Taxonomic reexamination of two *Huperzia* species (Lycopodiaceae) in Northeast Asia

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ABSTRACT: A comparison of the external morphology and spores clearly distinguished *Huperzia lucidula* (Michaux) Trevis. in northeast Asia and North America in terms of leaf shape, leaf margin, distribution of stomata on leaves, and spore shape. Therefore, the northeast Asian plants should be treated as a separate species, *H. asiatica* (Ching) B.-Y. Sun & J. Lim. In addition, we believe that *H. javanica* (Sw.) C. Yang, regarded as conspecific or infraspecific with *H. serrata* (Thunb.) Trevis., is a distinct species based on the presence of a leaf petiole and serrated leaf margins, and the shape of the gemmiferous branchlets.

Keywords: *Huperzia*, *H. asiatica*, *H. javanica*, Mt. Baekdu

적 요: *Huperzia lucidula* (Michaux) Trevis.의 동북아시아 집단 및 북미 집단을 대상으로 외부형태와 포자형태를 비교한 결과 잎의 형태, 엽연부, 잎에서의 기공의 분포 및 포자의 형태에 있어서 뚜렷히 구분되었다. 따라서, 동북아시아 집단을 북미 지역의 *H. lucidula*와는 독립된 종 *H. asiatica* (Ching) B.-Y. Sun and J. Lim으로 분리, 승격하였다. 또한, *H. serrata* (Thunb.) Trevis.와 동일 종 또는 종내 분류군으로 인식되어 오던 *H. javanica* (Sw.) C. Yang은 영양엽에서 엽병의 발달 유무, 엽연 거치의 수 그리고 무성아가지의 중앙 열편 모양으로 별개의 종으로 처리하는 견해를 지지하였다.

주요어: 뱀톱속, *Huperzia asiatica*, *Huperzia javanica*, 백두산

Huperzia Bernh. (*sensu stricto*) includes about 55 taxa distributed in temperate, alpine, and arctic regions, and tropical Asian mountains (Zhang and Iwatsuki, 2013). There are four recognized taxa in Korea (Sun, 2007), four in northeast China (Zhang and Iwatsuki, 2013), eight in Japan (Iwatsuki et al., 1995), and five in Far East Russia (Kharkevich, 2002). The genus *Huperzia* is characterized by erection of stems, the presence of sporangia at the axils of fertile leaves, gemmiferous

branchlets, and gemmae (Boivin, 1950; Wagner and Beitel, 1992, 1993; Sun, 2007; Zhang and Iwatsuki, 2013).

Lycopodium lucidulum [= *Huperzia lucidula* (Michaux) Trevis.] was described as a new species from North America based on spreading and narrowly lanceolate leaves with irregular teeth on the margin and sporangia at the axils of fertile leaves (Michaux, 1803). Ching (1981) described a new variety, *H. lucidula* var. *asiatica* Ching, based on a specimen collected on Mt. Jangbaek, Jilin Province, China, stating that its leaves were more reflexed, darker green, and smaller than those of *H. lucidula*. Recently, some authors have treated it as a synonym of *H. lucidula*, insisting that there are no obvious differences between the two taxa (Zhang and Kung, 2000;

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Table 1. Materials used for this study.

Taxon	Voucher specimen
<i>H. asiatica</i> (Ching) B.-Y. Sun & J. Lim	China. Jilin-seong, Yanbian, Baekdusan Mt., 14 Jun 2008, <i>Doudkin s.n.</i> China. Jilin-seong, Yanbian, Baekdusan Mt., 10 Jun 2014, <i>Lee et al. baekdu 2308</i>
<i>H. javanica</i> (Sw.) C. Yang	Korea. Jeju-do, Seogwipo-shi, Seondol, 18 Sep 2011, <i>Hwang et al. 60582</i> Japan. Nakasaki, Tsushima, 4 May 2014, <i>Moon dae 1</i>
<i>H. lucidula</i> (Michaux) Trevis.	U.S.A. Colorado, Mt. White, 17 Aug 1999, <i>Zhang 2891</i> U.S.A. New Hampshire, Mt. Monadnock, 22 Jun. 2014, <i>Boufford 43754</i>
<i>H. serrata</i> (Thunb.) Trevis.	Korea. Jeju-do, Hallasan Mt., Yeongsil, 17 Jun 2010, <i>Lim et al. 50431</i> Korea. Gwangwon, Daeamsan Mt., 26 Sep 2013, <i>Lim & Lim s.n.</i> China. Jilin-seong, Yanbian, Baekdusan Mt., 10 Jun 2014, <i>Lee et al. baekdu 1</i>

Zhang and Iwatsuki, 2013).

