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# New records of *Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak (Bryaceae) from two separate populations in the Mediterranean region

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## ABSTRACT

*Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak is a widespread moss from tropical and subtropical areas of the world. It has been also reported from Europe. However, the recent re-evaluation of those records indicate they have been mistaken with unrelated *Bryum* Hedw. species and thus, its actual presence in Europe is doubtful. During independent bryological surveys, samples from two distant Mediterranean localities in Spain and Israel were collected. These samples differed from any other Bryaceae Rchb. species reported to date but matched the morphological traits described for *A. apiculatum*, which is here newly reported for Spain and Israel. A detailed morphological study of specimens from the two localities revealed conspicuous variation at vegetative traits related to leaf arrangement and shape. This variation in vegetative traits contrasted with the similarity of tubers. Plants from both populations showed rhizoidal and axillary tubers of the distinctive features described for *A. apiculatum* s.l., including their large size (166-359 µm), brown to dark-brown colour and strongly protuberant cells. Tuber traits make *A. apiculatum* readily distinguishable from all other tuberous species of *Bryum* s.l. in the Mediterranean, including *Ptychostomum rubens* (Mitt.) Holyoak & N.Pedersen. This latter species also occurs on disturbed soil, and has axillary and rhizoidal tubers with protuberant cells, but with distinctive red colouration. Its leaves have a conspicuous limbidium, and are dentate in the upper part, contrasting with the entire margin and absence of limbidium in those of *A. apiculatum*. These traits allow a clear differentiation between both species.

**KEY WORDS**  
Mediterranean,  
bryophytes,  
tropical mosses,  
*Bryum*,  
new records.

## RÉSUMÉ

*Nouveaux signalements d'Anomobryum apiculatum (Schwägr.) D. Bell & Holyoak (Bryaceae) provenant de deux populations distinctes de la région méditerranéenne.*

*Anomobryum apiculatum* (Schwägr.) D. Bell & Holyoak est une mousse répandue dans les régions tropicales et subtropicales du monde. Elle a également été signalée en Europe. Or, la récente réévaluation de ces enregistrements indique qu'elle a été confondue avec des espèces de *Bryum* Hedw. non apparentées et que sa présence réelle en Europe peut être mise en doute. Au cours de travaux bryologiques indépendants, des échantillons provenant de deux localités méditerranéennes éloignées en Espagne et en Israël ont été collectés. Ces échantillons différaient de toutes les autres espèces de Bryaceae Rchb. signalées à ce jour, mais correspondaient aux traits morphologiques décrits pour *A. apiculatum*, qui est ici nouvellement signalée pour l'Espagne et Israël. Une étude morphologique détaillée des spécimens des deux localités a révélé une variation notable des traits végétatifs liés à la disposition et à la forme des feuilles. Cette variation des traits végétatifs contrastait avec la similitude des tubercules. Les plantes des deux populations présentaient des tubercules rhizoïdaux et axillaires possédant les caractéristiques distinctives décrites pour *A. apiculatum s.l.*, notamment leur grande taille (166-359 µm), leur couleur brune à brun foncé et leurs cellules fortement protubérantes. Les caractéristiques des tubercules permettent de distinguer facilement *A. apiculatum* de toutes les autres espèces tubéreuses de *Bryum s.l.* en Méditerranée, notamment *Ptychostomum rubens* (Mitt.) Holyoak & N. Pedersen. Cette dernière espèce est également présente sur des sols perturbés et possède des tubercules axillaires et rhizoïdaux avec des cellules protubérantes, mais avec une coloration rouge distinctive. Ses feuilles ont un limbe bien visible et sont dentées dans la partie supérieure, contrastant avec toute la marge et l'absence de limbe chez celles d'*A. apiculatum*. Ces traits permettent une différenciation claire entre les deux espèces.

