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Diatom flora of genus *Stauroneis* (Bacillariophyta) from mainly the mountain peatlands of Korea

Gyeongje Joh*

Department of Environmental Science and Engineering, Inje University, Gimhae 621–749, Korea

Abstract

In a survey of periphytic and benthic diatoms in Korea, diatoms of genus *Stauroneis* were found to be widely distributed over freshwaters, rivers and streams, lakes and reservoir, wetlands in lowland and mountain areas, and even subaerial terrestrial habitats. However, it is clear that *Stauroneis* diatoms prefer peatlands, which can be more or less acidic or oligotrophic environments in freshwaters. In this study, *Staurones* diatoms were collected mainly from mountain peatlands. Twenty five taxa were confirmed to be species, while some specimens remain unidentified. Approximately twenty species have been reported in Korea in the past, but these are largely *S. anceps* Ehremberg sensu lato, *S. phoenicenteron* (Nitzsch) Eherenberg sensu lato, and their infraspecies variety or forma. Sixteen of the twenty five *Stauroneis* taxa found in this survey are reported for the first time in Korea.

Key words: benthic diatoms, genus *Stauroneis*, mountain peatlands, oligotrophic habitat

INTRODUCTION

The diatoms belonging to genus *Stauroneis* are distinguished from the other naviculoid species by a thickened hyaline fascia in the central parts of the valve known as stauros, and it is a primary criterion (Andrews 1981). The stauros is characteristic and easily recognized under light microscopy (Cox and Williams 2000). In additions, features used to identify species of *Stauroneis* diatoms are the outline and dimensions of the valve, the structure of the raphe and its external central endings, the number of striae and poroids occurring in a 10 μm segment, and the presence of pseudosepta at the ends (Van de Vijver et al. 2004).

Diatoms of this genus include obligate freshwater ones, cosmopolitan ones as benthic diatoms in various habitats and subaerial diatoms in moist soil and moss (Round et al. 1990, Van de Vijver et al. 2004). The 820 species and infraspecific taxa have been reported over the world, of which 143 have been currently accepted taxonomically (Guiry and Guiry 2012). *Stauroneis* diatoms are distributed worldwide in temperature regions (Bahls 2010), in the Antarctic and Arctic regions (Van de Vijver et al. 2004), and in the tropical area (Metzeltin and Lange-Bertalot 1998). A large numbers of *Stauroneis* species are endemic, being restricted to a local and regional habitat. Many species are newly reported, including 40 species, among the 63 *Stauroneis* described in the Arctic and Antarctic regions (Van de Vijver et al. 2005), 21 of the 52 species in the northern Rockies (Bahls 2010), and 19 *Stauroenis* species in tropical South America (Metzeltin and Lange-Bertalot 1998, 2007). Bahls (2012) reported the characteristic distribution of genus *Staurones* and its biogeographic disjunction.

Approximately 20 taxa of *Stauroneis* have been previously found in a floristic study of freshwater diatoms in Korea (Lee et al. 1995, Lee 1997), and they were primarily

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***Corresponding Author**
E-mail: kjcho@inje.ac.kr
Tel: +82-55-320-3216

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S. anceps Ehrenberg, *S. phoenicenteron* (Nitzsch) Eherenberg, and their varieties or forma. This paper reports the species of genus *Staurones* residing largely in the mountain peatlands and provides detailed information on their biogeography in Korea.

MATERIALS AND METHODS

Stauroneis diatoms were collected from various areas, including many mountain wetlands, headwaters and reservoirs of streams and rivers, lowland wetland, and other habitats. In the case of wetlands, the collection was primarily from peatlands, which are largely concentrated on the summit of mountains from 600 m to 1,100 m elevations, while some are at lower altitudes. The locations of the sampling areas are depicted in Fig. 1, and a few or many materials were collected in each locality. The mountain peatlands of Korea are commonly covered with Japanese moor grass (*Molinia japonica*) and other grasses, and surrounded by konara oak (*Quercus serrata*) and pine trees (*Pinus densiflora*) at their borders. These grass plants provide the major contribution to peat deposit and formation. Small pools or water holes are scattered throughout the mountain wetlands. In these pools, the slurries or suspension in the water holes were collected to sample the benthic diatoms in the bogs. The top sediments or deposited peats represent a temporally and spatially integrated sample of recent years.

Preparations of the diatom specimens, from digestive oxidation to permanent mounting, followed the standard procedures of APHA (1995). Diatoms were observed under oil immersion by using an Axioplan microscope (Carl Zeiss, Oberkochen, Germany). For each sample, the percentage of each taxon was evaluated by counting 350 to 400 valves. The identification and confirmation of *Stauroneis* species are done according to the work of Hustedt (1959), Krammer and Lange-Bertalot (1986), Van de Vijver et al. (2004), and many other articles. The synonym and the taxonomical informations of the species are referred to CAS (2014) on-line version. The description made by Noh (1991) and check-lists authorized by Lee et al. (1995) and Lee (1997) were the source documents used to sum up the *Stauroneis* flora reported or described in Korea. The water quality of the water holes, pH, alkalinity and some inorganic nutrients were measured by using standard methods in order to assess the environmental conditions.

RESULTS AND DISCUSSION

Stauroneis diatoms were collected from the 38 sites in 32 freshwater areas (Fig. 1). A total of twenty five *Stauroneis* species were found in these local areas, but mainly in the peatlands, mountain areas, and oligotrophic freshwaters. Some highly contaminated freshwaters were chosen for this study, but the *Stauroneis* were not found at all or scarce, and these areas were ignored. Important morphological characters in the classification of *Stauroneis* diatoms are the outline of the valve, the form of the valve ends, the density of striae and areola on a stria, and the shape of hyaline stauros in the central area (Van de Vijver et al. 2004). The characteristics of each species are given as follow and the morphological difference among all neighboring species are emphasized. The dimensions of the valve and strial density are presented as the local data of each species. The distributional patterns are briefly summarized. Among twenty five species, sixteen are newly reported to Korea and are marked with asterisks (*) in front of the scientific name.

(1) *Stauroneis alabamae* Heiden in Schmidt et al. 1903 (Pl. 4, Fig. 6) (Schmidt 1903, pl. 242: 2; Hustedt 1930, p. 257, f. 412). Valves broadly elliptical-lanceolate in outline, the breadth of the valve abruptly narrow towards the ends. The hyaline stauros of the central area narrow rectangular, hardly expanded towards the ends. The ends of the valve not protracted, obtusely round. Valves 168–170 μm in length, 22.5–23.5 μm in breadth, striae coarse 21–23 rows in 10 μm, puncta in a stria distantly spaced, 18–19 in 10 μm. Occurring rarely in lowland wetlands in Haman (Chung and Noh 1987) and recently in Dongsong Reservoir in Cheolwon.

(2) **Stauroneis amphicephala* Kützing 1844 (Pl. 1, Figs. 4–6) (Van de Vijver et al. 2004, p. 20, pl. 51: 1–10, pl. 52: 1–5, pl. 53: 1–4, pl. 54: 1–5). Valves elliptical-lanceolate in outline, the ends of the valve protracted and rostrate. The stauros more expanded towards the ends. Valves 45–55 μm in length, 11–13 μm in breadth and striae 19–22 rows in 10 μm. Occurring rarely in a rice paddy in Wando, in June 2012, and newly reported to Korea.

