

***Lewinskya lamyana* sp. nov. (Orthotrichaceae, Bryopsida), a distinct moss from an exceptional habitat in the Southern Iberian Peninsula**

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Abstract – A new species, *Lewinskya lamyana* F.Lara, Garilleti, Draper & Mazimpaka, is described. It is a mainly epiphytic moss, so far exclusively found in southernmost Spain on the summit area of Sierra Bermeja, a coastal mountain, which is exceptional in several environmental aspects. The new moss is characterized by a set of morphological traits, most of them easily observed: medium to large plants; leaves lanceolate and acuminate with recurved margins; calyptra campanulate with scattered stout hairs; capsule fully immersed, brown, cylindrical, with 8 broad and prominent ribs; exostome of 8 pairs of teeth easily splitting, all fused basally in a continuous low ring; teeth opaque, cream-coloured, recurved to revolute when dry; endostome of 8 hyaline, linear and relatively stout segments; operculum convex to conic, wider than capsule mouth, long rostrate, with a conspicuous red basal rim. The new moss is illustrated and compared to similar taxa.

Bryophytes / *Abies pinsapo* forests / *Orthotrichum* / Sierra Bermeja / Spain / Taxonomy / Western Mediterranean

INTRODUCTION

The Mediterranean Basin is considered one of the world's major biodiversity hotspots, being the one with the highest vascular plant diversity outside the tropics (Myers *et al.*, 2000). The bryophyte flora of this area is also remarkably diverse (Ros *et al.*, 2007, 2013), although still far from well known in spite of the outstanding advances in several Mediterranean countries in recent decades (Geissler, 2001; Ros *et al.*, 2007; Frey, 2010). Numerous novelties are reported every year from the different continental and island territories, with occasional descriptions of new species (see for example, Garcia *et al.*, 2006; Hedderson & Blockeel, 2006; Cezón *et al.*, 2010; Dirkse & Brugués, 2010; Guerra *et al.*, 2010; Blockeel *et al.*, 2017). In the case of the genus *Orthotrichum* s.l., nowadays split into *Orthotrichum* Hedw. s.str., *Lewinskya* F.Lara, Garilleti & Goffinet, and several smaller genera (Lara *et al.*,

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2016), recent advances in the Mediterranean area have been incorporated into the accounts of Lara *et al.* (2009) and Lara & Garilleti (2014). Since the publication of *O. comosum* F.Lara, R.Medina & Garilleti (Medina *et al.*, 2013) no new species have been described for that area within the tribe Orthotricheae.

In the course of the International meeting of the British and Spanish bryological societies (BBS-SEB) held in Western Andalusia (Spain) in spring 2016 (Lara & Draper, 2016; Vigalondo & Lara, 2017), thirty bryologists from several European countries explored a selected set of Mediterranean localities of great bryological interest. One of these sites was Los Reales de Sierra Bermeja Natural Area, a very peculiar mountain range near the Malaga coast, where we found a strange and unknown epiphytic *Lewinskya* species. Subsequent study of the specimens from both the original sample and further collections revealed that this moss exhibits an unparalleled combination of morphological characters that justifies its description as a new, very distinctive species. We name the new species in honor of Denis Lamy, as a tribute to his outstanding dedication to Cryptogamic Botany, and in particular to Bryology.

SPECIES DESCRIPTION

Lewinskya lamyana F.Lara, Garilleti, Draper & Mazimpaka **sp. nov.** **Figs 1-19**

