

# Two new species of *Hypodematium* (Hypodematiaceae) from limestone areas in Guangdong, China

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**ABSTRACT.** *Hypodematium humile* F. G. Wang & F. W. Xing and *H. villosum* F. G. Wang & F. W. Xing, two new species of Hypodematiaceae from Guangdong, southern China, are described and illustrated. Their spore morphology, ecology and conservation status are also presented. *Hypodematium villosum* differs from *H. fordii* in having glabrous petiole except on the base, both surfaces of lamina, rachis and costa densely covered with long acicular hairs ca. 1 mm long, and apex of pinnulets acute. *Hypodematium humile* differs from *H. glandulosum* in having leaves 8-11 cm long with both surfaces of lamina, rachis and costa sparsely covered with rod-shaped glandular hairs and caducous indusium. A key to the species of *Hypodematium* known from Guangdong Province is provided. The systematic relationship of *Hypodematium* with *Leucostegia* is also discussed.

**Keywords:** China; Endemism; Guangdong; *Hypodematium humile*; *Hypodematium villosum*; Limestone; New species; Rare plant; Spore morphology.

## INTRODUCTION

Described in 1833, *Hypodematium* Kunze is the only genus of the Hypodematiaceae. Iwatsuki (1964) reviewed the genus and recognized four species including one subspecies. More recently, over 18 species of *Hypodematium*, mainly distributed in subtropical and temperate areas of Asia and Africa, have been described (Shing et al., 1999; Tsai and Shieh, 1994). China, with 14 species and one variety of *Hypodematium*, is regarded as the center of distribution of this genus. *Hypodematium* is a unique fern genus, because it grows on soils derived from limestone rocks and has distinctive swollen scaly base of stipe and indusium. *Hypodematium* is closely related to *Cystopteris* and some authors consider it to be a distinct section of this (Ching, 1935). Due to its unique morphology (Iwatsuki, 1964), *Hypodematium* has been placed in different suprageneric taxa, e.g. Athyriaceae (Woodsiaceae), Dryopteridaceae, and Thelypteridaceae.

During a field-trip to the limestone area of Guangdong Province (southern China), we collected some specimens of *Hypodematium* that we were unable to assign to any of the previously described taxa. Thus, they are described here as two new species.

## MATERIAL AND METHODS

Herbarium materials for morphological study were obtained from PE, IBSC and SYS. Some taxa were studied during our field-trips expeditions to Guangdong in 2005 and 2008. For the SEM studies, spores were placed on aluminum stubs with double-sided tape and sputter-coated with gold. Spores were observed and photographed under a Hitachi JSM-6360LV scanning electron microscope.

Morphological observations and measurements on collections were made with a ruler or binocular light microscope fitted with an eyepiece graticule. Only mature plant parts were measured. Details of plant growth habit and size, colour of fresh leaves and scales, and information on the habitat and locality were taken from the collector's notes recorded on the herbarium label and from our field observations.

The mature spores were put in a centrifuge tube, 70% ethanol was added, and spores shaken with an ultrasonic wave bath for 10 min. After 4 min in an Eppendorf centrifuge, they were thrice washed with 70% ethanol and thrice shaken with an ultrasonic wave bath for 10 min after a liquid exchange each time. Finally, the spores and ethanol were moved to double-sided adhesive tape with Eppendorf. They were then treated by dessication and spray-gold when ethanol volatilized, and SEM was used to study their microstructure.

