

***Ulota drummondii* (Orthotrichaceae, Bryopsida) in the Iberian Peninsula**

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Abstract – *Ulota drummondii* (Hook. & Grev.) Brid. is a Suboceanic Boreal-montane epiphytic moss whose disjunct distribution includes both coasts of North America, East Asia, as well as northern and central Europe, being an extraordinarily rare moss in its southernmost known localities in Europe. It was reported some years ago from northern Spain, but the revision of the specimens on which the record was based demonstrate to be misidentified. Therefore, this species was not included in the treatment of the genus *Ulota* in the *Flora Briofítica Ibérica*. Recently, the species was collected 140 km away of the previous erroneous record, and this led to a search for other specimens from the main Iberian herbaria. Here, we present a description of this moss based on the Spanish material in order to complete certain shortcomings or inaccuracies found in previous descriptions. Additionally, the species is illustrated with pictures from both stereo and light microscopes. A key for the discrimination of the *Ulota s.l.* species (including genus *Plenogemma* Plášek, Sawicki & Ochyra) recognised in Europe and surrounding territories is presented.

Chorology / epiphytic mosses / Europe / identification key / Spain

INTRODUCTION

The genus *Ulota* D. Mohr has one of its world diversity centres in Europe and surroundings (Macaronesia and south west Asia) (Garilleti *et al.*, 2015). After the recognition that the traditional concept of *Ulota crispa* (Hedw.) Brid. *s.l.* includes actually three different species (Caparrós *et al.*, 2016), the number of species in *Ulota s.l.* [including *Plenogemma phyllantha* (Brid.) Sawicki, Plášek & Ochyra (\equiv *Ulota phyllantya* Brid.)] amounted to 12 in this area, of which three are endemics, namely *U. bruchii* Hornsch., *U. calvescens* Wilson, and *U. macrospora* Baur & Warnst. As described in Garilleti *et al.* (2015), this diversity is comparable to that of other diversity centres around the world in number of species, although not in endemism rate, as is the case of North-Eastern Asia (13 species/5 endemics) or Southern Australasia (14 species/11 endemics), but it is clearly below the values of the Southern South America centre (22 species/18 endemics).

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The genus is well known for involving epiphytic and some saxicolous species preferentially linked to oceanic environments (Garilleti *et al.*, 2015). *Ulot*a species are widespread in Western Europe, becoming scarcer towards the north, the east and the south, being very rare in territories under Mediterranean climate. In the Iberian Peninsula, where Mediterranean climate predominates but an Atlantic marginal band exists at the north and northwest, up to seven species of the genus are presently recognized (Caparrós *et al.*, 2014, 2016): *U. bruchii*, *U. calvescens*, *U. coarctata* (P. Beauv.) Hammar, *U. crispa*, *U. crispula* Bruch, *U. hutchinsiae* (Sm.) Hammar, and *U. intermedia* Schimp., after the reinstatement of the later by Caparrós *et al.* (2016) and the segregation of *U. phyllantha* into *Plenogemma phyllantha* by Plášek *et al.* (2015). Only four European species were apparently absent: *U. curvifolia* (Wahlenb.) Sw., *U. drummondii* (Hook. & Grev.) Brid., *U. macrospora*, and *U. rehmannii* Jur.

*Ulot*a *drummondii* was included by Fernández Ordóñez & Collado Prieto (2003) in their guide to the bryophytes of Muniellos Nature Reserve (Asturias, N Spain). The finding was relevant because the species seemed to be unknown in southern Europe territories south of the Alps, and even in those mountains it is a very rare moss (Hodgetts, 2015). Fernández Ordóñez & Collado Prieto (2003) did not include comments on the distribution of any species, and this finding remained largely unnoticed despite its biogeographical interest. As far as we know, no further papers about this subject were subsequently published, and the presence in Spain of this moss went largely unnoticed until the synthesis of genus *Ulot*a for the *Flora Briofítica Ibérica* (Caparrós *et al.*, 2014). During the revision of herbarium material for this work, the specimens collected by Fernández Ordóñez & Collado Prieto in Muniellos Nature Reserve were studied, finding out that the presence of *U. drummondii* in this territory was based on the misidentification of two samples, FCO 007010 and FCO 007014, corresponding to *U. coarctata* and *U. bruchii*, respectively. Accordingly, *U. drummondii* was not included in the Iberian bryoflora (Caparrós *et al.*, 2014). Nevertheless, shortly after the appearance of this work, the senior author (FL) found in 2015 a good population of *Ulot*a *drummondii* in the north of León province, 140 km away of the locality of Muniellos Nature Reserve.

