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浙江乌岩岭国家级自然保护区凤尾蕨属物种多样性研究

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摘要：报道了浙江省乌岩岭国家级自然保护区 12 种凤尾蕨属(*Fissidens*)植物，其中内卷凤尾蕨济州岛变种(*F. involutus* Wilson ex Mitt. var. *jejuensis* Y.-J. Yoon, B.C. Tan & B.-Y. Sun)为中国首次报道，该变种此前只分布在日本和韩国，其特征是背翅基部明显下延，鞘部细胞的每个角都有 1 个不明显的疣。异形凤尾蕨(*F. anomalus*)和锐齿凤尾蕨(*F. serratus*)为浙江省新记录。在该保护区，凤尾蕨属植物物种多样性随海拔升高呈单峰分布。与我国东南部地区其它保护区相比，乌岩岭的凤尾蕨多样性仅次于广西的雅长自然保护区。而且，这一地区凤尾蕨的多样性并没有表现出随着纬度的降低而增加的趋势。因此，建议进一步加强对我国东南部地区凤尾蕨的调查和研究。

关键词：生物多样性; 浙江; 乌岩岭国家级自然保护区; 新记录; 凤尾蕨属; 植物分布

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Diversity of *Fissidens* in Wuyanling National Nature Reserve, Zhejiang Province, China

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Abstract: Twelve species of *Fissidens* are reported for Wuyanling National Nature Reserve, Zhejiang Province, China. *Fissidens involutus* Wilson ex Mitt. var. *jejuensis* Y.-J. Yoon, B.C. Tan & B.-Y. Sun, a new variety previously known only from Japan and South Korea, is reported here for the first time from China. This species is characterized by the bases of dorsal leaves are distinctly decurrent, and cells of vaginant lamina have single indistinctly papilla at each corner. Detailed description and illustrations of *F. involutus* var. *jejuensis* are provided. In addition, two species, viz. *F. anomalus* and *F. serratus* are new provincial records for Zhejiang Province. In Wuyanling, a humped distribution is observed of the *Fissidens* species diversity with the elevation. Compared with other nature reserves in southeastern region of China, the number of species of *Fissidens* in Wuyanling is the second only to Yachang Nature Reserve (Guangxi). Furthermore, species diversity of *Fissidens* does not increase as the latitude decreases in this region. Hence, it is recommended to carry out further investigation and study on the diversity of *Fissidens* in southeastern region of China.

Key words: Biodiversity; Wuyanling National Nature Reserve; Zhejiang; New Record; *Fissidens*; Plant distribution

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Knowledge of the number and distribution of species in a region is central to ecology and fundamental to biodiversity conservation efforts such as the prioritization of protected areas[1–2], but this information is lacking for the majority of species on earth[3]. Although broad-scale patterns of biodiversity are well documented, accurate descriptions of the distribution of biodiversity, however, break down at fine spatial temporal or taxonomic scales, even for well-described groups such as vascular plants or vertebrates[4]. Therefore, well-known groups and exhaustively inventoried areas are the exception rather than the rule, only a few local inventories and some sporadic uncoordinated captures exist[5].

The genus *Fissidens*, comprising ca. 440 species worldwide, is a morphologically homogeneous group characterized by a unique leaf structure. The leaf of the genus is composed of two vaginant laminae, an apical lamina and a dorsal lamina and the leaves are arranged in two rows oriented vertically on the stem in the same plane and equitant (clasping or straddling the stem)[6]. Most of the species are mainly distributed in the warm, humid tropics of the world, with the number increasing as latitude decreases[7]. Sixty-nine taxa of the genus are hitherto known from China[8–10]. The taxonomic study of Chinese *Fissidens* began in 1848 when W. Wilson reported some Chinese mosses collected by T. Anderson. Since Wilson[11] first reported *F. adianthoides* Hedw. (now *F. anomalus* Mont.) from China, a series of studies of the genus have been carried out in China[12]. However, as noted by Iwatsuki et al[13], the genus *Fissidens* is one of the most diversified genera of mosses and a well-defined but taxonomically very difficult genus. Hence, although a considerable number of species of *Fissidens* were described from China, the genus is considered not well surveyed since many species are minute and easily overlooked during previous bryophyte explorations in the field[14], which were usually based on random, haphazard collecting along trails. Taking Guangxi Zhuang Autonomous Region for example, based on a province-wide investigation of bryophytes with special attention to the genus *Fissidens*, the number of the genus in the region has raised from 33 species to 46 species[9].