(3) **Stauroneis ancepsopsis* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito 2003 (Pl. 2, Figs. 1 and 2) (Lange-Bertalot et al. 2003, p. 132, pl. 38: 15, pl. 125: 2–7). Valves elliptical-lanceolate to elliptical in outline, the ends of the valve abruptly long protracted and rostrate. The stauros rectangular and not expand-

ed towards the margins. Valves 55–60 µm in length, 13.5–14 µm in breadth, striae 18–20 rows and puncta of the striae 17–19 in 10 µm. This species is differentiated with *S. anceps* Ehrenberg sensu stricto from the form of the valve ends. Occurring rarely in rice paddy in Wando, and newly reported to Korea.

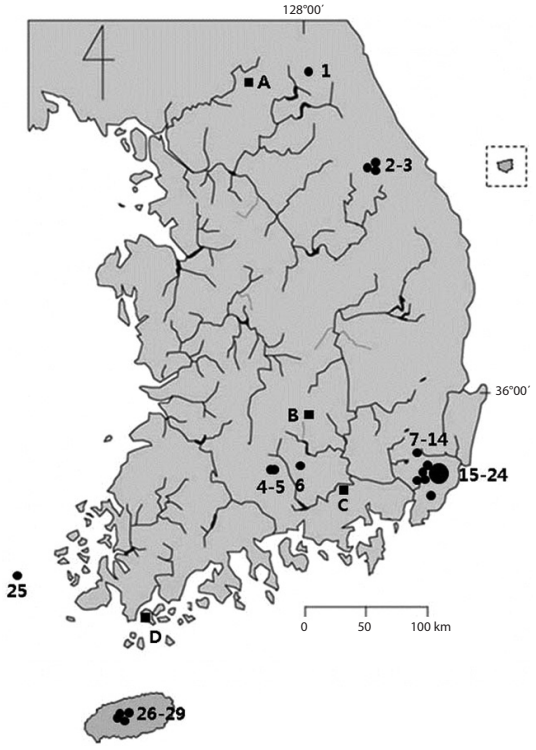

Fig. 1. The locations of mountain peatlands or bogs (black circles) to collect *Stauroneis* diatoms in Korea. Twenty-nine mountain peatlands are as follow: 1, The Yong (YN) of Daeam Mountain in Inje; 2, The Sohwangbyeongsan (SHBS) of Odae Mountain in Pyeongchang; 3, An unnamed peatland in Daegwanryeong Pasture (DGR) in Pyeongchang; 4, The Wangdeungjae (WDJ) of Jiri Mountain in Sancheong; 5, The Oegogyeneup (OGG) of Jiri Mountain in Sancheong; 6, The Duncheol (DC) of Duncheol Mountain in Yangsan; 7, The Hwaeom (HO) of Wonhyo Mountain in Yangsan; 8, Milbat (MB) of Cheonseong Mountain in Yangsan; 9, The Sinbulsan A (SBSA) in Yangsan; 10, The Sinbulsan B (SBSB) in Yangsan; 11, The Sinbulsan C (SBSC) in Yangsan; 12, The Danjo (DJ) of Yeongchuk Mountain in Yangsan; 13, The Sandeul (SD) of Jaeyak Mountain in Miryang; 14, Janggun (JG) of Geumjeong Mountain in Busan; 15, The first Mujechi (MJC1) in Ulsan; 16, The second Mujechi (MJC2) in Ulsan; 17, The third Mujechi (MJC3) in Yangsan; 18, The Daeseongdwi (DSD) in Yangsan; 19, The Daeseongkeun (DSK) in Yangsan; 20, A small water pool near the Daeseongkun (DSKP); 21,. The Daeseong A (DSA); 22, The Daeseongam D (DSAD) in Yangsan; 23, The Anjeok B (AJB) in Yangsan; 24, The Anjeok C (AJC) in Yangsan; 25, Jangdo (JD) in Sinan; 26, The Sumeunmulbaengdwineup (SMBD) in Jeju; 27, The 1100 wetland (TH) in Jeju; 28, Lake Eoseungsaengak (OSSA); 29, Lake Saraoreum (SROR). Sites 4–6, Peatlands of Jiri and Duncheol Mountain in Sancheong; 7–14, Mountain peatlands in southeastern regions of South Korea; 15–24 Peatlands in Ulsan and Yangsan near Jeongjok Mountain; 26–29, Peatlands (26 and 27) and crator lakes (28 and 29) of Halla Mountain in Jeju Island. Except for the peatlands, important sampling areas are presented (black rectangules): A, Dongsong Reservoir in Cheolwon; B, Streams of Odo Mountain in Hapcheon; C, Lowland wetlands in Haman; D, Rice paddies in Wando.

(4) *Stauroneis anceps* Ehrenberg 1843 sensu stricto (Pl. 1, Figs. 7 and 8) (Lange-Bertalot et al. 2003, p. 132, pl. 35: 1-12, pl. 38: 14; Van de Vijver et al. 2004, pl. 43: 1, 2; Bahls 2011a). Valves lanceolate to linear-lanceolate in outline, the ends of the valve moderately protracted and rostrate. The stauros rectangular and slightly expanded towards the margins. Valves 32.5–43 µm in length, 9.5–10 µm in breadth, striae 22–24 rows and puncta of the striae 20–28 in 10 µm. Reichardt (1995) designated the lectotype for this species from a specimen in Ehrenberg's type material collected from Cayenne, French Guyana (Van de Vijver et al. 2004). This species is the most popular and common in Korean freshwaters and was reported 22 times before 1997 (Lee 1997). However, *S. anceps* sensu stricto is found less frequently, occurring rarely in lowland wetlands in Haman.

(5) **Stauroneis borgei* Manguin 1941 (Pl. 5, Fig. 8). Synonym: *Stauroneis smithii* var. *borgei* (Manguin) Hustedt 1959 (Hustedt 1959, p. 811, f. 1157h–k). Valves elliptical to rhombic-lanceolate with convex margins, the ends of the valve not protracted, and pseudosepta developed near the ends. Axial area narrow and stauros in the central area rectangular, extending to the margins of the valve. Valves 20 µm in length, 7.6 µm in breadth and striae fine and not resolved in light microscopy. Occurring only in a lake, Dongsong Reservoir in Cheolwon, and newly reported to Korea.

(6) **Stauroneis elena* Kulikovskiy, Lange-Bertalot & Witkowski 2010 (Pl. 3, Figs. 9 and 10) (Kulikovskiy et al. 2010, p. 59, pl. 92: 1, 2). Valves elliptical-lanceolate in outline, the ends of the valve protracted and broadly rostrate. The stauros in central area expanded towards the margins. Valves 121–133 µm in length, 26–26.5 µm in breadth and striae 17–18 rows in 10 µm. Occurring rarely in mountaion peatlands, YN Peatland of Daeam Mountain in Inje and WDJ Peatland of Jiri Mountain in Sancheong, and newly reported to Korea.

(7) **Stauroneis circumborealis* Lange-Bertalot & Krammer 1999 (Pl. 6, Fig. 1) (Van de Vijver et al. 2004, p. 31, pl. 10: 1-4, pl. 11: 1-3). Valves broadly elliptic-lanceolate in outline, the ends of the valve slightly protracted and rounded. The central ends of the raphe strongly curved and the terminal pores of the raphe drop-like expanded. The hyaline stauros of the central area rectangular, strongly expanded towards the margins, and some shortened striae in the margins. Valves 101-111 µm in length, 24-25.5 µm in breadth, striae 17-18 rows in 10 µm, and puncta in a stria 14-16 in 10 µm.

