SHORT COMMUNICATION in ECOLOGY

An Unusual Epiphytic Habitat for *Hedwigia ciliata* (Bryophyta: Hedwigiaceae) in Poland (Central Europe)

Adam Stebel 1*, Monika Staniaszek-Kik 2, Stanisław Rosadziński 3, Mariusz Wierzgoń 4, Barbara Fojcik 4, Michał Smoczyk 5, Grzegorz Vončina 6

1 Department of Pharmaceutical Botany, Faculty of Pharmaceutical Sciences, Medical University of Silesia in Katowice, Ostrogórska 30, Sosnowiec, 41-200, Poland
2 Department of Geobotany and Plant Ecology, Faculty of Biology and Environmental Protection, University of Łódź, Banacha 12/16, Łódź, 90-237, Poland
3 Department of Plant Ecology and Environmental Protection, Faculty of Biology, Adam Mickiewicz University in Poznań, Umultowska 89, Poznań, 61-614, Poland
4 Institute of Biology, Biotechnology and Environmental Protection, Faculty of Natural Sciences, University of Silesia in Katowice, Jagiellońska 28, 40-032 Katowice, Poland
5 Stanisław Staszic High School in Rzepin, Wojska Polskiego 30, Rzepin, 69-110, Poland
6 Pieniny National Park, Jagiellońska 107B, Krościenko nad Dunajcem, 34-450, Poland

* To whom correspondence should be addressed. Email: astebel@sum.edu.pl

Abstract

In Poland, *Hedwigia ciliata* (Hedw.) P. Beauv., an obligatory epilithic moss species, has in recent years also been observed on the bark of trees. In this paper, we describe 25 recently identified sites in which epiphytic *H. ciliata* has been observed, and provide a plausible explanation to account for this phenomenon.

Keywords

bryophyte; moss; epiphyte; distribution; habitat preference; climate change

1. Introduction

*Hedwigia ciliata* (Hedw.) P. Beauv. (Bryophyta: Hedwigiaceae) is a moss species widely distributed in Europe, North America, and Asia, wherein it is generally found in temperate and boreal zones. This moss also grows at higher altitudes in Central and South America, Africa, South Australia, and New Zealand (Eckel, 2014; Ochyra et al., 1988). It typically colonizes sunny, dry, acidic rock substrates, including exposed erratic boulders, rock outcrops, stones, and rocks in abandoned quarries (Dierßen, 2001; Ochyra et al., 1988). Considerably less often, it is also found on the bark of trees (Marques et al., 2005; Mazimpaka & Lara, 1995). Similar to other xerophytic species, this medium-sized moss is characterized by a number of morphological features (including hyaline hair on leaves and incrassate cells with papillae) that facilitate growth in strongly insolated habitats (Smith, 2004).

The formation of sporophytes and capsules hidden between the leaves on short setae are also characteristic features of this taxon (Ignatova et al., 2016).

In Poland, *H. ciliata* is found at numerous sites in the south (particularly in the Sudetes), and in the moraine belt in the northern part of the country (West Pomerania, Masurian Lakeland, and Wielkopolska region) (Bednarek-Ochyra, 1998; Ochyra et al., 1988). Until relatively recently, at all sites in Poland in which this moss has been reported, it had been found exclusively on acidic rocky substrates (Bednarek-Ochyra, 1998; Fojcik, 2011; Górski et al., 2014; Górski, Fudali, et al., 2017; Górski, Pawlikowski, et al., 2017; Ochyra et al., 1988; Stebel, 2006; Wierzcholska et al., 2010; Żarnowiec & Stebel, 2014). Interestingly, however, in recent years, *H. ciliata* has also been found on limestone rocks (Stebel et al., 2010;
Vončina & Stebel, 2016), and notably observed on the bark of trees (Stebel & Vončina, 2014). In this paper, we present data on the current distribution of the sites of epiphytic *H. ciliata* in Poland and the characteristics of colonized substrates, and also propose an explanation to account for this phenomenon.

