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The genus *Pilophorus* (Lichenized Ascomycota, Cladoniaceae) from China

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Abstract: A comprehensive taxonomic study of the genus *Pilophorus* from China is performed in this paper. Six species of *Pilophorus* are recognized from China. Among them, four are previously recorded: *P. acicularis*, *P. cereolus*, *P. clavatus*, *P. curtulus*, and two were recently described: *P. fruticosus* and *P. yunnanensis*. Brief description of each species is presented with morphological and chemical characters. A key to the genus is also provided.

Key words: lichenized fungi, taxonomy

中国柱衣属小志

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摘 要：对中国柱衣属 *Pilophorus* 进行了系统的分类学研究。通过标本采集发现了 6 个种，包含过去报道的 4 个种：*P. acicularis*，*P. cereolus*，*P. clavatus* 和 *P. curtulus*，以及两个作者近期发表的种：*P. fruticosus* 和 *P. yunnanensis*。对这 6 个种进行了形态学，解剖学以及化学特征的描述，并且提供了中国柱衣属的检索表和形态特征。

关键词：地衣型真菌，分类

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INTRODUCTION

The genus *Pilophorus* Th. Fr. (Cladoniaceae; Lumbsch & Huhndorf 2007), is characterized by the crustose primary thallus, short and simple pseudopodetia, green epihymenium, simple spores, and presence of the cephalodia. The genus has been well studied world wide and it comprises circa eleven species distributed in temperate and alpine regions of the world where they typically grow on rocks (Jahns 1981; Timdal 1988). The genus name *Pilophorus* which had been adopted by Hawksworth *et al*. (1972) and Jahns (1970), is used in this paper, and is considered as the correct name. *Pilophoron* which was suggested by Culberson (1970) is not acceptable, which is a later homonym (Mcneill *et al*. 2006, ICBN Art. 53.3).

At present, seven species are known to occur in Southeast Asia, including five preciously reported: *P. acicularis* (Ach.) Th. Fr., *P. cereolus* (Ach.) Th. Fr., *P. clavatus* Th. Fr., *P. curtulus* Kurok. & Shibucihi and *P. nigricaulis* M. Sato (Harada *et al*. 2004; Lai 2001; Park 1990; Wei 1991), and two newly established *P. yunnanensis* L.S. Wang & X.Y. Wang (Wang *et al*. 2010) and *P. fruticosus* L.S. Wang & X.Y. Wang (Wang *et al*. 2011). Except for *P. nigricaulis*, the rest Asian species were discovered from China. In this paper, a survey of the genus in China is presented, including brief descriptions of the known Chinese species and discussion about the distinctions among them.

1 MATERIALS AND METHODS

Specimens for this study were collected from China, mainly from south-western part. They are deposited in the herbarium of Kunming Institute of Botany, China (KUN) and Korean Lichen Research Institute (KoLRI), Sunchon National University, Korea.

Specimens were hand-sectioned under NIKON SMZ 645 dissecting microscope and examined under the light microscope (NIKON Eclipse E 200). All measurements were made on material mounted in water. For characteristics such as size of thallus and apothecia, and thickness of epihymenium, hymenium and subhymenium, five measurements were recorded for each specimen; 10 measurements per specimen were recorded for ascospores. Secondary metabolites were identified by TLC as described by Elix *et al*. (1987), Orange *et al*. (2001) and White & James (1985). HPLC was carried out using column YMC-PAck ODS-A (5μm, 150×4.6mm), mobile phase: CH_3OH:H_2O:H_3PO_3=80:20:1. Terminology for tissues generally follows that of Jahns (1981).

2 TAXONOMY

Key to the known species of *Pilophora* from China

1. Podetia sorediate ····· *P. cereolus*
1. Podetia esorediate ····· 2
2. Podetia dichotomously branched ····· *P. fruticosus*
2. Podetia simple or with very few branches ····· 3
3. Podetia more than 2cm high ····· *P. acicularis*
3. Podetia relatively short (less than 1.5cm) ····· 4
4. Apothecia elongate ····· *P. clavatus*
4. Apothecia spherical ····· 5
5. Podetia more than 0.5cm high ····· *P. curtulus*
5. Podetia less than 0.2cm high ····· *P. yunnanensis*

2.1 *Pilophorus acicularis* (Ach.) Th. Fr., De *Stereocaulis* et *Pilophoris* Comm.: 41 (1857). Fig. 1-A

≡ *Baeomyces acicularis* Ach., Meth. Lich.: 328 (1803).