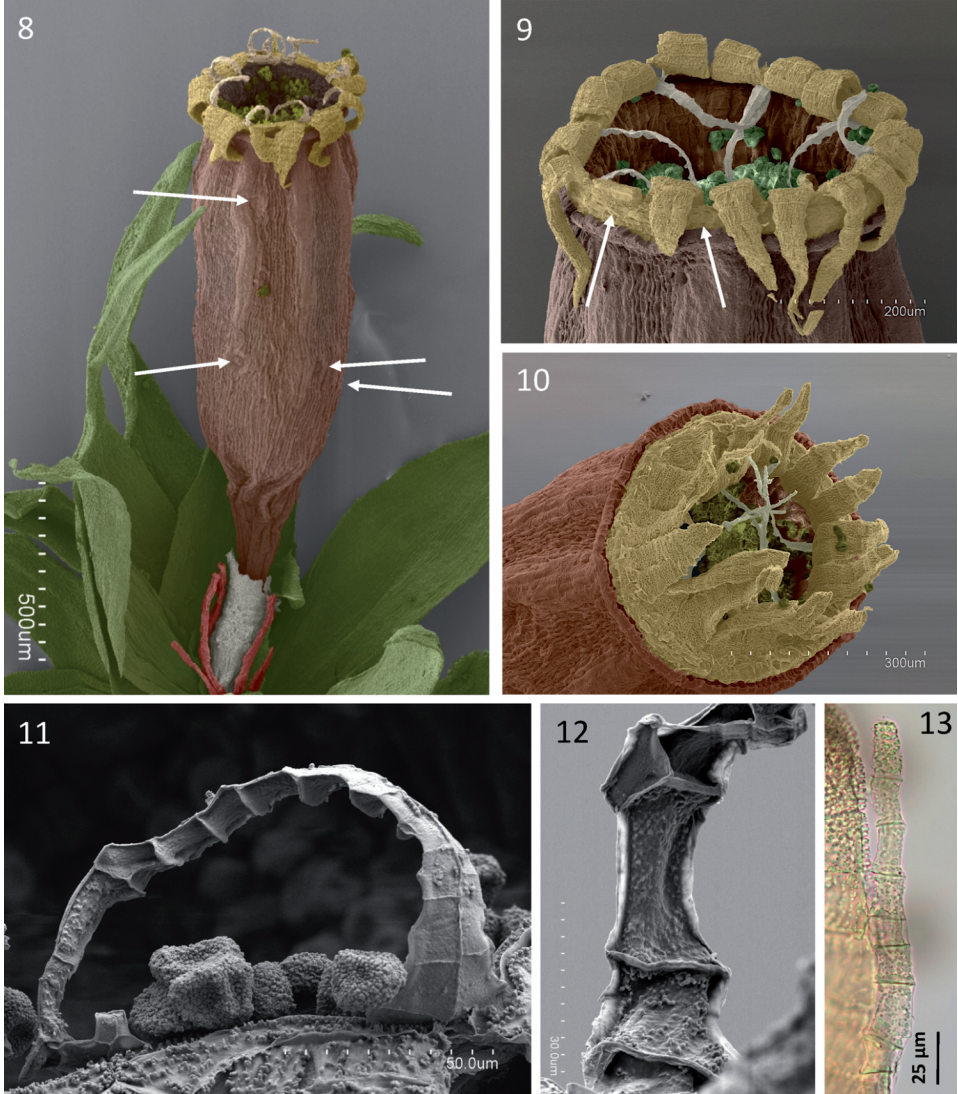
Diagnosis: *Plantae ad 4.5 cm altae, in laxis vel densis pulvinis crescentes. Folia longa, lanceolata vel anguste ovata-lanceolata, marginibus recurvatis vel revolutis, apice plerumque acuminato. Calyptra campanulata, pilis validis sparsis ornata. Capsula immersa, fusca, cylindrica, 8 costis latis prominentibusque. Peristoma duplex. Exostoma 8 dentium paribus; dentes facile findentes, omnes basin connati et annulum curtum continuum formantes, opaci, cremei, in sicco recurvati vel revoluti. Endostoma 8 segmentis hyalinis, linearibus et relative validis, in sicco irregulariter erectis vel deflexis, varie papillosis atque interna facie parietibus transversalibus prominentibus munitis. Operculum convexum vel conicum, capsulae ostio latius, longe rostratum, annulo basilari conspicue rubro ornatum. Sporae subtiliter papillosae, diametro plerumque 18-23 µm.*

Type: SPAIN, Andalusia, Malaga prov.: Los Reales de Sierra Bermeja Natural Place, Estepona, eastern slope near the top of the mountain, 36°29'06.1"N, 5°12'27.3"W, 1440 m, on branches of *Abies pinsapo* in a Spanish fir forest on peridotite ground, *F. Lara 1606/40*, 4-June-2016 (Holotype: P, Isotypes: MAUAM 5127 and VAL).