**MOTS CLÉS**  
Méditerranée,  
bryophytes,  
mousses tropicales,  
*Bryum*,  
signalements nouveaux.

## INTRODUCTION

The Bryaceae Rchb. is one of the most taxonomically complex families of acrocarpous mosses (Holyoak 2021). It has been subject to many systematic rearrangements during the last decades, some of which have evidenced conflicting results between morphological and molecular data (Pedersen & Hedenäs 2002, 2003, 2005; Pedersen *et al.* 2007; Holyoak 2021). In the most recent European checklist, Hodgetts *et al.* (2020) recognised 73 species in six genera, where most of the previously recognised *Bryum s.l.* species were reassigned to the genera *Imbriobryum* N. Pedersen and *Ptychostomum* Hornsch. and one species, *Bryum apiculatum* Schwägr., to *Anomobryum* Schimp., based on molecular grounds (Hodgetts *et al.* 2020; Holyoak 2021).

*Anomobryum apiculatum* (Schwägr.) D. Bell & Holyoak is a widespread species in tropical and subtropical areas of the world, extending to south-eastern United States, Central and South America, Africa, India, south-east Asia, Australia, New Zealand, Hawaiian Islands, and many other Pacific islands (Spence & Ramsay 2006; Holyoak 2009; Kalinowski Canestraro & Fernandes Peralta 2022), often occurring as a weed on disturbed soil (Ochi 1980; Holyoak 2009). Its taxonomy has been controversial because of its notorious variability in vegetative traits and the interpretation of asexual reproduction structures (see Holyoak 2009). Indeed, the consultation of national floras where the species has been reported evidences this controversy based on the diversity of shapes, cellular types and size ranges of rhizoidal tubers reported (van Rooy & Magill 1987; Spence & Ramsay 2006; Spence 2014; Kalinowski Canestraro & Fernandes Peralta 2022), suggesting the need

of a detailed revision. As currently circumscribed, it contains in its synonymy the Afro-American *Bryum cruegeri* Hampe and the African and Australasian *Bryum nitens* Hook. ex Harv. (Ochi 1972, 1974, 1985), together with other 54 synonyms listed in Tropicos (2023), including species of *Pohlia* Hedw. Outside its typically tropical range it was reported from the United Kingdom by Holyoak (2009). Notwithstanding, subsequent molecular studies indicated that plants from the United Kingdom may represent an undescribed species close to *Bryum dichotomum* Hedw. (see Hodgetts *et al.* 2020; Holyoak 2021). Another record of this species, based on a specimen collected by E. Bourgeon (BM) from Tenerife Island, labelled as *B. turbinatum* (Hedw.) Turner, was communicated in Ochi (1972) as *B. nitens*. Thus, subsequent studies have listed this species as *B. apiculatum* (González-Mancebo *et al.* 2008; Holyoak 2009) in the Canary Islands until Hodgetts *et al.* (2020) argued it could have been mistaken with *Bryum gemmiparum* De Not., a locally common species which was not reported by Ochi (1972), and also because no further collections of *A. apiculatum* have been done (see Hodgetts *et al.* 2020; Holyoak 2021). Therefore, the current presence of *A. apiculatum* in the Canary Islands remains unclear as is for Europe and consequently has not been recorded in a recent account of the European Bryaceae (Holyoak 2021).

During independent bryological work, the two authors found samples of a *Bryum* in two separate Mediterranean localities that did not match previously recorded species in the European Bryophyte flora (Hodgetts *et al.* 2020; Holyoak 2021) but which showed the distinctive traits of *A. apiculatum* (Whitehouse 1978; Egunyomi 1980). The present contribution provides a detailed description of those samples.