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## NEW SPECIES

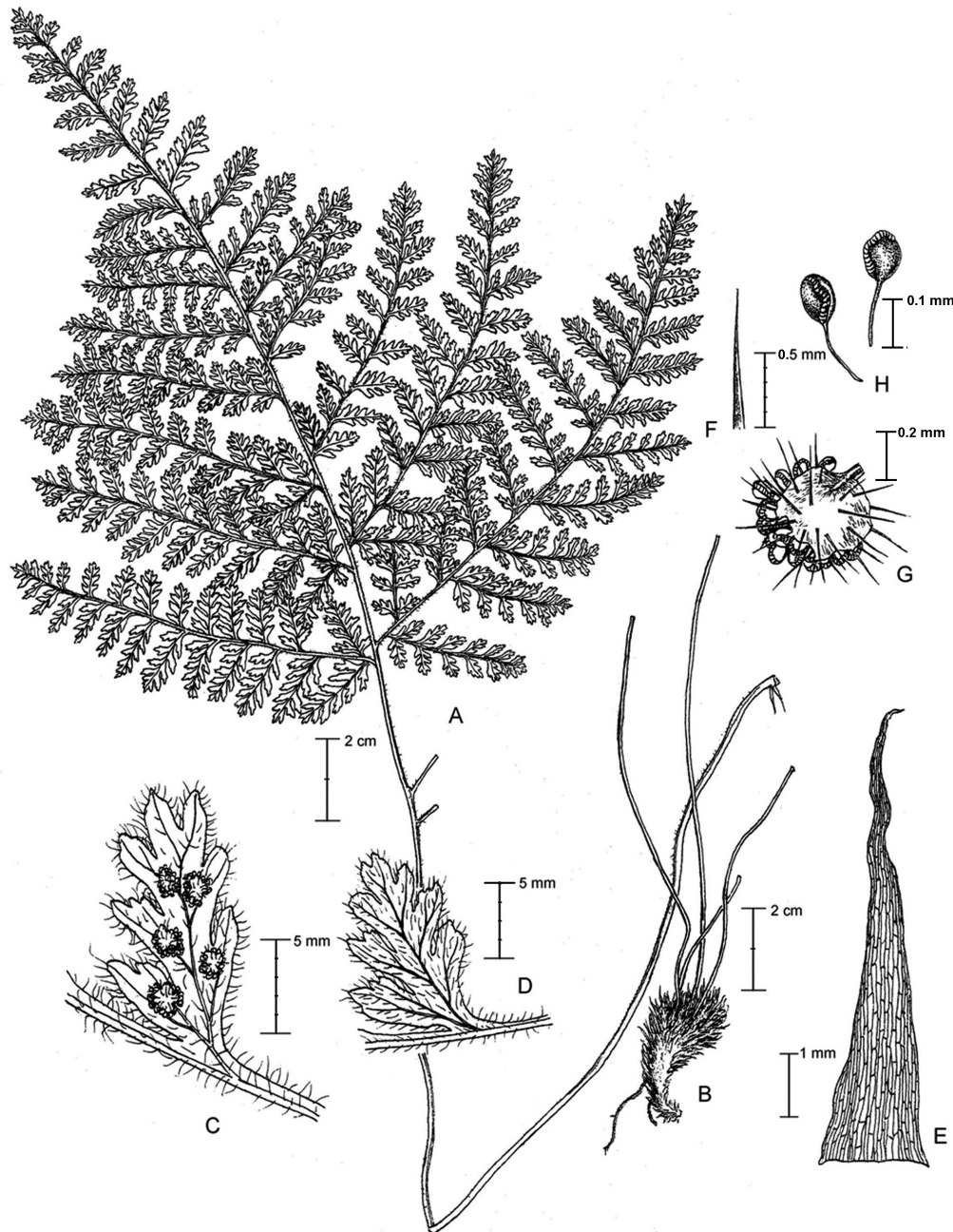
1. *Hypodematium villosum* F. G. Wang & F. W. Xing, sp. nov. —TYPE: CHINA. Guangdong Province: Meizhou City, Jiaoling County, Xingfu Town, Changlong Village, limestone mountain, altitude 50 m, 15 Nov 2005, *Faguo Wang et al.* 1251. (Holotype: IBSC). 毛葉腫足蕨

Figure 1

*Species affinis H. fordii, sed petiolo praeter basim glabro, lamina 25-30 cm longa basi 35-40 cm lata, lamina utrinque, rhachi et costa villis acicularibus densis*

*obtectis, pinnis 12-15-jugatis, lobis acutis, margine villis acicularibus densis obtectis. Affinis H. microlepioidi, sed lamina quadripinnata, petiolo pinnae ca. 1.5 cm longo, lobis acutis integris, pinnis utrinque sine squamis differt.*