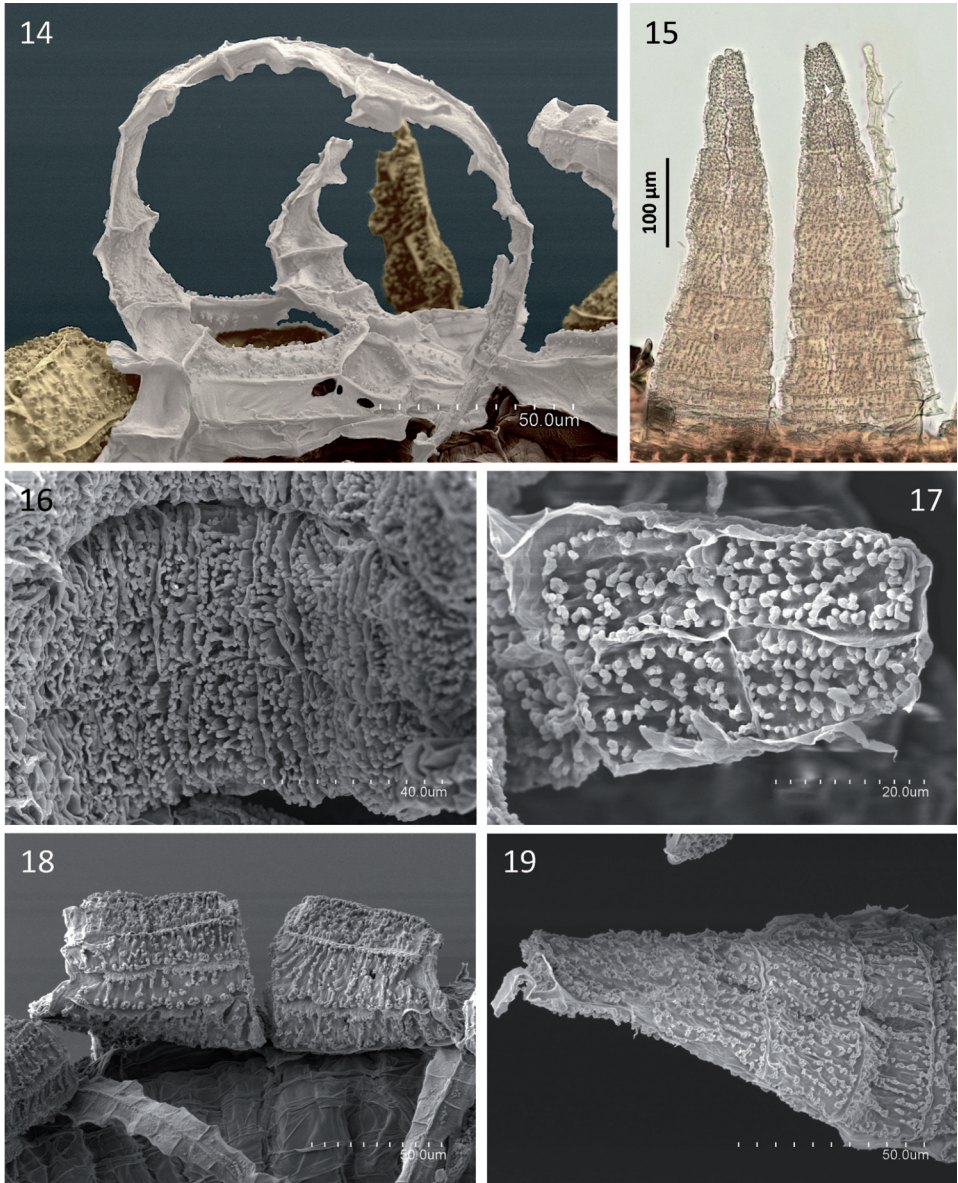
Plants up to 4.5 cm tall, usually 2.0-3.5 cm, irregularly branched, olive-green at tips, dark green to brownish below, in lax or dense cushions. **Stems** orange to reddish brown, rounded-pentagonal in section, completely covered by leaves. **Axillary hairs** formed by (2)3-4 rectangular hyaline cells and 1(2) basal shorter and coloured cell(s). **Rhizoids** reddish brown, smooth, in lower part of stems. **Vegetative leaves** erect to appressed when dry, erect-patent to patent when moist, long lanceolate to ovate-lanceolate, gradually increasing in size along the stem, the lower 2.0-2.8(-4.2) × 0.5-0.6 mm, the upper 3.0-4.2 × 0.6-1.0 mm, unistratose throughout; **leaf apex** acuminate, frequently asymmetric, acute or somewhat rounded in some leaves; **margins** recurved to revolute, distally plane. **Costa** ending below