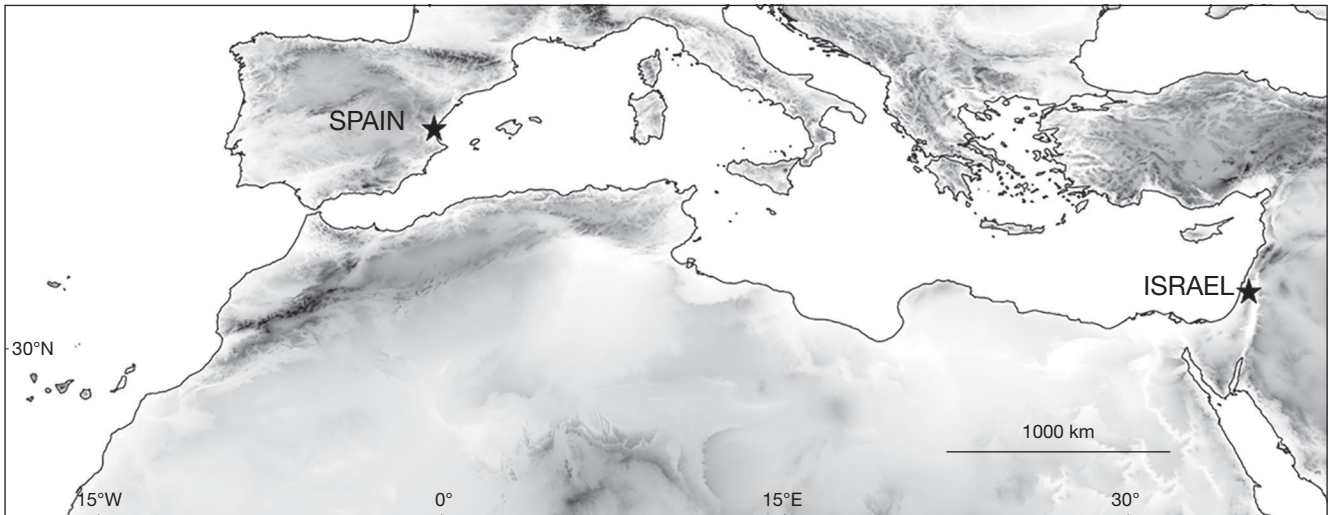


Fig. 1. — Geographical location of the new populations of *Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak in the Mediterranean region.

## MATERIAL AND METHODS

### SAMPLED MATERIAL AND LIGHT MICROSCOPY ANALYSES

Plant materials used in this study consisted of fresh collections collected during bryological sampling from urban areas in the Botanical Garden of Valencia (Spain) and Tel-Aviv (Israel). Specimens were deposited in VAL-Briof. (VAL-Briof.[13443, 13444]) and HUI (HUIJ MOS[905592]) herbaria. For comparison of vegetative and reproductive structures, herbarium material of *Ptychostomum rubens* (Mitt.) Holyoak & N.Pedersen, the only European species with superficially similar rhizoidal tubers to *A. apiculatum*, was also studied (VAL-Briof.[7772]).

For morphological study of plants, measurements of vegetative characters were taken using the interactive measurement module of Leica Application Suite (LAS) v. 3.8 (Leica microsystems, Barcelona, Spain) calibrated to the nearest 0.01  $\mu\text{m}$  on digital images. All measurements were taken through a DMLB 100S light microscope (Leica). A DFC425 digital camera (Leica) was used for producing high resolution images. For each population, 11 gametophores were measured for all traits considered (Table 1).

## RESULTS

Two samples, one from Israel and the other from Spain were identified as belonging to a non-previously reported species in the Mediterranean region (Fig. 1):

Family BRYACEAE Rchb.  
Genus *Anomobryum* Schimp.

*Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak

*Journal of Bryology* 42: 5 (Hodgetts *et al.* 2020). — *Bryum apiculatum* Schwägr., *Species Muscorum Frondosorum, Supplementum Primum* 2: 102 (Schwägrichen 1816).

*Bryum nitens* Hook. ex Harv., *Icones Plantarum* 1: pl. 19, fig. 6 (Hooker 1836).

*Bryum cruegeri* Hampe, *Synopsis Muscorum Frondosorum Omnium Hucusque Cognitorum* 1: 300 (Müller 1848).

MATERIAL STUDIED. — **Israel.** Tel-Aviv, Dolchin st., 19 m, 32°7'4.88"N, 34°47'32.09"E, in a drainage opening in a garden wall made of granulite, constant dampness caused probably by a gutter drain, 14.II.2022, D. Melamed (HUIJ MOS[905592], VAL-Briof.[13443]).

