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VP conceived and performed the taxonomic research, completed the species descriptions, compiled a key to determination, and prepared the figures; RO provided nomenclatural comments on and clarified the questions associated with occurrence of *Orthotrichum schimperi* in Poland; VP and RO wrote jointly the manuscript

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## ORIGINAL RESEARCH PAPER in RECENT DEVELOPMENTS IN TAXONOMY AND PHYLOGENY OF PLANTS

# *Orthotrichum alpestre*, a New Addition to the Moss Flora of Poland, with Notes on *O. schimperi* (Orthotrichaceae: Bryophyta)

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## Abstract

The occurrence of two epiphytic moss species, *Orthotrichum alpestre* Bruch & Schimp. and *O. schimperi* Hammar, in the moss flora of Poland is discussed. The former represents an entirely new country record based on a specimen collected from the Polish Eastern Carpathians, whereas the latter is reinstated as a member of the Polish moss flora. The complex and entangled taxonomic and nomenclatural history of *O. schimperi* is outlined, sources of its confusion are discussed, and two correctly determined specimens from Poland are cited. The two species are briefly characterized and illustrated, and a key to the genera and species of Polish orthotrichaceous mosses is presented.

## Keywords

keys to determination; *Lewinskya*; Musci; *Nyholmiella*; *Plenogemma*; *Pulviger*; *Ulota*; taxonomy

## 1. Introduction

*Orthotrichum* Hedw. is one of the most distinctive of all moss genera, which is at a glance distinguished by its immersed to short-exserted capsules that are most often ribbed and only seldomly smooth with large campanulate-mitrate and usually hairy calyptrae covering the entire capsule. Plants lacking sporophytes are recognized by their orthotropic, sympodially branched stems and small, isodiametric, and mostly papillose laminal cells with incrassate walls. These xerophytic adaptations are associated with the ecological preferences of the species of *Orthotrichum*, which generally grow in dry, sunny habitats, either as epiphytes on the bark of deciduous trees or shrubs, or epipetrically on rocks, boulders, or stone walls.

Twenty species of the broadly interpreted genus *Orthotrichum* have been recorded from Poland in the latest catalog of Polish mosses (Ochya et al., 2003). A subsequent reexamination of the herbarium specimen showed that *O. microcarpum* De Not. was erroneously reported from Poland because the voucher specimen collected by A. Żmuda in 1910 proved to be *O. pallens* Brid. (Plášek & Sawicki, 2009). Accordingly, this species was excluded from the moss flora of Poland. However, this loss was compensated by *O. shawii* Schimp., whose record from Poland was resurrected from obscurity. This species was found in the second half of the nineteenth century near Barwice in northwestern Poland by Ruthe (1873), but the record has been generally overlooked. This species has not been rediscovered in Poland, yet Ruthe's record is confirmed by the voucher specimens deposited in BM and TR (Garilleti et al., 2006).

The traditionally interpreted *Orthotrichum* is one of the largest of all moss genera, consisting of approximately 150 taxa distributed across all continents. In a

worldwide synopsis of species and infrageneric taxa of *Orthotrichum*, Lewinsky (1993) recognized 116 species and 11 varieties; however, since then, 54 new species have been described in, transferred to, or reinstated as distinct species of *Orthotrichum* and/or its segregates. This is because the broadly understood genus *Orthotrichum* was recently split into four segregates (Damsholt et al., 1969; Lara et al., 2016; Plášek, Sawicki, & Ochyra, 2016; Plášek et al., 2015; Sawicki et al., 2017), including *Nyholmiella* Holmen & E. Warncke with three species (Damsholt et al., 1969; Otnyukova, 2001, 2019); *Pulviger* Plášek, Sawicki & Ochyra with four species (Lara et al., 2020); *Lewinskya* F. Lara, Garilleti & Goffinet with 68 species and six varieties (Eckstein et al., 2017; Lara et al., 2016, 2018; Plášek, 2019; Procházková & Plášek, 2020); and *Orthotrichum* (Kiebacher & Lüth, 2016; Lara et al., 2016). *Nyholmiella* is represented by two species in Poland, *N. obtusifolia* (Hedw.) Holmen & E. Warncke and *N. gymnostoma* (Brid.) Holmen & E. Warncke; *Pulviger* by a single species, *P. lyellii* (Hook. & Taylor) Plášek, Sawicki & Ochyra; *Lewinskya* by five species and one variety, namely *L. affinis* (Schrad. ex Brid.) F. Lara, Garilleti & Goffinet, *L. affinis* var. *bohemica* (Plášek & Sawicki) Plášek, *L. rupestris* (Schwägr.) F. Lara, Garilleti & Goffinet, *L. speciosa* (Nees) F. Lara, Garilleti & Goffinet, *L. striata* (Hedw.) F. Lara, Garilleti & Goffinet, and *L. shawii* (Wilson) F. Lara, Garilleti & Goffinet; and *Orthotrichum* s. str. by 11 species, including *O. anomalum* Hedw., *O. cupulatum* Brid., *O. diaphanum* Brid., *O. pallens* Brid., *O. patens* Brid., *O. pulchellum* Brunt., *O. pumilum* Sw., *O. rogeri* Brid., *O. scanicum* Grönvall, *O. stramineum* Brid., and *O. tenellum* Brid. In the present account, two additional species of the genus are recorded for Poland, including *O. alpestre* Bruch & Schimp. and *O. schimperi* Hammar. The former was newly found in the country, whereas the latter was reinstated from obsolescence as a member of the Polish moss flora.