Primary thallus granulose, gray to grayish-brown, usually evanescent in old thallus. Pseudopodetia 1—3cm tall, 0.5—1mm in diameter, pale grey to yellowish-grey, mostly simple, rarely branched. Surface tightly covered

with small scales. Cephalodia on the primary thallus, brown and hemispherical, some of them could also be found on the lower part of the pseudopodetia.

Pycnidia growing on the tips of sterile pseudopodetia. Apothecia abundant, growing on the apices of the pseudopodetia, hemispherical and black, 1－1.5mm in diameter. Hymenium pigmented, dark purple. Asci containing eight spores. Spores spindle-shaped, 20－26.5×4－5μm.

Chemistry: Atranorin and zeorin.

World distribution: Japan (Kurokawa & Shibuichi 1970); South Korea (Hur *et al*. 2005) the Continental United States and Canada (Esslinger & Egan 1995). This species is most widespread species of the genus. It prefers an oceanic climate without extremely low temperatures (Jahns 1981).

Remarks: The species is characterized by its long and simple pseudopodetia. This character separate the fungus from all the other species reported from China. Some specimens of *P. acicularis* might be confused with *P. fruticosus*. The latter species has richly dichotomously branched pseudopodetia and the primary thallus usually persist, while *P. acicularis* has the simple pseudopodetia and usually lacking the primary thallus. It is the most common species of the genus from China.

Representative specimens examined: Yunnan Prov., Lijiang Co., Mt. Laojunshan 26° 37′N, 99° 43′E, alt. 2,550m, L.S. Wang 05-25082. Luquan Co., Mt. Jiaozixueshan, 26° 05′N, 102° 08′E, alt. 3,850m, Fang Rueizhen 90-11578. Sichuan, Muli Co., Yiqu village,

Fig. 1 Habit of the *Pilophorus* species. A: *P. acicularis* (L.S. Wang 03-22863); B: *P. cereolus* (L.S. Wang 06-26111); C: *P. clavatus* (Lu Dingan 549); D: *P. curtulus* (L.S. Wang 05-25069) without isousnic aicd; E: *P. curtulus* (L.S. Wang 10-31279) containing isousnic acid; F: *P. fruticosus* (L.S. Wang 06-26204); G: *P. yunnanensis* (L.S. Wang 03-22641).

alt. 3,700m, L.S. Wang 83-2401; Mt. Ninglangshan, alt. 4,050m, Xuan Yu 82-1781; Luding Co., Mt. Gonggaxueshan, alt. 2,800m, L.S. Wang 96-16226; Xizang (Tibet), Shejila, alt. 4,200m, Chen Shukun 76.

2.2 *Pilophorus cereolus* (Ach.) Th. Fr., Lich. Scand. 1: 55 (1871). Fig. 1-B

≡ *Lichen cereolus* Ach., Lich. Scand. 1, 1: 55 (1871).

Primary thallus gray to grayish-brown, granulose, loosely aggregate, 0.1 — 0.2mm in diameter, and sorediate. Pseudopodetia simple without branches, 2—6mm high, c. 1mm broad, the whole surface is covered with farinose sorediate. The stalk is usually broad in the middle part and curved. Cephalodia brown to black, sessile on the primary thallus, 1—2mm in diameter.

Pycnidia bottle-shaped and black, usually growing on the tips of the pseudopodetia. Apothecia spherical and black, rare. Growing on the terminal of the pseudopodetia, c. 1.5mm in diameter. Hymenium pigmented, dark purple. Asci containing eight spores. Spores spindle-shaped, 15—20×5—6μm.

Chemistry: Atranorin, zeorin.

World distribution: The continental United States and Canada (Esslinger & Egan 1995). This species is the most common species of the genus in Europe (Jahns 1981).

Remarks: The species is characterized by sorediate pseudopodetia and primary thallus, the middle part of the stalk is relatively thick so it is usually curved. This is the only sorediate species in China. It can be distinguished from all other species of the genus by having sorediate thallus and pseudopodetia.

Specimen examined: Yunnan, Luquan Co., Jiaozixueshan Mt. 26° 05′N, 102° 08′E, 4,000m elevation, on rock, L.S. Wang 00-20404.