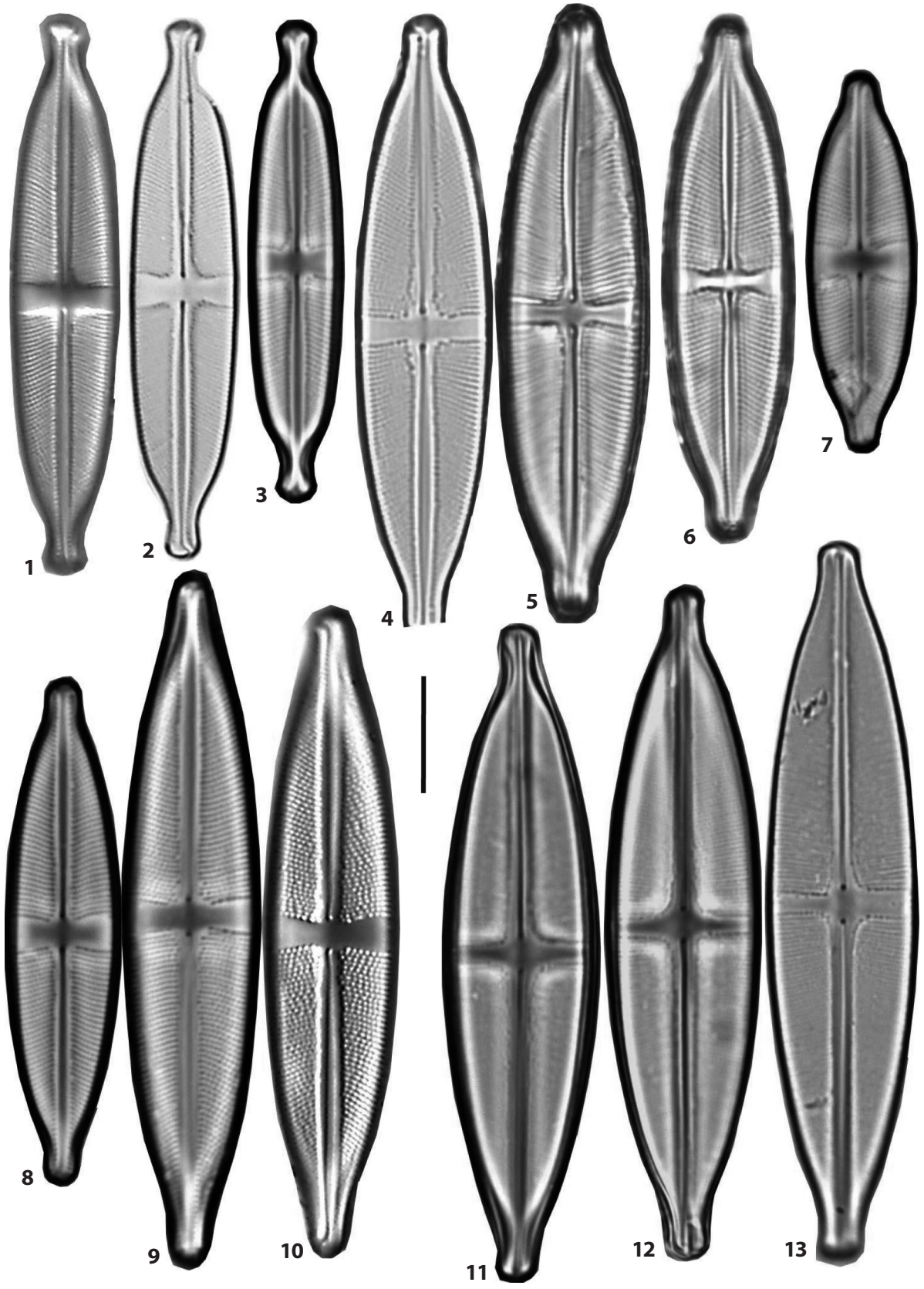

Plate 1. **Figs. 1–3.** *Stauroneis reichardtii*, **Figs. 4–6.** *S. amphicephala*, **Figs. 7, 8.** *S. anceps*. **Figs. 9, 10.** *S. jarensis*, **Figs. 11–13.** *S. siberica*. Scale bars, 10 μm (×2000 magnification).