Additionally, the genus *Ulot* proved to be a heterogeneous taxon and for one of its species, *U. phyllantha* Brid., the monotypic genus *Plenogemma* Plášek, Sawicki & Ochyra was established to accommodate it as *P. phyllantha* (Brid.) Plášek, Sawicki & Ochyra (Plášek et al., 2015; Sawicki et al., 2017). This species was once recorded in Western Pomerania in northwestern Poland (Ochyra & Bednarek-Ochyra, 1991).

Most of the orthotrichaceous mosses reported in *Census Catalogue of Polish Mosses* (Ochyra et al., 2003) are common and frequent species that are widespread, although sometimes scattered throughout the country. Nevertheless, several species have been recorded in Poland only in the nineteenth and/or in the first half of the twentieth century and are known only from these historical collections and have not been recorded after World War II. These are *Nyholmiella gymnostoma*, *Orthotrichum scanicum*, *Plenogemma phyllantha*, *Ulot drummondii* (Hook. & Grev.) Brid., *U. hutchinsiae* (Sm.) Hammar, and *U. rehmannii* Jur. It is worth noting that *U. rehmannii* was described from the material collected in the Tatra by A. Rehmman (Juratzka, 1864). In contrast, *Orthotrichum pulchellum* (Plášek et al., 2013), *O. rogeri* (Stebel, 2010), and *Ulot coarctata* (P. Beauv.) Hammar (Plášek, Smoczyk, & Ochyra, 2016) have recently been rediscovered in Poland after a long time.

## 2. Methods

The two species of *Orthotrichum* that are considered to be new records to the moss flora of Poland were found during a revision of the herbarium holdings of the genus in the bryological herbarium in the W. Szafer Institute of Botany, Polish Academy of Sciences (KRAM).

The specimens were identified and photographed by routine microscopic and laboratory techniques.

## 3. Results

### 3.1. *Orthotrichum alpestre* Bruch & Schimp.

Bryol. Eur. 3: 75, pl. 213 [Fasc. 42. Monogr. Suppl. 1: 1, pl. 1]. 1849.

#### 3.1.1. Specimen Examined

POLAND. Polish Eastern Carpathians, Bieszczady Zachodnie Range, Bieszczadzki National Park, SE of the Ustrzyki Górne village, in the Terebowiec stream valley,

collection point No. 26, ca. 49°05'53" N, ca. 22°43'06" E, alt. 900–930 m a.s.l., bark of *Acer pseudoplatanus*, ATMOS grid square Gf–69, June 13, 1993, leg. J. Żarnowiec & M. Szymocha, det. J. Żarnowiec as *Orthotrichum pumilum* [KRAM B-108863, dupl. in SOSN 15711 (collection “Mchy Doliny Terebowca”), not seen].

### 3.1.2. Remarks

*Orthotrichum alpestre* is a small to medium-sized moss that has strongly papillose leaves, which can provide a glaucous tinge to the plants (Figure 1A). The papillae of the leaf cells are more or less prominent and commonly forked (Figure 1B). The capsules are 1/2–3/4 emergent, with an urn obloid-ovoid when mature. The peristome is double, formed by eight pairs of the exostome teeth and eight endostome segments (Figure 1C). The outer peristome layer (OPL) ornamentation of the exostome teeth is formed by dense papillae below and a mixture of papillae and distinct striae above (Figure 1D). The calyptra is covered with usually scattered, stout papillose hairs (Figure 1A,C).

The voucher material of this species was originally determined by the collector J. Żarnowiec as *Orthotrichum pumilum* and its duplicate was deposited in the bryophyte collection at KRAM. It was subsequently published under this name in a paper dealing with the mosses of the Terebowiec stream valley (Żarnowiec, 2010) and, secondarily, this record is cited in a monograph of the moss flora of the Western Bieszczady Mountains (Żarnowiec & Stebel, 2014).

## 3.2. *Orthotrichum schimperi* Hammar in Hammar & Piscator

Monogr. Orthotrich. Ulot. Suec. 2: 9. 1852.

### 3.2.1. Specimens Examined

POLAND. (i) Pojezierze Wschodniobałtyckie, Pojezierze Mazurskie: Węgorzewko hamlet of the Kalskie Nowiny village east of Węgorzewo, ca. 54°12'48" N, ca. 21°45'58" E, alt. 130 m a.s.l., on trunk of *Malus domestica* associated with *Nyholmiella obtusifolia*, ATMOS grid square Af–90, April 24, 1991, leg. A. Stebel 1018 (KRAM B-113864, SOSN 17569, not seen); (ii) Wyzyna Małopolska, Wyzyna Kielecka, Świętokrzyski National Park, in the forest section 22.91, ca. 50°57'19" N, ca. 20°48'53" E, alt. 365 m a.s.l., on bark at the base of the trunk of *Quercus* sp. associated with *Lewinskya affinis*, ATMOS grid square Ee–65, December 30, 2015, leg. T. Paciorek s.n. (KRAM B-223810).

The two aforementioned specimens of *Orthotrichum schimperi* were originally determined by A. Stebel as *Orthotrichum pumilum* and their duplicates were donated to the bryophyte herbarium at KRAM. The first of these from Węgorzewko in the Pojezierze Mazurskie was published under this name by Stebel (1997), whereas the second specimen from the Świętokrzyski National Park was published by Paciorek et al. (2016) and it is also cited in the unpublished doctoral thesis of its collector (Paciorek, 2017).

