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Powdery Mildews on Trees and Shrubs in Botanical Gardens, Parks and Urban Green Areas in the Czech Republic

Barbora Mieslerová [1], Michaela Sedlářová [1], Markéta Michutová [1], Veronika Petřeková [1], Roger Cook [2] and Aleš Lebeda [1,*]

[1] Department of Botany, Faculty of Science, Palacký University in Olomouc, Šlechtitelů, 2778371 Olomouc-Holice, Czech Republic; barbora.mieslerova@upol.cz (B.M.); michaela.sedlarova@upol.cz (M.S.); marketa.michutova@upol.cz (M.M.); veronika.petrekova@upol.cz (V.P.)

[2] 30 Galtres Avenue, York YO311JT, UK; rtacook@hotmail.com

* Correspondence: ales.lebeda@upol.cz

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Abstract: A total of 103 tree and shrub samples infected with powdery mildew were collected during 2002–2019 from locations within parks, botanical gardens and urban green areas within the Czech Republic and the powdery mildews were morphologically analyzed and identified. The most frequently represented genera were: *Erysiphe* (27, including former genera *Microsphaera* and *Uncinula*), *Podosphaera* (11, including former genus *Sphaerotheca*), *Phyllactinia* (3), *Sawadaea* (2) and *Arthrocladiella* (1). New records for the Czech Republic were: *E. (U.) arcuata*, *E. (M.) deutziae*, *E. (M.) euonymicola*, *E. (U.) flexuosa*, *E. (M.) platani*, *E. (M.) symphoricarpi*, *E. (M.) vanbruntiana* var. *sambuci-racemosae*, *E. (U.) ulmi*, *Po. amelanchieris*, *Po.* (*Sph.*) *pruinosa* and *Po.* (*Sph.*) *spiraeae*. The results were compared with the spectrum of powdery mildew species in the surrounding countries (Slovakia; Hungary; Poland and Germany (Bavaria)).

Keywords: Erysiphales; anamorph and teleomorph state; morphological characteristics; host specificity; geographic distribution; survey

1. Introduction

Recently, the recognition of the importance of trees and shrubs in parks and urban green areas within cities has been growing. Urban green areas play a crucial role in helping to keep the air clean and improving community well-being. Shrubs and trees are able to remove both harmful gases and particles from the air, whilst promoting a better quality of health and well-being [1]. Diseases on these trees and shrubs can reduce their durability, and in the most extreme cases totally destroy them (e.g., *Pseudomonas syringae* pv. *aesculi* on horse chestnut).

Powdery mildews are biotrophic, highly specialized pathogens, attacking nearly 10,000 species of vascular plants [2]. Somewhat confounding is the fact that more than one powdery mildew species can parasitize a single host plant. A deeper understanding of the taxonomy of this group has brought about an ever increasing number of powdery mildew species described, which in 2012 stood at 873, including 794 holomorphs; i.e., those with described asexual and sexual morphs [2]. The taxonomy of this group, after many revisions, is now greatly different, thus complicating some comparisons with historical data. Until the 1990s, the taxonomy and identification of powdery mildew fungi were based primarily on the characteristics of the teleomorph, such as the shape of the appendages on the chasmothecium (cleistothecium), or on the number of asci in the ascocarps [3]. However, studies under the scanning electron microscope showed an increased importance of the anamorphic forms in the

taxonomy of powdery mildews [4]. Then, studies based on the molecular data, e.g., [5–8], confirmed that the shape of the appendages has a secondary importance. The genus *Erysiphe* was found to be polyphyletic, the sections *Erysiphe*, *Galeopsidis* and *Golovinomyces* were elevated to generic rank [9–11], and sect. *Galeopsidis* transferred to a new genus *Neoerysiphe*. On the other hand, *Erysiphe* sect. *Erysiphe*, *Microsphaera* (including *Bulbomicrosphaera* and *Medusosphaera*) and *Uncinula* (including *Bulbouncinula*, *Furcouncinula* and *Uncinuliella*) with pseudoidium anamorphs (hyphal appressoria lobed, conidia formed singly) were united to form *Erysiphe* emend containing three morphological sections based on shape of chasmothecial appendages, i.e., *E*. sects *Erysiphe*, *Microsphaera* and *Uncinula* with respectively mycelioid, dichotomously branched and circicinate appendages [9]. A molecular phylogenetic study of representatives of the genus *Erysiphe* showed these sections to be non-phylogenetic [12]. However, the older names are still useful, since those species with uncinula-type and microsphaera-type appendages mostly parasitize trees or shrubs, and those with myceloid appendages occur mostly on herbaceous plants. This suggests that appendage morphology evolved in close relationship with the host [12]. Indeed, the evolution from ancestral tree-parasites with branched or circinate appendages to those with myceloid appendages seemed to have occurred convergently at multiple times as an adaptation to herb-parasitism [13].

A similar situation exists in the genus *Podosphaera*, when the previous genera, *Sphaerotheca* and *Podosphaera* were only distinguished morphologically by having either simple or branched appendages on their chasmothecia. However, according to molecular analysis, they did not form separate monophyletic clades [10]. Therefore, they were subsumed into a single genus, *Podosphaera*, having the morphological, but non-phylogenetic sections and subsections *Podosphaera* sect. *Podosphaera*, *P.* sect. *Sphaerotheca* and *P*. sect. *Sphaerotheca* subsect. *Magnicellulatae*. The same principle applies here, in that *P*. sect. *Podosphaera* (appendages branched) occurs mostly on trees or shrubs, whereas *P*. sect. *Sphaerotheca* (appendages myceloid) is found mostly on herbaceous plants.