2. Material and Methods

A list of sites with epiphytic *H. ciliata* was compiled based on the ATMOS grid square system (Ochyra & Szmajda, 1981) and is presented in Table S1. The nomenclature used for mosses follows that described by Hodgetts et al. (2020) and the one used for phorophytes follows that of Mirek et al. (2002). The locations of the epiphytic *H. ciliata* sites are indicated on the map shown in Figure 1.

3. Results

3.1. The Geographical Distribution of Epiphytic Sites

The first documented occurrence of *H. ciliata* growing on bark in Poland was on that of a roadside *Populus × canadensis* Moench tree found in the Western Carpathians (Stebel & Vončina, 2014) in 2011, and to date, epiphytic *H. ciliata* have been recorded at a total of 25 sites in Poland (Figure 1) distributed in 22 ATMOS squares. The distribution of these sites spans virtually the entire length and breadth of Poland, although with an evident concentration in the south-west region of the country. Few of these sites are distributed in mountainous areas, with records from only one site in the Sudetes and three in the Carpathians. The highest altitude at which *H. ciliata* has been found growing epiphytically is 890 m above sea level in the Beskid Żywiecki range of the Carpathian Mountains.
3.2. Habitats

Epiphytic *H. ciliata* has been most frequently found on solitary trees growing along roadsides or in parks, although less often in forests. Typically, recorded populations have been small (single tufts of several square centimeters in area) and found colonizing tree bases, trunks, and even crowns, in both rural and urban areas. The moss has been recorded growing epiphytically on 12 types of phorophytes, both those native (*Acer pseudoplatanus* L. (two sites), *Fagus sylvatica* L. (one), *Fraxinus excelsior* L. (six), *Quercus robur* L. (three), *Populus × canescens* (Aiton) Sm. (one), *Salix fragilis* L. (one), and *S. ×rubens* Schrank (one)] and alien [*Fraxinus pennsylvanica* Marshall (two), *P. ×berolinensis* (K. Koch) Dippel (one), *P. ×canadensis* (four), *Q. rubra* L. (one), and *S. ×sepulcralis* Simonk. ‘Chrysocoma’ (two)] to Poland. The numerical distribution of *H. ciliata* populations on different phorophytes is presented in Figure 2.

4. Discussion

To date, the occurrence of epiphytic *H. ciliata* has only rarely been reported in Europe [e.g., Spain, Germany, Portugal (Geyer & Margenburg, 2015; Marques et al., 2005; Mazimpaka & Lara, 1995; Meinunger & Schröder, 2007; Otte, 2002; Rätzle et al., 2000, 2001), and Turkey (Erdağ et al., 2003)] and North America (Eckel, 2014), with all authors emphasizing the atypical nature of this epilithic growth habit on trees. Epilithic and epiphytic habitats tend to have certain physical characteristics in common, notably strong insolation and alternating periods of humidity and extreme drought (Vitt, 1981), and this ecological similarity implies that many bryophyte species can colonize both types of substrates (Mazimpaka & Lara, 1995). It has been suggested that a change in bryophyte habitat of this type may be associated with climatic factors. Barkman (1958), for example, concluded that as the climate becomes drier, epiphytic species move onto phorophytes, which have a greater water-holding capacity, sometimes on decaying wood, and finally rocks and soil. Moreover, with growth, the conditions on trees can begin to resemble those typical on rocks, and thus epilithic species increasingly often colonize trees (Vitt, 1981). This habitat transition is facilitated to a large extent by the xeromorphic features of bryophytes that confer a certain degree of resistance to desiccation or contribute to reducing insolation. In this regard, *H. ciliata* is noted as a desiccation-tolerant bryophyte (Streusand et al., 1986), with several adaptations designed to minimize exposure, including hyaline leaf tips and upwardly curved branch tips (Glime, 2020). Changes in the ecological niche occupied by epilithic mosses and its association with
climate change has also been discussed by Bates et al. (2004), who presented the examples of Syntrichia ruralis (Hedw.) F. Weber & D. Mohr, Grimmia pulvinata (Hedw.) Sm., and Tortula muralis Hedw., which are commonly found on the walls of buildings in Great Britain, whereas in localities characterized by warm dry climates, they typically grow only as epiphytes. It can thus be speculated that the observed expansion of the habitat range of H. ciliata to the trunks of trees, a new habitat type for this species in Poland, may represent a response to the ongoing changes in climate in this region of Europe (increases in temperature and the number of dry days per year, along with short but very heavy rainfall, alternating with long periods of drought) (Kundzewicz & Mateczak, 2012). Given the large number of sites, their broad distribution, and the diversity of phorophyte hosts and habitats, it would appear that we are witnessing a particularly interesting phenomenon, which is certainly worthy of further investigation and monitoring. Moreover, H. ciliata is far from unique in this respect, given that in recent years in Poland, other moss species, hitherto known as obligatory epiliths, have also been increasingly found on the bark of trees, such as Cynodontium strumiferum (Hedw.) Lindb., Grimmia hartmanii Schimp. (Stebel, 2006), G. pulvinata (Fudali & Szymanowski, 2019; Fudali & Żołnierz, 2019; Wilhelm et al., 2015), Orthotrichum anomalum Hedw. (Fudali & Szymanowski, 2019; Stebel & Fojcik, 2016), and Tortula muralis (Fudali & Szymanowski, 2019; Plášek et al., 2014).