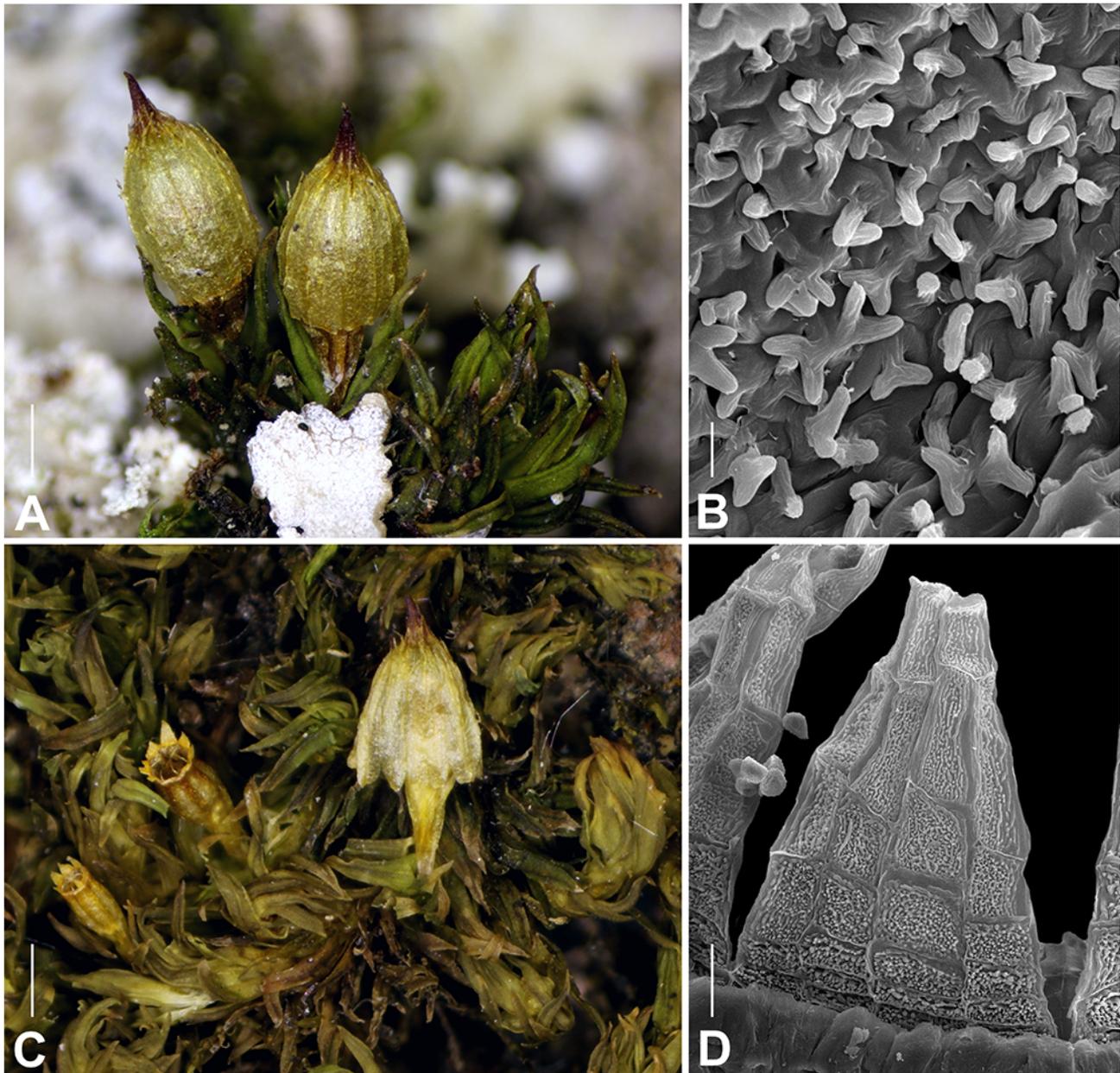
### 3.2.2. Remarks

*Orthotrichum schimperi* is a small epiphytic moss. The plants are green-colored above and brownish below. The leaves are erect and loosely-appressed when dry, ovate-oblong to oblong-lanceolate. The capsules are immersed to shortly emergent (Figure 2A,C), ovoid or pyriform when moist, abruptly contracted into the seta. The stomata are immersed, scarcely covered by the guide cells. The peristome is double, formed by eight pairs of the reflexed exostome teeth and eight endostome segments with a conspicuously broad base, 1/2–3/4 as long as the exostome teeth (Figure 2C,D). The calyptra is naked (Figure 2B).

## 4. Discussion

*Orthotrichum alpestre* is a subarctic-subalpine species. In Europe, it is most often found in the subalpine or alpine zones (Martínez-Abaiagar et al., 1995), and outside Europe, it is known from North America and Southeast and Central Asia.

