

Article ID: 9111
DOI: 10.5586/asbp.9111

Publication History
Received: 2022-01-13
Accepted: 2022-05-07
Published: 2022-08-17

Handling Editor
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Authors' Contributions
GV: designed and coordinated the study, collected specimens, analyzed the data, and wrote the manuscript; AS: collected specimens, analyzed the data, and wrote the manuscript; AR, MSz, SR, MSm, and PK: collected specimens and contributed to the final version of the manuscript

Funding
This study was funded by the Medical University of Silesia in Katowice [grant No. PCN-1-037/K/1/F (A. Stebel)].

Competing Interests
No competing interests have been declared.

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ORIGINAL RESEARCH PAPER in TAXONOMY AND PHYTOGEOGRAPHY

Further Data About the Distribution of the Moss *Bryum gemmiferum* (Bryophyta, Bryaceae) in Poland

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Abstract

This paper presents the information on the distribution of the moss *Bryum gemmiferum* R. Wilczek & Demaret in Poland. The first species site from southern Poland was published, but further research and revision of the herbarium materials provided information about its occurrence in different parts of the country. Currently, this species is known in 20 locations. A brief discussion about its ecology, taxonomy, and geographical distribution is given.

Keywords

distribution; chorology; ecology; introduced alien species; *Bryum dichotomum* complex

1. Introduction

Bryum gemmiferum R. Wilczek & Demaret is a small moss that forms scattered loose turf and is easily recognized in the field due to its yellowish color and numerous minute gemmae in the leaf axils (Figure 1). It was described by Wilczek and Demaret (1976) from Belgium, the Canary Islands and the Netherlands. In the following years, many new locations were discovered, and now *B. gemmiferum* is known to occur in almost all European countries (Holyoak, 2021). Vanderpoorten and Zartman (2002) reported *B. gemmiferum* from California, USA, where this species was later confirmed in other sites (Carter, 2015; Kellman, 2003). Currently, California is the only region of distribution of this species in North America (Spence, 2014). The origin of the species is unknown. It could have been brought into Europe, or it may have occurred here. However, due to it being indistinguishable from the highly variable *B. dichotomum* Hedw., it was overlooked by bryologists.

The first report from Poland was in 2016 (Vončina in Ellis et al., 2016). A review of the herbarium materials showed that specimens belonging to *B. gemmiferum* were collected as early as 1997. Further research (revision of herbarium materials and field investigation) revealed its locations.

The aim of the study is to provide (i) the geographical distribution of *B. gemmiferum* in Poland, (ii) information on important diagnostic features, mainly gemmae, and (iii) ecological characteristics of the sites.



Figure 1 Characteristics of the plants from Ruska Strona (photo P. Kalinowski, September 11, 2018).

2. Material and Methods

Data on the occurrence of *Bryum gemmiferum* from Poland come from materials collected by the authors during fieldwork and from herbarium collections in KTU, POZG, and SOSN. A total of 66 specimens from the *Bryum dichotomum* complex were revised. The list of sites was grouped voivodeships from north-west to south-east, and the ATMOS grid square system was used (Ochyra & Szmajda, 1981). The distribution of *B. gemmiferum* in Poland was plotted on a map. The gemmae size, a key characteristic in the correct species identification, was measured. The lengths of five–seven gemmae with leaf buds were measured for 12 sites from different locations of its current range in Poland. The measurement was made using the Zeiss Primo Star optical microscope and a micrometric scale. The names of mosses and liverworts cited in this paper follow Hodgetts et al. (2020).

3. Results

3.1. Distribution in Poland

Bryum gemmiferum was found in 20 sites in Poland (see List of Localities in Poland). During the fieldwork, the authors found 13 sites (65% of the total number of records), while the herbarium revisions enriched the list with another seven (35%). Its records come from stations scattered throughout the country, although they are concentrated mainly in the central and southern parts (Figure 2). Based on herbarium material collected in the Silesian Upland, southern Poland, the first information on this species comes from the late 1990s. A decade later, it was collected from the north-central part of the country, followed by the eastern and