In 1801, Swartz published a new species, *Lycopodium javanicum* Sw. [= *Huperzia javanica* (Sw.) C. Yang], characterized by lanceolate or obovate leaves and dichotomously branched stems. However, Makino (1898) treated this taxon as a variety, *L. serratum* var. *javanicum*. Separately, Spring (1850) described *L. serratum* var. *longipetiolatum* Spring as a new variety, which was characterized by leaves forming petioles narrowing towards the base. Ching (1981) treated this taxon as a form of *L. serratum* Thunb., while Yang (1982) recognized it as a distinct species, *H. longipetiolata* (Spring) C. Yang, emphasizing that it has long petiolate leaves. Subsequently, he combined *L. javanicum* with *H. longipetiolata*, treating *H. longipetiolata* as a synonym of *H. javanica* (Yang, 1989), and Shrestha and Zhang (2015) concurred. However, Zhang and Kung (2000) and Zhang and Iwatsuki (2013) recognized this taxon as a variety of *H. serrata*. The distribution of *L. serratum* var. *longipetiolatum* in the Korean Peninsula has not been confirmed since Park (1961) first reported it.

In this study, we reexamined the taxonomic status of northeast Asian *H. lucidula* by comparing the morphology of northeast Asian and North American *H. lucidula*. In addition, we reexamined the taxonomic position of *H. javanica*, which has been recognized as conspecific with *H. serrata*. Finally, we verified the distribution of this species within the Korean Peninsula.

Materials and Methods

Plants were collected from various localities in Korea, China, Japan, and the USA from 2008 to 2014 (Table 1). Voucher specimens are kept in the Herbarium of the National Institute of Biological Resources (KB) and Chonbuk National

University (JNU). In addition, we studied specimens on loan from the Chinese Academy of Sciences, Beijing (PE), New York Botanical Garden (NY), and Harvard University Herbaria (GH).

We examined the external morphology and used the results to compare species and describe each taxon in this study. We measured the number of stomata per 0.1 mm² in the trophophores of 20 individuals from each taxon, as well as the size of 10 stomata per individual. We then calculated the minimum, average, and maximum number and size of the stomata. To examine spore micromorphology, we sampled spores from mature sporangia and immediately photographed them by scanning electron microscopy (SEM) without pretreatment.

Results and Discussion

Huperzia asiatica has been treated as conspecific or intraspecific with *H. lucidula* and is regarded as a good example of a disjunct distribution between northeast Asia and North America (Brunton et al., 1992; Zhang and Kung, 1998; Zhang and Iwatsuki, 2013; Xiang et al., 2015). However, on comparing the external morphology and spore micromorphology, these two taxa seem to be different enough to be treated as distinct species.

In terms of trophophyll morphology, the two species have different patterns. *Huperzia lucidula* typically has oblanceolate trophophylls with the above mid-part being the widest and irregular margins with 1–9 teeth, while *H. asiatica* always has linear-lanceolate trophophylls with the margins parallel from the base to the mid-part and 0–4 minute teeth or papillate margins restricted from the middle part to the end of the leaves (Fig. 1, Table 3). Since the delimitation of *Huperzia* species is based mainly on leaf shape and the serration of the leaf

margin (Ching, 1981; Wagner and Beitel, 1993; Sun, 2007), even serration pattern has been used to distinguish sections *Serratae* and *Huperzia* (Zhang and Kung, 1998, 2000; Zhang and Iwatsuki, 2013). Consequently, the differences in trophophyll shape and marginal serration between these two taxa imply that they should be treated as different species.

In addition, *H. lucidula* has stomata only on the abaxial leaf surface, whereas *H. asiatica* has stomata on both sides of the leaves (Fig. 4, Table 2). *H. lucidula* was described as a new species based on the characteristics of narrowly obovate leaves and stomata only on the abaxial surface of the leaf, and was regarded as distinct from other species in North America,

which are characterized by linear-lanceolate leaves and stomata on both sides of the leaves (Wagner and Beitel, 1993). Lim and Sun (2015) suggested that the distribution of stomata on the leaf is a key character for identifying taxa within the genus *Huperzia*, reporting that *H. serrata* and *H. javanica* have stomata only on the abaxial leaf surface, while *H. miyoshiana* (Makino) Ching and *H. jejuensis* B.-Y. Sun & J. Lim have stomata on both sides of their leaves.