Wuyanling National Nature Reserve, located between 27º40′38″–27º43′42″ N and 119º38′29″–119º41′27″ E, covering an area of 14.95 km^2, and with an elevation range of 450–1 611 m above sea level, represents the transition zone from northern subtropical vegetation to southern subtropical one[15]. The reserve has a mid-subtropical monsoon climate with four distinct seasons, i.e., warm spring and autumn, hot and wet summer, and slightly dry and cold winter. The dome or U-shaped peak (1 611 m) of the mountain blocks the cold northwestern air mass from flowing in during winter and permits the entrance of the warm southeastern monsoon current from the ocean and retains it over an extended period of time. This peculiar climatic pattern, characterized by the combination of a warm winter and a wet summer, is expected to create a rich diversity of *Fissidens* in Wuyanling. Zhu[15] reported 358 species of bryophytes for Wuyanling. According to Zhu[16], however, only six species of *Fissidens* has been recorded in the reserve. Meanwhile, based on the comparison of the richness of the genus in a series of mountains at different latitudes, we expect to understand the knowledge gaps of species diversity and sampling efforts of *Fissidens* in China.

1 Materials and methods

In August 2020, in order to obtain a representtative sample of *Fissidens* diversity of Wuyanling, a systematic sampling of the genus along the elevational gradients was carried out. All of the potential habitats in the main forested sites, such as Shuangkengkou, Huangqiao, Tieluji, Huangjiadai, Huanglianshan and Xidou Village, were surveyed thoroughly from low to high elevations. All the specimens are deposited in the herbarium of Guangxi Institute of Botany (IBK). Identifications were based mainly on major taxonomic works on *Fissidens* in China and Japan[13,17–18] and other references mentioned under the following section. Species are arranged alphabetically. For taxa newly recorded to China, a detailed description is provided based on the cited specimens. The morphological and

anatomical characters were observed and photographed using an Olympus SZX7 stereomicroscope and an Olympus BX43 light microscope equipped with a digital camera (Mshot MH125).

2 Results and discussion

A total of 45 specimens of *Fissidens* representing 12 species were collected. Compared with the previous study[16], six species are newly reported in Wuyanling. Among them, two species proved to be new to the bryoflora of Zhejiang Province based on reference to the published literature[19]. *Fissidens involutus* Wilson ex Mitt. var. *jejuensis* Y.-J. Yoon, B.C. Tan & B.-Y. Sun, previously known only from Japan (as *F. bushii*)[20] and South Korea[21], is reported here for the first time from China. Most of the species of *Fissidens* in Wuyanling grow on rock covered with a thin layer of soil, and occasionally on tree bark, soil and rocks. In China, *Fissidens* species are distributed from sea level to 3 800 m above sea level[22]. In Wuyanling, a humped relationship is observed between species richness and the elevation, with a maximum richness between 500 and 800 m (Fig. 1). *Fissidens dubius* has the widest range of elevation distribution, ranging from 194 to 1 286 m.

