

## Epiphyllous bryophytes in Arboretum Stradch (Ukraine)

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The aim of this work done in Arboretum Stradch was to investigate bryophytes growing on leaves of woody understory, which are poorly studied in Central Europe. It was identified two facultative epiphyllous bryophytes considered as generalists and common species of Ukraine bryoflora: *Brachythecium salebrosum* and *Hypnum cupressiforme*. The most abundant was *H. cupressiforme*. Total surface area of its mats was about 218 cm<sup>2</sup>, while the total surface area of *B. salebrosum* mats was about 10 cm<sup>2</sup>. Both identified species occurred mainly on young individuals of *Abies alba*, which grew near tree trunks abundantly covered by the same moss species. *H. cupressiforme* also occurred rarely on leaves of two deciduous angiosperm phorophytes *Corylus avellana* and *Ulmus glabra*. *B. salebrosum* occurred also on one individual of *Rubus caesius* and on one individual of *Ulmus glabra*. This study brings new information about the ecology of the two identified mosses – their ability to grow on silver fir spindles and also on leaves of some deciduous phorophytes.

**Keywords:** epiphyllous mosses, epiphylls, generalists, epiphytes, phorophytes

### 1 Introduction

Bryophytes as non-vascular plants are able to grow on various substrates: rocks (epilites), soil (epigeits), tree bark (epiphytes), rotting logs (epixilics) and on leaves. The latter are called epiphyllous or foliicolous bryophytes or epiphylls (Smith, 1982; Glime, 2020). The typically epiphyllous species, which grow exclusively on leaves occur mostly in the tropical regions and most of them are liverworts (Pócs, 1996; Gradstein, 1997). Many epiphyllous species are facultative and grow also on other substrates or even as generalists (without certain substrate preference). It was shown that some of facultative epiphyllous species (mainly liverworts) occur in sub-tropical and temperate regions around the world (Smith, 1982; Pócs, 1989; Risk et al., 2011; Lepp, 2012) up to British Columbia (Vitt et al., 1973) and even Great Britain (Porley, 1996), but in consequence of the strong dependency of leaf moisture and atmospheric humidity (Burkhardt & Hunsche, 2013) they are mostly confined to highly humid localities or localities often affected by mist (Glime, 2020). The ability of some moss species with broad substrate preference to grow on leaves of woody phorophytes in a temperate region with

relatively dry climatic conditions was shown recently in Arboretum Mlyňany (Central Europe, Slovakia), where average annual rainfall is about 577.1 mm and fog forms not often (Pundiak & Michalko, 2020). In the arboretum Mlyňany such mosses grew mostly on leaves of subtropical woody evergreen understory planted exclusively near trees or rocks densely covered by the same moss species. Such limiting conditions may be the cause why epiphyllous bryophytes in Central Europe didn't get attention of famous bryologist, investigator of the epiphylls around the whole world, hungarian Tamás Pócs (Orbán & Péntes-Kónya, 2013). Although unfortunately in Central Europe biological diversity and ecology of bryophytes growing on leaves of woody phorophytes are almost unexplored, the fact that among all identified bryophytes in Mlyňany there were only mosses and they grew exclusively near the objects densely covered by moss carpets points out certain peculiarities of Central European epiphyllous bryoflora. For the elucidation of such peculiarities we chose the Arboretum Stradch (Ukraine), which has a good collection of wide-spread woody species of local flora and of temperate regions around the world.

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Thus our goal was to explore diversity and estimate the bryophyte cover on leaves of woody understory plants in the Arboretum Stradch. For the quantitative cover evaluation analogically to Pundiak and Michalko (2020) it was used the total surface area of bryophyte mats (reflecting the general spread scales), the percentage of available phorophyte leaf area bearing the epiphylls (reflecting the ecological niche filling) and the maximal surface area per an epiphyll mat (reflecting growth opportunities).

## 2 Material and methods

The study site, Arboretum Stradch, a part of the Botanical Garden of Ukrainian National Forestry University, is located in the village Stradch in Yavoriv district of Lviv region, Western-Ukraine. It is situated in the south-eastern part of Ukrainian Roztochia, 20 km to the west of Lviv city (49° 54' 09" N, 23° 45' 39" E). Several kilometers from the Arboretum Stradch further to the west there located the Roztochia Nature Reserve (Pundiak, 2020). The average temperature in January is -3 °C, in July +17.5 °C, the average annual rainfall is 673 mm (<https://www.karpaty.info/ua/>, 2005).