Regarding spore shape, *H. lucidula* has only normal triangular spores, while *H. asiatica* has a mixture of normal and irregular shapes which may indicate a hybrid origin (Fig. 5). Hybrids taxa are very common in this genus, and taxa with hybrid origins have a great variety of spore sizes and irregularly shaped spores (Knobloch, 1976; Wagner and Beitel, 1992, 1993).

Since *H. javanica* was described as a new species based on its long leaf petioles, this taxon has been recognized as conspecific or intraspecific with *H. serrata*. Recently, Shrestha and Zhang (2015) treated it as distinct from *H. serrata* because

Fig. 1. Shapes of trophophyll. A. Linear-lanceolate (*H. asiatica*); B. Oblanceolate (*H. lucidula*, *H. serrata*); C. Narrowly elliptic (*H. javanica*, *H. serrata*).

Table 2. Number of stomata per 0.1 mm² in trophophyll of four species investigated.

Trophophyll	<i>H. asiatica</i>	<i>H. lucidula</i>	<i>H. javanica</i>	<i>H. serrata</i>
Adaxial surface	1(1)2	0 (absent)	0 (absent)	0 (absent)
Abaxial surface	2(3)5	3(5)7	1(2)4	1(3)7

Table 3. Comparison of diagnostic characters among *H. asiatica*, *H. javanica*, *H. lucidula* and *H. serrata*.

	<i>H. asiatica</i>	<i>H. lucidula</i>	<i>H. javanica</i>	<i>H. serrata</i>
Leaf shape/apex	linear lanceolate/acute	oblanceolate/acute	narrowly elliptic, elliptic/caudate	narrowly elliptic, oblanceolate/acute, acuminate
Broadest part of leaf	at mid-part	above mid-part	at mid-part	at or above mid-part
Petiole	absent	absent	> 1 mm	absent or < 1 mm
Leaf margin	irregularly minutely dentate	irregularly dentate	irregularly serrate	irregularly serrate
Number of teeth(n)*	0 (2) 4	1 (3) 9	10 (17) 25	1 (9) 18
Serration	above mid-part	whole part	whole part	whole part
Shape of large central lobe on gemmiferous branchlet	ovate	ovate	lanceolate	ovate
Apex of gemma leaf	cuspidate	mucronate	cuspidate	mucronate
Distribution of stomata on leaf	both surfaces, more on lower side	lower surface only	lower surface only	lower surface only
Length of stomata(μm)*	51.9 (54.9) 62.1	45.7 (51.2) 57.6	51.4 (62.0) 70.9	38.4 (54.0) 70.5
Spores	trilete with frequent misshapes	trilete	trilete	trilete

* Minimum (mean) maximum

of its petiolate trophophylls and reduced sporophylls. Our results also indicated that *H. javanica* is a separate species from *H. serrata*: *H. serrata* has narrowly elliptic or oblanceolate trophophylls with an acute or acuminate apex, 1–18 teeth on irregular margins, obovate central lobes (ratio of width to length > 0.2) of gemmiferous branchlets, and a mucronate apex of the gemmae leaf. In comparison, *H. javanica* has narrowly elliptic to elliptic trophophylls with a caudate apex, 10–25 teeth on an irregular margin, a linear central lobe (ratio of width to length < 0.2) on gemmiferous branchlets, and a cuspidate apex of the gemmae leaf (Table 3). In this study, we found that the central lobe shape of the gemmiferous branchlets is a useful character for distinguishing *H. javanica* from *H. serrata*. We also verified that this species occurs in the Sun-dol area of Jeju-do and Duryun-san at Haenam, based on an examination of specimens in the herbarium of the National Institute of Biological Resources (KB).

In conclusion, we recognize the northeast Asia populations, which Zhang and Kung (2000) and Zhang and Iwatsuki (2013) considered conspecific with *H. lucidula*, as a distinct species based on external morphology. *Huperzia javanica* should be treated as a distinct species independent of *H. serrata*. We also rediscovered it in the Korean Peninsula after it was first reported by Park (1961, 1979).