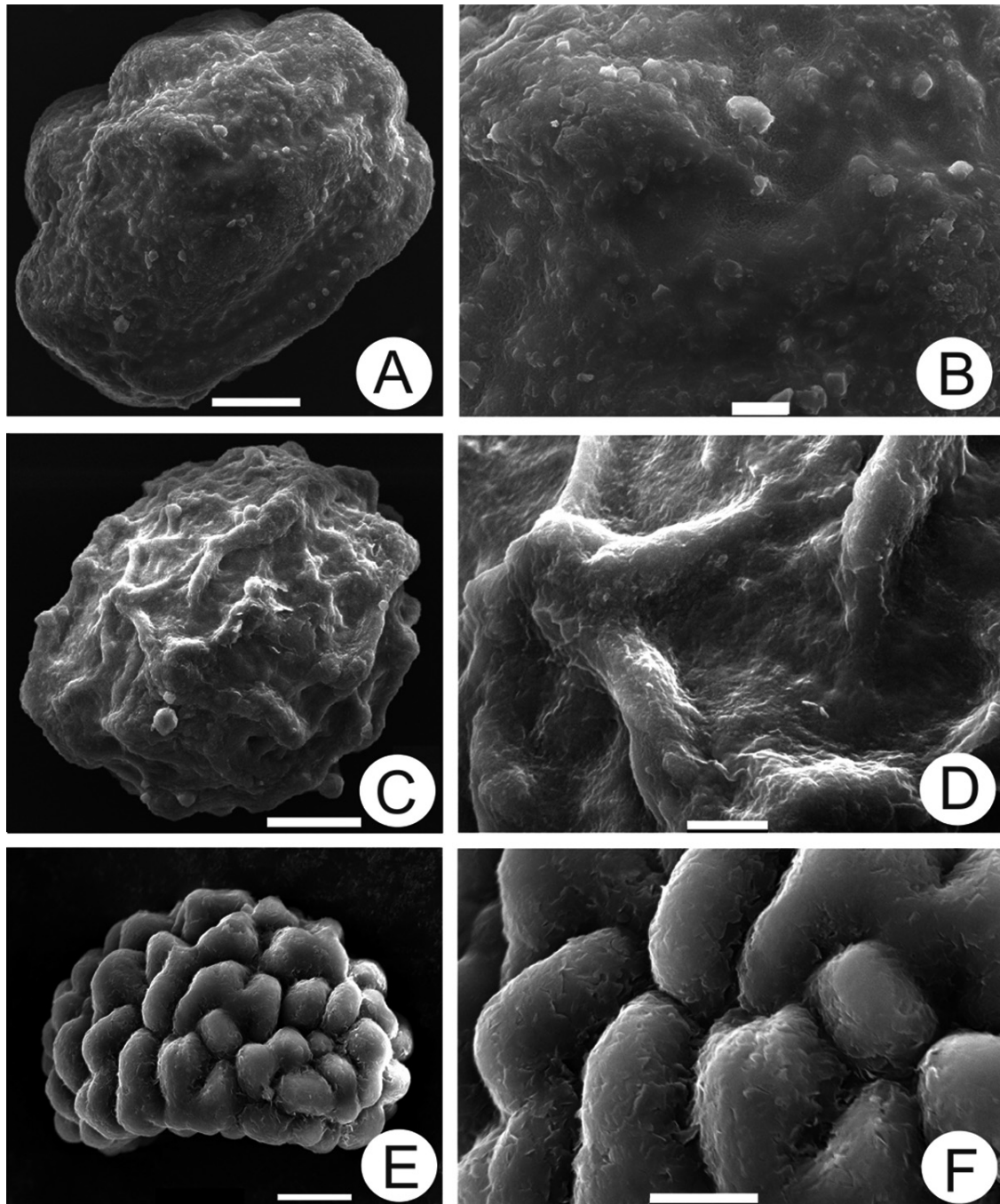
Plants slender, 50-65 cm tall; rhizomes short-creeping, covered with scales; scales reddish-brown, narrowly lanceolate, 0.6-1 cm long, ca. 1 mm broad near the base, membranaceous, lucid. Leaves close together; petiole 25-30 cm long, ca. 1 mm in diameter, stramineous, covered with scales the same to the rhizome, glabrous upward; lamina 25-30 cm long, base 35-40 cm broad,



**Figure 1.** *Hypodematium villosum* F. G. Wang & F. W. Xing. A, Habit; B, Rhizome and lower portion of petiole; C, Abaxial view of portion of pinnule rachis with pinnulet; D, Adaxial view of portion of pinnule rachis with pinnulet; E, Scale from rhizome; F, Hair from lamina; G, Sori; H, Sporangia. Drawn from *Wang Faguo et al.* 1251 (IBSC).

