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TAXONOMIC NOVELTIES

Selaginella kualaensis (Selaginellaceae), a new spikemoss from Malay Peninsula

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ABSTRACT

Selaginella kualaensis (Selaginellaceae), a new species from Malay Peninsula, is described and illustrated based on evidence from gross and micro-morphology. The new species prefers to grow on damp banks in mangrove forests. Morphologically, the new species mostly resembles *S. ornata* in stem creeping, stem and ultimate branches broad. However, it can be distinguished from the latter by the tightly spaced and imbricate (or contiguous) ventral leaves, margins of sterile leaves denticulate-ciliolate, shorter and compact strobili, features of megaspores (verrucate, with dense spinules microsculpture) and microspores (densely verrucate and covered with fine grains microsculpture).

Keywords: endemic, new species, mangrove forest, Malay Peninsula, Selaginellaceae, taxonomy

РЕЗЮМЕ

Шалимов А.П., Чжан М.-Х., Чжан С.-Ч. *Selaginella kualaensis* (Selaginellaceae), новый вид селягинеллы с Малайского полуострова. *Selaginella kualaensis* (Selaginellaceae), новый вид с полуострова Малайзия, описан и иллюстрирован на основе данных общей и микро-морфологии. Новый вид предпочитает расти по влажным берегам в мангровом лесу. Морфологически, новый вид напоминает *S. ornata* своим ползучими стеблями, широкими стеблями и боковыми ветвями. Однако от последнего его можно отличить по плотно расположенным и черепитчатым (или сближенным) вентральным листьям, зубчато-реснитчатому краю вегетативных листьев, коротким и компактным стробилам, признакам мегаспор (бородавчатые, с плотно игольчатой микроскульптурой) и микроспор (плотно бородавчатые, покрытые мелкозернистой микроскульптурой).

Ключевые слова: мангровые леса, новый вид, Малайский полуостров, Selaginellaceae, таксономия, эндемик

The cosmopolitan lycophyte genus *Selaginella* P. Beauv. (Selaginellaceae Willk.) is widely distributed in tropical and subtropical regions, with more than 700 species (Jermy 1986, Valdespino 1993, Zhang et al. 2013, Zhou et al. 2015a, PPG I 2016, Weststrand & Korall 2016, POWO 2023).

The first taxonomic studies on the genus *Selaginella* in Malay Peninsula were conducted in the first half of the 20th century by Van Alderwerelt van Rosenburgh (1915), Ridley (1919), and Alston (1934). Later, Wong (1982 and 2010) performed a comprehensive taxonomic and morphological study on the Malay Peninsula species of *Selaginella*, estimating 29 species. Zhang & Tan (2013) added *S. braunii* Baker and *S. siamensis* Hieron. as new record for Malay Peninsula. According to Wong (1982, 2010), there are only nine species of anisosporophyllous *Selaginella* distributed in Malay Peninsula, including *S. alutacea* Spring, *S. ciliaris* (Retz.) Spring, *S. curtisii* Ridl., *S. minutifolia* Spring, *S. morgani* Zeiller, *S. ornata* (Hook. & Grev.) Spring, *S. polita* Ridl., *S. scabrida* Ridl. and *S. repanda* (Desv. & Poir.) Spring.

During the audit of herbarium collections of *Selaginella* from Southeast Asia, one specimen from Malay Peninsula in the Herbarium of Moscow State University (MW) caught our attention (Fig. 1). Subsequent analysis of relevant literature for the East and Southeastern Asian *Selaginella* (Van Alderwerelt van Rosenburgh 1915, Ridley 1919, Alston 1934, 1945, 1951, Tagawa & Iwatsuki 1979, Wong 1982, 2010, Zhang et al. 2013, Huang et al. 2022) showed that this unknown species did not match in morphology characters with previously known species with dimorphic strobilus. Critical examination of herbarium specimens and comparison with type material and protologues for Malaysian, Chinese, and Indo-Chinese anisosporophyllous *Selaginella* species, led to the conclusion that it is a new species. The species is similar to *S. ornata*, such as the creeping or slightly ascending and broad main stems, the shape of the ventral and dorsal leaves, but distinct in the vegetative leaf margins being denticulate-ciliolate, shorter and compact strobili, and spore morphology.

