

Hainan tree ferns (Cyatheaceae): morphological, ecological and phytogeographical observations

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Based on extensive field surveys and studies of numerous herbarium collections, a taxonomic revision on the tree ferns (Cyatheaceae) from Hainan Island, South China is made. Some formerly used diagnostic characters are critically reassessed, while others with taxonomic value are introduced for the first time. As a result, two genera and six species are recognized for the island. *Alsophila denticulata* is a new record for Hainan. *Alsophila gigantea* var. *polynervata* and *Cyathea hainanensis* are reduced to synonymy. A lectotype is designated for *Alsophila podophylla*. The habitat and geographical distribution of the Hainan tree ferns are briefly discussed. Their distribution patterns indicate affinities either to the fern flora of Malesia, the eastern Himalayas, or southern Japan.

Key words: Cyatheaceae, distribution, floristics, lectotype, taxonomy

Introduction

Hainan, an island in the South China Sea, lies between 18°9′–20°11′N and 108°36′–111°4′E, and has an area of 33 600 km² (R. Z. Zhang 2004). It is the second largest island in China, and abounds in pteridophytes. However, the pteridophyte flora is not well documented because there is no modern revision since *Flora Hainanica* vol. 1 (Ching *et al.* 1964). In order to revise the fern flora of Hainan, we made intensive explorations throughout the island, and checked all Hainan fern specimens in the major Chinese herbaria. The present paper is a study contributing to this revised flora.

Plants of the family Cyatheaceae, usually called tree ferns, are distinct from most other

ferns by having trunk-like, erect stems. Worldwide there are about 500 extant species in the tropics and subtropics (Tryon & Gastony 1975). In Asia, tree ferns are concentrated in Malesia; 14 species are known in China (X. C. Zhang 2004), of which six occur in Hainan Island. Originally, Ching and his students (Ching & Wang 1959, 1964, Ching *et al.* 1964) recognized six locally endemic and three widely distributed tree ferns. Except for *Sphaeropteris hainanensis*, Xia (1989) reduced five of these Hainan endemics to synonyms of very common tropical Asian taxa. More recently, X. C. Zhang (2004) treated *S. hainanensis* as conspecific with *S. brunoni-ana*, but Wu (2006) kept it as a separate species. Besides *S. hainanensis*, another taxon, *Alsophila gigantea* var. *polynervata* is also controversial

because this variety, represented only by a single herbarium sheet, was thought to be distinct by having more veins in its lobes than the name variety (Miau 1980, Xia 1989).

Due to their very large lamina, which cannot be pressed as a single herbarium specimen, and insufficient field observations, the taxonomy of Hainan Cyatheaceae is not yet clear. Many morphological characters, especially those seen in the living state, as well as habitat and distributional data are hitherto not well documented.

Morphological and taxonomical treatment

As mentioned by Holttum (1965) and Xia (1989), some characters such as structure of stipe scales, the presence and shape of indusia, and the number of spores in a sporangium are stable and useful in the taxonomy down to the subgeneric level. Below we list some other characters that we consider useful for species delimitation, but which were either neglected or not well understood in previous taxonomical works on Cyatheaceae.

TRUNK HEIGHT. The height of the trunk separates Hainan tree ferns in two distinct groups. *Sphaeropteris brunoniana*, *A. spinulosa*, and *A. latebrosa* are arborescent with trunks that can reach over 5 m high (for *S. brunoniana*, we recorded an extreme of 16 m). The other three species, *A. podophylla*, *A. denticulata* and *A. gigantea* are shrub-like, with trunks usually less than 3 m high.

STIPE COLOR. This is a valuable character for the classification of Hainan tree ferns. Basically, three colors i.e., black, dark red and green, are found in this group. The stipe of *A. gigantea* is black, that of *A. podophylla*, *A. spinulosa*, and *A. denticulata* is dark red, and the stipe of *A. latebrosa* and *S. brunoniana* is green when young and turns brown when very old.