2.3 *Pilophorus clavatus* Th. Fr., Bot. Notiser: 214 (1888). Fig. 1-C

= *Pilophorus hallii* (Tuck.) Vain., Bot. Mag., Tokyo 35: 59 (1921).

= *Pilohphorus aciculare* (Ach.) Th. Fr., Stereoc. Piloph. Comm.: 41 (1857).

= *Pilophorus japonicum* Zahlbr. (nomen nudum), Catal. Lich. 4: 432 (1926); Bot. Mag., Tokyo 41: 337 (1927).

Primary thallus brown to brownish-yellow, closely attached to the substrate, forming areolae. Pseudopodetia 2—5mm tall, 0.3mm wide, surface covered with scales, closely attached, pseudopodetia simple, without branches. Cephalodia brown-black, irregular, growing on the primary thallus.

Pycnidia black, bottled-shaped, on the short pseudopodetia, Apothecia black, triangular in longitudinal section, often spread some distance down the stalk, growing on the tips of the pseudopodetia. Hymenium pigmented, blue-green. Asci containing eight spores. Spores fusiform, 19.5—25×5—6μm.

Chemistry: Atranorin.

World distribution: Japan (Harada *et al*. 1974); South Korea (Hur *et al*. 2005); the continental United States and Canada (Esslinger & Egan 1995). The distribution of this species is identical with *P. acicularis*, mostly on the coasts of the northern Pacific Ocean (Jahns 1981).

Remarks: This species could be easily distinguished from all other species in China by its bottle shaped apothecia which is triangular in longitudinal section. It is similar to *P. acicularis*, but the latter species usually has no primary thallus, whereas, *P. clavatus* has persist primary thallus yellowish in color.

Specimens examined: Anhui, Huangshan Mt., Lianhuafeng, Lu Dingan 549.

2.4 *Pilophorus curtulus* Kurok. & Shib., Journ. Jap Bot. 45(3): 78 (1978). Fig. 1-D

Primary thallus whitish-gray to brownish-gray, granulous, closely adnate, less than 0.2mm in diameter, forming areolae. Pseudopodetia simple and pin-like, short and single, usually without branches, 1.5—3mm long, c. 0.5mm in diameter, surface of the pseudopodetia covered with continuous small scales, having the same color with the primary thallus. Cephalodia disc-like, dark brown, growing between the squamules of the primary thallus.

Pycnidia black, growing directly on the primary thallus. Apothecia black and ball-shaped, always single, growing on the apices of the pseudopodetia, about 1mm in diameter. Hymenium pigmented, purple. Asci

containing eight spores. Spores spindle shape, 21.5－25×7－10μm.

Chemistry: Chem type Ⅰ, atranorin and zeorin. Chemotype Ⅱ: Isousnic acid (Fig. 2) and some unknown compounds.

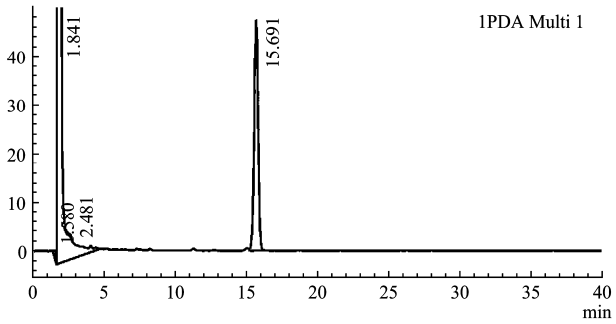

Fig. 2 Chromatogram of *Pilophorus curtulus* showing isousnic acid.

World distribution: It has been reported only from Japan (Kurokawa & Shibuichi 1970) and China (Jahns 1981).

Remarks: The species resembles *P. yunnanensis* by having small pseudopodetia, but its primary thallus is usually closely aggregated and has cephalodia which is flattened disc-shaped growing between the primary thallus, these characters separates it from *P. yunnanensis*. It has also larger pseudopodetia, while those of *P. yunnanensis* are no more than 1mm tall.

The color of some specimens, due to containing isousnic acid, is obviously brown (Fig. 1-E), while the others without this acid appear to be whitish-gray. Except for the difference in color, all the other characters of these two chemotypes are same.