Figs 1-7. *Lewinskya lamyana* sp. nov. 1. Habit. 2. Detail of a mature capsule with the typical position of the peristome when dry. 3. Calyptra on an almost mature capsule immersed in the perichaetial leaves. 4. Scanning Electron Microscope micrograph of the lid of a mature capsule; note that the lid is wider than the capsule mouth diameter. 5. Light microscope view of the operculum, where the red-orange rim is clearly visible. 6. Vegetative leaves; on the top a representative of the upper stem leaves, below a small one that represents the lower stem leaves. 7. Detail of leaf apices. (All from the holotype).



Figs 8-13. *Lewinskya lamyana* sp. nov. **8.** Scanning Electron Microscope (SEM) micrograph of the sporophyte and inner perichaetial leaves; arrows point at stomata. **9.** SEM micrograph of the capsule mouth and peristome; arrows indicate the continuous ring formed by the fused basal portion of the exostome; it is common for the endostome segments to be bent towards the inside of the capsule. **10.** SEM micrograph of the capsule mouth just after detachment of the lid. **11.** SEM general view of an endostome segment; note the variable papillosity of the inner surface and the prominent transverse walls. **12.** SEM detail of the ornamentation of the basal third of the inner side (IPL) of an endostome segment. **13.** Light microscope view of the endostome ornamentation. Figs 8-10 with false color. (All from the holotype).



Figs 14-19. *Lewinskya lamyana* sp. nov. **14.** Scanning electron microscope (SEM) micrograph with false color to best differentiate the peristome structures; an exceptional endostome configuration (in white) is illustrated here, with a tall incomplete connective membrane and a short intermediate segment. **15.** Light microscope view of peristome; note the strong ornamentation of the inner side (PPL) of the exostome teeth, in which vertically aligned papillae predominate. **16.** SEM micrograph of the basal outer side (OPL) of the exostome, with a reticule almost hidden by papillae. **17.** SEM micrograph of the upper outer side (OPL) of an exostome tooth. **18.** SEM micrograph of the basal inner section (PPL) of the exostome, with a pair of endostome segments in the foreground. **19.** SEM micrograph of the upper inner side (PPL) of the exostome. (All from the holotype).

apex to shortly excurrent, usually percurrent, 50-80 μm wide at leaf base, 40-70 μm at mid leaf. **Basal leaf cells** irregularly elongate, (14-)26-70(-99) \times (6-)8-13(-16) μm , shorter at margin, smooth, with straight to nodulose cell walls, scarcely to moderately thickened, mostly hyaline but with several, usually short, intercalated rows of orange cells, with walls usually thicker and nodulose; extreme proximal base and corners of leaves orange-coloured, occasionally with well differentiated auricles. **Median and upper leaf cells** isodiametric to ellipsoid, thick walled, (9-)11-18(-23) \times (8-)9-13(-15) μm , with 1-2(-3) simple and weak papillae. Goniatocous. **Perigonia** lateral on main axes and branches; perigonial leaves ovate, obtuse at apex. **Perichaetia** terminal; **perichaetial leaves** differentiated, longer than vegetative ones, with wider bases and narrower distal portions, finely recurved at margins, except the inner leaves which have plane margins, usually with many rows of orange basal cells variably ascending. **Vaginula** naked. **Calyptra** campanulate with scattered more or less short and stout hairs.