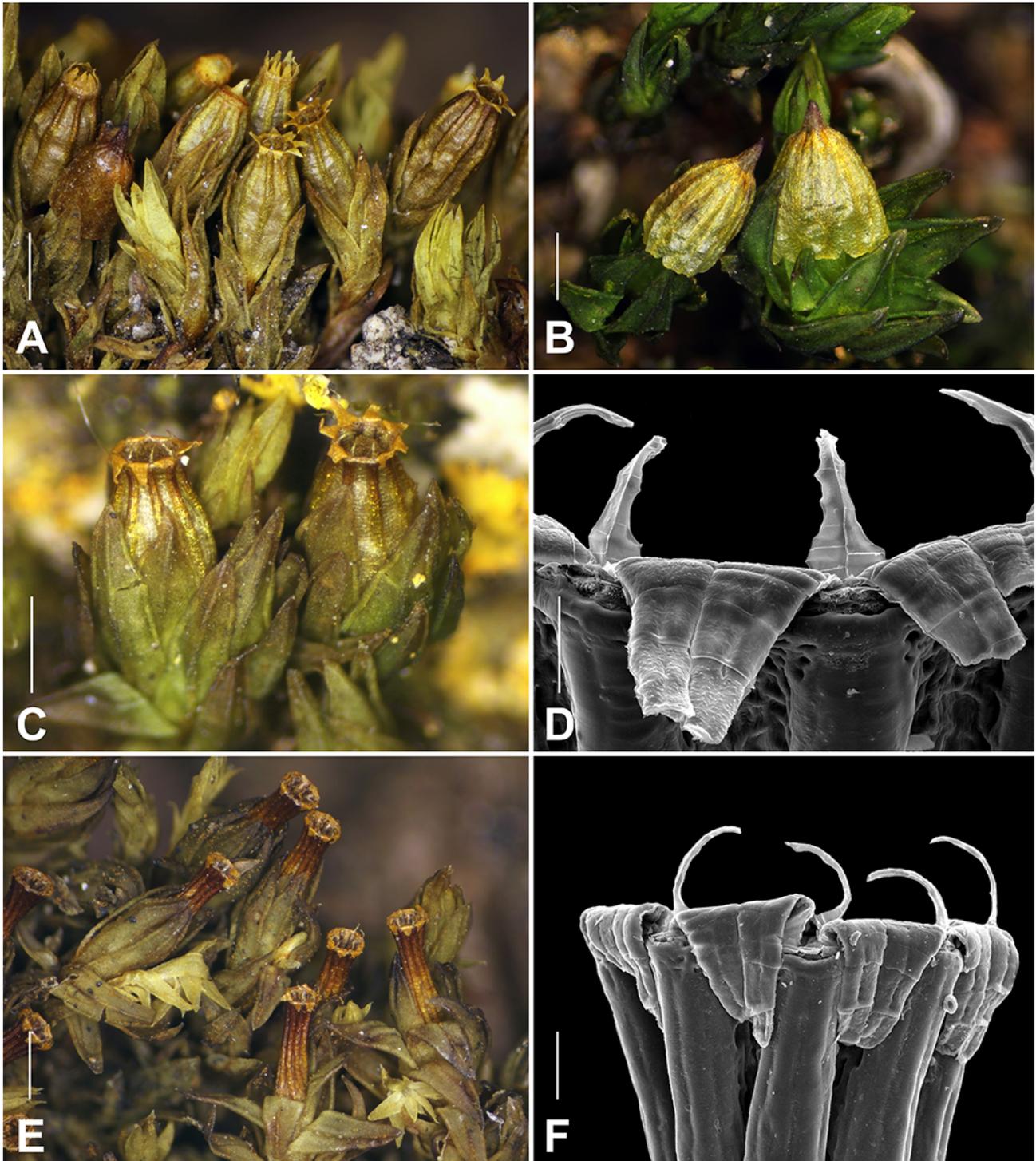
*Orthotrichum alpestre* is morphologically similar to *O. stramineum*, but it can be distinguished mainly by having (i) tall and commonly forked papillae of the laminal



**Figure 1** *Orthotrichum alpestre*. (A) Habit of the plants with capsules covered with calyptrae. (B) Scanning electron microphotograph showing forked papillae on the leaf cells. (C) Deoperculate mature capsules showing the double peristome. (D) Scanning electron microphotograph of the ornamentation of the outer peristome layer (OPL) side of the exostome teeth. All taken from Żarnowiec & Szymocha s.n., June 13, 1993 (KRAM B-108863). Scale bars: (A,C) 1 mm; (B) 5  $\mu$ m; (D) 20  $\mu$ m.

cells (Figure 1B), whereas the latter species usually has shorter and only rarely branched papillae of the laminal cells; **(ii)** an OPL that is densely papillose below and striate-papillose above (Figure 1D), whereas the exostome teeth in *O. stramineum* are uniformly papillose on the outer side, and the ornamentation of the upper part does not contrast with that of the lower part; **(iii)** a short capsule neck, mostly shorter than the urn, whereas in *O. stramineum* the neck is long, commonly as long as the urn, and gradually tapered to the seta; and **(iv)** a naked or sparsely haired vaginula with a few variable hairs, whereas in *O. stramineum*, the vaginula is covered with long papillose hairs (cf. Blockeel & Lara, 2015).

*Orthotrichum schimperi* is a member of a difficult and critical complex of species centered around *O. pumilum*, which also includes *O. pallens* and *O. philibertii* Venturi. The most important difference between *O. schimperi* and *O. pumilum* is in the shape of the capsule (cf. Blockeel, 2019). It is narrowly ovoid, widest at the middle, and somewhat constricted below the mouth in *O. schimperi* (Figure 2A,C)



**Figure 2** Comparison of *Orthotrichum schimperi* (A–D) and *O. pumilum* (E,F). (A,E) Fertile populations with mature capsules. (B) Plants with the capsules covered by the naked calyptrae. (C) Deoperculate capsules showing the double peristomes. (D) Scanning electron microphotograph of the primary peristome layer (PPL) side of the peristome – The segments are distinctly broad at the base. (F) Scanning electron microphotograph of the PPL side of the peristome with linear segments. (A–D) Taken from Paciorek s.n., December 30, 2015 (KRAM B-223810); (E,F) from Plášek s.n., May 25, 2011 (OSTR B-2643). Scale bars: (A–C,E) 1 mm; (D,F) 100  $\mu$ m.

and its base is abruptly contracted to the seta. In contrast, *O. pumilum* has slightly longer and narrower capsules (Figure 2E), which gradually taper at the base into the seta. There are also differences in the details of the peristome between these two species. In *O. schimperi*, the endostome segments are shorter, 1/2–3/4 as long as the exostome teeth, and conspicuously broad at the base (Figure 2D). In *O. pumilum*, the segments are long and narrow, almost as tall as the exostome teeth (Figure 2F), and not or only slightly widened at the base.