ovate-quinquangular, apex acuminate and pinnatifid, quadripinnate, tripinnate upward; pinnae 12-15 pairs, basal two pairs sub-opposite, alternate upward, oblique, first basicopic pair enlarged, 5-6 cm apart from upper one, 16-20 cm long, 6-8 cm broad at the base, triangular-ovate, apex acuminate, with petiole ca. 1.5 cm long, tripinnate; pinnules ca. 12 pairs, alternate, anadromous, oblique, close together, basicopic pinnule bigger than acroscopic ones; secondary pinnules 8-10 pairs, alternate, first basal

pairs opposite and enlarged, ca. 4 cm long, base decurrent with narrow wing, pinnate; third pinnules ca. 6 pairs, apex acute, base decurrent, margin lobed to 1/2; pinnulets 3-4 pairs, apex acute, entire, margin densely covered with long acicular hairs; veins prominent abaxially, veinlet simple, 1-2 on each lobes, ending in margin. Lamina papyraceous, virescent when dry, densely covered with gray long acicular hairs ca. 1 mm long, especially on the rachis and costa. Sori small, dorsiferous on the middle of veinlet,



**Figure 2.** SEM photographs of *Hypodematium* spores. A-B, *Hypodematium villosum* (spore from F. G. Wang 1251. A,  $\times 1,500$ , scale bar 10  $\mu\text{m}$ ; B,  $\times 6,000$ , scale bar 2  $\mu\text{m}$ ); C-D, *Hypodematium humile* (spore from F. G. Wang 1255. C,  $\times 1,600$ , scale bar 10  $\mu\text{m}$ ; D,  $\times 8,500$ , Scale bar 2  $\mu\text{m}$ ); E-F, *Leucostegia immersa* (Spore from J. S. Xin 626 (PE), E,  $\times 1,800$ , scale bar 10  $\mu\text{m}$ ; F,  $\times 5,000$ , scale bar 5  $\mu\text{m}$ ).



one on each lobe; indusium rounded nephroid, grayish, membranaceous, densely covered with long acicular hairs, persistent; spore monolete, perispore psilate, with some granular ornamentation.

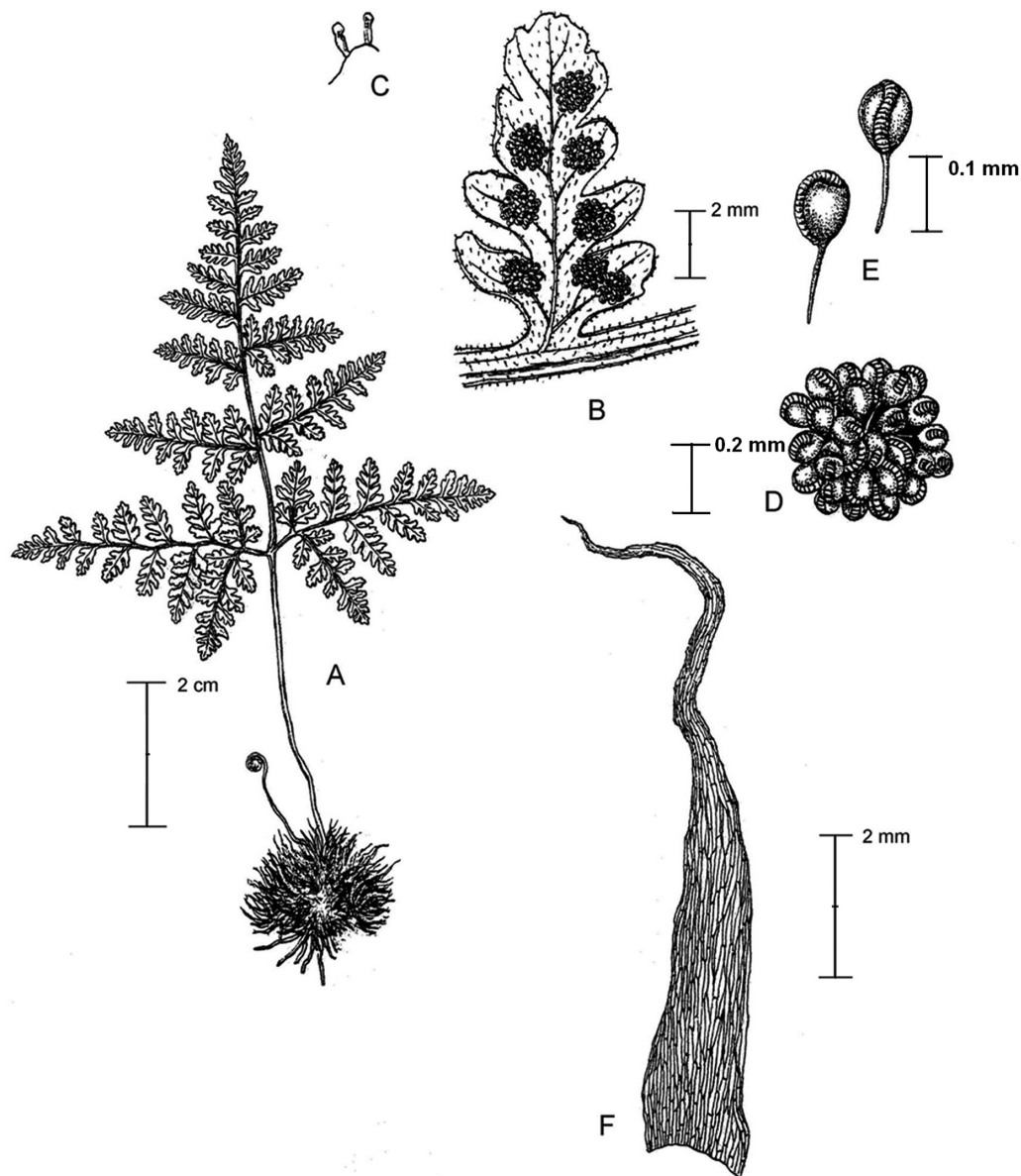
*Ecology.* *Hypodematium villosum* is a calcicolous fern that attaches to rocky tunnels on limestone mountain in Fung Shui Wood near a village. Plants were collected in association with *Ctenitopsis devexa* (Kunze ex Mett.) Ching & Chu H. Wang, *Pteris plumbea* H. Christ, *P. deltodon* Baker, *Pterolobium punctatum* Hemsl., and *Alocasia macrorrhiza* Schott.