With the recognition of the presence of this species in Spain, two species, namely *Ulot*a *intermedia* (Caparrós *et al.*, 2016) and *U. drummondii*, have been added to the Iberian bryoflora since the publication of the treatment of the genus in *Flora Briofítica Ibérica* (Caparrós *et al.*, 2014). Whereas a comprehensive description of the former was published by Caparrós *et al.* (2016), there is no complete, modern account of *U. drummondii*, as previous descriptions of this moss are in some extent incomplete or even imprecise for certain critical points.

At this point, the objectives of this work are defined as: i) to locate other possible unnoticed samples of this species; ii) to establish the morphological variability of the species throughout its range; iii) to present a new description of *Ulot*a *drummondii* that fits with modern standards in the genus and completes the revision of the genus *Ulot*a in *Flora Briofítica Ibérica*; and iv) to provide an identification key to facilitate the identification of the species in the European continent.

MATERIAL AND METHODS

The discovery of *Ulota drummondii* in Spain led us to a new revision of the Iberian records of the genus *Ulota*, specifically searching for unnoticed gatherings of this species. A search in the main Iberian herbaria with important collections from northern Spain and Portugal (BCB, FCO, LISU, MA, MACB, MAUAM, MUB, PAMP, VAL, and VIT) was carried on.

The description of the species here presented is based exclusively on Spanish specimens. They were studied using both standard light and stereo microscopies, following classic dissection methods. No type material of any name included in the present concept of *Ulota drummondii* was studied.

Specimens of *U. drummondii* from different areas of the world have been checked for the study; however, data for morphological comparison are based on bibliography, as some detailed studies are available, namely Noguchi (1989) for Japan, Crum & Anderson (1981) and Vitt (2014) for North America, and Lewinsky-Haapasaari (1998) and Smith (2004) for Europe.

RESULTS

The revision of the specimens collected by Fernández Ordóñez & Collado Prieto from Muniellos Nature Reserve provided with an additional true individual of *Ulota drummondii*, apparently never noticed by the collectors, as it was found in a sheet misidentified as *U. crispa* (FCO 007008), which actually included *U. bruchii* and, very scarce, *U. drummondii*. Besides this, no further specimens of this moss were found in any of the herbaria studied, in addition to the locality in León province found by the senior author (FL), the only other record of this species in the Iberian Peninsula. The confirmed presence of the species is thus limited to the two localities and three specimens detailed below.

This section is divided in three units: i) the known localities in the Iberian Peninsula, *i.e.*, the transcription of the herbarium labels of the Spanish specimens; ii) the description of *U. drummondii* based in Spanish materials following the structure used in *Flora Briofítica Ibérica* (Caparrós *et al.*, 2014); and iii) a new key to genus *Ulota*, including *Plenogemma phyllantha*, in Europe.

