

Ulota panchengiana, a new species from China and notes on the taxonomy of *U. morrisonensis* Horik. & Nog. (Orthotrichaceae)

Qing-Hua WANG^a & Yu JIA^{a*}

^aState Key Laboratory of Systematic and Evolutionary Botany, Institute of Botany, Chinese Academy of Sciences, Beijing, 100093, China

Abstract – *Ulota panchengiana* Q.H.Wang & Y.Jia is described and illustrated as a new species from China. It is characterized by both stomata that are scattered throughout the urn and by naked calyptra, two remarkable characters that are rarely found in *Ulota* species from the northern Hemisphere. *Ulota panchengiana* is easily recognized by the combination of the following characters: lanceolate leaves with an ovate base, the presence of a few rows of hyaline cells at the basal leaf margin, and long seta. The ecology, geographical distribution, variation, and morphological comparison with related taxa are discussed. *Ulota morrisonensis*, endemic to Taiwan, is easily misidentified as *U. crispa*. However, based on a study of an isotype of the former species and in response to a recent reevaluation of the circumscription of *U. crispa*, we confirm its rank as a species and discuss obvious morphological differences between the two species. A revised key to Chinese *Ulota* species is provided.

Morphology / Mosses / Stomata / Taxonomy / *Ulota crispa*

INTRODUCTION

As per Garilleti *et al.* (2015), the genus *Ulota* Mohr contains 65 species worldwide, of which three species in the *U. crispa* complex were recently recognized by Caparrós *et al.* (2016). However, seven new synonyms were simultaneously proposed by Wang & Jia (2016) in their taxonomic revision of *Ulota* species from Central and South America. *Ulota* species often grow in cushions on tree trunks or branches, and are rarely found on rocks. Important diagnostic characters for this genus are: 1) leaves that are usually flexuose, twisted or crisped when dry; 2) leaves in lanceolate shape with a broad base; 3) one or more rows of hyaline cells at the basal leaf margin; and 4) exserted capsules bearing only phaneroporous stomata.

In 1892, Bescherelle reported the first *Ulota* species found in China: *Ulota bellissima* Besch. (= *U. robusta* Mitt.). Later, Brotherus (1929) described *Ulota macrocarpa* Broth. (= *U. crispa* (Hedw.) Brid.) found in Hunan and Sichuan. *Ulota morrisonensis* Horik. & Nog. was found in Taiwan and described by Noguchi (1937). The first record of *Ulota crispa* in China was also from Taiwan (Nakanishi, 1963). In 2004, *Ulota curvifolia* (Wahlenb.) Lilj. and *U. gymnostoma* S.L.Guo, Enroth & Virtanen were reported as a new record and a new name, respectively (Guo *et al.*, 2004; Mamtimin *et al.*, 2004). Guo *et al.* (2010) also later added two

* Correspondence and reprints: yjia@ibcas.ac.cn.

new records to the Chinese flora: *Ulota perbreviseta* Dixon & Sakurai and *U. robusta*. Soon afterwards, *Ulota gigantospora* F.Lara, Caparrós & Garilleti and *U. yunnanensis* F.Lara, Caparrós & Garilleti, were described as new species from Yunnan (Caparrós *et al.*, 2011). Recently, a taxonomic revision of Asian *Ulota* made new additions and exclusions (Wang & Jia, 2012). This revision included two new species (*U. delicata* Q.H.Wang & Y.Jia and *U. latisegmenta* Q.H.Wang & Y.Jia), two new records of *U. rehmannii* Jur. and *U. yakushimensis* Z.Iwats., and removed two taxa from the Chinese moss flora (*U. eurystoma* Nog. and *U. reptans* Mitt.). In total, twelve species of *Ulota* have been recognized in China in previous studies. These include two widespread species, *Ulota crispa* and *U. curvifolia*; a Himalayan endemic species, *U. robusta*; two Asian species, *U. perbreviseta* and *U. yakushimensis*; a Eurasian species, *U. rehmannii* and six species endemic to China, *U. delicata*, *U. gigantospora*, *U. gymnostoma*, *U. latisegmenta*, *U. morrisonensis*, and *U. yunnanensis*.

In the study of *Ulota* presented in this paper, we describe a new species from Southwest China, and reevaluate the morphology of *Ulota morrisonensis*, which is often confused with *U. crispa*. Finally, we provide an amended key for all Chinese *Ulota* species.

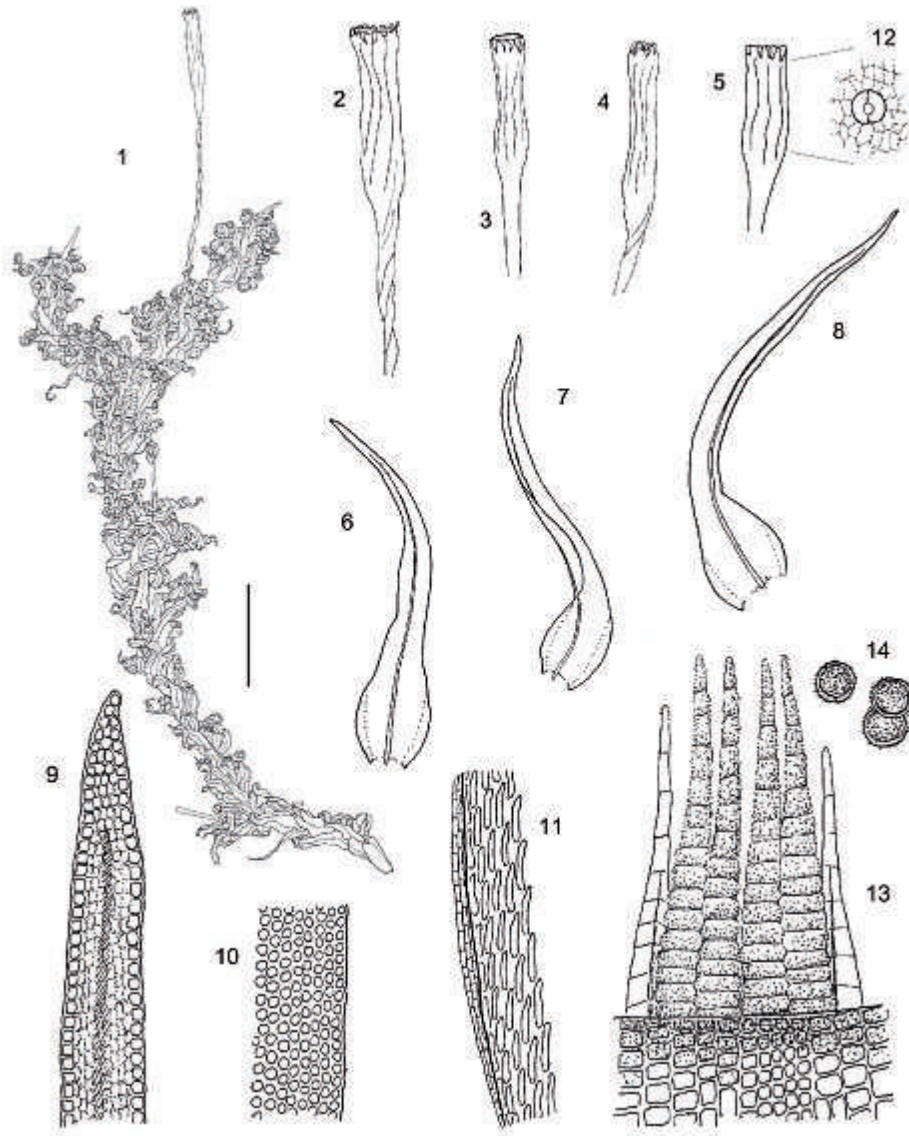
Ulota panchengiana Q.H.Wang & Y.Jia, *sp. nov.*