*Distribution.* *Hypodematium villosum* is endemic to Changlong village, Xingfu Town, Jiaoling County, eastern Guangdong, southern China (Figure 4).

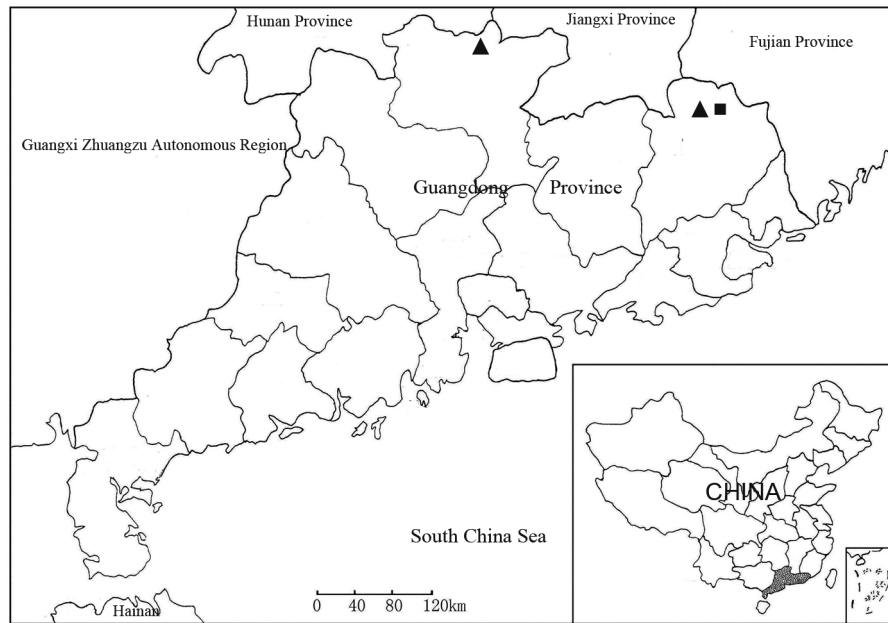
*Conservation status.* *Hypodematium villosum* is only known in a single locality and has a very small population size. Therefore, it has a Critically Endangered (CR) designation according to the IUCN (2001).

*Etymology.* Named from the Latin word 'villosum', referring to the long acicular hairs on the lamina that distinguish other species of *Hypodematium* except *H. microlepioides*.

*Spore morphology.* Light microscope observation showed the spore of *Hypodematium* is eudipleural and monolete, and the corrugation of the perispore is striate, reticulate or circinate (Zhang et al., 1976). Scanning electron microscope observation found the spore of *Hypodematium villosum* to be monolete and the perispore psilate with some granular ornamentation (Figure 2).