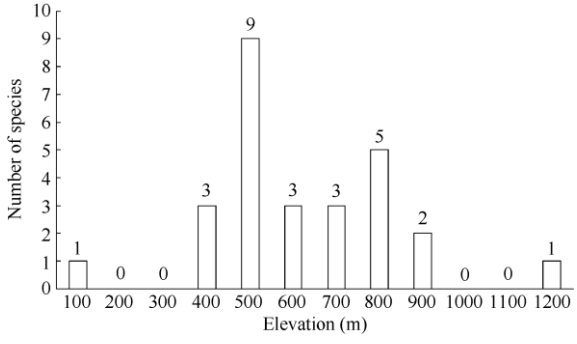

Fig. 1 *Fissidens* richness in relation to elevations (m) in Wuyanling

3 Species of *Fissidens* in Wuyanling

3.1 *Fissidens anomalus* Mont., Ann. Sci. Nat. Bot. sér. 2, **17**: 252. 1842.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, Shuangkengkou, 722 m, on tree bark, J. Wang & X. Chen 20200810-4.

Distribution: China (Chongqing, Fujian, Gansu, Guangxi, Guizhou, Henan, Hong Kong, Hubei, Hunan, Jiangxi, Shaanxi, Shandong, Sichuan, Taiwan, Xinjiang, Yunnan, new to Zhejiang), India, Indonesia, Japan, Myanmar, Nepal, the Philippines, Sri Lanka, Thailand and Vietnam[8,23].

3.2 *Fissidens crispulus* Brid., Muscol. Recent. Suppl. **4**: 187. 1819.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, Huangqiao, 474 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200804-30; from Tieluji to Huangjiadai, 561 m, on soil, J. Wang & X. Chen 20200805-45.

Distribution: China (Anhui, Chongqing, Fujian, Guangdong, Guizhou, Hainan, Hong Kong, Hubei, Hunan, Macao, Shandong, Taiwan, Yunnan, Zhejiang), widespread in the paleotropics, also reported from northern Australia[8,24].

3.3 *Fissidens dubius* P. Beauv., Prodr. Aethéogam. 57. 1805.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, from Tieluji to Huangjiadai, 584 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200805-41; from Huanglianshan to Xidou Village, 571 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200806-13; Shuangkengkou, 807 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200808-4.

Distribution: China (Anhui, Chongqing, Fujian, Gansu, Guangdong, Guangxi, Guizhou, Hebei, Heilongjiang, Hong Kong, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Nei Mongol, Ningxia, Sichuan, Shaanxi, Shandong, Shanghai, Taiwan, Xinjiang, Xizang, Yunnan, Zhejiang), Bangladesh, India, Indonesia, Japan, Nepal, North Korea, Pakistan, Papua New Guinea, Philippines; Africa, Central America, Europe and South America[8].

3.4 *Fissidens gymnogynus* Besch., J. Bot. (Morot) **12**: 292. 1898.

Specimens examined: Taishun Co., Wuyanling

National Nature Reserve, Huangqiao, 474 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200804-38A; from Tieluji to Huangjiadai, 575 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200805-84; from Huanglianshan to Xidou Village, 571 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200806-6.

Distribution: China (Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Henan, Hong Kong, Hubei, Hunan, Jiangxi, Sichuan, Shaanxi, Shandong, Taiwan, Yunnan, Zhejiang), Japan, North Korea, Pakistan, Philippines, Thailand[8].

3.5 *Fissidens involutus* Wilson ex Mitt., J. Proc. Linn. Soc. Bot. Suppl. **1**: 138. 1859.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, from Huanglianshan to Xidou Village, 571 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200806-5; Shuangkengkou, 807 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200808-6.

Distribution: China (Chongqing, Fujian, Guangxi, Guizhou, Henan, Hubei, Hunan, Jiangxi, Sichuan, Shaanxi, Shandong, Taiwan, Xizang, Yunnan, Zhejiang), India, Japan, Laos, Myanmar, New Guinea, Nepal, Pakistan, Philippines, Thailand and Vietnam[8,25].