Figs 1-28

Type: CHINA. Sichuan. Wenchuan Co., Weizhouzhen, Qipangoucun, Mt. Guangguangshan, 31°24'13" N, 103°35'55" E, 2400 m, on tree trunk, 27 Aug. 2002, Y. Jia 06671b (holotype: PE!; isotype: MO!).

Diagnosis: Plant forming cushions, leaves strongly crisped when dry, wide concave bases with few marginal hyaline rows of cells. Vaginule with uniseriate hairs, long setae, dry capsules not constricted or constricted toward the mouth, and stomata are scattered throughout the urn. Exothecial cells differentiated into bands of three to four cells wide that reach the mouth of the capsule. Exostomes often united into 8 pairs, and sometimes lie on the exothecium. Endostome segments 8, robust. Operculum usually with a reddish basal rim, calyptra naked, medium to large spores. **Plants** 1-3 cm tall, in moderately dense cushions, yellowish green to olive-green above, dark brown to black below. **Rhizoids** reddish-brown, smooth, densely growing at stem base. **Stems** usually branched. **Leaves** strongly crisped when dry, erect-patent to patent when moist, (1.6-) 2.2-3.7 (-4.3) mm long, **leaf lamina** lanceolate, unistratose; **leaf base** wide, ovate, distinctly concave; **apex** long acuminate; **leaf margin** weak and irregularly recurved on one or both sides; **costa** strong, ending shortly below the apex. **Upper and middle laminal cells** irregularly rounded, (5-) 7-9 (-11) × (6-) 8-9 (-12) μm, thick-walled, often with two low simple papillae per cell, rarely branched; **basal inner cells** linear, rectangular to vermicular, (8-) 14-20 (-44) × (3-) 5-6 (-11) μm, with thick wall, smooth; **basal marginal cells** weakly differentiated, no more than four rows, hyaline, quadrate to rectangular, with only thickened transverse walls.

Cladautoicous. Perichaetial leaves somewhat longer, 4.1-5.2 mm. **Vaginula** strongly hairy, 0.4-0.7 mm, uniseriate, smooth, hyaline. **Seta** (1.5-) 4-6 (-8) mm long, twisted anticlockwise when dry. **Capsule** long exserted. **Urn** cylindrical, (1.1-) 1.4-1.7 (-2.3) mm long, yellow to brown, more or less constricted below the mouth when dry and empty, eight furrows along the entire length, with prominent ribs alternately, yellow to brown. **Neck** short, abruptly narrowed to the seta. **Exothecial cells** distinctly differentiated into eight bands, almost as long as urn, three to four cells wide, differentiated cells with only extremely thickened longitudinal walls. **Stomata** superficial, scattered throughout the urn. **Preperistome**



Figs 1-14. *Ulota panchengiana* Q.H. Wang & Y. Jia. 1. Plant. 2-5. Capsules. 6-7. Leaves. 8. Perichaetial leaves. 9. Upper laminal cells. 10. Median laminal cells. 11. Basal marginal and laminal cells (little folded). 12. Stomata. 13. Portion of peristome. 14. Spores. Scale bar: 1, 2.1 mm. 2-5, 1 mm. 6-8, 1.05 mm. 9-11, 97.7 μ m. 12, 11.1 μ m. 13-14, 82.6 μ m. All drawn from *Y. Jia 06671b* (holotype).