**Figure 3.** *Hypodematium humile* F. G. Wang & F. W. Xing. A, Habit; B, Abaxial view of portion of pinnule rachis with pinnulets; C, Glandular hair from lamina; D, Sori; E, Sporangia; F, Scale from rhizome. Drawn from Wang Faguo et al. 1255 (IBSC).



**Figure 4.** Distribution of *Hypodematium villosum* (black square) and *H. humile* (black triangle) in Guangdong, China. (from Yan, 2004).

However, the perispores of the related species *H. fordii* and *H. microlepioides* are circinate and striate, respectively (Zhang et al., 1976).

Spore surface is unclearly observed of contaminated small spores collected from herbarium specimens. After being soaked in 70% ethanol and shaken in the ultrasonic wave bath, the treated spore surface becomes clearer than untreated ones under SEM. This method is easy to carry out and obviously more effective than routine procedures.

**Morphological notes.** *Hypodematium villosum* can be differentiated from other species of *Hypodematium* by its slender individual plants, long acicular hairs and small sori on the lamina. It resembles *H. fordii* (Shing et al., 1999), which is distributed in Guangdong, Guangxi, Fujian, and Anhui Provinces of China and Japan, although *H. villosum* plants have a more slender texture. However, the former

differs primarily as follows: petiole glabrous except the base, lamina 25-30 cm long, base 35-40 cm wide, surfaces of lamina, rachis and costa densely covered with long acicular hairs ca. 1 mm long; pinna 12-15 pairs; apex of pinnulets acute, margin densely covered with long acicular hairs, and perispore psilate.

*Hypodematium villosum* also resembles *H. microlepioides* (Shing et al., 1999), a plant endemic to Yunnan Province in China. Both species have glabrous petiole, and the rachis and costa of both are densely covered with long, grayish acicular hairs. However, the latter differs from *H. villosum* in having the lamina 3-pinnate; the pinnule sessile; the pinnulet oblong, and the apex with 2-4 teeth; both surfaces of pinna have rufous and narrowly lanceolate scales. A morphological comparison between *Hypodematium villosum*, *H. fordii*

**Table 1.** Diagnostic characters among *Hypodematium villosum*, *H. fordii* and *H. crenatum*.

Characters	<i>H. villosum</i>	<i>H. fordii</i>	<i>H. microlepioides</i>
Petiole	Glabrous upside the base	Sparsely covered with rod-shaped glandular hairs upside the base	Glabrous upside the base
Lamina	25-30 × 35-40 cm, densely covered with gray long acicular hairs ca. 1 mm long	15-20 × 12-18 cm, sparsely covered with rod-shaped glandular hairs	12-18 × 9-12 cm, densely covered with gray long acicular hairs ca. 0.8 mm long and few rufous scales
Rachis and costa	Densely covered with gray long acicular hairs	Sparsely covered with rod-shaped glandular hairs	Densely covered with gray long acicular hairs and few rufous scales
Pinna	12-15 pairs, with petiole ca. 1.5 cm long	8-10 pairs, with petiole 2-3 mm long	8-12 pairs, sessile
Pinnulet	Apex acute, margin densely covered with gray long acicular hairs	Apex acute, margin without hairs	Apex oblong, with 2-4 teeth, margin without hairs
Spore	Perispore psilate	Perispore circinate	Perispore striate

and *H. crenatum* is given in Table 1.

**2. *Hypodematium humile*** F. G. Wang & F. W. Xing, sp. nov. —TYPE: CHINA. Guangdong Province: Meizhou City, Jiaoling County, Xinpu Town, Youkeng Village, Xianyan temple, limestone mountain, altitude 100 m, 15 xi. 2005, *Faguo Wang et al. 1255*. (holotype: IBSC). 矮腫足蕨 Figure 3

*Species affinis H. glanduloso, sed foliis 8-11 cm longis, squamis 0.4-0.6 cm longis, petiolo c. 0.5 mm diametro, pinnis praeter eas basicopicas sessilibus, lamina, rhachi et costa pilis sparsis bacillaribus glandiferis obtectis, pinnulis apice obtusis, indusiis caducis differt.*