**Spain.** Valencia, Tropical greenhouse of the University of Valencia Botanical Garden, 18 m, 39°28'37.41"N, 0°23'12.83"W, shaded crevices of pavement, 10.XI.2022, J.G. Segarra-Moragues (VAL-Briof.[13444]).

### DESCRIPTION

A detailed description based on the study of specimens from the newly reported populations of *A. apiculatum* is presented below. The sizes and character states of the corresponding quantitative and qualitative respective traits are based on the combination of measurements from both populations to account for its variability except where otherwise specified. In Table 1, the variation in all quantitative traits measured and morphologically informative qualitative traits is specified separately for Israeli and Spanish populations. For quantitative traits, average and range values are given in parentheses.

Plants (3.5-) 6.2 (-7.8) mm long, loosely caespitose to caespitose, green to yellowish green, green or reddish brown to brown below; stems (80.5-) 173.6 (-223.3)  $\mu\text{m}$  wide, simple or branching by innovations, red to reddish brown, green in youngest parts, without tomentum; stems and bases of branches usually buried becoming radiculose; stem apices deciduous, becoming propaguliferous; rhizoids light brown or reddish brown, papillose; rhizoidal tubers abundant, on short and long rhizoids, in clusters at stem base, brown to dark brown, irregularly spherical, elliptical to pyriform, (166.5-) 233.0 (-359.2)  $\times$  (129.1-) 169.7 (-219.5)  $\mu\text{m}$ , with cells strongly protuberant; axillary tubers clustered in leaf axils, brown, spherical to pyriform, (122.4-) 180.6 (-218.5)  $\times$  (105-) 141.2 (-201.9)  $\mu\text{m}$ , with cells strongly

TABLE 1. — Summary of the morphological characters studied in samples of *Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak. For quantitative characters, average and range values are given in parentheses.

	Israel	Spain
Plant length (mm)	(6.0-) 7.1 (-7.8)	(3.5-) 5.3 (-6.8)
Stem		
Colour	Reddish-brown, green in youngest parts	Reddish-brown, green in youngest parts
Width (µm)	(80.5-) 146.9 (-212.0)	(174.8-) 204.9 (-223.3)
Axillary tubers		
Shape, colour, cell types	Spherical to pyriform, brown, cells strongly protuberant	Spherical to pyriform, brown, cells strongly protuberant
Size (µm)	(151.3-) 194.0 (-218.5) × (117.7-) 153.9 (-201.9)	(122.4-) 167.5 (-196.1) × (105.0-) 133.0 (-178.4)
Rhizoidal tubers		
Shape, colour, cell type	Irregularly spherical, elliptical to pyriform, brown to dark brown, cells strongly protuberant	Irregularly spherical, elliptical to pyriform, brown to dark brown, cells strongly protuberant
Size (µm)	(210.7-) 249.7 (-359.2) × (162.9-) 189.2 (-219.5)	(166.5-) 220.4 (-290.1) × (129.1-) 150.3 (-180.4)
Leaves		
Shape	Concave, elliptical to oblong-lanceolate	Plane, oblong-lanceolate to lanceolate
Margin	Entire, not bordered	Entire, not bordered
Size (mm)	(0.8-) 0.9 (-1.1) × (0.3-) 0.4 (-0.5)	(1.0-) 1.1 (-1.2) × (0.3-) 0.3 (-0.5)
Nerve	Weak above, ending at apex or slightly percurrent	Weak above, slightly percurrent
Width at base (µm)	(31.5-) 40.3 (-54.3)	(37.5-) 49.4 (-61.8)
Basal cells		
Shape, colour	Quadrate to rectangular, green to reddish	Quadrate to rectangular, green to reddish
Size (µm)	(30.2-) 46.4 (-61.4) × (17.8-) 21.4 (-27.1)	(22.1-) 35.5 (-48.4) × (16.3-) 21.6 (-27.7)
Midleaf cells		
Shape	Shortly rectangular, rhomboidal to polygonal	Shortly rectangular, rhomboidal to polygonal
Size (µm)	(64.1-) 86.5 (-99.4) × (11.9-) 15.2 (-19.0)	(64.4-) 85.6 (-101.7) × (11.5-) 14.4 (-15.9)
Upper laminal cells		
Shape	Oblong-rhomboidal	Long rhomboidal
Size (µm)	(46.8-) 64.7 (-88.8) × (11.4-) 14.8 (-19.9)	(57.6-) 75.0 (-91.0) × (11.0-) 12.9 (-13.9)
Marginal cells		
Shape	Rhomboidal to long-rhomboidal	Rhomboidal to long-rhomboidal
Size (µm)	(58.2-) 81.1 (-124.8) × (5.4-) 8.7 (-10.9)	(71.0-) 104.8 (-128.1) × (9.0-) 10.8 (-12.5)
Sexual condition	Presumably dioicous, only archegonia present in perichaetium	Gametangia not seen
Sporophyte	Not seen	Not seen