5. Supplementary Material

The following supplementary material is available for this article:
Table S1. List of sites with epiphytic Hedwigia ciliata in Poland.

References

Barkman, J. J. (1958). Phytosociology and ecology of cryptogamic epiphytes: Including a taxonomic survey and description of their vegetation units in Europe. Van Gorcum & Comp. N.V.

Bates, J. W., Roy, D. B., & Preston, C. D. (2004). Occurrence of epiphytic bryophytes in a "tetrad" transect across southern Britain. 2. Analysis and modelling of epiphyte–environment relationships. Journal of Bryology, 26(3), 181–197. https://doi.org/10.1179/037366804X5288

Bednarek-Ochyra, H. (1998). Hedwigia ciliata (Musci, Hedwigiaceae) in the Kraków-Częstochowa Upland (central Poland). Fragmenta Floristica et Geobotanica, 43(2), 296–298.

Dierßen, K. (2001). Distribution, ecological amplitude and phytosociological characterization of European bryophytes. J. Cramer.

Eckel, P. M. (2014). Hedwigiaceae Schimp. In Flora of North America Editorial Committee (Eds.), Flora of North America north of Mexico (pp. 83–90). Oxford University Press.

Erdaǧ, A., Kirmaci, M., & Kürschner, H. (2003). The Hedwigia ciliata (Hedw.) Ehr. ex P.Beauv. complex in Turkey, with a new record, H. ciliata var. leucophaea Bruch & Schimp. (Hedwigiaceae, Bryopsida). Turkish Journal of Botany, 27, 349–356.

Fojcik, B. (2011). Mchy Wyżyny Krakowsko-Częstochowskiej w obliczu antropogenicznych przemian sztytu roślinnego [Mosses of the Cracow-Częstochowa Upland in relation to anthropogenic transformations of the plant cover]. Wydawnictwo Uniwersytetu Śląskiego.

Fudali, E., & Szymanowski, M. (2019). Epiphytic bryophytes on alien host-tree species in Wroclaw (SW Poland). Cryptogamie, Briologie, 40(11), 119–129. https://doi.org/10.5252/cryptogamie-briologie2019v40a11

Fudali, E., & Żołnierz, L. (2019). Epiphytic bryophytes in urban forests of Wroclaw (SW Poland). Biodiversity: Research and Conservation, 53, 73–83. https://doi.org/10.2478/biorc-2019-0005

Geyer, H. J., & Margenbarg, B. (2015). Hedwigia ciliata – Wimpern-Hedwigsmoos (Hedwigiaceae), Moos des Jahres 2014 [Hedwigia ciliata – Hedwigiaceae, the moss of the year 2014]. Jahrbuch des Bochumer Botanischen Vereins, 6, 225–228.