3.6 *Fissidens involutus* Wilson ex Mitt. var. *jejuensis* Y.-J. Yoon, B.C. Tan & B.-Y. Sun, Arctoa **24**: 38. 2015. (Fig. 2)

Plants 1.0–3.5 cm tall, light green to dark green; stems usually branched; axillary hyaline nodules differentiated, observed in most of leaf axils; cortical cells in cross section small, thick-walled, central strand not differentiated. Leaves 13–25(–40) pairs; upper leaves contiguous to imbricate, oblong-lanceolate, 2.5–3.5 mm long, 0.4–0.6 mm wide, broadly acute and apiculate, lower leaves gradually decreasing in size towards the stem base, distant; base of dorsal lamina wedge shaped, usually distinctly decurrent; Costa percurrent, Bryoides-type; margins serrulate throughout; Vaginant lamina 1/2–3/5 of leaf length, unequal; Lamina unistratose; cells of apical lamina irregularly quadrate to hexagonal, 5–10 μm long, mammillose, thin walled to moderately thick walled, cells of vaginant lamina indistinctly pluripapillose along each cell edge. Dioicous (refer to Suzuki and Iwatsuki 2012); perichaetia axillary; perigonia and sporophytes not seen.

Fissidens involutus var. *jejuensis* can be separated from the typical variety by 1) the bases of dorsal leaves are distinctly decurrent, while those of the typical variety are mostly rounded or cuneate, 2) cells of vaginant lamina have single indistinctly papilla at each corner, while those of the typical variety have mamillae. *Fissidens teysmannianus* may be confused with this variety of *F. involutus*, but it differs from the latter in having non-decurrent leaf bases and the absence of hyaline nodules on the stem[21].

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, from Tieluji to Huangjiadai, 617 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200805-77; from Huanglianshan to Xidou Village, 756 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200806-3.

Distribution: Japan and Korea [21], new to China (Zhejiang).

3.7 *Fissidens nobilis* Griff., Calcutta J. Nat. Hist. **2**: 505. 1842.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, from Tieluji to Huangjiadai, 585 m, on soil, J. Wang & X. Chen 20200805-67; from Huanglianshan to Xidou Village, 756 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200806-2.

Distribution: China (Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Henan, Hong Kong, Hubei, Hunan, Jiangsu, Jiangxi, Shandong, Sichuan, Taiwan, Yunnan, Zhejiang), Cambodia, Fiji, India, Indonesia, Japan, Malaysia, Myanmar, Nepal, North Korea, Papua New Guinea, Philippines, Russian Far East, Sri Lanka, Thailand, Vietnam[8,26].

3.8 *Fissidens oblongifolius* Hook. f. & Wilson., London J. Bot. **3**: 547. 1844.