Taxonomic Treatment

1) *Huperzia asiatica* (Ching) B.-Y. Sun & J. Lim, stat. nov. (Fig. 2)

Huperzia lucidula var. *asiatica* Ching in Acta Bot. Yunnan. 3(3): 296. 1981. Type : China, Jilin, without date, S. L. Soong 197. (Holotype: PE)

H. lucidula (Michaux) Trevis. auct. non. Acta Phytotax. Sin. 38: 21. 2000.

Korean name: Baek-du-baem-top 백두뱀툼

Plant evergreen herb, terrestrial. **Stems** erect or ascending, subterranean stems decumbent, 1–2 dichotomously branched, 15.3–25.0 cm tall, together with leaves 1.3–1.8 cm wide, clustered at base without main stem; annual constrictions present. **Gemmiferous branchlets** present in 1 pseudowhorl at end of each annual growth cycle, zygomorphic, comprising 6 lobes, with 1 large central lobe (outer), 1 small central lobe (inner), and 2 pairs of small lateral lobes, large central lobe lanceolate, $2.6\text{--}4.0 \times 0.5\text{--}0.8$ mm; gemmae eliminated after maturity, obtriangular, $3.2\text{--}3.7 \times 2.8\text{--}3.9$ mm, zygomorphic, comprises 5 leaves, 1 central leaf, 2 large lateral leaves with

Fig. 2. *Huperzia asiatica* (Ching) B.-Y. Sun & J. Lim. A. Habit, B. Fertile zone of stem, C. Trophophyll, D. Sporophyll, E. Gemma, F. Gemmiferous branchlet, G. Gemma attached at gemmiferous branchlet, H. Sporangia.

apex cuspidate, 1 abaxial, and 1 adaxial leaf. **Leaves** monomorphic or dimorphic, attached at right angles or angled downward with stem, densely spirally arranged, green, herbaceous, glabrous; vein only midrib; stomata on both sides, $51.9\text{--}62.1$ μm . **Trophophylls** linear-lanceolate, straight in lower half, $6.7\text{--}8.8 \times 0.8\text{--}1.2$ mm, apex acute, margins irregularly minutely dentate or papillate above middle, teeth 1–4. **Sporophylls** linear-lanceolate, $4.1\text{--}6.3 \times 0.7\text{--}1.0$ mm, slightly smaller than trophophylls, margins irregularly minutely dentate or papillate above middle, teeth 2–3, not forming distinct cones. **Sporangia** reniform, $0.6\text{--}1.1 \times 1.2\text{--}1.6$ mm, axillary of sporophylls, sessile, yellowish; spores trilete with truncate lobes, and irregular shape, 17–28, foveolate, fossulate, scabrate.

Specimens examined: CHINA. Jilin: Mt. Baekdu, elev. 2040 m, 14 Jun. 2008, Doudkin s.n. (KB, 5 sheets); Mt. Baekdu, elev. 980 m, 10 Jun. 2014. Lee et al. baekdu 2307 (KB); Mt. Baekdu, elev. 892 m, 10 Jun. 2014. Lee et al. baekdu 2308 (KB); Mt. Baekdu, elev. 1780 m, 30 Jul. 1957, ? 466 (PE); Mt. Baekdu, elev. 1500m, 18 Jul. 1982, ? 4192 (2 sheets) (PE).

Distribution: Restricted to Mt. Baekdusan

Fig. 3. *H. javanica* (Sw.) C. Yang. A. Habit, B. Fertile zone of stem, C. Sporophyll, D. Trophophyll, E. Gemmiferous branchlets, F. Sporangia, G. Gemma.

Habitat: Terrestrial in shaded conifer forests and mixed forests, moist areas covered with many mosses.

2) *H. javanica* (Sw.) C. Yang, Bull. Acad. Mil. Med. Sci. 13: 368. 1989. (Fig. 3)

L. javanicum Sw. J. Bot. (Schrader), 1800: 114. 1801; *L. serratum* var. *javanicum* (Sw.) Makino, Bot. Mag. Tokyo 12: 13. 1898. Type : Indonesia, Java, without date, Thunberg s.n. (Holotype: UPS)

L. serratum Thunb. var. *longipetiolatum* Spring, Monogr. Lycop. 2: 18. 1850; *H. serrata* Thunb. f. *longipetiolata* (Spring) Ching, Acta Bot. Yunnan 3: 294. 1981; *H. longipetiolata* (Spring) C. Yang, Chin. Trad. Herbal Drugs 16: 33. 1982.