Information about the spectrum of powdery mildew species in the Czech Republic is fragmentary. Klika [14] compiled the first Czech monograph on powdery mildews in 1923. Twenty-five species in seven genera with morphological differences were described. They contained five species of *Erysiphe* (including *Blumeria*, *Golovinomyces* and *Neoerysiphe*); four each of *Microsphaera* (now *E. sect. Microsphaera;* only on tree hosts), *Trichocladia* (now *E. sect. Microsphaera*; two of them on tree hosts), *Uncinula* (now *E. sect. Uncinula;* only on tree hosts), *Sphaerotheca* (now *Podosphaera* sect. *Sphaerotheca*), three of *Podosphaera* sect. *Podosphaera* (only on tree hosts) and one of *Phyllactinia* (only on tree hosts). In addition, Klika [14] cited very sporadic collections of powdery mildews by Opitz, Bubák, Kabát and Petrák in the 19th and early 20th centuries in the area of the Czech Republic. In the last 20 years, some notes on the occurrence of new powdery mildew species on trees and shrubs in the Czech Republic were published, e.g., *Erysiphe azaleae* on *Rhododendron* spp. [15,16], *Erysiphe palczewskii* on *Caragana arborescens* Lam. [17,18], powdery mildew on *Homalocladium platycladum* (F. Muell.) Meisn. [19] and contributions to the knowledge of *Erysiphe* sp. on *Catalpa* Scopoli in Europe [20].

In Slovakia (for a long time part of former Czechoslovakia), Paulech [21] published the Slovak monograph of powdery mildews; later it was primarily Pastirčáková and co-workers who made a greater contribution to the study of powdery mildews, especially on trees, e.g., the first recordings of the occurrence of *Erysiphe platani* on *Platanus* L. [22], of *E. magnifica* on lili magnolia [23], *E. arcuata* on *Carpinus* L. [24], *E. elevata* on *Catalpa* [25] and *E. flexuosa* on *Aesculus* L. [26].

The aims of our work were to provide an up-to-date check-list of powdery mildews on trees and shrubs in the Czech Republic, to compare this with check-lists of neighbouring countries and to point out which new powdery mildew species during the last decades have been spreading on trees and shrubs within and throughout central and eastern Europe.

2. Materials and Methods

2.1. Field Survey

Between 2002 and 2019, samples of leaf materials infected with powdery mildew were collected from trees and shrubs in parks, botanical gardens and urban green areas in the Czech Republic. Figure 1 shows the locations of the collected samples that are analysed microscopically. All the samples are deposited in the collections of Department of Botany, Faculty of Science, Palacký University in Olomouc.

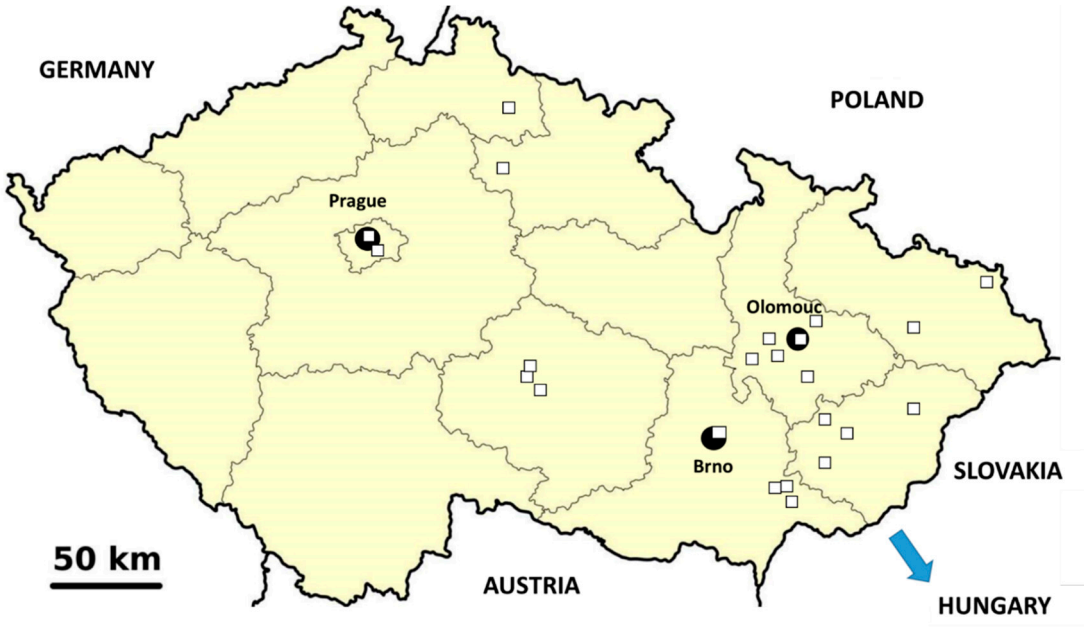

Figure 1. Map of the locations in the Czech Republic where the samples of powdery mildew infection on trees and shrubs are collected, and boundaries of neighbouring countries.

The Czech survey was compared with check-lists from the following three neighbouring countries: Slovakia by Paulech [21], Poland by Dynowska et al. [27], Germany/Bavaria by Bresinsky [28] and one close non-adjoining country, Hungary by Nagy and Kiss [29], as well as some later recordings in these countries.