Known localities in the Iberian Peninsula

Fig. 1

SPAIN: ASTURIAS. Ibías, Monte Valdebois, Sierra Carzamoso, Parcela de Muestreo 8: Robledal de la *Avenello ibericae-Quercetum orocantabrica*, 29TPH8569, 1415 m, ramas de *Quercus orocantabrica*, junto con *Ulota crispa* var. *norvegica* (Grönvall) A.J.E. Smith & H. Hill, M.C. Fernández Ordoñez & M.A. Collado *s.n.*, 22-10-2001 (FCO-Briof 007008). **LEÓN.** Picos de Europa National Park, Oseja de Sajambre, Pass of El Pontón, 43°06'08"N, 005°00'53"W, 1250 m a.s.l., on branches of young beeches (*Fagus sylvatica*) in the limit of beech forest, growing with *Ulota bruchii*, *U. crispula*, and *Lewinskya speciosa*, F. Lara 1511/01, 7-11-2015 (MAUAM-Brio 3178); *Ibidem*, on branches of beech (*Fagus sylvatica*) in the limit of beech forest, growing with *U. crispa*, *U. crispula*, *U. bruchii*, *U. coarctata*, *Lewinskya striata*, and *Orthotrichum stramineum*, F. Lara 1511/02, 7-11-2015 (VAL-Briof *s.n.*).



Fig.1. Known localities of *Ulota drummondii* in the Iberian Peninsula. Dot indicates the first record from Asturias province and the star the locality from León province.

Species description

Ulota drummondii (Hook. & Grev.) Brid., *Bryol. Univ.* 1(1): 299. 1826 **Figs 2-14**

Orthotrichum drummondii Hook. & Grev., *Scott. Crypt. Fl.* 2: pl. 115. 1824.

Lectotype: E (selected in Wang & Jia (2012) without indication of specimen number).

Orthotrichum subrepens Sommerf., *Suppl. Fl. Lapp.* 59. f. 1. 1826.

Ulota bicolor Brid., *Bryol. Univ.* 1: 792. 1827.

Ulota funstonii Grout, *Moss Fl. N. Amer.* 2: 137. pl. 57: A. 1935.

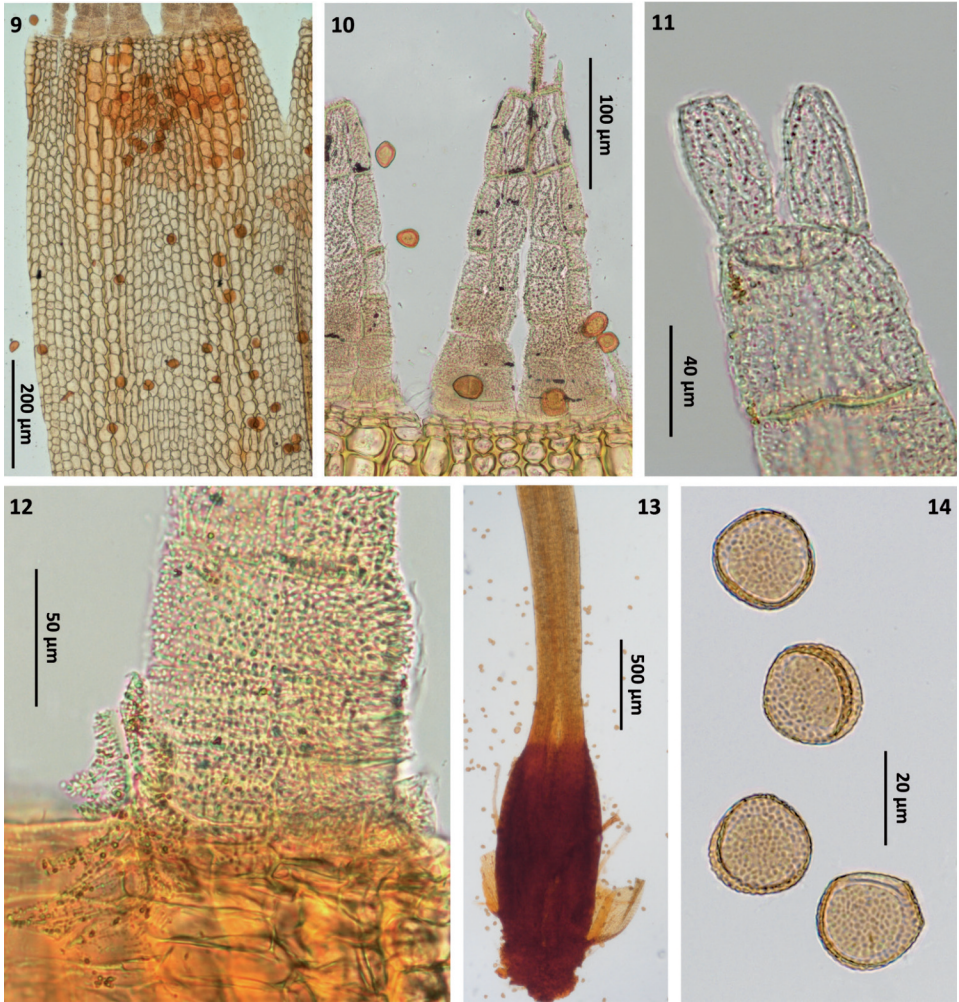
Ulota japonica var. *stenocarpa* Cardot, *Bull. Herb. Boissier, sér. 2* 8: 336. 1908.