protuberant; axillary bulbils absent; leaves glossy, (0.8-) 1.0 (-1.2) × (0.3-) 0.4 (-0.5) mm, widest below midleaf, leaf-margins entire throughout, plane, not bordered; in Spanish plants distant below, crowded above, plane, erect-spreading when dry, erect-spreading to wide spreading when wet, oblong-lanceolate to lanceolate; in Israeli plants densely imbricate, concave, not differing in dry plants, elliptical to oblong-lanceolate. Nerve weak above, brown to reddish-brown (except on young leaves), ending at apex or slightly percurrent, (31.5-) 44.8 (-61.8) µm wide at base, tapering to apex; basal laminal cells rectangular to quadrate, green to reddish, (22.1-) 41.2 (-61.4) × (16.3-) 21.5 (-27.7) µm; midleaf laminal cells shortly rectangular, rhomboidal to polygonal, (64.1-) 86.1 (-101.7) × (11.5-) 14.8 (-19.0) µm; upper laminal cells oblong-rhomboidal to long-rhomboidal, (46.8-) 70.3 (-91.0) × (11.0-) 13.7 (-20.0) µm; marginal laminal cells rhomboidal in Israeli plants to long rhomboidal in Spanish plants, becoming progressively narrower from nerve to margin; marginal cells, rhomboidal to long rhomboidal,

(58.2-) 93.9 (-128.1) × (5.4-) 9.8 (-12.5) µm; apparently dioicous (antheridia lacking) in Israeli plants, sterile in Spain. Sporophytes not seen.

#### Genus *Ptychostomum* Hornsch.

##### *Ptychostomum rubens* (Mitt.) Holyoak & N.Pedersen

MATERIAL STUDIED. — **Spain**. Valencia, Gátova, Monte el Rodeno II, 39°46'26.43"N, 0°31'37.24"W, suelo, 10.II.2006, F. Puche (VAL-Briof.[7772]).

#### DISCUSSION

##### CONFUSION WITH OTHER SPECIES

In the absence of reproductive structures *A. apiculatum* is superficially similar to a number of other small and ruderal *Bryum*