2.2. Microscopic Analysis of Morphological Characteristics

Pieces (ca. 20 × 20 mm) of severely infected leaves were used for evaluation by light microscopy (Olympus BX60, Japan). The pathogen was not separated from the host tissue, and the microscopy was done on leaf segments fixed in glacial acetic acid (acetic acid 99%; Lach-Ner, Neratovice, Czech Republic) for 48 h, and stored in glycerol (glycerolum 85%; Tamda, Olomouc, Czech Republic). The conidia and conidiophores, mostly on the upper leaf surfaces, were microscopically examined after staining with cotton blue (Methyl Blue, Sigma-Aldrich, Prague, Czech Republic) [30]. The presence of fibrosin bodies in the conidia were assessed by mounting fresh conidia in 3% KOH (diluted from potassium hydroxide 90%, Fichema, Czech Republic) [31]. The sexual morph (chasmothecia) was inspected without any staining. In cases where dried leaf samples were analyzed, a modified method of Shin [32] was used, i.e., the heating of herbariumised tissues in fuchsine (Sigma-Aldrich, Prague, Czech Republic) in lactic acid (80% Lach-Ner, Neratovice, Czech Republic). For statistical analyses (means, standard deviations and range), 30 measurements of each characteristic (where possible) were calculated using MS Excel (2010).

2.3. Taxonomic Determination

The names of the host plants were used according to Kubát et al. [33] and Biolib (www.biolib.cz) and names of the powdery mildews according to the Taxonomic Manual of the Erysiphales [2], Mycobank (www.mycobank.org), and in some cases according to recent taxonomic literature.

3. Results

In total, during 2002–2019, 103 samples of trees and shrubs infected by powdery mildew were collected. A list of the host plants complemented with recently valid names of the powdery mildews according to Braun and Cook [2], along with their basic morphological characteristics are listed in Table 1. From our survey, it was clear that the upper sides of the leaves were most frequently colonised. However, the chasmothecia were frequently found on the lower sides of leaves. Powdery mildew anamorphs occurred most frequently in spring and summer, while teleomorphs were found mostly in autumn. On trees and shrubs in the Czech Republic our survey confirmed: one species of the genus *Arthrocladiella*, 27 species of *Erysiphe*, three species of *Phyllactinia*, 11 species of *Podosphaera* and two species of *Sawadaea* as detailed in Table 2. For simplicity, Table 3 indicates the additional species in each region compared with the Czech Republic. (Thus, species that were recorded in both another country and the Czech Republic do not appear in this Table). Figure 2 shows the leaves of the trees and shrubs with symptoms of powdery mildew, while Figure 3 shows the variability in the shapes of appendages of the chasmothecia of selected powdery mildew species.

Although the older descriptions of powdery mildews were very broadly based and involved wide host ranges, most of the species described in Klika [14] were re-confirmed in our survey as displayed in Table 2. On the other hand, there were several differences as detailed below.

