

## Epiphyllous bryophytes in Arboretum Mlyňany (Slovakia)

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Article Details: Received: 2019-10-28 | Accepted: 2020-04-01 | Available online: 2020-06-30

<https://doi.org/10.15414/afz.2020.23.02.51-57>



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In this work we screened for the diversity of epiphyllous bryophytes covering leaves of evergreen plants growing in temperate region of Arboretum Mlyňany (Slovakia). We identified five taxa of not typically epiphyllous bryophytes, all belonging to mosses: *Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp, *Hypnum cupressiforme* Hedw., *Hypnum cupressiforme* var. *filiforme* Brid., *Platygyrium repens* (Brid.) Schimp., *Pylaisia polyantha* (Hedw.) Schimp. All these taxa are considered as obligate members of bryoflora of Slovakia at low risk of extinction. The most abundant was the generalist *H. cupressiforme*, while the rarest was the typical epiphyte *P. polyantha*. All identified epiphylls occurred on nine species of evergreen angiosperm phorophytes: *Prunus laurocerasus* L., *Hedera helix* L., *Mahonia aquifolium* (Pursh) Nutt., *Ilex aquifolium* L., *Rubus caesius* L., *Viburnum × burkwoodii* auct., *Rhododendron catawbiense* Michx., *Viburnum rhytidophyllum* Hemsl., *Aucuba japonica* Thunb.; on one gymnosperm phorophyte *Cephalotaxus harringtonii* var. *drupacea* (Siebold. & Zucc.) Koidz; and on one fern *Asplenium scolopendrium* L. The most often species of phorophyte for epiphyllous bryophytes was *P. laurocerasus*, while the rarest taxa were *R. caesius*, *V. rhytidophyllum*, *R. catawbiense*, *A. japonica*, *V. × burkwoodii*.

**Keywords:** epiphyllous bryophytes, epiphylls, epiphytes, phorophytes

### 1 Introduction

Bryophytes are simple and small land plants. They have numerous important adaptations, including the alternation of gametophytic and sporophytic generations, specialization of gametangia, and the adaptation to desiccation. The bryophytes are considered to be the closest extant relatives of the plants that first colonized land. Due to their phylogenetic position, they are crucial for understanding the evolutionary transition from freshwater algae to land plants and from structurally relatively simple early land plants to more complex forms (Bennici, 2008; Ligrone et al., 2012; Bowman et al., 2017). Thus, they adapt to various environments ranging from harsh Antarctic conditions to extremely drought niches (Glime, 1982). Bryophytes play important roles in nutrient cycling and can act as bio-indicators of air and water pollution especially by heavy metals (Blagnyté and Paliulis, 2010).

Phyllosphere of vascular plants represents a complex micro-habitat inhabited by a diverse spectrum of epiphyllous organisms such as bacteria, fungi, algae, cyanobacteria, lichens and bryophytes (Pócs, 1996). Epiphyllous bryophytes are considered as plant semi-parasites because they lightly (in comparison with lichens) reduce photosynthesis, phosphorous content and hydration of host leaves (phorophytes), but can also be beneficial: deter herbivores, provide suitable micro-habitat for N-fixing cyanobacteria, provide some nutrients to plant, for example carbon (Berrie and Eze, 1975; Lepp, 2012; Zhou et al., 2014).

Many epiphyllous species are typically epiphylls, but some may also often be found on other plant parts (twigs, branches, trunks) or even on non-plant substrates such as soil or rocks. The typically epiphyllous species are only confined to the tropics. Majority of them are liverworts. But not typically epiphyllous species have been found also in sub-tropical to temperate regions in various