STIPE SPINES. Though spines are not always present on the stipe in every tree fern, we found it a useful character. Among the Hainan tree ferns, *A. spinulosa* is the only species with obvious, long and sharp spines on the stipe and rachis. In the other species, stipes are usually spineless though occasionally there are some short spines at the base of the stipes.

STIPE PNEUMATHODES. Pneumathodes occur along each side of the stipe and rachis and often provide distinctive characters in *Cyathea*, unfortunately they are usually not seen in herbarium specimens (Holttum 1963). The presence of either discontinuous or nearly continuous pneumathodes was used as a key character to separate *Sphaeropteris* from *Alsophila* by Xia (1989). Our observations show that the shape of pneumathodes is useful in the classification of species but cannot be used to divide groups at the level of genus. Actually, nearly continuous pneumathodes occur not only in *Sphaeropteris* but also in some species of *Alsophila*, e.g., *A. latebrosa*.

LAMINA OUTLINE. In most Hainan tree ferns the outline of the lamina is broadly lanceolate, i.e., broadest in the middle and gradually narrowing towards the base and the apex. *Alsophila denticulata* is the notable and only exception, and has a triangular lanceolate lamina with the base broadest. Besides the overall shape of the lamina, its distal part also differs among species. A pinnate and gradually narrowing apex is the common pattern for the majority of taxa, though in *A. podophylla*, the distal part is usually a pinna that is conform to the lateral pinnae.

PINNA ARRANGEMENT ALONG THE RACHIS. The arrangement of the pinnae along the rachis is useful to distinguishing different tree ferns in the field. *Alsophila latebrosa* and *A. gigantea* are characterized by mostly opposite lateral pinnae (except those near the apex). In the other species, the pinnae are generally alternate but the lower 1–3 pairs of pinnae are sometimes subopposite. This character helps to distinguish two shrub-like and very common species, *A. gigantea* and *A. podophylla*, from a distance.

PETIOLULE LENGTH OF BASAL PINNA. This character usually cannot be seen in herbarium collections and its taxonomical value has seldom been noticed. In Hainan tree ferns it shows three character states. The basal pinna has either a long petiolule, from 2 to 8 cm, in *A. podophylla* and *S. brunoniana*, a short stalk less than 2 cm, in *A. denticulata* and *A. spinulosa*, or is not petiolulate at all in *A. gigantea* and *A. latebrosa*.

VEINS. Veins single or 2-forked was one of the characters used to distinguish subgenus *Alsophila* from subgenus *Gymnosphaera* by X. C. Zhang (2004). In Zhang's opinion, veins are single in

subgenus *Gymnosphaera* but usually 2-forked in subgenus *Alsophila*. Our observations show that this character cannot be used at the subgeneric level. For instance, the veins are single or more often 2-forked in *A. denticulata*, which belongs to subgenus *Gymnosphaera*.

SORUS POSITION AND NUMBER. The position and the number of sori in a lobe are generally stable and distinctive in a given species. Sori are medial in *A. denticulata* and *S. brunoniana*, or close to the costule as in *A. spinulosa*. An interesting case of soral arrangement is found in *A. gigantea*, where sori are medial on the basal veinlets but become gradually closer to the costule on distal veinlets, consequently sori in a lobe form a V shape. The number of sori in a lobe varies from 2 to 11 in different species.