The Arboretum Stradch was established in 1962 as a scientific and didactic part of the Ukrainian National Forestry University (UNFU, 2021). It consists of a collection part (5.7 ha) and a forest part, which is a formerly managed 140 years old hornbeam-beech-pine-oak forest of 9.8 ha (Pundiak, 2019; Pundiak, 2020; UNFU, 2021). In both parts of the Arboretum the undergrowth consists of regionally wide-spread species *Carpinus betulus*, *Corylus avellana*, *Euonymus europaea*, *Fagus sylvatica*, *Sambucus nigra*, *Swida alba*, *Ulmus glabra* and individuals germinated from the seeds, which had matured on the neighboring collection plants (Pundiak, 2019; Pundiak, 2020).

Close to the firs collection plot there is located the linden collection plot with 20 individuals of 50 year-old *Tilia cordata* and about 1,200 young individuals of *Abies alba*.

Within the territory of the arboretum, bryophytes grow abundantly on trunks of old trees, especially of oak *Quercus robur* in the forest part (about 140 years old) and also 50 year-old lindens *T. cordata* in the collection part (Figure 1).

The investigation was carried out in September and October 2020. The occurrence of epiphyllous bryophytes was surveyed on all leaves of woody undergrowth plants



**Figure 1** *Quercus robur* (right) and *Tilia cordata* (left) trunks densely covered by mosses with nearby woody species of undergrowth

(0–2.5 m above the ground level) growing on the most shaded plots of the forest and collection parts of the arboretum. The leaves were considered as covered by a bryophyte only if the bryophyte was firmly attached to them. Surface areas ( $S_i$ ) of each mat ( $i$ ) of each bryophyte species were measured. Then the total surface areas of each bryophyte species ( $S$ ) on certain phorophytes species were calculated:

$$S = \sum_{i=1}^n S_i$$

where:

$n$  – the number of mats

It was measured also available for bryophytes the total leaf surface area of certain phorophyte ( $S_a$ ) 1.5 m around the tree trunks where at least one bryophyte mat was found as epiphyllous. Then the percentage of available phorophyte leaf area bearing the epiphylls ( $P$ ) was calculated:

$$P = \frac{S}{S_a} \times 100\%$$

(Pundiak & Michalko, 2020)

The author names for identified bryophytes are provided according to Boiko (2008), while for woody phorophytes according to Tasjenkevič (1998).

### 3 Results and discussion

In the forest and collection parts of the arboretum there were found only mosses *Brachythecium salebrosum* and *Hypnum cupressiforme* growing on leaves (Figure 3) of the woody understory. Analogically as in Slovakia (Mišíková et al., 2020), both taxa are considered as common species of bryoflora of Ukraine (Boiko, 2008) and they were also the most abundant epiphylls in the arboretum Mlyňany (Pundiak & Michalko, 2020). *H. cupressiforme* and *B. salebrosum* are considered as generalists in Ukraine, Poland, Great Britain and Ireland (Danylkiv et al., 2002; Hill et al., 2007; Nowińska et al., 2009; Wierzgoń & Fojcik, 2014). In the arboretum Stradch they abundantly grew on the ground, on rotting logs, on tree bark. *B. salebrosum* grew in Stradch also on understory stems (Pundiak, 2019). As in the arboretum Mlyňany no epiphyllous liverworts were found in Stradch.

In the forest part both epiphylls occurred only on leaves of *Ulmus glabra* (Figs 3, 4), while on leaves of *Corylus avellana* occurred *H. cupressiforme* (Figure 3). Leaves with



**Figure 2** Mosses *Hypnum cupressiforme* (right) and *Brachythecium salebrosum* (left) on needles of *Abies alba*

bryophyte mats grew exclusively on twigs near several oak trunks covered by the same moss species (Figure 1, right photo).

In the linden collection plot there occurred both epiphyllous moss taxa on spindles of young individuals of *Abies alba* (Fig 1, 2). *B. salebrosum* grew there also on leaves of *Rubus caesius* adjacent to trunks of *Tilia cordata* covered by the same moss species (Figs 4). On leaves far from the oak or linden trunks (as in the arboretum Mlyňany at the distance longer than 1.5 m) there were no epiphyllous bryophytes observed.

According to Table 1 as in Mlyňany the most abundant epiphyll in the arboretum Stradch was *H. cupressiforme*. In the collection part the total surface area of its mats (*S*) was  $212.7 \pm 5.1 \text{ cm}^2$  (it was almost in 35 times higher than the surface area of *B. salebrosum* in the same plot), while in the forest part the surface area of *H. cupressiforme* mats was  $5.2 \pm 0.5 \text{ cm}^2$  (it was close with the surface area of *B. salebrosum* in the same plot). In the collection part the percentage of available phorophyte leaf area bearing *H. cupressiforme* was  $5.3 \pm 0.4\%$  (that was in 88 times bigger than for *B. salebrosum* in the same plot), while in the forest part *P* for *H. cupressiforme* was  $0.020 \pm 0.007\%$  (it was close to the percentage of available phorophyte leaf area bearing *B. salebrosum* in the same plot). In the collection part the maximal surface area of *H. cupressiforme* per an epiphyllous mat was  $12.8 \pm 1.1 \text{ cm}^2$  (it was almost in 6 times higher than for *B. salebrosum* in the same plot), while in the forest part  $S_{\text{max}}$  for *H. cupressiforme* was  $1.1 \pm 0.2 \text{ cm}^2$  (it was slightly less than  $S_{\text{max}}$  for *B. salebrosum* in the same plot).