Specimens examined: Taishun Co., Wuyanling

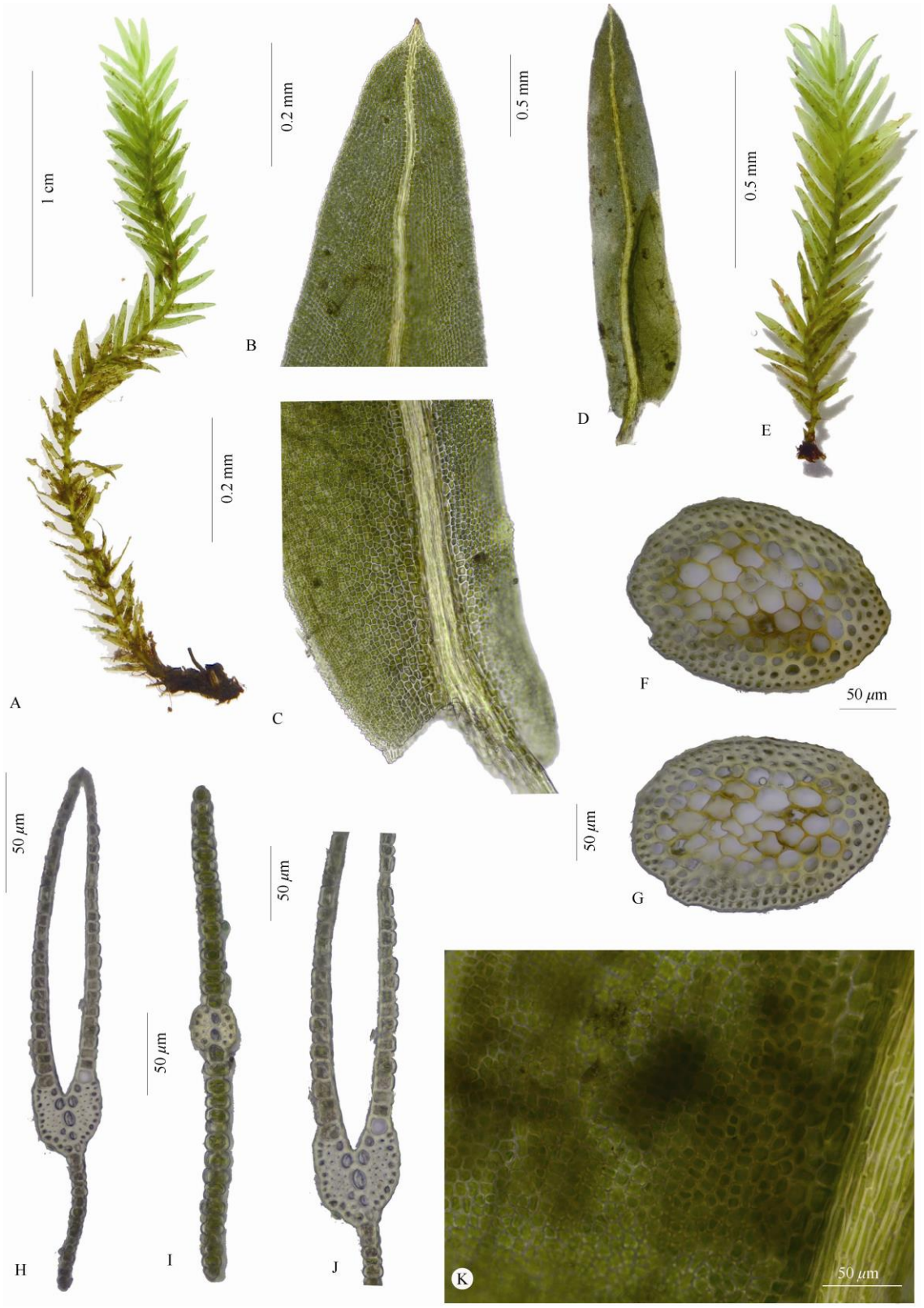

Fig. 2 *Fissidens involutus* Wilson ex Mitt. var. *jejuensis* Y.-J. Yoon, B.C. Tan & B.-Y. Sun. A, E: Plant; B: Leaf apex; C: Leaf base; D: Leaf; F, G: Transverse section of stem; H–J: Transverse section of leaf; K. Cells of vaginant laminae. (All figures taken from J. Wang & X. Chen 20200806-3)

National Nature Reserve, from Tieluji to Huangjiadai, 585 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200805-64.

Distribution: China (Fujian, Guangdong, Guizhou,

Hainan, Hong Kong, Jiangxi, Macao, Sichuan, Taiwan, Xizang, Yunnan), Indonesia, Japan, Malaysia, Philippines and Thailand; Australia, New Zealand, South and Central America, Mexico and West Tropical Africa[8,26].

3.9 *Fissidens perdecurrens* Besch., J. Bot. (Morot) **12**: 293. 1898.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, from Tieluji to Huangjiadai, 617 m, on rock, J. Wang & X. Chen 20200805-76; Shuangkengkou, 661 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200810-5.

Distribution: China (Fujian, Guizhou, Hubei, Hunan, Jiangxi, Sichuan, Taiwan, Xinjiang, Yunnan, Zhejiang) and Japan[8].

3.10 *Fissidens serratus* Müll. Hal., Bot. Zeitung (Berlin) **5**: 804. 1847.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, Shuangkengkou, 807 m, on tree bark, J. Wang & X. Chen 20200808-51B.

Distribution: China (Hainan, Hong Kong, Shandong, Taiwan, new to Zhejiang), Indonesia, Japan, Fiji, Malaysia, Papua New Guinea, Philippines, Singapore and Africa, Australia, The Americas[8,26].