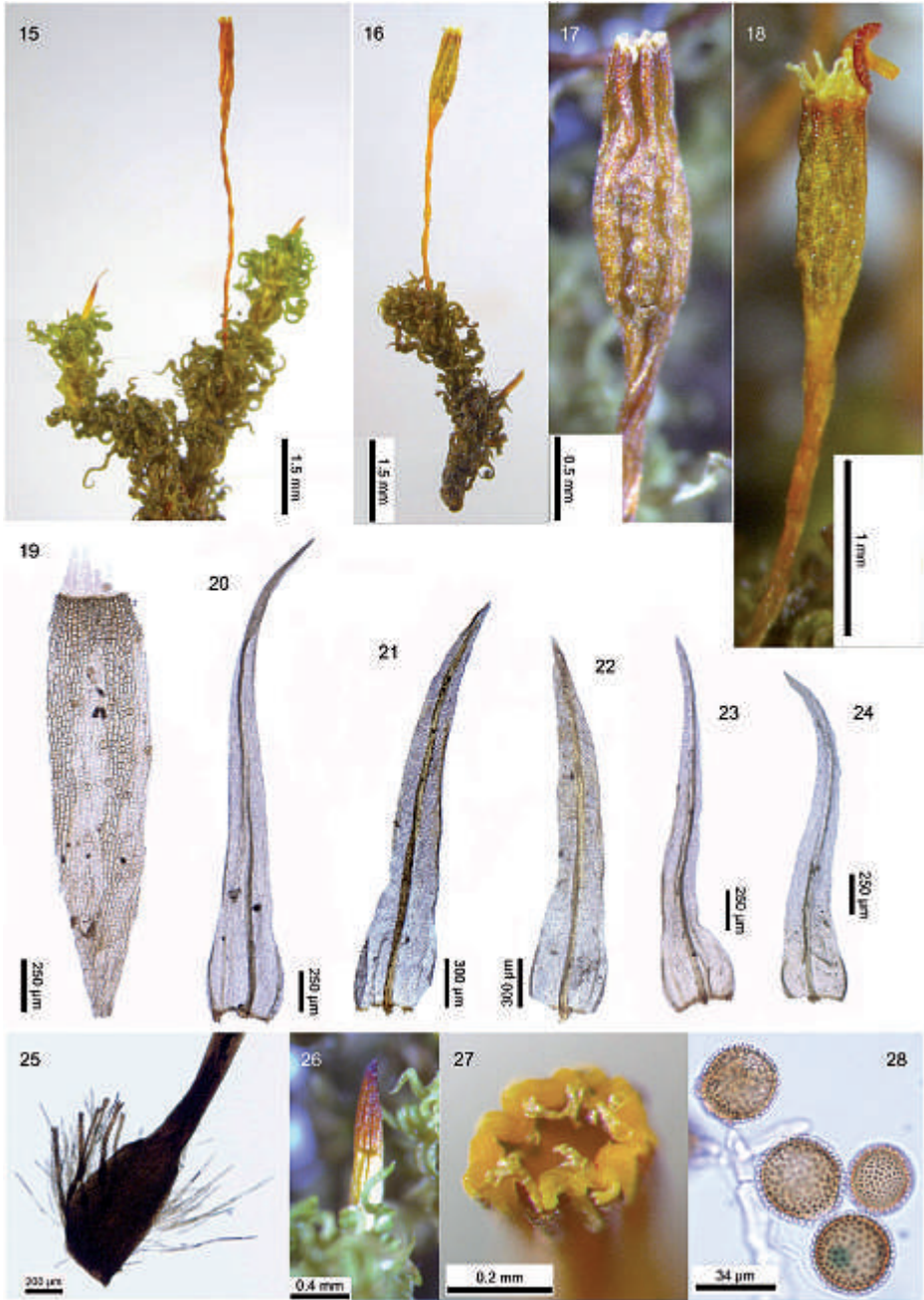
not seen. **Peristome** double. **Exostome teeth** 16, often united into 8 pairs, variably recurved when dry, sometimes lying on the exothecium, lanceolate, densely papillose on the outside, striate and papillose on the inside. **Endostome segments** 8, rarely with eight additional intermediate, shorter processes, principal segments linear-lanceolate, 180-230 μ m tall, 2/3 to almost reaching the exostome teeth, uniseriate

upper, irregularly biseriate at the base, hyaline, variably incurved when dry, smooth on the outside surface, slightly scabrous on the inside surface. **Opercula** plane to convex, rostrate, yellowish, usually with a reddish basal ring. **Calyptra** conic, naked, plicate. **Spores** spherical, finely papillose, (16.5-) 22.9-32.7 (-45.6) μm in diameter. **Etymology:** The specific epithet *panchengiana* is named after Pan-Cheng Wu, for his outstanding contribution to Chinese Bryology.

Ecology and distribution: *Ulotia panchengiana* is epiphytic on tree trunks and branches, the only phorophyte recorded is *Populus*. The elevation range is from 1720 to 3470 m. This new species has so far only been found in the Midwest region of Sichuan Prov. and the southernmost part of Gansu Prov. (Fig. 29). These areas are in the northeastern part of the Hengduan Mountains and the western part of the Qinling Mountains, respectively. They are ecologically unique and therefore possess a high degree of biological diversity. Thus, it is not surprising that new species are found in this region, such as the recently described species *Ulotia gigantospora* and *U. yunnanensis* (Caparros *et al.*, 2011).

Discussion: *Ulotia panchengiana* is a unique species, and differs considerably from its Chinese congeners in the distribution of stomata. In addition, *U. panchengiana* has lanceolate leaves with an ovate base, weakly differentiated basal cells at the leaf margin, long setae (often > 4.5 mm, sometimes up to 8 mm), stomata scattered all over the urn (Fig. 25), and naked calyptra. In most cases, the setae are more than 4.5 mm in length but may sometimes be only 1.5 mm (in specimen of *Q. Li 1005*). In addition, endostome segments are often eight, rarely sixteen (in specimen of *N.R. Gaowa Z650*). To date, most *Ulotia* species found in the northern Hemisphere have stomata restricted to the basal part of the urn or to the transition zone between the urn and neck, while several species in the southern Hemisphere have stomata present at the upper part of the urn, such as *U. fuegiana* Mitt., *U. macrocalycina* Mitt., and *U. pusilla* Malta. A species with stomata occurring at the central and upper part of the urn has been reported only once in the northern Hemisphere, i.e. *Ulotia rhytiore* (B.H.Allen) F.Lara, Garilleti, Albertos & Mazimpaka. However, this species is easily distinguished from *Ulotia panchengiana* by the presence of distinctly differentiated basal cells (up to eight rows) at the leaf margin, fusiform capsules, and densely hairy calyptra, as well as the absence of the peristome. Naked calyptra are also rarely found in the northern Hemisphere, and are present on only one species, *Ulotia rehmannii* (Wang & Jia, 2012). However, this species has more rows (up to seven) of hyaline cells at the leaf base, as well as remarkable ornamentation of semitransparent and strongly striolate exostome teeth, and stomata located at the junction between the urn and neck. Naked calyptra are relatively more common in *Ulotia* species from the southern Hemisphere, such as *Ulotia fuegiana* and *U. macrocalycina*. Moreover, *Ulotia panchengiana* is also unusual because it has leaves with few (<4) rows of hyaline cells at the base, and this character is also less common in *Ulotia* species in the northern than in the southern Hemisphere.