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parts of the world (Gradstein, 1997) however, their distribution and community structure remains largely unexplored. Epiphyllous bryophytes are widespread and often quite common in the tropical areas, but they occur in extratropical regions only amongst the most oceanic humid climatic conditions – e.g. Japan, China, Southern Appalachians (USA), Macaronesian Islands, Caucasus Mountains (Russia), British Columbia (Canada), Blue Mountains (Australia) and even Great Britain (Vitt et al., 1973; Smith, 1982; Pócs, 1989; Porley, 1996; Risk et al., 2011; Malombe et al., 2016). Leaf wetness having a large influence on phyllospheric organisms usually depends more on atmospheric than on soil humidity (Burkhardt and Hunsche, 2013). Thus foliicolous bryophytes need more humid microclimatic conditions than epigeic, epilithic or epiphytic ones. Therefore epiphylls are more vulnerable than other bryophytes. So, in the tropics with high humidity, but also high solar radiation, the invasion of exotics or the replacement of the original canopy by plantation trees usually means the total loss of the epiphyllous flora (Pócs, 1996). In temperate zones the diversity, roles and interactions of epiphyllous bryophytes are largely unknown. Thus, a question can be raised: does the partial replacement of the original canopy by more dense exotic trees and shrubs in temperate regions cause appearance de novo of epiphyllous bryophlora? For the answer on this question we have chosen Arboretum Mlyňany (Slovakia). So our goal was to estimate the diversity of bryoepiphylls on leaves of evergreen plants in the Arboretum, where is one of the largest collection of leafy evergreens in Eastern Europe (Hořka and Barta, 2012).

## 2 Material and methods

The study site, Arboretum Mlyňany, Detached Branch of the Institute of Forest Ecology, Slovak Academy of Sciences, is located in Vieska nad Žitavou near the town Nitra (Podunajská pahorkatina upland, foot of the Western Carpathians – Tribeč Mts. and Pohronský Inovec Mts., lat: 48.319656, long: 18.368701). It is situated in one of the warmest and driest areas of Slovakia with an average annual temperature of 9.8 °C and an average annual rainfall of 577.1 mm. The area is characterized by a prolonged dry periods during the height of summer with, sometimes, almost no rain at all (Hořka and Barta, 2012).

Arboretum Mlyňany is considered to be the first evergreen park in Central Europe established in 1892 (Hořka and Barta, 2012). Old Semper Vireo Park of 40 hectares as the main part of Arboretum Mlyňany was founded 127–105 years ago near to the native oak-hornbeam forest. The neighboring plot of Eastern Asian dendroflora of 14 hectares was established in 1965. The age of the

majority of adult trees growing there is determined by the time of the plots foundation.

The undergrowth in these areas consisted mainly of native species *Hedera helix* L., *Rubus caesius* L. and artificially planted *Prunus laurocerasus* L., *Mahonia aquifolium* (Pursh) Nutt., *Ilex aquifolium* L. (Hořka and Barta, 2012). Less frequently occurs *Viburnum × burkwoodii* auct., *Rhododendron catawbiense* Michx., *Viburnum rhytidophyllum* Hemsl., *Aucuba japonica* 'longifolia' Thunb., a conifer *Cephalotaxus harringtonia drupacea* (Siebold. & Zucc.) Koidz. and a fern *Asplenium scolopendrium* L. The undergrowth densely covered the ground (about 1 individual per a m<sup>2</sup>) around the trunks of mature trees.

In the territory of Arboretum Mlyňany bryophytes grew abundantly on rocks of several alpine gardens and trunks of old trees, especially on the oaks *Q. cerris* and *Q. robur* (Figure 1), but also on *Acer campestre* L., *Quercus × turneri* 'Pseudoturneri', *Ilex aquifolium* L., *Rhododendron catawbiense* Michx., *Malus* sp., *Taxodium distichum* (L.) Rich., *Carpinus betulus* L., *Cercidiphyllum japonicum* Siebold & Zucc., *Lonicera maackii* (Rupr.) Maxim., *Prunus serrulata* 'Amanogawa'.

