazium taiwanense Tagawa	rugate-retate	echinate

So far, spore ornamentation of *Diplazium* can be used as a good character for supporting species determination in some species, such as *D. esculentum*, *D.*

leptophyllum, *D. pallidum*, *D. subserratum* and *D. subsinuatum*. Because, there is only one species in each type. So spore ornamentation is a useful character in identifying in species level.

Table 3.3 Spore size and ornamentation type in Thai *Diplazium*.

SPECIES	SIZE (E/P) in μm	ORNAMENTATION TYPE
Diplazium bantamense Blume	62.5-67.5 by 30-40	rugate-retate
Diplazium conterminum Christ	47.5-57.5 by 32.5-37.5	rugulate
Diplazium cordifolium Blume	47.5-50 by 35-45	reticulate
Diplazium crenato-serratum (Blume) T. Moore	35-37.5 by 20-22.5	rugulate
Diplazium dilatatum Blume	40.5-45 by 25-29.5	rugate-retate
Diplazium donianum (Mett.) Tardieu	55-72.5 by 35-50	reticulate
Diplazium esculentum (Retz.) Sw.	35-42.5 by 20-2.5	pustulate
Diplazium griffithii T.Moore	44-46.5 by 28-32	rugate-retate
Diplazium heterophlebium (Mett. ex Baker) Diels	60.5-62 by 36-40	rugate-retate
Diplazium leptophyllum Christ	30-37.5 by 17.5-20	echinate
Diplazium lobatum (Tagawa) Tagawa	61.5-63 by 31-32	rugate-retate
Diplazium malaccense C.Presl	32.5-35 by 20-22.5	rugate-retate
Diplazium megaphyllum (Baker) Christ	52.5-60 by 20-22.5	rugate-retate
Diplazium mettenianum (Miq.) C. Chr.	66-68 by 39-42	rugate-retate
Diplazium muricatum (Mett.) Alderw.	32.5-40 by 22.5-27.5	rugate-retate
Diplazium pallidum (Blume) T. Moore	59-65.6 by 35.5-38.5	smooth

Table 3.3 Spore size and ornamentation type in Thai *Diplazium*. (Continued)

SPECIES	SIZE IN µm (E/P)	ORNAMENTATION TYPE
Diplazium petrii Tardieu	30-42.5 by 20-22.5	rugulate
Diplazium polypodioides Blume	37.5-45 by 22.5-25	rugate-retate
Diplazium prescottianum (Wall. ex Hook.) T. Moore	40.5-43 by 23.5-25.5	rugulate
Diplazium procumbens Holttum	47.5-57.5 by 25-32.5	rugate-retate
Diplazium proliferum (Lam.) Kaulf.	49.5-51 by 31-35.5	rugate-retate
Diplazium riparium Holttum	42.5-50 by 25-30	rugate-retate
Diplazium siamense C. Chr.	35-40 by 22.5-27.5	reticulate
Diplazium sorzogonense (C.Presl) C. Presl	37.5-45 by 22.5-25	rugate-retate
Diplazium subintegrum Holttum	37.5-45 by 25-27.5	rugate-retate
Diplazium subserratum Blume	55.5-62 by 37.5-44.5	rugate
Diplazium subsinuatum (Wall. ex Hook. & Grev.) Tagawa	30-37.5 by 20-32.5	baculate
Diplazium sylvaticum (Bory) Sw.	56-60.5 by 32-40	rugate-retate
Diplazium taiwanense Tagawa	32.5-35 by 17.5-22.5	rugate-retate
Diplazium tomentosum Blume	30-34.5 by 24.5-26	rugate-retate
Diplazium xiphophyllum (Baker) C. Chr.	32.5-40 by 25.5 -27	rugate-retate

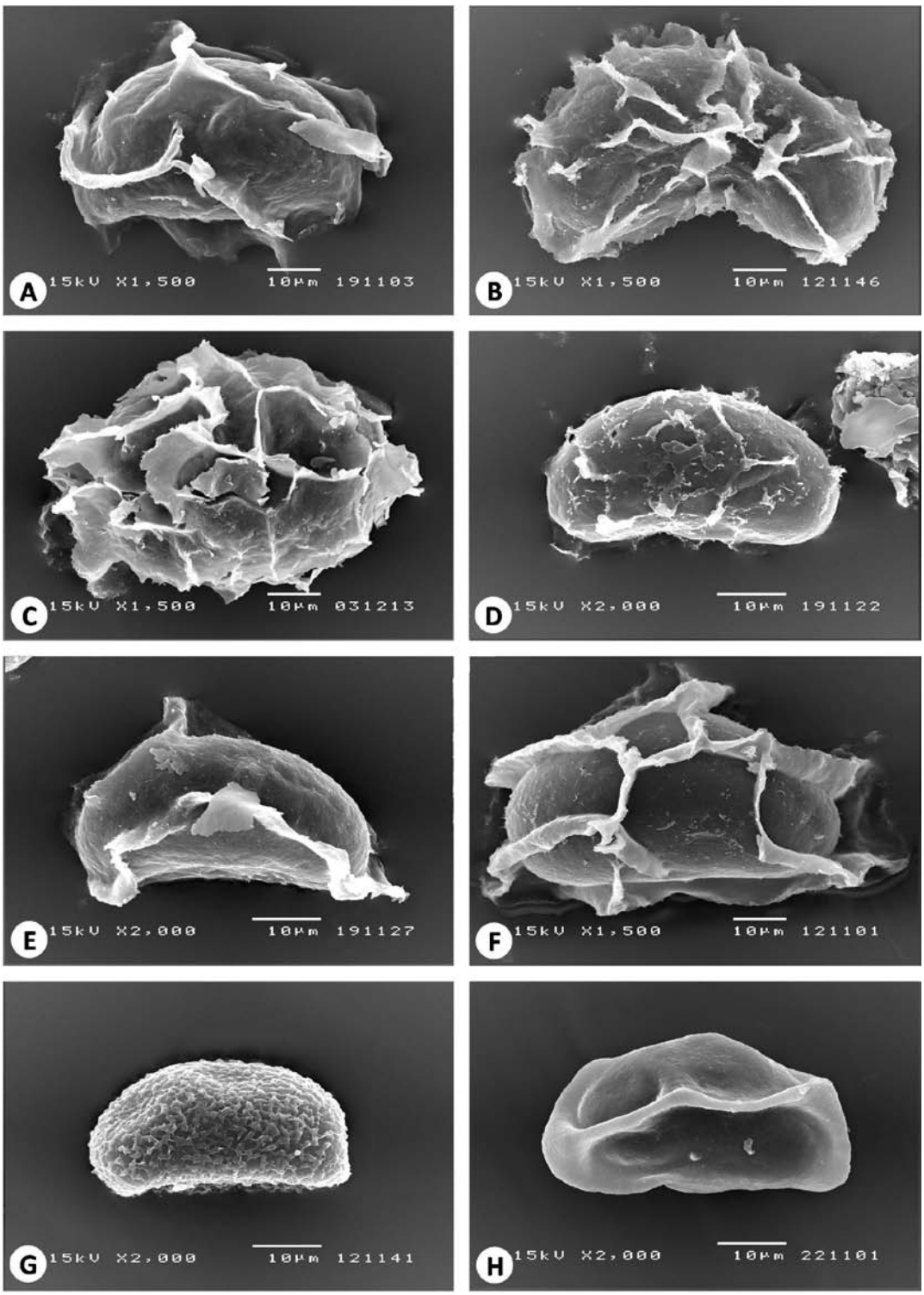

Figure 3.1 SEM micrographs of *Diplazium* spores. A: *D. bantamense*; B: *D. conterminum*; C: *D. cordifolium*; D: *D. crenato-serratum*; E: *D. dilatatum*; F: *D. donianum*; G: *D. esculentum* and H: *D. griffithii*.

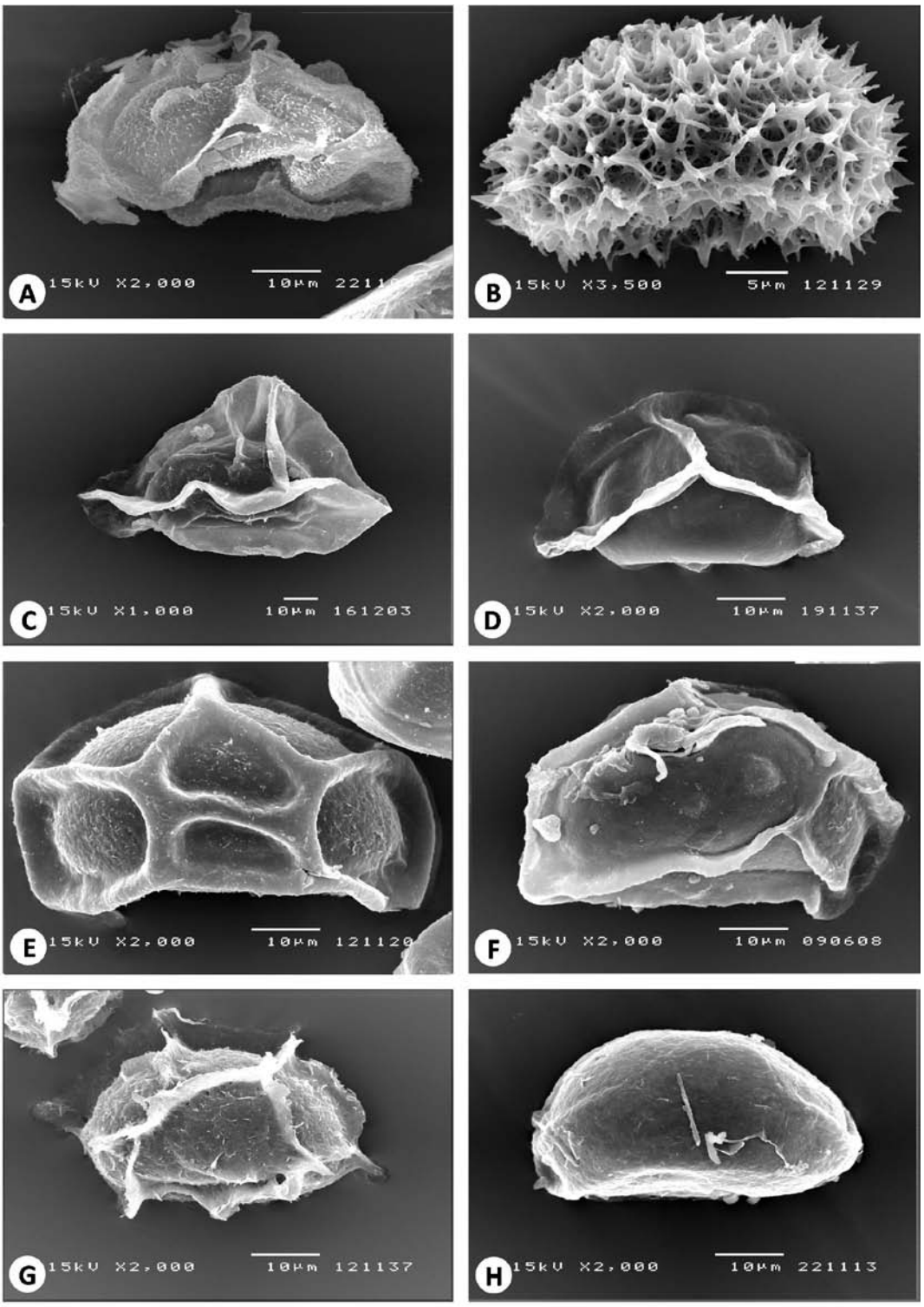

Figure 3.2 SEM micrographs of *Diplazium* spores. A: *D. heterophlebium*; B: *D. leptophyllum*; C: *D. lobatum*; D: *D. malaccense*; E: *D. megaphyllum*; F: *D. mettenianum*; G: *D. muricatum*; and H: *D. pallidum*.

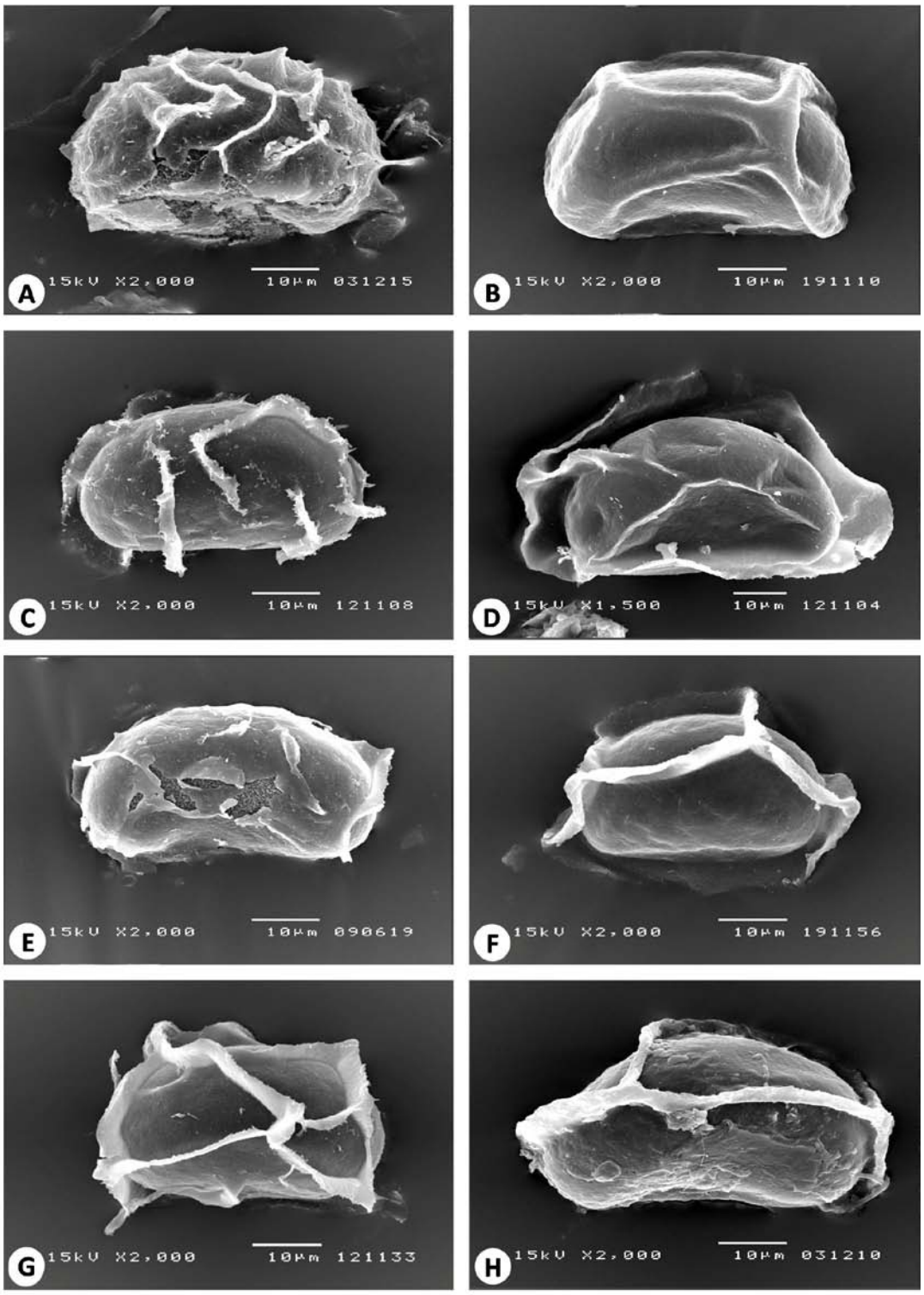

Figure 3.3 SEM micrographs of *Diplazium* spores. A: *D. petrii*; B: *D. polypodioides*; C: *D. prescottianum*; D: *D. procumbens*; E: *D. proliferum*; F: *D. riparium*; G: *D. siamense* and H: *D. sorzogonense.*

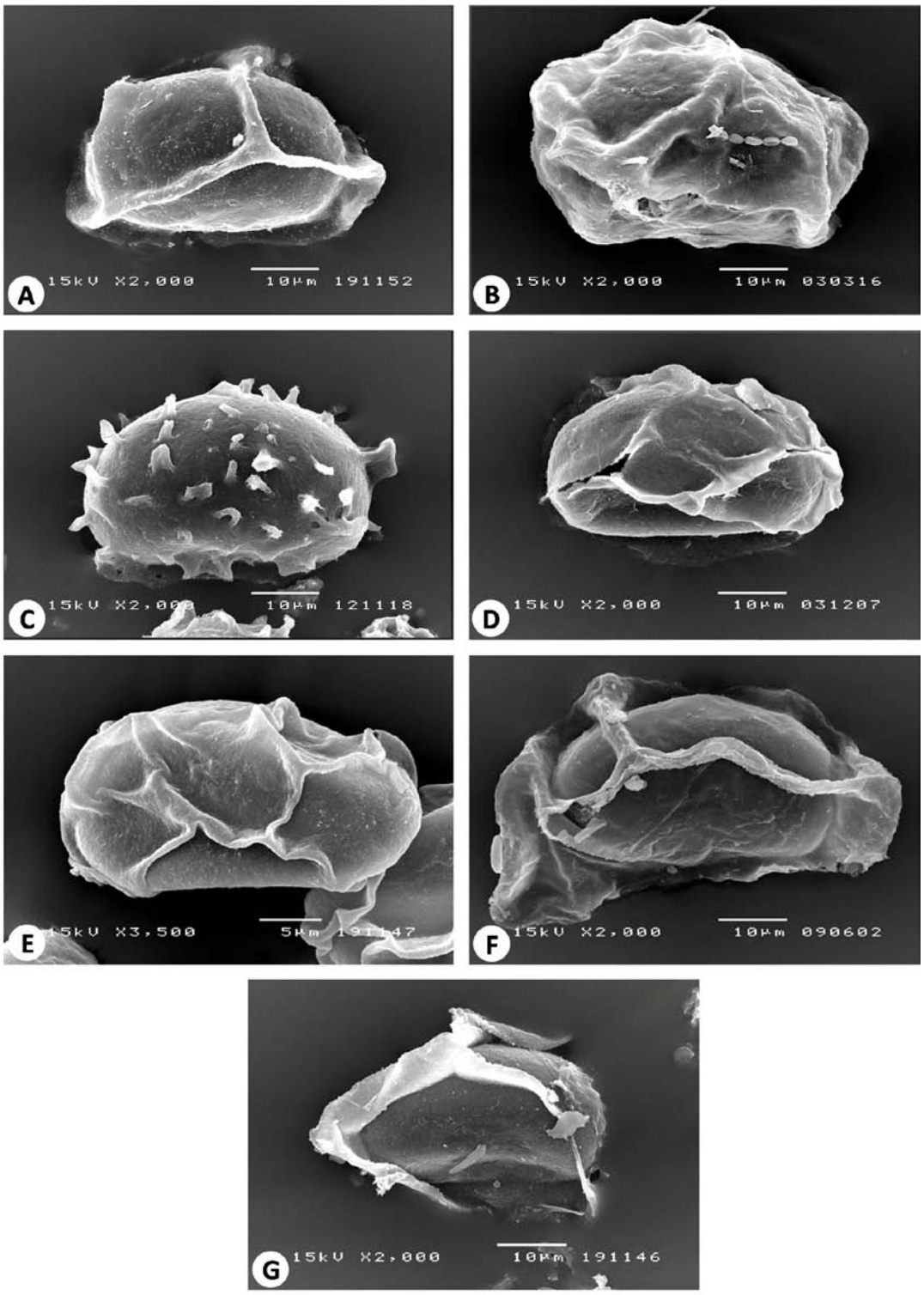

Figure 3.4 SEM micrographs of *Diplazium* spores. A: *D. subintegrum*; B: *D. subserratum*; C: *D. subsinuatum*; D: *D. sylvaticum*; E: *D. taiwanense*; F: *D. tomentosum* and G: *D. xiphophyllum*.

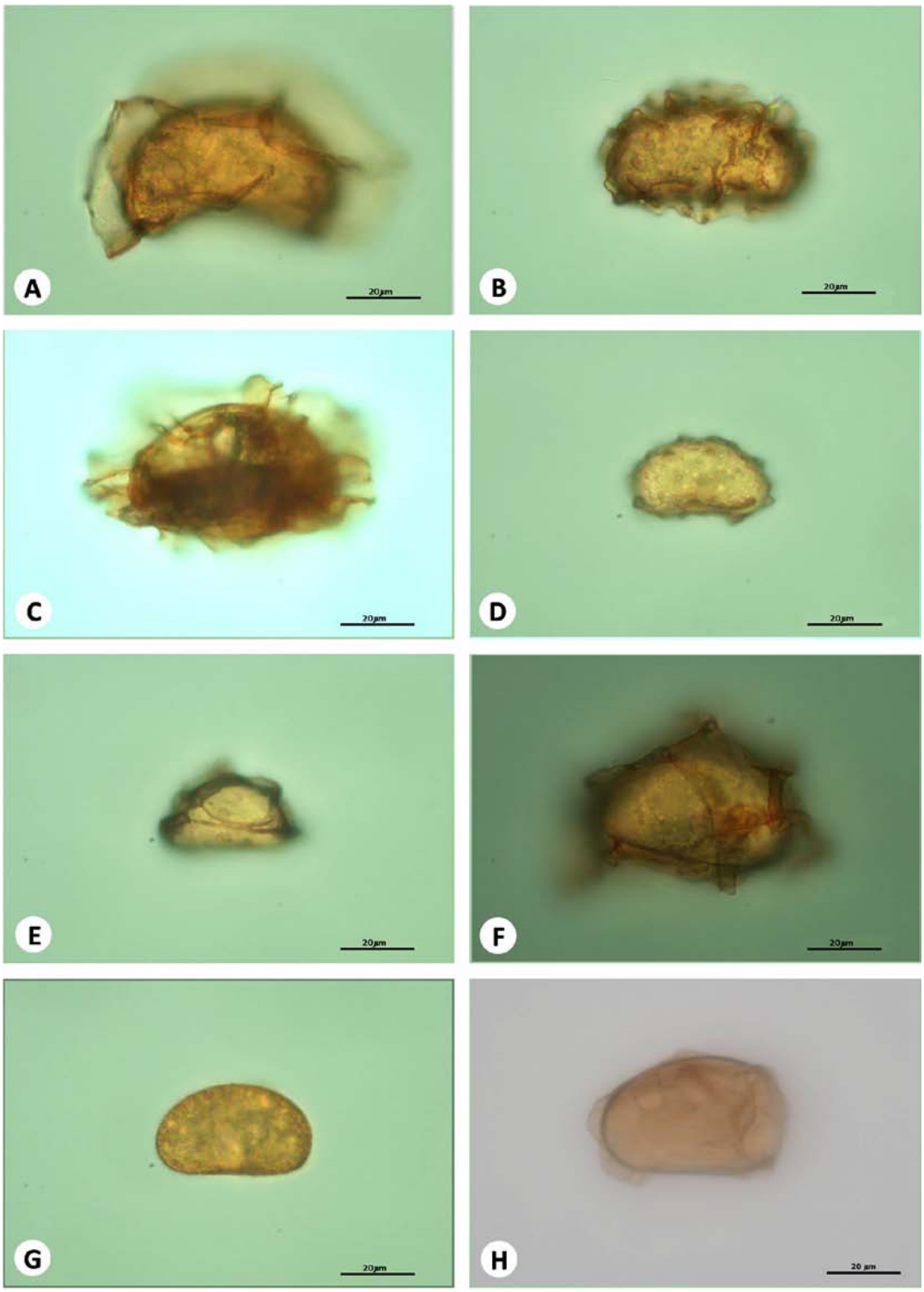

Figure 3.5 Light micrographs of *Diplazium* spores. A: *D. bantamense*; B: *D. conterminum*; C: *D. cordifolium*; D: *D. crenato-serratum*; E: *D. dilatatum*; F: *D. donianum*; G: *D. esculentum* and H: *D. griffithii*.

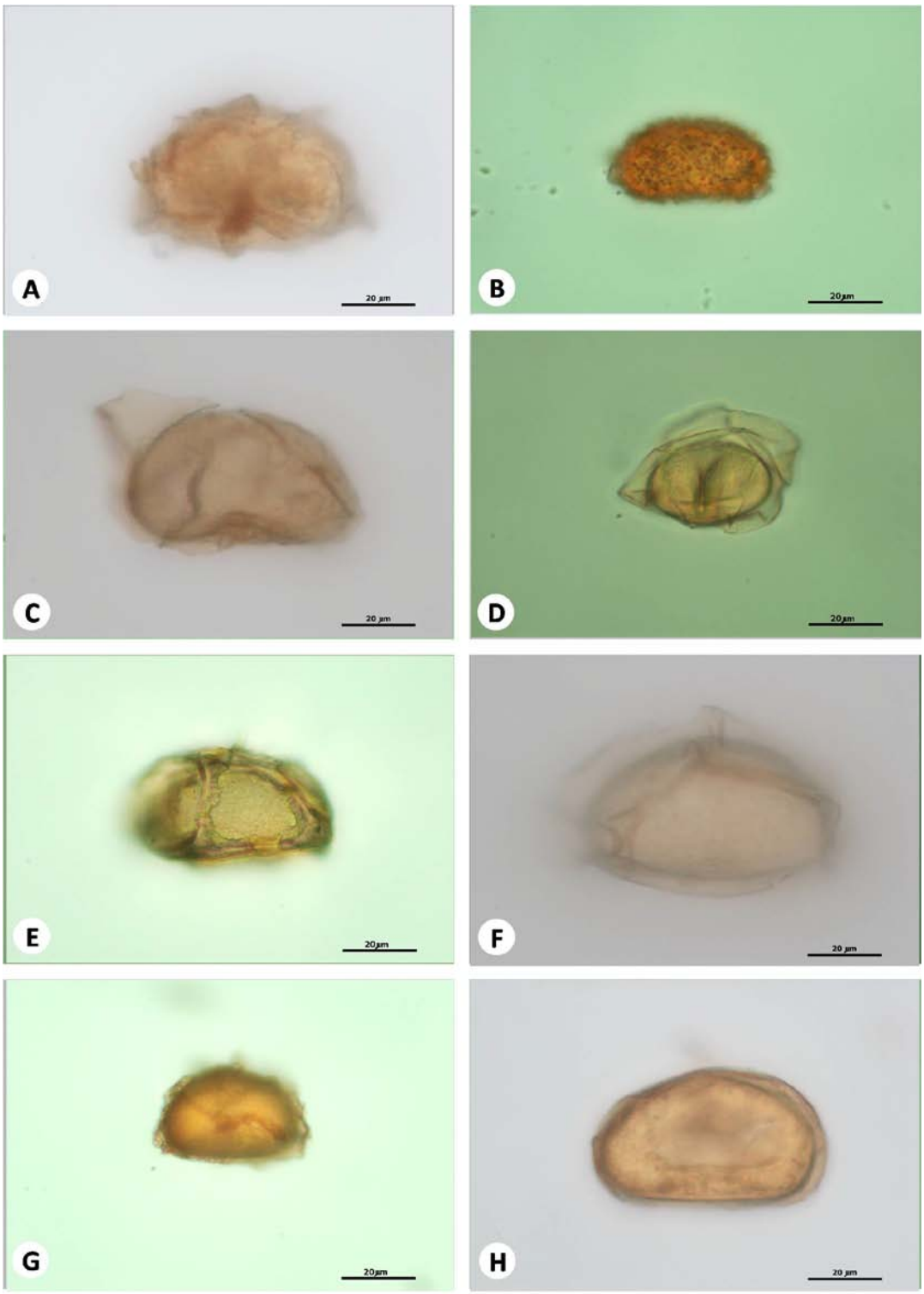

Figure 3.6 Light micrographs of *Diplazium* spores. A: *D. heterophlebium*; B: *D. leptophyllum*; C: *D. lobatum*; D: *D. malaccense*; E: *D. megaphyllum*; F: *D. mettenianum*; G: *D. muricatum*; and H: *D. pallidum*.

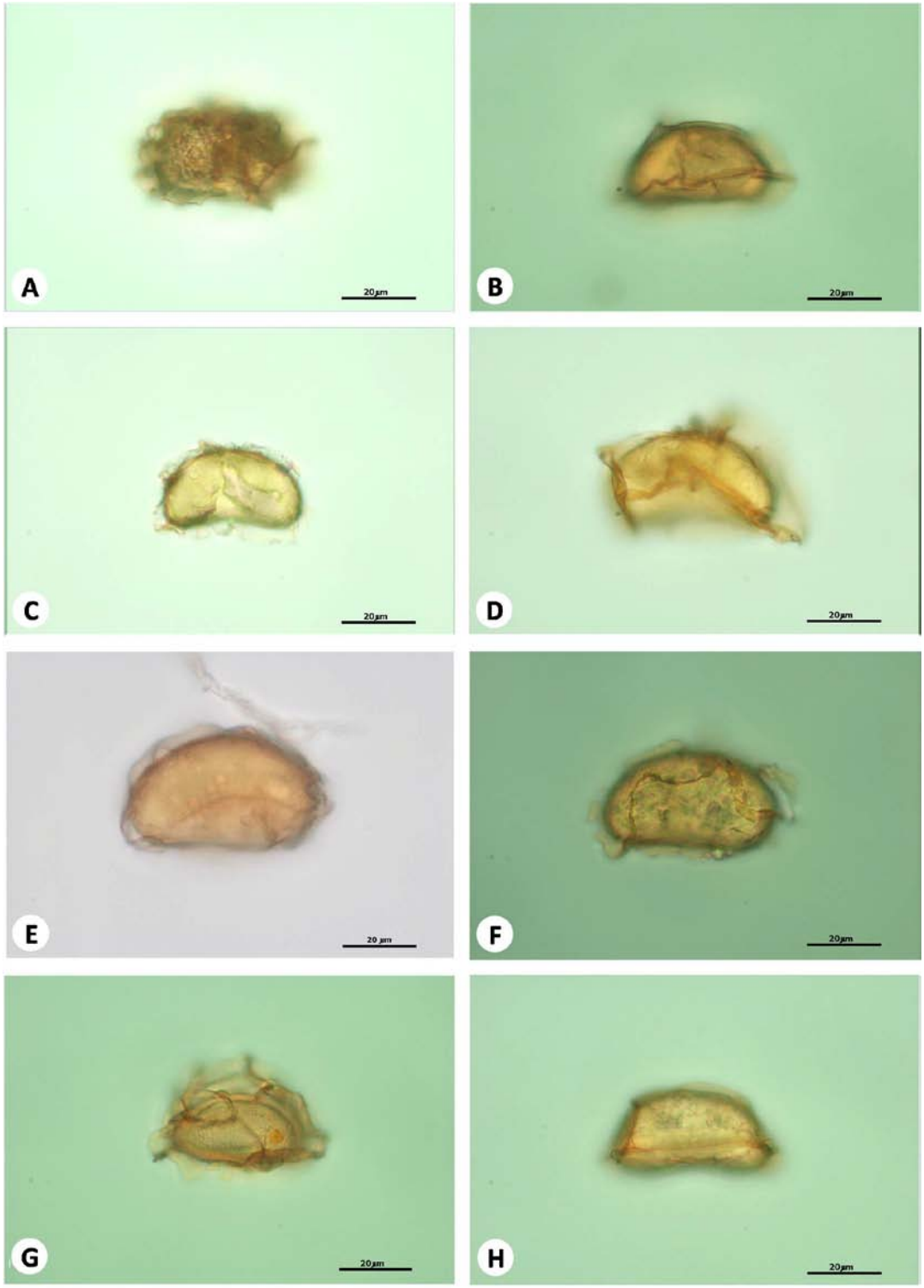

Figure 3.7 Light micrographs of *Diplazium* spores. A: *D. petrii*; B: *D. polypodioides*; C: *D. prescottianum*; D: *D. procumbens*; E: *D. proliferum*; F: *D. riparium*; G: *D. siamense* and H: *D. sorzogonense.*

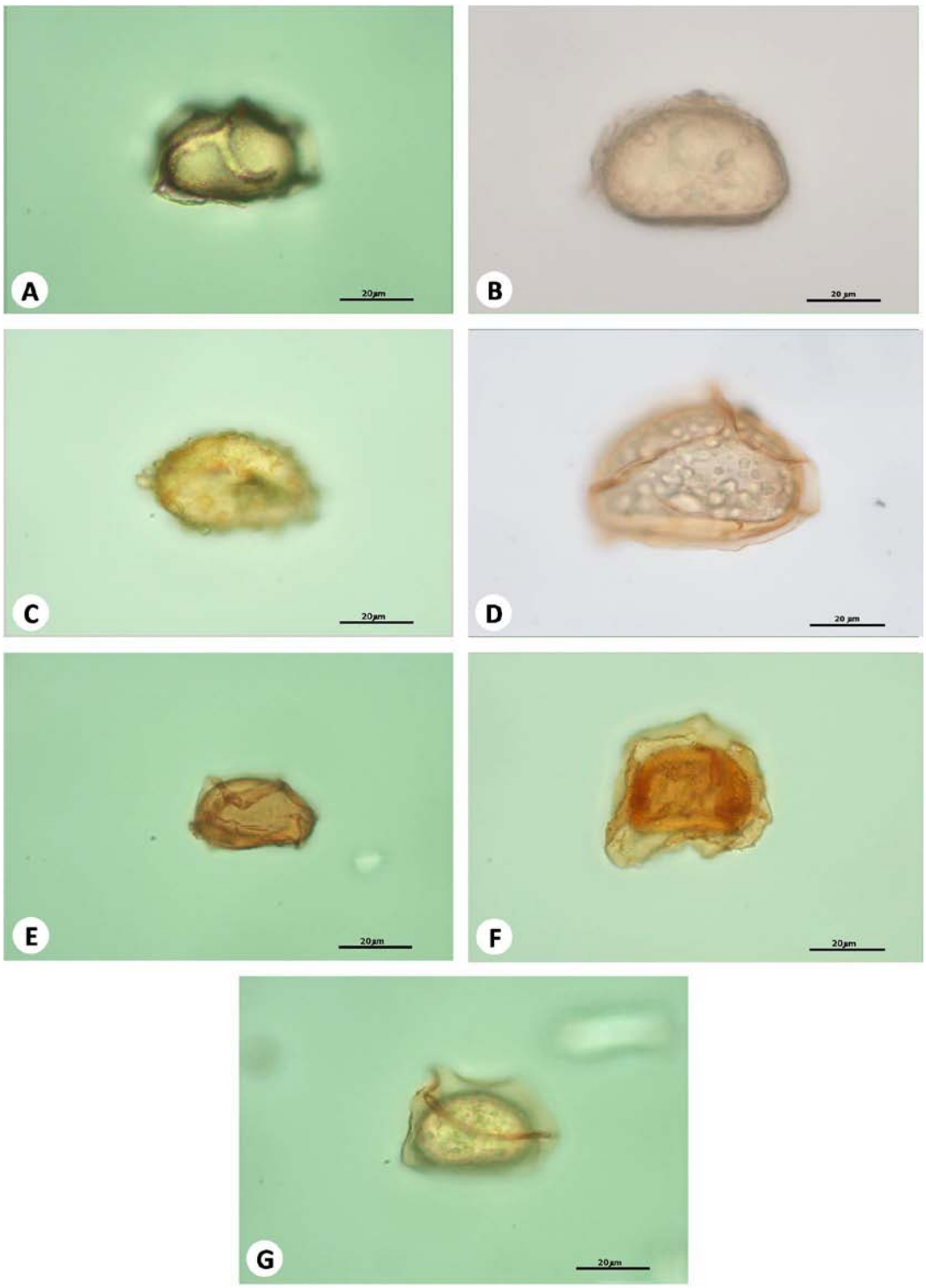

Figure 3.8 Light micrographs of *Diplazium* spores. A: *D. subintegrum*; B: *D. subserratum*; C: *D. subsinuatum*; D: *D. sylvaticum*; E: *D. taiwanense*; F: *D. tomentosum* and G: *D. xiphophyllum*.