Within China, *Ulotia panchengiana* resembles *U. gigantospora* in having few rows of hyaline cells at the leaf base, but the latter species has stomata scattered throughout the lower part of the urn and in the neck, as well as fragile endostome segments and multicellular spores. In addition, *Ulotia panchengiana* shares many characters with *U. yunnanensis*: both have twisted leaves, more or less inconspicuous hyaline cells at the leaf base, densely hairy vaginula, and eight well-developed narrow endostome segments. However, *Ulotia yunnanensis* has stomata located along the neck or at the urn base, exostome teeth with obvious striate in the upper half, multicellular spores, and hairy calyptra. Furthermore, the long seta of *Ulotia panchengiana* resemble those of *U. latisegmenta* and *U. robusta*, but *U. panchengiana*



Figs 15-28. *Ulota panchengiana* Q.H. Wang & Y. Jia. 15-16. Plants. 17. Capsules in dry condition. 18. A dry capsule with operculum. 19. Exothecial cells with stomata scattered throughout the urn. 20-24. Leaves. 25. Vaginula. 26. A young calyptra. 27. Peristome in dry condition. 28. Spores. 15 & 18 taken from *Y. Jia 09278b*. 16, 19 & 26 taken from holotype. 17 taken from *M. Z. Wang 49928*. 20 & 23-25, 28 taken from *N. R. Gaowa Z650*. 21-22 taken from *Q. Li 1005*. 27 taken from *Y. Jia 08188*.

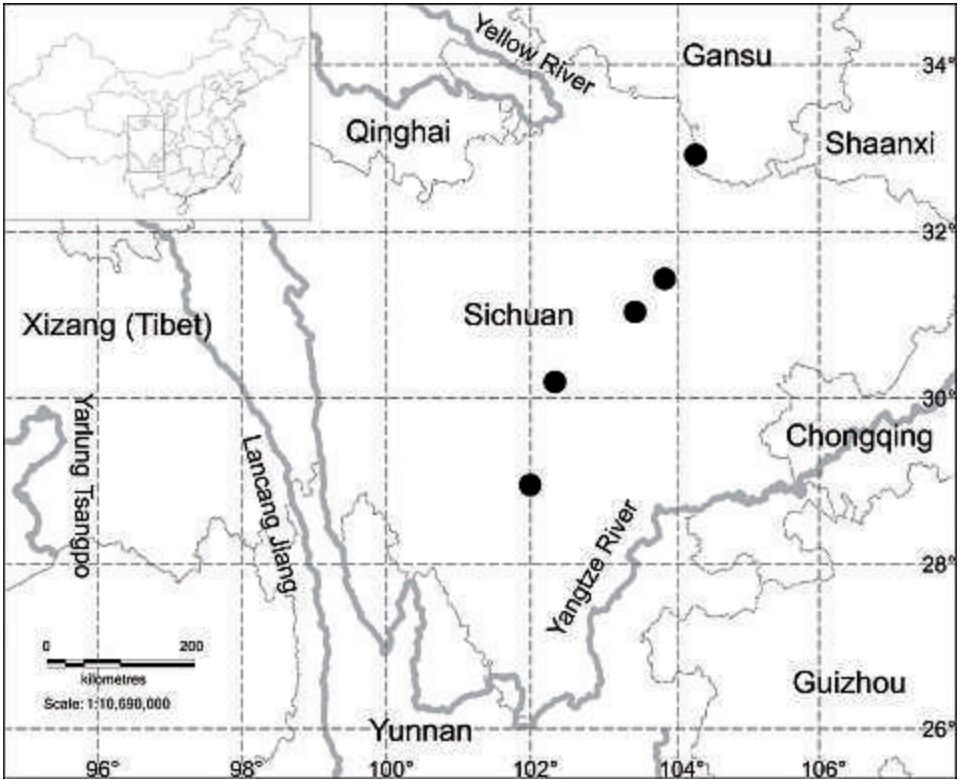


Fig. 29. Distribution of *Ulota panchengiana* Q.H. Wang & Y. Jia.

is distinguished by weakly differentiated cells at the leaf base, stomata scattered throughout the urn, narrow endostome segments, and naked calyptra. Among species outside China, *Ulota panchengiana* seems most closely related to *U. splendida*, a species endemic to Papua New Guinea. These species superficially look alike, and share strongly crisped leaves, weakly differentiated cells at the leaf base, long setae, and somewhat constricted cylindrical capsules. However, *Ulota splendida* reaches a larger overall plant size ((2-) 3.5-7 (-9) cm), and has lanceolate leaves with a narrower base, longer capsules (2-3 mm), stomata located at the base of capsules, finely papillose endostome segments, and densely hairy calyptra (Wang & Jia, 2012). **Additional specimens studied (Paratypes):** CHINA. Gansu, Wen Co., *Y. Jia* 09278b (PE01417683), 09288 (PE), 09326(3) (PE01743775). Sichuan, Dujiangyan, *M.Z. Wang* 49928 (PE00650246), *P.C. Wu* 25350 (PE00650267); Mianning Co., *Y. Jia* 08188 (PE01087967); Tianquan Co., *N.R. Gaowa* Z650 (PE02123095), *Q. Li* 1005 (KUN0878548); Wenchuan Co., *Y. Jia* 06817 (PE00656566).

Ulota morrisonensis Horik. & Nog., *J. Sci. Hiroshima Uni., Ser. B, Div. 2* (Botany) 3: 37. 1. 1937.

Figs 30-38

Type: CHINA. Taiwan, Tainan, Mt. Yushan (Japanese name: Mt. Niitaka), alt. ca. 3300 m, 19 Aug. 1932, *A. Noguchi* 5985 (holotype: HIRO (n.v.); isotype: NICH!).