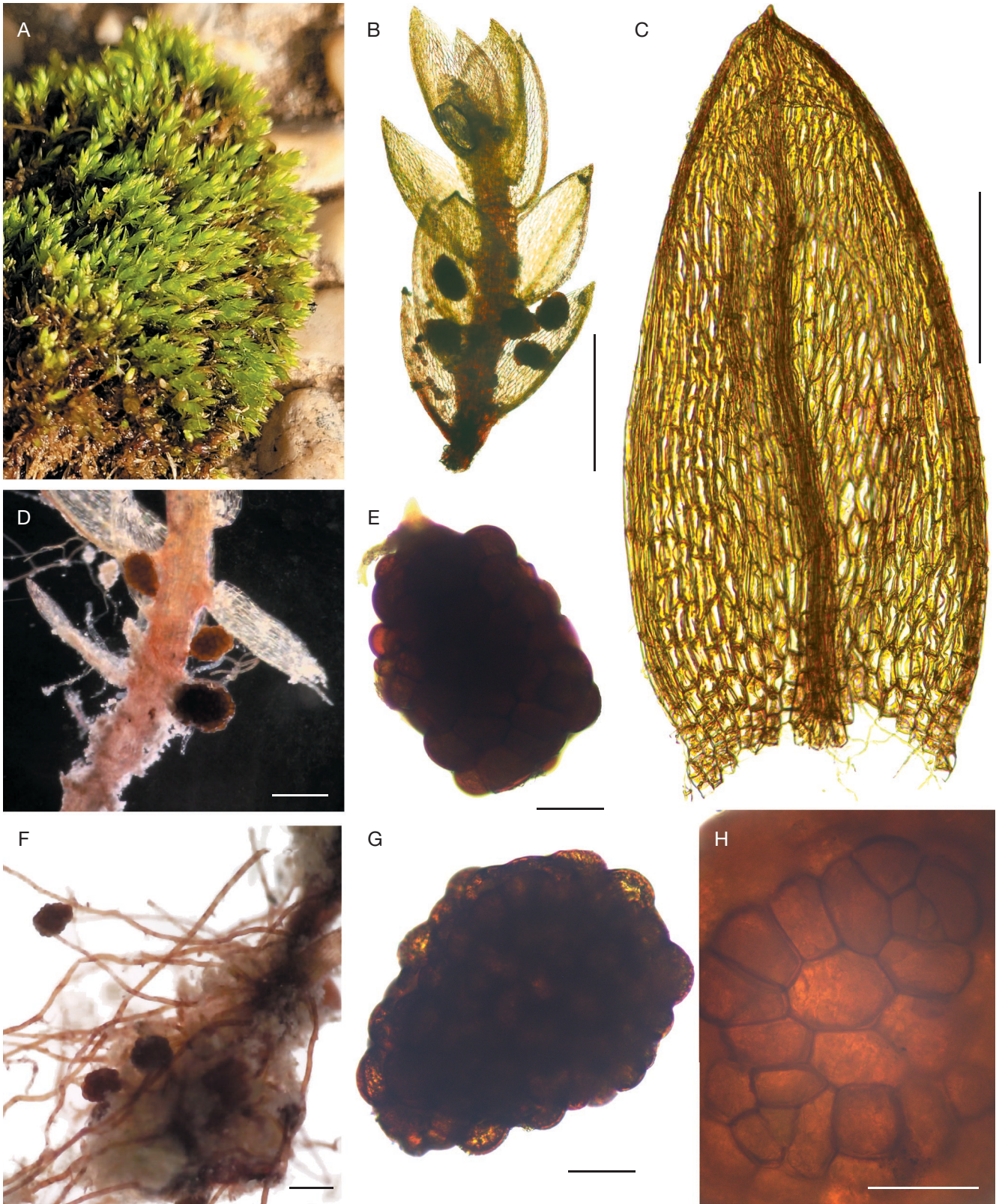


FIG. 2. — Habit and light microscopy images of *Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak from Israel: **A**, plant habit; **B**, deciduous apical portion of stem with axillary tubers; **C**, leaf; **D**, median part of stem showing axillary tubers; **E**, axillary tuber; **F**, basal part of stem showing rhizoidal tubers; **G**, rhizoidal tuber; **H**, detail of cells from rhizoidal tubers (all from VAL-Brief.[13443]). Scale bars: B, 500  $\mu$ m; C, D, F, 200  $\mu$ m; E, G, H, 50  $\mu$ m.