Key to Hainan tree ferns

1. Scales at base of stipe light brown, almost transparent, consisting of uniform cells with minute dark spines along the margin (genus *Sphaeropteris*)
..... *S. brunoniana*
1. Scales at base of stipe brown to dark brown, not transparent, median cells more compact and darker brown than marginal cells (light brown), scale margin usually erose but without dark spines (genus *Alsophila*) 2
2. Sori indusiate; 16 spores per sporangium (subgenus *Alsophila*) 3
2. Sori exindusiate; 64 spores per sporangium (subgenus *Gymnosphaera*) 4
3. Stipe and rachis with strong spines; indusia spherical, enclosing the sori before maturity *A. spinulosa*
3. Stipe and rachis spineless or with short spines; indusia minute, scalelike and hidden by the sori *A. latebrosa*
4. Stipe and rachis black, with dense and spreading scales along lateral sides *A. gigantea*
4. Stipe and rachis dark red or castaneous, without spreading scales along lateral sides 5
5. Lamina lanceolate with conform terminal pinna; pinnules slightly serrate to shallowly lobed, rarely pinnatifid; pinnule-costules with small lanceolate scales beneath *A. podophylla*
5. Lamina triangular without conform terminal pinna; pinnules 1-pinnate to 2-pinnatifid; pinnule-costules with ± bullate scales beneath *A. denticulata*

Sphaeropteris brunoniana (Hook.) R.M. Tryon

Contr. Gray Herb. 200: 21. 1970. — *Alsophila brunoniana* Hook., Sp. Fil. 1: 52. 1844. — TYPE: Bangladesh. Sylhet, Wallich 7073 (holotype K!).

Cyathea hainanensis Ching, Acta Phytotax. Sin. 8: 147, 168, pl. 21. fig. 23. 1959. — *Sphaeropteris hainanensis* (Ching) R. M. Tryon, Contr. Gray Herb. 200: 21. 1970. — TYPE: China. Hainan, Sanya, H.-Y. Liang 62675 (holotype PE!; isotype IBSC!).

Cyathea contaminans auct. non Copel.: Chun et al., Fl. Hainan. 1: 139. 1964.

HABITAT. On road sides in forest areas or in valley forest, alt. 270–1250 m.

DISTRIBUTION. China (Hainan, Xizang, Yunnan), India, Bhutan, Sikkim, Bangladesh, Myanmar, Vietnam (Fig. 1).

Trunk 5–10(16) m high; stipe-scales light brown to nearly white, with regular black setae along the margins; stipes green or brown, without spines or rarely with few and short spines at the base; pneumathodes on either side of stipe nearly continuous; lamina broadly lanceolate, the middle part broadest, 2-pinnate and gradually narrowed towards apex; pinnae 18–24 pairs, alternate or sometimes lower 3–4 pairs subopposite; petiolules of basal pinnae 2–7 cm long; pinnules deeply lobed, some needle-like hairs abaxially on pinnule-costule; veinlets 3-branched or 2-branched in two times; sori exindusiate, medial, often 6 pairs per lobe.

When Ching (in Ching & Wang 1959) described *Cyathea hainanensis* he did not compare his new species with any other tree fern and did not give diagnostic characters. Xia (1989) recognized the affinity of *S. hainanensis* and *S. brunoniana*, and supplied the following key:

1. Fronds 2-pinnate, pinnules deeply lobed, needle-like hairs only present dorsally along distal part of pinnule-costule *S. brunoniana*
1. Fronds 2- to 3-pinnate, several needle-like hairs present dorsally along the whole pinnule-costule, or at least along the middle to apical part, and on the lower surface of the costule of ultimate segments *S. hainanensis*

Based on our observations, whether the pinnule is deeply lobed or pinnate is of no significance to distinguish *S. hainanensis* from *S. brunoniana* because the pinnules tend to be more deeply lobed in larger fronds. On the other hand, we always found needle-like hairs along the middle to apical part of the pinnule-costule in all populations of *S. brunoniana*. So there is no morphological character separating *S. hainanensis* from *S. brunoniana*. Furthermore, Wang