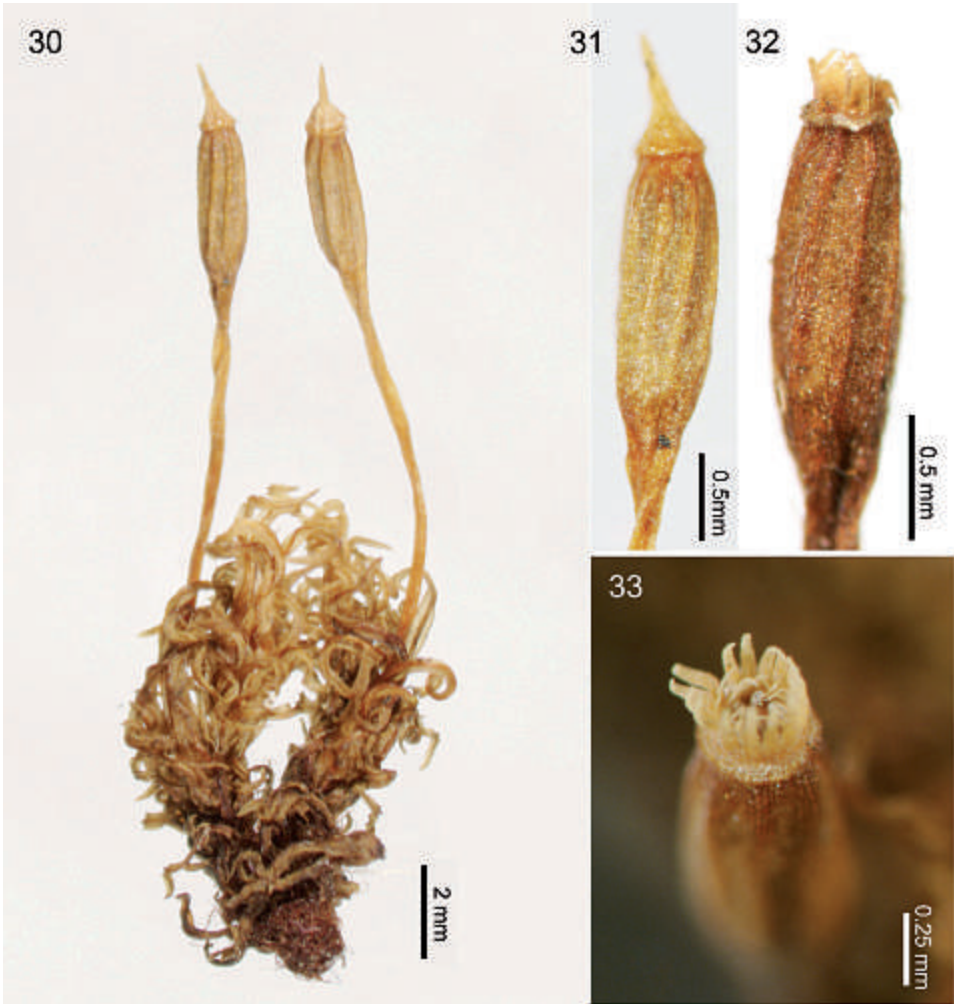
Description: see Wang & Jia (2012).

Ecology and distribution: epiphytic, reported only from Taiwan of China.

Discussion: Two species of *Ulota* were hitherto reported from Taiwan: *U. crispa* and *U. morrisonensis* (Noguchi, 1937; Nakanishi, 1963). The former is a widespread species, and the latter has been found only in Taiwan at two recorded locations (i.e. Mt. Yushan, Tainan and Mt. Notaka, Taizhong). In the recent revision of Asian *Ulota* (Wang & Jia, 2012), *U. morrisonensis* was distinguished from *U. crispa* mainly by the number of endostome segments, which is sixteen in the former and usually eight in the latter. The segment number in *Ulota crispa* varies: in most cases there are eight, but sometimes more (up to sixteen), and this can easily lead to it being confused with *U. morrisonensis*. This confusion necessitates a re-appraisal of the relationship between *Ulota morrisonensis* and *U. crispa*.