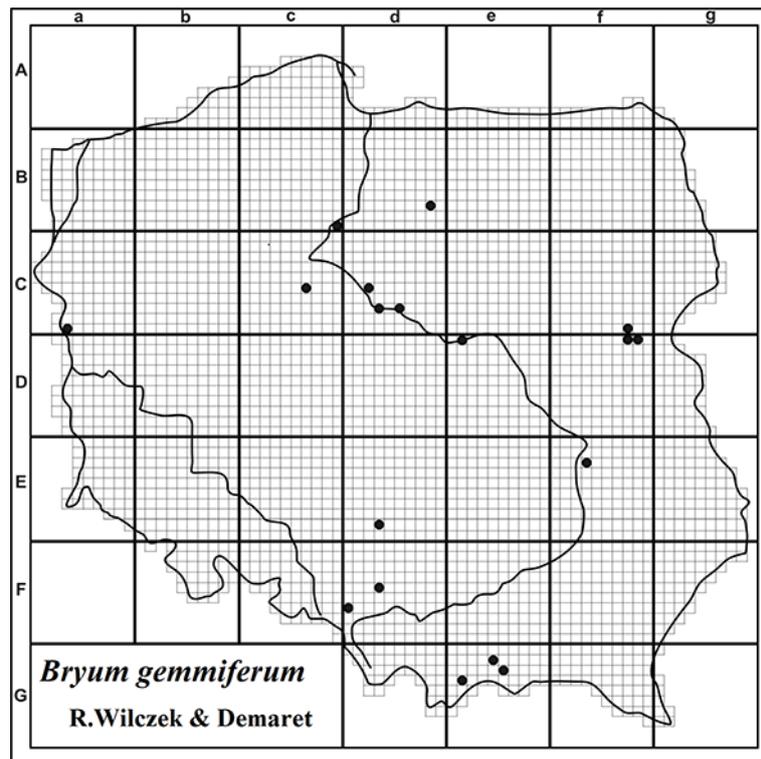


Figure 2 Distribution of *Bryum gemmiferum* in Poland in the ATMOS grid.

western parts and the Carpathians, the site of the first publication (Vončina in Ellis et al., 2016). The lowest site of *B. gemmiferum* was found at an altitude of 30 m in the Pomeranian Lakeland, while the highest was at 528 m in the Carpathians.

List of Localities in Poland:

Warmia-Masuria Voivodeship:

- (Bd 78) **Losy**, interglacial lake chalk, former local lake chalk mine – currently a landfill, shallow shaded hollow without water, initial habitat, 165 m a.s.l. (leg. M. Szczepański, April 3, 2017, herb. M. Szczepański).

Kujawy-Pomerania Voivodeship:

- (Bc 99) **Wiąg** (Wiąskie Góry), sandy landslide, 30–80 m a.s.l. (leg. M. Szczepański, April 3, 2010, herb. M. Szczepański).
- (Cc 56) **Wapienno** near Barcin, open pit limestone mine, bank of little stream, 20 m above the bottom of open cast, 100 m a.s.l. (leg. A. Rusińska, S. Rosadziński, May 14, 2009, POZG); as *Bryum bicolor* in Rusińska and Rosadziński (2010).
- (Cd 52) **Przypust Górny**, sandy soil, large gravel pit, sliding walls, 60 m a.s.l. (leg. M. Szczepański, October 9, 2010, herb. M. Szczepański).
- (Cd 73) **Włocławek**, dam on the Vistula River, right bank, on exposed soil, steep sunny slopes (xerothermic habitat), 70 m a.s.l. (leg. M. Szczepański, April 2, 2011, herb. M. Szczepański).
- (Cd 75) **Dobrzyń nad Wisłą**, 1 km N from Góra Zamkowa, sandy loam soil, landslides, 60 m a.s.l. (leg. M. Szczepański, March 19, 2010, herb. M. Szczepański).

Masovian Voivodeship:

- (Cf 97) **Starczewice**, sandy soil on the Bug River bank, 110 m a.s.l. (leg. P. Kalinowski, January 7, 2018, herb. G. Vončina).
- (De 01) **Wyszogród**, 0.5 km W from the bridge over the Vistula River, sandy soil on the river bank, 84 m a.s.l. (leg. M. Szczepański, March 31, 2012, herb. M. Szczepański).
- (Df 07) **Ruska Strona**, 0.5 km S of Drohiczyń, sandy soil on the Bug River bank, 113 m a.s.l. (leg. P. Kalinowski, September 28, 2017, herb. G. Vončina).