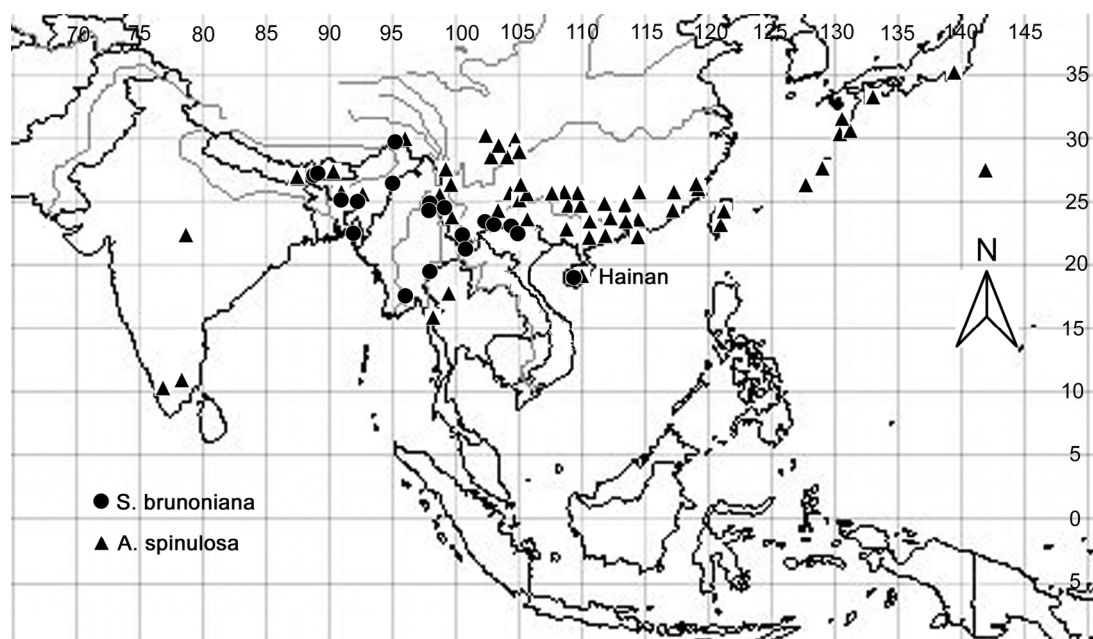


Fig. 1. Distribution map of *Sphaeropteris brunoniana* (filled circles) and *Alsophila spinulosa* (triangles).

et al. (2003) could not distinguish two distinct species using chloroplast *trnL* intron and *trnL-trnF* intergenic spacer sequences. Curiously, the paratype of *S. hainanensis* (*Acad. Sin. Hainan Veg. Surv.* 286, PE) was cited by Xia (1989) as a representative specimen of *S. brunoniana*.

Alsophila spinulosa (Wall. ex Hook.) R.M. Tryon

Contr. Gray Herb. 200: 32. 1970. — TYPE: Nepal. Without precise locality, *Wallich 178* (holotype K!).

HABITAT. On stream sides in forest or along forest edges, alt. 470–1250 m.

DISTRIBUTION. China (Fujian, Guangdong, Guangxi, Guizhou, Hainan, Sichuan, Taiwan, Hong Kong and Yunnan), Japan, Vietnam, Thailand, Cambodia, Myanmar, Bhutan, Sikkim, Nepal, India and Bangladesh (Fig. 1).

Trunk 2–8 m; stipe-scales brown, nearly entire; stipes dark red when living, sharp long spines present on stipes and rachises; pneumathodes on either side of stipe discontinuous; lamina broadly lanceolate, the middle part broadest, 2-pinnate and gradually narrowed towards the apex; pinnae 18–22 pairs, alternate or some-

times the lower 2–3 pairs subopposite; pinnae sessile or shortly petiolulate (stalks less than 2 cm long); pinnules pinnatisect; ovate, more or less bullate scales on abaxial surface of costules; veinlets 2-branched; sori indusiate, indusia spherical before maturity; sori closely costular, 5–7(11) pairs per lobe.

Alsophila latebrosa Wall. ex Hook.

Sp. Fil. 1: 37. 1844. — TYPE: Malaysia. Penang, *Wallich 318* (holotype K!; isotype PE!, a pinnule).