MATERIAL AND METHODS

This study was based on examination of specimens deposit at CDBI, KUN, MW, MHA, and PE, and high-resolution digital images including type collections from B, BM, BR, DUKE, E, K, KLU, L, MICH, MO, NY, P, SING, U, UC and US. All morphological characters were observed and photographed with the Olympus DP74 camera attached to the Olympus SZX16 stereomicroscope at the Altai State University (Barnaul, Russia). Digital images were montaged using Helicon Focus and Zerene Stacker software. The application ImageJ (https://imagej.nih.gov/ij/) was used to measure morphological characteristics (such as axillary, dorsal, ventral leaves, stems and strobili).

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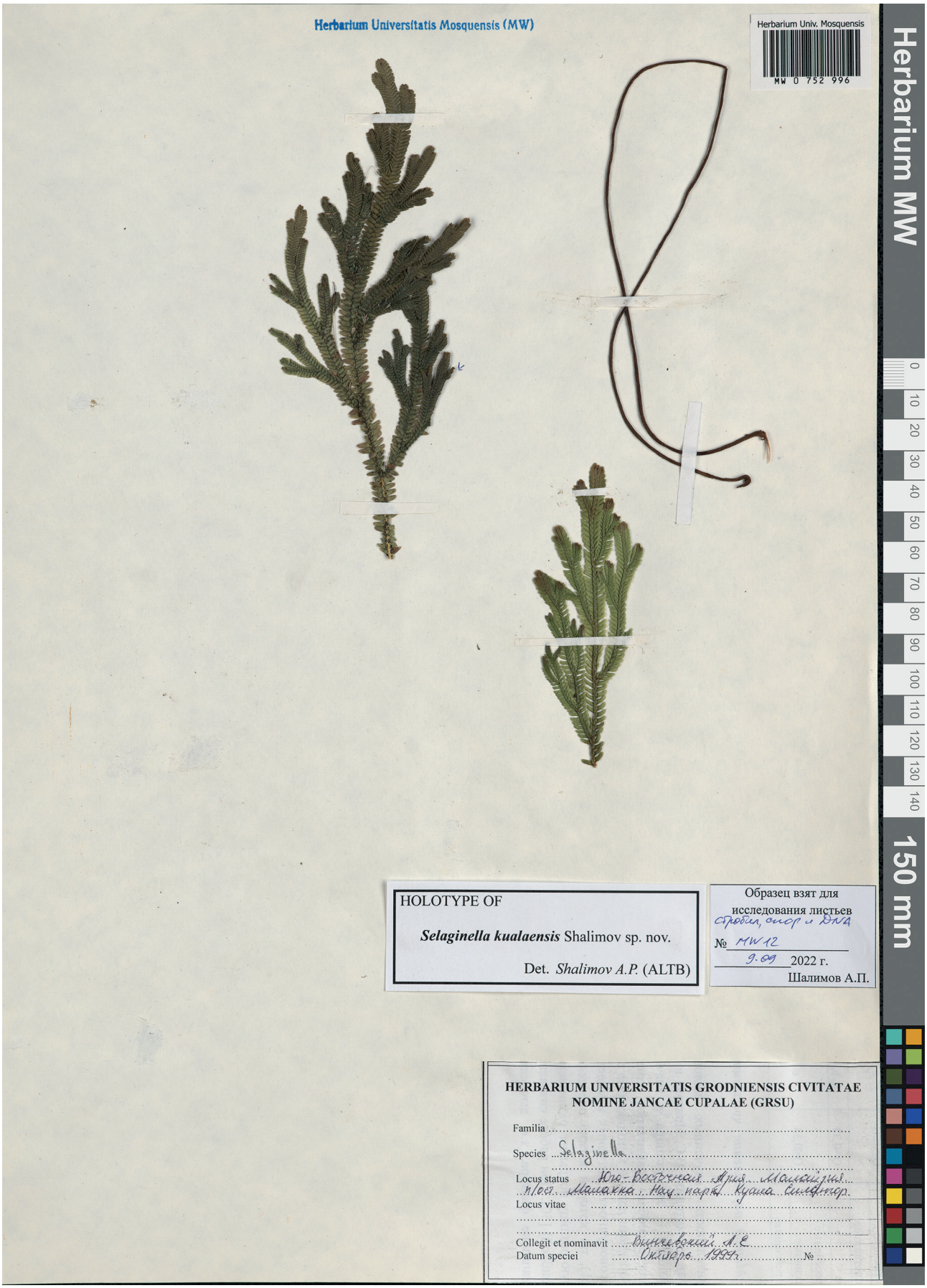