In the collection part the total surface area covered by *B. salebrosum* was  $6.3 \pm 0.8 \text{ cm}^2$ . It was slightly higher than analogical value for the same moss species in the forest plot. In the collection part the percentage of available phorophyte leaf area bearing *B. salebrosum* was  $0.06 \pm 0.03\%$ . It was in 6 times bigger than for the same moss

taxon in the forest plot. The value of  $S_{\text{max}}$  for *B. salebrosum* in the collection part was  $2.3 \pm 0.3 \text{ cm}^2$ . It was close to analogical value for the same moss species in the forest plot.

Summarizing all the above mentioned, one can say that in the forest part there was no considerable differences between coverage characteristics of the epiphylls, while in the collection part the differences were drastic. The relations of the epiphylls coverage characteristics in the forest and collection parts for *H. cupressiforme* were considerably bigger than these for *B. salebrosum*. As mentioned previously, in the forest part there grew only deciduous phorophytes, which are able to bear the epiphylls only during one vegetative season, while in the collection part – only evergreen phorophytes allowing the epiphylls to grow during several years. Primary investigators of foliicolous bryophytes considered these plants as common features of aging leaves (Vitt et al., 1973). Risk et al. (2011) had shown, that the ability of *Rhododendron maximum* to bear some epiphyllous species (including moss *Platygyrium repens*) increases with the age of a leaf. Seemingly in our case it is valid for *H. cupressiforme*, but not for *B. salebrosum*, which possibly prefers young leaves.

According to Table 2 all phorophytes bearing the epiphylls in the arboretum Stradch can be divided onto three groups: coniferous, deciduous and leafy evergreens.

To the first group belongs exclusively *A. alba*. The total surface area of the mosses growing on its spindles was  $217.3 \pm 5.2 \text{ cm}^2$  (among them  $212.7 \pm 5.1 \text{ cm}^2$  belongs to *H. cupressiforme*). It was more than in 5 times higher than for the most abundant phorophyte *Prunus laurocerasus* growing in the arboretum Mlyňany and more than in 10 times higher than the sum of the total surface areas of epiphyllous mosses growing on leaves of the other phorophytes in Stradch. The percentage of available spindle area of *A. alba* (*P*) bearing the epiphylls

**Table 1** The list of found in Arboretum Stradch epiphyllous and phorophyte species, followed by the values of *S*, *P*, *n* and  $S_{\text{max}}$

Recorded epiphyllous taxa	Recorded phorophyte taxa	Bryophyte mats			Phorophyte leaves	
		the total surface area of epiphyll mats ( <i>S</i> ±SE) (cm <sup>2</sup> )	number of mats, <i>n</i>	maximal surface area per an epiphyll mat ( $S_{\text{max}}$ ±SD) (cm <sup>2</sup> )	the percentage of available phorophyte leaf area bearing the epiphylls ( <i>P</i> ±SE) (%)	Number of investigated leaves, <i>n</i>
<i>Hypnum cupressiforme</i>	<i>Corylus avellana</i> <i>Ulmus glabra</i>	$5.2 \pm 0.5$	5	$1.1 \pm 0.2$	$0.020 \pm 0.007$	133
	<i>Abies alba</i>	$212.7 \pm 5.1$	42	$12.8 \pm 1.1$	$5.3 \pm 0.4$	527
<i>Brachythecium salebrosum</i>	<i>Ulmus glabra</i>	$4.1 \pm 0.4$	3	$1.7 \pm 0.3$	$0.010 \pm 0.005$	68
	<i>Abies alba</i> <i>Rubus caesius</i>	$6.3 \pm 0.8$	7	$2.3 \pm 0.3$	$0.06 \pm 0.03$	538