Cyathea tsangii Ching & S.H. Wu, *Acta Phytotax. Sin.* 9: 366. 1964. — TYPE: China. Hainan, Chengmai, *W. T. Tsang 729* (non 739) (holotype PE!; isotype PYU!).

HABITAT. In forest or on stream sides in forest, alt. 370–1300 m.

DISTRIBUTION. China (Hainan), Thailand, Laos, Cambodia, Malaysia and Indonesia (Fig. 2).

Trunk 3–5 m; stipe-scales brown, nearly entire; stipes usually green at adaxial side and brown at abaxially, without long spines but occasionally with short spines at the base; pneumathodes on either side of stipe nearly continuous; lamina broadly lanceolate, the middle part broadest, 2-pinnate and gradually narrowed towards apex; pinnae 15–20 pairs, opposite or

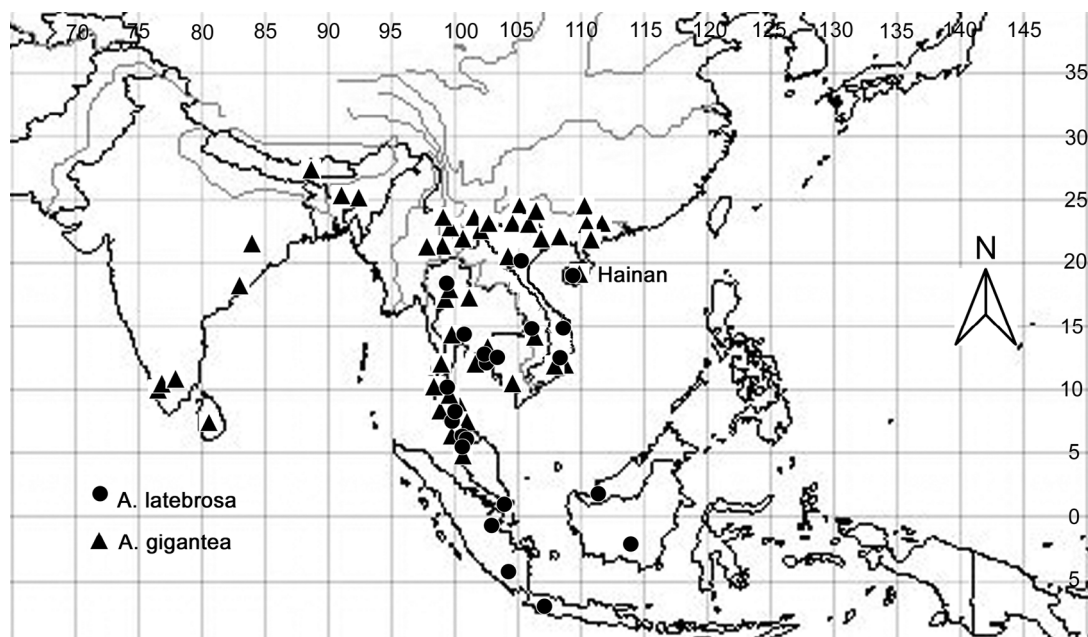


Fig. 2. Distribution map of *Alsophila latebrosa* (filled circles) and *A. gigantea* (triangles).

occasionally several pairs of distal pinnae alternate; pinnae sessile; pinnules deeply lobed; bul-
 lulate scales on abaxial side of costules; veinlets
 2-branched; sori indusiate, indusia lepidoid and
 covered by sori; sori medial but occasionally
 more close to the costule, 2–3 pairs per lobe.

This species is very similar to *S. brunoniana*,
 but the scales at the stipe base and on the abaxial
 side of the costules are very different in the two
 species.

Alsophila gigantea Wall. ex Hook.

Sp. Fil. 1: 53. 1844. — TYPE: Nepal. Without precise locality,
Wallich 321 (holotype K!).

Cyathea tinganensis Ching & S.H. Wu, Acta Phytotax.
 Sin. 9: 366. 1964. — TYPE: China. Hainan, Dingan, *H.-Y.*
Liang 64353 (holotype PE!).