Figure 2. *Cont.*

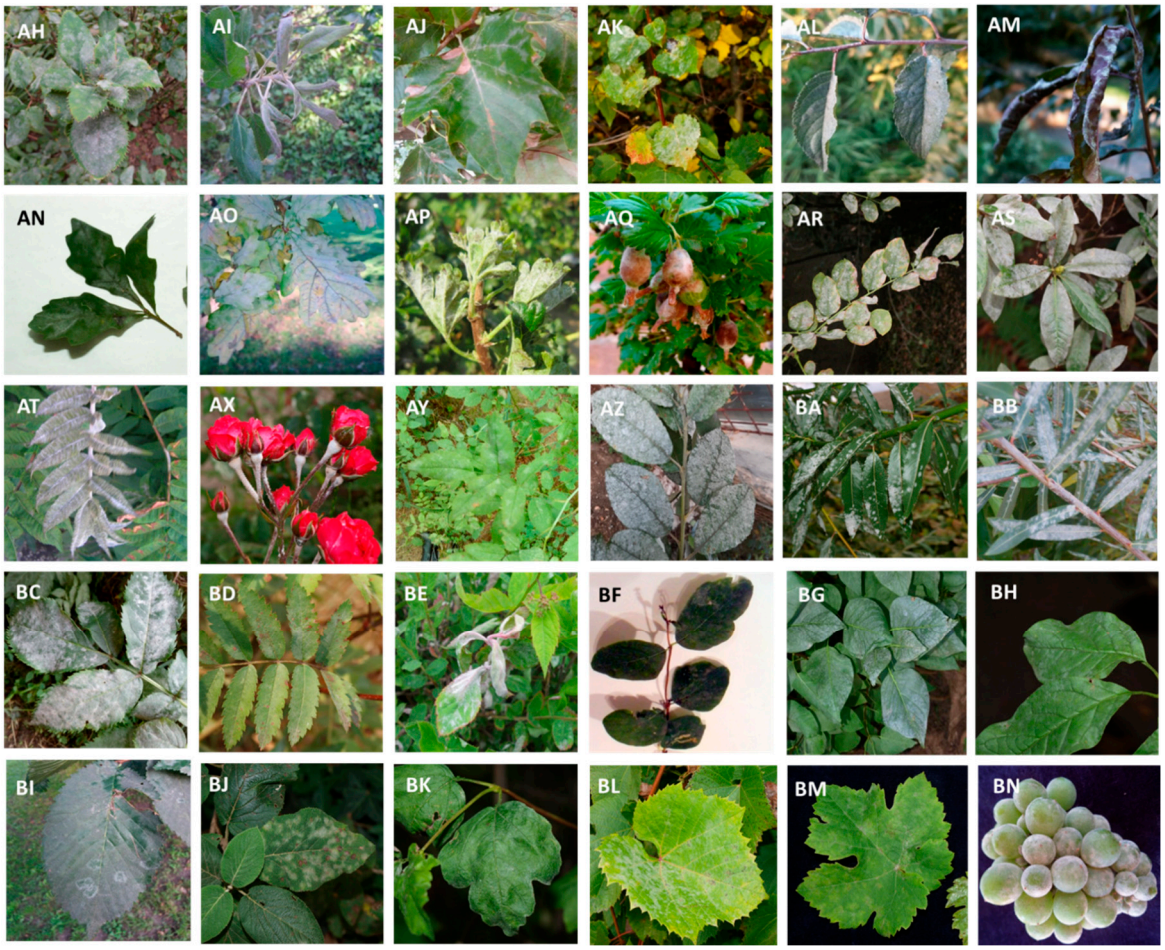

Figure 2. Symptoms of powdery mildew infection on hosts examined in our survey cross-referenced to lists of hosts and powdery mildews in Table 1: **A**—*Acer campestre* L. (MM), **B**—*Acer negundo* L. (BM), **C**—*Acer platanoides* L. (MM), **D**—*Acer tataricum* L. (BM), **E**—*Aesculus* × *carnea* Zeyh. (MM), **F**—*Aesculus hippocastanum* L. (BM), **G**—*Alnus glutinosa* (L.) Gaertn. (MM), **H**—*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem. (MM), **I**—*Amelanchier ovalis* Medik. (BM), **J**—*Berberis vulgaris* L. (BM), **K**—*Betula pendula* Roth (BM), **L**—*Caragana arborescens* Lam. (BM), **M**—*Carpinus betulus* L. (BM), **N**—*Catalpa bignonioides* Walter (VP), **O**—*Cornus mas* L. (BM), **P**—*Cornus sanguinea* L. (BM), **Q**—*Corylus avellana* L. (AV), **R**—*Crataegus monogyna* Jacq. (BM), **S**—*Deutzia scabra* Thunb. (BM), **T**—*Euonymus europaeus* L. (MM), **X**—*Euonymus fortunei* (Turcz.) Hand.-Mazz. (MM), **Y**—*Fagus sylvatica* L. (BM), **Z**—*Forsythia* × *intermedia* Zabel (VP), **AA**—*Frangula alnus* Mill. (MM), **AB**—*Fraxinus excelsior* L. (BM), **AC**—*Ligustrum vulgare* L. (BM), **AD**—*Lonicera periclymenum* L. (BM), **AE**—*Lonicera tatarica* L. (VP), **AF**—*Lycium barbarum* L. (EK), **AG**—*Mahonia aquifolium* (Pursh) Nutt. (BM), **AH**—*Mahoberberis* × *neubertii* C. K. Schneid. (VP), **AI**—*Malus domestica* Borkh. (BM), **AJ**—*Platanus* × *hispanica* Münchh. (MM), **AK**—*Populus tremula* L. (BM), **AL**—*Prunus insititia* L. (MM), **AM**—*Prunus persica* (L.) Batsch (BM), **AN**—*Quercus petraea* (Matt.) Liebl. (BM), **AO**—*Quercus robur* L. (BM), **AP**—*Ribes uva-crispa* L. (BS), **AQ**—*Ribes uva-crispa* (BM), **AR**—*Robinia pseudoacacia* L. (BM), **AS**—*Rhododendron* sp. L. (BM), **AT**—*Rhus typhina* L. (BM), **AX**—*Rosa multiflora* Thunb. (BM), **AY**—*Rosa pendulina* L. (MM), **AZ**—*Salix caprea* L. (BM), **BA**—*Salix daphnoides* Vill. (BM), **BB**—*Salix purpurea* L. (AL), **BC**—*Sambucus nigra* L. (MM), **BD**—*Sorbus aucuparia* L. (BM), **BE**—*Spiraea japonica* L. (MM), **BF**—*Symphoricarpos albus* (L.) S.F.Blake (MA), **BG**—*Syringa vulgaris* L. (BM), **BH**—*Syringa josikaea* J.Jacq. ex Rchb.f. (BM), **BI**—*Ulmus minor* Mill. (MM), **BJ**—*Viburnum lantana* L. (BM), **BK**—*Viburnum opulus* L. (BM), **BL**—*Vitis amurenensis* Rupr. (BM), **BM**—*Vitis vinifera* L. (BM), **BN**—*Vitis vinifera* (VP). Photo: AL—Aleš Lebeda, AV—Abigail Vrbovská, BM—Barbora Mieslerová, BS—Božena Sedláková, EK—Eva Křístková, MA—Marie Ascherová, MM—Markéta Michutová, VP—Veronika Petřeková.