**Figure 3** *Hypnum cupressiforme* on leaves of *Ulmus glabra* (right) and *Corylus avellana* (left)

was  $6.1 \pm 1.1\%$  (among them  $5.3 \pm 0.4\%$  belongs to *H. cupressiforme*). It was close to the analogical value for *P. laurocerasus* in the arboretum Mlyňany and about 2 times lesser than for *Rhododendron maximum* in temperate eastern North America (Risk et al., 2011). Thus the leafy area shading by *H. cupressiforme* is bigger than 3% of the whole leafy area per an individual of *A. alba* adjacent to the moss source. It allows us to say that for such fir individuals *H. cupressiforme* is semi-parasite because it considerably shaded host leaves and as some liverworts studied by Berrie & Eze (1975) may reduce phosphorous content and hydration of host leaves. But epiphyllous *H. cupressiforme* may also be

beneficial for the firs: it may deter herbivores, provide suitable micro-habitat for N-fixing cyanobacteria, provide some nutrients, and slightly increase effectivity of host photosynthesis compensating the shading (Lepp, 2012; Zhou et al., 2014). The maximal surface area per an epiphyllous mat growing on *A. alba* ( $S_{max}$ ) was  $12.8 \pm 1.1 \text{ cm}^2$ . It was more than 4 times higher than for *P. laurocerasus* in the arboretum Mlyňany and about 3 times bigger than for *Rhododendron maximum* in temperate eastern North America (Risk et al., 2011). Thus mosses (especially *H. cupressiforme*) comparably grow well on *A. alba* spindles in the arboretum Stradch. We can assume that comb-like structure of *A. alba* spindles,

**Table 2** The list of surveyed phorophytes, followed by the values of  $S$ ,  $P$ ,  $n$  and  $S_{max}$

Phorophyte name	Number of the epiphylls taxa	Bryophyte mats			Phorophyte leaves	
		the total surface area of epiphylls mats ( $S \pm SE$ ), $\text{cm}^2$	number of mats, $n$	maximal surface area per an epiphyll mat ( $S_{max} \pm SD$ ) ( $\text{cm}^2$ )	the percentage of available phorophyte leaf area bearing the epiphylls ( $P \pm SE$ ) (%)	number of investigated leaves, $n$
<i>Abies alba</i>	2	$217.3 \pm 5.1$	44	$12.8 \pm 1.1$	$6.1 \pm 1.1$	527
<i>Corylus avellana</i>	1	$5.2 \pm 0.5$	3	$1.1 \pm 0.2$	$0.020 \pm 0.007$	65
<i>Ulmus glabra</i>	2	$9.1 \pm 0.8$	5	$1.7 \pm 0.3$	$0.04 \pm 0.01$	68
<i>Rubus caesius</i>	1	$1.7 \pm 0.2$	2	$0.7 \pm 0.2$	$0.03 \pm 0.01$	11



**Figure 4** *Brachythecium salebrosum* on leaves of *Rubus caesius* – up and *Ulmus glabra* down

which are not shed every year like deciduous broad-leaved angiosperms promotes long lasting fixation of moss branchlets.

*Corylus avellana* and *Ulmus glabra* can be corresponded to the second group of deciduous phorophytes. The order of the value  $S$  for them was 1–10 cm<sup>2</sup>,  $P \sim 0.01$ –0.1%,  $S_{\max} \sim 1$  cm<sup>2</sup>. Thus both taxa have some ability to bear mosses and allow them to grow but, as they are deciduous, for a short time (only one vegetative season – about half a year).

Further taxon *R. caesius* belong to the third group of leafy evergreen plants. The values of its  $P$  and  $S_{\max}$  were close

to the analogical values for the taxa of the second group, while the value of  $S$  was considerably lesser. All measured data for *R. caesius* were close to these for the arboretum Mlyňany. Thus we can think that although *R. caesius* leaves are able to live for several years, its young leaves are more preferable substrate for the epiphylls, then old ones.

As in the arboretum Mlyňany, in the arboretum Stradch it was found epiphyllous mosses growing exclusively near the trunks densely covered by the same species. Thus our results affirm that *B. salebrosum* and *H. cupressiforme* are able to grow on leaves of natural woody understory in temperate Central Europe, though the leaves of such phorophytes are only additional substrate for these mosses. It contributes to the knowledge on ecology of both mosses and may stimulate further research in this field.

#### 4 Conclusions

In the Arboretum Stradch two taxa of epiphyllous bryophytes were found. Both were generalists and common species of Ukraine bryoflora: *Brachythecium salebrosum* and *Hypnum cupressiforme*. The most abundant was *H. cupressiforme*. Both identified epiphylls occurred on one gymnosperm phorophyte *Abies alba*, two deciduous angiosperm phorophytes *Corylus avellana*, *Ulmus glabra* and one evergreen angiosperm phorophyte *Rubus caesius*. The most often species of phorophyte for epiphyllous bryophytes was *Abies alba*. These results contribute to the knowledge on ecology of the mosses *B. salebrosum* and *H. cupressiforme*: they are able to grow on leaves of natural woody understory in temperate Central Europe.

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