Sporophyte immersed, completely hidden or visible among erect-patent perichaetial leaves that clearly exceed the capsule. **Seta** 0.4-0.5 mm long. **Capsule** dark brown, oval-cylindrical when dry and full of spores, cylindrical or slightly constricted below mouth when dry and empty, tapering into seta through a short neck; with 8 ribs, moderately to strongly marked in upper 2/3. **Exothecial cells** hyaline, mostly rectangular, with moderately thickened, yellowish walls; **exothecial bands** broad, of 5-8 rows of light brown, rectangular cells with moderately thickened walls, usually well differentiated along distal 3/4 of urn; **suboral ring** differentiated, formed by (3-)5-7 rows of obscure, short and irregular cells, where bands partially penetrate; suboral ring and bands strongly darkened in old capsules. **Stomata** superficial, scattered in a long central portion of the urn, occasionally reaching its upper or lower parts. **Peristome** double. **Exostome** of 8 pairs of teeth easily splitting to 16, occasionally some pairs remaining intact, all teeth fused at their bases forming a continuous short ring; teeth opaque, cream-coloured, recurved to revolute when dry; external surface (Outer Peristome Layer, OPL) densely and coarsely papillose, except for the basal ring which is predominantly smooth; internal surface (Primary Peristome Layer, PPL) more openly papillose, mostly formed by compound papillae vertically aligned. **Endostome** of 8 hyaline segments, linear although relatively stout, as long as or a bit longer than teeth, sometimes irregularly appendiculate; unevenly erect or deflexed when dry; occasionally with some vestigial or undeveloped intermediate segments; external surface (PPL) usually smooth, sometimes irregularly rough or with scattered thickenings; internal surface (Inner Peristome Layer, IPL) mostly uniseriate, with prominent transverse walls, ornamented with more or less fine, prominent and densely disposed papillae, sometimes only clearly papillose in the distal part; IPL frequently a bit wider than PPL becoming visible as a partial thin hyaline halo-like border; fragments of a connective membrane, partially ornamented with papillae, sometimes observed linking some main and intermediate segments. **Operculum** convex to almost conic, long rostrate, when still attached conspicuously wider than capsule mouth, with an obvious red to crimson basal rim formed by cells with coloured and strongly thickened walls. **Spores** finely papillose, (15-)18-23(-26) μm in diameter.

Other specimens seen (paratypes): SPAIN, Andalusia, Malaga prov.: Los Reales de Sierra Bermeja Natural Place, Estepona, eastern slope near the top of the mountain, 36°29'06.0"N, 5°12'27.3"W, 1440 m, lower branches of *Abies pinsapo*, F. Lara 1606/43, 4-June-2016 (MAUAM 5128). *Ibidem*, north-eastern slope, 36°29'07.6"N, 5°12'24.7"W, 1425 m, on peridotite boulders under Spanish fir trees, F. Lara 1712/04, 31-December-2017 (MAUAM 5129). *Ibidem*, eastern slope near the top of the mountain, 36°29'06.1"N, 5°12'27.3"W,

1440 m, on branches of a dead tree (*Abies pinsapo*), F. Lara 1712/06, 31-December-2017 (MAUAM 5130). *Ibidem*, on internal twigs in a dense stand of Spanish fir trees, F. Lara 1712/07, 31-December-2017 (MAUAM 5131). *Ibidem*, on stones and boulders in a dense stand of Spanish fir trees, F. Lara 1712/08, 31-December-2017 (MAUAM 5132). *Ibidem*, 36°29'06.3"N, 5°12'27.2"W, 1440 m, on internal branches of a large *Abies pinsapo* tree, F. Lara 1712/09, 31-December-2017 (MAUAM 5133). *Ibidem*, Casares, western slope near the top of the mountain, 36°29'05.6"N, 5°12'29.9"W, 1437 m, on creeping branches of an exposed, low pyramidal *Abies pinsapo* tree, F. Lara 1712/11, 31-December-2017 (MAUAM 5134). *Ibidem*, Genalguacil, northern slope, 36°29'08.7"N, 5°12'31.3"W, 1414 m, on lower and median branches and twigs of young *Abies pinsapo* trees, F. Lara 1712/12, 31-December-2017 (MAUAM 5135).