The investigation was carried out in July 2019. The occurrence of epiphyllous bryophytes was surveyed on all leaves of undergrowth plants (0–2.5 m above the ground level) growing along all paths of old Semper Vireo Park and on the plot of Eastern Asian dendroflora. The leaves were considered as covered by a bryophyte only if the bryophyte was firmly attached to the leaf. All collected specimens were identified (Atherton et al., 2010; Danyluk et al., 2002; Frahm, 2009) after their macroscopic (under 5×, 10×, 16× magnification) and microscopic evaluation (under 200× magnification). Surface area (*S*) of bryophyte mats was measured.

## 3 Results and discussion

There occurred only mosses on leaves growing on understory twigs approximated or touching rocks or trunks densely covered by mosses (Figure 1). Far from such rocks or tree trunks (more than 1.5 m) no epiphyllous bryophytes were found. All observed moss species were not typically epiphylls. No epiphyllous liverworts were found in the investigated area.

In Arboretum Mlyňany we determined *Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp., *Hypnum cupressiforme* Hedw., *Hypnum cupressiforme* var. *filiforme* Brid., *Platygyrium repens* (Brid.) Schimp., *Pylaisia polyantha* (Hedw.) Schimp. growing on leaves (Figure 2). The same moss taxa were found on the adjacent rocks or trunks of the trees. All these taxa are considered as



**Figure 1** The occurrence of moss carpets on neighboring rocks (left) and *Quercus cerris* trunk (right) with bushes of *Prunus laurocerasus* (both photos) and an individual of the fern *Asplenium scolopendrium* (left photo)

obligate members of bryoflora of Slovakia at low risk of extinction (Mišíková et al., 2020).

The values of the surface area ( $S$ ) of bryophyte mats, the percentage of available for moss branchlets (1.5 m around the rocks or tree trunks covered by the mosses) phorophyte leaf area bearing the epiphylls ( $P$ ) and the maximal surface area per a leaf ( $S_{\max}$ ) for are presented in Table 1 and 2.

According to Table 1 the most abundant epiphyllous moss in Arboretum Mlyňany was *H. cupressiforme*. The leafy surface area covered by its mats ( $S$ ) was  $51.8 \pm 2.5 \text{ cm}^2$  (it was in 5 times higher than the sum of the surface areas of the other epiphylls). The percentage of available phorophyte leaf area bearing *H. cupressiforme* ( $P$ ) was  $4.7 \pm 0.5\%$  (it was in 6 times higher than the sum of the quantities  $P$  for the other epiphylls) and the maximal surface area per a leaf ( $S_{\max}$ ) was  $3.0 \pm 0.4 \text{ cm}^2$  (it was almost equal with the sum of  $S_{\max}$  for the other epiphylls). *H. cupressiforme* is considered as generalist (Nowińska et al., 2009; Mišíková et al., 2015; Wierzgoń and Fojcik, 2014) and occurred in Arboretum Mlyňany on the bark of different tree species (for example *A. campestre*, *C. betulus*, *I. aquifolium*, *L. maackii*, *P. serrulata* 'Amanogawa', *Q. cerris*, *Q. robur*, *R. catawbiense*), on the ground, on stones

and also on the leaves of seven phorophyte species: *A. scolopendrium*, *H. helix*, *I. aquifolium*, *M. aquifolium*, *P. laurocerasus*, *R. catawbiense*, *R. caesius*.

The second place for the surface area was possessed by *B. salebrosum*. The value of  $S_{\max}$  for this species was of the same order with that for *H. cupressiforme*, while the orders of the quantities  $S$  and  $P$  for *B. salebrosum* were lesser than these for *H. cupressiforme*. Thus we can assume that *B. salebrosum* has not so good ability to bind with a leaf surface as *H. cupressiforme*, but like the latter taxon can grow there. Mišíková et al. (2015) reported this species as epigeic for several Slovakian villages, while in Poland and in Ukraine *B. salebrosum* is considered as generalist (Danylkiv et al., 2002; Wierzgoń and Fojcik, 2014). In Arboretum Mlyňany *B. salebrosum* abundantly grew not only on ground, but also on stones, on the *C. japonicum* and *L. maackii* trunks, on adjacent *C. harringtonii* var. *drupacea* needles and on *I. aquifolium* leaves correspondently.