CHAPTER IV

TAXONOMIC TREATMENT

4.1 Taxonomic History

The genus *Diplazium* Sw. was segregated from the genus *Asplenium* L. and was firstly described in 1800 by Olof Peter Swartz in Journal für die Botanik, containing 2 species, i.e. *D. plantagineum* (L.) Sw. and *D. grandifolium* (Sw.) Sw. (Swartz, 1800). Swartz (1800) described this new genus due to its having elongated sori along both sides of lateral veins or veinlets. However, some *Diplazium* species have very few double sori. Therefore, the generic boundary between *Diplazium* and *Asplenium* in the past is not very clear. Moore (1857) maintained *Diplazium* as separate genera, and included all species which produced twin sori with this genus. However, the status of *Diplazium* as a separate genus was still problematic. Some taxonomists transfered *Diplazium* to *Athyrium* Roth while some authors maintained them as separate genera. Beddome (1892) also maintained *Diplazium* as a separate genus based on the difference in sori shape of *Athyrium* which having reniform or round sori.

Copeland (1908) revised the *Athyrium* in the Philippines, he moved *Diplazium* species to the *Athyrium*. Then, Holttum (1940) noticed that *Diplazium* and *Athyrium* in Malaya are quite distinct. He described that *Diplazium* has pinnae and pinnules with subequal base, sori are born and elongated along the veins with lateral indusium, the diplazoid sori usually cover with two quite separate indusial. In contrast, *Athyrium* usually has pinnules with very equal bases, its sori are always short and broad sometimes having the appearance of a horse-shoe shape. Later Holttum (1960) added that the genus *Diplazium* should be kept because the chromosome number of the two genera were constantly different. He found that basic chromosome number (X) for *Athyrium* is 40 while *Diplazium* has X = 41.

Ching (1964) transferred chiefly species of *Diplazium* to *Allantodia* R. Br., most of them do not have distinct terminal pinna. Nine species i.e. *D. conterminum* Christ, *D. dilatatum* Blume, *D. griffithii* T. Moore, *D. leptophyllum* Christ, *D. megaphyllum* (Baker) Christ, *D. mettenianum* (Miq.)C.Chr., *D. petrii* Tardieu, *D. sorzogonense* (C.Presl) C. Presl and *D. taiwanense* Tagawa are found in Thailand (Table 5.3). However, most authors accept only the genus *Diplazium* and do not recognize any of the sattelite genera, for example, *Allantodia*, *Dictyodroma*, *Rhachidosorus* and *Athyriopsis* etc. (Kato, 1977; Tagawa and Iwatsuki, 1988; Iwatsuki, 1992; Shieh, Devol and Kuo, 1997; Khullar, 2000).

So far, the genus *Diplazium* was recognized in many Floras or Manuals, for example, Fern of British India (Beddome, 1892), Flora of Thailand (Tagawa and Iwatsuki, 1988). Ferns and Ferns Allies of Japan (Iwatsuki, 1992), Flora of Taiwan (Shieh, Devol and Kuo, 1997), An Illustrated Fern Flora of the West Himalaya (Khullar, 2000), Illustrated Manual of Ferns of Assam (Borthakur et al., 2001).

Taxonomic study of *Diplazium* in Thailand

The first taxonomic account of Thai *Diplazium* was reported in Flora of Koh Chang in 1901 from the specimens collected by Johannes Schmidt during 1989-1900. Two species of *Diplazium*, i.e. *D. bantamense* Blume and *D. silvaticum* (Bory) Sw. are enumerated (Christ, 1901).

Tagawa and Iwatsuki studied the existing herbarium specimens collected by many oversea collectors in collaboration with Thai botanists from BK and BKF. They also had additional collections of pteridophytes from some protected sites in Thailand. Thirty four families, 132 genera, 633 species were recorded for Pteridophyte Flora of Thailand

(Tagawa and Iwatsuki, 1988). Of these 29 species are Thai *Diplazium* which included an endemic species, i.e. *D. siamense* C. Chr.

Boonkerd and Pollawatn (2000) compiled data from various sources as well as from their own field trips. A total of 671 species, 4 subspecies, and 28 varieties in 139 genera from 35 families were enumerated. They also recorded 29 species of *Diplazium* in Thailand.

Boonkerd et al. (2004) reported 19 new recorded pteridophytes taxa, which included *Diplazium procumbens* Holttum. The specimen was collected from Phetchaburi (Kaeng Krachan National Park).

4.2 Materials and Methods

Herbarium specimens of all recorded Thai species, both wild and cultivated plants, were examined for the taxonomic descriptions. Specimens from the following herbaria were used: BCU, BK, BKF, CMU, KKU, PSU, together with the specimens from the herbarium, Department of Biology, Faculty of Science, Chiang Mai University. The images of the type specimens from BM, C, E, K, L and P have been studied. Acronyms of herbaria are abbreviated according to the Index Herbariorum (Holmgren and Holmgren, 2007). Living plants were also studied from collections in various natural sites throughout Thailand. Species determinations are based on keys to the species and descriptions in Flora of Thailand (Tagawa and Iwatsuki, 1988), Flora of Malaya (Holttum, 1960), Flora of Taiwan (Shieh, Devol, and Kuo, 1997), Fern of Malaysia in colour (Piggott, 1988), and Illustrated Manual of Ferns of Assam (Borthakur, Deka and Nath, 2001). A description below is based on Thai materials. The synonyms of each taxon are listed. The species distribution in Thailand is based on localities in Flora of Thailand, volume 3 (Tagawa and Iwatsuki, 1988), and additional localities from the above mentioned herbarium specimens together with the findings from this present study were added.

4.3 Taxonomic Account

DIPLAZIUM

Sw., Schrad. J. Bot. 1800(2): 61. 1801; T. Moore, Ind. Fil.: 330. 1859; C. R. H. Beddome Fern of British India: 174. 1892; J. Schmidt, Fl. Koh Chang: 108. 1900; D. B. Lellinger, Fern & Fern-Allies of the United States & Canada: 252. 1985; E. A. C. L. E. Schelpe & N. Anthony, Fl. Southren Africa: 227. 1986; C. J. Goudey, Handbook of Ferns for Australia and New Zealand: 96. 1988; J. T. Mickel & J. M. Beitel, Pteridophyte Flora of Oxaca, Mexico: 151. 1988; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 449. 1988; G. R. Proctor, Fern of Puerto Rico and the Virgin Islands: 237. 1989; M. Kato, Fl. North America: 252. 1993. Lectotype Species: *D. plantagineum* (L.) Sw.— *Athyrium* Roth, Röm. Mag. 2(1): 105. 1799, p.p.; Copel., Gen. Fil.: 147. 1947, p.p.— *Callipteris* Bory, Voy. Îles Afrique 1: 282. 1804.— *Allantodia* R. Br., Prodr.: 149. 1810.— *Anisogonium* C. Presl, Tent. Pterid.: 115–116. pl. 4. f. 6, 13, 18. 1836.— *Digrammaria* C. Presl, Tent. Pterid.: 116. 1836.— *Oxygonium* C. Presl, Tent. Pterid.: 117. 1836.— *Microstegia* C. Presl, Abh. Königl. Böhm. Ges. Wiss., ser. 5 6: 450. 1851.— *Ochlogramma* C. Presl, Abh. Königl. Böhm. Ges. Wiss., ser. 5 6: 453–454. 1851.— *Diplaziopsis* C. Chr., Index Filic. 4: 227. 1905.— *Monomelangium* Hayata, Bot. Mag. (Tokyo) 42(499): 343–344. 1928.— *Dictyodroma* Ching, Acta Phytotax. Sin. 9(1): 57–58. 1964.— *Rhachidosorus* Ching, Acta Phytotax. Sin. 9(1): 73–74. 1964.

Plant terrestrial, or epipetric, small to large sized. *Rhizome* creeping, ascending or erect, sometimes forming a short trunk, scaly, especially on younger part; scales linear or lanceolate with long tail apex, concolorous brown to black or black at margin, entire or toothed at margin. *Stipes* with 2 vascular strands at the base, uniting upwards to form a single U or V or W shaped bundle, or non united two-bundles; glabrous or scaly. *Laminae* simple, unipinnate to bipinnate; texture herbaceous to papery; veins

free or anastomosing. *Sori* single or paired back-to-black (diplazoid) along vein, oblong to linear, straight or slightly falcate; indusia thin, linear, persistent. *Spore* monolete, kidney-shaped, 30-68 by 20-50 µm, concavo-convex to plano-convex; perispore present.

A genus of about 400 species mainly from tropical regions, 31 species in Thailand.

KEY TO THE SPECIES

1a	Fronds simple……	2
1b	Fronds compound……..	4
2a	Rhizome creeping……..	27. *D. subsinuatum*
2b	Rhizome erect……	3
3a	Scales margin entire……	3. *D. cordifolium*
3b	Scales margin toothed……	26. *D. subserratum*
4a	Fronds unipinnate……..	5
4b	Fronds bipinnate……	25
5a	Rhizome creeping……..	6
5b	Rhizome erect……	9
6a	Upper pinnae not reduced; terminal pinna distinct……	7
6b	Upper pinnae gradually reduced; terminal pinna not distinct……	8
7a	Terminal pinna lobes at margin; scales concolorous……..	11. *D. lobatum*
7b	Terminal pinna subentire at margin; scale-margin black ……..	6. *D. donianum*
8a	Veinlets simple or once forked, 3-4 pairs; sori cresentic, 2-3 mm long……..	17. *D. petrii*
8b	Veinlets all free, 4-5 pairs; sori elongate along vein, 4-5 mm long…….....	14. *D. mettenianum*

9a	Scales entire……..	10
9b	Scales toothed……	14
10a	Terminal pinna not distinct……..	11
10b	Terminal pinna distinct……..	21
11a	Veins anastomosing……..	9. *D. heterophlebium*
11b	Veins all free……	12
12a	Stipes and rachis tomentose……	30. *D. tomentosum*
12b	Stipes and rachis glabrous……..	13
13a	Auricle at basiscopic base of pinnule distinct; pinnae-stalks about 5 mm long……	19. *D. prescottianum*
13b	Auricle not distinct; pinnae-stalk less than 3 mm long….....	12. *D. malaccense*
14a	Terminal pinna distinct……..	15
14b	Terminal pinna not distinct……...	17
15a	Lateral pinnae 10-15 pairs; terminal pinna subdeltoid, unlike lateral pinnae; lobed at margin……..……	16
15b	Lateral pinnae 3-5 pairs; terminal pinna similar to lateral one; entire at margin……..	1. *D. bantamense*
16a	Veins anastomosing; pinnae subentire to crenate at margin; gammae absent……..……...	13. *D. megaphyllum*
16b	Veins free; pinnae serrate at margin; gammae usually present between rachis and pinnae……..	21. *D. proliferum*
17a	Veins all free……	18
17b	Veins anastomosing……..	7. *D. esculentum*
18a	Pinnae subentire or crenate at margin; auricle present at acroscopic base……	19
18b	Pinnae lobed at margin; auricle absent……	20

19a	Veinlets 1-2 pairs; pinnules 2.5-4 cm broad; distinctly auricled at base……..	4. *D. crenato-serratum*
19b	Veinlets 3-4 pairs; pinnules 1-1.5 cm broad; moderately auricled at base ……	28. *D. sylvaticum*
20a	Pinnae suddenly becoming smaller upwards, stalks up to 2 cm long ……..…...	23. *D. siamense*
20b	Pinnae gradually becoming smaller upwards, stalks less than 0.5 cm long……	24. *D. sorzogonense*
21a	Lateral pinnae more than 10 pairs; pinnae 2 cm wide; veins all free……...	22
21b	Lateral pinnae less than 7 pairs; pinnae more than 3 cm wide; veins anastomosing……..	23
22a	Veinlets 1 pairs, stalks 1-2 mm long……...	16. *D. pallidum*
22b	Veinlets 2 pairs, stalks more than 3 mm long……	25. *D. subintegrum*
23a	Pinnae ovate-lanceolate, long acuminate at apex, obtuse at base; gammae usually present at junction between rachis and base of pinnae……	3. *D. cordifolium*
23b	Pinnae oblong, acuminate at apex, acute at base; gammae absent…….…….....	24
24a	Terminal pinna entire at margin; fronds less than 40 cm long; pinnae 2-4 pairs……..……	22. *D. riparium*
24b	Terminal pinna lobe at margin; fronds more than 40 cm long; pinnae 4-7 pairs……	31. *D. xiphophyllum*
25a	Rhizome creeping ……..……..	26
25b	Rhizome erect or ascending……..…….	30
26a	Scales-margin black ……	27
26b	Scales concolorous……...	28
27a	sori submarginal; Veins 4-5 pairs …….....	2. *D. conterminum*
27b	sori close to costule; Veins 5-6 pairs…….……....	8. *D. griffithii*

28a	Sori curved or cresentic, usually lie on acroscopic veinlets of vein group…….....	29
28b	Sori oblong, usually lie on all veinlets……	20. *D. procumbens*
29a	Sori submarginal, 2-3.5 mm long……	17. *D. petrii*
29b	Sori close to costule, 3-5 mm long……	10. *D. leptophyllum*
30a	Scales-margin black ……	31
30b	Scales concolorous……...	33
31a	Sori linear, more than 5 mm long…….....	32
31b	Sori oblong, less than 3 mm long……	18. *D. polypodioides*
32a	Veins free; pinnules lobed at margin ……	5. *D. dilatatum*
32b	Veins anastomosing; pinnules subentire at margin ……	7. *D. esculentum*
33a	Sori half way between costule and margin of; lobe Veinlets 5-6 pairs……..….	29. *D. taiwanense*
33b	Sori close to costule; Veinlets 7-8 pairs……	15. *D. muricatum*

1. *Diplazium bantamense* Blume, Enum. Pl. Javae 2: 191. 1828; Bedd., Handb.: 177. f. 86. 1892; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 103. 1967; Acta Phytotax. Geobot. 23: 56. 1968; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 455. 1988; A.G. Piggott., Fern of Malaya in colour: 305, f. 937-939. 1996.

— *Athyrium bantamense* (Blume) Milde, Bot. Zeitung. 1870 : 353; Holtt., Rev. Fl. Malaya 2: 558, f. 330. 1955.

— *Asplenium bantamense* (Blume) Baker, Syn. Fil.: 231. 1867.

Rhizome erect or ascending, 1-2.5 cm in diam., clothed with scales on younger part; scales, about 8 by 1 mm, narrowly lanceolate, long-tail at apex, margin black, dark brown, irregularly toothed at margin. *Stipes* up to 35 cm or more long, brown, dark at lower portion, grooved above. *Fronds* imparipinnate, 20-25 by 18-25 cm, oblong in outline, terminal pinna distinct, like lateral one, gemmae often present at junction between rachis and costa of terminal pinna; lateral pinnae 3-4 pairs, 10-20 by 4-5 cm, ovate-lanceolate, shortly-stalked, 2-4 mm long, acuminate at apex, round to acute at base, margin entire or subentire; veins free simple or one forked, extending to margin; *Sori* elongate along veins, longest on acrocsopic veinlets of vein group; indusia thin. *Spores* monolete, 62.5-67.5 by 30-40 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.1; Pl. 1: A).

Specimens Examined.– P. Pongkai 32, 33, 36, 39 (BCU); B. Sangkachan 716, 749, 1392 (BKF); C. F. van Beusekom & C. Phengkhlai 754 (BKF); C. Niyomdham 3071 (BKF); C. Phengklai et al. 10555 (BKF); E. Hennipman 3683, 3784, 3798, 3885, 3980 (BKF); K. Iwatsuki, C. Phengklai, M. Wakabayashi & M. Kato 40 (BKF); Kai Larsen et al. 45868 (BKF); Kai Larsen, T. Smitinand & E. Warncke 313 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T5303 (BKF); T. Smitinand 1047, 5908 (BKF).

Thailand.– PENINSULAR: Surat Thani (Khao Khieo range), Nakhon Si Thammarat (Khao Luang, Khao Nan), Trang (Khao Chong), Yala (Ban Chana, Ban Malao, Banang Sata).

Distribution.– W. Malaysia, Indonesia (type from Java).

Ecology.– On mountain slopes near streams in dense evergreen forests at low to medium altitudes.

Note.– This species is very similar to *D. donianum* but differed in having erected rhizome, scales with irregularly toothed at margin. Gemmae are usually found at junction between rachis and costa of terminal pinna. Lower stalks shorter than *D. bantamense*, less than 5 mm long.

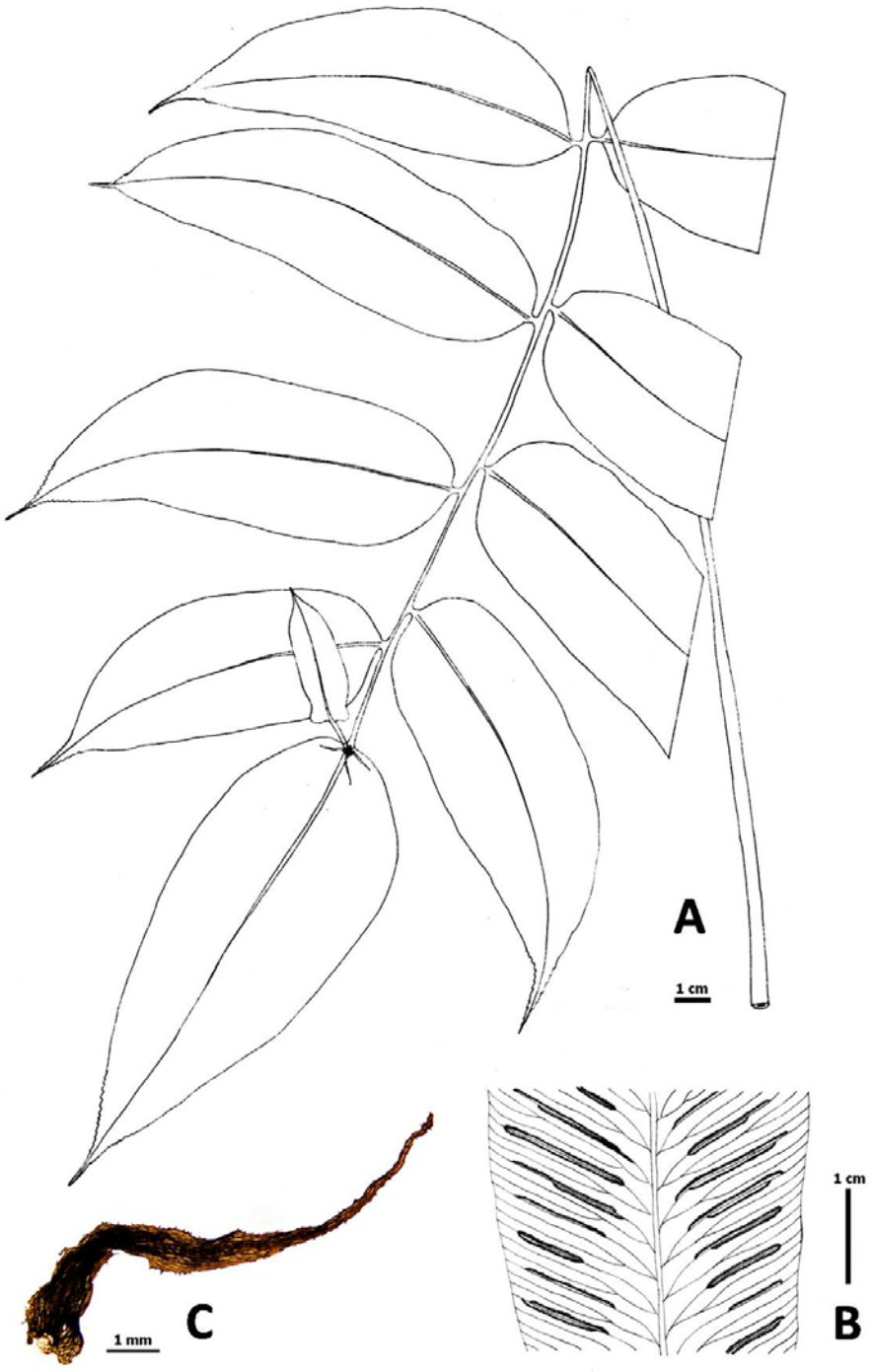

Figure 4.1 *Diplazium bantamense* Blume. A: frond; B: vein and sori and C: scale.

2. ***Diplazium conterminum*** **Christ**, J. Bot 19: 67. 1905; Tard. & C. Chr., Fl. Indo-Chine 7(2): 258. 1940; Tagawa & K. Iwats., Southeast As. St. 5: 105. 1967; Tagawa & K. Iwats., Fl. Thailand 3(3): 462. 1988.

— *Allantodia conterminar* (Chirst) Ching, Acta Phytotax. Sin. 9(1): 47. 1964.

Rhizome long creeping, about 0.5 cm in diam., densely scaly on younger part; scales, about 10 by 1 mm, linear long tail, dark brown to nearly black, margin black, toothed at margin. *Stipes* up to 50 cm long, glabrous, brown, dark at lower portion. *Fronds* bipinnate, about 50 by 40 cm, subdeltoid in outline, papyraceous, dark green, terminal pinna not distinct; lateral pinnae about 30 by 15 cm, long stalk, up to 4 cm long, gradually narrowing towards acute apex; pinnules about 8 by 2 cm, sessile or shortly stalked, oblong, acuminate at apex, cordate or subtruncate at base, crenate to lobed at margin, veins pinnate, 4-5 pairs, veinlets all free. *Sori* about 1-2 mm long, oblong, usually along posterior half of veinlets, submarginal; indusia thin but firm; *Spores* monolete, 47.5-57.5 by 32.5-37 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: regulate (Fig. 4.2; Pl. 1: B).

Specimens Examined.– P. Pongkai 15 (BCU); T. Shimizu, K. Iwatsuki, N. Fukuoka, M. Hutoh & D. Chaiglom T11603 (BKF).

Thailand.– NORTHERN: Phitsanulok (Phu Miang); PENINSULAR: Nakhon Si Thammarat (Khao Luang).

Distribution.– Vietnam (type), S. China, Ryukyu, and SW. Japan.

Ecology.– On mountain slopes in dense forests at 900- 1,500 m alt.

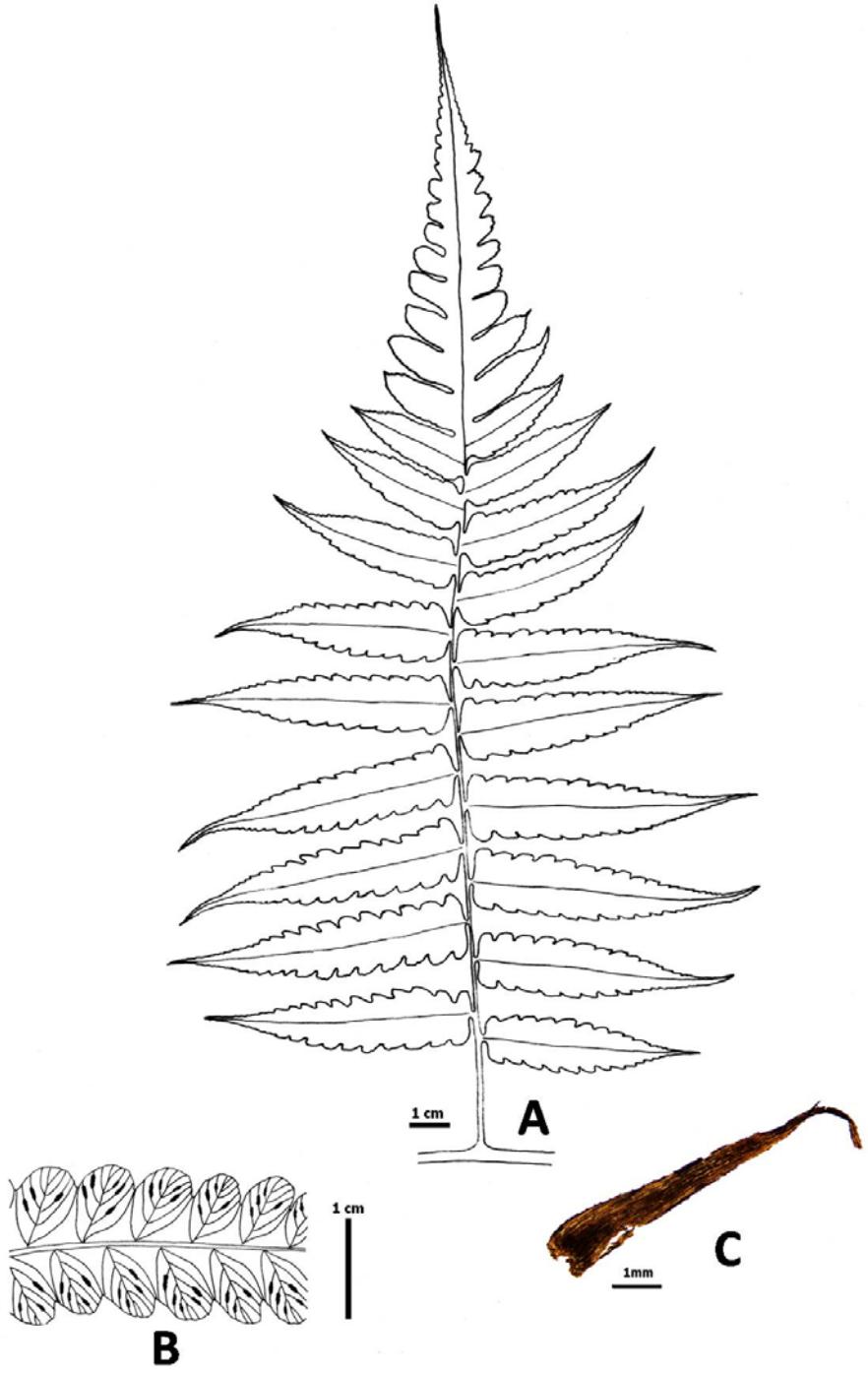

Figure 4.2 *Diplazium conterminum* Christ. A: pinna; B: vein and sori and C: scale.

3. ***Diplazium cordifolium*** **Blume**, Enum. Pl. Javae 2: 190. 1828; Tagawa & K. Iwats., SouthE. Asian. Stud. 5: 102. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 453. 1988; A.G. Piggott., Fern of Malaya in colour: 293. f. 901-905. 1996.

— *Diplazium integrifolium* Blume, Enum. Pl. Javae.: 190. 1828.

— *Anisogonium cordifolium* (Blume) Bedd., Ferns Brit. India.: t. 331. 1870; Handb. Fern Brit. India, 191, f. 92. 1883.

— *Athyrium cordifolium* (Blume) Copel., Philipp. J. Sci. 3: 300. 1908; Holtt., Rev. Fl. Malaya 2 : 548. 1955.

Rhizome short, erect, about 1-2 cm in diam., covered with scales at apex; scales about 6-12 by 1-1.5 mm, narrowly lanceolate with long tail, brown, margin entire, black. *Stipes* up to 40 cm or more long, stramineous to brown, black in lower part, grooved above. *Fronds* simple or imparipinnate; simple frond about 25-30 by 8-12 cm, oblong, acuminate at apex, cordate at base, subentire to undulate at margin, coriaceous; midrib distinctly raised beneath, glabrous; veins branching a few times near midrib, irregulary anastomosing near margin; gemmae usually present at junction between stipe and midrib; imparipinnate frond, about 30 by 20 cm, deltoid in outline; terminal pinna present; usually bigger than lateral ones, about 15 by 5 cm, ovate-lanceolate, acuminate at apex, obtuse at base, subentire at margin; lateral pinnae 3-4 pairs, becoming smaller upward, about 10-15 by 3-5 cm, lower pinnae the largest, sessile, bearing gemmae at junction between rachis and costa, ovate-lanceolate, acuminate at apex, obtuse at base, subentire at margin; vein anastomosing. *Sori* elongate along veinlets, up to 4 cm or more long, on both side of each veinlets; indusia thin but persistent. *Spores* monolete, 47.5-50 by 35-45 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: reticulate (Fig. 4.3; Pl. 1: C).

Specimens Examined.– P. Pongkai 34, 37, 42, 60 (BCU); T. Boonkerd & R. Pollawatn 193, 252 (BCU); A.F.G. Kerr 12008 (BK); B. Hansen & T. Smitinand 12100

(BKF); B. Sangkhachand & B. Nimanong 1333 (BKF); B. Sanghachand 732 (BKF); C. F. van Beusekom & C. Phengkhlai 944 (BKF); C. Niyomdham, P. Phudjaa & S. Chonkunjana 6038 (BKF); C. S. S. 261 (BKF); E. Hennipman 3815 (BKF); E. Smith 1921 (BKF); K. Iwatsuki, H. Hpyama, M. Hutoh & A. Chintayungkum T8402 (BKF); Kai Larsen & Supee S. Larsen 32894 (BKF); Kai Larsen et al. 45770, 45926 (BKF); Kyoji Yoda 630 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T4631, T4833, T6816 (BKF); R. Geesink, T. Hattink & C. C. Charoenphol 7286 (BKF); R. Schlechter 17821 (BKF); T. Smitinand 918, 920 (BKF); Blume s.n. (Holotype L!).

Thailand.– PENINSULAR: Chumphon, Surat Thani (Lang Suan), Nakhon Si Thammarat (Khao Luang), Trang (Khao Chong), Narathiwat (Waeng), Pattani, Songkhla, Yala (Ban Chana).

Distribution.– Malesia throughout eastwards to the Solomon Islands, type form Java .

Ecology.– On moist sandy mountain slopes in dense gloomy forests at low or medium altitudes, locally fairly abundant.

Note.– This species have two forms of frond but pinnate frond is rarely found.

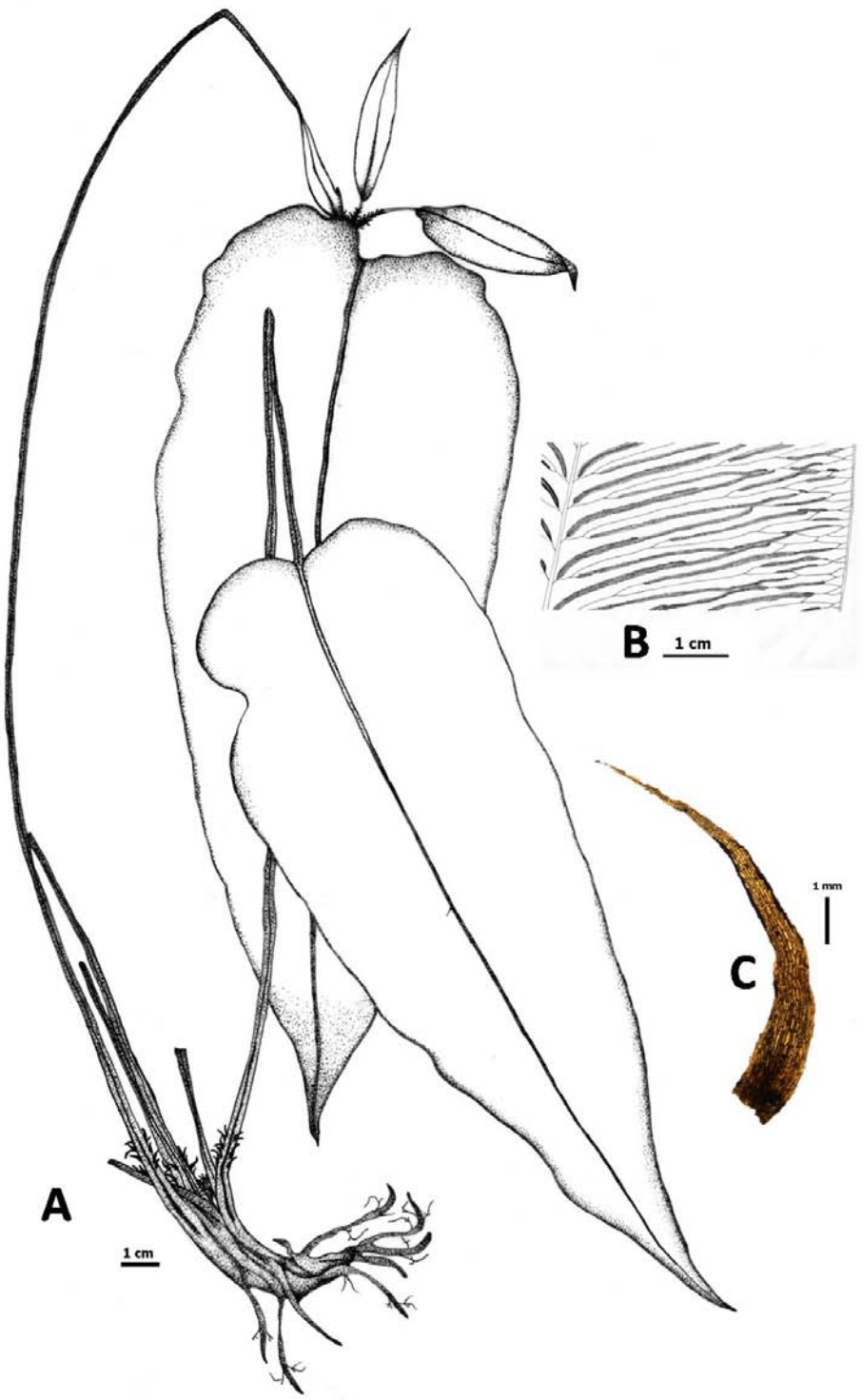

Figure 4.3 *Diplazium cordifolium* Blume. A: habit; B: vein and sori and C: scale.