Plants 8-11 cm tall; rhizome short, suberect, covered with scales; scale ca. 0.9 cm long, reddish-brown, narrowly lanceolate, apex acuminate, glabrous, membranaceous. Leaves 1 or 2, petiole 4-5 cm long, ca. 0.5 mm in diameter, stramineous, base and middle glabrous, sparsely covered with rod-shaped lemon-yellow glandular hairs upward; lamina 4.5-5.5 cm long, base 5-7 cm wide, ovate-quinquangular, apex acuminate and pinnatifid, base rounded cordate, tripinnate; pinnae 6-7 pairs, slightly oblique, basal 1-4 pairs subopposite, 0.4-1.2 cm apart, alternate upward, first basicopic pair enlarged, 2.5-3.5 cm long, base 2-2.5 cm wide, triangular-ovate, apex obtuse, base cordate, with petiole c. 3 mm, bipinnate; pinnule 4-5 pairs, anadromous, alternate, slightly oblique, close together each other, basicopic pinnule bigger than acroscopic ones, oblique, close together; first basal pairs of secondary pinnules opposite and enlarged, 1-1.1 cm long, base c. 1 cm wide, triangular-ovate, apex obtuse, base nearly truncate, decurrent to short petiole with narrow wing, pinnate; secondary pinnule 3-5 mm long, base c. 3 mm wide, triangular-ovate, apex obtuse, base connate with costa more or less, pinnatifid; pinnulet nearly trapeziform, apex obtuse, entire; other pairs of pinnae shorten upward, apex obtuse, base rounded truncate, sessile, bipinnatifid, pinnule on both sides nearly with same size. Veins obvious abaxially, veinlet forked or pinnate, ending in margin;

lamina herbaceous, yellowish green when dry, sparsely covered with rod-shaped lemon-yellow glandular hairs on both surfaces; rachis and costa sparsely covered with hairs the same to the lamina. Sori rounded, dorsiferous on the upper part of veinlet, one on each lobe; indusium caducous; spore monolete, ellipsoid, perispore irregularly lophate.

*Additional specimen examined.* CHINA. Guangdong Province, Shaoguan City, Renhua County, Danxia Mountain, Guangdong Province, China, alt. 200 m. 12 Mar 2005, *Faguo Wang et al. 1024* (IBSC).

*Distribution.* *Hypodematium humile* is restricted to the type locality (Figure 4).

*Ecology.* It is a rock plant that occurs on rocky tunnels, limestone cliffs, or Danxia (literally, red cloud) mountain. Plants were collected in association with *Ctenitopsis devexa* (Kunze ex Mett.) Ching & Chu H. Wang, *Pteris deltodon* Baker, *P. ensiformis* Burm., *Selaginella moellendorffii* Hieron. and *Lemmaphyllum microphyllum* C. Presl.

*Conservation status.* It is known only from two sites and its populations are small. Therefore, we consider this species Critically Endangered (CR) according to the IUCN (2001) conservation categories.

*Etymology.* Named from the Latin word ‘*humile*’, a reference to the short individual that distinguishes other species of *Hypodematium* except *H. microlepioides*.

*Spore morphology.* The spore of *H. humile* is monolete and ellipsoid, and the perispore is irregularly lophate (Figure 2). However, the perispores of related species *H. glandulosum* and *H. crenatum* are circinate and striate, respectively.

*Morphological notes.* *Hypodematium humile* resembles *H. glandulosum* Ching ex Shing, which is distributed in Hunan and Guizhou Provinces of China (Shing et al., 1999). Both species have rod-shaped glandular hairs on lamina, rachis, and costa. However, the former differs primarily by having leaf 8-11 cm long; scale 0.4-0.6 cm

**Table 2.** Diagnostic characters among *Hypodematium humile*, *H. glandulosum* and *H. crenatum*

Characters	<i>H. humile</i>	<i>H. glandulosum</i>	<i>H. crenatum</i>
Leaf length	8-11 cm	12-20 cm	15-55 cm
Petiole	0.5 mm in diameter, sparsely covered with rod-shaped glandular hairs upward	1-1.5 mm in diameter, densely covered with rod-shaped glandular hairs upward	1-3 mm in diameter, pallid pubescent
Lamina	4.5-5.5×5-7 cm, sparsely covered with rod-shaped glandular hairs	7.5-13×8-10 cm, densely covered with rod-shaped glandular hairs	10-30×10-30 cm, densely pallid pubescent
Rachis and costa	Sparsely covered with rod-shaped glandular hairs	Sparsely covered with rod-shaped glandular hairs	Densely pallid pubescent
Pinna	Sessile except first basicopic pair	With petiole	With petiole
Pinnulet	Apex obtuse	Apex acute	Apex obtuse
Spore	Perispore irregularly lophate	Perispore circinate	Perispore striate
Indusium	Caducous	Persistent	Persistent

long; petiole c. 0.5 mm in diameter; pinna sessile except first basiscopic pair; surfaces of lamina, rachis, and costa sparsely covered with rod-shaped glandular hairs; apex of pinnule obtuse; indusium caducous; perispore irregularly lophate.