Plants up to 1.0-1.5 cm tall, forming creeping patches of not or slightly crisped appearance when dry, dark olive green above, brownish to blackish below. *Stems* both plagiotropic and orthotropic, well branched. *Rhizoids* reddish-brown, smooth, on bases and lower part of erect stem, and along the stems when prostrated. *Axillary hairs* 3-6 cells long, the basal cell short and brown. *Leaves* erect, flexuose or curved when dry, erect-patent when moist, lanceolate to oblong-lanceolate, carinate, with wide base, 1.1-2.5 × 0.3-0.6 mm; *leaf base* elliptical to rounded, gradually or eventually abruptly narrowed to lamina, concave; *leaf apex* acute; *leaf margins* plane at base, finely recurved at one or both sides in the transition from



Figs 2-8. Photographs of *Ulota drummondii* from the Iberian Peninsula. 2. Habit. 3. Capsules dry and empty. 4. Lateral view of upper part of a capsule. 5. Vegetative leaves. 6. Perichaetial leaf. 7. Base of a vegetative leaf showing the basal marginal bands of differentiated hyaline cells. 8. Calyptra of a young sporophyte still surrounded by perichaetial leaves. All from *F. Lara 1511/02*.

base to lamina, entire or scarcely crenate towards apex. *Costa* ending well below apex, (44-)50-75 µm wide at base, (24-)27-33 µm at middle leaf. *Basal leaf cells* rectangular to linear, thick-walled, mostly nodulose, 13-25 × 6-12 µm, those in the proximal zone wider and orange coloured; *basal marginal cells* differentiated in 2-5(-6) rows, hyaline, shortly rectangular to quadrate, with longitudinal and transversal thickened-walls; *median and upper laminal cells* rounded, 10-15 × 8-13 µm, generally thick-walled, smooth or with 1(2) simple, low and broad papillae, sometimes branched, easily eroded and more visible in young leaves; cells at margins somewhat differentiated, usually forming a row of oblate cells. Gonioautoicous. *Perichaetia* terminal. *Perichaetial leaves* somewhat differentiated, appressed to seta to patent when dry, (2.4-)3.0-3.6 × (0.5-)0.7-1.0 mm, longer and with longer leaf base than vegetative leaves. *Vaginula* elliptical to long ovate, 0.8-1.0 mm, naked.



Figs 9-14. Photographs of *Ulota drummondii* from the Iberian Peninsula. **9.** Exothecial bands reaching the mouth; note the uncommon nodulous cell walls. **10.** General view of exostome teeth. **11.** Detail of upper part of exostome teeth showing the open pattern of longitudinally aligned papillae. **12.** Endostome rudimentary segment on the left lower part of an exostome tooth. **13.** Vaginula. **14.** Spores. All from *F. Lara 1511/02*.