The third place for the moss mats surface area belongs to *H. cupressiforme* var. *filiforme*. The quantities  $S$  and  $P$  for this species were of the same order with these for *B. salebrosum*, while the order of the value of  $S_{\max}$  for *H. cupressiforme* var. *filiforme* was lesser than that for



**Figure 2** Occurrence of non-specialized epiphyllic moss *Hypnum cupressiforme* (A–C) firmly attached to the leaves of (A) *Prunus laurocerasus*, (B) the fern *Asplenium scolopendrium*; (C) *Mahonia aquifolium*; (D) the moss *Brachythecium salebrosum* on needles of *Cephalotaxus harringtonii* var. *drupacea*

*B. salebrosum*. It allows us to assume that *H. cupressiforme* var. *filiforme* can poorly grow on the leaf surface, but like *B. salebrosum* it can easily bind to such a surface. Wierzgoń and Fojcik (2014) considered this species as epiphyte, which can grow also on logs of fallen trees, while Frahm (2009) stated that *H. cupressiforme* var. *filiforme* can grow also on rocks. In Arboretum Mlyňany *H. cupressiforme* var. *filiforme* grew on the trunks of *Q. cerris*, *Q. × turneri* 'Pseudoturneri', *T. distichum*, and also on adjacent leaves of 3 phorophyte species: *H. helix*, *P. laurocerasus*, *A. japonica* correspondently.

The next species in the list of recorded epiphyllous taxa was *P. repens*. The quantities  $S$  and  $S_{max}$  for this species were of the same order with these for *H. cupressiforme* var. *filiforme*, while the order of the quantity  $P$  for *P. repens* was lesser than that for *H. cupressiforme* var. *filiforme*. So we can think that the abilities of *P. repens* to bind with the leaf surface and grow there are considerably limited. For several villages in Slovakia *P. repens* reported as epiphyte (Mišíková et al., 2015), while this species commonly is

considered as facultative epiphyte (Király and Ódor, 2010).

In Arboretum Mlyňany it was found on leaves of 2 phorophyte species: *P. laurocerasus*, *V. rhytidophyllum*, and on the adjacent trunks of *C. betulus* and *A. campestre* correspondently. The quantities  $S$ ,  $P$ ,  $S_{max}$  for *P. polyantha* were the smallest in the list. This species was reported only as epiphyte (Danylkiv et al., 2002; Wierzgoń and Fojcik, 2014; Mišíková et al., 2015). Probably therefore in Arboretum Mlyňany it occurred incidentally on the leaves of two phorophyte species: *I. aquifolium*, *V. × burkwoodii*, adjacent to trunks of *I. aquifolium* and *Malus* sp., which abundantly covered by this moss.

According to Table 2 all phorophyte species for epiphyllous bryophytes in Arboretum Mlyňany can be divided into three groups.

To the first group belongs only the most abundant *P. laurocerasus*. Its leaf surface area covered by mosses ( $S$ ) was  $40.0 \pm 1.8 \text{ cm}^2$  (it was almost 2 times higher than the

**Table 1** The list of recorded epiphyllous and phorophyte taxa, followed by the values of the surface area ( $S$ ) of bryophyte mats, the percentage of available phorophyte leaf area bearing the epiphylls ( $P$ ) and the maximal surface area per a leaf ( $S_{max}$ )