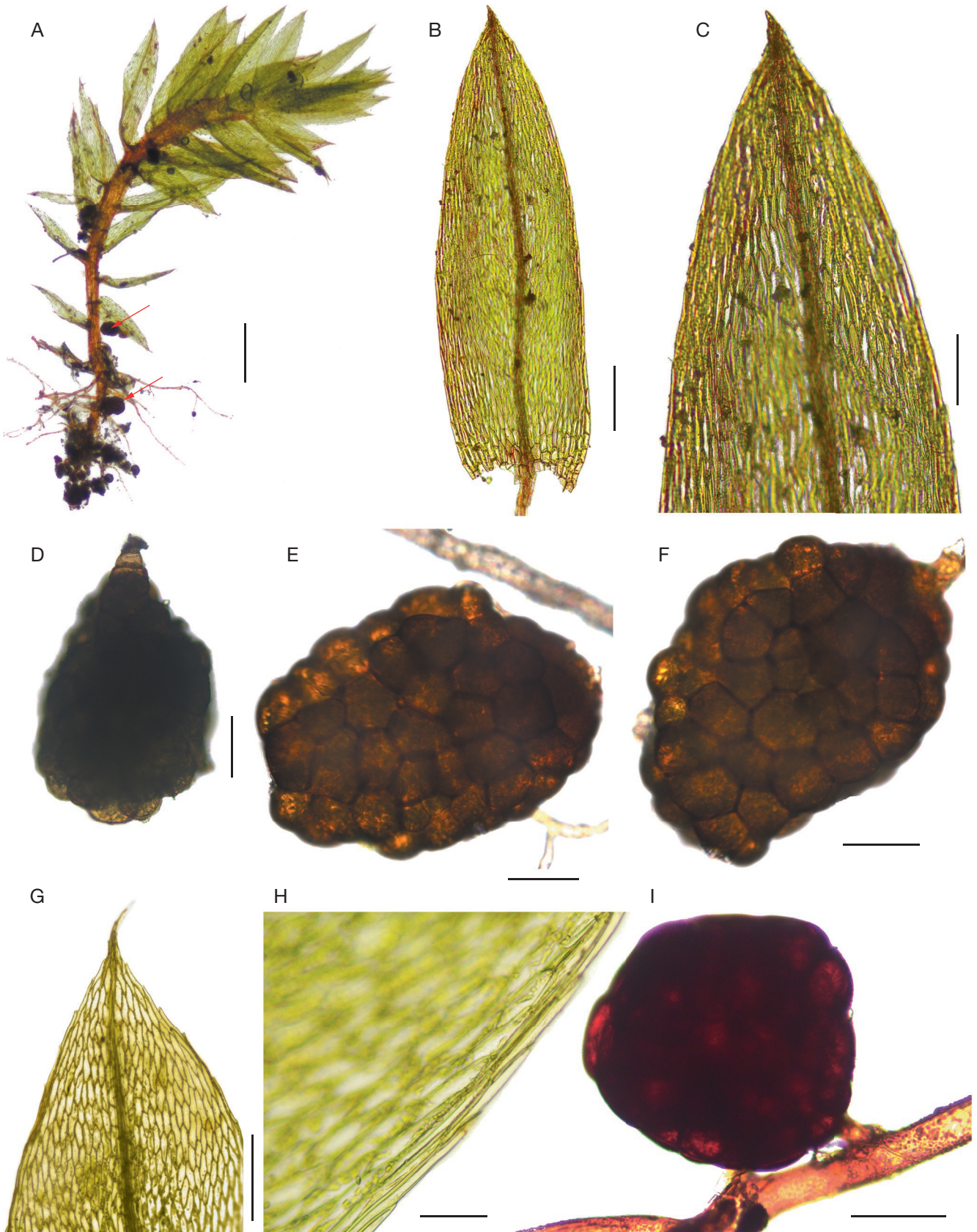


FIG. 3. — Light microscopy images of *Anomobryum apiculatum* (Schwägr.) D.Bell & Holyoak from Spain (A-F), and *Ptychostomum rubens* (Mitt.) Holyoak & N.Pedersen (G-I): A, plant habit with tubers (arrows); B, leaf; C, apical part of leaf showing the entire margin; D, axillary tuber; E, F, rhizoidal tubers; G, apical part of leaf showing the dentate margin; H, margin of leaf showing the limbidium; I, rhizoidal tuber (A-F, VAL-Brief.[13444]; G-H, VAL-Brief.[7772]). Scale bars: A, 500 µm; B, G, 200 µm; C, 100 µm; D-F, H, I, 50 µm.