Cyathea pectinata Ching & S.H. Wu, Acta Phytotax.
 Sin. 9: 365. 1964. — TYPE: China. Hainan, *C. Wang 35217*
 (holotype IBSC!).

Cyathea pseudogigantea Ching & S.H. Wu, Acta Phyto-
 tax. Sin. 9: 365. 1964. — TYPE: China. Hainan, Mt. Wuzhis-
 han, *Hainan Exped. 692* (holotype PE!; isotype IBSC!).

Cyathea petiolulata Ching & S.H. Wu, Acta Phytotax.
 Sin. 9: 365. 1964. — TYPE: China. Hainan, *L. Tang 3162*
 (holotype PE!; isotype IBSC!).

Cyathea gigantea var. *polynervata* R.H. Miao, Acta
 Sci. Nat. Univ. Sun. 1: 100. 1980, *syn. nov.* (“*giganthea*”)

— *Alsophila gigantea* var. *polynervata* (R.H. Miao) Q. Xia,
 Acta Phytotax. Sin. 27: 11. 1989. — TYPE: China. Hainan, *P.*
Zeng 13132 (holotype SYS!).

HABITAT. In valley forest or along forest mar-
 gins, alt. 220–1250 m.

DISTRIBUTION. China (Guangdong, Guangxi,
 Hainan, Yunnan), India, Sri Lanka, Nepal,
 Sikkim, Bangladesh, Myanmar, Thailand, Laos,
 Vietnam, Malaysia and Indonesia (Fig. 2).

Trunk 0.5–3.5 m high; stipe-scales dark
 brown to black, margin fragile and erose; stipe
 black, without long spines or rarely with short
 spines at the base; pneumathodes on either side
 of stipe distinctly discontinuous; lamina broadly
 lanceolate, the middle part broadest, 2-pinnate
 and gradually narrowed towards the apex or
 sometimes with an apical pinna similar to lateral
 pinnae; pinnae 11–15 pairs, opposite or occa-
 sionally some distal pinnae alternate; pinnae ses-
 sile; pinnules lobed 1/2–3/4 towards the costule,
 small lanceolate scales abaxially on costules;
 veinlets simple, rarely 2-branched; sori exindus-
 iate, medial on the basal veinlet but gradually
 getting closer to the costule on the distal veinlets
 and forming a V shape, sori 4–7 pairs per lobe.

This species is very distinct by its combina-
 tion of black stipes with dense and patent scales