Korean name: Kuen-baem-top 큰땀톱

Plant evergreen herb, terrestrial. **Stems** erect or ascending, subterranean stems decumbent, 1–2 dichotomously branched, 9.2–23.8 cm tall, together with leaves 2.0–3.9 cm wide, clustered at base without main stem; annual constrictions

Fig 4. Light microscopic photographs of stomata at adaxial surface of leaf. A. *H. asiatica*; B. *H. javanica*; C. *H. lucidula*; D. *H. serrata* (Note that only *H. asiatica* has stomata on adaxial surface)

present. **Gemmiferous branchlets** present in 1 pseudowhorl at end of each annual growth cycle, zygomorphic, comprising 6 lobes, with 1 large central lobe (outer), 1 small central lobe (inner), and 2 pairs of small lateral lobes, large central lobe lanceolate, $2.7\text{--}4.3 \times 0.5\text{--}0.7$ mm; gemmae eliminated after maturity, obtriangular, $2.4\text{--}3.5 \times 2.3\text{--}3.6$ mm, zygomorphic, comprises 5 leaves, 1 central leaf, 2 large lateral leaves with apex cuspidate, 1 abaxial, and 1 adaxial leaf. **Leaves** dimorphic, attached at right angles or angled downward with stem, densely spirally arranged, dark green, herbaceous, glabrous; vein only midrib; stomata on lower side only, $51.4\text{--}70.9$ µm. **Trophophylls** narrowly elliptic or elliptic, broadest at mid-part, $10.8\text{--}18.8 \times 1.9\text{--}4.2$ mm, apex caudate, margins irregularly serrate, teeth 10–25. **Sporophylls** linear-lanceolate or lanceolate or obovate, variable in form, $2.1\text{--}5.0 \times 0.3\text{--}1.0$ mm, margins irregularly serrate, in whole part, teeth 21–10, not forming distinct cones. **Sporangia** reniform, $0.6\text{--}1.1 \times 1.2\text{--}1.6$ mm, axillary of sporophylls, sessile, yellowish; spores trilete with truncate lobes, $13\text{--}22$ µm, foveolate, fossulate, scabrate.

Specimens examined: **CHINA.** **Anhui:** Mt. Hwang, Songkokam, 2 Nov. 1951, ? 6501 (PE); **Fujian:** Jianglexian, elev. 550m, 22 May 1991, ? 279 (PE); **Guizhou:** Anlongxian, Mt. Long, 15 Jun. 1960, Zhang & Zhang 4529 (PE); **Hunan:** Sangzhixian, Mt. Cheonpyeong, elev. 1370, Oct. 1987, Moon 870514 (PE, 2 sheets); Wugangsi, Mt. Wun, elev. 1000m, 13 Oct. 1963, ? 15957 (PE); Yizhangxian, Mt. Mang, elev. 900m, Feb. 2005, ? 602017 (PE, 2 sheets); Chalingxian, elev. 670m, 2 Dec. 2007, ? 70455 (PE); **Jiangxi:** Hwangkang, elev. 750m, 25 Aug. 1959, ? 1633 (PE); **Sichuan:** Muchuanxian, Mt. Wuzhi, elev. 1100m, 7 May 1976, ? s.n. (PE); **Zhejiang:** Longquan, Mt. Pyeongan, elev. 1100m, 18 Aug. 1983, ? 3253 (PE).

Fig 5. Scanning electron microscopic photographs of spore. A~C. *H. asiatica*; D~E. *H. javanica*; F~G. *H. lucidula*; H~I. *H. serrata*.

JAPAN. Honshu: Shoshazan, Harima, elev. 200m, 10 Nov. 1975, *Y. Saiki s.n.* (PE); **Nakasaki:** Tsushima, 4 May 2014, *Moon I.*(KB).

KOREA. Jeju-do: Seogwipo-si, Sanghyo-dong, Seondol, 18 Sep 2011, *Hwang et al.* 60580, 60582 (KB); Seogwipo-si, Sanghyo-dong, Seondol, 15 Dec. 2008, *Kim J. O.* EWLEE080564 (KB); Seogwipo-si, Sanghyo-dong, Seondol, 19 Sep. 2009, *Lee S. J.* 09-P312 (KB); **Jeollanamdo:** Jangheung-gun, Mt. Duryun, 23 Apr 2010, *Hwang & Choi* CH50153 (KB).