Seta 2.5-3.7 mm long. *Capsule* long exserted, 1.6-2.2 mm in length, oblong-cylindrical to ellipsoidal when wet, fusiform when dry and full of spores, when dry and empty fusiform to ellipsoidal-cylindrical, with 8 strongly marked well separated ribs, pale brown, becoming darker in the upper third when mature; capsule mouth star-shaped (upper view) when dry; neck long, gradually narrowing to seta. *Exothecial cells* irregularly polygonal, thin-walled, delicate in appearance; *exothecial bands* formed by 4-5(-6) rows of irregular, quadrate to short rectangular cells, with cell-walls variably thickened, usually sinuose to nodulose, running from the base of the urn

and reaching the mouth, orange-brownish in distal part of capsule, yellowish until becoming concolorous with the exothecial cells below. *Stomata* superficial, numerous (36-41), located in lower half of capsule, mainly found in the urn-neck transition. *Peristome* double. *Prostome* remnants frequently present, reticulate. *Exostome* formed of 8 pairs of teeth easily splitting into 16 teeth, although some pairs frequently remain joined at basal and distal parts; teeth 235-315 µm tall, delicate, yellowish to cream fading to whitish at distal part, long triangular, cancellate, sometimes fenestrate, erect, patent or irregularly recurved when dry, not leaning against the exothecium; *external side of teeth* (Outer Peristomial Layer, OPL) with a papillose reticulate in the lower 1/3-1/2, upper part forming an open pattern of aligned papillae; *internal side of teeth* (Primary Peristomial Layer, PPL) with tall papillae arranged in short longitudinal or transversal lines in the lower 1/3, in the upper 1/3 ornamented with papillose or sometimes smooth longitudinal lines, with walls thickened forming papillose trabeculae. *Endostome* lacking or with 8+n rudimentary segments, densely ornamented with papillae and papillose lines. *Operculum* conic at base with outer border undulate and usually with a thin orange-tinted rim, long rostrate, frequently the rostrum somewhat curved. *Calyptra* campanulate, straw-yellowish with dark beak, hairy, with pluriseriate, papillose hairs. *Spores* rounded to elliptical, finely papillose, 20-26 µm in diameter.

Key to the species of genus *Ulota* s.l. in Europe

1. Plants dioicous; upper leaves with costa excurrent in a broad and relatively long mucro, frequently covered with brown, cylindrical to fusiform propagules *Plenogemma phyllantha*
- 1'. Plants monoicous; upper leaves with costa always ending below apex or percurrent, without propagules *Ulota* (2)
 2. Capsule pyriform, only ribbed near mouth when dry and empty *U. coarctata*
 - 2'. Capsule variable, cylindrical to fusiform, campanulate or urceolate, never pyriform, furrowed in most of its length when dry and empty 3
3. Plants saxicolous, with leaves mostly curved when dry, distal cells with prominent, mostly ramified papillae, exostome teeth translucent, striolate with mostly vertical lines *U. curvifolia*
- 3'. Plants epiphytic or if saxicolous then with traits different from the above signalled 4
 4. Plants not or slightly crisped, with most leaves erect or more or less curved to somewhat tortuose when dry 5
 - 4'. Plants strongly crisped, with most leaves strongly curved, contorted and circinate when dry 10
5. Calyptra naked or with scattered very short hairs, exostome teeth largely papillose below, largely ornamented with curved lines above *U. rehmannii*
- 5'. Calyptra hairy, with long hairs, exostome teeth predominantly papillose along their length 6
 6. Capsule cylindrical, ellipsoidal-cylindrical, or fusiform, frequently contracted to the mouth when dry and empty, capsule mouth star shaped (upper view) when dry 7
 - 6'. Capsule cylindrical, campanulate or urceolate, not contracted to the mouth and constricted or not below mouth when dry and empty, capsule mouth rounded (upper view) when dry 9