4. *Diplazium crenato-serratum* (Blume) T. Moore, Index Fil.: 121. 1859; Tagawa & K. Iwat., SouthE. Asian. Stud. 5: 104.1967; M. Tagawa & K. Iwatsuki., Acta Phytotax. Geobot. 23: 56. 1968; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 459. 1988; A.G. Piggott., Fern of Malaya in colour: 308. f. 947-950. 1996.

— *Asplenium crenato-serratum* Blume., Enum. Pl. Javae: 177. 1828.

— *Athyrium crenato-serratum* (Blume) Milde, Bot. Zeit. 1870: 353; Holtt., Rev. Fl. Malaya 2: 561. f. 332. 1955.

Rhizome erect, about 1.5-2 cm in diam., scaly, bearing wiry roots; scales 5-6 by 0.8-1.5 mm, narrowly lanceolate, concolorous, dark brown to black, irregularly toothed at margin. *Stipes* 30-40 cm long, stramineous, dark brown and scaly at base. *Fronds* unipinnate, 35-40 by 15-20 cm, usually longer than stipe, subdeltoid in outline, gradually narrowing upwards, attenuate at apex, widest at base, terminal pinna not distinct; rachis grooved above, minutely hairy, gammae usually confined to apical portion; lateral pinnae 20-25 pairs, 8-10 by 1 cm, narrowly oblong, subfalcate, acuminate at apex, truncate at base, distinctly auricle at acroscopic bases, dentate to serrate at margin, sessile or shortly stalked at lower pinnae, about 2-3 mm long, longest at lower pinnae; veins pinnate with simple veinlets, veinlets 1 pair. *Sori* elongate along veinlets, about 5-6 mm long, usually on acroscopic veinlets of vein group; indusia thin but firm, persistent. *Spores* monolete, 35-37.5 by 20-22.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: regulate (Fig. 4.4; Pl. 1: D).

Specimens Examined.– P. Pongkai 26, 27, 28, 29, 40, 46, 47, 61, 64 (BCU); A.F.G. Kerr 14494, 14590 (BK); B. Sangkhachand 1167, 692 (BKF); D. J. Middleton, M. Phuphat, R. Pooma & K. Williams 1881, 2884 (BKF); E. Hennipman 3799, 3915 (BKF); K. Iwatsuki, H. Hpyama, M. Hutoh & A. Chintayungkum T14639 (BKF); Kai Larsen, T. Smitinand & E. Warncke 1783 (BKF); Kyoji Yoda 517, 520, 618 (BKF); M. Tagawa, K.

Iwatsuki & N. Fukuoka T4627, T4628, T4633, T5271 (BKF); T. Shimizu et al. T27214 (BKF); T. Smitinand 911, 925, 1051 (BKF); J.F. Maxwell 84-481, 86-385, 86-745 (PSU)

Thailand.– SOUTH-EASTERN: Chanthaburi; PENINSULAR: Surat Thani (Ban Don, Klong Ton), Nakhon Si Thammarat (Khao Luang, Khao Huai Pampun, Khao Nan, Chawang), Satun, Trang, Yala (Kiong Bla Hot, Ban Mae Prik, Betong).

Distribution. – Malesia (type from Java).

Ecology.– On moist mountain slopes in dense evergreen forests at low to medium elevations, lower than 1,000 m alt.

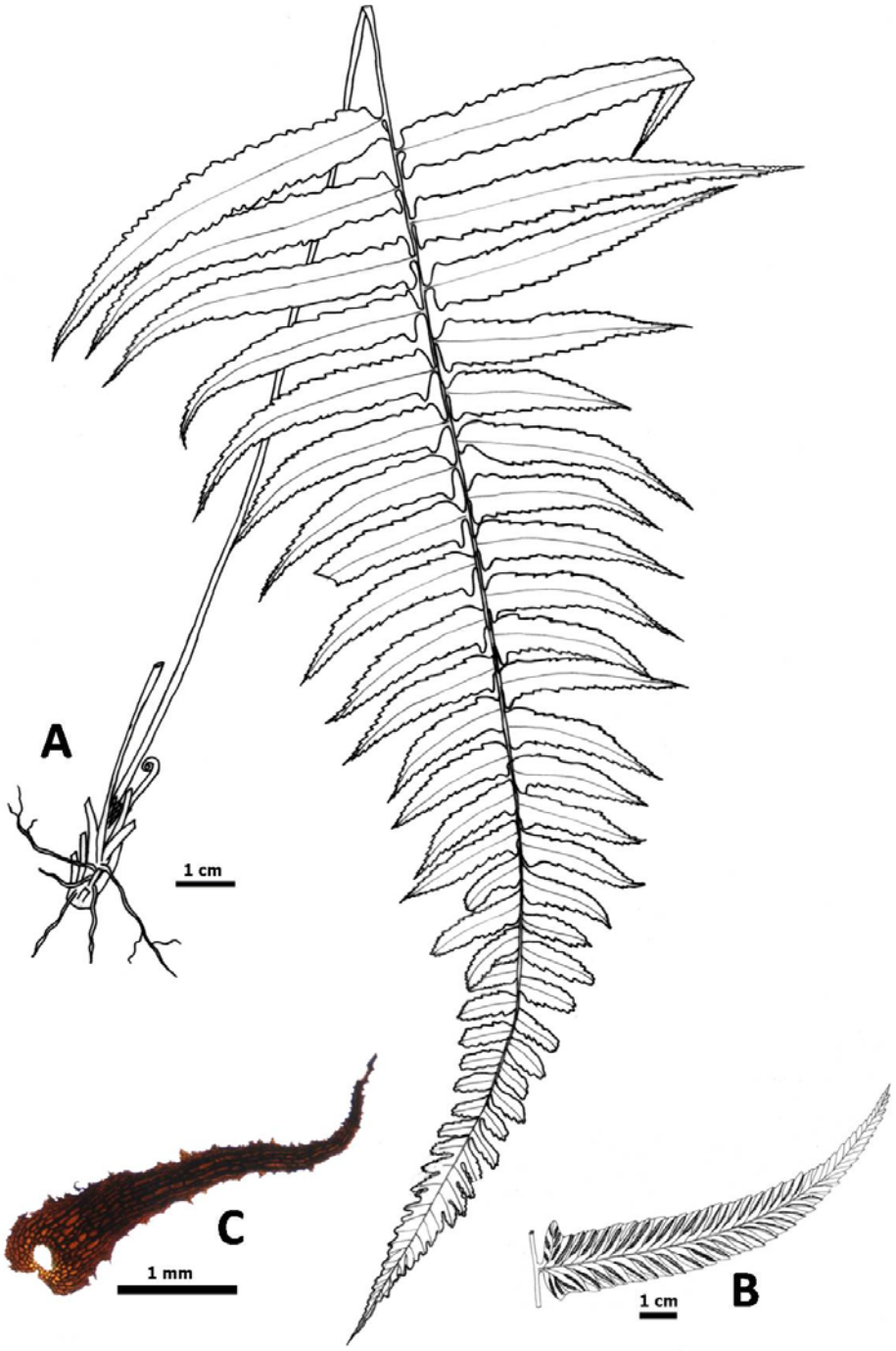

Figure 4.4 *Diplazium crenato-serratum* (Blume) T. Moore. A: habit; B: vein and sori and C: scale.

5. ***Diplazium dilatatum*** **Blume**, Enum. Pl. Javae 2: 194. 1828; Holtt., Gard. Bull. Straits Settlem. 11: 85. 1940; Sledge, Bull. Brit. Mus. (Nat. Hist.), Bot. 2: 303. 1962; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 3(3): 87. 1965; 5:106. 1967; Tagawa & K. Iwats., Fl. Thailand 3(3): 464. 1988.

— *Asplenium bellum* C.B. Clarke, Trans. Linn. Soc. London, Bot. 1: 496, t. 63, f. 2. 1880.

— *Asplenium maximum* D. Don, Prodr. Fl. Nepal. 8: 1825.

— *Asplenium umbrosum* J. Sm. var. *bellum* (C.B. Clarke) Hosseus, Beih. Bot. Centralbl. 28(2): 364. 1911.

— *Diplazium simplicivenium* Holttum, Gard. Bull. Straits Settlem. 11: 100. 1940; Tagawa & K. Iwats., SouthE. Asian Stud. 3(3): 88. 1965; 5: 106. 1967.

— *Diplazium maximum* (D. Don) C. Chr., Index. Fil.: 235. 1905; Tard. & C. Chr., Fl. Indo-Chine. 7(2): 263. 1940.

— *Athyrium dilatatum* (Blume) Milde, Bot. Zeitung. 353: 1870; Holtt., Rev. Fl. Malaya 2: 574. f. 341. 1955.

— *Allantodia dilatata* (Blume) Ching, Acta Phytotax. Sin. 9(1): 54. 1964.

Rhizome massive, erect, densely covered with scales at apex; scales, about 15 by 1 mm, linear with long tail apex, brown to dark brown, margin black, toothed. *Stipes* 60-70 cm long, brown, densely scaly at base, black at lower portion. *Fronds* bipinnate, about 1 m by 60-70 cm, terminal pinna not distinct; pinnae about 30 by 20 cm, stalks distinct, 1-1.2 cm long, oblong in outline, acuminate at apex; pinnules 10 by 2-2.5 cm, sessile or shortly stalked, oblong, acuminate at apex, subtruncate, truncate to cordate at base; subentire to lobed at margin, ¼ to ½ way to costule; veinlets 4-6 pairs, free, simple or once forked. *Sori* elongate along veinlets, usually more than 5 mm long, diplazoid; indusia thin. *Spores* monolete, 40.5-45 by 25-29.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.5; Pl. 1: E).

Specimens Examined.– P.Pongkai 4, 6, 13, 14 (BCU); T. Boonkerd 1245, 1339 (BCU); A.F.G. Kerr 9928, 14561 (BK); B. Sangkachun 750 (BKF); C.F. van Bensekom & C. Phengklai 290, 3074 (BKF); C.F. van Bensekom & T. Santisuk 2894 (BKF); C.F. van Bensekom, C. Phengklai, R. Geesink & B. Wongwan 4407 (BKF); E. Hennipmam 3132, 3969 (BKF); G. marata, K. Iwatsuki, C. Phengklai & C. Charamphol T15751 (BKF); H. koyama, H. Terao & T. Wongprasert T33684 (BKF); J.F. Maxwell 93-747,95-51, 96-603, 97-135, 98-583 (BKF); K. Iwatsuki & N. Fukuoka T3568, T7184, T7427 (BKF); K. Iwatsuki , N. Fukuoka, H. Koyama & A. Chintayungkun T8608 (BKF); K. Iwatsuki , N. Fukuoka, M. Hutoh & D. Chaiglom T10894, T10906, T10916 (BKF); K. Iwatsuki, C. Phengklai, M. Wagabayashi & M. Kato 45, 162 (BKF); K. Larsen, T. Smitinand & E. Warncke 278 (BKF); M. Tagawa & I. Yamada T31(BKF); M. Tagawa T3849 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T642, T1269, T2041 (BKF); M. Thagahashi & MN. Taruma T63459 (BKF); Phengklai et al. 7134 (BKF); Somkhit 200, 202 (BKF); T. Shimitsu et al. T11360 (BKF); T. Smitinand 2483 (BKF); J.F. Maxwell 93-109, 93-747, 95-51, 95-209, 97-135, 98-583 (CMU).

Thailand.– NORTHERN: Chiang Rai (Doi Pacho, Mae Kok), Chiang Mai (Doi Chiang Dao, Doi Khun Huai Pong, Doi Suthep, Kang Kat, Doi Inthanon), Phitsanulok (Thung Salang Luang, Phu Rom Rot), Tak (Ban Musoe); NORTH-EASTERN: Phetchabun (Phu Maing), Loei (Phu Luang, Puh Kradueng); SOUTH-WESTERN: Kanchanaburi (Khao Ngi Yai), Uthai Thani (Ban Rai); CENTRAL: Nakhon Nayok (Khao Yai); SOUTH-EASTERN: Chanthaburi (Khao Soi Dao); PENINSULAR: Surat Thani (Khao Khieo range), Nakhon Si Thammarat (Khao Luang, Khao Nan), Phangnga (Khao Pok), Trang (Khao Chong) Satun, Yala (Muang Wing).

Distribution.– India, Myammar, S. China, Taiwan, Ryukyu, S. Japan, Indochina, Malesia throughout (type from Java) to N. Australia.

Ecology.– On moist or humus-rich mountain slopes in dense gloomy forests at 400 – 1,500 m alt.

Note.– According to Holttum (1960), *D. dilalatum* and *D. simplicivenium* are differed in venation and stalk of pinnule. However, it is found from this study that veinlets are often simple or free forked in all lobes of pinnules of both species. Pinnules stalks are also short or sessile in both species. In addition, spores morphology, scale morphology, type of stomata and anatomy of stipe of these two species are also the same. To sum up the result from this study more or less supports the reduction of *D. simplicivenium* as a synonym of *D. dilatatum*.

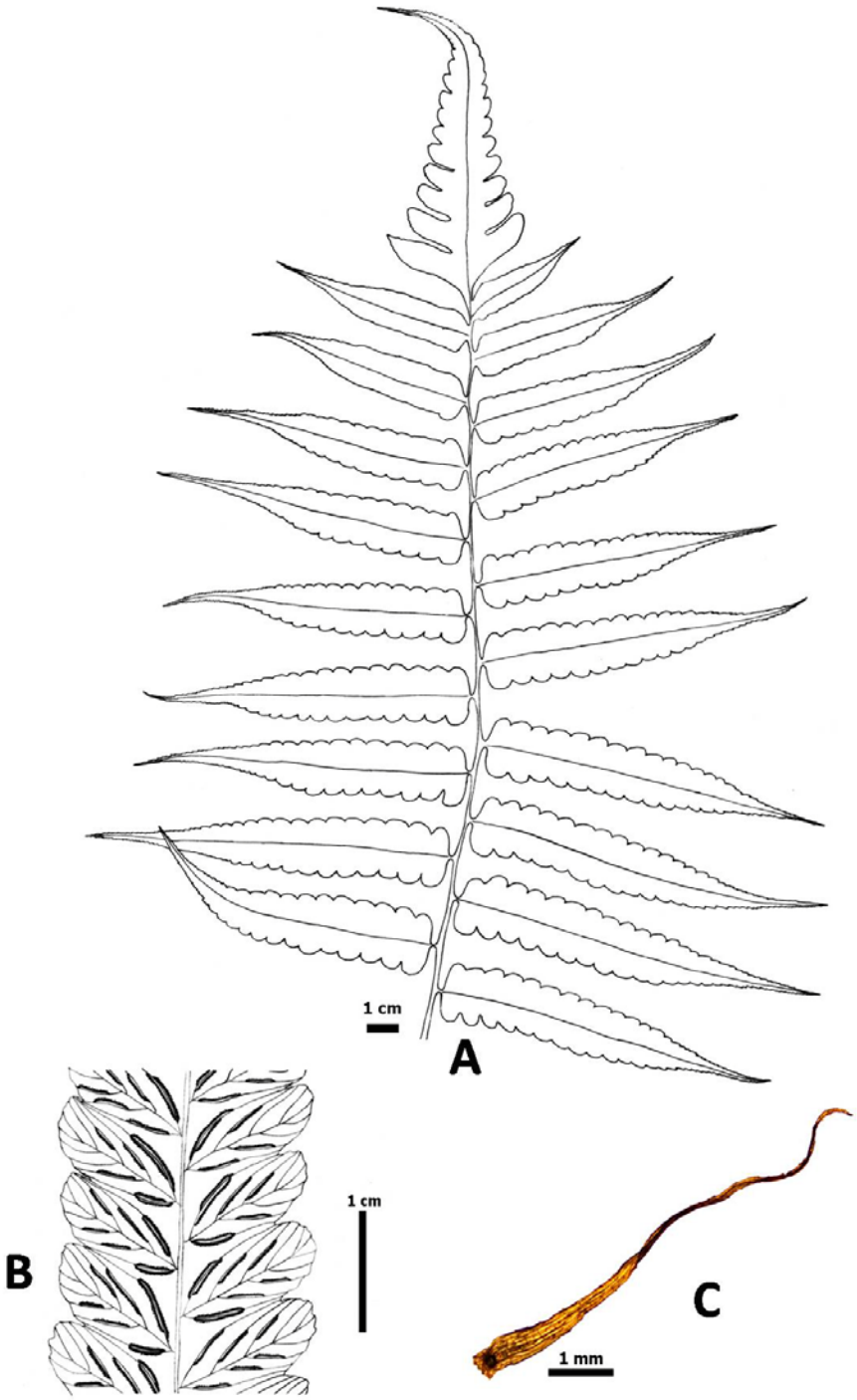

Figure 4.5 *Diplazium dilatatum* Blume. A: pinna; B: vein and sori and C: scale.

6. *Diplazium donianum* (Mett.) Tardieu, Aspl. Tokin: 58. t. 5. 1932; Tard. & C. Chr., Fl. Indo-Chine 7(2): 249. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 102. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 455. f. 48. 4. 1988; Devol & Kuo, Fl. Taiwan 1. 436: 1994.

— *Asplenium donianum* Mett., Fil. Lechl.: 177. 1859.

— *Athyrium bantamense* auct. non (Blume) Milde: Bedd., Handb. Ferns Brit. India: 177. F. 86. 1833; Christ, Bot. Tidsskr. 24: 108. 1901; Holtt., Dansk Bot. Ark. 20: 32. 1961.

Rhizome creeping, about 3-5 mm in diam., covered with scales at apex; scales 4-6 by 0.6-1 mm, narrowly lanceolate, dark brown, margin black, toothed at margin. *Stipes* 20-40 cm long, brown, black at lower portion, grooved above. *Fronds* imparipinnate, 30-40 by 20-30 cm, oblong in outline, terminal pinna distinct like lateral one; lateral pinnae 1-3 pairs, 15-20 by 3.5-5 cm, oblong, stalks 6-10 mm or more long, acuminate at apex, acute or obtuse at base, margin entire or subentire; costa grooved with minute hairs on adaxial surface; veins free, simple or forked, extending to margin. *Sori* elongate along veins, longest on acroscopic side of veinlets; indusia thin. *Spores* monolete, 55-72.5 by 35-50 μm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: reticulate (Fig. 4.6; Pl. 2: A).

Specimens Examined.– P. Pongkai 21, 22, 50 (BCU); T. Boonkerd et al. 248 (BCU); G. murata, N. Fukuoka & C. Phengklai T16254 (BKF); K. Iwatsuki & N. Fukuoka T7392 (BKF); K. Iwatsuki, C. Phengklai, M. Wakabayashi & M. Kato 41, 163 (BKF); K. Iwatsuki, H. Koyama, M. Hutoh & A. Chintaungkun T14641 (BKF); Kyoji Yoda 511, 537 (BKF); M. Tagawa & N. Kitagawa T3859 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T2039, T5269 (BKF); S. Chongko 9 (BKF); T. Shimizu et al. T23691 (BKF); T. Smitinand 7494 (BKF).

Thailand.– NORTHERN: Chiang Mai (Doi Suthep), Tak (Doi Musoe), Phitsanulok (Thung Salaeng Luang); NORTH-EASTERN: Loei (Phu Kradueng); EASTERN: Nakhon

Ratchasima; CENTRAL: Nakhon Nayok (Khao Yai); SOUTH-EASTERN: Chanthaburi, Prachin Buri, Trat (Koh Chang); PENINSULAR: Nakhon Si Thammarat (Khao Luang, Khao Nan, Ron Phibun, Khiriwong).

Distribution.– N. India (type) to S. China and Taiwan, north to S. Japan, southwards to Indochina.

Ecology.– On mountain slopes in light shade or in dense evergreen forests, usually below 800 m alt.

Note.– This species is similar to *D. bantamense* in the fields, but they can be separated by having creeping rhizome and lacking gemmae in *D. donianum*. and lower stalk longer than *D. bantamense*, more than 5 mm long.

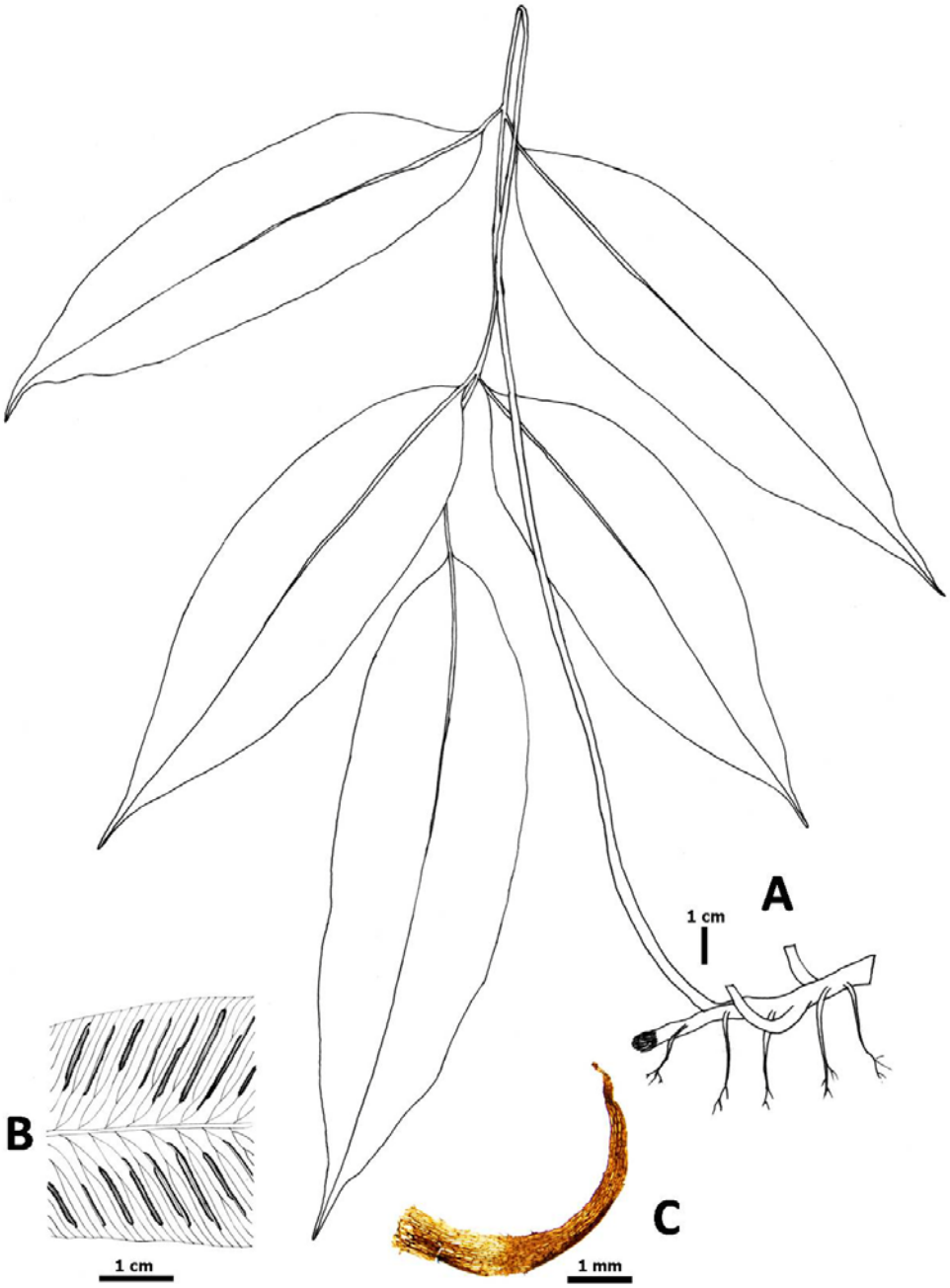

Figure 4.6 *Diplazium donianum* (Mett.) Tardieu. A: habit; B: vein and sori and C: scale.

7. *Diplazium esculentum* (Retz.) Sw., Schrad. J. Bot. 1801(2): 312. 1803; Tard & C. Chr. In Fl.Gen. I-C. 7(2): 269. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud.3(3): 88. 1965; 5 . 106. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 466. 1988; K. Iwatsuki, Ferns and Fern Allies of Japan: 257. Pl. 176-1,2. 1992; Devol & Kuo, Fl. Taiwan 1. 1994; A.G. Piggott., Fern of Malaya in colour: 303. f. 932-936. 1996.

— *Hemionitis esculenta* Retz., Observ. Bot.: 38. 1791.

— *Anisogonium esculentum* (Retz.) Copel., Philipp. J. Sci. 3: 295. 1908; Holtt., Rev. Fl. Malaya 2: 562, f. 333. 1955.

Rhizome erect, covered with scales; scales, 12 by 1.2 mm, linear with long tail, brown, margin black, toothed. *Stipes* 50-70 cm long, brown, dark brown and scaly at lower portion. *Fronds* 1-2 pinnate, variable in size, often more than 1 m long, deltoid in outline; pinnae about 35-40 by 25-30 cm, stalks about 8 cm long, longest at lower pinnae, oblong in outline, rather suddenly narrowing towards acute apex; pinnules about 10 by 2 cm, sessile, oblong, acuminate at apex, truncate or subtruncate at base; subentire to lobed at margin, about ¼ way to costule, round at apex, serrate at margin; papyraceous; vein anastomosing, pinnate, veinlets up to 10 pairs of pinnate groups in each lobe, lower 2-3 pairs of adjacent groups anastomosing, forming an irregular intermediate excurrent veins leading towards a sinus between adjacent lobes. *Sori* elongate nearly the whole length of veinlets, often uniting with the opposite ones; indusia thin. *Spores* monolete, 35-42.5 by 20-25 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: postulate (Fig. 4.7; Pl. 2: B).

Specimens Examined.– O. Neamsuvan 103 (BCU); O. Ratana 25 (BCU); P. Ratchata 202, 208 (BCU); S. Pimpa 45 (BCU); T. Boonkerd 17, 191 (BCU); U. Damsri 43 (BCU); C. F. van Beusekom & C. Phengkhlai 97 (BKF); C. F. van Beusekom, C. Phengkhlai, R. Geesink & B. Wongwan 4179 (BKF); Gordon H. Spare 36050 (BKF); J. F. Maxwell 95-959, 97-25 (BKF); K. Iwatsuki & N. Fukuoka T7395 (BKF); K. M. laid 23381

(BKF); Kai Larsen & Supee S. Larsen 32875 (BKF); L. Mousset 48 (BKF); Lita M. Banoc 47 (BKF); Michio Matsuoka 193 (BKF); Pai 145 (BKF); R. Geesink, T. Hattink & C. Phengklai 7115 (BKF); R. Schlechter 17313 (BKF); T. Voungthavone 128 (BKF); T. Voungthavone 157 (BKF); J.F. Maxwell 88-867 (PSU).

Thailand.– NORTHERN: Chiang Rai (Mae Kok), Chiang Mai (Fang, Ban Mae Kon, Mae Klang, Kang Kat, Sop Aep), Mae Hong Son (Mae La Noi, Mae Su Rin), Lanpang, Tak; NORTH-EASTERN: Loei (Nong Hin); EASTERN: Chiyaphum (Nam Phrom); SOUTH-WESTERN: Kanchanaburi (Kroeng Kawia, Phomphi, Sai Yok); CENTRAL: Nakhon Nayok (Khao Yai), Saraburi (Muak Lek), Krung Thep (Bangkok); SOUTH-EASTERN: Chon Buri (Si Racha), Prachin Buri, Rayong (Ban Khai); PENINSULAR: Surat Thani (Khao Pok, Ban Don), Satun, Narathiwat (Waeng).

Distribution.– Tropics of Asia (type from India), north to Central China and S. Japan, east to S. Pacific Islands.

Ecology.– Usually on moist ground in paddy fields or along stream banks in open places or at least in light shade at low or medium elevation.

Note.– Young fronds locally consumed as vegetable.

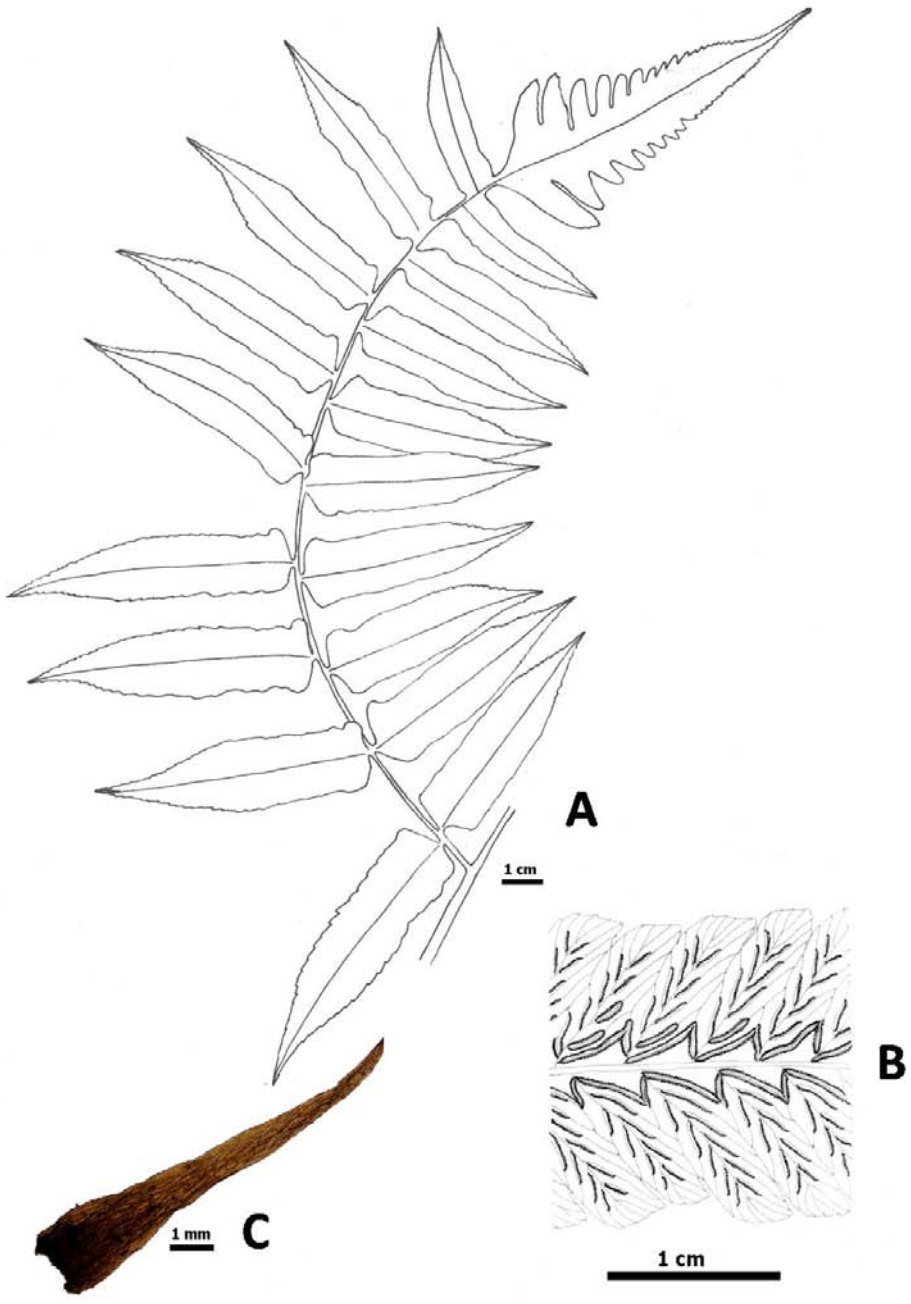

Figure 4.7 *Diplazium esculentum* (Retz.) Sw. A: pinna; B: vein and sori and C: scale.

8. ***Diplazium griffithii*** **T. Moore,** Index. Fil. 330. 1861; C. Chr. Ind. Fil. 233. 1905.

— *Asplenium griffithii* (T. Moore) Baker, Syn. Fil. 239. 1867.

— *Athyrium griffithii* (T. Moore) Milde, Bot. Zeitung. 28: 354. 1870.

— *Allantodia griffithii* (T. Moore) Ching, Acta Phytotax. Sin. 9(1): 52. 1964.

Rhizome creeping, about 1.5-2 cm in diam., covered with scales at apex; scales about 10-12 by 0.8-1 mm, narrowly lanceolate with long tail, margin black, brown, toothed at margin. *Stipes* about 40-50 cm long, brown, black and densely scaly at lower portion. *Fronds* bipinnate to tripinnatisec, subdeltoid in outline; pinnae about 20 by 10 cm, stalks 2-2.5 cm long, longest at lower pinnae, oblong in outline, narrowing towards acute apex; pinnules about 5 by 1.5 cm, sessile or very short stalk, less than 1 mm long, subdeltoid, acuminate at apex, truncate at base; lobed at margin, ¾ way to costule, about 7 by 4 mm, papyraceous; veins all free, pinnate, veinlets 5-6 pairs, simple or once forked. *Sori* elongate along veinlets, about 1-2 mm long, oblong, close to costule; indisia thin. *Spores* monolete, 44-46.5 by 28-32 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.8; Pl. 2: C).

Specimens Examined.– T. Boonkerd 492 (BCU); T. Boonkerd 1330 (BCU); E. Hennipman 3041(BKF); E. Hennipman 3259 (BKF); E. Hennipman 3415 (BKF); F. Konta, C. Phengklai & S. Khao-Iam Hab 4864 (BKF);F. Konta, C. Phengklai & S. Khao-Iam Hab 4903 (BKF); F. Konta, C. Phengklai & S. Khao-Iam Hab 11389 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T1820 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T2656 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T2879 (BKF); W. Griffith s.n. (holotype, isotype BGBM!).

Thailand.–NORTHERN: Chiang Mai (Doi Chiang Dao, Doi Inthanon), Tak (Um Pang, Mae Sod), Nakhon Sawan (Doi Musur); NORTH-EASTERN: Loei (Phu Luang)

Distribution.– China, India (type form Assam) and Vietnam.

Ecology.– Terrestrial on hill slope in shady areas at 1,250-2,500 m alt.

Note.– This species is a new record for Pteridophyte Flora of Thailand.