*Hypodematium crenatum* is widely distributed in subtropical Asia and Africa, and resembles *H. humile* in having an obtuse pinnulet. However, plants of *H. humile* have short leaves that are sparsely covered with rod-shaped glandular hairs and perispores that are irregularly lophate. In contrast, plants of *H. crenatum* have long leaves that are pallid pubescent and perispores that are striate. A morphological comparison between *Hypodematium humile*, *H. glandulosum*, and *H. crenatum* is given in Table 2 (Shing et al., 1999; Zhang et al., 1976).

*Hypodematium humile* is characteristic by its short leaf and caducous indusium, two features that may well have an adaptive value to dry environment where this species occurs. It was observed that *H. humile* prefers the southern slopes of the mountain where it grows, this area being dryer than the sites where *H. crenatum* and *H. fordii* occur in Guangdong.

### Key to the species of *Hypodematium* from Guangdong

The species of *Hypodematium* known from Guangdong Province, south China, can be identified with the following key adapted from Wu (2006) and modified to include *H. humile*, *H. villosum*, and *H. hirsutum*.

1. Leaf with rod-shaped glandular hairs.
  2. Leaf 35-50 cm tall; indusium persistent.....*H. fordii*
  2. Leaf 8-11 cm tall; indusium caducous.....*H. humile*
1. Leaf without rod-shaped glandular hairs.
  3. Petiole pallid pubescent.....*H. crenatum*
  3. Petiole glabrous except the base.
    4. Pinnulet acute, apex without tooth; lamina without rufous and lanceolate scales abaxially .....  
.....*H. villosum*
    4. Pinnulet oblong, apex with 2-4 teeth; lamina with rufous and lanceolate scales abaxially .....  
.....*H. hirsutum*

### The relationship of *Hypodematium* to related taxa

*Leucostegia* has long been assigned to Davalliaceae because of its creeping, dorsiventral rhizome densely covered by scales, dissected leaves, and indusia (Copeland, 1927; Ching, 1940, 1978; Holttum, 1949; Kato, 1985; Nooteboom, 1992; Wu, 1999). Molecular phylogenetic analysis has shown that *Leucostegia* is closely related to *Hypodematium* (Tsutsumi and Kato, 2006), a genus that has been previously included in Dryopteridaceae but never placed in the Davalliaceae (Smith et al., 2006). Kato and Tsutsumi (2008) discussed the exclusion of *Leucostegia* from Davalliaceae based on their molecular phylogenetic

results and on morphological and growth form similarities. The spore of *Leucostegia immersa* is monolete and bean-like, with an irregular and closely verrucate arrangement (Figure 2), which resembles that of *Cyrtogonellum caducum* (Lu et al., 2007), but differs from *Davallia*, *Humata*, *Araiostegia* and *Hypodematium*. The results of spore morphology support the exclusion of *Leucostegia* from Davalliaceae and its placement in Dryopteridaceae. With its dense, persistent and big scales and crowded petioles, *Hypodematium* is distinct from *Leucostegia*.

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## 中國廣東石灰岩地區腫足蕨屬兩新種

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本文報導中國廣東產腫足蕨屬兩新種：矮腫足蕨 (*Hypodematium humile*) 和毛葉腫足蕨 (*H. villosum*)，提供線繪圖以資辨別，並報導其孢粉形態、生態和保育狀況。毛葉腫足蕨與福氏腫足蕨 (*H. fordii*) 相似，但葉柄基部以上無毛，葉面兩面連同葉軸和羽軸密被灰白色的細長針狀毛長約 1 mm，裂片先端急尖，可資區別。矮腫足蕨與腺毛腫足蕨 (*H. glandulosum*) 近似，不同在於葉長僅 8-11 cm，葉片兩面連同葉軸和羽軸下麵疏被球杆狀腺毛，囊群蓋早落，可資區別。文中提供中國廣東腫足蕨屬種的檢索表，並討論了腫足蕨屬與大膜蓋蕨屬的系統關係。

**關鍵詞：** 中國；特有；廣東；矮腫足蕨；毛葉腫足蕨；石灰岩；新種；稀有植物；孢粉形態。