Distribution: Korea, Laos, Malaysia, Vietnam, India, Japan, China, Taiwan, Philippines (Iwatsuki et al., 1995; Zhang and Iwatsuki, 2013; Shrestha and Zhang, 2015)

Habitat: Terrestrial in shaded conifer forests and mixed forests, moist areas covered with many mosses.

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Literature Cited

- Boivin, B. 1950. The problem of generic segregates in the form-genus *Lycopodium*. American Fern Journal 40(1): 32–41.
- Brunton, D. F., W. H. Wagner and J. M. Beitel. 1992. Pacific fir-moss (*Huperzia miyoshiana*) (Lycopodiaceae) in eastern North America at Gros Morne National Park, Newfoundland. American Fern Journal 82(2): 63–66.
- Ching, R. C. 1981. The Taxonomy of Chinese Lycopodiaceae (Sen. Lat.) 2. Acta Botanica Yunnanica 3(3): 291–305.
- Iwatsuki K., T. Yamazaki, D. E. Boufford and H. Ohba. 1995. Flora of Japan. vol. 1. Pteridophyta and Gymnospermae. Pp. 4–11.
- Kharkevich, S. S. 2002. Flora of The Russian Far East: Alphabetical indexes to the “Vascular plant of the Soviet Far East” 1: 116.
- Knobloch, I. W. 1976. Pteridophyte hybrids. Publications of the Museum, Michigan State University Biological Series 5: 273–352.
- Lim J. and B.-Y. Sun. 2015. A new species of *Huperzia* (Lycopodiaceae) from Jeju Island, Korea: *Huperzia jejuensis*. Korean Journal of Plant Taxonomy. 45(1): 17–21.

- Makino, T. 1898. *Plantae Japonenses novae vel minus cognitae*. The Botanical Magazine, Tokyo 12(136): 45–52.
- Michaux, A. 1803. *Flora Boreali-Americana*. Class X X IV. Cryptogamia. Parisiis et Argentorati, apud fratres Levrault 2: 261–332.
- Park, M. 1961. *Flora of Korean Pteridophyta*. Kyohakdoso Co. Seoul. Pp. 19–28.
- Park, M. 1979. *Illustrated Encyclopedia of Fauna and Flora of Korea* Vol. 16 Pteridophyte. Samhamunhwasa, Seoul.
- Shrestha, N. and X. C. Zhang. 2015. Recircumscription on *Huperzia serrata* Complex in China using morphological and climatic data. *Journal of Systematics and Evolution* 53(1): 88–103.
- Spring, A. 1850. *Monographie de La Famille des Lycopodiacees*. Mémoires de l'Académie royale de Belgique 2: 17–20.
- Sun, B.-Y. 2007. The genera of Vascular Plants of Korea. Park, C, W. (eds.) Academy Publishing. Co, Korea. Pp. 3–5.
- Swartz, O. 1801. *Conspectus generum*. *Journal für die Botanik* 1800: 3–120.
- Wagner, W. H. J. and J. M. Beitel. 1992. Generic classification of modern North American Lycopodiaceae. *Annals of the Missouri Botanical Garden* 79: 676–686.
- Wagner, W. H. J. and J. M. Beitel. 1993. *Flora of North America*. Vol. 2. Pteridophytes and Gymnosperms. Oxford University press. Pp. 18–24.
- Xiang, J. Y., J. Wen and H. Peng. 2015. Evolution of the eastern Asian-North American biogeographic disjunctions in ferns and lycophytes. *Journal of Systematics and Evolution* 53(1): 2–32.
- Yang, C. Y. 1982. Botanical origin of Qiancengta (*Huperzia serrata*). *Chinese Traditional and Herbal Drugs* 13(12): 32–33.
- Yang, C. Y. 1989. Revision of Lycopodiales from China. *Bulletin of the Academy of Military Medical Sciences* 13: 366–370.
- Zhang L. and K. Iwatsuki. 2013. *Flora of China*. vol. 2. Pteridophytes. Pp. 13–34.
- Zhang L. and H. S. Kung. 1998. A taxonomic study of *Huperzia* Bernh.(s.s.) sect. *Huperzia* in China. *Acta Phytotaxonomica Sinica* 36(6): 521–529.
- Zhang L. and H. S. Kung. 2000. Taxonomy of the genus *Huperzia* Bernh. (sen. str.) sect. *Serratae* (Rothm.) Holub in China. *Acta Phytotaxonomica Sinica* 38(1): 13–22.