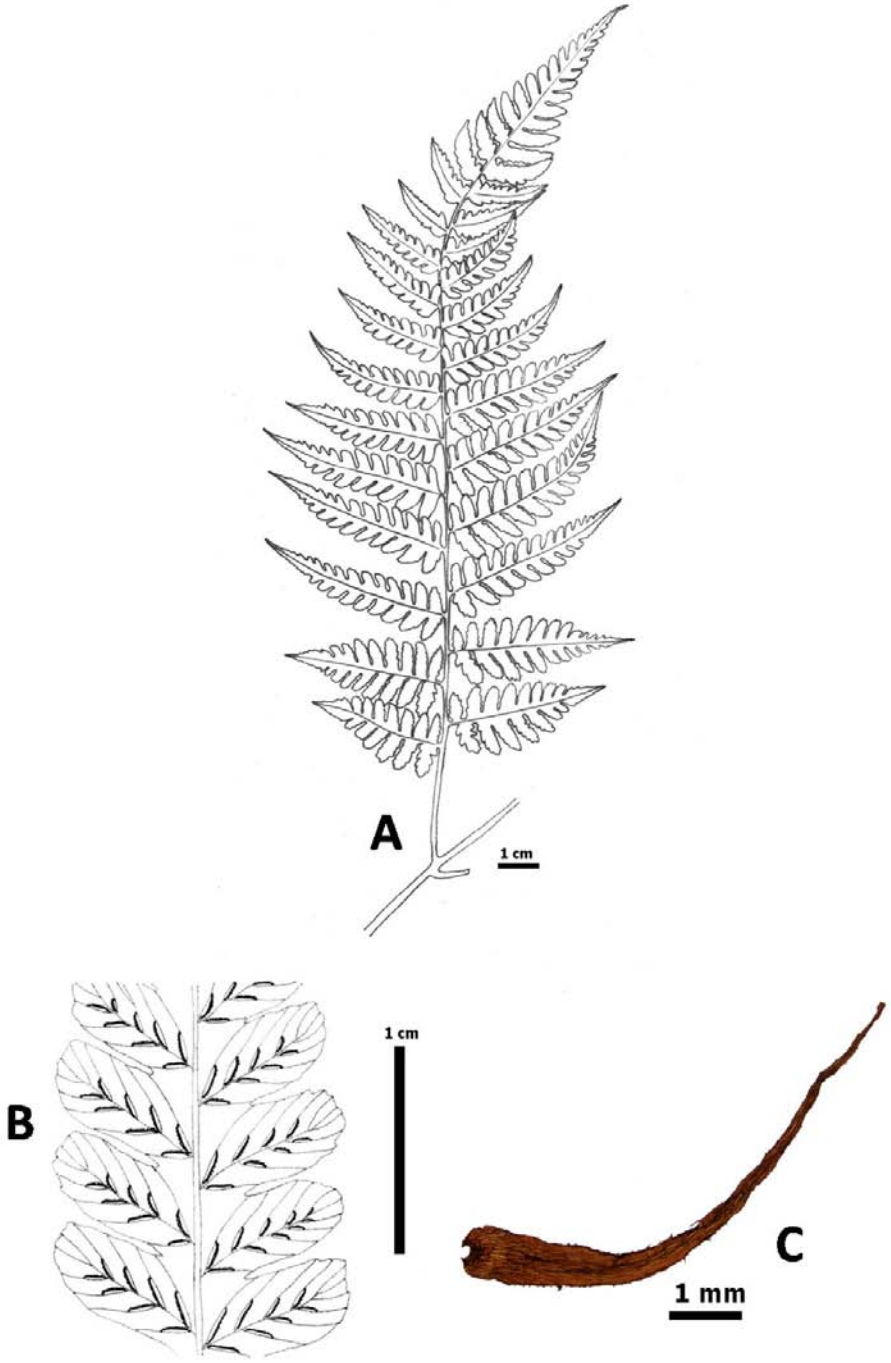

Figure 4.8 *Diplazium griffithii* T. Moore. A: pinna; B: vein and sori and C: scale.

9. *Diplazium heterophlebium* (Mett. ex Baker) Diels, Nat. Pflanzenfam. 1(4): 28. 1899; Tard. & C. Chr. In Fl. Indo-Chine 7(2): 268. 1940; Tagawa & K. Iwats., Acta Phytotax. Geobot. 24: 63. 1969; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 451. 1988; K. Iwatsuki, Ferns and Fern Allies of Japan: 257. Pl. 176-5. 1992.

— *Asplenium heterophlebium* Mett. ex Baker, Syn. Fil.: 243. 1867.

— *Anisogonium heterophlebium* (Mett. ex Baker) Bedd., Ferns Brit. India: t. 329. 1869; Handb. Ferns Brit. India: 191, f. 93. 1883.

— *Athyrium heterophlebium* (Mett. ex Baker) Copel., Philipp. J. Sci. 38: 142. 1929; Holtt., Rev. Fl. Malaya 2: 549. 1955.

Rhizome short erect or ascending, bearing wiry root, covered with scales at apex; scales 5-7 by 1-2 mm, ovate with long tail apex, concolorous, pale brown, membranous, entire margin with caducous membrane at margin near apex. *Stipes* up to 50 cm long, scaly at lower part, brown, black near base. *Fronds* unipinnate about 40-45 by 20-25 cm, oblong in outline, terminal pinna not distinct; lateral pinnae 5-6 pairs, 10-12 by 4 cm, sessile, oblong, attenuate at apex, truncate or cordate at base, undulate at margin; herbaceous, minutely hairy on surface; rachis minutely scaly as well as hairy; veins pinnate, anastomosing, forming areoles without included veinlets. *Sori* elongate along veinlets; indusia completely covering the sori, not so thin, brown. *Spores* monolete, 60.5-62 by 36-40 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.9; Pl. 2: D).

Specimens Examined.– W. Griffith s.n. (Type? B!); C. Phengklai et al. 10522 (BKF); E. Hennipman 3432 (BKF).

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

Distribution.– E. Himalaya to Yunnan, south to N. Vietnam and Malaya, north to southern edge of Japan (Yakushima Island).

Ecology.– Terrestrial along stream banks in moist hill evergreen forest at about 1,750 m alt.

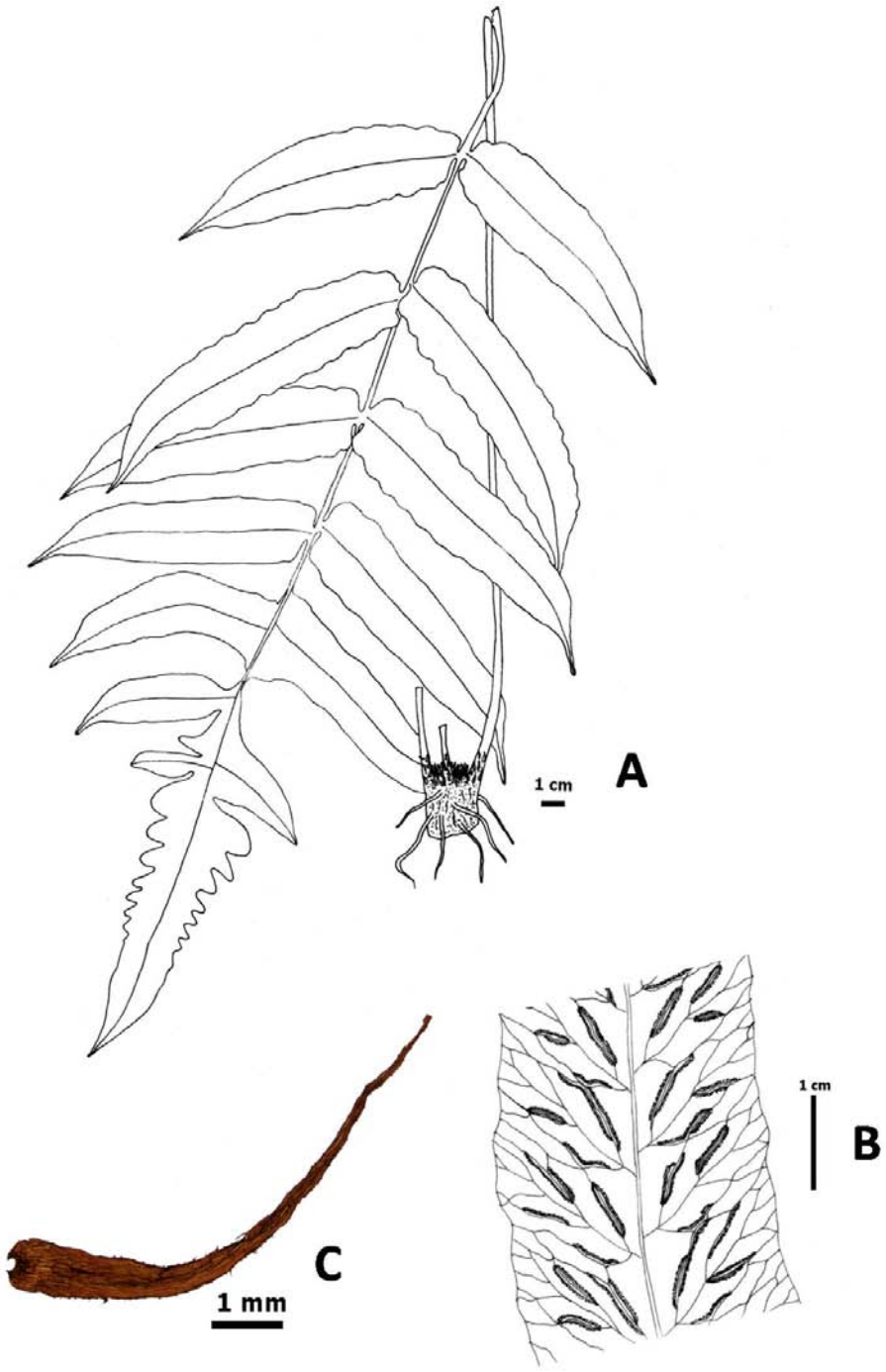

Figure 4.9 *Diplazium heterophlebium* (Mett.) Diels. A: habit; B: vein and sori and C: scale.

10. *Diplazium leptophyllum* Christ, Index Filic., Suppl.: 103. 1913, based on *Asplenium leptophyllum* Bak., Kew Bull. 1906: 10, non Sw. 1791; Tagawa & K. Iwats., SouthE. Asian Stud. 5 : 105. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 463. 1988.

— *Allantodia leptophylla* (Christ) Ching, Acta Phytotax. Sin. 9(1): 56. 1964.

Rhizome short creeping, about 1-1.5 cm in diam.; scales 10-12 by 1-1.5 mm, linear, concolorus, dark brown, entire at margin. *Stipes* 30-50 cm long, glabrous, brown, dark at lower portion. *Fronds* bipinnate to bipinnate-tripinnatifid, about 60-70 by 50-60 cm, subdeltoid in outline, terminal pinna not distinct; pinnae about 25-30 by 15 cm, stalks 1.5-2 cm long, oblong in outline, acuminate at apex; pinnule about 5-6 by 2.5-3 cm, shortly stalked, subdeltoid, acuminate at apex, subtruncate to truncate at base; lobed at margin, ¾ way to costule, round at apex, serrate at margin; herbaceous, light green; veins pinnate, veinlets 4-5 pairs, free, simple or once forked. *Sori* about 3-5 mm long, elongate along veinlets, diplazoid, usually on basal veinlets of vein group. *Spores* monolete, 30-37.5 by 17.5-20 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: echinate (Fig. 4.10; Pl. 3: A).

Specimens Examined.– A. Henry 13,106 (Type? B!); J. F. Maxwell 93-771, 98-1444 (BKF); M. Tagawa et al. T9324 (BKF); S. Premwichit 5 (BKF); T. Shimizu & M. Hutoh T10210 (BKF).

Thailand.– NORTHERN: Chiang Rai (Mae Lao), Chiang Mai (Doi Chiang Dao, Doi Suthep), Lamphun (Doi Khun Tan).

Distribution.– Yunnan (type) and Myanmar.

Ecology.– On moist ground or on mountain slopes in dense mixed or evergreen forests at 850 – 1,600 m alt.

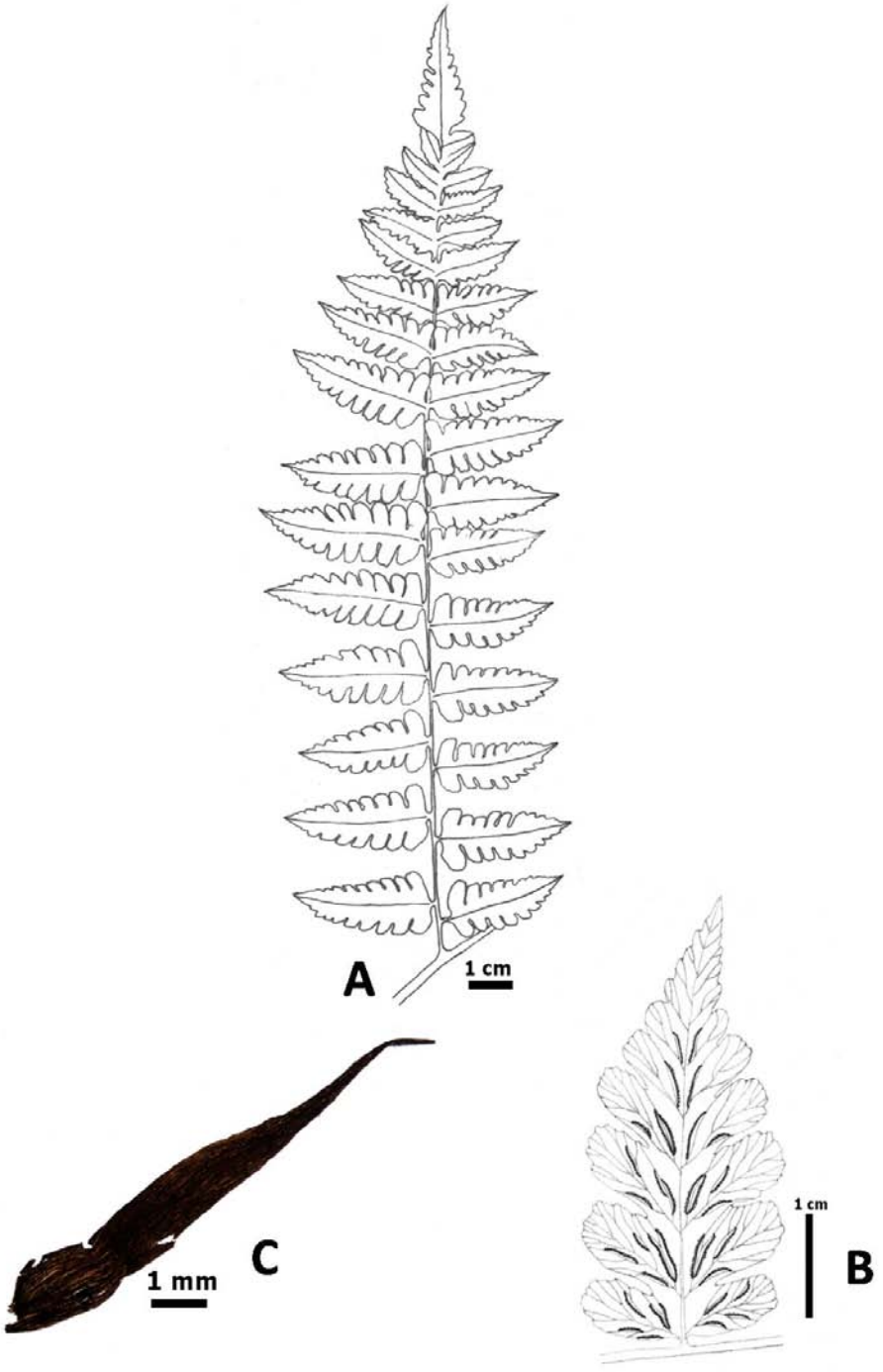

Figure 4.10 *Diplazium leptophyllum* Christ. A: pinna; B: vein and sori and C: scale.

11. *Diplazium lobatum* (Tagawa) Tagawa, Acta Phytotax. Geobot. 20: 215. 1926; K. Iwatsuki, Ferns and Fern Allies of Japan: 251, Pl. 168-1-2. 1992; Shieh et al., Fl. Taiwan 1: 441. 1994.

— *Diplazium donianum* (Mett.) Tardieu var. *lobatum* Tagawa in Acta Phytotax. Geobot. 10: 290. 1941.

Rhizome creeping, bearing wiry roots, covered with scales at apex; scales about 8-10 by 1 mm, narrowly lanceolate with long tail apex, concolorous, bark brown, toothed at margin. *Stipes* 35-40 cm long, stramineous, glabrous, scaly and black at base. *Fronds* imparipinnate, about 45-50 by 20-25 cm, oblong in outline, terminal pinna distinct; terminal pinna about 20 by 3-4 cm, oblong, attenuate at apex, crenate to lobed at margin; lateral pinnae 7 pairs, about 15-20 by 2.5-3 cm, oblong, acuminate at apex, subtruncate at base, subentire at margin, shortly stalked, about 5-6 mm long, veins all free, veinlets 3 pairs. *Sori* about 7-9 cm, along veinlets, about half way from costa to margin, diplazoid; indusia thin. *Spores* monolete, 61.5-63 by 31-32 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.11; Pl. 3: B).

Specimens Examined.– Pteridophyte trip 72 (BCU), W. Khwaiphan 29 (BCU).

Thailand.– NORTHERN: Phitsanulok (Phu Hin Rong Kla).

Distribution.– Japan, Taiwan. Type?

Ecology.– On mountain slopes in light shade at 1,700 m alt.

Note.– This species is a new record for Pteridophyte Flora of Thailand. It is similar to *D. donianum* but differed in terminal pinna crenate or lobed at margin and scales is not black at margin.

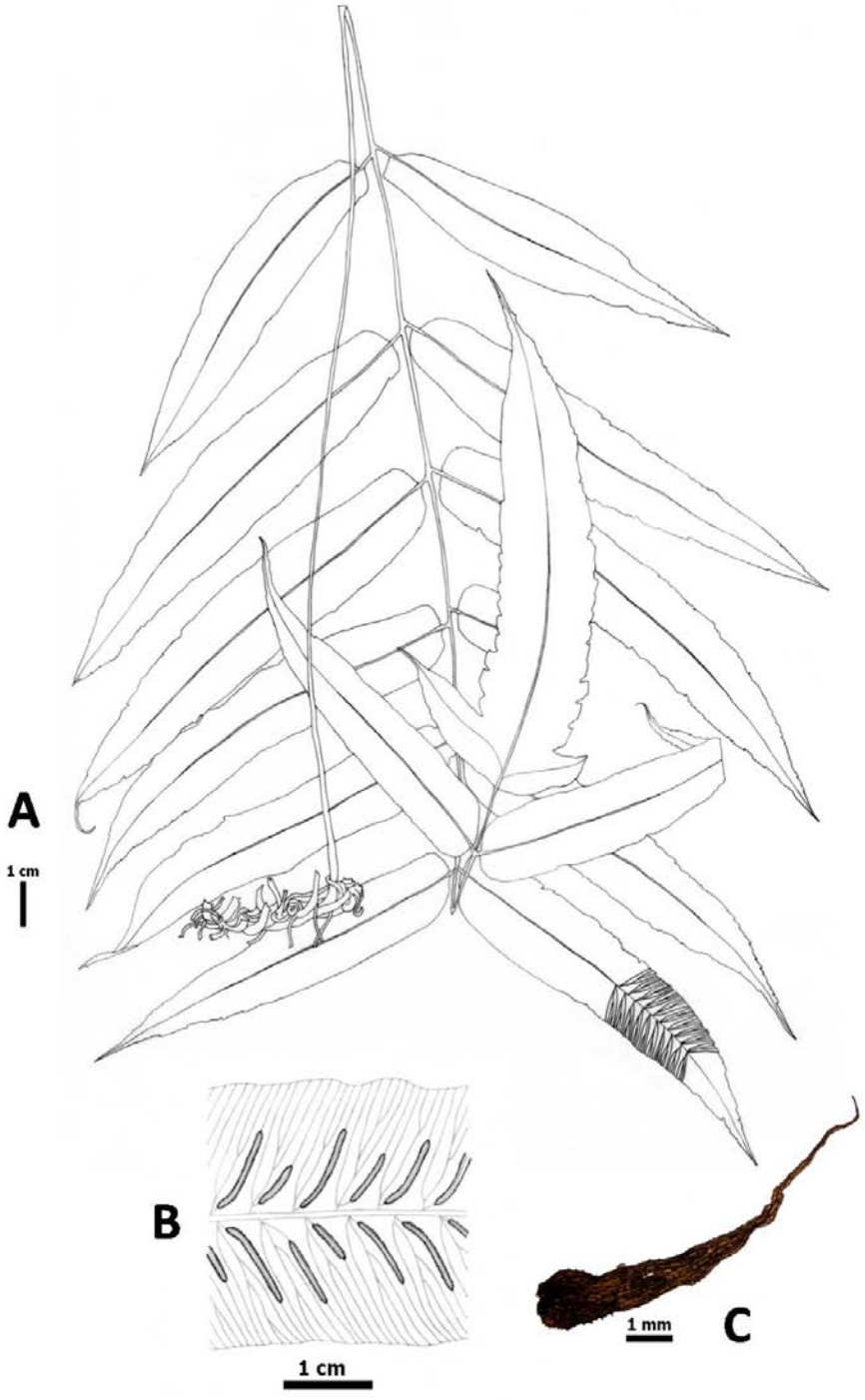

Figure 4.11 ***Diplazium lobatum*** (Tagawa) Tagawa. A: habit; B: vein and sori and C: scale.

12. *Diplazium malaccense* C. Presl, Epimel. Bot: 86. 1849; Tard. &C. Chr., Fl. Indo-Chine 7(2): 258. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian. Stud. 5: 104. 1967; Acta Phytotax. Geobot. 23: 1968; Tagawa & K. Iwats., Fl. Thailand 3(3): 458. 1988; A.G. Piggott., Fern of Malaya in colour: 297, f. 916-918. 1996.

— *Athyrium malaccense* (C. Presl) Holttum, Rev. Fl. Malaya 2: 552. 1995.

Rhizome short erect; scales about 10-12 by 1-1.5 mm, linear, concolorous, light brown, entire at margin. *Stipes* about 25-30 cm long, densly scaly at base, brown at base. *Fronds* unipinnate-bipinnatifid, about 55-60 by 25 cm, terminal pinna not distinct, oblong in outline, long acuminate at apex, gradually becoming smaller upwards; lateral pinnae 20-30 pairs, about 15 by 2 cm, shortly stalked, 1-2 mm long, oblong, long acuminate at apex, subtruncate at base; lobed at margin, 2/3 way to costa, about 5 mm wide, round or obtuse at apex, subentire at margin; papyraceous, green; veins pinnate, free, 5 pairs, all simple. *Sori* elongate along all veinlets; indusia drying brown, persistent. *Spores* monolete, 32.5-35 by 20-22.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.12; Pl. 3: C)

Specimens Examined.– C. Niyomtham & P. Puudjaa 5466 (BKF); Eryl Smith 1918 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T6830 (BKF); Winit 262 (BKF); Cuming 389 (Isotype MICH!, MO!)

Thailand.– PENINSULAR: Surat Thani (Ban Don), Trang (Khao Chong), Yala (Ban Mae Prik).

Distribution.– Indochina to Malaysia (type form Malacca).

Ecology.– On mountain slopes in dense evergreen forests at medium altitudes.

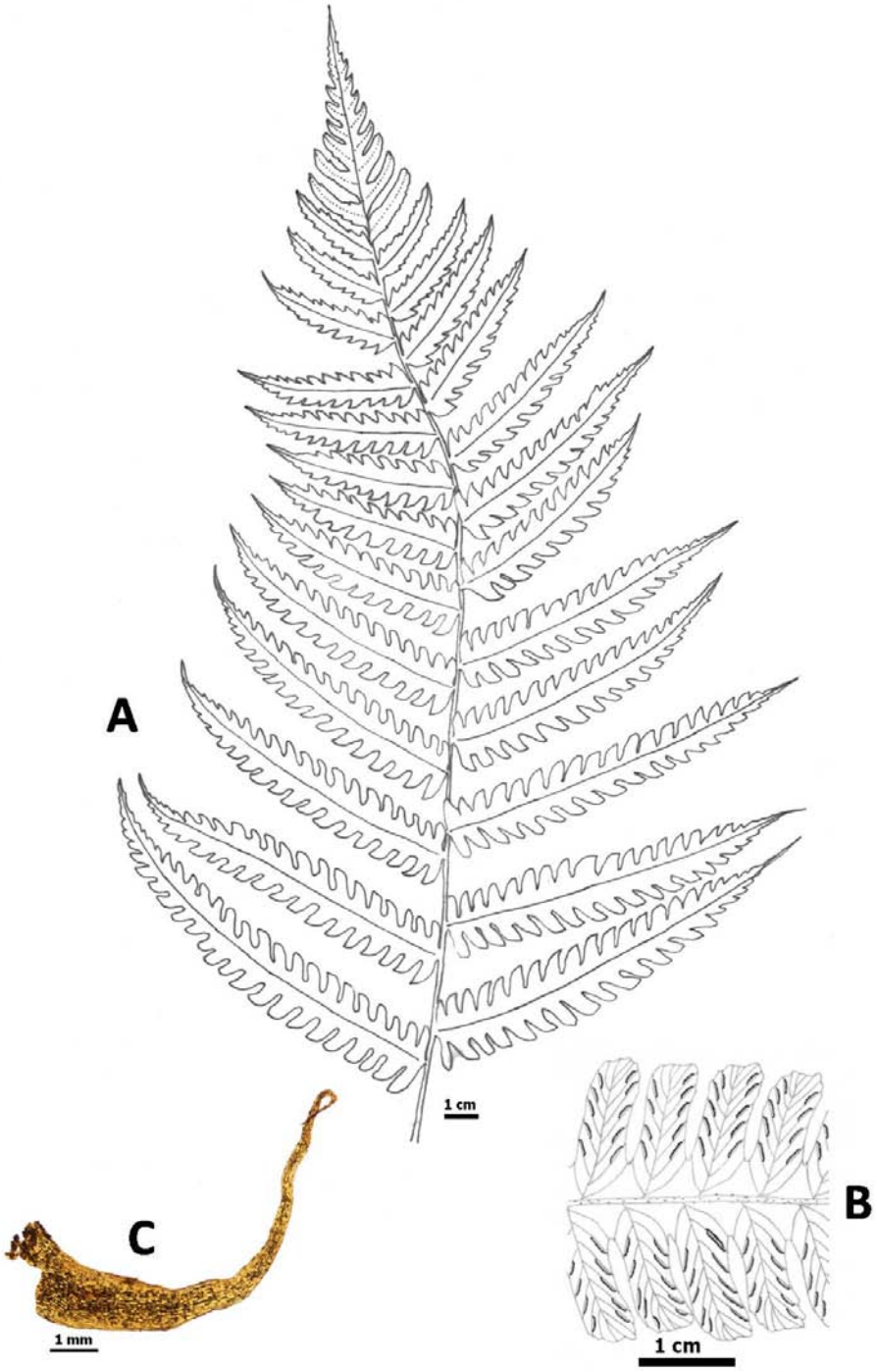

Figure 4.12 *Diplazium malaccense* C. Presl. A: pinna; B: vein and sori and C: scale.

13. *Diplazium megaphyllum* (Baker) Christ, Bull. Herb. Boissier. 6: 961. 1898; Tard. & C. Chr. In Fl. Gen. I.-c. 7(2): 251. 1940; M. Tagawa & K. Iwatsuki., Acta Phytotax. Geobot. 24: 63. 1969; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 456. 1988.

— *Asplenium megaphyllum* Baker, J. Bot. 28: 264. 1890.

— *Allantodia megaphylla* (Baker) Ching, Acta Phytotax. Sin. 9(1): 50. 1964.

Rhizome massive, erect, covered with scales at apex; scales 1-10 by 1-1.5 mm, lanceolate with long tail apex, dark brown, margin black and toothed. *Stipes* up to 50-60 cm long, scaly and dark at base. *Fronds* imparipinnate, about 60-70 by 40-50 cm, oblong in outline, acuminate at apex, terminal pinna distinct; terminal pinna, deltoid, acuminate at apex, subtruncate at base, lobed at margin; lateral pinnae suddenly becoming smaller upward, 10-12 pairs, about 15-20 by 4 cm, oblong, acuminate at apex, subtruncate at base, subentire to crenate at margin, sessile or shortly stalked, about 3-4 mm long, longest at lower pinnae; papyraceous; veins free, pinnate, veinlets 5 pairs. *Sori* elongate along veinlets, on all veinlets, diplazoid; indusia thin. *Spores* monolete, 52.5-60 by 20-22.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.13; Pl. 3: D).

Specimens Examined.– E. Hennipman 3064 (BKF); B. Balansa 1836 (Lectotype P!; Syntype P!).

Thailand.– NORTHERN: Tak (Doi Musoe), Nakorn Sawan.

Distribution.– E. Myanmar, SW. China (Kwangsi, Kweichow, Yunnan), Taiwan, Vietnam (type from Tonkin) and Annam.

Ecology.– Along streamlet banks in moist evergreen forests at about 800 m alt.

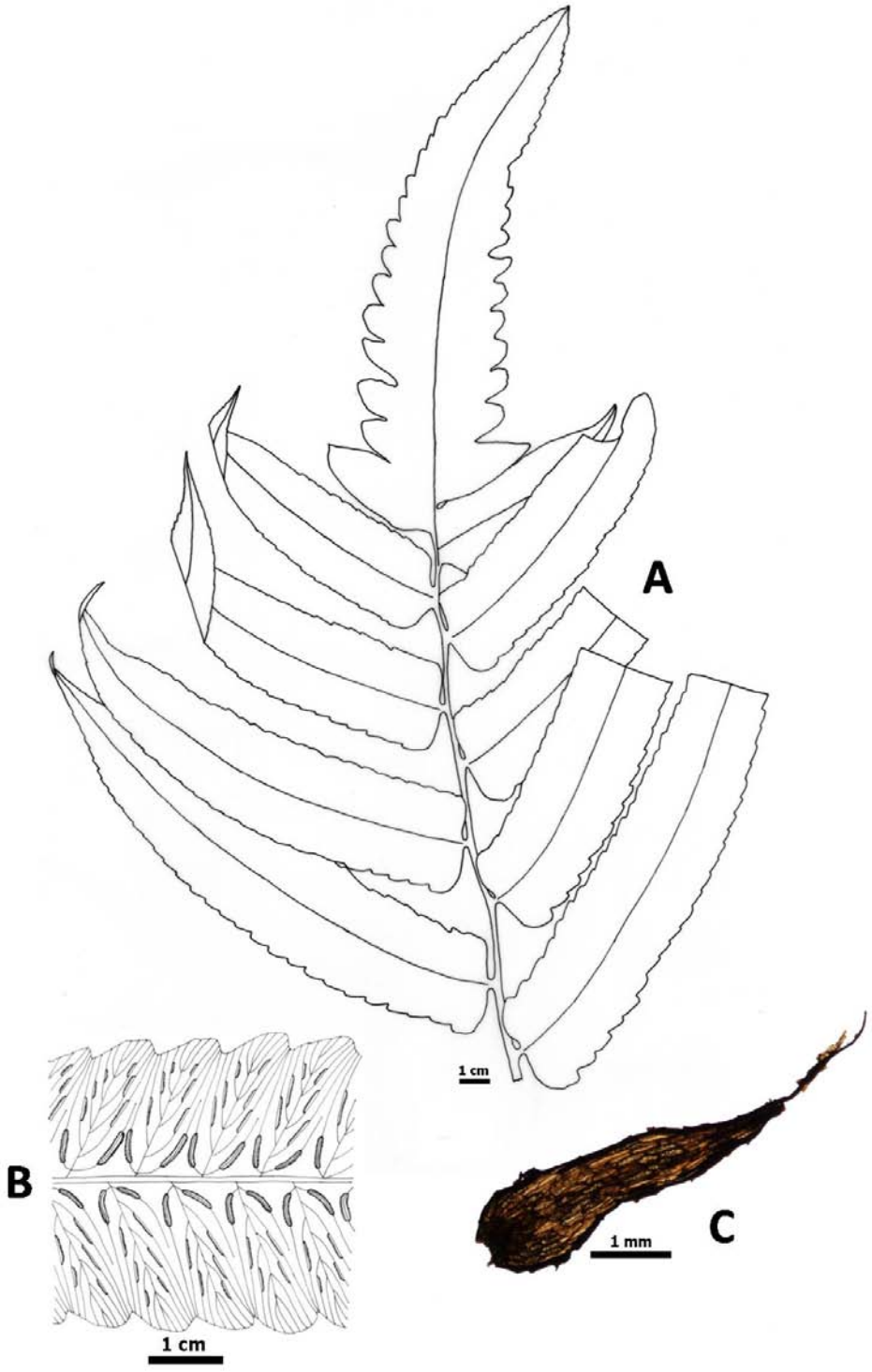

Figure 4.13 *Diplazium megaphyllum* (Baker) Christ. A: pinna; B: vein and sori and C: scale.

14. *Diplazium mettenianum* (Miq.) C. Chr., index Filic.: 236. 1906; Tard. & C. Chr., Fl. Indo-Chine. 7(2): 253. 1940; M. Tagawa & K. Iwatsuki., Southeast. As. St. 5: 103. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 460. 1988; Devol & Kuo, Fl. Taiwan 1. 442: 1994.

— *Asplenium mettenianum* Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 174. 1867.

— *Allantodia metteniana* (Miq.) Ching, Acta phytotax. sin. 9(1): 51. 1964.

Rhizome short creeping, about 1 cm in diam., covered with scales throughout; scales 8-10 by 0.8-1 mm, narrowly lanceolate, concolourous, light brown, toothed at margin. *Stipes* up to 70 cm long, glabrous, stramineous, black at lower portion. *Fronds* unipinnate about 60 by 40 cm, terminal pinna not distinct, oblong in outline, acuminate at apex; lateral pinnae about 25 by 4 cm, stalks 1.5-2 cm long, longest at lower pinnae, oblong, acuminate at apex, cordate at base, lobed at margin, about ¼ way to costa, oblique, round to obtuse at apex, subentire to serrate at margin; upper pinnae rather suddenly becoming smaller, adnate and gradually decurrent at base; thinly chartaceous, deep green when living, brown when dry; veins pinnate, 4-5 pairs, veinlets all free. *Sori* oblong, elongate along veins, about 4-5 mm long, longest at lower veinlets of vein group, diplazoid. *Spores* monolete, 66-68 by 39-42 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.14; Pl. 4: A).