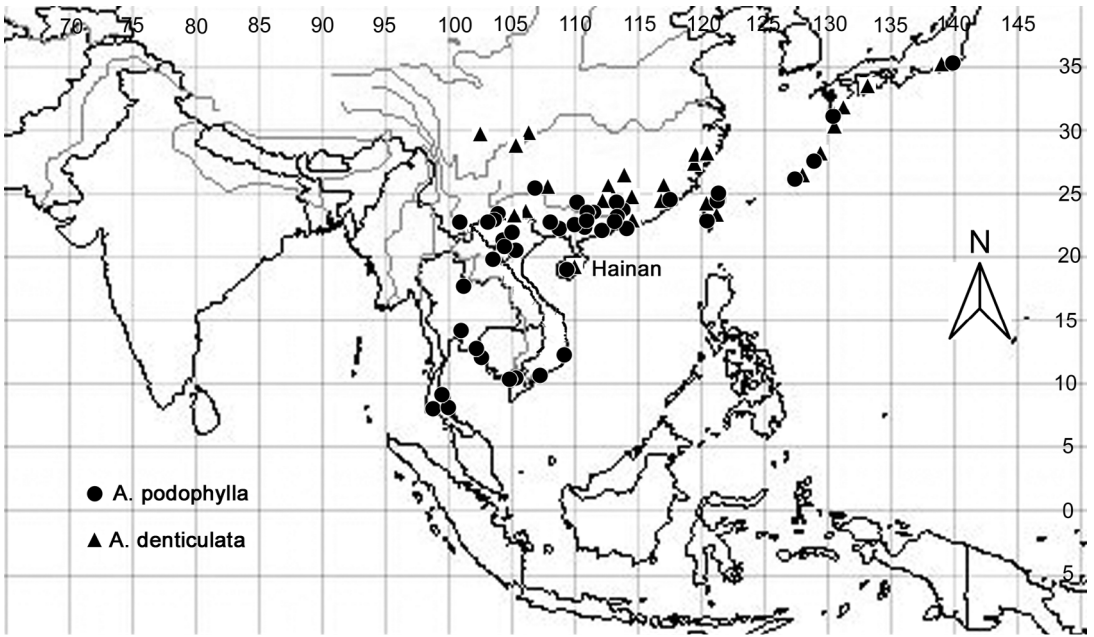


Fig. 3. Distribution map of *Alsophila podophylla* (filled circles) and *A. denticulata* (triangles).

along either side, opposite lateral pinna, and lobes with a V-shaped soral pattern. According to Miau (1980) and Xia (1989) *A. gigantea* var. *polynervata* was differentiated from var. *gigantea* by its longer pinnules (10 cm), ultimate pinna-lobes with 8–10 pairs of veinlets, and veinlets usually 2-branched. When checking the type, we found that the pinnules are 7–10 cm long and the veinlets are mostly single but few are 2-branched in the pinna-lobes. We don't think there is any difference between the holotype of *A. gigantea* var. *polynervata* and other specimens of *A. gigantea*, and consequently reduce var. *polynervata* to a synonym of *A. gigantea*.

Alsophila podophylla Hook.

Hook. J. Bot. 9: 334. 1857. — LECTOTYPE (designated here): China. Hong Kong, *Harland s.n.* (K!). Syntypes: *J. C. Bowring s.n.* (K!); Zhejiang, *T. Alexander s.n.* (K!).

HABITAT. In forest or along forest margins, alt. 540–1380 m.

DISTRIBUTION. China (Fujian, Guangdong, Guangxi, Guizhou, Hainan, Taiwan, Hong Kong, Yunnan and Zhejiang), South Japan, Vietnam,

Laos, Thailand and Cambodia (Fig. 3).

Trunk 1–2.5 m high; stipe-scales brown, sub-entire to erose; stipe dark red, without long spines but occasionally with some short spines at its base; pneumathodes on either side of stipe distinctly discontinuous; lamina 2-pinnate, broadly lanceolate, the middle part broadest, with the apical pinna conform to the lateral pinnae; pinnae 6–11 pairs, alternate or rarely the lower 3–4 pairs of pinnae subopposite; basal pinnae stalked, petiolules 6–12 cm long; pinnules serrate to shallowly lobed, rarely pinatifid; small lanceolate scales abaxially on the costules; veinlets simple; sori exindusiate, close to costule or sometimes similar to those of *A. gigantea* but not forming a distinct V shape, sori 3–5 pairs per lobe.

This species is easily distinguished from all others by its nearly entire pinnules, its basal pinna with a long stalk, and its lamina with a conform terminal pinna. When Hooker (1857) described *A. podophylla* he cited three syntypes: one collected in Chusan by T. Alexander, and two others from Hong Kong collected by J. C. Bowring and Dr. Harland, respectively. Five sheets of the syntypes are preserved in K: three sheets of Dr. Harland, one sheet of T. Alexander,

and one sheet collected by J. C. Bowring. The best of these syntypes is Dr. Harland's collection from Hong Kong, which is on three sheets, and is hereby selected as the lectotype.

Alsophila denticulata Baker

J. Bot. 23: 102. 1885. — TYPE: China, Taiwan, *Hancock* 55 (K).

HABITAT. In valley forest, alt. 900–1200 m.