- (Df 08) **Drażniew**, N of village, sandy soil on the Bug River bank, 116 m a.s.l. (leg. G. Vončina, August 11, 2017, herb. G. Vončina).

Lubuskie Voivodeship:

- (Ca 93) **Pamięcin**, clay-sandy soil, at the base of the sliding wall of the closed sand pit on the slope of the Odra valley, 25 m a.s.l. (leg. M. Smoczyk, February 12, 2018, KRAM-B).

Silesia Voivodeship:

- (Ed 83) **Częstochowa-Gnaszyn Górny (Dębica)**, moist, loamy soil, excavation at the brickyard (leg. B. Fojcik, March 25, 2015, KTU).
- (Fd 43) **Katowice-Bogucice**, clay bottom of the excavation (leg. B. Fojcik, April 1, 1999, KTU).
- (Fd 43) **Katowice-Brynów**, bottom of a drained pond on a wasteland (leg. B. Fojcik, April 20, 1998, KTU).
- (Fd 43) **Katowice-Giszowiec**, damp excavation slope, brickyard in the forest (leg. B. Fojcik, April 5, 1998, KTU).
- (Fd 60) **Żory-Hańcówka**, clay soil, excavation at the brickyard, 280 m a.s.l. (leg. A. Stebel, May 3, 1997, SOSN).

Małopolskie Voivodeship:

- (Ge 14) **Stary Sącz**, clay soil between small pebbles, 293 m a.s.l. (leg. G. Vončina, May 25, 2018, herb. G. Vončina).
- (Ge 25) **Stary Sącz**, slate slots on the banks of the Poprad River, 305 m a.s.l. (leg. G. Vončina, May 1, 2016, herb. G. Vončina).
- (Ge 31) **Huba**, small scattered turf, clay soil, backwater of Czorsztyn Reservoir, 528 m a.s.l. (leg. G. Vončina, November 8, 2015, KRAM, Vončina in Ellis et al., 2016).

Lublin Voivodeship:

- (Ef 23) **Kazimierz Dolny**, Korzeniowy Dół gorge, loess, shaded wall, 140 m a.s.l. (leg. M. Szczepański, March 10, 2018, herb. M. Szczepański).

3.2. Habitats

Bryum gemmiferum is most often a pioneer species in disturbed habitats (Figure 3) and grows on sandy, loamy, muddy soils, but sometimes on loess, lake chalk, limestone, or schist. Some places, such as river banks and backwaters, might be flooded periodically. Some sites were located in closed excavations of clay, sand, gravel, chalk, or limestone quarries. *B. gemmiferum* often grows associated with bryophytes such as *Barbula unguiculata*, *Bryum argenteum*, *B. barnesii*, *B. dichotomum*, *Calliergonella cuspidata*, *Ceratodon purpureus*, *Funaria hygrometrica*, *Leptobryum pyriforme*, *Riccia cavernosa*, *R. sorocarpa*, *Tortula acaulon*, *T. lanceola*, and rarely *Campyliadelphus chrysophyllus*, *Dicranella varia*, *Didymodon fallax*, and *D. tophaceus*.

3.3. Reproduction

Bryum gemmiferum reproduces both generatively and vegetatively. Sporophytes were found only in the collections from Żory-Hańcówka (Silesia Voivodeship) and Wapienno (Kujawy-Pomerania Voivodeship), collected in May and August, respectively. This species produces them very rarely. For example, in the Huba station in the Carpathians, *B. gemmiferum* was observed from November to March, but no sporophytes appeared. Unfortunately, the flooding of the site with the waters of the Czorsztyn Reservoir made further observations impossible. Also, numerous specimens were observed in January, March, August, and September in the Masovian Voivodeship, but sporophytes were not found.