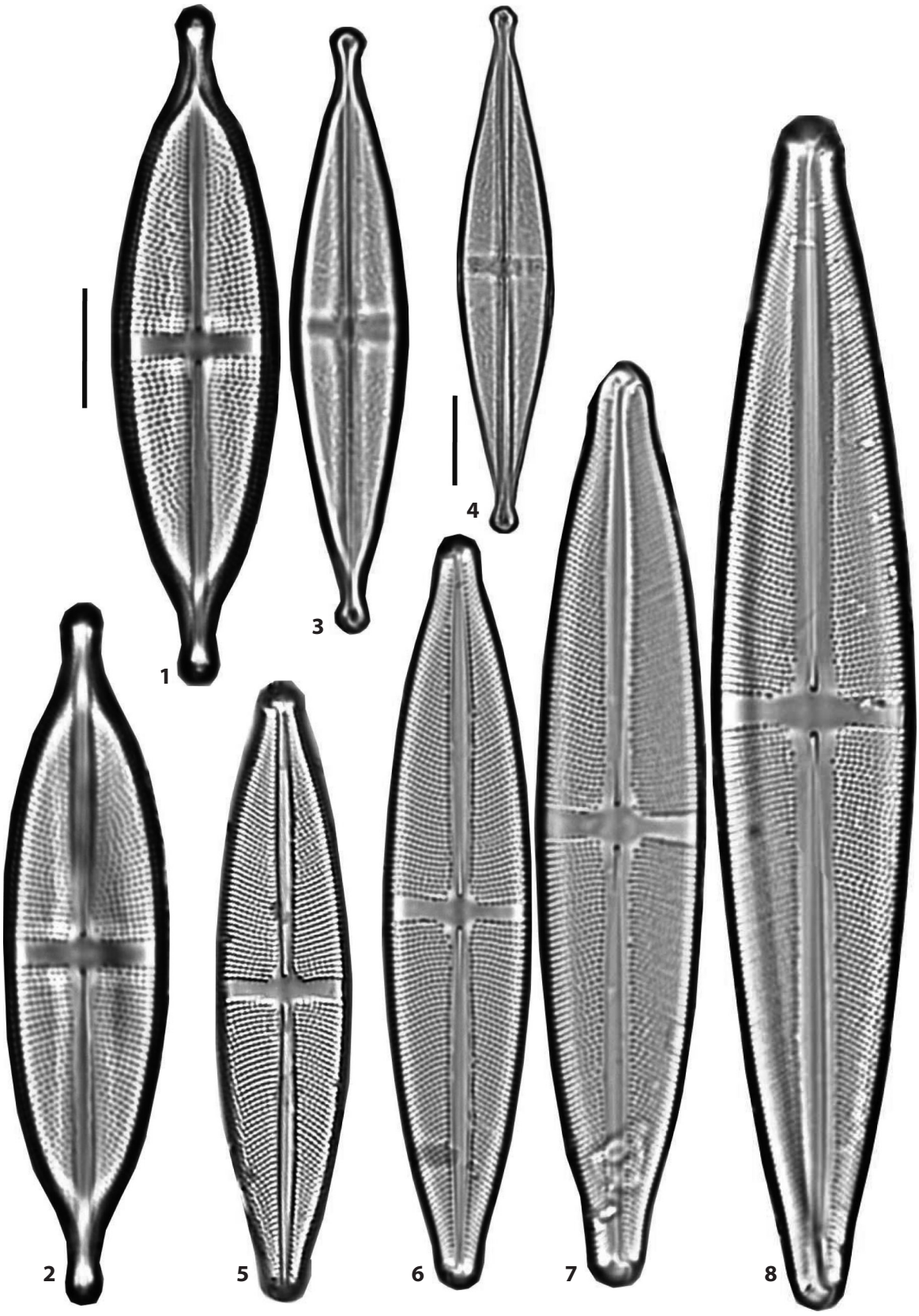

Plate 2. Figs. 1, 2. *Stauroneis ancepsopsis*, **Figs. 3, 4.** *S. gracilior*, **Figs. 5, 6.** *S. subgracilis*, **Figs. 7, 8.** *S. gracilis*. Scale bars, 10 μm (×1500 magnification in Fig. 4 and ×2000 in others).

Occurring very rarely in a lowland wetland in Haman and newly reported to Korea. The striae of the valve in the local specimens are sparsely arranged, 13-16 rows in 10 μm, less than 18-20 rows in 10 μm in the original description.

(8) *Stauroneis gracilior* Reichardt 1995 (Pl. 2, Figs. 3 and 4) (Lange-Bertalot et al. 2003. pl. 55: 1-11, pl. 56: 1, 2; Van de Vijver et al. 2004. p. 37. pl. 76: 1-10, pl. 77: 1-4). Replaced synonym: *Stauroneis anceps* f. *gracilis* Rabenhorst 1864, p. 247 (Krammer and Lange-Bertalot 1986, pl. 87: 9). Valves typically lanceolate, the breadth of the valve sharply narrow towards the ends, the ends of the valve long protracted and rostrate to capitate. The stauros rectangular and not expanded towards the ends. Valves 51–59 μm in length, 10–10.5 μm in breadth, and striae very fine and unresolved under light microscopy. *Stauroneis gracilior* Reichardt, *S. schroederi* Hustedt and *S. subgracilior* Lange-Bertalot et al., are closely related in the valve morphology, and make a group of species within the genus (Van de Vijver et al. 2004). Very rare in Dongsong Reservoir in Cheolwon.

(9) *Stauroneis gracilis* Ehrenberg 1843 (Pl. 2, Figs. 7 and 8) (Van de Vijver et al. 2004, p. 38, pl. 17: 1–4, pl. 18: 1–4, pl. 19: 1–4, pl. 20: 1–4). Valves lanceolate to somewhat linear-lanceolate in outline, the ends of the valve slightly protracted and broadly subrostrate. The stauros in central area weakly expanded towards the margins. Valves 66–100 μm in length, 14–17 μm in breadth and striae 18–19 rows in 10 μm. In a bibliotheca of genus *Stauroneis* written by Van de Vijver et al. (2004), *S. gracilis* and *S. subgracilis* were closely related in the valve morphology, and it was hard to discriminate two species each other. The dimensions or breadth of the valve and the density of striae are used to differentiate the species, and the valve of *S. gracilis* is wider than 14 μm in breadth and striae are less than 19 rows in 10 μm. Frequent in an unnamed peatland in DGR Pasture in Pyeongchang.

(10) **Stauroneis gracillima* Hustedt 1943 (Pl. 3, Figs. 1–6) (Krammer and Lange-Bertalot 1986, p. 248, pl. 90: 28–30; Simonsen 1987, p. 311, pl. 469: 7–10). Valves linear with parallel or slightly convex margins, the ends of the valve protracted and capitate. The stauros in central area extended to the margins. Valves 10–14 μm in length, 2.5–3 μm in breadth and striae unresolved in light microscopy. Widely distributed in mountain peatlands and oligotrophic freshwaters in Korea, and newly reported to Korea.

(11) **Stauroneis heinii* Lange-Bertalot & Krammer 1999 (Pl. 3, Figs. 7 and 8) (Van de Vijver et al. 2004, p. 40, pl. 1: 1). Valves lanceolate in outline, the ends of the valve slightly protracted and broadly subrostrate. The stauros in central area rectangular or weakly expanded towards the margins. Valves 99.5–168 μm in length, 20–33.5 μm in breadth and striae 16–17 rows in 10 μm. Frequently occurring in mountain wetlands, MJC3 Peatland in Ulsan and an unnamed peatland of DGR Pasture in Pyeongchang, and newly reported to Korea.

(12) **Stauroneis jarensis* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito 2003 (Pl. 1, Figs. 9 and 10) (Van de Vijver et al. 2004, p. 44, pl. 31: 1–10, pl. 32: 1–3, pl. 33: 1–6). Valves lanceolate to linear-lanceolate in outline, the ends of the valve protracted and rostrate. The stauros in central area expanded towards the margins. Valves 45–59.5 μm in length, 9–12 μm in breadth and striae 23–24 rows in 10 μm. Rare in YN Peatland of Daeam Mountain in Inje, and newly reported to Korea.

(13) *Stauroneis kriegeri* Patrick 1945 (Pl. 4, Figs. 1–5; Pl. 5, Fig. 11) (Van de Vijver et al. 2004, p. 45, pl. 59: 1–17). Valves linear with parallel or slightly convex margins, the ends of the valve broadly protracted and more or less capitate. The stauros in central rectangular extending to the margins. Valves 19–25 μm in length, 4–5 μm in breadth and striae unresolved in light microscopy. Widely distributed in mountain peatlands and some oligotrophic freshwaters, and more frequent in two mountain wetlands, DSA Peatland near Jeonjok Mountain in Yangsan and JD Peatland of Jang Island in Sinan.

(14) **Stauroneis kuelbsii* Lange-Bertalot 2004 (Pl. 6. Figs. 3–5) (Van de Vijver et al. 2004, p. 45, pl. 40: 17). Valves lanceolate to linear-lanceolate in outine, the ends of the valve more or less abruptly protracted, subrostrate or subcapitate. The central ends of the valve curved. The hyaline stauros of the central area rectangular and slightly expanded towards the margins. Valves 59-80 μm in length, 13-16 μm in breadth, and striae 16-17 rows in 10 μm. Occurring rarely in lowland wetlands in Haman and newly reported to Korea.