DISTRIBUTION. China (Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hunan, Jiangxi, Sichuan, Taiwan, Hong Kong, Yunnan and Zhejiang), South Japan (Fig. 3).

Trunk ca. 1 m high; stipe-scales brown, margin erose; stipe castaneous; pneumathodes on either side of the stipe distinctly discontinuous; lamina triangular, 3-pinnate and gradually narrowed towards the apex; pinnae 8–10 pairs, alternate but occasionally the lower 1–3 pairs subopposite; basal pinna petiolulate, stalks 1–2 cm long; pinnules 1-pinnate to 2-pinnatifid, with bullate scales abaxially on the costules; veinlets simple or more often 2-branched; sori exindusiate, medial, 5–6 pairs per lobe.

This species is distinct by having a triangular, 3-pinnate to 4-pinnatifid lamina, and usually 2-branched veinlets. During a survey of the fern flora of Mt. Yinggeling in August 2005, we found a small population of *A. denticulata* along a stream in tropical montane forest at 1200 m. This was the first time that *A. denticulata* was recorded from Hainan Island. In December 2006, we found a second population on Mt. Qixianling, a well known tourist attraction in southern Hainan. *Alsophila denticulata* is restricted to subtropical eastern Asia, and Hainan Island now represents its southernmost locality.

Ecology and phytogeography

Tree ferns occur in the central and southern mountains of Hainan. They usually grow along stream sides, in valley forests, or in forest margins, at altitudes between 220 m and 1380 m. Between 2002 to 2006, we surveyed 254 populations; about 76% of the populations grow at

altitudes 600–1100 m, i.e., where the majority of Hainan forests occur. Except for *A. denticulata* with only two known populations, the other five species are common in Hainan. Among these common species, *S. brunoniana* has the widest altitudinal distribution (270–1250 m). *Alsophila gigantea* may grow at the very low altitude of ca. 200 m, but the other three species, *A. latebrosa*, *A. spinulosa*, and *A. podophylla* were not recorded below 370 m, 470 m and 540 m, respectively. *Alsophila podophylla* trends to grow at higher altitudes, with the highest population occurring at 1380 m. The altitudinal distribution of these tree ferns indicates that *A. gigantea* is possibly more adapted to a tropical climate, while *A. podophylla* favours subtropical climate.

Phytogeographically, the following three distribution patterns can be distinguished among the six Hainan tree ferns: northern tropical Asian (Fig. 1), tropical Asian (Fig. 2) and tropical East Asian (Fig. 3). The distribution pattern of these species reflects the affinities of the fern flora of Hainan with those of Malaysia, the eastern Himalayas, and southern Japan, respectively.

Sphaeropteris brunoniana (Fig. 1) is concentrated in the southern Himalayas and neighbouring areas, with Hainan Island forming the most southeastern outpost of this species. *Alsophila spinulosa* has a very wide range with the eastern Himalayas nearly in its center. The Hainan populations of *S. brunoniana* and *A. spinulosa* may have come from the eastern Himalayas.

Alsophila latebrosa and *A. gigantea* (Fig. 2) are two tropical Asian–Malesian species. The former is concentrated in tropical Asia with northern Thailand and Hainan forming its northernmost border. *Alsophila gigantea* has a much wider range than *A. latebrosa*, and extends northwest to northeastern India and Nepal and west to southern and central India. As Malesia is a center of tree fern diversity with 191 species while the rest of Asia has only 25 (Holttum 1965, Tryon & Gastony 1975), Malesia may be the distribution center of both *A. gigantea* and *A. latebrosa*. The Hainan populations of these species may have come from Malaysia.

Alsophila podophylla and *A. denticulata* (Fig. 3) are distributed in the tropics and subtropics of East Asia. *Alsophila denticulata* is limited to South China with an extensions north to south-

ern Japan and south to Hainan. The distribution pattern of *A. podophylla* is essentially like that of *A. denticulata*, but *A. podophylla* has a more southern distribution extending into Indochina. South China is the distribution center of these two species.

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