7. Plants usually forming creeping patches; exostome teeth yellowish to whitish, erect to irregularly recurved when dry; endostome rudimentary or lacking.....
..... *U. drummondii*
- 7'. Plants usually in cushions; exostome teeth whitish, yellowish or orange, entirely recurved when dry; endostome of 8 well developed segments, at least 2/3 as tall as teeth.....8
8. Spores (25-)30-40 μ m in diameter; vaginula hairs mostly uniseriate, smooth or slightly papillose; operculum with base plane, not undulate, with a fine orange-reddish basal rim *U. macrospora*
- 8'. Spores (15-)18-27(-30) μ m in diameter; vaginula hairs mostly partially 2-3(-4) seriate, neatly papillose; operculum with base undulate, without an orange-reddish rim *U. bruchii*
9. Plants mainly saxicolous; leaves rigid, erect to slightly curved when dry, with margins visibly recurved; capsule long cylindrical..... *U. hutchinsiae*
- 9'. Plants mainly epiphytic; leaves more or less flexuose, curved to slightly contorted when dry, with margins partially and faintly recurved; capsule short cylindrical *U. crispula*
10. Capsule fusiform, not constricted below mouth when dry and empty; endostome segments striate at base *U. bruchii*
- 10'. Capsule cylindrical, campanulate or urceolate, frequently more or less constricted below mouth when dry and empty; endostome segments variably ornamented, never striate at base..... 11
11. Capsule not or slightly constricted below mouth when dry, with ribs separated by more or less broad furrows in the upper half of urn; exothelial bands of 2-4 rows of cells, visibly separated from capsule mouth by a ring of small thin-walled cells..... 12
- 11'. Capsule strongly constricted below mouth when dry, with ribs separated by narrow furrows, collapsed at the constricted area of the urn; exothelial bands of (3-)4-5(-6) rows of cells, reaching the mouth or nearly so..... 13
12. Endostome segments incurved when dry, uniseriate with incrassate and prominent transverse walls; all the cells of the exothelial bands hyaline with pale yellow incrassate lateral walls; leaves abruptly narrowing from a concave base *U. intermedia*
- 12'. Endostome segments variably bent when dry, uniseriate or irregularly biseriate with thin transverse walls; cells of the exothelial bands evenly pale yellow, at least in the two central rows; leaves gradually narrowing from a plane to slightly concave base *U. crispula*
13. Leaves with submarginal bands of elongate cells ascending from base to the lower third of the lamina; leaf base gradually tapering to lamina, slightly concave, usually with longitudinal plications on both sides of costa and incurved margins; exostome teeth pairs easily splitting *U. calvescens*
- 13'. Leaves without submarginal bands of elongate cells; leaf bases abruptly narrowing to lamina, concave, not plicate, with plane margins; exostome teeth pairs remaining intact in old capsules..... *U. crispa*

DISCUSSION

Ulota drummondii is a moss easy to differentiate from other species in the genus, well defined by the following particular set of qualitative characters: 1) creeping habit; 2) leaves straight to curved, giving the plant a non or slightly crisped appearance when dry; 3) capsule fusiform to ellipsoidal-cylindrical when dry and empty; 4) exothecial bands wide, near mouth with cell walls orange-brownish, thickened, sinuose to nodulose; 5) stomata numerous, sometimes two or more in contact, located in the urn base; 6) exostome teeth yellowish to whitish, erect-patent to irregularly recurved when dry, in 8 pairs with strong tendency to split into 16 teeth, often remaining joined at their tips, openly and coarsely ornamented with lines and papillae in the upper part of both surfaces; and 7) endostome lacking or rudimentary.