Gemmae size and shape are key features distinguishing *B. gemmiferum* from related species. The species produced them abundantly at all sites. The gemmae of Polish populations have characteristics typical for this species (Figure 4) and are mainly yellow-green (very rarely reddish, for example, at the Wapienno location).



Figure 3 Habitat on the bank of river in Dobrzyń nad Wisłą (photo M. Szczepański, March 20, 2010).

The smallest measured gemma was 90 μm , while the largest was 175 μm (Figure 5). However, most (72.6%) ranged from 121 to 160 μm (Figure 6).

4. Discussion

Since the description of *Bryum gemmiferum* (Wilczek & Demaret, 1976), the number of its identifications in Europe has started to increase, initially slowly (Düll, 1994), to significantly in recent years (Holyoak, 2021). It is not known whether this is due to bigger attention to this species by bryologists or whether it is starting to spread. Based on its spread and lack of data prior to 1940, Hill et al. (2006) speculated that this species could have been introduced into Europe. Indeed, over the past decade, information on the occurrence of the species in other countries has started to increase, which may prove the hypothesis. However, the origin of the species is not known, which is a weakness. Essl and Lambdon (2009) and Holyoak (2021) do not treat *B. gemmiferum* as species alien to Europe. Düll (1994) lists *B. gemmiferum* as a species with a south-sub-oceanic range type in Europe. Its appearance and spread in Poland fit well with this classification. The first sites (see List of Localities in Poland) were found in the southern part of the country, followed by the central, western, and

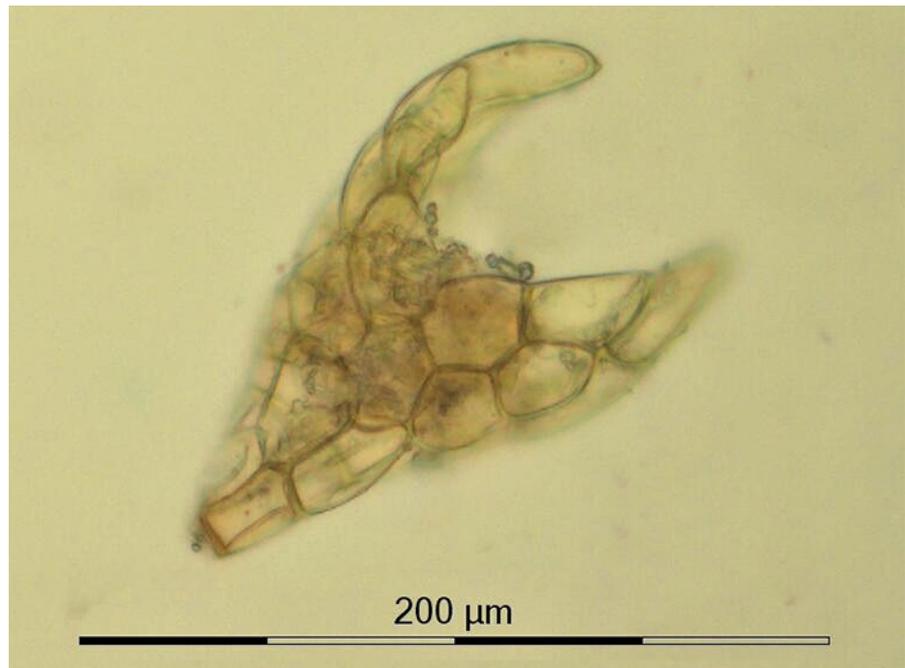


Figure 4 Gemma of *Bryum gemmiferum* from Wapienno (No. 226 POZG) (photo G. Vončina).