Specimens Examined.– P. Pongkai 20, 23 (BCU); E. Hennipman 3691 (BKF); K. Iwatsuki 508, 965 (BKF); M. Tagawa, K, Iwatsuki & N. Fukuoka T649 (BKF); N. Fukuoka 20, 368, 380, 509, 539, 1589 (BKF); T. Shimizu et al T22825 (BKF); Rosenstock 6970 (Type? P!).

Thailand.– NORTH-EASTERN: Loei (Phu Kradueng).

Distribution.– N. Vietnam, China, Taiwan to Japan (type).

Ecology.– On humus-rich slopes in dense forests at about 1,100 m alt.

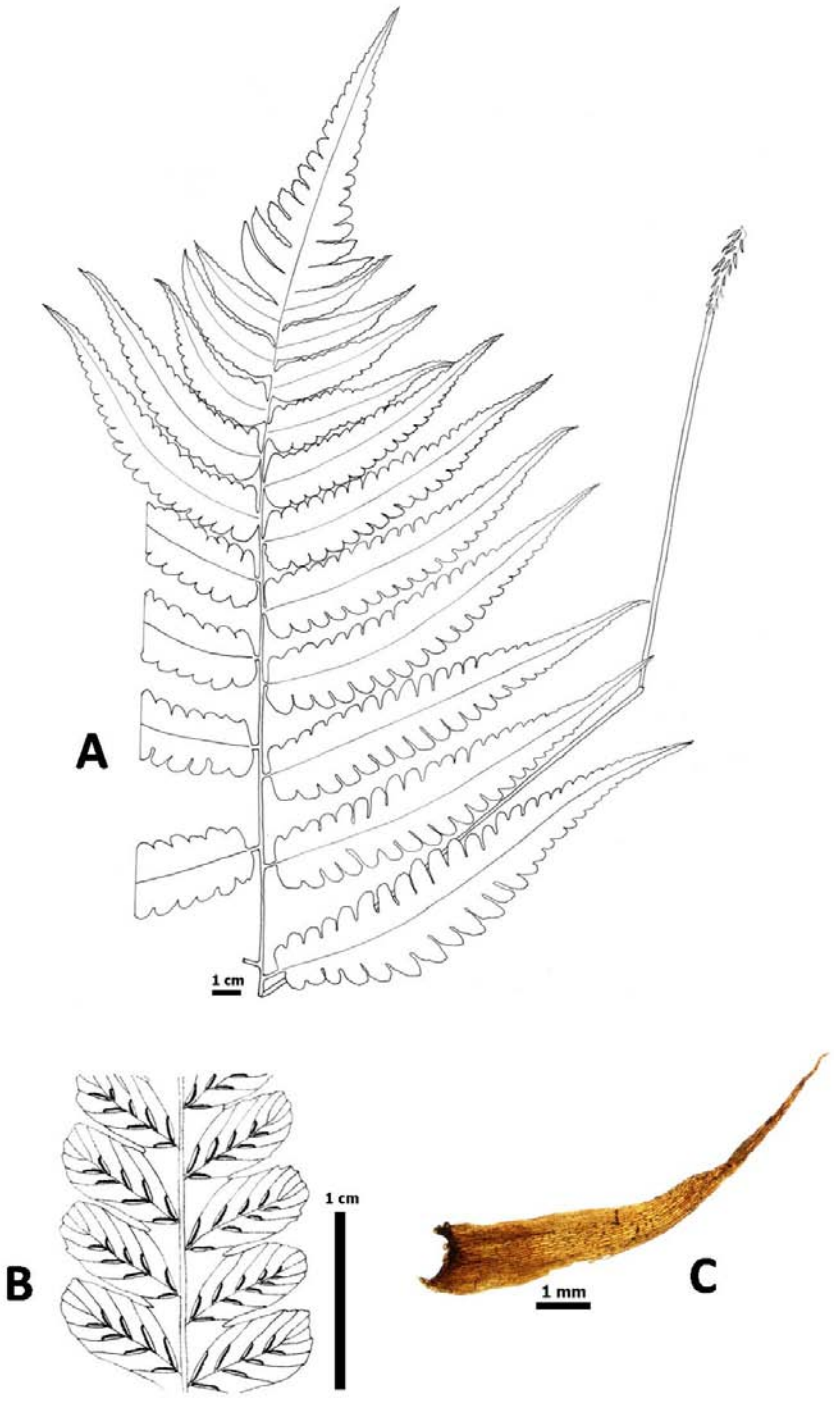

Figure 4.14 *Diplazium mettenianum* (Miq.) C. Chr. A: frond; B: vein and sori and C: scale.

15. *Diplazium muricatum* (Mett.) Alderw., Malayan. Ferns: 829. 1909; Sledge, Bull. Brit. Mus. (Nat. Hist.) Bot. 2: 312. 1962; Tagawa & K. Iwats., SouthE. Asian Stud. 5: 104. 1967; Tagawa & K. Iwats., Fl. Thailand 3(3): 461. 1988.

— *Asplenium muricatum* Mett., Ann. Mus. Bot. Lugduno-Batavi 2: 239. 1866.

Rhizome assending to erect, up to 5 cm in diam., densely scaly on apical part; scales 12-18 by 1-2 mm, narrow, concolorous, brown, minutely toothed at margin. *Stipes* up to 1 m long, densely scaly and dark colour at base. *Fronds* bipinnate-tripinnatifid, about 60-80 by 50-70 cm, subdeltoid in outline, gradually narrowing towards apex; pinnae 9 pairs, lower pinnae about 30 by 20 cm, stalks about 4-5 cm long, oblong in outline, acuminate at apex; pinnules 9-10 by 2 cm, stalks about 2 mm long, oblong, acuminate at apex, subtruncate at base; lobed at margin, nearly to costule, about 12 by 4 mm, oblong, round at apex, sharply serrate at margin; papyraceous, light green; veins pinnate, about 7-8 pairs, free, forked. *Sori* about 2-3 mm, oblong, close to midrib, rarely diplazoid; indusia thin, fragile. *Spores* monolete, 32.5-40 by 22.5-27.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.15; Pl. 4: B).

Specimens Examined.– P. Pongkai 12 (BCU): P. Ratchata 19, 49, 136, 137, 142 (BCU): A.F.G. Kerr 10407 (BK); CC. & CH. 329 (BKF); G. murata, K. Iwatsuki & C. Phengklai T15113 (BKF); G. murata, K. Iwatsuki, C. Phengklai & C. Charamphol T16062 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T2656, T4226 (BKF).

Thailand.– NORTHERN: Chiang Mai (Doi Chiang Dao, Doi Inthanon); SOUTH-WESTERN: Kanchanaburi.

Distribution.– Sri Lanka, India, Burma, Indonesia (type from Java).

Ecology.– On moist mountain slopes in dense forests at high altitudes.

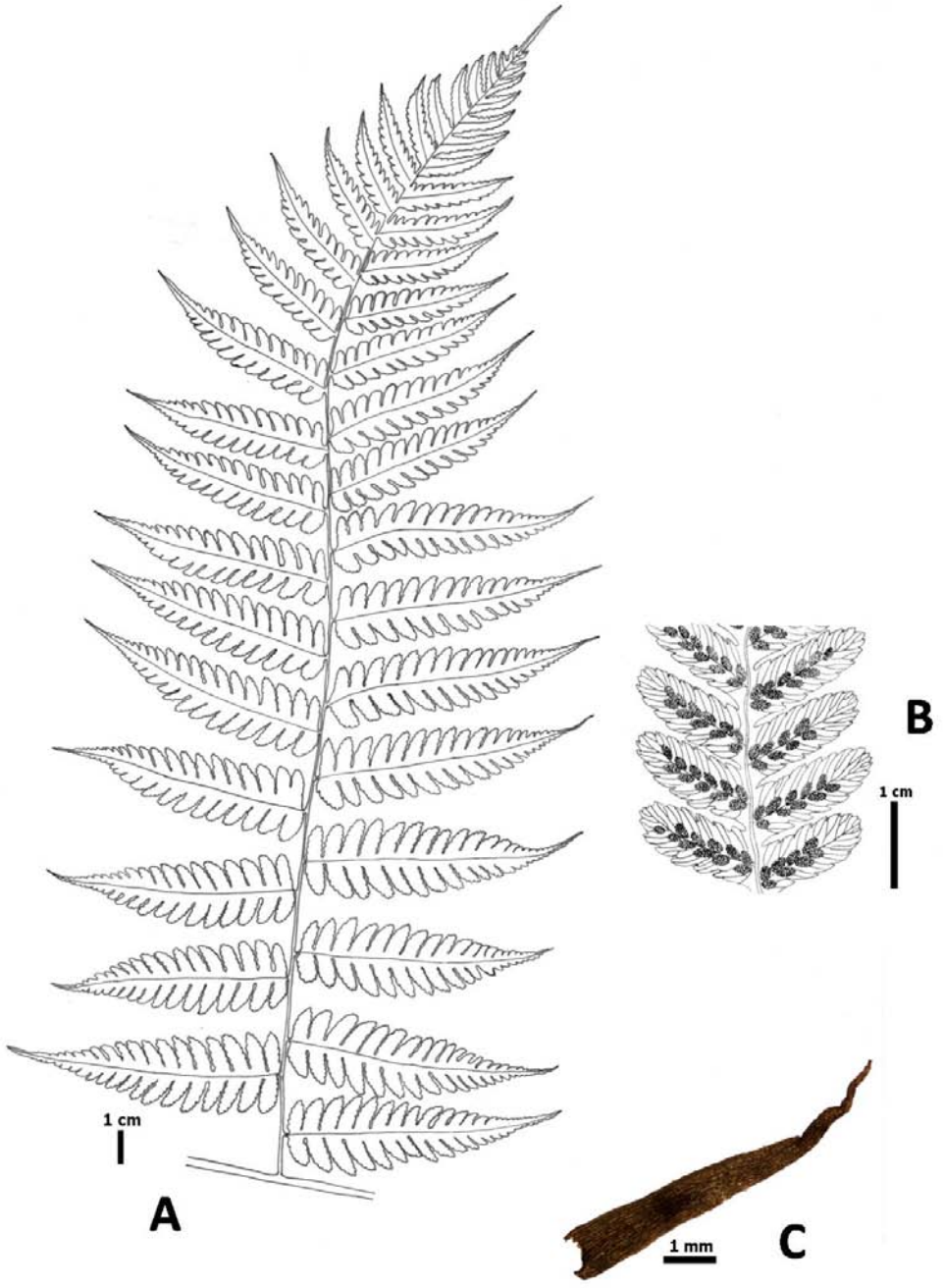

Figure 4.15 *Diplazium muricatum* (Mett.) Alderw. A: pinna; B: vein and sori and C: scale.

16. *Diplazium pallidum* (Blume) T. Moore, Index Fil.: 333. 1861; Bedd., Handb. Ferns Brit. India: 175. 1892; A.G. Piggott., Fern of Malaya in colour: 301. f. 926-928. 1996.

— *Asplenium pallidum* Blume, Enum. Pl. Javae.: 177. 1828.

Rhizome erect about 2.5-3 cm in diam., covered with scales at apex, bearing wiry roots; scales 8-10 by 0.5-0.8 mm, linear, concolorous, entire at margin. *Stipes* up to 40 cm long, glabrous, scaly and dark colour at base. *Fronds* 1-pinnate, 35-40 by 25 cm, oblong in outline; terminal pinna distinct, about 10 by 1.5 cm, oblong, acuminate at apex, subentire at margin, serrate near apex; lateral pinnae 12-13 pairs, about 15 by 2 cm, oblong, subfalcate, acuminate at apex, round or oblique at base, subserrate at margin, sessile or shortly stalked at lower pinnae, about 1-2 mm long, longest at lower pinnae; suddenly becoming smaller upwards; veins all free or once forked. *Sori* about 5 mm long, elongate along veinlets on acroscopic veinlets of vein groups; indusia thin but firm, persistent. *Spores* monolete, 59-65.6 by 35.5-38.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: smooth (Fig. 4.16; Pl. 4: C).

Specimens Examined.– E. Hennipman 3998 (BKF); Kai Larsen, T. Smitinand & E. Warncke 312 (BKF).

Thailand.– SOUTH-EASTERN: Prachin Buri (Khao Yai); PENINSULAR: Nakhon Si Thammarat (Khao Luang).

Distribution.– Malaysia, Philippines. Type?

Ecology.– On shady slopes near streamlets in dense evergreen forests at 600 m alt.

Note.– This species is a new record for Pteridophyte Flora of Thailand.

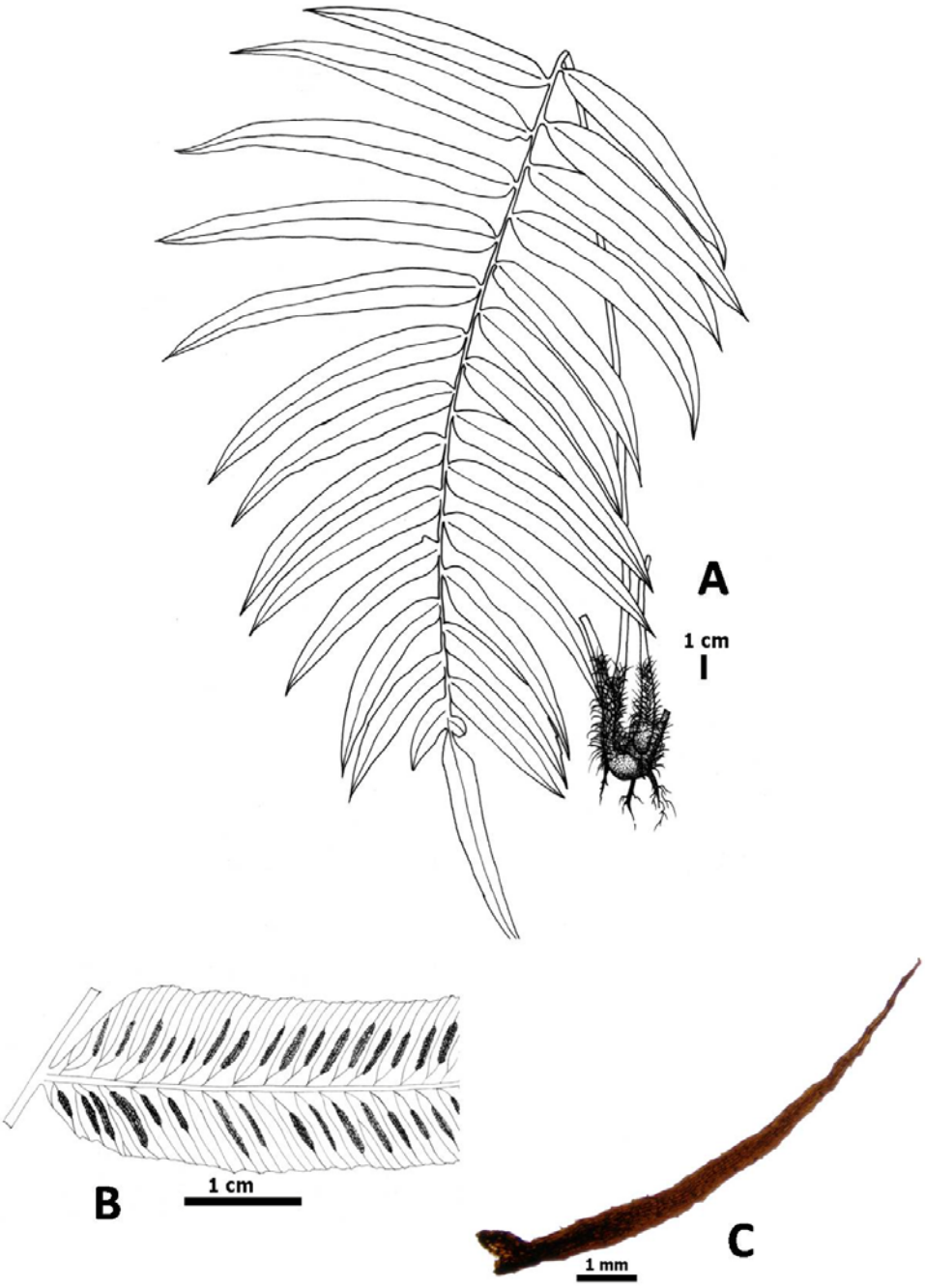

Figure 4.16 *Diplazium pallidum* (Blume) T. Moore. A: habit; B: vein and sori and C: scale.

17. *Diplazium petrii* Tardieu, Aspl. Tonkin: 667. pl. 9, 1-2. 1932; Tard. & C. Chr., Fl. Indo-Chine 7(2): 260. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 104. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 461. 1988; K. Iwatsuki, Ferns and Fern Allies of Japan: 253. Pl. 171-4. 1992; Devol & Kuo, Fl. Taiwan 1. 442: 1994.

— *Allantodia petrii* (Tardieu) Ching, Acta Phytotax. Sin. 9(1): 53. 1964.

Rhizome short creeping, about 2-2.5 cm, covered with scales throughout; scales 11-20 by 8-10 mm, linear long tail, concolorous, black, toothed at margin. *Stipes* 30-40 cm long, green when living, stramineous when dry, dark colour at lower portion, scaly at base. *Fronds* unipinnate-bipinnatifid to bipinnate, 40 by 30 cm subdeltoid in outline, terminal pinna not distinct, upper pinnae gradually becoming smaller upwards; lateral pinnae 20-22 pairs, 15-18 by 3-3.5 cm, narrowing upward, falcate, acuminate at apex, cordate to sub cordate at base, lobed at margin, stalks 1-1.7 cm, longest at lower pinna, the posterior pinnules usually decurrent to the next one; veins pinnate, veinlets 3-4 pairs, simple or once forked. *Sori* elongate, 2-3.5 mm long, cresentic. *Spores* monolete, 30-42.5 by 20-22.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: regulate (Fig. 4.17; Pl. 4: D).

Specimens Examined. – P. Pongkai 68, 69 (BCU); K. Iwatsuki & N. Fukuoka T7160 (BKF); K. Iwatsuki, C. Phengklai, M. Wakabayashi & M. Kato 48 (BKF); K. Iwatsuki, H. Koyama, M. Hutoh & A. Chintayungkun T8387 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T4777 (BKF); Colani 1990 (Syntype P!, Isosyntype MICH!); Peleter 1987 (Type? P!).

Thailand.– SOUTH-EASTERN: Chanthaburi (Khao Soi Dao, Pong Nam Ron); PENINSULAR: Nakhon Si Thammarat (Khao Luang).

Distribution.– Indochina (type), Ryukyu, and Taiwan.

Ecology. – On rather dry mountain slopes in dense evergreen forests at 1,000 – 1,400 m alt., rather rare.

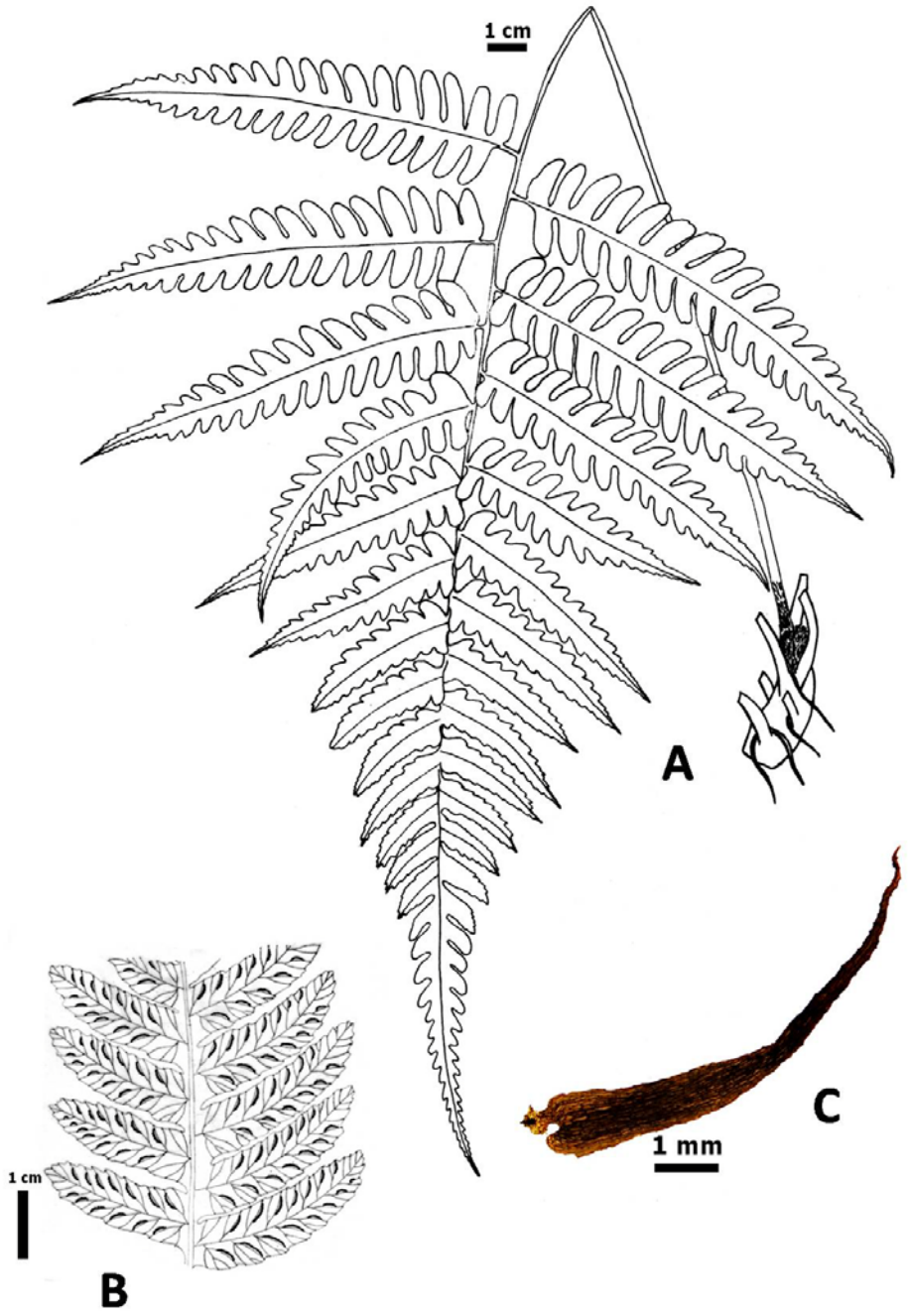

Figure 4.17 *Diplazium petrii* Tardieu. A: habit; B: vein and sori and C: scale.

18. *Diplazium polypodioides* Blume, Enum. Pl. Javae.: 194. 1828; Bedd., Handb. Fern Brit. India: 184. f. 89. 1883; Tard. & C. Chr., Fl. Indo-Chine 7(2): 266. 1940; Holtt., Gard. Bull. Straits Settlem 11: 93. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 3(3): 88. 1965; 5: 105. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 465. 1988.

— *Diplazium asperum* Blume, Enum. Pl. Javae: 195. 1828; Bedd., Handb. Fern Brit. India: 184, f. 88. 1883; Tard. & C. Chr., Fl. Indo-Chine 7(2): 265. 1940.

— *Athyrium asperum* (Blume) Milde, Bot. Zeitung. 1870: 353; Holtt., Rev. Fl. Malaya 2: 571 . f. 320. 1955.

Rhizome massive, erect; scales about 20 by 1-1.5 mm, linear long tail, dark brown to nearly black, toothed and black at margin. *Stipes* up to 1 m long, stout, surface prickly due to scars of fallen scales, densely scaly near base. *Fronds* bipinnate-tripinnatifid, up to 1 m by 70 cm; lower pinnae about 60 by 25 cm, stalks about 5 cm long, oblong in outline, acuminate at apex; pinnules 10-12 by 3 cm, stalks 2-3 mm long, oblong, acuminate at apex subtruncate at base; lobed at margin; almost to costule, about 10 by 5 mm, oblong, oblique, round or obtuse at apex, sharply serrate at margin; papyraceous, deep green; veins pinnate, about 10 pairs, free or forked. *Sori* along veinlets, less than 2 mm long, close to costule; indusia thin. *Spores* monolete, 37.5-45 by 22.5-25.0 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.18; Pl. 5: A).

Specimens Examined.– P. Pongkai 5 (BCU); P. Ratchata 12 (BCU); Syan Pheung Trip 79, 81 (BCU); Bertal Hansen and Tem Smitinand 12887 (BKF); C. Phengklai 11325 (BKF); E. Hennipman 3434 (BKF); Gen Murata, Kunio Iwatsuki, Chomlong Pengklai & Charal Charoenphol T15953 (BKF); J.F. Maxwell 87-1083, 97-1537 (BKF); K. Bunchuai & B. Nimanong 1421 (BKF); K. Iwatsuki & N. Fukuoka T7107 (BKF); L. Mousset 27 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T2880, T3010, T3027, T4518 (BKF); M.F. Newman, T. Boonthavikoon, C. Hemrat & D.J. Middleton 1095 (BKF); T. Smitinand 6675 (BKF); T.

Vougthavone 153 (BKF); W. Wanandorn 962 (BKF); Winit 960 (BKF); A. Henry 11526 (Holotype P!, Isotype MO!).

Thailand.– NORTHERN: Chiang Rai (Mae Lao), Chiang Mai (Doi Suthep, Mae Klang, Doi Inthanon), Phrae (Mae Sai), Tak, Phitsanulok (Phu Miang); SOUTH-WESTERN: Kanchanaburi, Phetchaburi; SOUTH-EASTERN: Chantaburi (Khao Soi Dao); PENINSULAR: Surat Thani (Ban Don), Ranong (Phato), Nakhon Si Thammarat (Khao Luang).

Distribution.– Sri Lanka, S. India, Himalaya, Indochina, Indonesia (type from Java), Malaysia throughout, north to Taiwan.

Ecology.– On humus-rich mountain slopes in high humidity areas at various elevations throughout the country, usually at edge of forests or in clearing, not in deep shade.

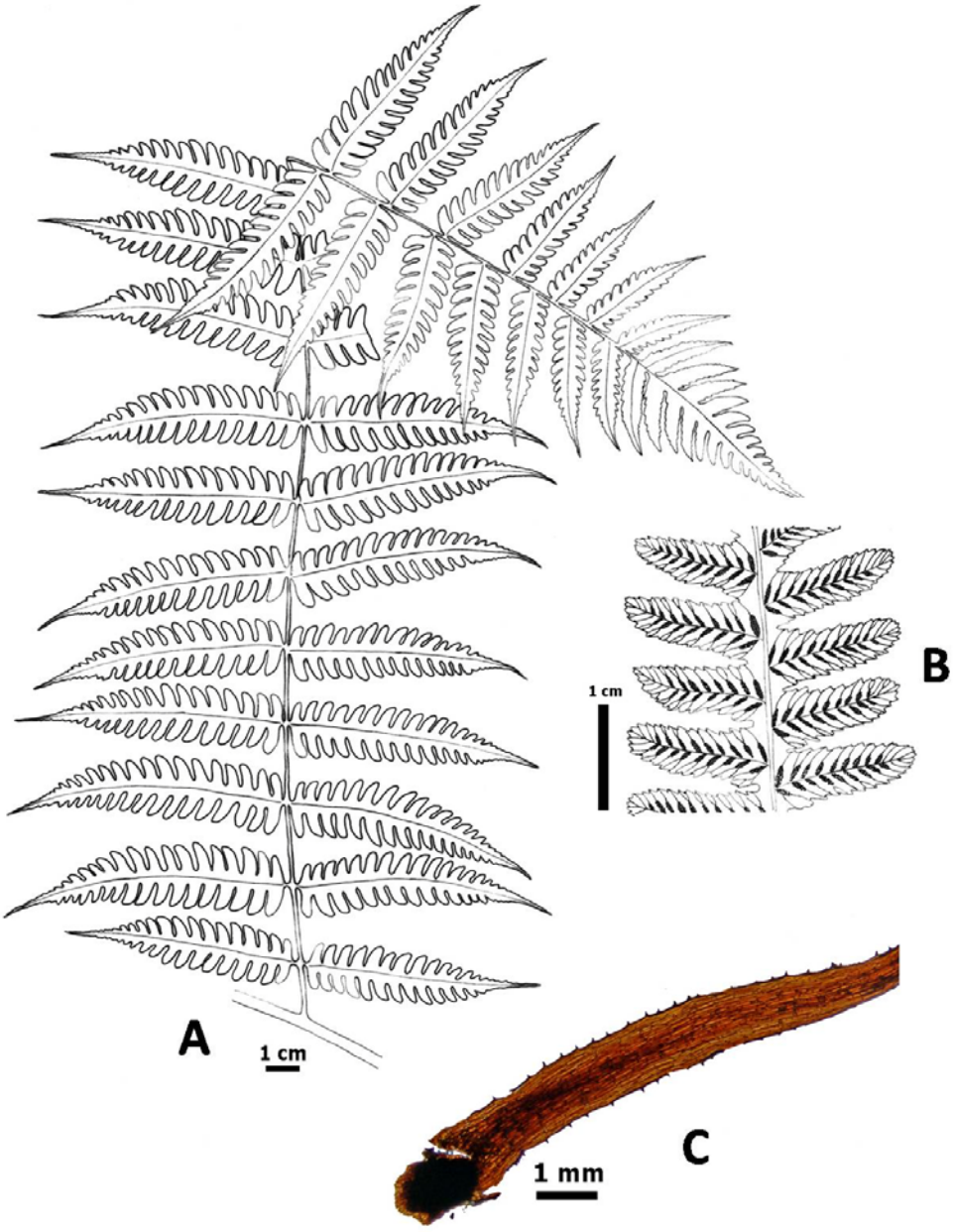

Figure 4.18 *Diplazium polypodioides* Blume. A: pinna; B: vein and sori and C: scale.

19. *Diplazium prescottianum* (Wall. ex Hook.) T. Moore, Index Fil.: 156, 334. 1859; Holtt., Gard. Bull. Straits. Setllem. 11: 94. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 103. 1967; Acta Phytotax. Geobot. 23. 56. 1968; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 457. 1988. Type from Singapore

— *Asplenium prescottianum* Wall. ex Hook., Sp. Fil. 3: 251. 1860.

— *Diplazium sylvaticum* (Bory) Sw. var. *prescottianum* (Wall. ex Hook.) Bedd., Handb. Fern Brit. India: 178. 1883.

— *Athyrium prescottianum* (wall. ex Hook.) Holtt., Rev. Fl. Malaya 2 : 557. 1955.

Rhizome short erect, beraing thick black roots; scales about 15 by 1 mm, narrowly lanceolate, concolorous, dark brown, entire at margin. *Stipes* about 80 cm long, glabrous, stramineous with dark brownish base. *Fronds* unipinnate, about 50 by 20 cm, oblong in outine, suddenly becoming smaller upword, long acuminate apex, terminal pinna not distinct; leteral pinnae 11-12 pairs, about 15 by 1.7-2 cm, long stalk, about 5 cm long, longest at lower pinnae, bolong, falcate, caudate-attenuate at apex, obtuse at base, crenate at margin, moderately auricle at acroscopic base; aucicle, round to obtuse at apex, subentire at margin; veins, pinnate, veinlets 3-4 pairs. *Sori* elongate along veinlets, diplazoid; indusia thin, firm. *Spores* monolete, 40.5-43 by 23.5-25.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: regulate (Fig. 4.19; Pl. 5: B).

Specimens Examined. – Kai Larsen, T. Smitinand & W. Warncke 312 (BKF); J. Sinclair 9376 (SING)

Thailand. – SOUTH-EASTERN: Trat (Ko Chang); PENINSULAR: Nakhon Si Thamarat (Khao Luang), Yala (Ban Chana, Ban Malao).

Distribution. – Malaya, Singapore.

Ecology. – On humus-rich mountain slopes in dense evergreen forests at medium altitudes.

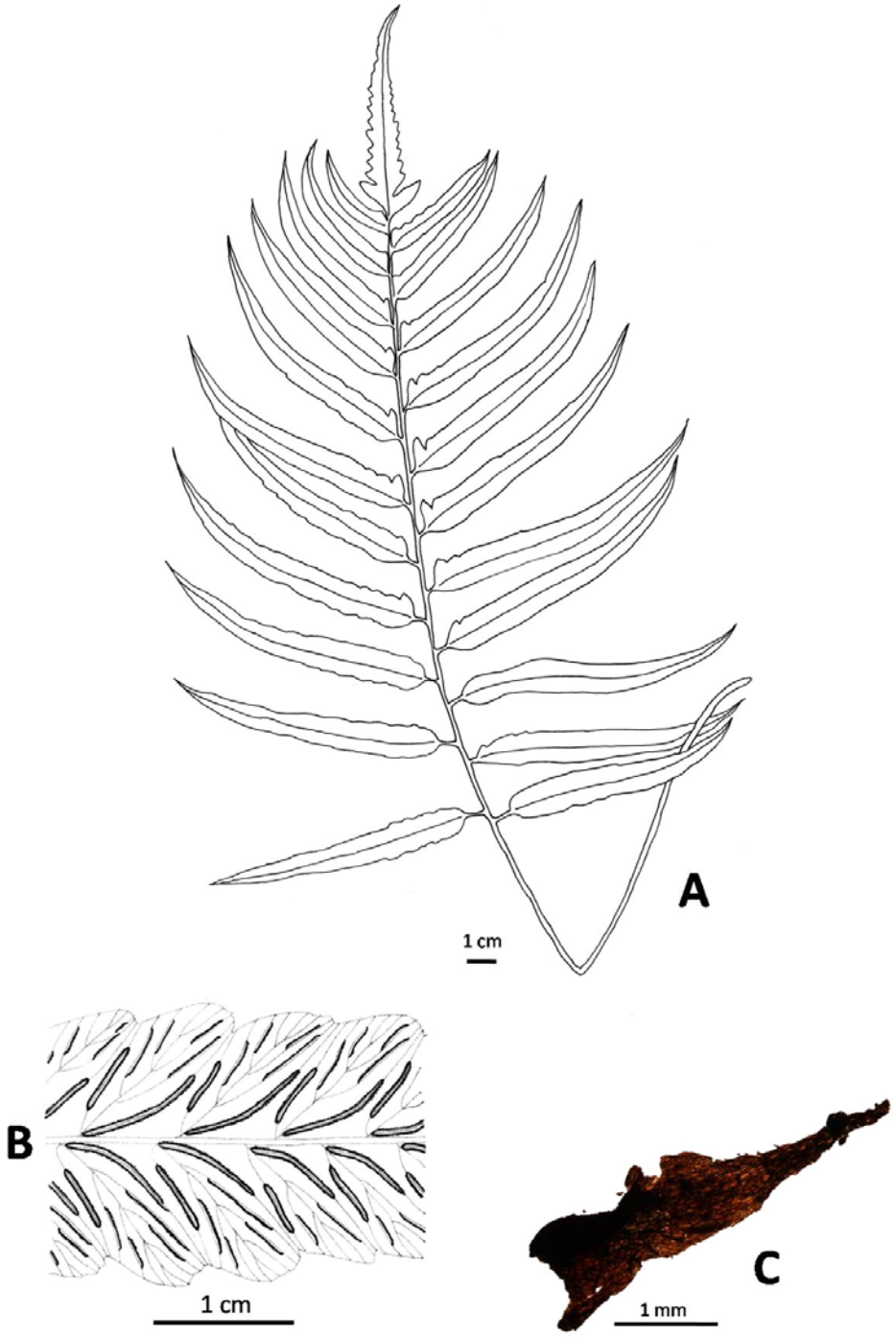

Figure 4.19 *Diplazium prescottianum* (Wall. ex Hook.) T. Moore. A: frond; B: vein and sori and C: scale.