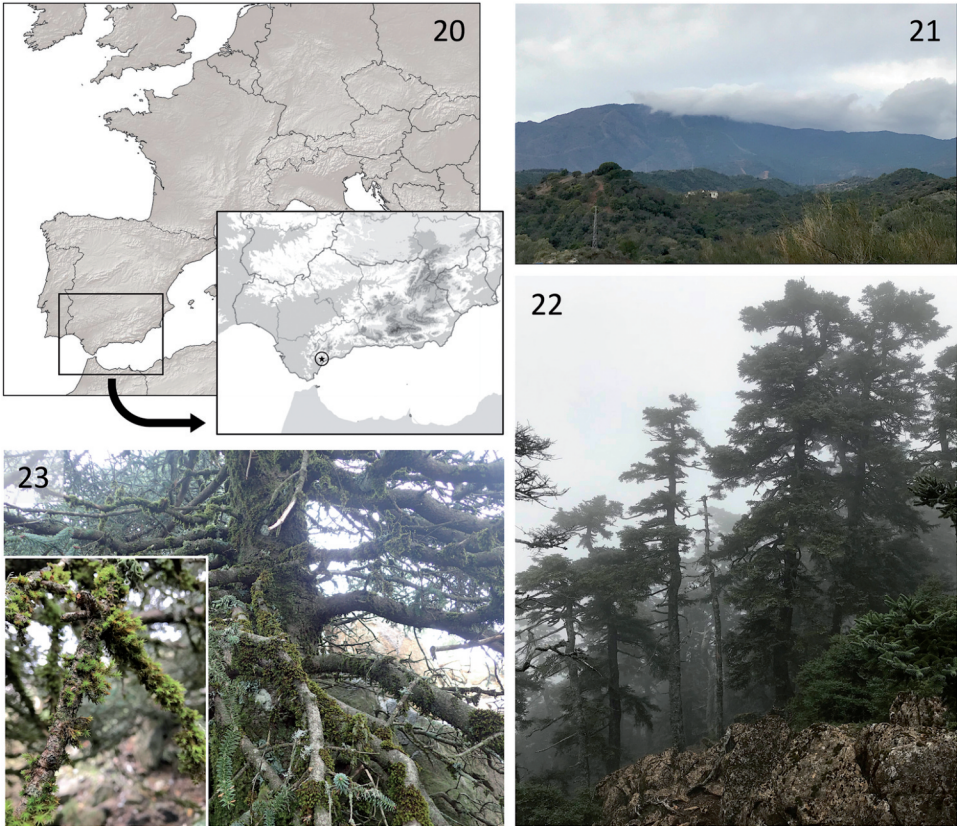
DISCUSSION

Ecology and distribution

The locality and habitat where the new moss grows are highly remarkable and unique in some aspects. Sierra Bermeja is a relatively high mountain very close to the Mediterranean Sea (Fig 20), as the summit is 1452 m a.s.l. and about 8 km from the nearest coastline. Close to the Gibraltar Strait, this mountain benefits from wet winds that allow the development of a Spanish Fir (*Abies pinsapo* Boiss.) forest. This is the southernmost fir forest in Spain and the only one on peridotite outcrops, being rich in vascular serpentinophytes, many of them highly restricted endemics (Pérez-Latorre *et al.*, 2013).

Bryophytes are relatively diverse in Sierra Bermeja, including some interesting Macaronesian-Mediterranean species, especially at upper levels where the climate becomes more humid (Guerra, 1982). In the upper parts of this mountain, mean annual temperature is about 14°C whereas mean annual precipitation reaches 1600 mm, probably up to 2000 mm due to horizontal rainfall (Gómez-Zotano *et al.*, 2014). In fact, the high parts of the mountain are frequently covered by fog (Figs 21-22).