Glime, J. M. (2020). Bryophyte ecology. https://digitalcommons.mtu.edu/bryophyte-ecology/

Górski, P., Fudali, E., Żołnierz, L., Smoćzyk, M., Wierzcholska, S., Rosadziński, S., & Dryderski, M. K. (2017). New distributional data on bryophytes of Poland and Slovakia, 10. Steciana, 21(2), 59–68. https://doi.org/10.12657/steciana.021.007
Stebel, A. (2006). Stebel, A., Ochyra, R., & Vončina, G. (2010). Changes in the epiphytic bryophyte flora in Katowice City.

Hodgetts, N. G., Söderström, L., Blockeel, T. L., Caspary, S., Ignatov, M. S., Konstantinova, N. A., Lockhart, N., Papp, B., Schröck, C., Sim–Sim, M., Bell, D., Bell, N. E., Blom, H. H., Bruggeman–Nannenga, M. A., Bruguës, M., Enroth, J., Flatberg, K. L., Garilleti, R., Hedenäs, L., … Porley, R. D. (2020). An annotated checklist of bryophytes of Europe, Macaronesia and Cyprus. Journal of Bryology, 42(1), 1–116.

Ignatova, E. A., Kuznetsova, O. I., Fedosov, V. E., & Ignatov, M. S. (2016). On the genus Hedwigia (Hedwigiaaceae, Bryophyta) in Russia. Acta Botanica Graeca, 11(2), 241–277.

Kundzewicz, Z. W., & Matczak, P. (2012). Climate change regional review: Poland. WIREs Climate Change, 3(4), 297–311. https://doi.org/10.1002/wcc.175

Marques, J., Hespanhol, H., Vieira, C., & Séneca, A. (2005). Comparative study of the bryophyte epiphytic vegetation in Quercus pyrenaica and Quercus robur woodlands from northern Portugal. Boletín de la Sociedad Española de Briología, 26–27, 75–84.

Mazimpaka, V., & Lara, F. (1995). Corticolous bryophytes of Gredos Mountains (Spain): Vertical distribution and affinity for epiphytic habitats. Nova Hedwigia, 61, 431–446.

Meinunger, L., & Schröder, W. (2007). Verbreitungsatlas der Moose Deutschlands [Distribution atlas of mosses in Germany] (Vol. 3). Regensburgische Botanische Gesellschaft.

Mirek, Z., Piękos–Mirkowa, H., Zając, A., & Zając, M. (2002). Flowering plants and pteridophytes of Poland – A checklist. W. Szafer Institute of Botany, Polish Academy of Sciences.

Ochyra, R., & Szmajda, P. (1981). La cartographie bryologique en Pologne [Bryological cartography in Poland]. In J. Szewykowski (Ed.), New perspectives in bryotaxonomy and bryogeography: Second Bryological Meeting, Poznań, June 26–29, 1980 (pp. 105–110). Adam Mickiewicz University in Poznań.

Ochyra, R., Szmajda, P., Bochenśki, W., & Karczmarz, K. (1988). M. 439. Hedwigia ciliata (Hedw.). P. Beauv. In Z. Tobolewski, & T. Wojterski (Eds.), Atlas of the geographical distribution of spore plants in Poland. Series V. Mosses (Musci) 4 (pp. 19–25). Państwowe Wydawnictwo Naukowe.

Otte, V. (2002). Untersuchungen zur Moos- und Flechtenvegetation der Niederlausitz – ein Beitrag zur Bioindikation [Investigations into the bryophyte and lichen vegetation of Niederlausitz – A contribution to the bioindication]. Peckiana, 2, 1–340.