Figure 1 *Selaginella kualaensis* Shalimov, **sp. nov.** Digitized images of holotype: Vintchevski A.E. (holo- MW0752996)

Samples of spores for Scanning Electron Microscopy (SEM) were taken without treatment from herbarium specimens. The spores were taken from mature sporangia, mounted on double-sided sticky tape, and sputter-coated with gold palladium. Spores were photographed and measured under different magnifications using a Hitachi – S3400 N at 10–20 kV in the Shared research facilities of microscopy and X-ray spectroscopy of the Institute for Water and Environmental Problems, Siberian Branch of the Russian Academy of Sciences (Barnaul, Russia). The morphological terminology of spores and gross morphology followed Lellinger (2002), Zhou et al. (2015), and Zhang et al. (2013).

TAXONOMIC TREATMENT

Selaginella kualaensis Shalimov **sp. nov.** (Figs 1–3).

Holotype: MALAYSIA: "Southeast Asia, Malaysia, Malay Peninsula, Kuala Selangor National Park, X 1999, A.E. Vintchevski" – [Юго-восточная Азия, Малайзия, полуостров Малакка, Национальный парк Куала Селангор, X 1999, A.E. Винчевский] (MW0752996).

Diagnosis. *Selaginella kualaensis* is morphologically similar to *S. ornata* in habit and gross morphology but differs in its the tightly spaced and imbricate (or contiguous) ventral leaves on main stems and branchlets (vs. distant or contiguous); ventral leaves ovate-triangular or oblong-ovate, 2.5–4.5 × 0.6–2.1 mm (vs. oblong or oblong-falcate, 3.5–5 × 1.2–2.2 mm), acroscopic margin denticulate-ciliolate (vs. denticulate); dorsal leaves broadly ovate, 2.0–4.5 × 0.8–1.1 mm (vs. ovate, 2.1–3.8 × 0.5–1.8 mm), apex aristate to cuspidate (vs. aristate with arista 1/4 – 1/3 as long as leaf), margin denticulate-ciliolate (vs. minutely denticulate); shorter and compact strobili (at less 10 mm), and features of mega- and microspores.

Description. Plants terrestrial, evergreen, main stems creeping or slightly ascending, 16–(?40) cm. Rhizophores at intervals throughout length of creeping stem and branches, borne on ventral side in axils of branches. Main stems branched from near base upward, stramineous, terete, main stem 0.6–1.8 mm in diam. in lower part; branch systems