Epiphytic bryophytes are very scarce in the whole mountain area and, even within the fir forest, epiphytic bryophyte communities are poorly developed. However, in the surroundings of the summit the situation is quite different and the bark of many trees is more or less colonized by bryophytes. On scattered trees, the trunk and lower branches can be densely covered by epiphytic mosses and liverworts (Fig. 23). This usually happens in sheltered situations, where epiphytic communities are protected from excessive insolation. There, *Lewinskya lamyana*, like other orthotrichaceous mosses in the area, mainly grows on the internal branches of trees of pyramidal architecture or on branches inside dense stands of fir trees. The epiphytic communities where the new species thrives are commonly dominated in cover and height by *Pulvigerella lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochrya, which abundantly forms sporophytes. In many cases, *L. lamyana* is the second moss in physiognomic importance of these communities that commonly include, in variable proportions, exemplars of *L. acuminata* (H.Philib.) F.Lara, Garilleti & Goffinet, *L. rupestris* (Schleich. ex Schwägr.) F.Lara, Garilleti & Goffinet, *L. striata* (Hedw.) F.Lara, Garilleti & Goffinet, *Orthotrichum scanicum* Grönvall, and *O. comosum*, together with *Neckera pumila* Hedw., and *Frullania dilatata* (L.) Dumort.



Figs 20-23. Geographical and ecological aspects of *Lewinskya lamyana* sp. nov. **20.** Location of the known population. **21.** A view of Sierra Bermeja from the East; as frequently occurs there, a cap of clouds is retained at summit and uppermost northern slopes. **22.** Image of the Spanish fir forest near the top of the mountain immersed in the fog. **23.** Branches of *Abies pinsapo* profusely colonized by orthotrichaceous mosses.

Lewinskya lamyana has also been found colonizing stones and boulders in the understory of dense canopies of *Abies pinsapo*. In this situation, the communities are usually dominated by saxicolous bryophytes [*Grimmia* spp., *Nogopterium gracile* (Hedw.) Crosby & W.R.Buck, *Antitrichia curtispindula* (Hedw.) Brid., *Frullania tamarisci* (L.) Dumort., etc.], as well as *Lewinskya rupestris*, which is much more abundant than on bark. Interestingly, *Orthotrichum tenellum* Bruch ex Brid. and all the bryophytes mentioned above as common components of the epiphytic communities are also part of these saxicolous communities.

Although *Lewinskya lamyana* is highly localised in a small area around the summit of Sierra Bermeja Mountain, it is not very scarce over the whole site since it appears scattered throughout the wettest parts of the fir forest and, in some cases, can be very abundant on the branches of appropriate trees. This moss has not been found in other *Abies pinsapo* forests in Spain and northern Morocco (Draper *et al.*, 2006) nor in similar humid montane forests surveyed by our research team throughout the Mediterranean Basin. If the restricted distribution of this moss is confirmed, monitoring of the population of Sierra Bermeja should be a priority

issue, since the southernmost European mountain forests in Andalusia might be among the most vulnerable areas for the loss of tree species due to climatic warming (Linares *et al.*, 2009).

Distinction and singularities of *Lewinskya lamyana*

The main distinguishing features of *Lewinskya lamyana*, most of them easy to observe, are: a) medium to large size of the plants (Fig. 1); b) leaves lanceolate and acuminate with recurved margins (Fig. 6), the perichaetial ones being somewhat longer, with wider bases and narrower distal portions; c) calyptra campanulate with scattered stout hairs (Fig. 3); d) capsule entirely immersed, brown, cylindrical, with 8 broad and prominent ribs (Figs 2, 4, 8); e) exostome of 8 pairs of teeth easily splitting, all fused basally in a continuous low ring (Figs 8-10); f) exostome teeth recurved to revolute when dry, opaque, cream-coloured, markedly contrasting with the exothecium (Fig. 2); g) endostome of 8 linear and relatively stout segments, hyaline, contrasting with the colored teeth, papillose, and with prominent transverse walls on the inner surface (Figs 2, 9, 11-15); h) operculum convex to conic, wider than capsule mouth, long rostrate, with a conspicuous red basal rim (Figs 4-5).