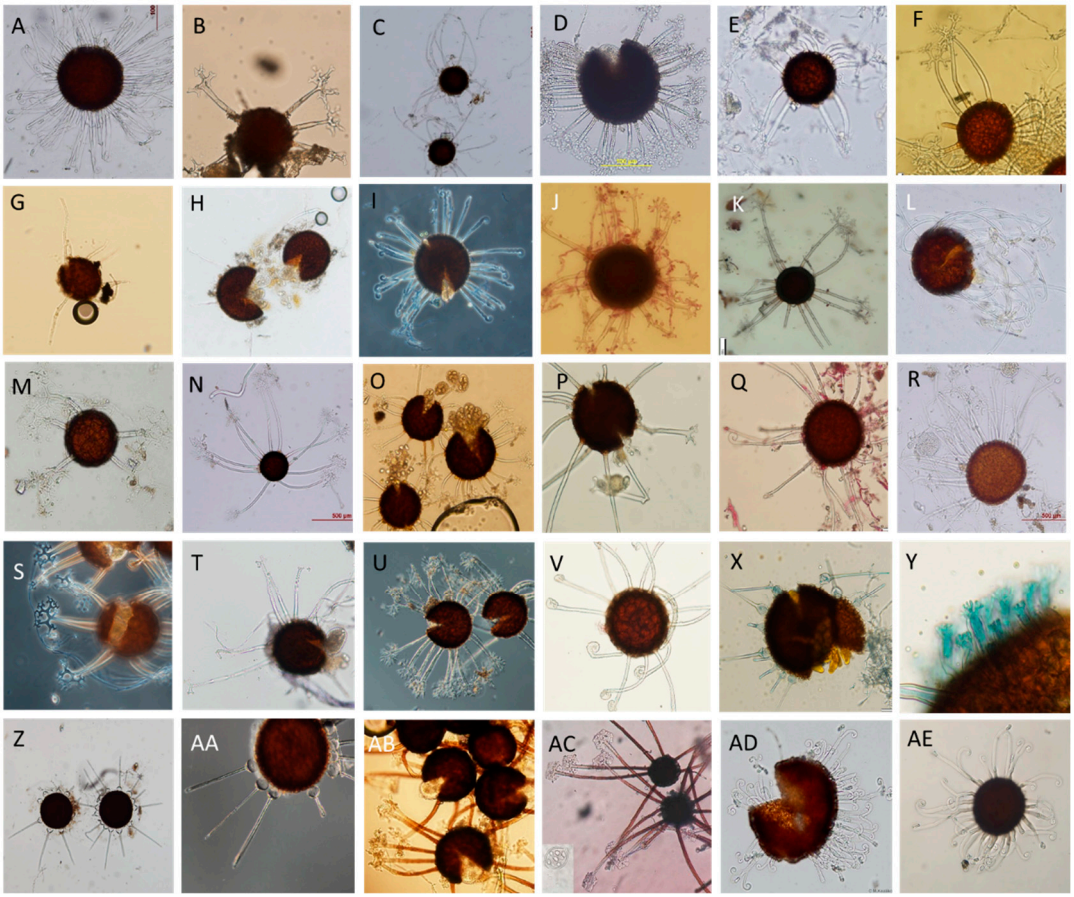

Figure 3. Variability of chasmothecia of selected species: **A**—*Erysiphe adunca* var. *adunca* (*Salix caprea*, VP), **B**—*Erysiphe alphitoides* (*Quercus robur*, BM), **C**—*Erysiphe arcuata* (*Carpinus betulus*, VP), **D**—*Erysiphe azaleae* (*Rhododendron* sp., MS), **E**—*Erysiphe berberidis* var. *berberidis* (*Berberis vulgaris*, MM), **F**—*Erysiphe berberidis* (*Mahonia aquifolium*, VP), **G**—*Erysiphe elevata* (*Catalpa bignonioides*, MM), **H**—*Erysiphe euonymi* (*Euonymus europaeus*, MM), **I**—*Erysiphe flexuosa* (*Aesculus* × *carnea*, JD), **J**—*Erysiphe grossulariae* (*Ribes uva-crispa*, VP), **K**—*Erysiphe lonicerae* var. *ehrenbergi* (*Lonicera tatarica*, VP), **L**—*Erysiphe necator* (*Vitis vinifera*, VP), **M**—*Erysiphe ornata* var. *europaea* (*Betula pendula*, VP), **N**—*Erysiphe palczewskii* (*Caragana arborescens*, VP), **O**—*Erysiphe penicillata* (*Alnus glutinosa*, VP), **P**—*Erysiphe platani* (*Platanus* × *hispanica*, MM), **Q**—*Erysiphe prunastri* (*Prunus insititia*, MM), **R**—*Erysiphe syringae* (*Ligustrum vulgare*, VP), **S**—*Erysiphe syringae* (*Syringa josikaea*, JD), **T**—*Erysiphe tortillis* (*Cornus mas*, MS), **U**—*Erysiphe vanbruntiana* var. *sambuci-racemosae* (*Sambucus racemosa*, MS), **V**—*Erysiphe ulmi* (*Ulmus minor*, MM), **X**—*Phyllactinia guttata* (*Corylus avellana*, AV), **Y**—*Phyllactinia guttata* (penicillate cells, *Corylus avellana*, AV), **Z**—*Phyllactinia fraxini* (*Fraxinus excelsior*, JD), **AA**—*Phyllactinia orbicularis* (*Fagus sylvatica*, MS), **AB**—*Podosphaera amelanchieris* (*Amelanchier ovalis*, MM), **AC**—*Podosphaera myrtillina* (*Vaccinium myrtillus*, MZ), **AD**—*Sawadaea bicornis* (*Acer platanoides*, MK), **AE**—*Sawadaea tulasnei* (*Acer tataricum*, JD). Photo: AV—Abigail Vrbovská, BM—Barbora Mieslerová, JD—Jitka Dvořáková, MM—Markéta Michutová, MS—Michaela Sedlářová, VP—Veronika Petřeková.

Table 1. List of representatives of trees and shrubs infected by powdery mildews collected during 2002–2019 in the Czech Republic.