(15) *Stauroneis nobilis* Schumann 1867 (Pl. 4, Fig. 7) (Krammer and Lange-Bertalot 1986, p. 242, pl. 87: 1, 2). Valves rhombic-lanceolate in outline, the ends of the valve long protracted and capitate. The stauros in central area rectangular and narrow towards the margins. Valves 80–108 μm in length, 16.5–25 μm in breadth, striae 16–17 rows in central area, but 19–21

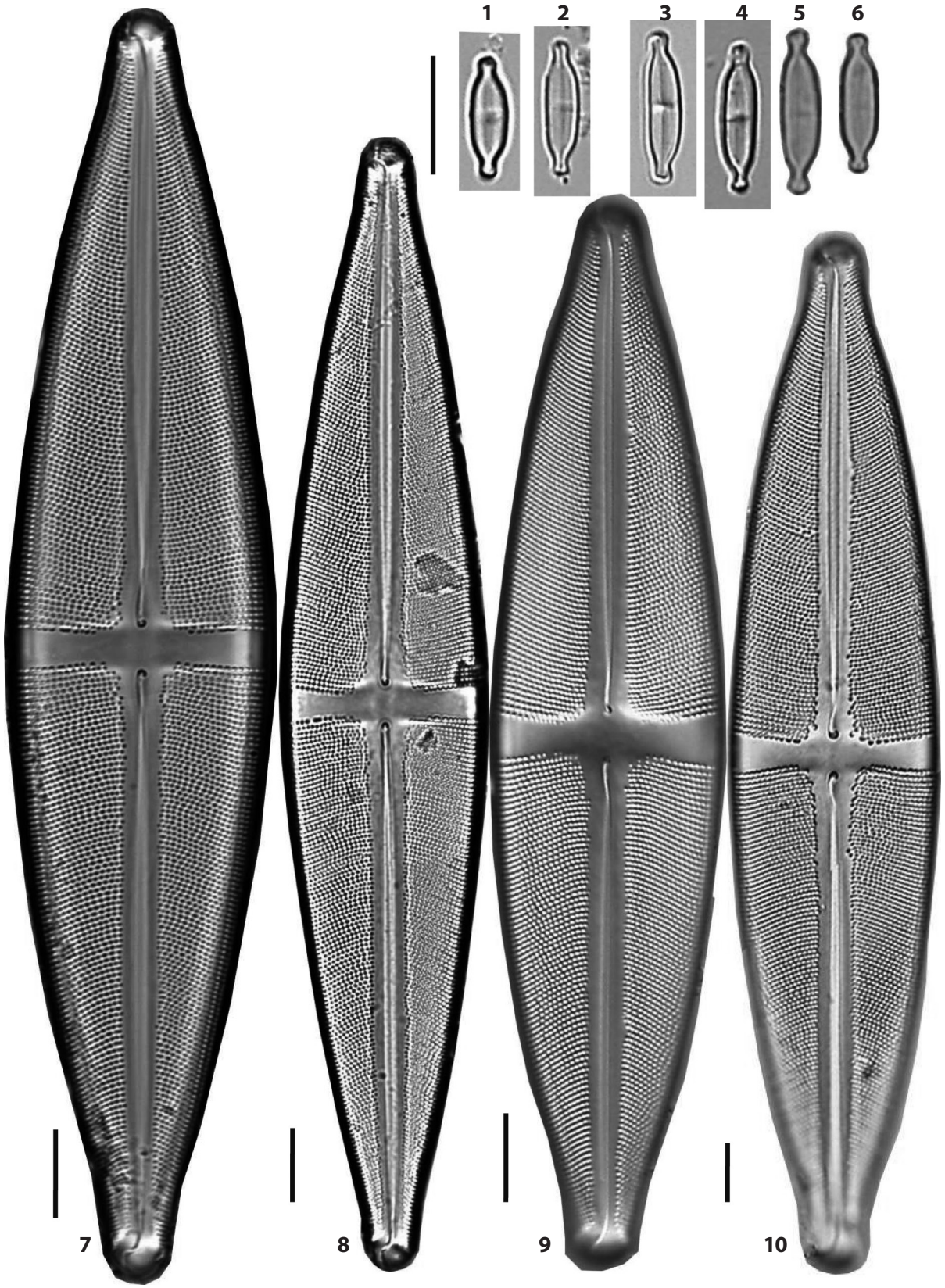

Plate 3. Figs. 1–6. *Stauroneis gracillima*, **Figs. 7, 8.** *S. heinii*, **Figs. 9, 10.** *S. elena*. Scale bars, 10 μm (×1000 magnification in Fig. 10, ×1250 in Fig. 8, ×1500 in Figs. 7 and 9, and ×2000 in others).

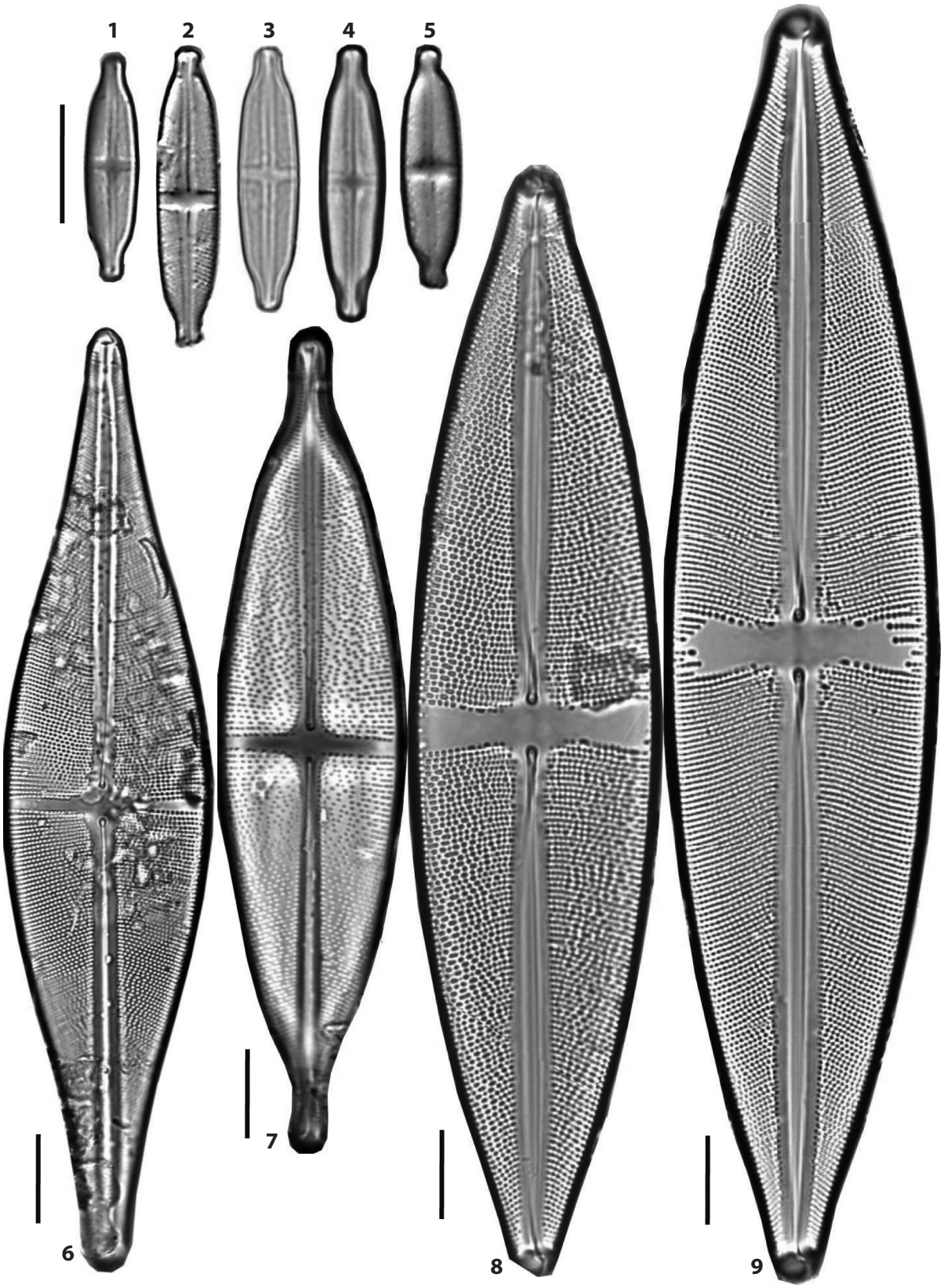

Plate 4. Figs. 1–5. *Stauroneis kriegeri*, **Fig. 6.** *S. alabamae*, **Fig. 7.** *S. nobilis*, **Figs. 8, 9.** *S. sonya*. Scale bars, 10 μm (×1500 magnification in Figs. 6–9 and ×2000 in others).