20. *Diplazium procumbens* Holttum,Gard. Bull. Straits Settlem. 11(1): 95, f. 4. 1940.

— *Athyrium procumbens* (Holttum) Holttum, Rev. Fl. Malaya 2: 572, f. 399. 1954.

Rhizome creeping, about 1 cm in diam., densely covered with scales at apex; scales 8-10 by 0.7-1 mm, narrowly lanceolate, concolorous brown, toothed at margin. *Stipes* up to 80 cm long, glabrous, brown, dark colour at lower portion. *Fronds* bipinnate, up to 80 by 80 cm, deltoid in outline, gradually narrowing upwards, long acuminate apex; pinnae, about 50 by 20 cm, oblong in outline, stalks up to 3 cm long, largest at lower pinnae; pinnules 8-9 by 2 cm, oblong, long acuminate to attenuate at apex, truncate at base, stalks 1-2 mm long; lobed at margin, about ¾ way to costule, obtuse at apex, subentire to dentate at margin; veins pinnate, 4-5 pairs, free, once forked. *Sori* elongate along veinlets, 2-4 mm long, diplazoid, close to midrib; indusia very thin; papyraceous. *Spores* monolete, 47.5-57.5 by 25-32.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.20; Pl. 5: C).

Specimens Examined.– D.J. Middleton et al 1762 (BKF), R.E. Holttum 36503 (holotype, isotype SING!).

Thailand.– SOUTH-WESTERN: Petchaburi (Kaeng Krachan National Park).

Distribution.– Malaysia (type).

Ecology.– On moist and shady area, near stream at about 1,300 m alt.

Note.– This species is a new record for Pteridophyte Flora of Thailand.

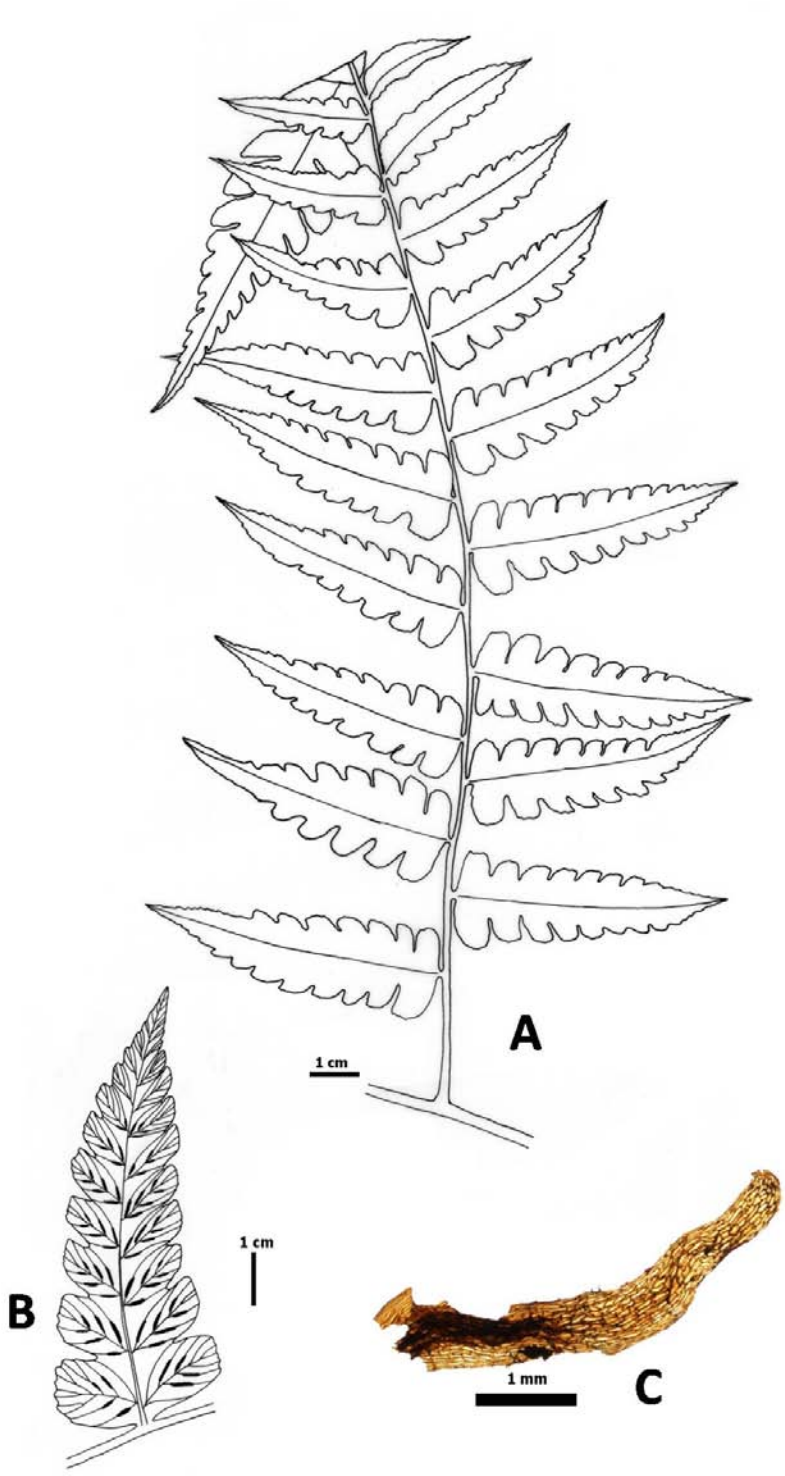

Figure 4.20 *Diplazium procumbens* Holttum. A: pinna; B: vein and sori and C: scale.

21. *Diplazium proliferum* (Lam.) Kaulf., Enum. Filic.: 182. 1824; R.J. Johns., Kew. Mag.: 8(3). 1991.

— *Asplenium proliferum* Lam., Encycle.. Meth. Bot. 2: 307. 1786.

— *Diplazium accedens* Blume, Enum. Pl. Javae: 192. 1828.

— *Athyrium accedens* (Blume) Milde, Bot. Zeitung 28: 353. 1870. Holtt., Rev. Fl. Mal. 2: 558, f. 329. 1955.

Rhizome massive, erect; scales, about 15 by 1 mm, narrowly lanceolate, concolorus, brown, toothed at margin. *Stipes* up to 50 cm long, brown, minutely scaly, spinose on lower part. *Fronds* pinnate, about 70 by 40 cm, oblong in out line, acuminate at apex, usually viviparous at apical portion between terminal pinna and rachis; terminal pinna distinct, about 15 by 10 cm, deltoid, acuminate at apex, subtruncate at base, lobe at margin; lateral pinnae 10-15 pairs, about 15 by 6 cm, oblong, attenuate at apex, truncate at base, serrate or subserrate at margin, sessile or shortly stalk about 5 mm long, longest at lower pinnae, papyraceous; vein strongly anastomosing. *Sori* along vein, on some or all the veinlets; indusia thin. *Spores* monolete, 49.5-51 by 31-35.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.21; Pl. 5: D).

Specimens Examined. – Charn Apasutaya 121a, 121b (BCU); H. Cuming 303 (BKF); C.G. Matthew s.n. (K)

Thailand. – PENINSULAR: Ranong (Phato), Yala (Banang Sata).

Distribution. – Malaysia throughout

Ecology. – On moist ground by streams in evergreen forests at low altitude.

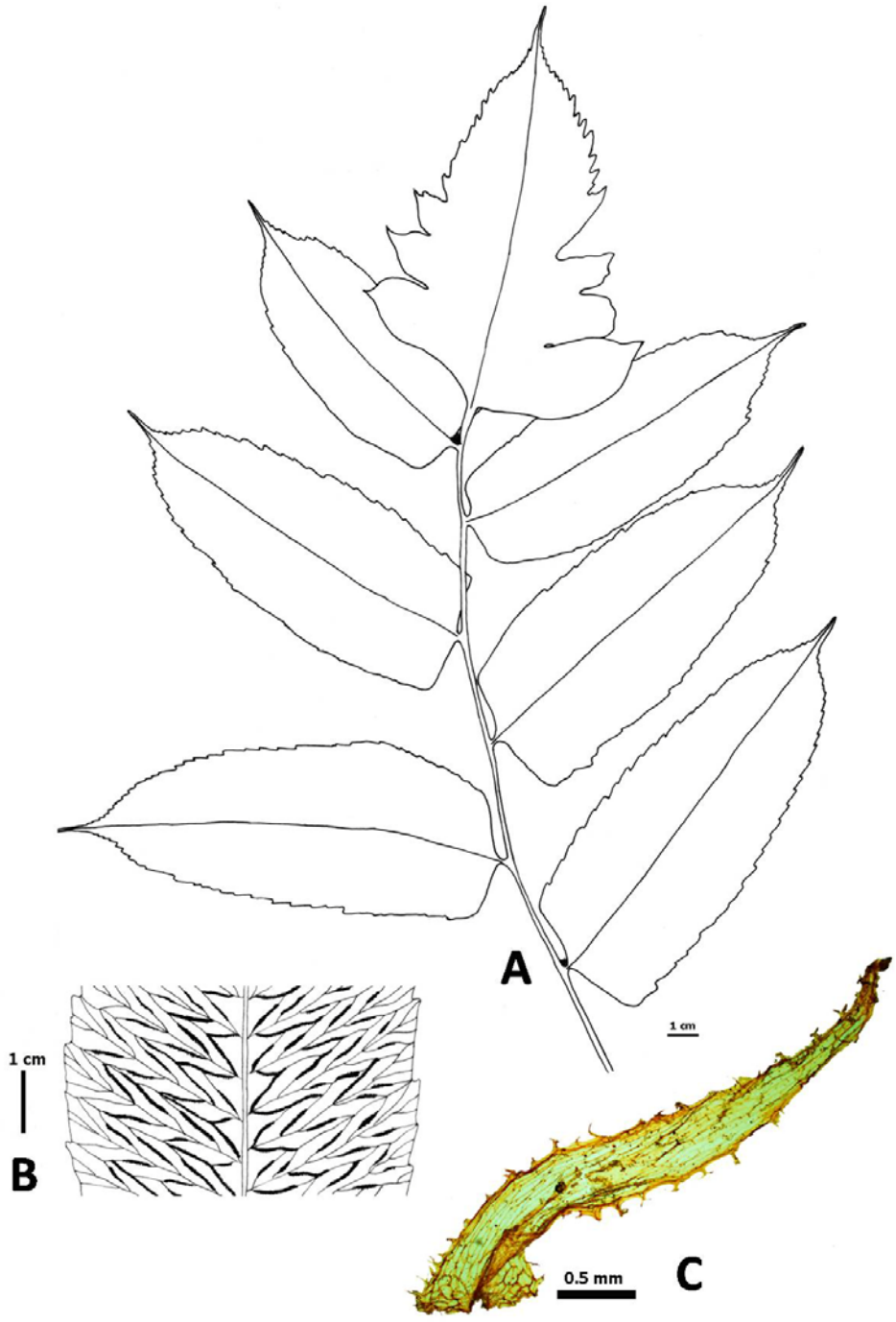

Figure 4.21 *Diplazium proliferum* (Lam.) Kaulf. A: frond; B: vein and sori and C: scale.

22. *Diplazium riparium* Holttum, Gard. Bull. Straits Settlem. 11(1) : 97, f. 5. 1940; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3) : 454. 1988; A.G. Piggott., Fern of Malaya in colour: 300. f. 926-928. 1996.

— *Athyrium riparium* (Holttum) Holttum, Rev. Fl. Malaya 2 : 554. f. 326. 1955.

Rhizome erect, about 1.5 – 2 cm in diam., bearing wiry roots, scaly at apex; scales up to 17 by 2 mm, narrowly lanceolate with long tail, concolorous, dark brown to nearly black, entire at margin with caducous membrane. *Stipes* up to 50 cm or more long, stramineous when dry, black at lower portion, scaly at base. *Fronds* imparipinnate, 25-30 by 21-25 cm, ovate-oblong in outline, terminal pinna distinct, like lateral one; lateral pinnae 2-4 pairs, 15-20 by 3-5 cm oblong, sessile or short-stalked, acuminate at apex, acute at base, margin entire or subentire; veins rarely anastomosing. *Sori* elongate along veins, often on every veinlets, longest on acrocsopic veinlets of vein group. *Spores* monolete, 42.5-50 by 25-30 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.22; Pl. 6: A).

Specimens Examined. – Charn Apasuthaya 126 (BCU); P. Pongkai 45, 48 (BCU), T. Seelanan 3 (BCU); Put 1689 (BK); J.F. Maxwell 85-975, 86-573 (BKF); H.L. Hume 8186 (Holotype SING!).

Thailand.– PENINSULAR: Nakhon Si Thammarat (Khao Luang, Khao Nan); Surat Thani (Tako, Ban Don); Satun; Yala (Ban Chana).

Distribution.– Malaya (type), Borneo, Philippines.

Ecology.– On muddy rocks or on earth by streams in dense forests at low altitudes.

Note.– This species is similar to *D. bantamense*, but difference in having concolorous scales. Scales are entire at margin with caducous membrane. Venation of *D. riparium* is rarely anastomosing.

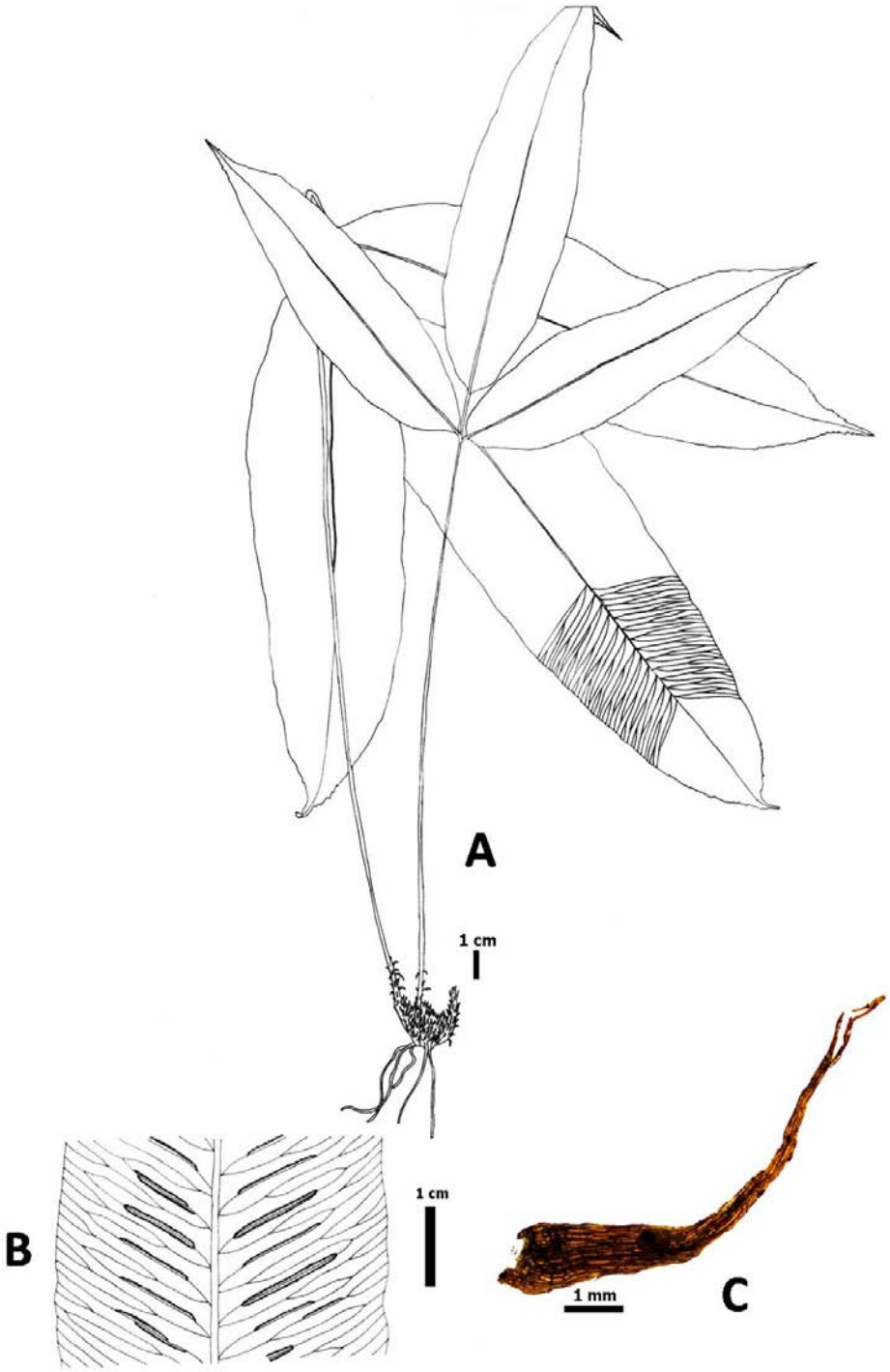

Figure 4.22 *Diplazium riparium* Holttum. A: habit; B: vein and sori and C: scale.

23. *Diplazium siamense* C. Chr., Contr. U.S. Natt. erb. 26: 332, t. 26. 1931; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 104. 1967; Acta Phytotax. Geobot. 23: 116. 1968; Tagawa & K. Iwats., Fl. Thailand 3(3): 460. 1988.

Rhizome erect, about 3 cm in diam. or more, densely scaly; scales 10-12 by 1.5 mm, linear, long tail at apex, brown, margin black, toothed. *Stipes* 30-50 cm long, stramineous, densely scaly at base, grooved above. *Fronds* imparipinnate, up to 70 by 35 cm, oblong in outline, acute at apex; terminal pinna distinct, up to 20 cm long, gradually narrowing towards attenuate apex, lobed at margin; lateral pinnae 6-8 pairs, about 20-25 by 4 cm, linear-oblong, acuminate at apex, subtruncate at base; lobed at margin, about half way to costa, stalks up to 2 cm long; rachis and costa often bearing minute scales; veins pinnate, veinlets 8-9 pairs, mostly simple. *Sori* elongate along veinlets, 3-4 mm long, close to main vein. *Spores* monolete, 35-40 by 22.5-27.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.23; Pl. 6: B).

Specimens Examined.– P. Pongkai 9, 16, 17 (BCU); E. Hennipman 3621 (BKF); Hiroshige Koyama, Hiroshi Terao & Thawatchai Wongprasert T33676 (BKF); K. Iwatsuki & N. Fukuoka T3681 (BKF); K. Iwatsuki T4462 (BKF); T. Shimizu et al. T11367 (BKF); Winit 959 (BKF).

Thailand.– NORTHERN: Chiang Rai (Doi Pacho), Chiang Mai (Doi Suthep), Phitsanulok (Phu Hin Rong Kla, Phu Rom Rot), Phrae (Mae Sai); NORTH-EASTERN: Phetchabun (Phu Miang), Loei (Phu Luang); SOUTH-WESTERN: Phetchaburi.

Distribution.– Endemic to northern Thailand (type).

Ecology.– On humus-rich mountain slopes in mixed or evergreen forests at 850 – 1,500 m alt.

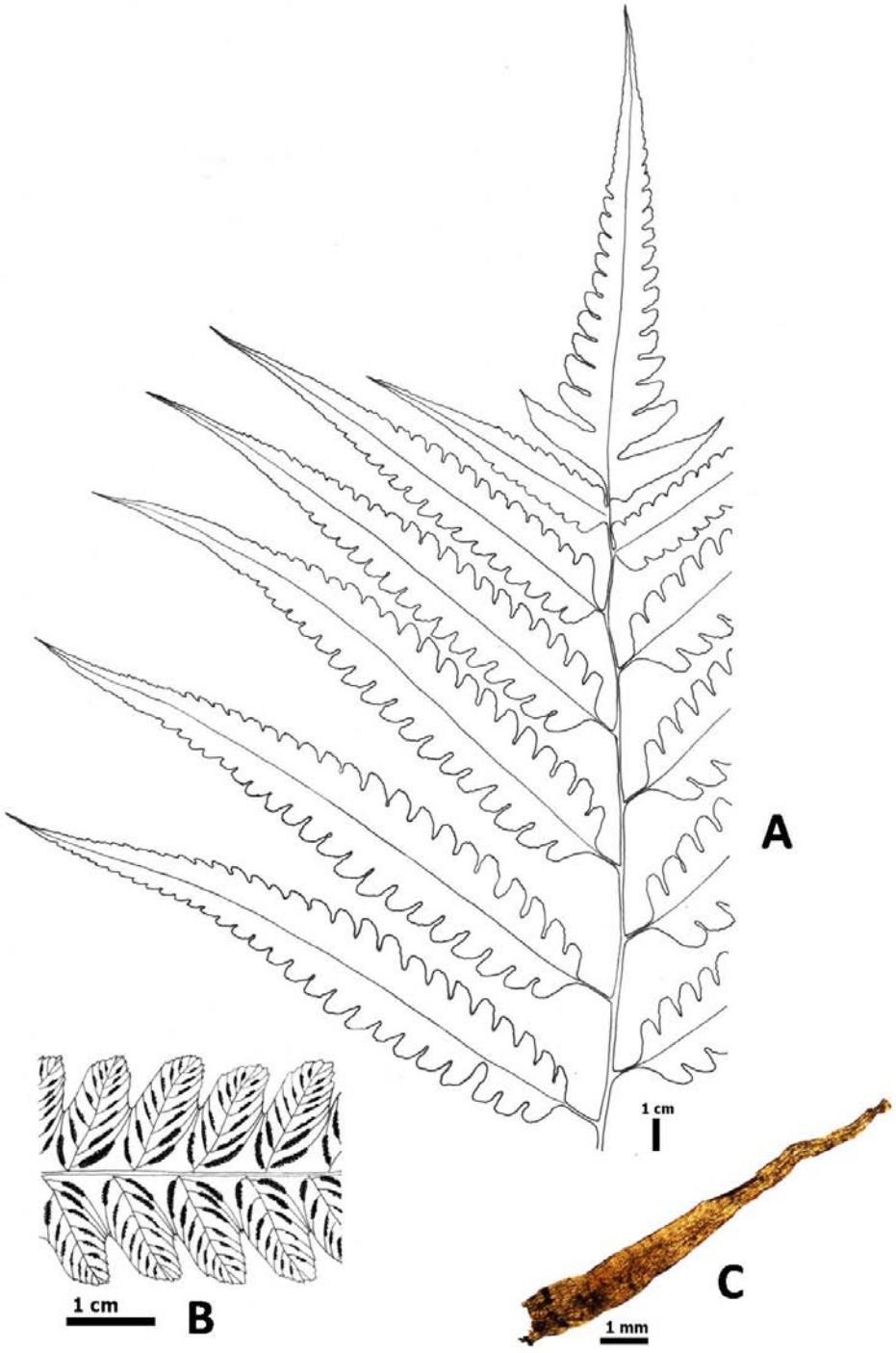

Figure 4.23 *Diplazium siamense* C. Chr. A: pinna; B: vein and sori and C: scale.

24. *Diplazium sorzogonense* (C. Presl) C. Presl, Tent. Pterid.: 114. 1836; Bedd., Handb. Ferns Brit. India: 181. 1883; Tard. & C. Chr., Fi. Indo-Chine 7(2): 254, f. 28, 3-4. 1940; M. Tagawa & K. Iwatsuki., Acta Phytotax. Geobot. 23: 56. 1968; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 456. 1988; A.G. Piggott., Fern of Malaya in colour: 296, f. 912-915. 1996.

— *Asplenium sorzogonense* C. Presl, Reliq. Haenk. 1: 45. 1825.

— *Athyrium sorzogonense* (Presl) Milde, Bot. Zeitung 1870: 354; Holtt., Rev. Fl. Malaya 2: 552, f. 325. 1955.

— *Allantodia sorzogonensis* (C. Presl) Ching, Acta Phytotax. Sin. 9(1): 52. 1964.

Rhizome erect, up to 5 cm in diam., densely scaly at apex; scales 12-15 by 2-3 mm, narrowly lanceolate with long tail apex, brown to dark brown, margin black, toothed. *Stipes* up to 40 cm long, stramineous, dark brown at lower portion, scaly throughout, grooved above. *Fronds* unipinnate-bipinnatipid, up to 90 by 40 cm, terminal pinna not distinct; rachis grooved above, scaly throughout; laterial pinnae 20-25 pairs, 15-20 by 2-3 cm, linear-oblong, basal one or two pairs more or less reflexed, upper pinnae sessile, lower and middle pinnae shortly stalk, acuminate at apex, truncate or subtruncate at base, deeply lobe at margin; lobes about 10 by 5 mm, to 4/5 way to costa, oblique, narrowly oblong, round at apex, dentate at margin; veins pinnate, veinlets 9-10 pairs, mostly simple. *Sori* elongate along veins, 2-3 mm long, nearly to the margin, not extending to main veins; indusia crescentic. *Spores* monolete, 37.5-45 by 22.5-25 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.24; Pl. 6: C).

Specimens Examined.– P. Pongkai 30, 49 (BCU); A.F.G. Kerr 11547, 18476 (BK); G.E. Edano 20643 (BK); Sakol 1235 (BK); C.J. Brooks 143 (Holotype MICH!).

Thailand. – PENINSULAR: Chumphon (Khao Tong), Nakhon Si Thammarat (Khao Luang, Khao Nan, Krung Ching), Phangnga (Khao Katha Khwam), Yala (Ban Malao, Khao Kalakhiri).

Distribution. – Veitnam to Malesis throughout (type from Philippines).

Ecology. – On rather dry mountain slopes in dense evergreen forests at 600 - 1,400 m alt.

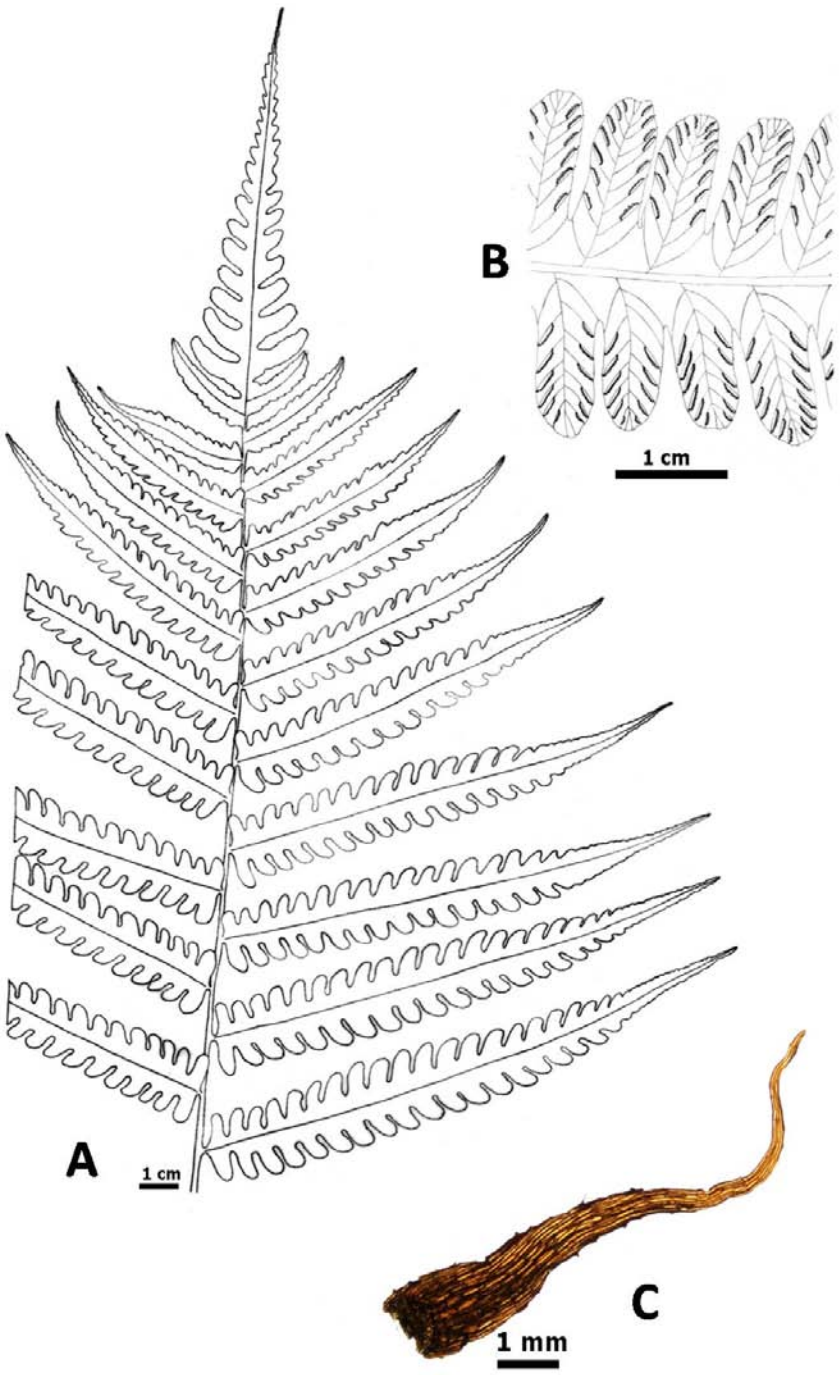

Figure 4.24 *Diplazium sorzogonense* (C. Presl) C. Presl. A: pinna; B: vein and sori and C: scale.

25. ***Diplazium subintegrum*** **Holttum**, Gard. Bull. Straits Settlem. 9: 125. 1937; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 103. 1967; Tagawa & K. Iwats., Fl. Thailand 3(3): 458. 1988; A.G. Piggott., Fern of Malaya in colour: 302. f. 929-931. 1996.

— *Athyrium subintegrum* (Holttum) Holttum, Rev. Fl. Malaya 2 : 557. f. 328. 1955.

Rhizome erect, up to 5 cm in diam., densely scaly at apex; scales about 15 by 3 mm, lanceolate with long tail, brown, concolorous, entire with caducous membrane at margin. *Stipes* 30-40 cm long, glabrous, densely scaly at lower part, stramineous, dark colour near base. *Fronds* unipinnate, about 35 by 20 cm, oblong in outline; terminal pinna distinct, about 10 by 4 cm, subdeltoid, acuminate at apex, lobed at margin; lateral pinnae 10-12 pairs, 10-15 by 2 cm, narrowly oblong, acuminate at apex, round at base, subentire to crenate at margin, dentate or serrate near apex, stalks about 2 mm long; veins pinnate, veinlets 2 pairs, free. *Sori* elongate along veinlets, about 8-10 mm long, diplazoid, usually on acroscopic veinlets of vein group; indusia thin, pale brown, persistent. *Spores* monolete, 37.5-45 by 25-27.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.25; Pl. 6: D).

Specimens Examined.– C. Khunwasi 54 (BCU); P. Pongkai 35, 65, 66, 67 (BCU); C. Niyomdham & P. Puudjaa 4646 (BKF); R.E. Holltum 31350 (Holotype SING!).

Thailand.– NORTHERN: Phitsanulok (Salaeng Haeng); CENTRAL: Nakhon Nayok (Khao Yai); SOUTH-EASTERN: Trat (Koh Chang); PENINSULAR: Yala.

Distribution.– Malaysia (type).

Ecology.– On rather dry ground near stream banks in light shade at medium altitudes.

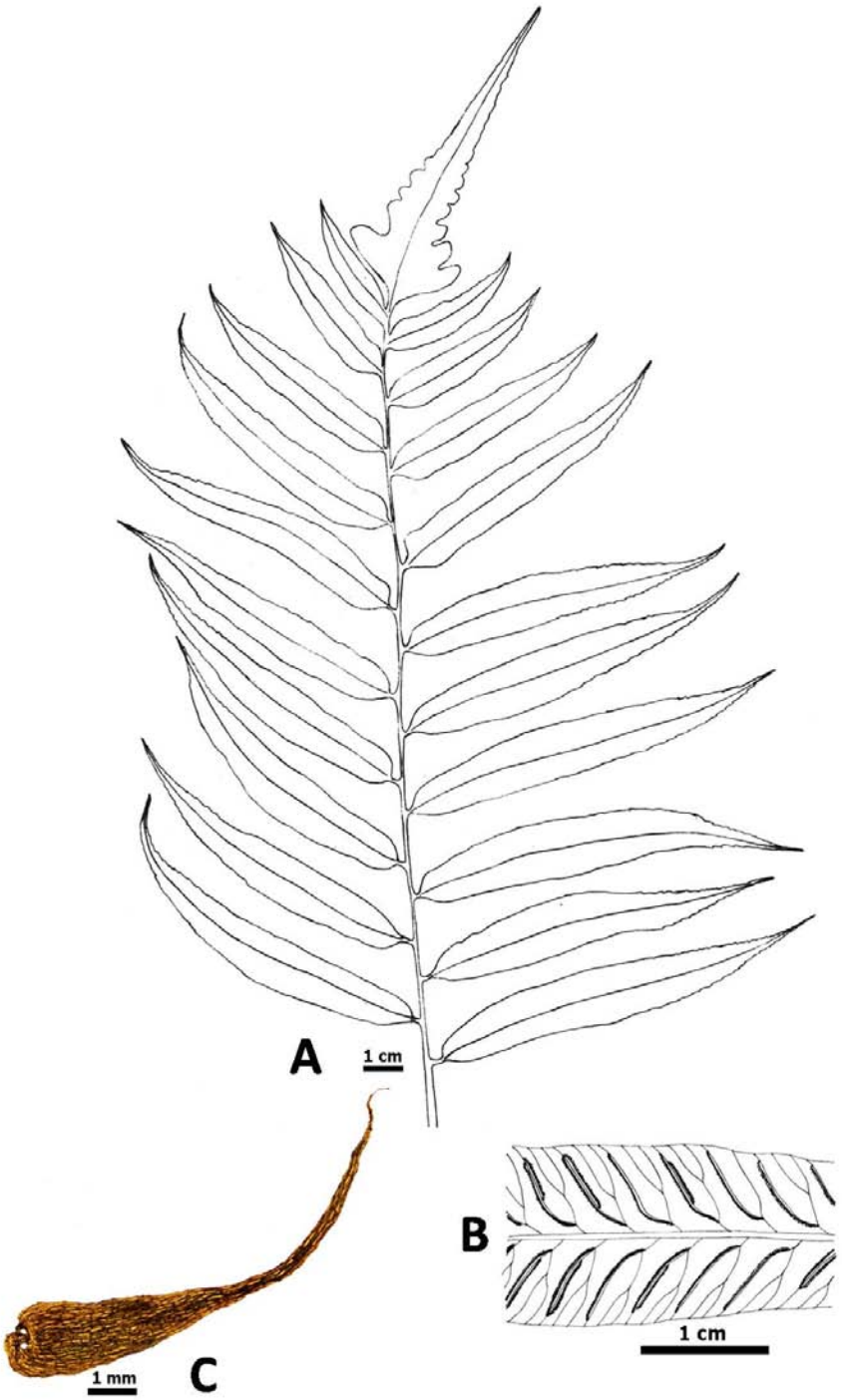

Figure 4.25 *Diplazium subintegrum* Holttum. A: pinna; B: vein and sori and C: scale.