*Orthotrichum pumilum* was one of the earliest recognized species of the genus and was described in 1799 from the material collected in Sweden, and its prestarting point name was validated by an anonymous author of a review of Swartz's (1799) work published on June 1, 1801 in *The Monthly Review* (Anonymous, 1801). The species was subsequently accepted by Dickson (1801) in his treatment of the cryptogams of the British Isles, which was published on October 4, 1801 (Sayre, 1959). He provided a short description of the species in Latin, cited one specimen from Ireland, and gave a full reference to Swartz's (1799) original description of the species whose name was then already validly published. Interestingly, some authors (e.g., Grout, 1935; Limpricht, 1890; Wilson, 1855) considered *O. pumilum* sensu Dickson as a validly published name, and in *Index muscorum* (Wijk et al., 1964, 1969), it was considered as an illegitimate homonym of *O. pumilum* Sw. The latter species was accepted in most floras and taxonomic treatments published in the first four decades of the nineteenth century, both in the British Isles (e.g., Smith, 1804; Turner, 1804) and continental Europe (e.g., Bridel, 1826–1827; Hübener, 1833; Schwaegrichen, 1816).

The real confusion regarding the taxonomic interpretation of *Orthotrichum pumilum* was introduced in *Bryologia europaea* (Bruch et al., 1837) because of an incorrect application of the name of this species. The authors of this opus, which was then considered to be the oracle of taxonomic and nomenclatural matters regarding European mosses, disregarded the principle of priority and ascribed the name *O. pumilum* to Schwaegrichen (1816), although this author did not describe a new species because he gave in his treatment full reference to *O. pumilum* sensu Swartz and in this way included the type of this species name in his *O. pumilum*. Thus, although the description and elegant, colorful plate represented a different species in Schwaegrichen (1816), Bruch and Schimper, the authors of the text and the taxonomic concept in *Bryologia europaea*, should have introduced a new name for this species and not adopt a name, which was used for a different and accepted species.

This already complicated situation was additionally aggravated by the fact that the authors of *Bryologia europaea* accepted *Orthotrichum pumilum* sensu Swartz but completely broke the principle of priority by accepting *O. fallax* Brid., which was described by Bridel (1826–1827) as a new species from the material collected by Ph. Bruch in Zweibrücken (Latin Bipontium), and placing *O. pumilum* Sw. in the synonymy of *O. fallax*. Hammar and Piscator (1852) tried to control this unusual nomenclatural chaos introduced in *Bryologia europaea* by Bruch and Schimper and quite sensibly accepted the correct name *O. pumilum* sensu Swartz for *O. fallax* sensu Bruch and Schimper, which he correctly placed in the synonymy of *O. pumilum* Sw. However, for *O. pumilum* sensu Bruch and Schimper, they introduced the name *O. schimperi* and stated that this species occurs in southern Sweden from Skåne to Jämtland, but because the species is confused with *O. pumilum*, localities indicated for this species in the literature were uncertain.

Schimper (1860, 1876) partially agreed with Hammar and Piscator (1852) and accepted only *Orthotrichum pumilum* Sw. with *O. fallax* Brid. as a synonym for this name. However, he continued to use *O. fallax* sensu *Bryologia europaea* and placed *O. schimperi* in the synonymy of this name. This concept did not gain wide acceptance, but it was used, among others, by Milde (1869) and Limpricht (1876), in two major floras related to Silesia. Later, Limpricht (1890) changed his mind and accepted *O. schimperi* as a species in its own right, as did other authors, for example, Philibert (1891), Roth (1904), and Brotherus (1923).

In the past and in the first decade of the present century, *Orthotrichum pumilum* and *O. schimperi* were usually treated as a single species (e.g., Corley et al., 1981;

Lewinsky-Haapasaari, 1998; Meinunger & Schröder, 2007; Nyholm, 1960; Smith, 2004), although sometimes they were retained as separate species (e.g., Smith, 1978; Szafran, 1961). However, in the past two decades, the distinctness of these two species is increasingly accepted (Cortini Pedrotti & Lara, 2001; Hill et al., 2006; Hodgetts et al., 2020; Lara & Garilleti, 2014; Lara et al., 2009; Ros et al., 2013). Only Hinneri (1976) gave *O. schimperi* a varietal status, *O. pumilum* var. *schimperi* (Hammar) Hinn.

*Orthotrichum schimperi* is a Holarctic species that has its main center of distribution in Europe, with some isolated occurrences in California in North America and Central Asia (Lara & Garilleti, 2014). It is rather common in the Mediterranean region where it extends to North Africa (Morocco, Algeria, Tunisia, Libya) and Turkey in the Near East (Ros et al., 2013), but in Central Europe, its geographical range is not well known, because it was not distinguished from the closely related *O. pumilum*. The species is absent from much of eastern Europe and is unknown from Russia and in the north extends to southwestern Finland (Hinneri, 1976) and southern Sweden and Norway (Hallingbäck et al., 2008). It is very rare and widely scattered in Britain, including southeastern Wales, southeastern England, and eastern Scotland (Blockeel, 2019).