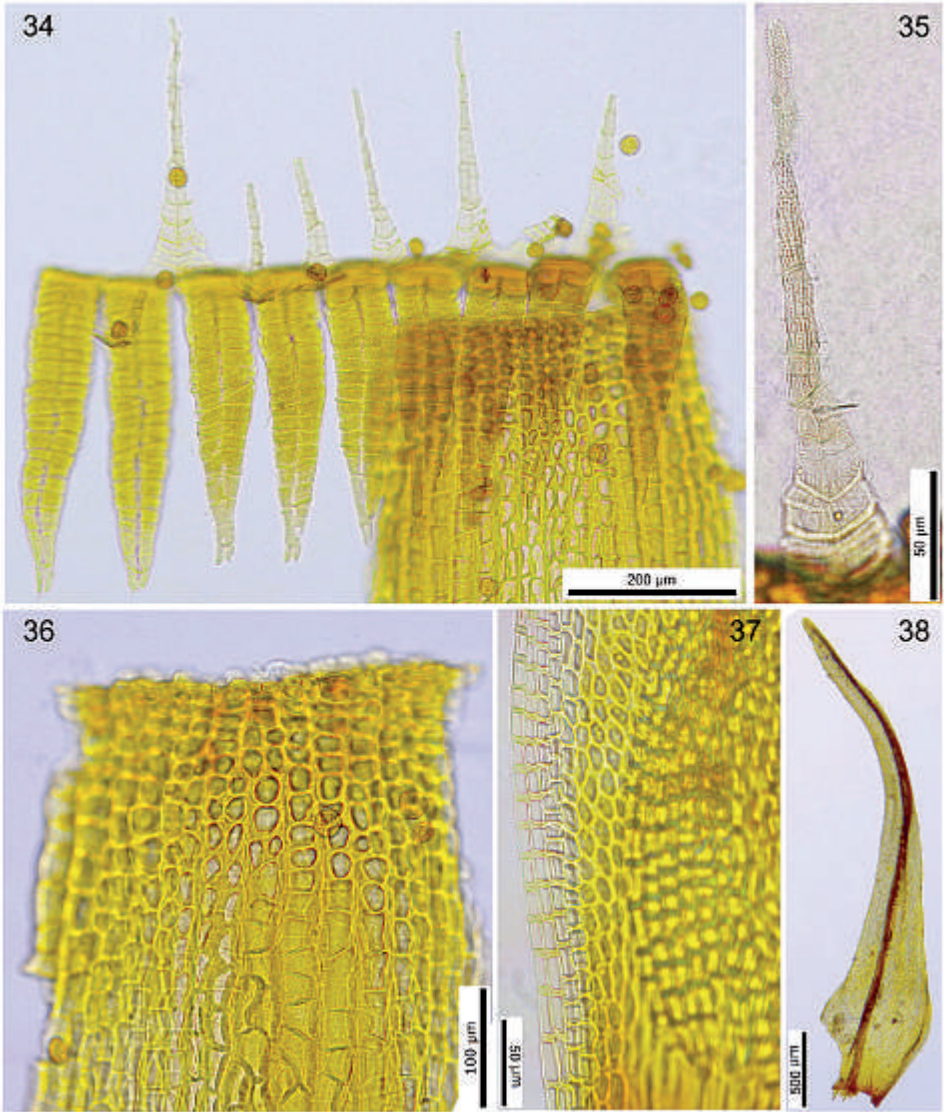
Noguchi (1937) stated that *Ulota morrisonensis* was closely related to *U. intermedia* Schimp., but was distinct from *U. intermedia* in the only 3-4 rows of hyaline cells at the basal part of the leaf margin, attenuated inner perigonal leaves, an oblong-cylindrical capsule with a longer neck, and endostome segments consisting of two rows of cells. Historically, *Ulota intermedia* had been generally considered to be an unimportant form or merely a synonym of *U. crispa* for a long time (Grout, 1935; Nyholm, 1956; Smith & Hill, 1975; Rosman-Hartog & Touw, 1987; Smith & Proctor, 1993). Recently, Caparrós *et al.* (2016) used molecular data and a complete morphological comparison to reassess the status of *Ulota intermedia*, and in doing so they reinstated its species rank. According to their description, *Ulota intermedia* has much in common with *U. morrisonensis*, which we examined the type material (see Figs 30-38). In both taxa the leaves are crisped when dry, the leaf bases are mostly obovate and distinctly concave, the capsule urn is oblong-cylindrical when dry and empty, exothecial bands are separated from the mouth by a ring of small round cells, the exostome teeth tend to split after being recurved, endostome segments are robust and incurved when dry, and an operculum without a differentiated basal rim is present. But these two species are still substantially different, as *Ulota morrisonensis* has leaves that gradually narrow into the lamina (Fig. 38), while those in *U. intermedia* abruptly narrow into the lamina. *U. morrisonensis* also has slightly constricted capsules when dry and empty, but these are not constricted in *U. intermedia*; moreover, the endostome segments are always finely papillose throughout in *U. morrisonensis*, but are smooth to finely papillose below and reticulate above in *U. intermedia*. Moreover, there are several quantitative characters that differ between these two species, i.e. only 3-6 rows of hyaline basal leaf cells (Fig. 37) are present in *U. morrisonensis*, but 3-14 rows in *U. intermedia*, and long sporophytes (6.5-7.5 mm in length) are present in *U. morrisonensis* but the ones present in *U. intermedia* are relatively shorter (3.2-6.5 mm).

As mentioned above, *Ulota morrisonensis* was thought to differ from *U. crispa* only in the number of endostome segments (Wang & Jia, 2012). However, the morphology of *Ulota crispa* was thoroughly discussed by Caparrós *et al.* (2016), who argued that the *U. crispa* complex represents three closely related but independent species, i.e. *U. crispa*, *U. crispula*, and *U. intermedia*. Based on this recent clarification of the circumscription of *Ulota crispa*, we found that the common characters it shares with *U. morrisonensis* are similar to those shared between *U. intermedia* and *U. morrisonensis*; these characters include crisped leaves, an obovate and concave leaf base, a cylindrical to ellipsoid capsule (when dry) that is full of spores, robust and incurved endostome segments, and an operculum without a differentiated basal rim. Moreover, distinguishing *Ulota morrisonensis* from *U. crispa* is possible not merely by the number of segments of the endostome, since



Figs 30-33. *Uloa morrisonensis* Horik. & Nog. **30.** Plant. **31.** Capsule with operculum. **32.** Capsule without operculum but filled with spores. **33.** Double perisomes. All taken from the isotype at NICH.

morphological comparisons revealed many other differences between them. Among qualitative characters, we found that *Uloa crispa* has exothecial bands that either reach the mouth (or nearly do), exostome teeth that remain tightly fused in pairs in empty capsules and are bordered by a hyaline halo, as well as endostome segments which are narrowly triangular to subulate. In contrast, in *Uloa morrisonensis* the exothecial bands are separated from the mouth by a visible ring of small round cells, the exostome teeth split in empty capsules and have no hyaline halo, and the endostome segments are linear with a more or less widened base. Among quantitative characters, we found that *Uloa crispa* has leaves with (5-) 7-16 (-20) rows of hyaline basal cells, exothecial bands formed by 4-6 rows of cells, and relatively smaller spores with a diameter ranging from 14-23 μm . In contrast, in *Uloa morrisonensis* the leaves have only 3-6 rows of hyaline basal cells, exothecial bands



Figs 34-38. *Ulota morrisonensis* Horik. & Nog. 34. Peristome. 35. Ornamentation of an endostome segment. 36. Exothecial bands. 37. Differentiation of marginal leaf base. 38. Leaf. All taken from the isotype at NICH.

are formed by 3-4 rows of cells, and spores are larger, having a diameter ranging from 24-26 µm.

Although *Ulota morrisonensis* does not resemble *U. crispula* as much as it does *U. crispa* and *U. intermedia*, they have a few characters in common. These include a leaf base that gradually narrows into the lamina, and narrow marginal bands with differentiated cells along the leaf base. However, *Ulota morrisonensis* differs from *U. crispula* mainly by its longer sporophytes (6.5-7.5 mm), cylindrical

Table 1. Morphological comparison between *Ulota morrisonensis*, *U. crispa* and *U. intermedia*. All the description of *U. crispa* and *U. intermedia* are from Caparrós *et al.* (2016). Characters in bold indicate the main distinctions between three species.