rows in 10 μm in the terminal ends. Occurring frequently in Korean freshwaters, the lowland wetlands in Haman (Chung and Noh 1987), in Gwang River of Uljin (Lee et al. 1994), and recently rare in Dongsong Reservoir in Cheolwon.

(16) **Stauroneis prominula* (Grunow) Hustedt 1959 (Pl. 5, Figs. 1 and 2) (Krammer and Lange-Bertalot 1986, p. 247, pl. 90: 16–20). Valves linear with slightly triundulate margins, the ends of the valve narrow protracted and rostrate, and pseudosepta developed. Axial area narrow. Axial area narrow and the stauros in the central area rectangular, extending to the margins of the valve. Valves 27–30 μm in length, 4–5 μm in breadth, and striae fine and unresolved in light microscopy. The species was found in two wetlands, JD Peatland of Jang Island in Sinan, and OGG Peatland of Jiri Mountain in Sancheon and is new to Korea.

(17) **Stauroneis pseudosmithii* Van de Vijver & Lange-Bertalot 2004 (Pl. 5, Figs. 4–7) (Van de Vijver et al. 2004, p. 58, pl. 103: 1–11, pl. 104: 1–14). Valves narrow linear-lanceolate with triundulate margins, the ends of the valve narrow protracted and rostrate, and pseudosepta developed near the ends. Axial area narrow and the stauros in the central area rectangular, extending to the margins of the valve. Axial area narrow. Valves 27–30 μm in length, 5–5.5 μm in breadth and striae fine and unresolved in light microscopy. Very rare in a small pool of Baekyang Mountain in Busan and JD Peatland of Jang Island in Sinan, and recently occurring in mosses of Daebong Reservoir in Changnyeong, and newly reported to Korea.

(18) **Stauroneis reichardtii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito 2003 (Pl. 1, Figs. 1–3) (Lange-Bertalot et al. 2003, p. 142, pl. 36: 1–8, pl. 37: 1–14, pl. 61: 6, 7; Van de Vijver et al. 2004, p. 60, pl. 54: 6–12, pl. 55: 1–13, pl. 56: 1–5). Valves linear to slightly linear-lanceolate, the ends of the valve protracted and capitate. The stauros of the central area almost rectangular, hardly expanded towards the ends. Valves 41–48 μm in length, 8–9 μm in breadth and striae 23–26 rows in 10 μm. *Stauroneis reichardtii* is closely similar to *S. acidoclinatopsis* Van de Vijver & Lange-Bertalot, and the former has more lanceolate outline of the valve and the bigger dimensions. It was found in some mountain peatlands, especially in DGR peatland in Pyeongchang and is new to Korea.

(19) **Stauroneis respectabilis* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito 2003 (Pl. 6, Fig. 2) (Lange-Bertalot et al. 2003, p. 144, pl. 31: 3, 4, pl. 32: 1-5, pl. 33: 1, 2). Valves lanceolate in outline, the ends of the valve weakly protracted or not protracted. The central ends of the raphe almost straight and the central pores of the raphe expanded. The hyaline stauros of the central area rectangular and more or less expanded towards the margins. Valves 102-133 μm in length, 21.5-25.3 μm in breadth, striae 16 rows in 10 μm, and puncta in a stria 16-18 in 10 μm. Occurring very rarely in lowland wetlands in Haman and newly reported to Korea. This species is very close to *S. phoenicenteron* (Nitzsch) Ehrenberg sensu stricto in the valve morphology, but differs in the dimensions, the lower valve length and breadth. *S. phoenicenteron* has large dimensions in valve, larger than 150 μm in length and 28 μm in breadth, though it has not been observed in this study.

(20) *Stauroneis sagitta* Cleve 1881 (Pl. 5, Figs. 9 and 10) (Van de Vijver et al. 2004, p. 63, pl. 101: 1–12, pl. 102: 1–4). Synonym: *Stauroneis smithii* var. *sagitta* (Cleve) Hustedt 1959 (Hustedt 1959, p. 810, f. 1158). Valves elliptical-lanceolate to rhombic-lanceolate with triundulate and convex margins, the ends of the valve narrow protracted and rostrate, and pseudosepta developed near the ends. Axial area narrow and the stauros in the central area rectangular, extending to the margins of the valve. Valves 31–41 μm in length, 8–9 μm in breadth and striae 23–24 rows in 10 μm. Occurring only in a lake, Dongsong Reservoir in Cheolwon.

(21) *Stauroneis siberica* (Grunow) Lange-Bertalot & Krammer in Lange-Bertalot and Metzeltin 1996 (Pl. 1, Figs. 11–13) (Lange-Bertalot and Metzeltin 1996, p. 104, pl. 35: 1, 2, pl. 104: 43, 44. Bahls 2011b). Basionym: *Stauroneis anceps* var. *siberica* Grunow in Cleve and Grunow 1880. Valves elliptical-lanceolate in outline, the ends of the valve protracted and rostrate to subcapitate. Axial area narrow. The stauros in central area narrow toward valve margins and areolae bordering the stauros coarse. Valves 55.5–62 μm in length, 13 μm in breadth and striae very fine, 26–27 rows in 10 μm. Transapical striae are very fine. This species was reported in the Kwang River in Uljin (Lee et al. 1994) and was rare in a pool of Odo Mountain in Hapcheon in this study.

(22) *Stauroneis smithii* Grunow 1860 (Pl. 5, Fig. 3) (Hustedt 1959, p. 810, f. 1157a–c). Valves lanceolate with triundulate and convex margins, the ends of the valve narrow protracted and rostrate, and pseudosepta developed near the ends. Axial area narrow and the stauros in the central area rectangular, extending to the margins of the valve. Valves 25 μm in length, 5.5 μm in breadth, and striae fine and unresolved in light