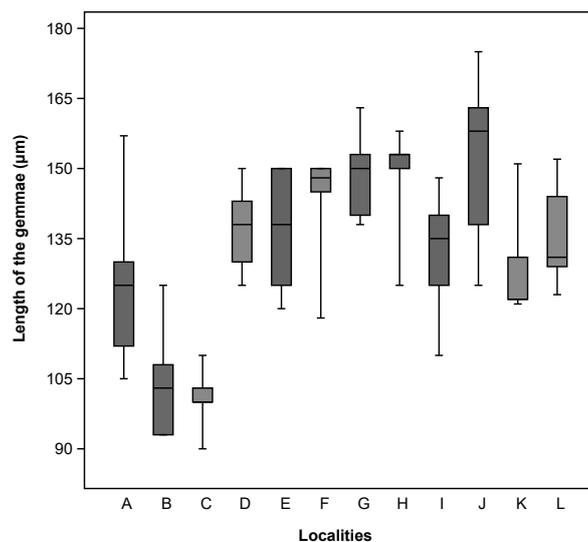


Figure 5 Box and whisker plot of gemmae length of *Bryum gemmiferum* studied in 12 localities in Poland. Box – first and third quartile with a median; whiskers – minimum and maximum value. (A) Wiąg; (B) Włocławek; (C) Dobrzyń nad Wisłą; (D) Losy; (E) Wyszogród; (F) Starzewice; (G) Drażniew; (H) Stary Sącz; (I) Huba; (J) Wapienno; (K) Żory-Hańcówka; (L) Pamięcin.

eastern parts. It is difficult to determine the pattern of its distribution in the country from 20 records, and only collection from other locations may provide insight into where the number of sites increases. Previous studies on neophytes found in Poland indicate a different direction of expansion progress, with the common part being their appearance in the western part of the country (Żarnowiec et al., 2019, 2020). The current state of knowledge about the distribution of *B. gemmiferum* in Poland does not entitle us to formulate such a conclusion. However, given the numerous sites in Germany near the border with Poland (Meinunger & Schröder, 2007) and the possibility of free spreading in mild climatic conditions, a significantly greater number of records in the western part of the country should be expected.

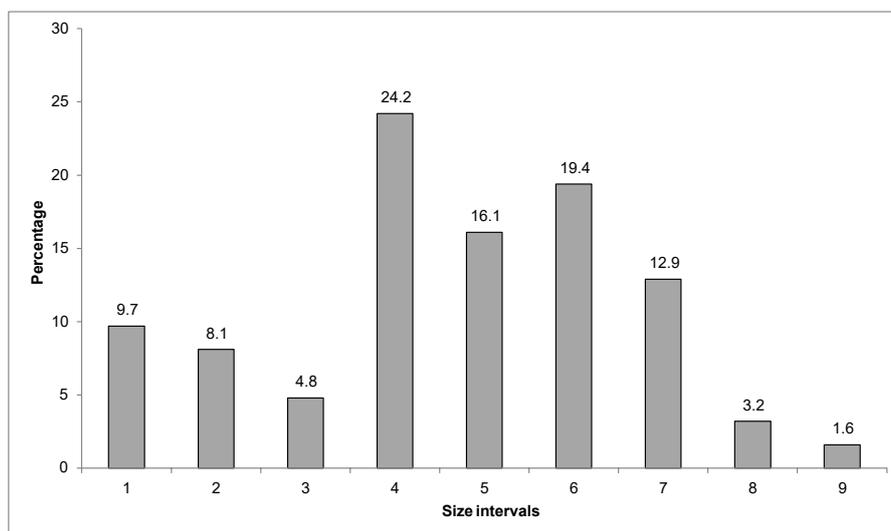


Figure 6 Percentage of the length of gemmae (number of measurements: 62) in intervals. 1: 91–100 μm ; 2: 101–110 μm ; 3: 111–120 μm ; 4: 121–130 μm ; 5: 131–140 μm ; 6: 141–150 μm ; 7: 151–160 μm ; 8: 161–170 μm ; 9: 171–180 μm .

The situation is different on the southern border of Poland. The lack of cross-border records with the Czech Republic (*“Bryum gemmiferum,”* 2022a) and the current lack of data on the presence of this moss in Slovakia suggests that there will be no significant increase in the number of sites from this area. Moreover, the Carpathian and Sudetes Mountains constitute a serious barrier to the migration of species. In general, data from Poland indicate that *B. gemmiferum* is probably more common in the country, but further field research is required to confirm this.