species (Fig. 2A) such as *B. dichotomum*, *B. radiculosum* Brid., and other related species of the *B. erythrocarpum* complex. However, it can be readily distinguished from these two species when axillary or rhizoidal tubers are present. The tubers produced in abundance, both at leaf axils (Figs 2B, D, E; 3D), and on rhizoids (Figs 2F, G; 3A, E, F), close to the base of the plants, showing conspicuously protuberant cells may resemble those of *Ptychostomum rubens* (Fig. 3H). However, in this latter species the tubers are bright red, more regularly spherical and smaller (149.6–181.8 (–218.2) × (146.1–) 167.9 (206.4) μm, with less protuberant cells (Fig. 3I), compared to the dark brown, pyriform, elliptical to irregularly spherical, larger (166.5–) 233 (–359.2) × (129.1–) 169.7 (–219.5) μm, with strongly protuberant cells of *A. apiculatum* (Figs 2D–G; 3D–F). The two species also differ in leaf traits including, the presence of a limbidium of 2–3 rows of elongate cells (Fig. 3H), the conspicuously dentate margin and excurrent nerve in *P. rubens* (Fig. 3G).

The plants from these new Mediterranean populations slightly differ in leaf blade, which is concave in the Israeli population (Fig. 2B, C) and plane in the Spanish one, giving the plants of this later locality a pohliaceous appearance (Fig. 3A–C). Vegetative traits are highly plastic in *Bryum* species, because of the influence of growing condition, and both these leaf shapes have been reported in *A. apiculatum* (Whitehouse 1978), suggesting the need of a critical taxonomical reevaluation. In the current state of knowledge, the most reliable traits for the species identification are derived from the tubers, which showed the same distinctive traits in the two Mediterranean populations and matched those previously reported from *B. cruegeri* (Whitehouse 1978) and *B. nitens* (Egunyomi 1980; van Rooy & Magill 1987), the two heterotypic synonyms of *A. apiculatum* (Ochi 1985).

#### HABITAT AND ECOLOGY

In the new populations, *A. apiculatum* occurs on soil in anthropogenic habitats. In Israel, the plants were growing in a dense tuft in an opening of a drainpipe with constant seepage, on a granolith wall surrounding a small garden at a residential neighbourhood in Tel-Aviv. In Spain, the plants were growing in the tropical exhibition greenhouse of the Botanical Garden of the University of Valencia. They were growing on shaded and humid crevices of the pavement. As many other ruderal Bryaceae species, *A. apiculatum* seems to favour disturbed ruderal habitats as confirmed by previous reports from other parts of its distribution range (Whitehouse 1978; Egunyomi 1980). No sporophytes were found in plants from both populations, which indicates the species is spreading vegetatively through deciduous branches and tubers which were produced in abundance both in rhizoids base of plants and leaf axils. This agrees with populations occurring in its tropical range (Mota de Oliveira & Cavalcanti Pôrto 2002). This likely suggests that *A. apiculatum* may have been introduced recently through garden management practices. However, given the high dispersal abilities of many bryophyte species it is also likely that it could have expanded its range by self-means (Hodgetts *et al.* 2020).

The fact that in the Spanish population it was not found growing outside the greenhouse could indicate that drier summer and/or colder winter outdoor conditions are not favoured by this species. Indeed, despite the large number of gardens found in the City of Valencia, an intensively sampled urban bryoflora did not account for this species, despite other human-spread species such as *Chenia leptophylla* (Müll. Hal.) R.H.Zander, *C. ruigteveleia* Hedd. & R.H.Zander, and *Leptobryum pyriforme* (Hedw.) Wilson, were found to be quite widespread in the city (Segarra-Moragues *et al.* 2019). On another hand, after its discovery in the tropical greenhouse, it was intensively searched in the other nearby monographic greenhouses (i.e., ferns, orchids, carnivorous and bromeliads) of the Botanical Garden without success. This also supports a recent introduction of *A. apiculatum*, as otherwise a rapid spread through vegetative propagules would have been expected during greenhouse management practices. Notwithstanding, given its overall morphological similarity to other widespread *Bryum* species, it could easily have gone unnoticed and, as a result, the species may be more abundant in the Mediterranean than the current records indicate.

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