26. *Diplazium subserratum* (Blume) T. Moore, Index Fili.: 338. 1862; Bedd., Handb Fern Brit. India: 174. 1883; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 452. 1988; A.G. Piggott., Fern of Malaya in colour: 292, f. 898-900. 1996.

— *Asplenium subserratum* Blume, Enum. Pl. Javae 2: 174. 1828.

— *Athyrium subserratum* (Blume) Milde, Bot. Zeitung 1870: 354; Holtt., Rev. Fl. Malaya 2: 546, f. 321. 1955.

Rhizome short, erect, 2-6 mm in diam., bearing a tuft of fronds and wiry roots; scales about 0.3 by 1 mm, ovate, subtriangular, concolorous, dark brown to black, toothed at margin. *Stipes* slender, 10-15 cm long, glabrous, dark brown at base. *Fronds* simple, 40-50 by 3-4 cm, narrowly oblong, gradually narrowing towards both ends, acuminate at apex, attenuate at base, margin subentire or irregulary undulate at middle, serrate at upper edges, dentate at lower edges; veins all free, simple or once forked, extending to margin. *Sori* elongate along veins, close to midrib, about 8-12 mm long, usually on acroscopic veinlets of vein group. *Spores* monolete, 55.5-62 by 37.5-44.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate (Fig. 4.26; Pl. 7: A).

Specimens Examined.– T. Boonkerd 1176 (BCU); T. Boonkerd & R. Pollawatn 287 (BCU); A.F.G. Kerr 14541 (BK).

Thailand.– PENINSULAR: Narathiwat (Hala-Bala), Satun (Khao Khieo range), Yala (Betong).

Distribution.– Malaysia, Borneo, Sumatra and Indonesia (type from Java).

Ecology.– On moist mountain slope by streams in evergreen forest at about 700 m alt.

Note.– This species resembles *D. subsinuatum* in general appearance. But *D. subserratum* has suberect rhizome with a tuft fronds, small darker scales with toothed

margin, thinner texture of frond, usually dark brown when dried, with serrate margin on upper portion of frond, and more oblique shorter sori.

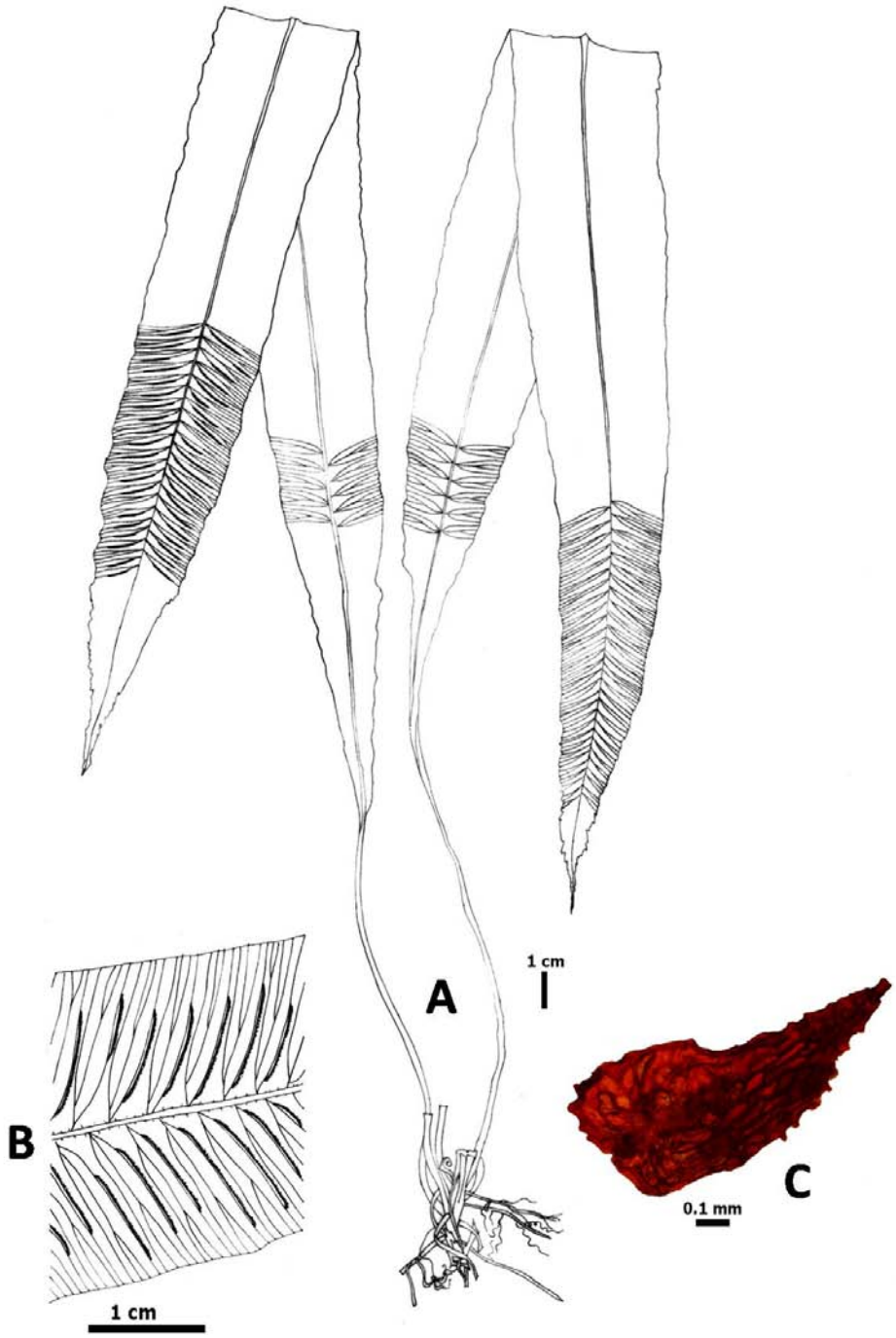

Figure 4.26 *Diplazium subserratum* (Blume) T. Moore. A: habit; B: vein and sori and C: scale.

27. *Diplazium subsinuatum* (Wall. ex Hook. & Grev.) Tagawa, Col. Ill. Jap. Pterid.: 135, 203. 1959; M. Tagawa & K. Iwatsuki., Acta Phytotax. Geobot. 24: 63. 1969; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 453. 1988.

— *Asplenium subsinuatum* Wall. ex Hook. & Grev., Icon. Filc. 1: t. 27. 1827.

— *Diplazium lanceum* (Thunb.) C. Presl, Tent. Pterid.: 113. 1863, non Bory, 1833: Bedd., Handb. Fern Brit. India: 174, F. 84. 1883; Tard. & C. Chr., Fl. Indo-Chine 7(2): 248. 1940.

Rhizome long creeping about 2-4 mm diam., covered with scales throughout; scales about 0.7 by 4.0 mm, narrowly lanceolate with long tail apex, concolorous dark brown, margin entire. *Stipes* 13-20 mm long, brown, dark in lower portion. *Fronds* simple, 27-31 by 2-2.5 cm linear-oblong, acuminate at apex, attenuate at base, margin subentire, coriaceous, glabrous, midrib raised beneath; veins free, veinlets 3 pairs, reaching to margin. *Sori* elongate along veins, about 6-9 mm long, usually on acroscopic veinlets of vein group. *Spores* monolete, 30-37.5 by 20-32.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: baculate (Fig. 4.27; Pl. 7: B).

Specimens Examined.– A. Sathapattayanon 576 (BCU); S. Pimpa 6 (BCU); E. Hennipman 3681 (BKF); G. Murata et al. T49576, T49588 (BKF); K. Iwatsuki, C. Phengklai, M. Wakabayashi & M. Kato 43, 165 (BKF); Y.W. Taam 1058(BKF).

Thailand.– NORTHERN-EASTERN: Loei (Phu Kradueng), Khon Kaen; EASTERN: Chaiyaphum (Phu-khew)

Distribution.– Sri Lanka, India (type) to China, Indochina, Taiwan to Japan, southwards to Luzon and Borneo.

Ecology.– On sandstone boulders along streams in evergreen forests at about 850 -1,175 m alt.

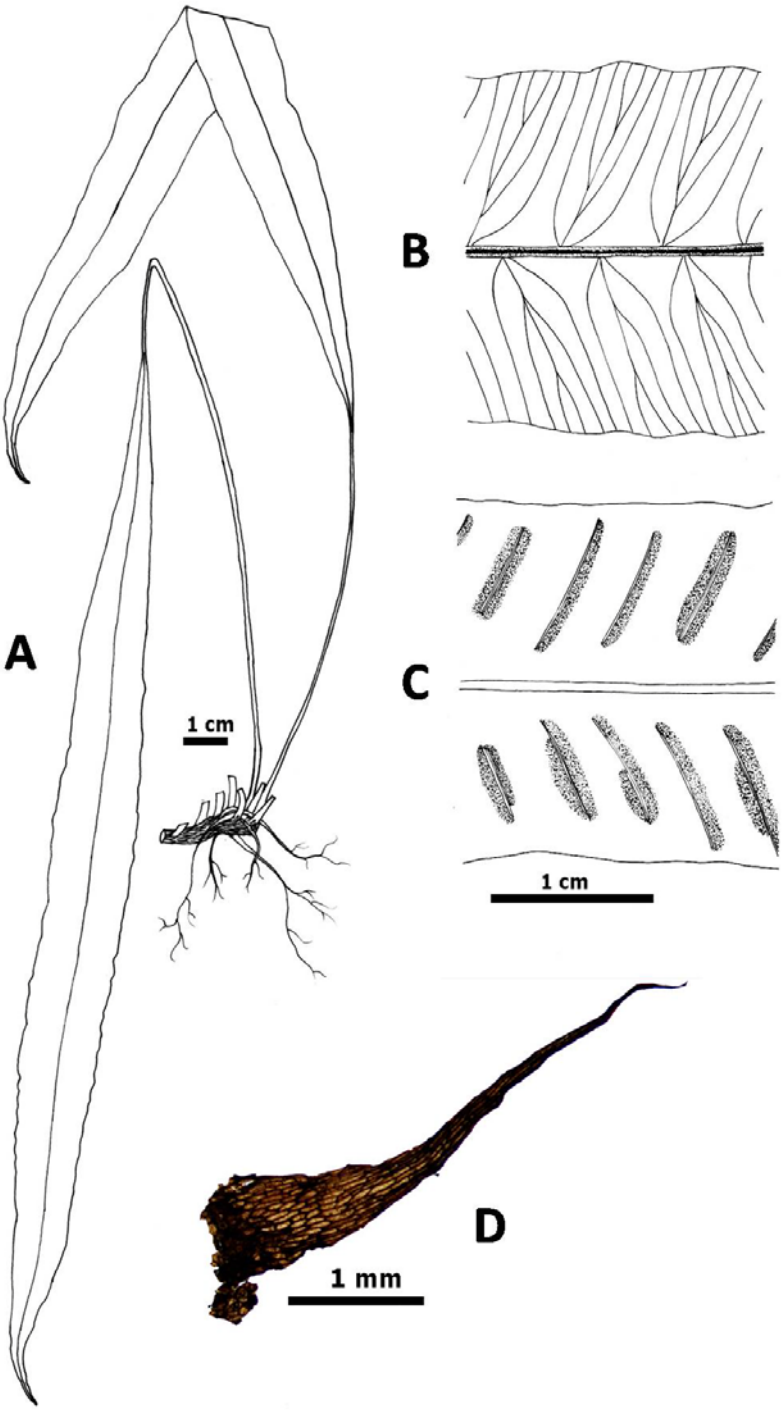

Figure 4.27 *Diplazium subsinuatum* (Wall. ex Hook. & Grev.) Tagawa. A: habit; B: vein; C: sori and D: scale.

28. *Diplazium sylvaticum* (Bory) Sw., Syn. Fil.: 92. 1806; Bedd., Handb. Fern Brit India: 177. 1883; Holtt., Gard. Bull. Straits Settlem. 11(1): 99. 1940; Tagawa & K. Iwats., SouthE. Asian Stud. 3(3): 87. 1965; Tagawa & K. Iwats., Acta Phytotax. Geobot. 23: 56. 1968; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 459. 1988; A.G. Piggott., Fern of Malaya in colour: 307, f. 944-946. 1996.

— *Callipteris sylvativum* Bory, Voy. Iles Atrique 1: 282. 1804.

— *Athyrium pinnatum* (Blanco) Copel., Philipp. J. Sci. Bot. 3: 297. 1908; Rev. Fl. Malaya 2: 560, f. 331. 1955.

Rhizome short, erect, 1–1.5 cm in diam., scaly at apex; scales 5.5-6 by 0.4-0.8 mm, linear with long-tail apex, concolorous, dark brown to nearly black, toothed at margin. *Stipes* 30-50 cm long, stramineous when dry, black at lower portion, glabrous, scaly at base. *Fronds* 1-pinnate, about 20-30 by 15-20 mm, ovate subdeltoid in outline, terminal pinna not distinct; lateral pinnae 8-11 pairs, 8-12 by 2-4.5 cm, lower pinnae short stalked, upper pinnae sessile or adnate with rachis, subfalcate, acuminate at apex, subtruncate or obtuse at base, less auricled at acroscopic base, crenate to lobed at margin, dentate to serrate at margin near apex; veins pinnate, 3-4 pairs. *Sori* elongate along veins, often on every veinlets, longest on acrocsopic veinlets of vein group. *Spores* monolete, 56-60.5 by 32-40 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.28; Pl. 7: C).

Specimens Examined.– P.Pongkai 18, 19 (BCU); T. Boonkerd 1113 (BCU); Staw 531 (BK); J.F. Maxwell 85-314 (BKF); Kyoji Yoda 646 (BKF); M. Takawa & I. Yamada T201 (BKF); T. Shimizu, N. Fukuoka & A. Nalampoon T7892 (BKF); J.F. Maxwell 85-314, 85-1127, 86-747 (PSU); M. Lindale s.n. (Holotype P!)

Thailand.– NORTHERN: Phitsanulok (Thung Salaeng Luang); NORTH-EASTERN: Loei (Phu Kradueng), Uthai Thani (Ban Rai); SOUTH-WESTERN: Kanchanaburi (Khao Ngi Yai); SOUTH-EASTERN: Chanthaburi (Kao Soi Dao), Trat (Koh Chang);

PENINSULAR: Chumporn (Khao Tong), Krabi (Phanom Bencha), Nakhon Si Thammarat (Khao Luang, Khao Nan), Phangnga, (Khao Pok), Satun, Yala (Betong), Surat Thani (Klong Ton, Ban Don), Trang (Khao Chong),

Distribution.– Mauritius (type), India, Myanmar, Malaya, Borneo, Indonesia (Java), and Philippines.

Ecology.– On mountain slopes in moist places in dense evergreen forests at low to medium elevations, usually below 1,200 m alt.

Note.– This species is similar to *D. crenato-serratum* but differed in having scales with distinctly toothed at margin, pinnae are more wider, and small auricle at acroscopic base.

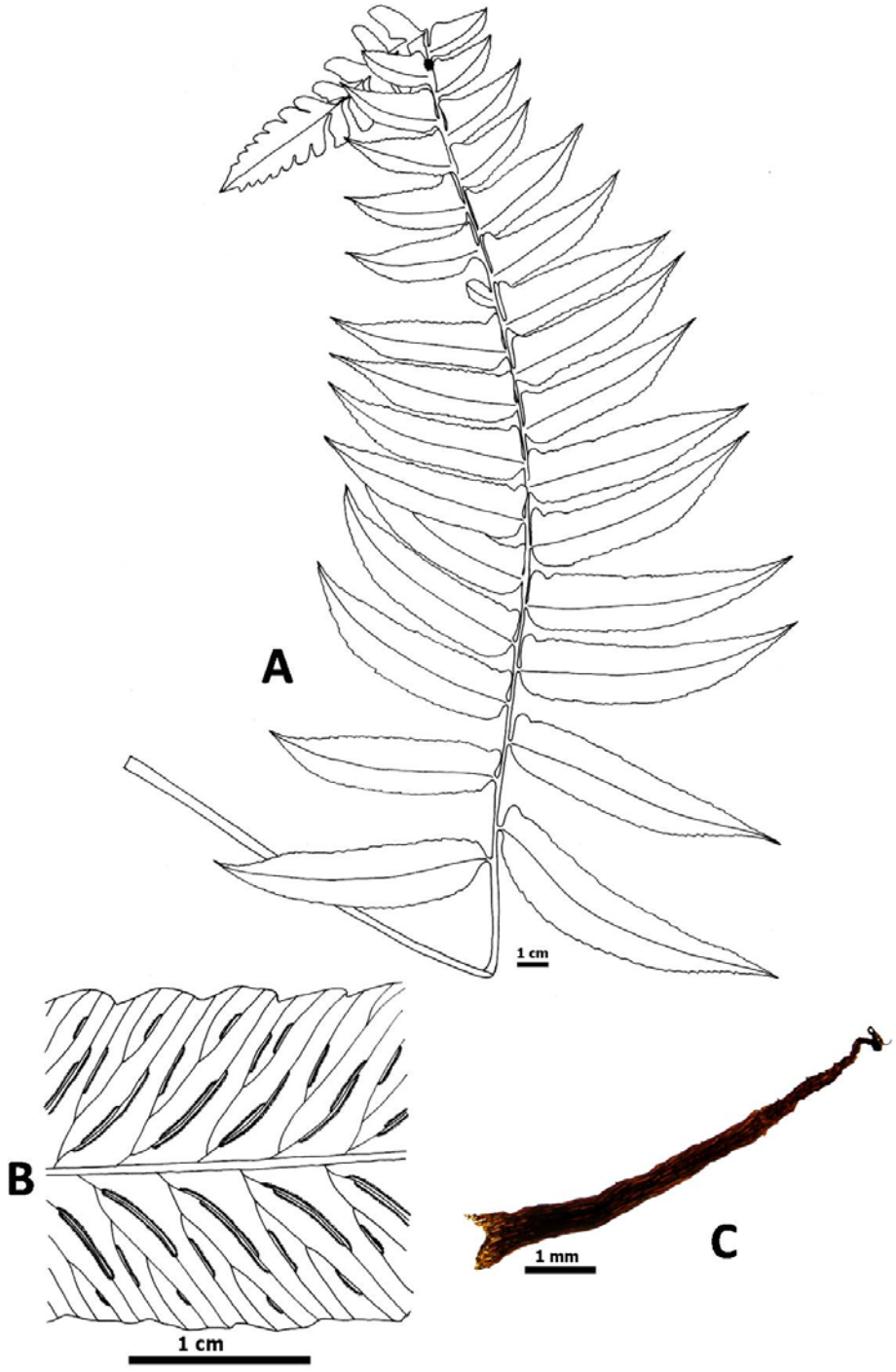

Figure 4.28 *Diplazium sylvaticum* (Bory) Sw. A: frond; B: vein and sori and C: scale.

29. *Diplazium taiwanense* Tagawa, Acta Phytotax. Geobot. 5: 259. 1936; M. Tagawa & K. Iwatsuki., SouthE. Asisn Stud. 5: 105. 1967; M. Tagawa & K. Iwatsuki., Fl. Thailand 3(3): 462. 1988; K. Iwatsuki, Ferns and Fern Allies of Japan. 254, Pl. 172-2. 1992; Devol & Kuo, Fl. Taiwan 1. 436: 1994.

— *Allantodia taiwanensis* (Tagawa) Ching, Acta Phytotax. Sin. 9(1): 53. 1964.

Rhizome ascending 2-2.5 cm in diam., covered with scales at apex; scales 7-10 by 0.5-0.6 mm, linear with long tail at apex, concolorous, dark brown to nearly black, toothed at margin. *Stipes* 40-50 cm long, densely scaly and dark colour at lower part. *Fronds* bipinnate, 60 by 50 cm, subdeltoid in outline, suddenly narrowing upwards; pinnae, about 30 by 15-20 cm, oblong in out line, stalks 3-4 cm long, gradually narrowing towards long acuminate apex; pinnule about 8 by 1.5-2 cm, oblong, shortly stalked, 2-3 cm long, long acuminate at apex, obtuse to subtruncate at base; lobed at margin, 1/3 way to costule, round at apex, dentate at margin; veins pinnate, 5-6 pairs, veinlets free, forked. *Sori* elongate along veinlets, 2-4 mm long, oblong, halfway between midrib and margin of lobe; indusia thin, papyraceous. *Spores* monolete, 32.5-35 by 17.5-22.5 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.29; Pl. 7: D).

Specimens Examined.– D.J. Middleton et al. 3772 (BKF).

Thailand.– CENTRAL: Nakhon Nayok (Khao Yai).

Distribution.– N. Veitnam and Taiwan (type) to SW. Japan.

Ecology.– On moist ground along stream banks in light shade at about 800 m alt.

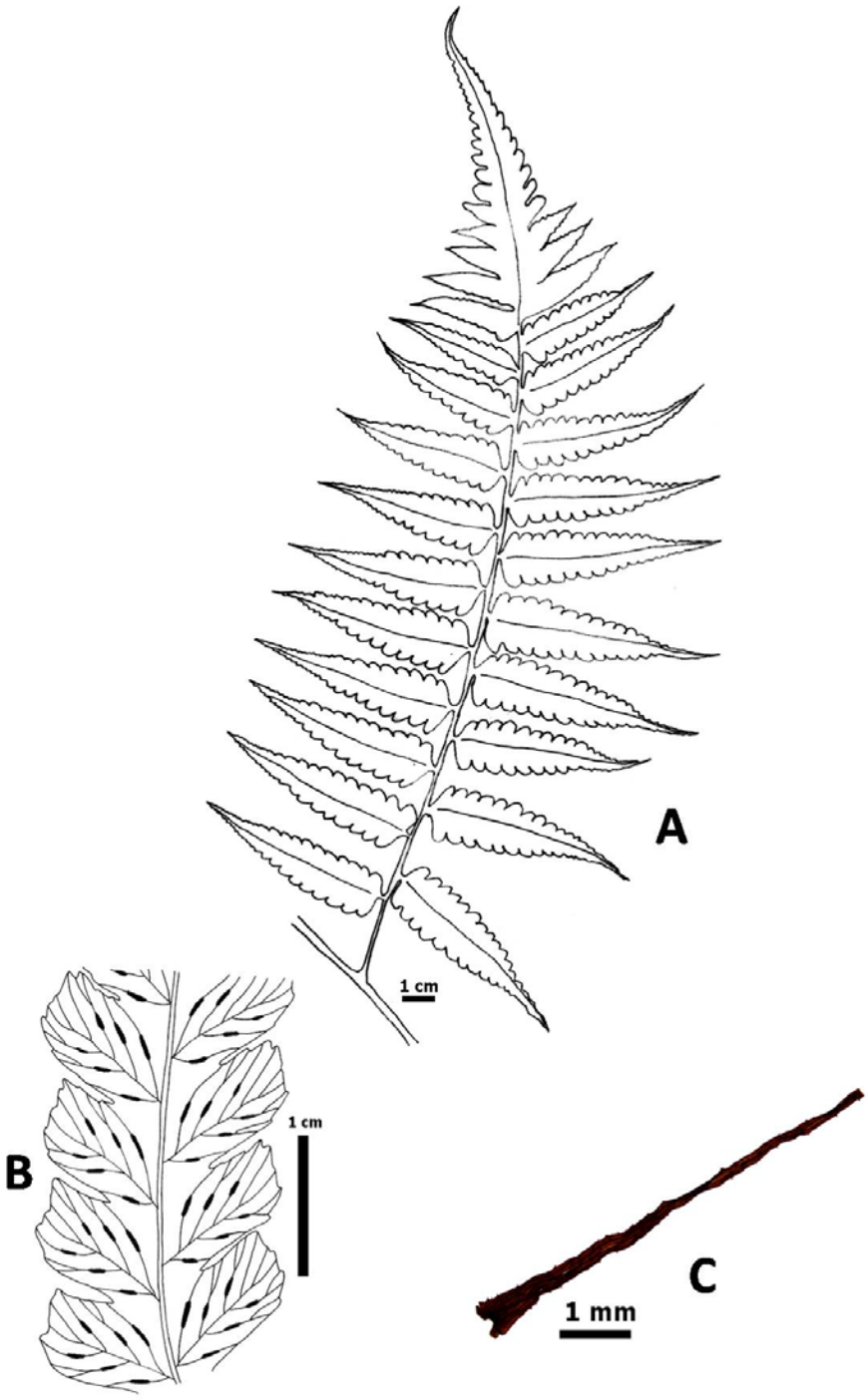

Figure 4.29 *Diplazium taiwanense* Tagawa. A: pinna; B: vein and sori and C: scale.

30. *Diplazium tomentosum* Blume, Enum. Pl. Javae 2: 192. 1828; Bedd., Handb.: 179. 1883; Tard. & C. Chr., Fl. Indo-Chine 7(2): 257. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 103. 1967; Tagawa & K. Iwats., Fl. Thailand 3(3): 457. 1988; A.G. Piggott., Fern of Malaya in colour: 295, f. 908-911. 1996.

— *Athyrium tomentosum* (Blume) Milde, Bot. Zeitung 1870: 354; Holtt., Rev. Fl. Malaya 2: 551, f. 324. 1955.

Rhizome short, erect, 0.4-1 cm in diam., bearing wiry roots, scaly at apex; scales about 1 by 3 mm, lanceolate with long-tail at apex, concolorous dark brown, entire at margin. *Stipes* 15-25 cm long, harry throughout, stramineous to brown, scaly in lower portion. *Fronds* unipinnate-bipinnatifid, about 20 by 10 cm, subdeltoid in outline, deep green, iridescent blue when living; rachis densely covered with short multicellular hairs with brown septa; pinnae 25-30 pairs, laterial pinnae gradually becoming smaller upwards forming no distinct terminal portion, lower pinnae largest, about 5 by 1 cm, linear-lanceolate, sessile or shortly stalked, upper pinnae sessile, lower and middle pinnae shortly stalked, basal pairs more or less reflexed, auricled at acroscopic base, acute at apex, subtruncate at base, serrate to lobe at margin; lobes about 5 by 3 mm, 1/3-2/3 way to costa, oblique, oblong, acute at apex; veins pinnate, veinlets simple or forked. *Sori* elongate along vein, on basal acroscopic veinlets; indusia firm, persistent. *Spores* monolete, 30-34.5 by 24.5-26 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.30; Pl. 8: A).

Specimens Examined.– Charn Apasuthaya 127 (BCU); P. Pongkai 31,38, 57, 58, 59 (BCU); T. Boonkerd 330, 1484, 1518, 1534 (BCU); T. Boonkerd & R. Pollwatn 253 (BCU); A.F.G. Kerr 9511, 12015, 18673 (BK); B. Sangkhachand 392 (BKF); C. Niyomtham & P. Puudjaa 5459, 5474 (BKF); C. Phengklai et al. 14918 (BKF); C.P. & T.S. 1194 (BKF); D.J. Middleton et al. 1875 (BKF); D.J. Middleton, S. Suddee & C. Hemrat 1425 (BKF); E. Hennipman 3818, 3988 (BKF); E. Smith 1934 (BKF); J.F. Maxwell 01-356

(BKF); K. Iwatsuki, H. Koyama, M. Hutoh & A. Chintayungkun T8343 (BKF); Kyoji Yoda 466, 512, 623 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T4622, T4681 (BKF); R. Pooma et al. 4436 (BKF); S. Chongko 24, 31 (BKF); T. Shimizu T26944 (BKF); T. Shimizu, K. Iwatsuki, N. Fukuoka & M. Hutoh M13241 (BKF); T. Smitinand 871 (BKF); Winit 55, 262 (BKF); B. ohusing et al. 3 (PSU); J.F. Maxwell 86-327, 87-259 (PSU).

Thailand.– CENTRAL: Nakhon Nayok; SOUTH-EASTERN: Chanthaburi (Khao Sabap), Trat (Bo Rai), Prachin Buri; PENINSULAR: Surat Thani (Khao Nom Sao), Krabi (Phanom Bencha), Nakhon Si Thammarat (Khao Luang, Khao Nan), Trang (Khao Sung), Narathiwat (Waeng).

Distribution.– Myanmar (Tenessarim), Malaysia, Veitnam, Sumatra, Java (type), Borneo, and Mindanao.

Ecology.– On mountain slopes in moist, shady evergreen forests at 200-1,250 m alt.

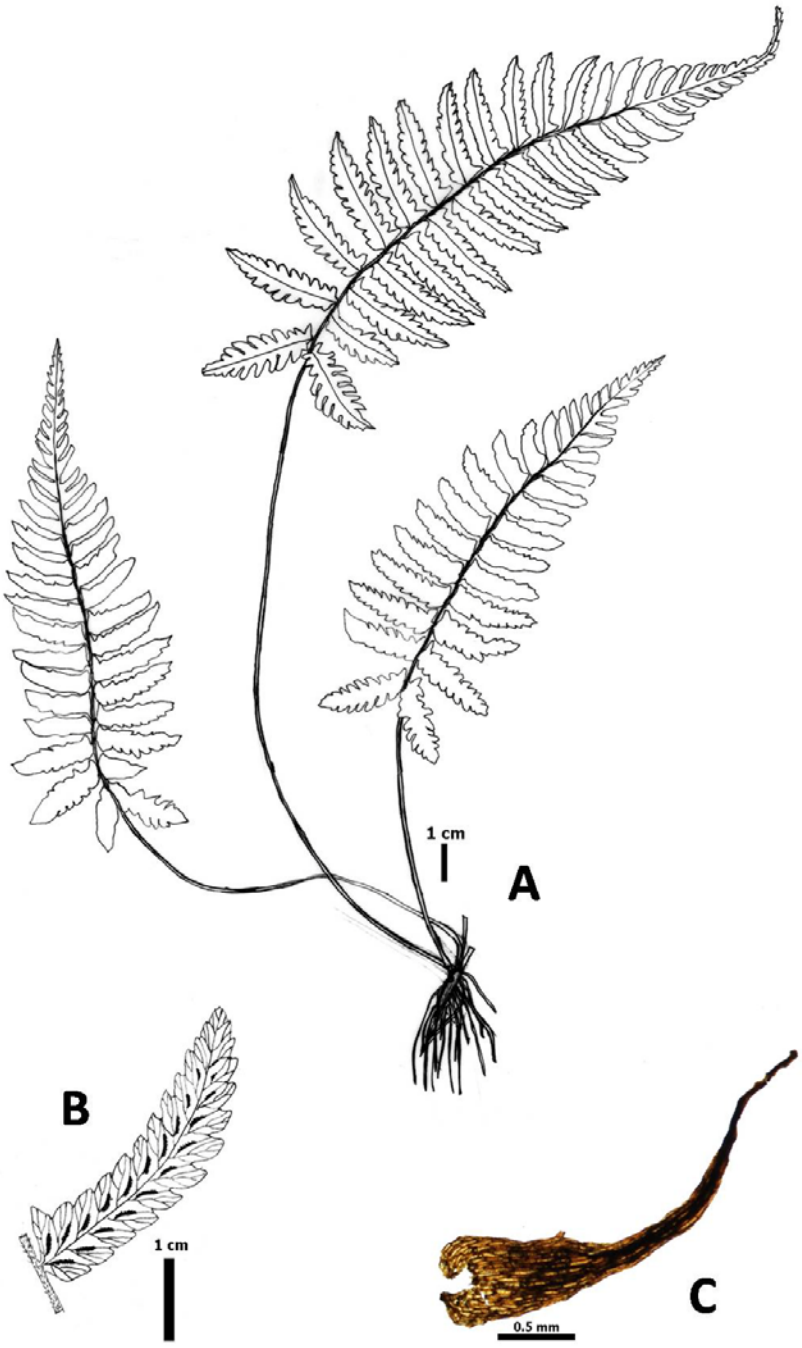

Figure 4.30 *Diplazium tomentosum* Blume. A: habit; B: vein and sori and C: scale.

31. *Diplazium xiphophyllum* (Baker) C.Chr., Index Filic.: 241. 1905; Holtt., Gard. Bull. Straits Settlem. 11(1): 106. 1940; M. Tagawa & K. Iwatsuki., SouthE. Asian Stud. 5: 102. 1967; Acta Phytotax. Geobot. 23: 56. 1968; Tagawa & K. Iwats., Fl. Thailand 3(3): 454. 1988; A.G. Piggott., Fern of Malaya in colour: 299. f. 921-923. 1996.

— *Asplenium xiphophyllum* Baker., J. Bot. 17: 40. 1879; Holttum, Rev. Fl. Malaya 2: 553. 1955.