Recorded epiphyllous taxa	Recorded phorophyte taxa	Surface area of bryophyte mats ( $S$ ) (cm <sup>2</sup> )	The percentage of available phorophyte leaf area bearing the epiphylls ( $P$ ) (%)	Maximal surface area per a leaf ( $S_{max}$ ) (cm <sup>2</sup> )
<i>Brachythecium salebrosum</i> (Hoffm. ex F. Weber & D. Mohr) Schimp.	<i>Ilex aquifolium</i> L. 2. <i>Cephalotaxus harringtonii</i> var. <i>drupacea</i> (Siebold. & Zucc.) Koidz.	6.8 ±0.7	0.60 ±0.15	1.5 ±0.3
<i>Hypnum cupressiforme</i> Hedw.	1. <i>Asplenium scolopendrium</i> L. 2. <i>Hedera helix</i> L. 3. <i>Ilex aquifolium</i> L. 4. <i>Mahonia aquifolium</i> (Pursh) Nutt. 5. <i>Prunus laurocerasus</i> L. 6. <i>Rhododendron catawbiense</i> Michx. 7. <i>Rubus caesius</i> L.	51.8 ±2.5	4.7 ±0.5	3.0 ±0.4
<i>Hypnum cupressiforme</i> var. <i>filiforme</i> Brid.	1. <i>Aucuba japonica</i> Thunb. 2. <i>Hedera helix</i> L. 3. <i>Prunus laurocerasus</i> L.	1.7 ±0.4	0.10 ±0.05	0.7 ±0.2
<i>Platygyrium repens</i> (Brid.) Schimp.	1. <i>Prunus laurocerasus</i> L. 2. <i>Viburnum rhytidophyllum</i> Hemsl.	1.3 ±0.3	0.020 ±0.007	0.4 ±0.2
<i>Pylaisia polyantha</i> (Hedw.) Schimp.	1. <i>Ilex aquifolium</i> L. 2. <i>Viburnum</i> × <i>burkwoodii</i> auct.	0.5 ±0.1	0.020 ±0.008	0.20 ±0.08

**Table 2** The list of examined phorophytes, followed by the values of the surface area ( $S$ ) of epiphyllous bryophyte mats, the percentage of available phorophyte leaf area bearing the epiphylls ( $P$ ), and the maximal surface area per a leaf ( $S_{max}$ )

Leafy phorophyte name	Number of moss species	Surface area of epiphyllous bryophyte mats ( $S$ ) (cm <sup>2</sup> )	The percentage of available phorophyte leaf area bearing the epiphylls ( $P$ ) (%)	Maximal surface area per a leaf ( $S_{max}$ ) (cm <sup>2</sup> )
<i>Prunus laurocerasus</i> L.	3	40.0 ±1.8	5.9 ±0.78	3.0 ±0.4
<i>Cephalotaxus harringtonii</i> var. <i>drupacea</i> (Siebold. & Zucc.) Koidz	1	6.0 ±0.6	0.6±0.15	1.5 ±0.3
<i>Mahonia aquifolium</i> (Pursh) Nutt.	1	5.7 ±0.5	0.6 ±0.31	2.0 ±0.3
<i>Hedera helix</i> L.	2	3.6 ±0.7	0.27 ±0.15	0.6 ±0.2
<i>Asplenium scolopendrium</i> L.	1	3.0 ±0.4	0.8 ±0.32	1.4 ±0.3
<i>Ilex aquifolium</i> L.	3	1.1 ±0.4	0.3 ±0.2	0.5 ±0.2
<i>Rubus caesius</i> L.	1	0.8 ±0.3	0.04 ±0.02	0.5 ±0.2
<i>Viburnum rhytidophyllum</i> Hemsl.	1	0.8 ±0.2	0.010 ±0.005	0.4 ±0.1
<i>Rhododendron catawbiense</i> Michx.	1	0.4 ±0.1	0.05 ±0.05	0.4 ±0.1
<i>Aucuba japonica</i> Thunb.	1	0.4 ±0.1	0.010 ±0.005	0.4 ±0.1
<i>Viburnum</i> × <i>burkwoodii</i> auct.	1	0.3 ±0.1	0.03 ±0.02	0.2 ±0.08

sum of the surface areas of the other phorophytes). The percentage of available *P. laurocerasus* leaf area bearing the epiphylls (*P*) was  $5.9 \pm 0.78\%$  and the maximal surface area per a *P. laurocerasus* leaf ( $S_{\max}$ ) was  $3.0 \pm 0.4 \text{ cm}^2$ . Thus we can assume, that *P. laurocerasus* leaves have the ability to bear mosses (especially *H. cupressiforme*, for which  $S = 38.8 \pm 2.1 \text{ cm}^2$ ,  $P = 6.1 \pm 0.81\%$ ,  $S_{\max} = 3.0 \pm 0.4 \text{ cm}^2$ ) and may allow them to grow there.