Plants from the Iberian Peninsula are morphologically coincident with specimens described from Europe (Lewinsky-Haapasaari, 1998; Smith, 2004; Blockeel, 2017), North America (Crum & Anderson, 1981; Vitt, 2014), and Japan (Noguchi, 1989). Only minor differences can be considered, although in some cases they may stem from disparities in the perception or in the description of the features. For qualitative traits, only variations in leaf position when dry are found in the literature, as leaves of Japanese mosses are described as “*slightly crisped*” (Noguchi, 1989) whereas American specimens have “*flexuose to ± contorted flexuose, loosely erect*” dry leaves (Vitt, 2014). European individuals of *U. drummondii* have erect to curved leaves when dry (Lewinsky-Haapasaari, 1998; this paper). Regarding quantitative traits, available data from different descriptions show little deviation for most structures (Table 1). Only values for the maximum length of the seta show important disparities, since it is considered to reach 7 mm long in North America (Crum & Anderson, 1981); however, Vitt (2014) indicated a maximum length of 5.5 mm for the same area, which is closer to the values encountered in British Isles (Smith, 2004). In Japan, as in the Iberian Peninsula, the recorded values for seta length are always below 4 mm.

The two known localities of *U. drummondii* in Spain are located in the Cantabrian Range, a wide mountainous region with Atlantic climate. In both cases,

Table 1. Variability of some quantitative traits in *Ulota drummondii* across its geographical distribution. Data of Japan after Noguchi (1989); North America after Crum & Anderson (1981), indicated as C & A (1981), and Vitt (2014); and Europe after Lewinsky-Haapasaari (1998), indicated as L-H (1998), and Smith (2004)

	<i>Japan</i>	<i>North America</i>	<i>Europe</i>	<i>Iberian Peninsula</i>
Leaf length (mm)	2-3	C & A (1981): 3-4 Vitt (2014): 1.7-3.7	–	1.1-2.5
Median leaf cells length (µm)	8-12	C & A (1981): 8-10 Vitt (2014): 7-11	L-H (1998): 10-12 Smith (2004): 8-10(-14)	10-15
Seta length (mm)	3.0-3.5	C & A (1981): 3-7 Vitt (2014): 5.0-5.5	Smith (2004): 3-5	2.5-3.7
Capsule length (mm)	1.8-2.0	C & A (1981): 2.5-3.0 Vitt (2014): 1.7-3.2	Smith (2004): 2-3	1.6-2.2
Spore size (µm)	20-30	C & A (1981): 21-25 Vitt (2014): 21-24	L-H (1998): 24-28 Smith (2004): 18-24	20-26

altitude (1250 and 1415 m) corresponds to the upper montane belt of vegetation. This could be considered as consistent with the ecological affinities of the species across its range although these new records largely expand the distribution range of the species in Europe. In fact, *U. drummondii* has a Suboceanic Boreal-montane character (Blockeel *et al.*, 2014) and a Holarctic disjunct distribution that includes northern and central areas of Europe, northern North America in both coasts, and Asia in Russia Far East and Japan (Ignatov *et al.*, 2006; Vitt, 2014). In Europe, this species seems to be only widespread in western Fennoscandia and northern Great Britain (Lönnell, 2008; Atherton *et al.*, 2010; Blockeel *et al.*, 2014).

In terms of conservation of the species, no data on the number, size and areal extension of the Spanish populations are available, but it is worthy to note that an important exploratory effort has been conducted in the Iberian Peninsula during the last years as a part of the project *Flora Briofítica Ibérica*, and no other populations could be found. Without further information, it seems inappropriate to assign a threat category to *U. drummondii* in the Iberian context beyond Data Deficient-n.

The presence in Spain of a species with boreal, disjunct distribution and oceanic affinities, as it is *Ulotia drummondii*, is not a unique event within the family Orthotrichaceae. Recently, the Arctic-alpine *Lewinskya laevigata* (J.E. Zetterst.) F. Lara, Garillete & Goffinet was found in the mountains of central Spain (Ellis *et al.*, 2014, as *Orthotrichum laevigatum* J.E. Zetterst.). Findings in the mountains of southern Europe, including the Iberian Peninsula, of other ecologically related species with similar biogeographical patterns cannot be discarded. Moreover, the Atlantic Region of Spain and Portugal has been shown to be an area of special importance for the Orthotrichaceae (Garillete & Albertos, 2012), so that the appearance of the three remaining European *Ulotia* species that have not yet been found in the territory cannot be ruled out.

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