*Orthotrichum schimperi* was mentioned from Poland in the old literature under this name but usually without citation of any specimens (Limpricht, 1876, 1890) or as *O. fallax* Schimp. non Brid. (Chałubiński, 1886; Krupa, 1878). A revision of these historical collections deposited in KRAM revealed that they all correctly represented *O. pumilum*. Likewise, the specimens of *O. schimperi* collected in Głogoczków in the Pogórze Wielickie in the Polish Western Carpathians were distributed in *Bryotheca Polonica* as No. 21 (Żmuda, 1911). The specimens in KRAM (B-001470 and B-171928) consist of *O. pumilum* Sw. mixed with *Nyholmiella obtusifolia*.

Following the generally accepted tendency to consider *Orthotrichum schimperi* to be conspecific with *O. pumilum*, the species has not been accepted in the recent checklists of the mosses in Poland (Ochyra & Szmajda, 1978; Ochyra et al., 2003). However, this species was previously included by Szafran (1961) in the moss flora of Poland, but the description of this species and a key to the determination of *Orthotrichum* species are highly confusing and misleading in this work. This author used the presence and abundance of gemmae as the only character distinguishing *O. schimperi* from *O. pumilum* in a key to species of this genus and stated (Szafran, 1961, p. 22) that the axillary gemmae occur in profusion in *O. schimperi*, whereas in *O. pumilum*, they are absent or very rare (only 1–3 per stem). The selection of this character is unfortunate and confusing because, apart from some species of the orthotrichalean mosses that regularly and abundantly produce gemmae, including *Nyholmiella obtusifolia*, *N. gymnostoma*, *Pulvigerella lyellii*, gemmiferous plants are only occasionally known in a number of *Orthotrichum* species, especially in the older stage of ontogenesis (cf. Plášek et al., 2007), and they have no taxonomic value. The presence versus absence of the gemmae in *O. schimperi* and *O. pumilum* cannot be considered a reliable distinguishing character because it appears that the occurrence of the gemmae varies markedly in the former species. In the plants from Poland and other regions in Central Europe, they occur sparingly as already noted by Limpricht (1890, p. 77) or are even missing, whereas they occur commonly in the plants from the Iberian Peninsula (Lara & Garilleti, 2014, p. 119).

Szafran (1961, pp. 34–35) introduced essential confusion in the description of the peristomes for the species in question. According to this author, *Orthotrichum pumilum* has an ovoid capsule with endostome segments that are conspicuously wide at the base. However, this shape of the capsules and the endostome segments is typical of *O. schimperi*. According to Szafran (1961, p. 34), *O. schimperi* has segments of the endostome as long as the exostome teeth, but actually, such segments occur in *O. pumilum*. Additionally, the calyptra is glabrous in *O. pumilum*, whereas Szafran (1961) stated that sometimes it is covered with scattered short hairs. Considering these inaccuracies in the treatment of the species, it was not possible to correctly identify them following the work of Szafran (1961); in fact, *O. schimperi* has not been recorded in the Polish bryological literature in the last half-century.

The true distribution of *O. schimperi* in Poland can be established only after a revision of the holdings of this complex in all Polish and foreign (especially German) herbaria. As mentioned above, most specimens cited as *Orthotrichum schimperi* from Poland proved to be mis-determinations; thus, it is likely that the specimens reported in the present account are the only true specimens of this species cited hitherto in the Polish literature. In the largest bryophyte herbarium in Poland at KRAM, approximately 170 specimens of *O. pumilum* are deposited and only two out of this number belong to *O. schimperi*, which means that the ratio of occurrence of *O. schimperi* and *O. pumilum* collected in Poland was approximately 1–2:100. It is difficult to expect that this ratio will be significantly different in other herbaria, especially if a similar proportion was also observed by the first author in the Czech herbaria. If this is confirmed by a revision of the holdings in other herbaria, *O. schimperi* may turn out to be a rare or very rare species in Poland, and this would not be surprising considering its clear Mediterranean affinities.

#### 4.1. Key to Genera and Species of Orthotrichaceous Mosses in Poland

The revolutionary taxonomic and classificational changes in the orthotrichalean mosses in recent decades, as well as a number of new additions to the moss flora of Poland, prompted the authors to compile a new key to the determination of the genera and species, which has traditionally been classified for the genera *Orthotrichum* and *Ulotia*. In the future, the Polish material of *Ulotia* needs revision to confirm recent taxonomic changes in the *U. crispa* (Hedw.) Brid. complex (Caparrós et al., 2016). However, two species of *Orthotrichum*, *O. stellatum* and *O. moravicum*, have been included because they are known from the coterminous countries, and they are very likely to also be discovered in Poland – The latter species has been described only recently from the Czech Republic (Plášek et al., 2009), and its global distribution is still poorly known. Both are marked with an asterisk (\*) in the key. The seventh genus of the Orthotrichaceae, *Zygodon* Hook. & Taylor, which consists of five species in Poland, is not included in the following key, and its species are keyed by Stebel and Żarnowiec (2017).