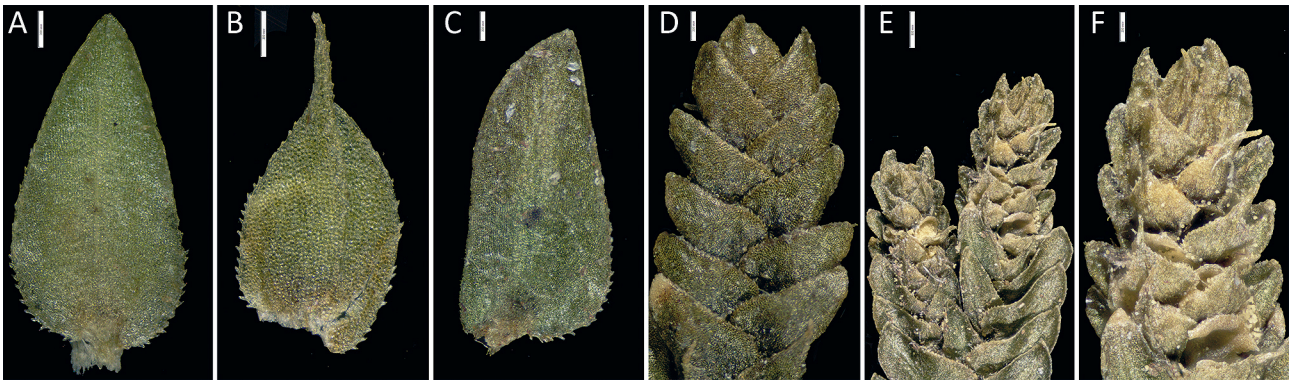

Figure 2 *Selaginella kualaensis* Shalimov. A – Axillary leaf, lower surface; B – Dorsal leaves, upper surface; C – Ventral leaf, lower surface; D – close-up section of strobilus, upper surface; E – Strobili, lower surface; F – close-up section of strobilus, lower surface. A, B, C, D, F Scalebar=200 μm, E Scalebar=500 μm. A–F Taken from the holotype Vintchevski A.E. (MW0752996)

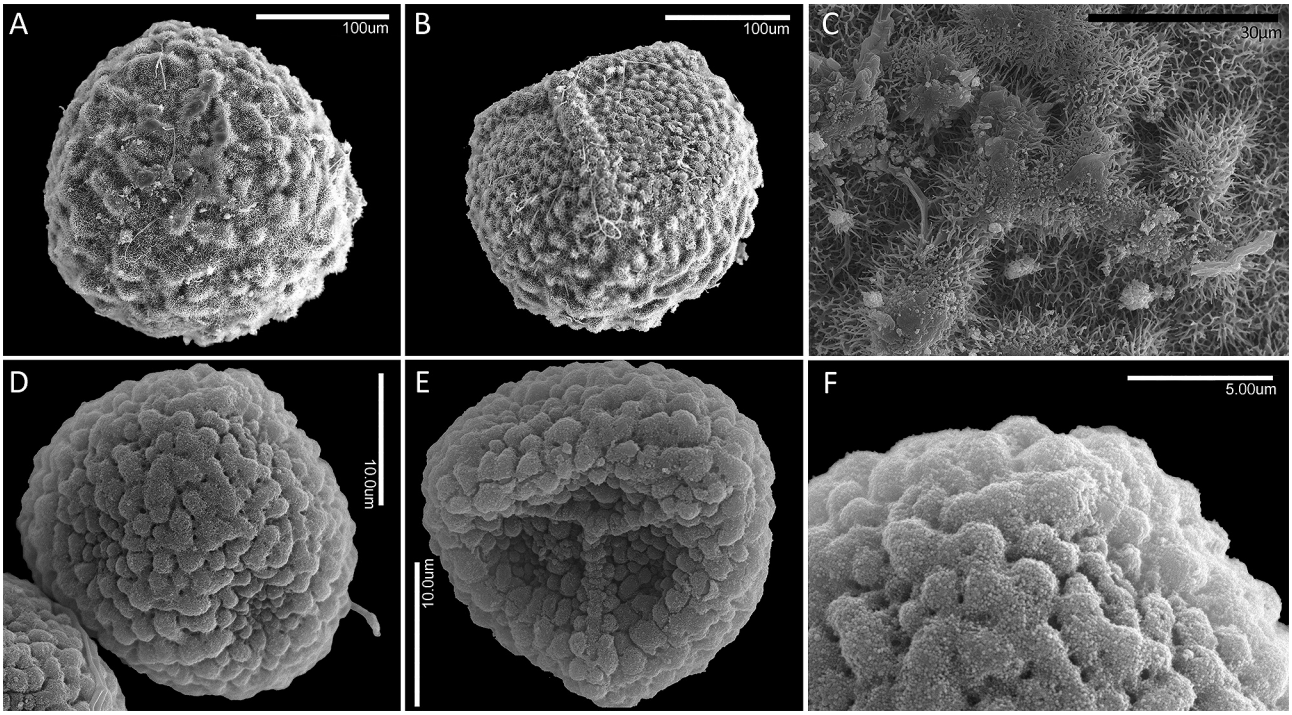

Figure 3 *Selaginella kualaensis* Shalimov. A, B, C – megaspore, A – distal face, B – proximal-equatorial face, C – close-up of megaspore surface, proximal face; D, E, F – microspore, D – distal face, E – proximal face, F – close-up of microspore surface, proximal face. A–F taken from the holotype Vintchevski A.E. (MW0752996)