Representative specimens examined: Yunnan, Lijiang Co., Mt. Laojuenshan 26° 37′N, 99° 43′E, alt. 3,600m, L.S. Wang 03-22864; Dali Co., Mt. Cangshan, 25° 41′N, 100° 06′E, alt. 3,150－3,500m, Aptroot 56860 (Duplicated ABL.); Luquan Co., Mt. Jiaozixushan, 26° 05′N, 102° 08′E, alt. 4,000m, L.S. Wang 00-20390; Zhongdian Co., Mt. Habaxueshan, 27° 20′N, 100° 04′E, alt. 3,500m, L.S. Wang 02-21710.

2.5 *Pilophorus fruticosus* Li. S. Wang & Xin. Y. Wang, Lichenologist 43(2): 137 (2011). Fig. 1-F

Primary thallus gray to greenish-gray, rather small and granulose, persist, often confluent to form aggregations. Pseudopodetia dichotomously and richly branched, about 1cm high, 1－2mm in diameter. Surface of the pseudopodetia covered with small granules, usually largely decorticate and exposing the brown to black medulla. Cephalodia brown to light brown, verrucose to brain shape, 1－2mm in diameter, mostly growing on the primary thallus, sometimes it could be found on the lower part of the pseudopodetia.

Pycnidia cylindrical, growing at the tips of pseudopodetia, usually 2 or 3 gathered at the tips. Apothecia apical, abundant and always single, globose and black, 1－2mm wide. Hymenium unpigmented, epihymenium pigmented, bluish-green, ca 5μm high. Asci containing eight spores. Spores spindle-shaped, 18－22.5×5－7.5μm.

Chemistry: Containing atranorin and zeorin.

World distribution: Only known from Yunnan Province, China.

Remarks: The species resembles some specimens of *P. acicularis* possessing small fruitbodies, but the pseudopodetia of *P. acicularis* is mostly simple without any branches, usually longer than 1cm, and its hymenium is up to 240μm high, and having larger ascospores (up to 29.5μm), whereas, in *P. fruticosus*, they are up to 100μm and 22.5μm respectively. It resembles *P. curtulus* to some extend, but the pseudopodetia of the *P. curtulus* is rather small (up to 3mm tall), and it has continuous layer of the scales, and the pseudopodetia are usually unbranched. Pycnidia are produced on the primary thallus.

Specimens examined: Yunnan, Dali Co., Mt. Cangshan 25° 40′N, 100° 06′E, alt. 3,570m, L.S. Wang 06-26204 (Holotype: KUN). Hur CH 060323.

2.6 *Pilophorus yunnanensis* Li. S. Wang & Xin. Y. Wang, The Bryologist 113(2): 345 (2011). Fig. 1-G

Primary thallus persistent, small, consisting of loosely attached tiny flat scales, scattered to rarely aggregated, less than 0.2mm in diameter, white-gray to yellowish-gray when dry. Pseudopodetia simple, without any branches, small, very thin, less than 1mm tall and 0.2mm broad, surface of pseudopodetia covered with

scales which are concolorous with the primary thallus and form small areoles. Pseudopodetia partly ecorticate and exposing the brown to blackish-brown medulla. Cephalodia verrucose to granulose, growing on the primary thallus or between the squamules, 0.2－1mm in diameter, light brown to brown.

Pycnidia not found. Apothecia apical on mature pseudopodetia, globose and black, 0.2 － 0.4mm in diameter, solitary. Epihymenium pigmented, bluish-green, hymenium unpigmented, c. 120μm high. Asci containing 8 spores. Spores spindle-shaped when mature, 20－22.5×5－7μm.

Chemistry: Atranorin and zeorin.

World distribution: Only known from Yunnan Province, China.

Remarks: This fungus is characterized by the extremely tiny pseudopodetia and scattered primary thallus, and is the smallest *Pilophorus* species from China. It might be confused with *P. curtulus*, but *P. yunnanensis* has much smaller and tiny pseudopodetia and the primary thallus is always loosely distributed, while *P. curtulus* has higher and thicker pseudopodetia and continuous primary thallus.

Specimens examined: Yunnan, Luquan Co., Mt. Jiaozixueshan 26° 05′N, 102° 08′E, alt. 3,600m. L.S. Wang 03-22641 (Holotype!, KUN 18956); Lijiang Co., Mt. Laojuenshan 26° 39′N, 99° 46′E, alt. 3,690m elevation, L.S. Wang 05-25057.

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