Plaśek, V., Nowak, A., Nobis, M., Kusza, G., & Kochanowska, K. (2014). Effect of 30 years of road traffic abandonment on epiphytic moss diversity. Environmental Monitoring and Assessment, 186, 8943–8959. https://doi.org/10.1007/s10661-014-4056-3

Rätzel, S., Meinunger, L., Müller, F., & Schröder, W. (2001). Bemerkenswerte Moosfunde aus Brandenburg IV [Remarkable bryophyte findings from Brandenburg IV]. Verhandlungen des Botanischen Vereins von Berlin und Brandenburg, 134, 155–168.

Rätzel, S., Müller, F., & Otte, V. (2000). Bemerkenswerte Moosfunde aus Brandenburg III [Remarkable bryophyte findings from Brandenburg III]. Verhandlungen des Botanischen Vereins von Berlin und Brandenburg, 133, 483–509.

Smith, A. J. E. (2004). The moss flora of Britain and Ireland (2nd ed.). Cambridge University Press.

Stebel, A. (2006). The mosses of the Beskidy Zachodnie as a paradigm of biological and environmental changes in the flora of the Polish Western Carpathians. Medical University of Silesia in Katowice; Sorus.

Stebel, A., & Fojcik, B. (2016). Changes in the epiphytic bryophyte flora in Katowice City (Poland). Cryptogamie, Bryologie, 37(4), 399–414. https://doi.org/10.7872/cryb.v37.iss4.2016.399

Stebel, A., Ochrya, R., & Vončina, G. (2010). Mosses of the Pieniny Range (Polish Western Carpathians). Sorus.

Stebel, A., & Vončina, G. (2014). Bryophyte diversity in the flora of the Orawsko-Jordanowskie Foothills (Polish Western Carpathians). Muzeum Tatranskie w Zakopanem.

Struessand, V. I., Weber, J. A., & Ikuma, H. (1986). Desiccation tolerance in mosses. II. Differences in the responses of Hedwigia ciliata and Mnium cuspidatum to desiccation and rehydration. Canadian Journal of Botany, 64(11), 2393–2398. https://doi.org/10.1139/b86-317
Vitt, D. H. (1981). Adaptive modes of the moss sporophyte. *The Bryologist, 84*(2), 166–186. https://doi.org/10.2307/3242820

Vončina, G., & Stebel, A. (2016). Materiały do flory mchów (Bryophyta) pienińskiego pasa skalowego (Karpaty Zachodnie) [Contribution to the moss flora (Bryophyta) of the Pieniny Klippen Belt (Western Carpathians)]. *Pieniny – Przyroda i Człowiek, 14*, 79–89.

Wierzcholska, S., Plášek, V., & Krzysztofiak, A. (2010). Mszaki (Bryophyta) [Bryophytes (Bryophyta)]. In L. Krzysztofiak (Ed.), *Słuzowce Myxomycetes, grzyby Fungi i mszaki Bryophyta Wągierskiego Parku Narodowego* [Slime molds Myxomycetes, fungi Fungi and bryophytes Bryophyta of the Wigry National Park] (pp. 229–298). Stowarzyszenie Człowiek i Przyroda.

Wilhelm, M., Rusińska, A., Stebel, A., Górski, P., Vončina, G., Fojcik, B., Rosadziński, S., Fudali, E., Salachna, A., & Zubel, R. (2015). Contribution to the bryoflora of the Wolin Island (NW Poland). *Steciana, 19*(2), 75–87. https://doi.org/10.12657/steciana.019.009

Żarnowiec, J., & Stebel, A. (2014). *Mchy polskich Bieszczadów Zachodnich i Bieszczadzkiego Parku Narodowego – stan poznania, ekologia, zagrożenia* [Mosses of the Polish part of Western Bieszczady Mts and the Bieszczady National Park – State of recognition, ecology, threats]. Ośrodek Naukowo-Dydaktyczny Bieszczadzkiego Parku Narodowego.