Characters	<i>U. crispa</i>	<i>U. intermedia</i>	<i>U. morrisonensis</i>
habit and aspect when dry	medium to large cushions, generally strongly crisped	medium to large cushions, markedly crisped	small to large cushions, moderately to strongly crisped
leaf shape when dry	tortuose or circinate, occasionally falcate	tortuose or circinate, occasionally falcate-tortuose or circinate	tortuose or circinate
leaf base	mostly obovate, distinctly concave, abruptly narrowing into the lamina	mostly obovate, distinctly concave, abruptly narrowing into the lamina	mostly obovate, distinctly concave, gradually narrowing into the lamina
width of band with differentiated leaf basal cells	broad, (5-) 7-16 (-20) cell rows	narrow to broad, (2-) 3-14 (-16) cell rows	narrow, 3-6 cell rows
sporophyte total length (mm)	(3-) 3.2-6.8 (-7.4)	(3-) 3.2-6.5	6.5-7.5
spore size (µm)	(12-) 14-23 (-25)	(15-) 18-35 (-38)	(21-) 24-26 (-27)
capsule shape when dry and full of spores	cylindrical to ellipsoid	ellipsoid to cylindrical-ellipsoidal, rarely long ovoid	cylindrical to cylindrical-ellipsoidal
urn shape when dry and empty	urnecolate	cylindrical, oblong-cylindrical, obconic or elongate-ovoid	cylindrical to oblong cylindrical
constriction below mouth when dry and empty	strongly constricted	not constricted	slightly constricted
width of capsule furrows when dry and empty	commonly uniformly narrow, collapsed at the constricted area of the urn	broad, not collapsing anywhere	often broad, not collapsing anywhere
number of cell rows of exothelial bands	4-5 (-6)	2-4 (-5)	3-4
cell colour of exothelial bands	evenly yellow to pale orange	hyaline with pale yellow incrassated lateral walls	evenly golden yellow
differentiation at capsule mouth	nearly reaching the mouth or vaguely separated by ring of small, thin-walled cells in 1-3 (-4) layers	not reaching the mouth, visibly separated by a ring of small, thin-walled cells in (1-) 2-6 (-7) layers	not reaching the mouth, visibly separated by a ring of small round cells in 5-7 layers
tendency of teeth pairs to split	no , most teeth remain tightly fused in pairs even in old capsules	yes, teeth tend to split after being recurved	yes, teeth split easily after being recurved

<i>Characters</i>	<i>U. crispa</i>	<i>U. intermedia</i>	<i>U. morrisonensis</i>
external visibility of principal peristomial layer (PPL) at marginal parts of teeth	robust and persistent	no	no
endostome segment appearance and durability	robust and persistent	robusta and usually persistent	robusta and often persistent
endostome segment position when dry	incurved	incurved	incurved
endostome segment shape	long triangular to subulate	broadly linear with a more or less widened base or subulate	linear with a more or less widened base
endostome segment cell pattern at the inner peristome layer (IPL)	uniseriate, with transversal walls incrassate	variably uniseriate, with incrassate and prominent transversal walls	uniseriate or irregularly biseriate, with prominent transversal walls
internal ornamentation (IPL) of endostome segment	smooth to finely papillose below, variably papillose above, but never opaque because of the papillae density	smooth to very finely papillose below, variably reticulate above, but never opaque because of the ornamentation density	finely papillose
operculum colour	yellowish, without a differentiated basal rim	yellowish, without a differentiated basal rim	yellowish, without a differentiated basal rim

dry capsules, robust and persistent endostome segments, which are finely papillose inside and always incurved when dry, and its operculum, which is without a differentiated basal red rim. In *U. crispula*, the sporophytes are distinctly shorter (2-3.8 mm), the capsule is short and cylindrical to urnceolate when dry and empty, the endostome segments are slender and fragile, and are sometimes incurved when dry and covered by a reticulum inside, and its operculum usually has a differentiated basal red rim. In addition, several more subtle distinctions exist between these species, such as the fact that *U. crispula* has 2-4 layers of small round cells around the capsule mouth, but this number increases to 5-7 in *U. morrisonensis*.

Here, we describe twenty-one characters of *Ulota morrisonensis* (Table 1) that correspond to the characters of the table in Caparrós *et al.* (2016) and compared them to *U. crispa* and *U. intermedia*. Furthermore, the observable distinctions between *Ulota morrisonensis* and *U. crispa*, *U. crispula*, or *U. intermedia* confirm its rank as a species.

Additional specimens studied: *U. crispa*: CHINA. Taiwan, Mt. Taiheizan, *S. Suzuki s.n.* (H3205517); Mt. Yu, *J. R. Chen 97467* (PE00353581); Tainan, *M. Tagawa s.n.* (KYO); Taizhong, *Q. Gao&T. Cao 980200* (IFP00038863). *U. delicata*: CHINA. Taiwan, Mt. Nanhuta shan, *C. C. Chuang 1791* (UBC-B58028). *U. morrisonensis*: CHINA. Taiwan, Mt. Notaka, *K. Sawada s.n.* (TNS14606).

A revised key to *Ulota* species in China

- 1. Stomata scattered over the urn, sometimes only the central and lower part of urn; few rows (≤ 4) of hyaline cells at marginal leaf base; naked calyptra*U. panchengiana*
- 1. Stomata restricted to the junction between urn and neck; often up to 8 rows, sometimes ≤ 4 , of hyaline cells at marginal leaf base; usually hairy calyptra, rarely naked2
 - 2. Spores large, 78-115 μm , multicellular.....3
 - 2. Spores small, 18-45 μm , unicellular5
- 3. Capsules subglobose, not constricted when dry; peristome single.....*U. yakushimensis*
- 3. Capsules short cylindrical, constricted when dry; peristome double4
 - 4. Leaves mainly curved and falcate when dry; only 1-2 rows of hyaline cells at the leaf basal margin; vaginula naked or hairy; exostome teeth densely papillose *U. gigantospora*
 - 4. Leaves mainly twisted to circinate when dry; usually > 2 rows of hyaline cells at the leaf basal margin; vaginula densely hairy; Exostome teeth striate on the upper half of the outside surface, almost smooth on the inner surface*U. yunnanensis*
- 5. Capsules oblong-ovoid, puckered mouth, with 8 furrows that occur only near the mouth when dry; peristome absent..... *U. gymnostoma*
- 5. Capsules cylindrical, sometimes ovoid, with 8 furrows along almost the entire length when dry; peristome present6
 - 6. Upper leaf cells often with tall and branched papillae; exostome teeth with obvious vertical striolae in the upper half; grow on rocks.....*U. curvifolia*
 - 6. Upper leaf cells often with short papillae; exostome teeth mostly with dense papillae, rarely striolate on the upper half; grow on trees7