simple and shorten, pseudo pinnate, branchlets regular, adjacent primary branches on main stem 1.3–2.5 cm., leafy portion of main stem including leaves 0.7–1.0 cm wide at middle, ultimate branches 4–7 mm wide including leaves. Axillary leaves ovate, 1.8–4 × 0.7–1.5 mm, base obtuse, margin denticulate-ciliolate, apex acuminate. Dorsal (median) leaves ± symmetrical, dorsal leaves on branches contiguous or imbricate, ascending, broadly ovate, 2.0–4.5 × 0.8–1.1 mm, carinate on abaxial surface, base obtuse to slightly subcordate, margin denticulate-ciliolate, apex aristate to cuspidate. Ventral (lateral) leaves on branches contiguous or imbricate, spreading, asymmetrical, ovate-triangular or oblong-ovate, 2.5–4.5 × 0.6–2.1 mm, margin denticulate-ciliolate, apex obtuse to subacute, basiscopic base decurrent, margin entire; acroscopic base rounded, strongly overlapping stem and branches, margin denticulate-ciliolate. Strobili solitary, terminal, compact, dorsiventrally complanate, 2.0–7.0 × 1.5–2 mm, strongly dimorphic; dorsal sporophylls ovate, carinate, with a complete and denticulate laminar flap, margin denticulate-ciliolate, apex acute to acuminate; ventral sporophylls ovate-triangular, strongly carinate in middle part, margin denticulate, apex long acuminate; megasporophylls in basal portion on ventral side of strobilus; microsporophylls in ventral and dorsal rows throughout strobili; megaspores white, 233.0–247.3 × 206.3–216.0 μm, verrucate, micro-sculpture of dense spinules; microspores yellowish, 23.4–28.1 × 12.0–16.1 μm, densely verrucate on proximal and distal faces, covered with fine grains microsculpture.

Etymology. The specific epithet "kualaensis" comes from the type locality Kuala Selangor Nature Park where it was collected, at the Malay language "Kuala" means river mouth.

Distribution. *Selaginella kualaensis* is endemic to Malay Peninsula, and known only from the type collection, in Kuala Selangor National Park in Malay Peninsula. This species presumably grows on damp banks in mangrove forest.

Note. *Selaginella kualaensis* is morphologically similar to *S. ornata* and clearly distinguishable from all other anisosporophyllous *Selaginella* species distributed in Malay Peninsula by its branches with densely imbricate ventral leaves (especially on lateral branches), with ovate-triangular or oblong-ovate ventral leaves, acroscopic side overlaps stem and branches all over the plant; further by broadly ovate dorsal leaves with obtuse or subcordate bases, denticulate-ciliolate margins and aristate to cuspidate apex; strobili short and compact c. 10 mm long.

Among Malay Peninsula anisosporophyllous *Selaginella* species, *S. kualaensis* can be confused with *S. polita* Ridl. and recent described Chinese species *S. zhangii* S.Y. Dong.

Main differentiation between *S. kualaensis* and related species are listed in Table 1.

The mega- and microspores of *S. kualaensis* demonstrate that they are morphologically different from the spores of related species studied by Zhou et al. (2015b) and Huang et al. (2022); however, spore morphology of *S. polita* has not been described. Megaspores of *S. kualaensis* have dense verrucae on proximal and distal side, with densely spinu-

Table 1. Comparison of *Selaginella kualaensis* and related species.