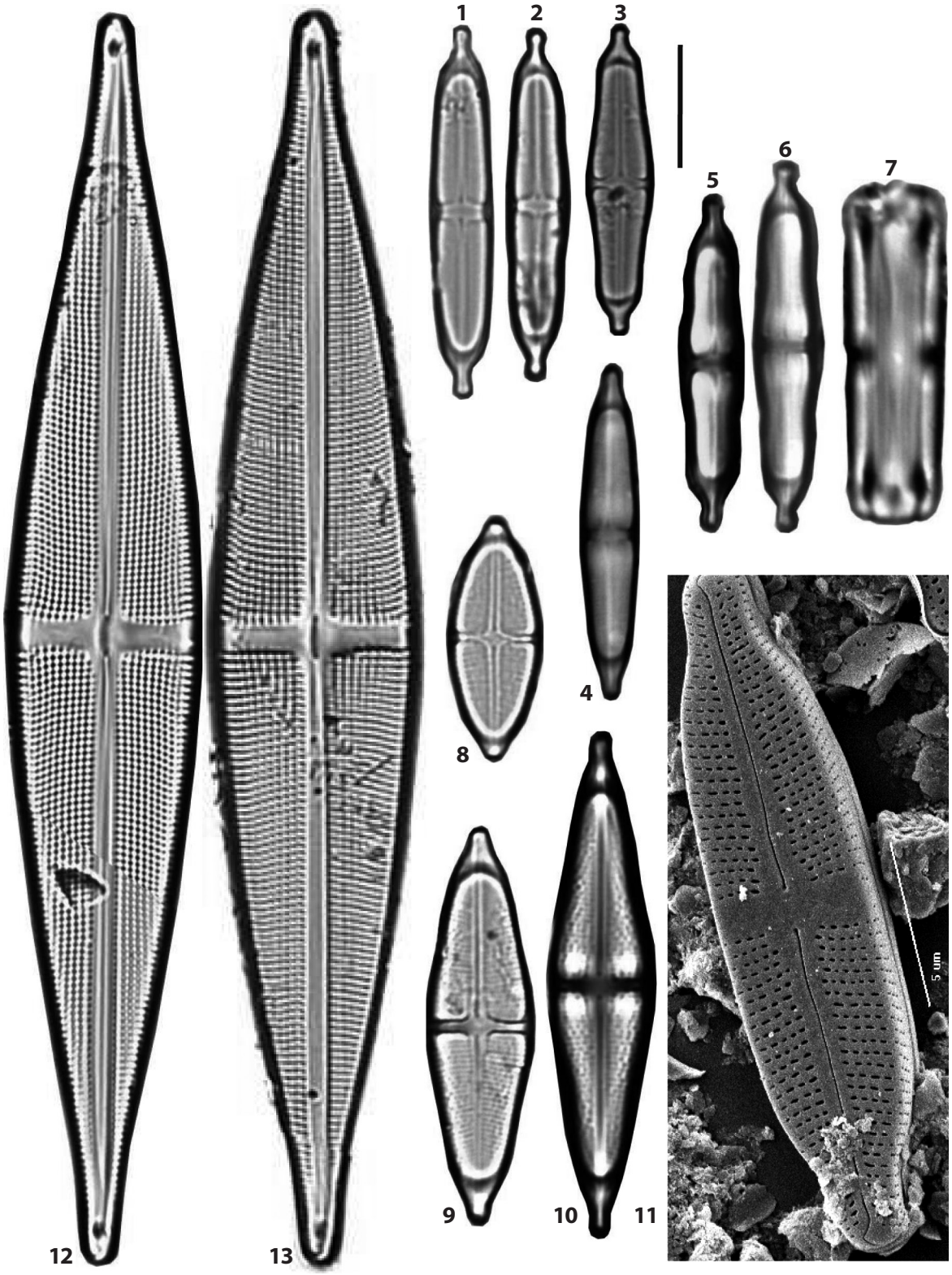

Plate 5. Figs. 1, 2. *Stauroneis prominula*, **Fig. 3.** *S. smithii*, **Figs. 4–7.** *S. pseudosmithii*, **Fig. 8.** *S. borgei*, **Figs. 9, 10.** *S. sagitta*, **Fig. 11.** *S. kriegeri*, **Figs. 12, 13.** *S. sturolineata* var. *japonica*. Scale bars, 10 μm (×2000 magnification).

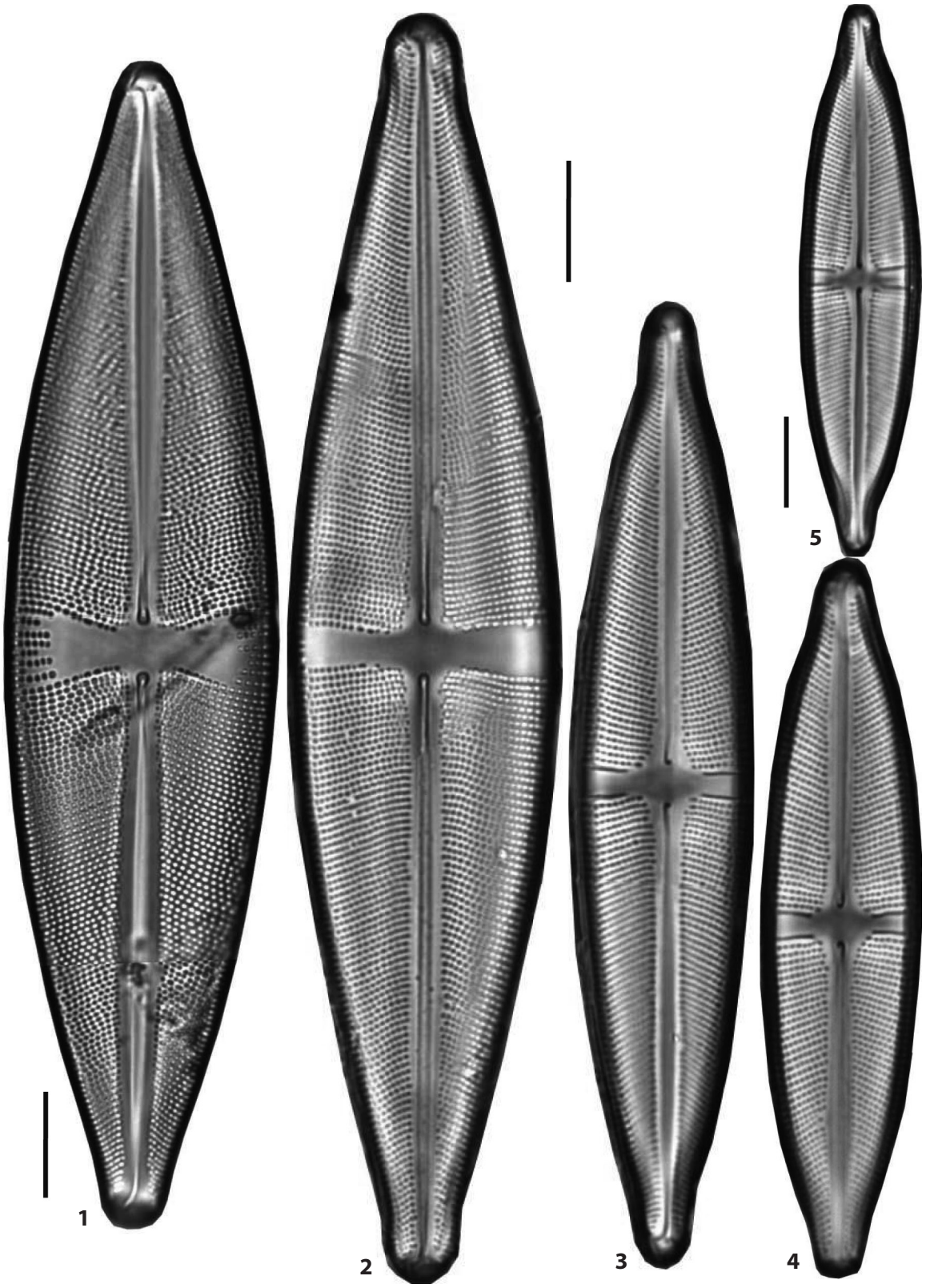

Plate 6. **Fig. 1.** *Stauroneis circumborealis*. **Fig. 2.** *Stauroneis respectabilis*. **Figs. 3–5.** *Stauroneis kuelbsii*. Scale bars, 10 μm (×1750 magnification in Fig. 1, ×1500 in Fig. 5, and ×2000 in others).

microscopy. Very rare in the JD Peatland of Jang Island in Sinan.