Overall, *Lewinskya lamyana* is a distinct moss, well differentiated from all other Mediterranean and European species of the genus. Macroscopically, it recalls *L. rupestris* and *L. affinis* (Schr. ex Brid.) F.Lara, Garilleti & Goffinet owing to its furrowed and immersed capsules. However, it can be easily differentiated from the first by the peristome, which in *L. lamyana* has opaque exostome teeth, recurved to revolute when dry, and a hyaline endostome with long and papillose segments. The very variable *L. rupestris* always has more or less translucent exostome teeth that characteristically remain erect to spreading when dry. Additionally, the Mediterranean populations of *L. rupestris* almost always have leaves with bistratose areas or strands in the upper half of lamina (Lara *et al.*, 2009; Lara & Garilleti, 2014), whereas the leaf lamina is evenly unistratose in *L. lamyana*. As for the distinction from *L. affinis*, which is also a quite variable moss (Lara & Garilleti, 2014), characters of the capsule, peristome and leaves can be safely used. The capsule in *L. affinis* is more or less emergent, yellowish, completely furrowed, and narrowly cylindrical or constricted below the mouth when dry, whereas it is immersed, dark brown, distinctly furrowed only in the upper part and oval-cylindrical when dry and empty in *L. lamyana*. The peristome of *L. affinis* consists of 8 pairs of exostome teeth recurved when dry, no splitting and not contrasting in colour with the exothecium, and 8 endostome segments a little shorter than the teeth and ornamented on the inside by sinuose lines, with inconspicuous transverse walls. In *L. lamyana* the exostome teeth pairs easily split and contrast strongly with the exothecium as they are much lighter in colour. Additionally, the segments are as long as the teeth, papillose and with prominent transverse walls on the internal side. Finally, the leaves in *L. affinis* are clearly less long acuminate than in *L. lamyana*.

Other Mediterranean species which may be confused with *L. lamyana* are *L. shawii* (Wilson) F.Lara, Garilleti & Goffinet and *L. tortidontia* (F.Lara, Garilleti & Mazimpaka) F.Lara, Garilleti & Goffinet. However, the distinction is easy in both cases since *L. shawii* has ovoid capsules, only slightly and very short-furrowed below the mouth, with endostome segments lacking or rudimentary; *L. tortidontia*, very similar to *L. affinis*, can be differentiated also by the irregular twisting of the exostome teeth when recurved, and by the contour of its capsule mouth not rounded in top view but star-shaped when dry.

The new moss is a typical representative of the genus *Lewinskya* (Lara *et al.*, 2016) although its peristome morphology presents two interesting peculiarities. The most significant is the existence of a basal exostome structure formed by the fusion of the bases of all the teeth (Figs 9-10). From this continuous base, no more than 50 µm in height, arise the distal parts of the teeth, originally grouped in 8 pairs that subsequently split into 16 after the first hygroscopic movements, without affecting the basal ring. As has been described for several species in the closely related genus *Ulot*a (Caparrós *et al.*, 2011; Garilleti *et al.*, 2012, 2015; Caparrós 2015; Muñoz-Puelles *et al.*, 2017), this basal exostome ring does not perform hygroscopic movements. So, the teeth are recurved in a peculiar way, the proximal parts of the free portions being more or less elevated over the capsule mouth, usually without touching it (Figs 8-9).

The second singular trait found in *Lewinskya lamyana* is the presence of fragments of an endostome connective membrane (Fig. 14). As Lewinsky (1993) stated, the presence of a connecting membrane in the endostome is a characteristic found in several genera of Orthotrichaceae, namely *Zygodon*, *Pleurorthotrichum*, *Schlotheimia*, and *Orthotrichum s.l.* Within the latter, this endostome structure has been reported only for members of subgenus *Pulchella*, the most diverse group of cryptopore orthotrichaceous mosses (Lewinsky, 1993; Lewinsky-Haapasaari & Hedenäs, 1998). Subsequently, the presence of a differentiated, sometimes incomplete, connecting membrane has been considered a distinctive character of *Orthotrichum s.str.* (Lara *et al.*, 2016). In the case of *L. lamyana*, the connective membrane is ordinarily completely absent, and only in some capsules are there occasional fragments whose development appears to be associated with intermediary segments, which are also uncommon in this species. To our knowledge, similar fragments of connective membrane have been reported only for one other member of the genus, *L. leiolecythis* (Müll.Hal.) F.Lara, Garilleti & Goffinet, (Lewinsky, 1992).

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