3.11 *Fissidens taxifolius* Hedw., Sp. Musc. Frond. 155, pl. **39**: f. 1–5. 1801.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, from Tieluji to Huangjiadai, 585 m, on soil, J. Wang & X. Chen 20200805-70.

Distribution: China (Chongqing, Gansu, Guangxi, Guizhou, Heilongjiang, Henan, Hong Kong, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Shandong, Shanghai, Sichuan, Taiwan, Yunnan, Zhejiang), and widely distributed in the world[8].

3.12 *Fissidens teysmannianus* Dozy & Molk., Pl. Jungh. 317. 1854.

Specimens examined: Taishun Co., Wuyanling National Nature Reserve, Huangqiao, 474 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200804-38B; from Tieluji to Huangjiadai, 563 m, on rock covered with a thin layer of soil, J. Wang & X. Chen 20200805-3.

Distribution: China (Chongqing, Fujian, Guangdong, Guizhou, Hainan, Henan, Hong Kong, Hubei, Hunan, Jiangsu, Jiangxi, Shandong, Sichuan, Taiwan, Yunnan, Zhejiang), Indonesia, Japan, Malaysia, Papua New Guinea, North Korea, Russia and Vietnam[8,26].

According to the geographical and climatic condition, three regions of *Fissidens* in China were recognized by Li[22]. Among them, the richest geographic area is Southeastern and Southwestern Region, which is located along the coastal provinces in southeastern China (including Fujian, Guangdong, Guangxi, Hainan, Taiwan and Zhejiang), as well as three southwestern provinces (including Guizhou, Sichuan and Yunnan). Southeastern region, characterized by evergreen broad-leaved forests in the subtropical zones and tropical monsoon forests and tropical rain forests in the tropical area (including Leizhou Peninsula of Guangdong Province, Hainan Province and southern part of Taiwan Province), are strongly affected by the southeastern monsoon from the Pacific Ocean[22]. It provides a favourable condition for the development of *Fissidens*. To understand the limitations in our knowledge of species diversity and sampling efforts of *Fissidens* in southeastern region, we compared the richness of the genus in nine nature reserves at different latitudes (Table 1). Given the presence of a latitudinal diversity gradient in *Fissidens*[6] the number of species is expected to increase as the latitude decreases. Compared with other nature reserves, the number of species of *Fissidens* in Wuyanling is only lesser than that of Yachang Nature Reserve, which has been systematically sampled by Dr. Yu-Mei Wei. Since most of nature reserves lie south of Wuyanling, it is apparent that there are gaps of species diversity of *Fissidens* in these reserves, especially in tropical areas such as Jianfengling National Nature Reserve. Given that southeastern region is one the richest geographic area of *Fissidens* and should be a hot spot for the conservation of the genus in China, more systematic investigations should be carried out and more note-

Table 1 Species number of *Fissidens* in nine nature reserves at different latitudes

Locality	Latitude (N)	Number of species	Reference
Jianfengling National Nature Reserve, Hainan	18°23′–18°52′	9	[27]
Shimentai National Nature Reserve, Guangdong	24°17′–24°31′	10	[28]
Yachang Orchidaceae National Nature Reserve, Guangxi	24°44′–25°53′	26	Unpublished data
Maoershan National Nature Reserve, Guangxi	24°48′–25°58′	9	[29]
Qiyunshan National Nature Reserve, Jiangxi	25°24′–25°55′	9	[30]
Daiyunshan National Nature Reserve, Fujian	25°38′–25°43′	11	[31]
Wuyanling National Nature Reserve, Zhejiang	27°40′–27°43′	12	This study
Fengyangshan National Nature Reserve, Zhejiang	27°46′–27°58′	7	[32]
Tianmushan National Nature Reserve, Zhejiang	30°18′–30°24′	9	Unpublished data

worthy discoveries of the genus could be anticipated in this region.

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