(23) **Stauroneis sonya* Kulkovskiy, Lange-Bertalot & Dorofeyuke 2010 (Pl. 4, Figs. 8 and 9) (Kulikovskiy et al. 2010, p. 62, pl. 93: 1–3, pl. 94: 1–3). Valves lanceolate to elliptical-lanceolate in outline, the ends of the valve not protracted and obtusely rounded. Axial area wide, the stauros in the central area rectangular, expanding towards the margins, and irregularly shortened striae in the margins. The central ends of the raphe reversely curved. Valves 121–142 µm in length, 26.5–34.5 µm in breadth, and striae 15–17 rows in 10 µm. Occurring more frequently in a mountain peatland of Jang Island in Sinan and an unnamed peatland of DGR Pasture in Pyeongchang and newly reported to Korea.

(24) **Stauroneis staurolineata* var. *japonica* Kobayasi & Ando 1978 (Pl. 5, Figs. 12 and 13) (Kobayasi and Ando 1978, p. 15–16, pl. 2: 18–20). Valves lanceolate in outline, the ends of the valve not protracted and acute. The stauros in central area rectangular extending to the margins. Valves 99–114.5 µm in length, 16–18 µm in breadth and striae 15–18 rows in 10 µm. Only occurring in TH Peatland of Halla Mountain in Jeju Island and newly reported to Korea.

(25) **Stauroneis subgracilis* Lange-Bertalot & Krammer in Lange-Bertalot and Genkal 1999 (Pl. 2, Figs. 5 and 6) (Van de Vijver et al. 2004, p. 71, pl. 27: 1–6, pl. 28: 1–6, pl. 29: 1–6). Valves lanceolate to elliptical-lanceolate in outline, the ends of the valve weakly protracted and broadly subrostrate. The stauros in central area rectangular extending to the margins. Valves 43–71 µm in length, 11–14 µm in breadth and striae 20–24 rows in 10 µm. This species is most similar in morphology of *S. pergracilis* Van de Vijver & Lange-Bertalot but distinguished by the lanceolate form of the valve rather than the linear to linear-lanceolate form. Rare in mountain wetlands, DJ Peatland of Yeongchuk Mountain in Yangsan and SMBD Peatland of Halla Mountain in Jeju Island, and newly reported to Korea.

Stauroneis diatoms occurred in most samples collected from peatlands and oligotrophic bodies of water, whereas they were scarcely found in eutrophic or polluted habitats. The relative abundance of *Stauroneis* diatoms in peatlands ranged from 0.1% to 3.4% of all diatom frustules, while two sites showed an exceptional abundance with about 7.6% and 10%, respectively. It was found that individual peatlands are typically inhabited by 2–6 *Stauroneis* species. On the other hands, two sampling areas, the mountain peatland of Jang Island in Sinan and an unnamed peatland of DGR Pasture in Pyeongchang showed high species richness of genus *Staurones*. The influence of pH and alkalinity on the abundance and richness of *Stauroneis* diatoms was evident, despite the relatively low abundance of this genus's diatoms. More strongly acidic areas are characterized by low abundance and richness.

Throughout the whole sampling area, the most frequent and abundant species in the peatlands were *S. kriegeri* Patrick in the small forms and *S. elena* Kulikovskiy et al. in the large forms. Many species occurred in only one or two localities, including *S. sonya* Kulikovskiy et al., *S. elena* Kulikovskiy et al., *S. ancepsopsis* Lange-Bertalot et al. and *S. gracilior* Reichardt in the large forms, and *S. smithii* and its infraspecific taxa in the small forms.

This survey of the *Staurones* diatoms was restricted to the mountain peatlands, the headwaters of the streams, upstream waters, pools and reservoirs, and oligotrophic waters. Through this survey, it was evident that *Stauroneis* diatoms prefer acidic or oligotrophic freshwaters. *Stauroneis* was scarce in rivers and lakes, while a variety of *Stauroneis* taxa were found in the mountain peatlands or oligotrophic habitats.

Small forms of *Stauroneis* diatoms, *Stauroneis gracillima* (Grunow) Hustedt and *S. kriegeri* Patrick, were more widely distributed over the sampling area than large forms, as large forms tend to be discretely dispersed. Large-sized taxa were found to be restricted to only one or sometimes two areas or one island, for example, *S. ancepsopsis* Lange-Bertalot et al. only in a rice paddy, *S. staurolineata* var. *japonica* Kobayasi & Ando in TH Peatland of Halla mountain, and *S. sonya* Kulkovskiy, Lange-Bertalot & Dorofeyuke in JD peatland of Jang Island and DGR Pasture in Pyeongchang. The high degree of endemism of genus *Stauroneis* is shown in the Antarctic regions and northern Rocky Mountains (Van de Vijver et al. 2005, Bahls 2012).

Peatlands in mountainous area are likely a kind of isolated and undisturbed habitats, differing from the homogeneous surrounding areas. A large number of *Stauroneis* taxa have also been newly discovered in Antarctica and the Arctic, the Rocky Mountains, Sardinia and tropical regions (Lange-Bertalot et al. 2003, Van de Vijver et al. 2004, Metzeltin and Lange-Bertlaot 2007, Bahls 2010). The local endemics of *Stauroneis* species can be applied to this work. In Korea, a total of 22 taxa have been reported from a variety of freshwaters according to Lee et al. (1995) and Lee (1997). They accounted for 12 taxa mainly *S. anceps* Ehremberg sensu lato and *S. phoenicenteron* (Nitzsch) Ehrenberg sensu lato and their infraspecies, variety or

forma. The two species of *Stauroneis* are well known to be widely distributed over the freshwaters. However, *S. anceps* and *S. phenicenteron* sensu lato taxon have been revised on the basis of the narrow species concept, thus being separated from the existing taxa, with a number of new species described in the Antarctic regions, Sardinia in the Mediterranean Sea and some other regions (Lange-Bertalot et al. 2003, Van de Vijver et al. 2004). In the current study, of the twenty five species are reported, sixteen are described for the first time in Korea.

Regardless of the endemics of *Stauroneis* diatoms, they are less abundant and diverse in particular various habitats. The algal assemblages in peatlands are largely dominated by diatoms and *Stauroneis* diatoms that are large in size compared with other diatoms. The largeness of *Staurones* can be correlated with their biomass. Species diversity has significant correlation with algal biomass. The significant negative linear correlation between largeness and algal biomass exists and algal biomass is dominated by the smaller diatoms (Eloranta 1993). Besides of the genus *Stauroneis*, other species-rich genera are *Pinnularia*, *Eunotia*, *Neidium*, and *Frustulia*, and the mountain peatlands support the abundance and species diversity of these diatoms. Thus, the protection of the habitat for the diatom biodiversity should be very important.

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