Rhizome short, erect, 2-3 cm in diam., clothed with scales at apex; scales 10-15 by 2 mm, lanceolate with long tail apex, concolorous brown, entire at margin. *Stipes* up to 80 cm long, glabrous, stramineous, dark brown and scaly near base. *Fronds* unipinnate, about 50-60 by 40-50 cm, oblong in outline; terminal pinna distinct like lateral one, about 20 by 4 cm, oblong, attenuate at apex, cuneate at base, subentire or lobed at margin; lateral pinnae 4-7 pairs, 25-30 by 4-5 cm, oblong, attenuate at apex, cuneate at base, subentire at margin, shortly stalked, 2-3 mm long; veins pinnate, veinlets 2 pairs, free, occasionally anastomosing but never copiously; light green; gemmae sometimes present on rachis. *Sori* elongate along veinlets, about 2 cm long, usually longest on basal veinlets of vein group, diplazoid; indusia thin. *Spores* monolete, 32.5-40 by 25.5 -27 µm, bilateral, concavo-convex to plano-convex, perispore present; ornamentation: rugate-retate (Fig. 4.31; Pl. 8: B).

Specimens Examined.– T. Boonkerd et al. 62 (BCU); K. Iwatsuki, H. Koyama, M. Hutoh & A. Chintayungkun T8441 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T4675 (BKF); M. Tagawa, K. Iwatsuki & N. Fukuoka T5304 (BKF); Plernjit 1854 (BKF); T. Smitinand 1003 (BKF).

Thailand.– PENINSULAR: Nakhon Si Thammarat (Khao Luang, Khao Nan), Narathiwat (Ban Waeng), Yala (Ban Chana).

Distribution.– Malaysia (type) and Borneo.

Ecology.– On moist mountain slopes in shady dense evergreen forests at medium altitudes.

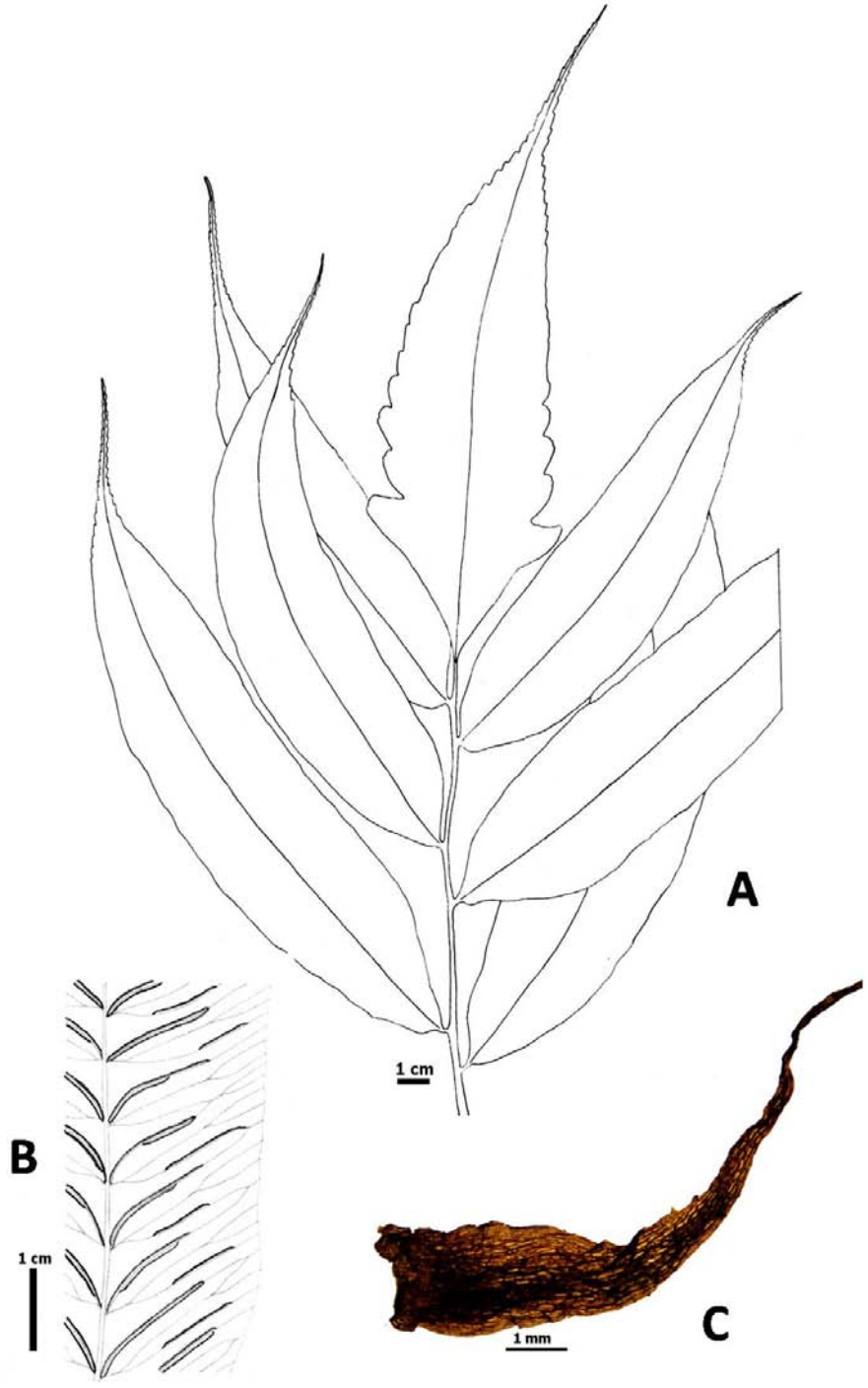

Figure 4.31 *Diplazium xiphophyllum* (Baker) C. Chr. A: pinna; B: vein and sori and C: scale.

Table 4.1 Species, Floristic Region and Altitudinal distribution of *Diplazium* Sw. found in Thailand. N: NORTHERN; NE: NORTH-ESTERN; E: EASTERN; SE: SOUTH-EASTERN; C: CENTRAL; SW: SOUTH-WESTERN; P: PENINSULAR.

No.	SPECIES	FLORISTIC REGION							ALTITUDINAL DISTRIBUTION
		N	NE	E	SW	C	SE	P	
1	*D. bantamense* Blume							+	400 - 1,000 m
2	*D. conterminum* Christ	+						+	900 - 1,000 m
3	*D. cordifolium* Blume							+	200 - 1,800 m
4	*D. crenato-serratum* (Blume) T. Moore						+	+	100 – 1,100 m
5	*D. dilatatum* Blume	+	+		+	+	+	+	400 – 1,500 m
6	*D. donianum* (Mett.) Tardieu	+	+	+		+	+	+	300-1,000 m
7	*D. esculentum* (Retz.) Sw.	+	+	+	+	+	+	+	250 – 1,200 m
8	*D. griffithii* T. Moore	+	+						1,250 – 2,500 m
9	*D. heterophlebium* (Mett. ex Baker) Diels	+							1,300 – 1,750 m
10	*D. leptophyllum* Christ	+							850 – 1,600 m
11	*D. lobatum* (Tagawa) Tagawa	+							1,700 m
12	*D. malaccense* C. Presl							+	650 – 1,250 m
13	*D. megaphyllum* (Baker) Christ	+							800 m
14	*D. mettenianum* (Miq.) C. Chr.	+	+						1,100 -1,280 m
15	*D. muricatum* (Mett.) Alderw.	+			+				700 – 2,900 m
16	*D. pallidum* (Blume) T. Moore						+	+	600 m
17	*D. petrii* Tardieu						+	+	700 – 1,800 m
18	*D. polypodioides* Blume	+			+		+	+	100 – 2,600 m
19	*D. prescottianum* (Wall. ex Hook.) T. Moore						+	+	600 m
20	*D. procumbens* Holttum				+				1,300 m
21	*D. proliferum* (Lam.) Kaulf.							+	600 m
22	*D. riparium* Holttum							+	250 – 500 m
23	*D. siamense* C. Chr.	+	+		+				850 – 1,500 m
24	*D. sorzogonense* (C. Presl) C. Presl							+	600 – 1,400 m
25	*D. subintegrum* Holttum	+				+	+	+	600 – 1,000 m
26	*D. subserratum* Blume							+	700 m
27	*D. subsinuatum* (Wall. ex Hook. & Grev.) Tagawa		+	+					850 - 1,200 m
28	*D. sylvaticum* (Bory) Sw.	+	+		+		+	+	100 – 1,200 m
29	*D. taiwanense* Tagawa					+			800 m
30	*D. tomentosum* Blume					+	+	+	200 – 1,250 m
31	*D. xiphophyllum* (Baker) C. Chr.							+	150 – 1,100m

4.3 Discussion and Conclusion

4.3.1 Distribution

Diplazium occur throughout the country, especially in the north and peninsular Thailand. Previously, *Diplazium siamense* is recognized as endemic species to Thailand (Tagawa and Iwatsuki, 1988). Lately, it was also found in China (Chen, Wen Li et al. 2007). The most common species is the vegetable fern, *D. esculentum* which can be found in all floristic regions. However, some species naturally occur only in peninsular Thailand and should be assigned as malesian elements, i.e. *D. proliferum*, *D. bantamense*, *D. cordifolium*, *D. malaccense*, *D. riparium* , *D. subserratum* and *D. xiphophyllum* (Tagawa and Iwatsuki, 1988). While *Diplazium heterophlebium*, *D. leptophyllum*, *D. lobatum* and *D. megaphyllum* are confined in the mountainous areas of northern provinces (Table 4.1). Their geographical distribution are also in the northern countries above Thailand (Tagawa and Iwatsuki, 1988; Shieh, Devol and Kuo, 1994).

4.3.2 The present account of Thai *Diplazium*

Table 4.2 demonstrates the present checklist of 33 species of *Diplazium* in Thailand as compare with the previous accounts of 29 species in Tagawa and Iwatsuki (1988) and Boonkerd and Pollawatn (2000).

Three species from this study are new records for Pteridophyte Flora of Thailand, i.e *Diplazium griffithii* T. Moore, *D. lobatum* (Tagawa) Tagawa, and *D. pallidum* (Blume) T. Moore. Therefore, these 3 species are added to the Checklist of Thai *Diplazium* (Table 4.2).

The specimens of *D. griffithii* were collected from the north and north-east of Thailand at 1,250–2,500 m altitudes from Chiang Mai, Tak, Nakhon Sawan and Loei. They are deposited at BCU and BKF. This species was previously recorded from India (Christensen, 1906).

D. lobatum was collected from Phu Hin Rong Kla National Park, Phitsanulok province, northern Thailand at 1,700 m altitude. The specimen is deposited at BCU. It was former reported from Japan and Taiwan (Shieh, Devol, and Kuo, 1997).

D. pallidum was collected from Prachin Buri and Nakhon Si Thammarat provinces at about 600 m altitude. The specimens are deposited at BKF. It was previously reported from Malaysia and the Philippines (Beddome, 1892).

In addition, *D. procumbens* Holttum is not included in Tagawa and Iwatsuki (1988) and Boonkerd and Pollawatn (2000). Because it is a new record in Boonkerd et al. (2004). It was recently collected from Kaeng Krachan National Park, Phetchaburi province, south-western Thailand at 1,300 m alt. Therefore, this species were also added to the list of *Diplazium* species in Thailand.

It is important to note here that *D. petelotii* Tardieu was not existing for this study. Though, an attempt has been made to search this species from main Thai herbaria, main herbaria in Europe as well as field works. This species was formerly collected form Chiang Rai and Phitsanulok provinces northern Thailand (Tagawa and Iwatsuki, 1988). It was firstly described from a specimen collected from Lao Cai province, northern Vietnam (Missouri Botanical Garden, 2012). This species is also reported from Yunnan, China (Missouri Botanical Garden, 2012). In my opinion the presence of this species in Thailand is doubtful. Therefore, it is not included in the present checklist of the Thai *Diplazium*.

Table 4.2 The present checklist of *Diplazium* Sw. in Thailand. Note *, new record for Thailand; ✓, present; ×, not present.

No.	SPECIES	Tagawa & Iwatsuki 1988	Boonkerd & Pollawatn 2000	This Study 2012
1	*D. bantamense* Blume	✓	✓	✓
2	*D. conterminum* Christ	✓	✓	✓
3	*D. cordifolium* Blume	✓	✓	✓
4	*D. crenato-serratum* (Blume) T. Moore	✓	✓	✓
5	*D. dilatatum* Blume	✓	✓	✓
6	*D. donianum* (Mett.) Tardieu	✓	✓	✓
7	*D. esculentum* (Retz.) Sw.	✓	✓	✓
8	*D. griffithii* T. Moore *	×	×	✓
9	*D. heterophlebium* (Mett. ex Baker) Diels	✓	✓	✓
10	*D. leptophyllum* Christ	✓	✓	✓
11	*D. lobatum* (Tagawa) Tagawa *	×	×	✓
12	*D. malaccense* C. Presl	✓	✓	✓
13	*D. megaphyllum* (Baker) Christ	✓	✓	✓
14	*D. mettenianum* (Miq.)C. Chr.	✓	✓	✓
15	*D. muricatum* (Mett.) Alderw.	✓	✓	✓
16	*D. pallidum* (Blume) T. Moore *	×	×	✓
17	*D. petiotii* Tardieu	✓	✓	×
18	*D. petrii* Tardieu	✓	✓	✓
19	*D. polypodioides* Blume	✓	✓	✓
20	*D. prescottianum* (Wall. ex Hook.) T. Moore	✓	✓	✓
21	*D. procumbens* Holttum *	×	×	✓
22	*D. proliferum* (Lam.) Kaulf.	✓	✓	✓
23	*D. riparium* Holttum	✓	✓	✓
24	*D. siamense* C. Chr.	✓	✓	✓
25	*D. simplicivenium* Holttum	✓	✓	*= D. dilatatum*
26	*D. sorzogonense* (C. Presl) C. Presl	✓	✓	✓
27	*D. subintegrum* Holttum	✓	✓	✓
28	*D. subserratum* Blume	✓	✓	✓
29	*D. subsinuatum* (Wall. ex Hook. & Grev.) Tagawa	✓	✓	✓
30	*D. sylvaticum* (Bory) Sw.	✓	✓	✓
31	*D. taiwanense* Tagawa	✓	✓	✓
32	*D. tomentosum* Blume	✓	✓	✓
33	*D. xiphophyllum* (Baker) C. Chr.	✓	✓	✓

4.3.5 Dubious species

It is interesting to note here that a specimen of fern collected by Joh. Schmidt from Koh Chang, Trat province in 1899. This specimen was determined by Christ (1901) as *Asplanium vulcanicum* Blume. Then, Carl Chirstensen recognized that it should be a species of it own, so he described a new species, namely *Asplenium schmidtii*. After examined the specimen carefully I and my thesis advisor found that the specimen should belong to a *Diplazium* species, since it has a diplazoid sori and the scales are not clatrate. We tried to search for the living specimen from the type locality at Lam Dan, but could not find it so far.

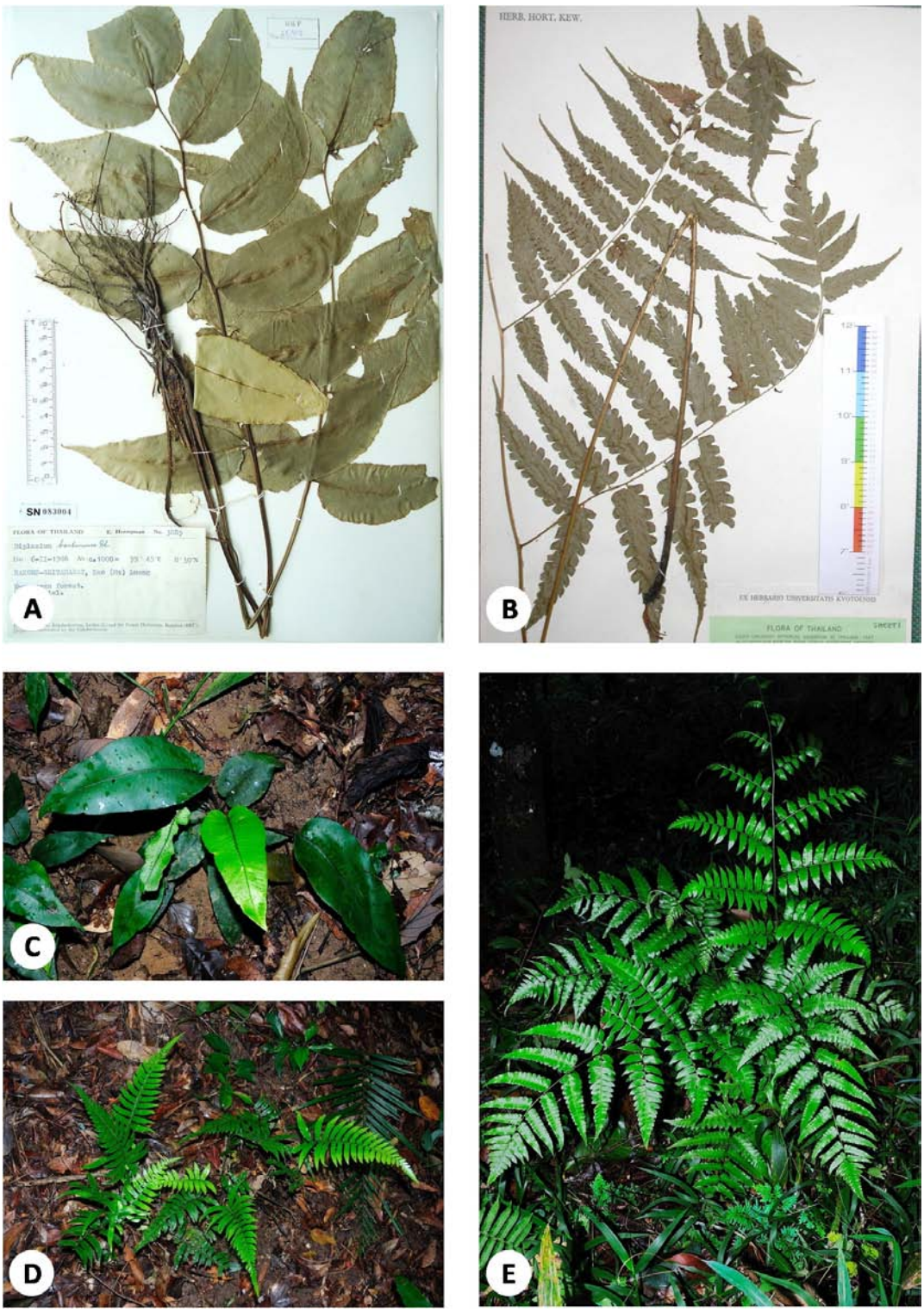

Plate 1 Figure of *Diplazium* Sw. A: *D. bantamense* Blume; B: *D. conterminum* Christ; C: *D. cordifolium* Blume; D: *D. crenato-serratum* (Blume) T. Moore and E: *D. dilatatum* Blume.

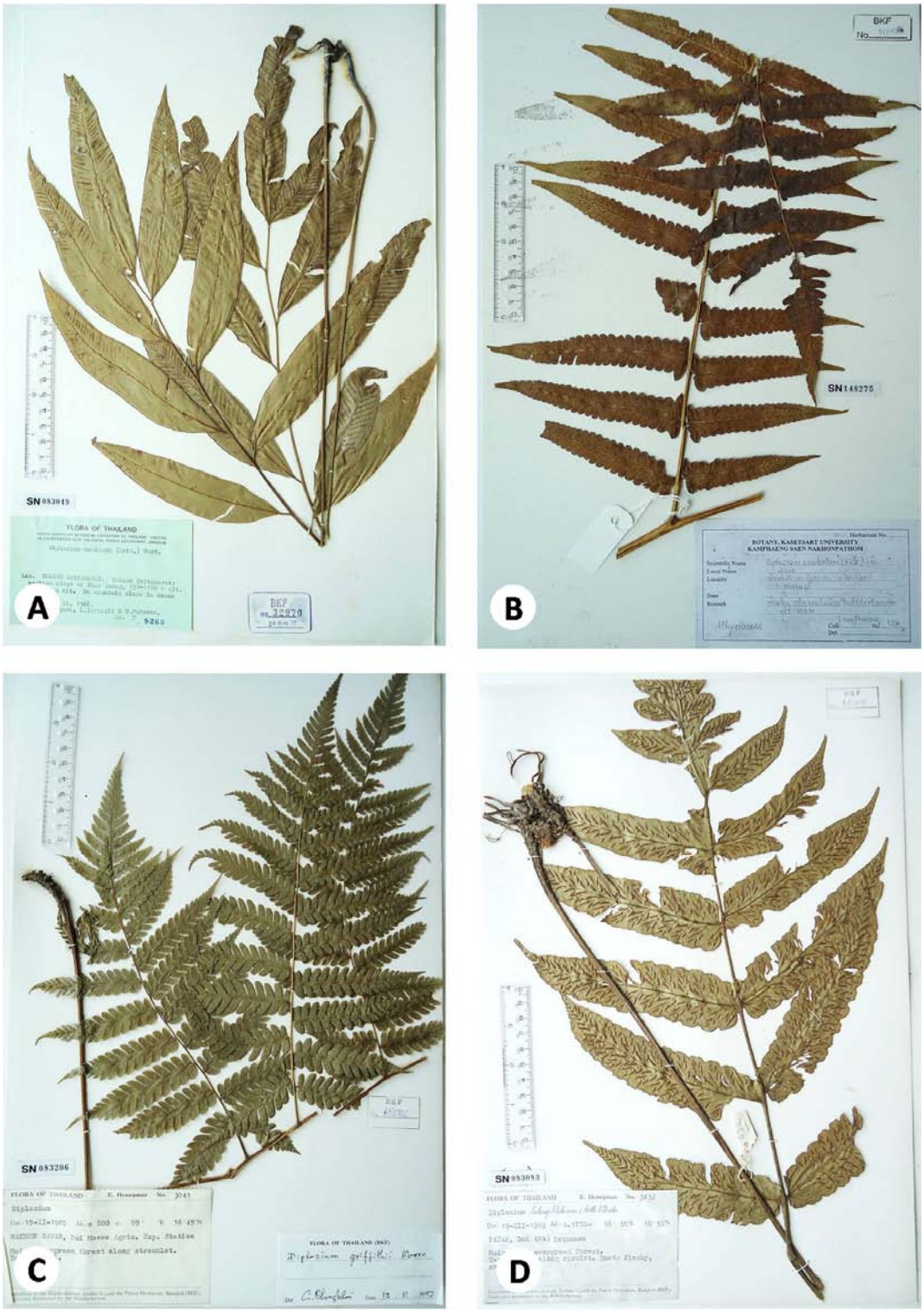

Plate 2 Figure of *Diplazium* Sw. A: *D. donianum* (Mett.) Tardieu; B: *D. esculentum* (Retz.) Sw.; C: *D. griffithii* T. Moore and D: *D. heterophlebium* (Mett. ex Baker) Diels.

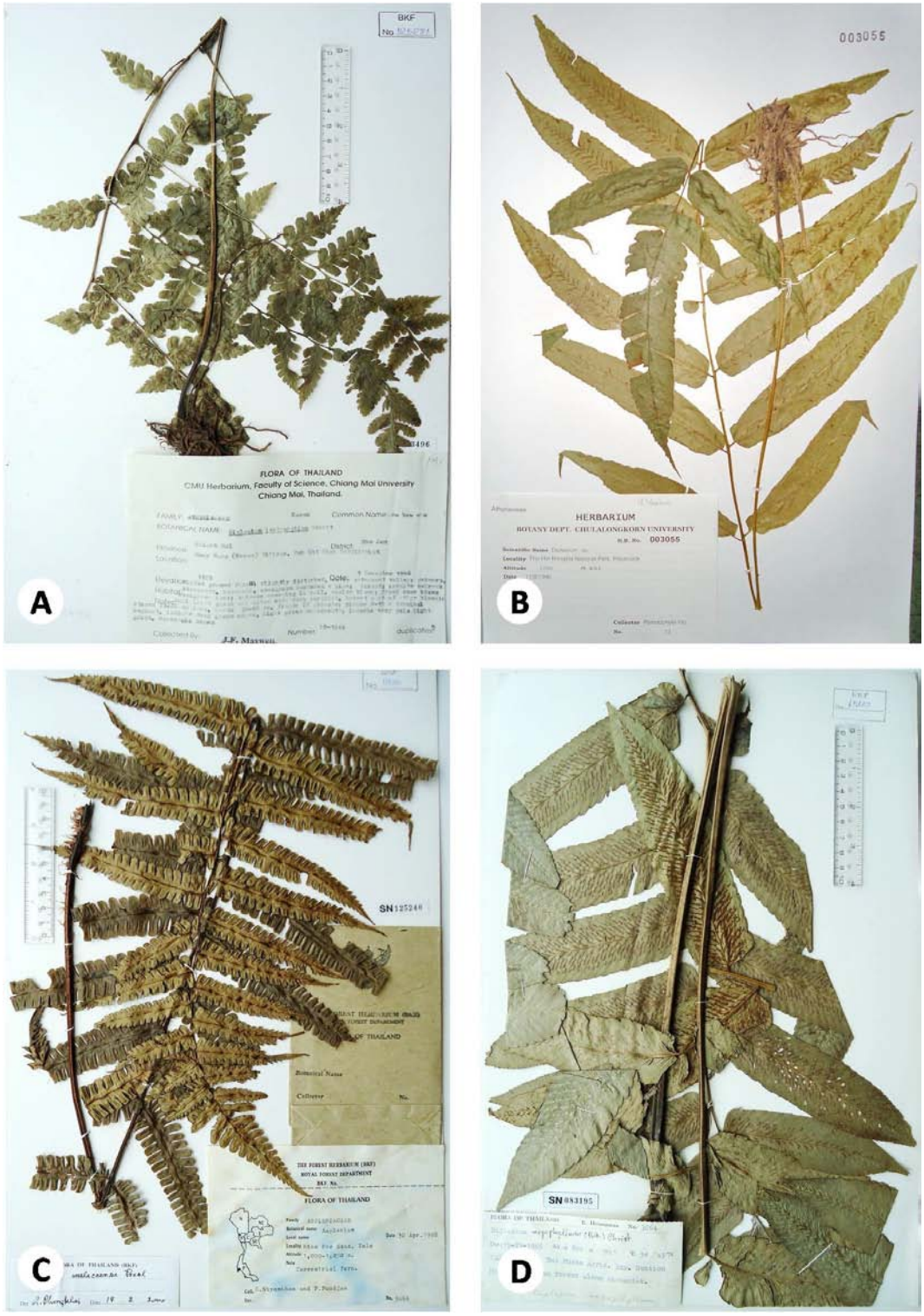

Plate 3 Figure of *Diplazium* Sw. A: *D. leptophyllum* Christ; B: *D. lobatum* (Tagawa) Tagawa; C: *D. malaccense* C. Presl and D: *D. megaphyllum* (Baker) Christ.

Plate 4 Figure of *Diplazium* Sw. A: *D. mettenianum* (Miq.) C. Chr.; B: *D. muricatum* (Mett.) Alderw.; C: *D. pallidum* (Blume) T. Moore and D: *D. petrii* Tardieu.

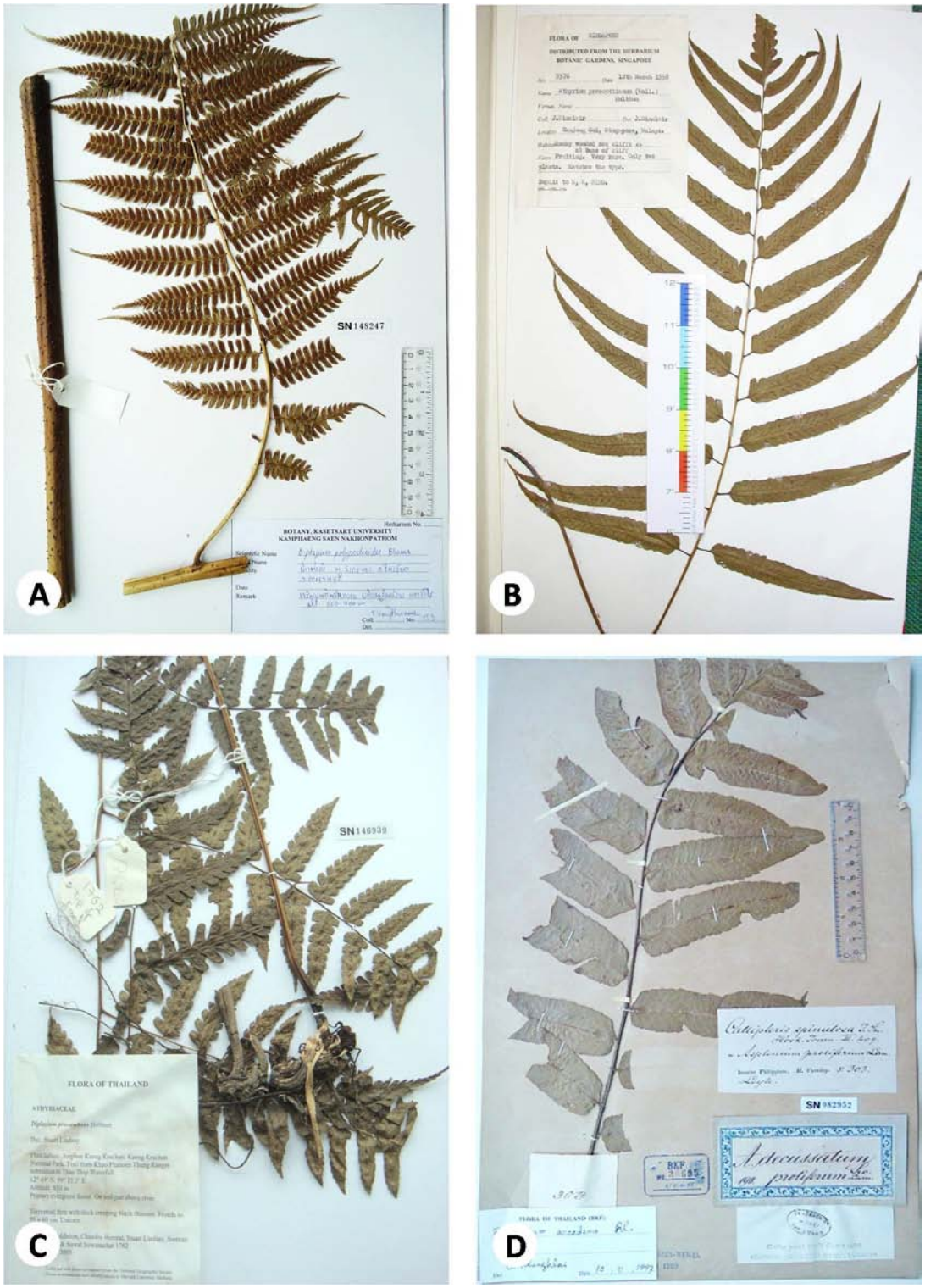

Plate 5 Figure of *Diplazium* Sw. A: *D. polypodioides* Blume; B: *D. prescottianum* (Wall. ex Hook.) T. Moore; C: *D. procumbens* Holttum and D: *D. proliferum* (Lam.) Kaulf.

Plate 6 Figure of *Diplazium* Sw. A: *D. riparium* Holttum; B: *D. siamense* C. Chr.; C: *D. sorzogonense* (C. Presl) C. Presl and D: *D. subintegrum* Holttum.

Plate 7 Figure of *Diplazium* Sw. A: *D. subserratum* Blume; B: *D. subsinuatum* (Wall. ex Hook. & Grev.) Tagawa; C: *D. sylvaticum* (Bory) Sw. and D: *D. taiwanense* Tagawa.

Plate 8 Figure of *Diplazium* Sw. A: *D. tomentosum* Blume; B: *D. xiphophyllum* (Baker) C. Chr.

CHAPTER VI

GENERAL CONCLUSION

This research was designed to explore additional data for species determination in the Thai *Diplazium* by examining the morphological, anatomical and palynological characters of the available species. The outputs were used as basic characters for key construction as well as a basis to delimit the species boundaries within *Diplazium*.

In general, *Diplazium* has two vascular strands at lower portion of stipes. A single vascular bundle at upper portion of stipes was observed which are varying in shape among studied species. They are U-shaped, V-shaped or W-shaped in transverse section. Instead of having a merging vascular bundle some species have two free vascular bundles throughout their stipe length. So this anatomical feature is useful in species determination. On the other hand, studying of the epidermal peels revealed that there are two stomatal types, i.e. polocytic and copolocytic stomata. Unfortunately, they can be found in the same leaf of each species and can not be used in species determination.

Palynology of 31 species of *Diplazium* are investigated by LM and SEM. All studied spores are monolete, bilateral and having perispore. The exospore sculpture can be divided in to 8 types, i.e. baculate, echinate, reticulate, rugate, rugate-retate, regulate and smooth types. These are other microscopic characters that can be used as taxonomic characters in supporting species determination, especially species with homogeneous ornamentation pattern of spores.

On account of the general plant morphology the *Diplazium* species are more or less different in their growth form of rhizome, indumenta, stipe and lamina characters

(Table 3.2). They are collectively useful in fern taxonomy (Holttum, 1960; Shieh, Devol and Kuo, 1997). It is found from this study that scales of the *Diplaziums* are good taxonomic characters.

Previously, the account of *Diplazium* in Thailand included 29 indigenous species (Table 4.1). Then *D. procumbens* Holttum was add to the Thai account as new records (Boonkerd et al., 2004). However, these new recorded species are not contained in keys to the species in the Flora of Thailand (Tagawa and Iwatsuki, 1988). So far, an attempt has been made to search for *D. petelotii* Tardieu from main Thai herbaria, main herbaria in Europe as well as field works in Thailand. Unsuccessfully, it can not be found. So this species is excluded from the present Thai account. It was found that some of the preceding 29 recognized species are rather difficult to determine up to species level, since there are some ambiguous characters in earlier keys to the species (Tagawa and Iwatsuki, 1988). To clarify this problem key to the species of Thai *Diplazium* was revised using some additional definite characters. It is also the result from the study of gross structures that *D. simplicivenium* Holttum were treated as a synonym of *D. dilatatum* Blume.

To sum up, 31 species of *Diplazium* in Thailand are recognized. Of these 3 species, namely *D. griffithii* T. Moore, *D. lobatum* (Tagawa) Tagawa, and *D. pallidum* (Blume) T. Moore are newly recorded for the Thai Flora.

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BIOGRAPHY

Mr. Puttamon Pongkai was born on April 30, 1986 in Bangkok province. He was graduated in Biology from Faculty of Science, Srinakharinwirot University in 2008. Then, he continued his study in Master of Science in Botany, Department of Botany, Faculty of Science, Chulalongkorn University, Bangkok, Thailand from 2008-2012.