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Acer campestre L.	16 August 2019	Kyjov	Figure 2A	MM	*Sawadaea bicornis* (Wallr.) Miyabe	Anamorph only	Euoidium 2–5
Acer negundo L.	8 October 2013	Olomouc Lazce	Figure 2B	BM	*Sawadaea bicornis* (Wallr.) Miyabe	Anamorph only	Euoidium
Acer platanoides L.	17 July 2017	Olomouc	-	MM	*Sawadaea bicornis* (Wallr.) Miyabe	Anamorph only	Euoidium 2–5
	15 July 2002	Bítouchov	Figure 2C	MZ	*Sawadaea bicornis* (Wallr.) Miyabe	mainly branched, some simple, tips circinate	-
	20 September 2019	Olomouc	Figure 3AD	BM	*Sawadaea bicornis* (Wallr.) Miyabe	0.5 – 1 × mainly branched, some simple, tips circinate	-
Acer tataricum L.	25 September 2013	Olomouc	Figures 2D and 3A,E	BM	*Sawadaea tulasnei* (Fuckel) Homma	0.5 – 1.3 × mainly simple, some branched, tips circinate	-
Aesculus × *carnea* Zeyh.	20 September 2018	Olomouc	Figure 3I	MM	*Erysiphe flexuosa* (Peck) U. Braun and S. Takam.	0.7 – 1.4 × undulate-helicoid, tips closely circinate	-
	5 September 2013	Arboretum Mendelu Brno	Figure 2E	BM	*Erysiphe flexuosa* (Peck) U. Braun and S. Takam.	0.73 – 1.29 × undulate-helicoid, tips closely circinate	-
Aesculus hippocastanum L.	15 September 2015	Olomouc	Figure 2F	BM, MA	*Erysiphe flexuosa* (Peck) U. Braun and S. Takam.	0.7 – 1.3 × undulate-helicoid, tips closely circinate	-
Alnus glutinosa (L.) Gaertn.	1 October 2018	Olomouc	Figures 2G and 3O	MM	*Erysiphe penicillata* (Wallr.) Link	0.6 – 1.3 × dichotomously branched	Pseudoidium

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Amelanchier alnifolia (Nutt.) Nutt. ex M. Roem.	31 August 2019	Rosarium Olomouc	Figure 2H	MM	*Podosphaera amelanchieris* Maurizio	1.7 – 3 × dichotomously branched, one ascus	-
Amelanchier ovalis Medik.	1 October 2018	Rosarium Olomouc	Figures 2I and 3AB	MM	*Podosphaera amelanchieris* Maurizio	1.2 – 2.7 × dichotomously branched, one ascus	-
	20 July 2019	Kroměříž	-	PM	*Podosphaera amelanchieris* Maurizio	1.3 – 2.3 × dichotomously branched, one ascus	-
Berberis vulgaris L.	31 August 2019	Rantířov	Figure 3E	MM	*Erysiphe berberidis var. berberidis* DC.	0.6 – 1.1 × dichotomously branched many asci	-
	28 September 2011	BG Prague Troja	Figure 2J	BM	*Erysiphe berberidis var. berberidis* DC.	0.3 – 1 × dichotomously branched many asci	Pseudoidium
Betula pendula Roth	28 September 2013	Olomouc Svatý Kopeček	Figures 2K and 3M	VP	*Erysiphe ornata* var. *europea* (U. Braun) U. Braun and S. Takam.	1.1 – 1.8 × dichotomously branched many asci	-
Caragana arborescens Lam.	1 August 2007	Smržice	-	AL	*Erysiphe palczewskii* (Jacz.) U. Braun and S. Takam.	1.8 – 4.1 × dichotomously branched many asci	Pseudoidium 2–3
	29 September 2011	BG UP Olomouc	Figures 2L and 3N	BM	*Erysiphe palczewskii* (Jacz.) U. Braun and S. Takam.	2 – 4 × dichotomously branched many asci	Pseudoidium 2–3
Carpinus betulus L.	23 August 2019	Jihlava	-	MM	*Erysiphe arcuata* U. Braun, V.P. Heluta and S. Takam.	Anamorph only	Pseudoidium 2–3
	8 October 2013	Olomouc	Figures 2M and 3C	BM	*Erysiphe arcuata* U. Braun, V.P. Heluta and S. Takam.	1.5 – 2.8 × Circinate, many asci	Pseudoidium 2–3
Catalpa bignonioides Walter	1 September 2018	Spa Darkov	Figure 3G	MM	*Erysiphe elevata* (Burrill) U. Braun and S. Takam.	1.5 – 3 × Apex closely dichotomously branched	-
	28 August 2015	Olomouc	Figure 2N	MA	*Erysiphe elevata* (Burrill) U. Braun and S. Takam.	Anamorph only	Pseudoidium1–3, foot-cells curved
	1 September 2007	Štítina	-	MS	*Erysiphe elevata* (Burrill) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–3
	13 October 2003	Smržice	-	AL	*Erysiphe elevata* (Burrill) U. Braun and S. Takam.	Anamorph only	