Characters		*S. kualaensis*	*S. ornata*	*S. polita*	*S. zhangii*
Habit and size (cm)		creeping or slightly ascending, 16–(?40)	creeping, with upper part ascending, 20–40	suberect, often up to 20–35	prostrate or hanging, ascending distally, 30–70
Width of main stem (mm)		7–10	8–12	5–11	11–15
Axillary leaves	*shape*	ovate	lanceolate or ovate-lanceolate	ovate to broadly ovate	elongate-ovate
	margin	denticulate-ciliolate	slightly denticulate	denticulate	serrulate proximally and entire distally
Dorsal leaves	*shape*	broadly ovate	ovate	ovate	broad-elliptic
	margin	denticulate-ciliolate	minutely denticulate	denticulate	sparsely serrulate and sometimes becoming entire toward bases
	apex	aristate to cuspidate	aristate (with arista $^1/_4$–$^1/_3$ as long as leaf)	acuminate to shortly aristate	obtuse and slightly apiculate
Ventral leaves	*shape*	ovate-triangular or oblong-ovate	oblong or oblong-falcate	ovate-lanceolate	oblong
	margin	denticulate-ciliolate	denticulate	denticulate	denticulate
Acroscopic margin of ventral leaves	*overlapping*	strongly overlapping stem and branches	overlapping stem and branches	overlapping stem and branches	slightly overlapping stem and branches
	margin	denticulate-ciliolate	denticulate	denticulate-ciliolate	denticulate
Strobili size (mm)		2.0–7.0 by 1.5–2	4–14 by 1.4–3.2	10.0–25.0 by 1.5–3.2	20–30(43)
Megaspore	*color, diameter (μm)*	white, 233.0–247.3 by 206.3–216.0	yellowish, (186.1–349.6)273.8 by 237.5 (304.2–274.6)*	n/d	cream-white or yellowish white, 290–380*
	ornamentation	verrucae	irregularly sized and spaced verrucae	n/d	coarsely verrucate/ baculate
	micro-sculptures	densely spinulose	spinulose	n/d	–
Microspore	*color, diameter (μm)*	yellowish, 23.4–28.1 by 12.0–16.1	yellow, (28.39–36.92)33.20 by 20.97 (15.54–25.15)*	n/d	brick-red, 25–31 **
	ornamentation	densely verrucae	irregularly with sized verrucae	n/d	colliculate
	micro-sculptures	fine grains	interconnected and blunt spinules	n/d	laevigate or echinulate

Note: * More detail and photo see in Zhou et al. (2015b); ** More detail and photo see in Huang et al. (2022).

lose micro-sculpture (Fig. 3, A–C). Microspores of *S. kualaensis* have verrucae ornamentation covered with fine grains microsculpture (Fig. 3, D, E, and F), which clearly differentiates it from related species. Additional data on the morphological differences of mega- and microspores between related species are summarized in Table 1.

Key to anisosporophyllous species of *Selaginella* in Malay Peninsula

1. Stems hairy, dorsal leaves strongly aristate ..... ***S. scabrida*** Ridl.

1. Stems glabrous, dorsal leaves aristate or not **2**

2. Main stems erect, plants less than 10 cm, leaves denticulate at margin ..... ***S. minutifolia*** Spring

2. Main stems creeping, ascending or suberect, plants up to 40 cm, leaves denticulate or ciliolate at margin **3**

3. Plants creeping **4**

3. Plants suberect or creeping with upper part ascending ... **6**

4. Ventral leaves ciliolate at margin **5**

4. Ventral leaves denticulate at margin ..... ***S. curtisii*** Ridl.

5. Fertile stem erect, dorsal leaves denticulate at margin, apex acuminate or shortly aristate ..... ***S. ciliaris*** (Retz.) Spring

5. Fertile stem not erect, dorsal leaves ciliolate at margin, apex aristate (with arista often 1/2 to 2/3 lamina length) ... . ***S. alutacea*** Spring

6. Plants creeping, with upper part ascending, ventral leaves oblong or oblong-ovate **7**

6. Plants suberect, ventral leaves ovate-lanceolate .... ***S. polita*** Ridl.

7. Ventral leaves on main stems and branches contiguous, densely imbricate, denticulate-ciliolate at margin; dorsal leaves aristate to cuspidate at apices, strobili compact less 10 mm ..... ***S. kualaensis*** Shalimov

7. Ventral leaves on main stems and branches distant or contiguous, spreading, denticulate at margin; dorsal leaves aristate (with arista 1/4 – 1/3 as long as leaf) at apices, strobili up to 14 mm ..... ***S. ornata*** (Hook. & Grev.) Spring

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