#### Key to genera and species of orthotrichaceous mosses in Poland.

1a	Stomata phaneroporous	2
1b	Stomata cryptoporous ( <i>Orthotrichum</i> s. str.)	6
2a	Monoicous; gemmae mostly absent	3
2b	Dioicous; gemmae always present	4
3a	Basal marginal cells of leaves shorter and pale with thickened cross-walls, forming a border sharply differentiated from inner cells ( <i>Ulotia</i> s. str.)	26
3b	Basal marginal cells of leaves not particularly differentiated ( <i>Lewinskya</i> )	21
4a	Leaf margins erect or involute throughout; leaves ovate, concave, broadly obtuse or rounded at the apex ( <i>Nyholmella</i> )	25
4b	Leaf margins plane above, partly recurved below; leaves lanceolate, narrower at the apex, acute or acuminate	5
5a	Gemmae forming conspicuous clusters on excurrent part of costa of uppermost leaves	<i>Plenogemma phyllantha</i>
5b	Gemmae scattered more or less equally on adaxial surface of the leaves	<i>Pulvigerella lyellii</i>
<b>6–20 <i>Orthotrichum</i></b>		
6a	Leaf apex with conspicuous serrate hyaline acumen, formed by elongated cells	<i>O. diaphanum</i>
6b	Leaf apex without hyaline acumen, sometimes with 1–2 short celled apical hyaline apiculus (formed by not elongate cells)	7
7a	Capsules exserted on long seta	8
7b	Capsules immersed or emergent	9
8a	Exostome teeth erect or patent when dry, leaves erect, calyptra hairy	<i>O. anomalum</i>
8b	Exostome teeth recurved when dry, leaves flexuose, calyptra naked	<i>O. pulchellum</i>
9a	Exostome teeth erect or patent when dry, epilithic species	10
9b	Exostome teeth recurved to touching the urn when dry, mainly epiphytic species	11
10a	Vaginula with long papillose hair, exostome teeth coarsely papillose, prostome never present	<i>O. urnigerum</i>
10b	Vaginula naked, exostome teeth striate or papillose-striate; prostome usually present	<i>O. cupulatum</i>
10ba	Capsules immersed, endostome segments lacking or rudimentary, calyptra more or less hairy	<i>O. cupulatum</i> var. <i>cupulatum</i>

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10bb	Capsules emergent, endostome segments well developed, calyptra naked	<i>O. cupulatum</i> var. <i>riparium</i>
11a	Matured capsules with exostome formed by 16 teeth and endostome by 16 appendiculate segments	<i>O. scanicum</i>
11b	Matured capsules with exostome formed by 8 teeth and endostome by 8 or 16 segments	12
12a	Exothecial bands 2(-3) cells wide, reaching from the mouth to the lower half of the capsule	<i>O. patens</i>
12b	Exothecial bands 4 or more cells wide, reaching from the mouth to the base of the capsule	13
13a	Endostome segments completely erect when dry, slightly striated on the base. Plants showing dimorphism of branch leaves: on branches producing archegonia, the leaves are ligulate with a broadly oval base and margin recurved almost along the entire length; on branches producing antheridia, the leaves are significantly smaller, with margins plane or just a little recurved in the middle part	<i>O. rogeri</i>
13b	Endostome segments incurved when dry, smooth or papillose. Plants without dimorphism of branch leaves	14
14a	Vaginula cover by hairs	15
14b	Vaginula naked	17
15a	Vaginula usually with abundant short and smooth hairs, mature capsules with exothecial band brown-reddish in upper part, different in color from the lower half of the capsule	<i>O. stellatum</i> *
15b	Vaginula with long and papillose hairs (usually reaching to the base of urn), mature capsules with exothecial band not contrasting in color to the lower half of the capsule	16
16a	Endostome segments 8, ornamentation of the exostome teeth formed by dense papillae below and a mixture of papillae and evident lines above; leaf cells with papillae more or less prominent and commonly forked	<i>O. alpestre</i>
16b	Endostome segments 16, ornamentation of the exostome teeth uniformly papillose, leaf cell papillae low, unbranched	<i>O. stramineum</i>
17a	Endostome segments 8	18
17b	Endostome segments 16	20
18a	Capsule ovoid or pyriform when moist, sharply contracted into seta, segments conspicuous broadly at base, 1/2 to 3/4 as long as the exostome teeth	<i>O. schimperi</i>
18b	Capsule oblong-cylindrical when moist, gradually contracted into seta, segments linear, almost as long as the exostome teeth	19
19a	Leaves oblong-lanceolate to broad-lanceolate with apex of sterile leaf often ending in 1-2 celled hyaline apiculus, stomata scattered in the middle and lower part of the urn, calyptra naked	<i>O. pumilum</i>
19b	Leaves ligulate to ovate-lanceolate with apex narrowed into channelled apiculus (formed by the involute margin), stomata located particularly in lower part of the urn, calyptra with few papillose hairs at top	<i>O. tenellum</i>
20a	Endostome segments as long as the exostome teeth, with conspicuous marginal appendages	<i>O. moravicum</i> *
20b	Endostome segments alternately longer and shorter, without appendages	<i>O. pallens</i>
<b>21-24 Lewinskya</b>		
21a	Exostome teeth erect or patent when dry, translucent and glossy, leaf lamina at least in the upper half with bistratose areas	<i>L. rupestris</i>
21b	Exostome teeth recurved when dry, opaque and dull, leaf lamina entirely unistratose	22
22a	Exostome of 8 teeth	23
22b	Exostome of 16 teeth	24
23a	Capsules fully emergent to exserted, smooth or lightly ribbed in the upper half, calyptra densely hairy	<i>L. speciosa</i>
23b	Capsules semiemergent, strongly ribbed along the entire length of the capsule, calyptra sparsely hairy	<i>L. affinis</i>
	8 endostome segments	<i>L. affinis</i> var. <i>affinis</i>
	16 endostome segments	<i>L. affinis</i> var. <i>bohemica</i>
24a	Peristome single, formed by 16 exostome teeth (endostome segments lacking or rudimentary)	<i>L. shawii</i>
24b	Peristome double, formed by both 16 exostome teeth and 16 conspicuous endostome segments	<i>L. striata</i>
<b>25 Nyholmiella</b>		
25a	Leaves with margin erect, upper leaf cells usually with a single central papilla, capsules emergent, peristome present (double)	<i>N. obtusifolia</i>