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Cornus mas L.	9 October 2013	Průhonice	Figures 2O and 3T	BM	*Erysiphe tortilis* (Wallr.) Link	3 – 8 ×	Pseudoidium 1–3
Cornus sanquinea L.	9 October 2013	Průhonice	Figure 2P	BM	*Erysiphe tortilis* (Wallr.) Link	Anamorph only	Pseudoidium 1–3
	12 September 2006	Praha	-	MS	*Erysiphe tortilis* (Wallr.) Link	1.1 – 1.5 × Dichotomously branched numerous asci	-
Corylus avellana L.	23 September 2019	Olomouc	Figures 2Q and 3X,Y	AV	*Phyllactinia guttata* (Wallr.) Lév.	0.3 – 1.1 × Bulbose base, presence of penicillate cells	-
Corylus maxima Mill.	8 September 2009	Arboretum Mendelu Brno	-	BM	*Phyllactinia guttata* (Wallr.) Lév.	0.2 – 1.5 × Bulbose base Many asci	-
Crataegus monogyna Jacq.	9 June 2015	Olomouc- Holice	Figure 2R	BM	*Podosphaera clandestina var. clandestina* (Wallr.) Lév.	Anamorph only	Euoidium
Deutzia scabra Thunb.	25 September 2013	Rosarium Olomouc	Figure 2S	BM	*Erysiphe deutziae* (Bunkina) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–3
Euonymus europaeus L.	27 July 2017	Střížov	Figures 2T and 3H	MM	*Erysiphe euonymi* DC.	1.8 – 3.7 × apex dichotomously branched	Pseudoidium 1–2
	28 September 2011	BG Prague Troja	-	BM	*Erysiphe euonymi* DC.	Anamorph only	Pseudoidium 2–3
	16 June 2007	Lhotky/Velké Meziříčí	-	ZDT	*Erysiphe euonymi* DC.	Anamorph only	Pseudoidium 1–2
Euonymus fortunei (Turcz.) Hand.-Mazz.	18 August 2019	Olomouc	Figure 2X	MM	*Erysiphe euonymicola* U. Braun	Anamorph only	Pseudoidium 1–2
	11 April 2008	Olomouc exhibition Flora	-	MS	*Erysiphe euonymicola* U. Braun	Anamorph only	Pseudoidium 1–2
Fagus sylvatica L.	5 October 2010	Vsetín	Figures 2Y and 3AA	MS	*Phyllactinia orbicularis* (Ehrenb.) U. Braun	1.1 – 1.5 × bulbose base	-
	27 October 2006	Lopeník	-	MS	*Phyllactinia orbicularis* (Ehrenb.) U. Braun	1 – 1.3 × bulbose base numerous asci numerous penicillate cells with apex often branched	-
Forsythia × *intermedia* Zabel	10 September 2015	Olomouc	Figure 2Z	VP	*Podosphaera pannosa* (Wallr.: Fr.) de Bary	Anamorph only	Euoidium 3-5

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Frangula alnus Mill.	7 July 2019	Plandry	Figure 2AA	MM	*Erysiphe divaricata* (Wallr.) Schltdl.	Anamorph only	Pseudoidium 1-3
Fraxinus excelsior L.	9 October 2013	Rosarium Olomouc	Figures 2AB and 3Z	BM	*Phyllactinia fraxini* (DC.) Fuss	0.6 – 1.69 × bulbose base	-
	6 October 2007	Olomouc	-	ZDT	*Phyllactinia fraxini* (DC.) Fuss	0.8 – 1.7 × bulbose base	-
	20 October 2006	Křtiny	-	MS	*Phyllactinia fraxini* (DC.) Fuss	0.9 – 1.6 × bulbose base	-
Fraxinus ornus L.	9 October 2013	Rosarium Olomouc	-	BM	*Phyllactinia fraxini* (DC.) Fuss	0.77 -1.8 × bulbose base	-
Ligustrum vulgare L.	8 October 2013	Olomouc	Figures 2AC and 3R	BM	*Erysiphe syringae* Schwein.	0.8 – 2.2 ×	Pseudoidium 2–3
Lonicera periclymenum L.	10 October 2015	Hrubá Voda	Figure 2AD	BM	*Erysiphe lonicerae* DC.	Anamorph only	Pseudoidium 1–3
Lonicera tatarica L.	8 July 2014	Arboretum Mendelu Brno	Figures 2AE and 3K	VP	*Erysiphe lonicerae* var. *ehrenbergii* (Lév.) U. Braun and S. Takam.	1.5-3.5× Apex dichotomously branched	-
Lycium barbarum L.	24 September 2018	Olomouc	Figure 2AF	MM	*Arthrocladiella mougeotii* (Lév.) Vassilkov	Anamorph only	Euoidium 2–4
Mahonia aquifolium (Pursh) Nutt.	1 September 2018	Olomouc	-	MM	*Erysiphe berberidis* DC.	Anamorph only	Pseudoidium 1–3
	21 6 2014	Arboretum Mendelu Brno	Figure 3F	VP	*Erysiphe berberidis* DC.	1.8 -2.8 × Apex dichotomously branched	-
	28 September 2011	BG Prague Troja	Figure 2AG	BM	*Erysiphe berberidis* DC.	Anamorph only	Pseudoidium 2–3
Mahoberberis × *neubertii* C.K.Schneid.	21 June 2014	Arboretum Mendelu Brno	Figure 2AH	VP	*Erysiphe berberidis* DC.	Anamorph only	Pseudoidium 2–3
Malus domestica Borkh.	31 August 2008	Rosarium Olomouc	Figure 2AI	BM	*Podosphaera leucotricha* (Ellis and Everh.) E.S. Salmon	Anamorph only	Euoidium 3–4