Bryum gemmiferum can spread along rivers, where more than half of the listed sites are found, but also occupies initial wet habitats such as abandoned clay, gravel, or sand pits. It is a pioneer species, growing on well-drained, often sandy, but periodically wet soil, particularly on river banks, by ponds and ditches, on mud and the margin of reservoirs, and in damp arable fields and quarries (Dierssen, 2001; Atherton et al., 2010). Dirkse and Kruijzen (1993) included this moss in the groups of pioneer species found on moist or dry, moderately fertile to very fertile or alkaline soils. In Hungarian sites, the species occurs on river and stream banks, in old sand pits, in loess cliffs on moist calcareous soil, sand, gravel, and loess (Erzberger & Schröder, 2013). Similarly, in North America, the species grows on moist soil with disturbed structure (on cultivated soil and at the base of trunks) (Kellman, 2003).

Sites of *B. gemmiferum* found in Poland are situated in lowlands, highlands, and at lower altitudes in the mountains ranging from 25 to 528 m above sea level.

The occurrence at lower altitudes has also been observed in other countries, e.g., up to 350 m in Great Britain and Ireland (Hill et al., 2007) and at 150–350 m in Hungary (Erzberger & Schröder, 2013). Most Swiss locations are at 270–600 m, but the highest position is at 800 m (*“Bryum gemmiferum,”* 2022b). Polish stations are at similar altitudes as in Baden-Württemberg, where the lowest sites were found at an altitude of about 100 m, while the highest is located at 585 m (Ahrens & Nebel, 2001).

The color of the gemmae produced in the leaf axils has already been discussed in the paper by Vanderpoorten and Zartman (2002), where the authors pointed to color differences in material from different countries – from orange to reddish from Great Britain, greenish from Belgium, and yellow, green, rarely brownish from America. On the material from Hungary, van Zanten (1999) wrote about green or light brown propagules, which was not referred to by Erzberger and Schröder (2013).

Observations carried out in Poland in the period from November 8, 2015, to March 12, 2016, at the Huba site in the Carpathians did not indicate a change in the color of the gemmae over time. They were yellow or yellow-green from the onset, and this color was maintained during the 4 months of observation. Their color is similar to that observed in the Czech Republic or Turkey, where it was specified as green to

yellowish (Soldán & Kučera, 2004; Ursavaş & Işin, 2018). Also, the size of the gemmae is a diagnostic feature that distinguishes *B. gemmiferum* from other *Bryum* species that produce them in the leaf axils. In the case of Poland, there are two more species, i.e., *B. dichotomum* (Ochyra et al., 2003) and the recently discovered *B. barnesii* (Stebel et al. in Ellis et al., 2020). Holyoak (2021) indicates the gemmae size of European species at $140\text{--}160 \pm 40 \mu\text{m}$. Measurements of the length of the gemmae from selected Polish populations are in the range of $90\text{--}175 \mu\text{m}$, with the most common size range from 121 to $160 \mu\text{m}$. Soldán and Kučera (2004) give the dimensions of the propagules of Czech specimens in the range of $100\text{--}250 \mu\text{m}$, which indicates their greater length span.

The size of the gemmae from Hungarian specimens ranges from 50 to $550 \mu\text{m}$ long and the most common values are between 75 and $150 \mu\text{m}$. The average lengths correspond to the data from Poland, but the maximum size of the gemmae stands out significantly, which is not confirmed by any subsequent literature.

Wilczek and Demaret (1976) distinguish juvenile gemmae in the length range of $65\text{--}150 \mu\text{m}$ and mature, fully developed ones with dimensions of $200\text{--}550 \mu\text{m}$. The measured material from Poland was collected throughout the growing season in the following months: January, February, March, April, May, August, and November; therefore, it should be assumed that the propagules could not only be juvenile. Despite the collection in most months of the year, the propagules of specimens collected in Poland did not reach $200 \mu\text{m}$. The variation in size and color of the size and color of propagules in *B. gemmiferum* requires more extensive research and observation.

Acknowledgments

The authors thank Alain Vanderpoorten (Liège, Belgium) for confirming the identification of the mosses from most of the described localities and Dr. Barbara Fojcik (University of Silesia in Katowice) for sharing the herbarium materials of *Bryum bicolor* s. l. Thanks are also due to Anna Wróbel for preparing a graph showing the variability of gemmae the *Bryum gemmiferum*.

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