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25b	Leaves with margin at least in the upper half conspicuously involute, upper leaf cells usually with 2–3 papillae, capsules immersed, peristome absent	<i>N. gymnostoma</i>
<b>26–32 <i>Ulota</i></b>		
26a	Capsule pyriform, smooth or ribbed only near mouth when dry and empty	<i>U. coarctata</i>
26b	Capsule cylindrical, campanulate or urceolate, ribbed at least into half of capsule or more often along almost entire length when dry and empty	27
27a	Plants not or only slightly crisped, with most leaves erect or only mildly curved when dry	28
27b	Plants strongly crisped, with most leaves strongly curved, contorted and circinate when dry	31
28a	Calyptra naked or rarely with scattered and short hairs, exostome teeth papillose mostly below, ornamented with curved lines above	<i>U. rehmannii</i>
28b	Calyptra hairy, with long hairs, exostome teeth papillose along their length	29
29a	Exostome teeth erect to irregularly recurved when dry, endostome lacking or rudimentary	<i>U. drummondii</i>
29b	Exostome teeth entirely recurved when dry, endostome segments well developed	30
30a	Leaf erect-appressed, straight when dry, plants mainly saxicolous	<i>U. hutchinsiae</i>
30b	Leaf more or less flexuose, curved to slightly contorted when dry, plants mainly epiphytic	<i>U. bruchii</i>
31a	Capsule not or slightly constricted below mouth when dry, with ribs separated by broad furrows in the upper half of urn; exothelial bands visibly separated from capsule mouth by a ring of small thin-walled cells	32
31b	Capsule strongly constricted below mouth when dry, with ribs separated by narrow furrows, collapsed at the constricted area of the urn; exothelial bands reaching the mouth	<i>U. crispa</i>
32a	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	<i>U. intermedia</i>
32b	Endostome segments variably bent when dry, uniseriate (or irregularly biseriata) with only thin transverse walls, cells of the exothelial bands evenly pale yellow, leaves gradually narrowing from a plane to slightly concave base	<i>U. crispula</i>

In *Census Catalogue of Polish Mosses* (Ochyra et al., 2003), some 700 species, eight subspecies, and 87 varieties have been recorded from the country. Since its publication, some 17 species have been added to the moss flora of Poland. These are *Orthotrichum shawii* Schimp. (Garilleti et al., 2006; Ruthe, 1873), *Bryoerythrophyllum alpigenum* (Jur.) P. C. Chen (Lisowski, 1959; Ochyra, 2020), *Fissidens rufulus* Bruch & Schimp. (Blockeel et al., 2006), *Zygodon stirtonii* Schimp. (Blockeel et al., 2007), *Leptophascum leptophyllum* (Müll. Hal.) J. Guerra & M. J. Cano (Fudali et al., 2009), *Grimmia teretinervis* Limpr. and *Didymodon validus* Limpr. (Ellis et al., 2010; Ochyra et al., 2011), *Thamnobryum neckeroides* (Hook.) E. Lawton (Ellis, Alegro, et al., 2012; Stebel & Vončina, 2018), *Pterygoneurum lamellatum* (Brid.) Jur. (Ellis et al., 2015; Stebel et al., 2016), *Ulota intermedia* Schimp. and *U. crispula* Brid. (Caparrós et al., 2016), *Bryum gemmiferum* R. Wilczek & Demaret (Ellis et al., 2016), *Cryphaea heteromalla* (Hedw.) D. Mohr (Müller, 2016), *Rhynchostegium rotundifolium* (Brid.) Schimp. (Vončina & Stebel, 2019), *Plagiothecium rossicum* Ignatov & Ignatova (Ignatova et al., 2019), and *Orthotrichum alpestre* Bruch & Schimp., and *O. schimperi* Hammar (present paper).

Additionally, one subspecies, *Pohlia nutans* subsp. *schimperi* (Müll. Hal.) Nyholm (Blockeel et al., 2005) and four varieties, namely *Barbula unguiculata* var. *robusta* Lindb. (Stebel et al., 2010), *Orthotrichum affine* var. *bohemicum* Plášek & Sawicki (Ellis, Bednarek-Ochyra, et al., 2012), *Microbryum davallianum* var. *conicum* (Schwägr.) R. H. Zander (Rusińska & Górski, 2012), and *Syntrichia ruralis* var. *epilosa* (Venturi) J. J. Amann (Ellis et al., 2018) have recently been recorded from Poland. Furthermore, two species have been excluded from the bryoflora of Poland, namely, *Plagiomnium drummondii* (Bruch & Schimp.) T. J. Kop. (Stebel & Ochyra, 2004) and *Orthotrichum microcarpum* De Not. (Plášek & Sawicki, 2009), because these records were based on misidentified specimens. Accordingly, if the aforementioned changes are considered, the moss flora of Poland will now include 715 species, nine subspecies, and 90 varieties.

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