7. Endostome segments very broad; few rows of hyaline cell at the basal leaf margin, often ≤ 4 rows8
7. Endostome segments narrow; many rows of hyaline cells at the basal leaf margin, usually > 4 rows.....9
8. Capsules cylindrical, usually constricted when dry; endostome segments 16, often 8 long 8 short; leaves strongly crisped when dry *U. latisegmenta*
8. Capsules obovoid, not constricted when dry; endostome segments 8; leaves flexuose, sometimes moderately crisped when dry..... *U. robusta*
9. Exostome teeth often semitransparent along the upper half and strongly striolate with variable orientation; calyptra almost naked; leaves flexuose, sometimes moderately crisped when dry..... *U. rehmannii*
9. Exostome teeth usually densely papillate, not semitransparent; calyptra densely hairy; leaves strongly crisped when dry.....10
10. Seta short, 0.5-0.7 mm; capsules emergent to short exserted, subglobose when moist, slightly constricted.....*U. perbreviseta*
10. Seta long, 1.5-6 mm; capsules long exserted, cylindrical when dry or moist, often moderately to strongly constricted..... 11
11. Endostome segments 16, alternative 8 often caducous, filiform, slender, densely papillose; exostome teeth strongly papillose.....*U. delicata*
11. Endostome segments usually 8 or 16 and are linear or narrow lanceolate, not slender, smooth, slightly scabrous or finely papillose; exostome teeth with relatively weak papillae 12
12. Leaves with only 3-6 rows of hyaline basal cells; exothecial bands formed by 3-4 rows of cells, separated from the mouth by a visible ring of small round cells; exostome teeth sometimes split in empty capsules, without a hyaline halo; spores are comparatively large (24-26 μm) *U. morrisonensis*
12. Leaves with often 7-16 rows of hyaline basal cells; exothecial bands formed by 4-6 rows of cells, reaching the mouth or nearly so; exostome teeth always tightly fused in pairs in empty capsules, bordered by a hyaline halo; spores are relatively small (14-23 μm) *U. crispa*

Acknowledgements. We thank the curators of the H, KUN, KYO, IFP, NICH, TNS and UBC herbaria for the loans of specimens that made this work possible. We thank Prof. Si He and Prof. Rui-Liang Zhu for their constructive comments and suggestions that improved this paper. This work was supported by the National Natural Science Foundation of China (No. 31400188).

REFERENCES

- BESCHERELLE É., 1892— Musci Yunnanensis. *Annales des sciences naturelles; botanique*, sér. 7, 15: 47-94.
- BROTHERUS V.F., 1929—Musci. *Symbolae Sinicae* 4: 70-71.
- CAPARRÓS R., LARA F., DRAPER I., MAZIMPAKA V.&GARILLETI R., 2016— Integrative taxonomy sheds light on an old problem: the *Ulota crispacomplex* (Orthotrichaceae, Musci). *Botanical journal of the Linnean society* 180: 427-451.
- CAPARRÓS R., LARA F., LONG D.G., MAZIMPAKA V. & GARILLETI R., 2011—Two new species of *Ulota* (Orthotrichaceae, Bryopsida) with multicellular spores, from the Hengduan Mountains, Southwestern China. *Journal of bryology* 33: 210-220.

- GARILLETI R., MAZIMPAKA V. & LARA F., 2015— *Ulotia larrainii* (Orthotrichoideae, Orthotrichaceae, Bryophyta) a new species from Chile, with comments on the worldwide diversification of the genus. *Phytotaxa* 217: 133-144.
- GROUT A.J., 1935— *Moss flora of North America north of Mexico*, vol. 2. Newfane, The Author, 284 p.
- GUO S.-L., ENROTH J. & VIRTANEN V., 2004—Bryophyte flora of Hunan Province, China. 10. *Ulotia gymnostoma* sp. nova (Orthotrichaceae). *Annales botanici Fennici* 41: 459-463.
- GUO S.-L., ZHEN Y.Y., CAO T. & HE S., 2010—New synonym and record of the genus *Ulotia* D. Mohr (Musci, Orthotrichaceae) in moss flora of China. *Acta bryolichenologica Asiatica* 3: 51-59.
- MAMTIMIN S., WU P.-C. & DEGUCHI H., 2004— New records of the mosses in Xinjiang, China. *Acta botanica Yunnanica* 26: 19-22.
- NAKANISHI S., 1963— A record of travels in Taiwan. *Hikobia* 3: 316-327.
- NOGUCHI A., 1937—Studies on the Japanese mosses of the orders Isobryales and Hookeriales II. *Journal of science of the Hiroshima university, Series B, Division 2 (Bot.)* 3: 37-56.
- NYHOLM E., 1956— *Illustrated moss flora of Fennoscandia. II. Musci. Fasc. 2*. Lund, Gleerups.
- ROSMAN-HARTOG N. & TOUW A., 1987— On the taxonomic status of *Ulotia bruchii* Hornsch. ex Brid., *U. crispa* (Hedw.) Brid. and *U. crispula* Bruch ex Brid. *Lindbergia* 13: 159-164.
- SMITH A.J.E. & HILL M.O., 1975— A taxonomic investigation of *Ulotia bruchii* Hornsch. ex Brid., *U. crispa* (Hedw.) Brid. and *U. crispula* Bruch ex Brid. European material. *Journal of bryology* 8: 423-433.
- SMITH A.J.E. & PROCTOR M.C.F., 1993— Further observations on the *Ulotia crispa* complex. *Journal of the Hattori botanical laboratory* 74: 171-182.
- WANG Q.-H. & JIA Y., 2012—A taxonomic revision of the Asian species of *Ulotia* Mohr (Orthotrichaceae). *The bryologist* 115: 412-443.
- WANG Q.-H. & JIA Y., 2016— A taxonomic revision of *Ulotia* Mohr (Orthotrichaceae) in South and Central America. *Plant diversity* 38: 82-109.
- WU P.-C., 2000 (ed.)— *Bryoflora of Hengduan Mts.* Beijing, Science Press, xviii + 742 p. (in Chinese)