The next five taxa can be corresponded to the second phorophytes group: *C. harringtonii* var. *drupacea*, *M. aquifolium*, *H. helix*, *A. scolopendrium*, *I. aquifolium*. The order of quantity *S* for them was  $1 \text{ cm}^2$ ,  $P \sim 0.1\%$ ,  $S_{\max} \sim 1 \text{ cm}^2$  (excepting *H. helix* and *I. aquifolium*, for which  $S_{\max} \sim 0.1 \text{ cm}^2$ ). All these taxa had smaller, but not incidental ability to bear mosses and (excepting *H. helix* and *I. aquifolium*) may allow them to grow there. Further five taxa belong to the third group: *R. caesius*, *V. rhytidophyllum*, *R. catawbiense*, *A. japonica*, *V. × burkwoodii*. The quantities  $S_{\max}$  for the species of this group were of the same order with these for the taxa of the second group, while the orders of the quantities *S* and *P* for the members of the third group were lesser than these for the members of the second. Thus we can think that their leaves have only incidental ability to bear mosses and don't allow them to grow there.

We found no epiphyllous species growing far from the sites abundantly covered by mosses which indicate that in Arboretum Mlyňany epiphyllous mosses probably do not develop from the spores, they reproduce vegetatively. All found moss species are not parasites in their common status (Wierzgoń and Fojcik, 2014), the leafy area shading by them is not bigger than 3% of the whole leafy area per an individual (Table 1, 2). We can assume that in the Arboretum Mlyňany there are suitable microclimatic conditions for the growth of epiphyllous mosses:

1. subtropical evergreen understory plants densely planted near old trees;
2. high density of old trees and understory shrubs providing the damping of wind and the high humidity level near the ground in relatively arid region of Slovakia.

Usually liverworts prevail as epiphyllous bryophytes in tropical rain forests (Gradstein, 1997; Pócs, 1989; Pócs, 1996). But in temperate regions it is not always so. Thus in Canada Vitt et al. (1973) reported four species of mosses, all in the genus *Orthotrichum* growing on *Thuja plicata* L. leaves. In Arboretum Mlyňany it was find similar situation: all epiphyllous taxa belonged to mosses and among phorophytes there was one conifer species.

## 4 Conclusions

1. The partial replacement of the original canopy by more dense exotic trees and shrubs in Arboretum Mlyňany (Slovakia) probably created microclimatic conditions for the appearance of epiphyllous bryophlora.
2. In the Arboretum Mlyňany (Slovakia) five taxa of epiphyllous bryophytes were found. All of them were facultative epiphyllous mosses: *Brachythecium salebrosum* (Hoffm. ex F. Weber & D. Mohr) Schimp., *Hypnum cupressiforme* Hedw., *Hypnum cupressiforme* var. *filiforme* Brid., *Platygyrium repens* (Brid.) Schimp., *Pylaisia polyantha* (Hedw.) Schimp.
3. All these taxa are considered as obligate members of bryoflora of Slovakia at low risk of extinction.
4. The most abundant epiphyllous moss was the generalist *H. cupressiforme*.
5. The rarest epiphyllous moss was the typical epiphyte *P. polyantha*.
6. The most often species of phorophyte for epiphyllous bryophytes was *P. laurocerasus*.
7. The rarest taxa of phorophytes for epiphyllous bryophytes were *R. caesius*, *V. rhytidophyllum*, *R. catawbiense*, *A. japonica*, *V. × burkwoodii*.

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