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Platanus × *hispanica* Münchh.	1 October 2018	Olomouc	Figures 2AJ and 3P	MM	*Erysiphe platani* (Howe) U. Braun and S. Takam.	1.2 – 3 × Apex dichotomously branched	-
Populus tremula L.	16 October 2013	Olomouc	Figure 2AK	VP	*Erysiphe adunca* var. *adunca* (Wallr.) Fr.	Anamorph only	Pseudoidium 2–3
Prunus insititia L.	24 September 2018	Plandry	Figures 2AL and 3Q	MM	*Erysiphe prunastri* DC.	1.2 – 1.8 ×Circinate, many asci	-
Prunus persica (L.) Batsch	20 August 2009	Arboretum Mendelu Brno	Figure 2AM	BM	*Podosphaera tridactyla* (Wallr.) de Bary	Anamorph only	Euoidium 3–8
Quercus faginea Lam.	20 August 2009	Arboretum Mendelu Brno	-	BM	*Erysiphe alphitoides* (Griff. and Maubl.) U. Braun and S. Takam.	Anamorph only	Pseudoidium 2–3
Quercus petraea (Matt.) Liebl.	20 August 2009	Arboretum Mendelu Brno	Figure 2AN	BM	*Erysiphe alphitoides* (Griff. and Maubl.) U. Braun and S. Takam.	Anamorph only	Pseudoidium 2–3
	28 August 2007	Velké Meziříčí	-	ZDT	*Erysiphe alphitoides* (Griff. and Maubl.) U. Braun and S. Takam	Anamorph only	Pseudoidium 2–3
Quercus robur L.	7 July 2019	Plandry	-	MM	*Erysiphe alphitoides* (Griff. and Maubl.) U. Braun and S. Takam.	Anamorph only	Pseudoidium 2–3
	29 July 2013	Staré město u Uher. Hradiště	-	VP	*Erysiphe alphitoides* (Griff. and Maubl.) U. Braun and S. Takam.	1 – 1.4 × Apex dichotomously branched	Pseudoidium 2–3
	20 September 2015	Olomouc	Figures 2AO and 3B	BM	*Erysiphe alphitoides* (Griff. and Maubl.) U. Braun and S. Takam.	1 – 1.4 × Apex dichotomously branched	Pseudoidium 2–3

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Ribes uva-crispa L.	17 July 2014	Nový Jičín	Figures 2AP and 3J	BS	*Erysiphe grossulariae* (Wallr.) de Bary	0.7 – 1.2 × Apex dichotomously branched	-
	15 May 2018	Protivanov	Figure 2AQ	MK	*Podosphaera mors-uvae* (Schwein.) U. Braun and S. Takam.	Anamorph only	Not possible to analyze
Robinia pseudoacacia L.	31 August 2008	Rosarium Olomouc	Figure 2AR	BM	*Erysiphe pseudoacaciae* (P.D. Marchenko) U. Braun and S. Takam.	0.6 – 14 × Apex dichotomously branched	-
Rhododendron L.	19 August 2019	Olomouc-Hněvotín		MM	*Erysiphe azaleae* (U. Braun) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–2
	20 July 2015	Rosarium Olomouc	Figures 2AS and 3D	BM	*Erysiphe azaleae* (U. Braun) U. Braun and S. Takam.	1.2 – 1.5 × Apex dichotomously branched	-
	20 June 2005	Rosarium Olomouc	-	MS, AL	*Erysiphe azaleae* (U. Braun) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–2
Rhododendron luteum Sweet	10 September 2006	Arboretum Mendelu Brno	-	MS AL	*Erysiphe azaleae* (U. Braun) U. Braun and S. Takam.	1 – 1.2 × Apex dichotomously branched 6-8 asci	-
	13 September 2006	Praha Prague Castle	-	MS AL	*Erysiphe azaleae* (U. Braun) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–2
	20 August 2007	Velké Meziříčí	-	ZDT	*Erysiphe azaleae* (U. Braun) U. Braun and S. Takam.	1 – 1.3 × Apex dichotomously branched	Pseudoidium 1–2
Rhus typhina L.	1 September 2008	Olomouc	Figure 2AT	BM	*Podosphaera* cf. *pruinosa* (Cooke and Peck) Braun and Takam	Anamorph only	Euoidium 3–6
Rosa multiflora Thunb.	25 September 2013	Rosarium Olomouc	Figure 2AX	BM	*Podosphaera pannosa* (Wallr.: Fr.) de Bary	Anamorph only	Euoidium 3–6
Rosa pendulina L.	27 July 2017	Střížov	Figure 2AY	MM	*Podosphaera pannosa* (Wallr.: Fr.) de Bary	Anamorph only	Euoidium 3–5

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Rubus sect. *caesii* Lej. and Court.	15July2000	Bitouchov	-	MZ	*Podosphaera aphanis* (Wallr.) U. Braun and S. Takam.	Anamorph only	Euoidium
Salix caprea L.	3 September 2019	Jihlava	Figure 2AZ	MM	*Erysiphe adunca* var. *adunca* (Wallr.) Fr.	1 – 1.3 × Apex circinate	-
	23 October 2013	Olomouc	Figure 3A	VP	*Erysiphe adunca* var. *adunca* (Wallr.) Fr.	1 – 1.3 × Apex circinate	Pseudoidium 1–2 long foot-cell
Salix daphnoides Vill.	30 September 2015	Arboretum Mendelu Brno	Figure 2BA	BM	*Erysiphe adunca* var. *adunca* (Wallr.) Fr.	1 – 1.5 × Apex slightly circinate	-
Salix × *reichardtii* A. Kern	8 September 2009	Arboretum Mendelu Brno	-	BM	*Erysiphe adunca* var. *adunca* (Wallr.) Fr.	Anamorph only	Pseudoidium 1–2
Salix purpurea L.	30 September 2015	Arboretum Mendelu Brno	-	VP	*Erysiphe adunca var. adunca* (Wallr.) Fr.	1 – 1.5 × Apex slightly circinate	-
	28 July 2013	Smržice	Figure 2BB	AL	*Erysiphe adunca var. adunca* (Wallr.) Fr.	Anamorph only	Pseudoidium
Sambucus nigra L.	17 July 2017	Střížov	Figure 2BC	MM	*Erysiphe vanbruntiana var. sambuci-racemosae* (U. Braun) U. Braun and S. Takam.	0.7 – 1.2 × Apex dichotomously branched	-
	14 August 2013	Rosarium Olomouc	-	BM	*Erysiphe vanbruntiana var. sambuci-racemosae* (U. Braun) U. Braun and S. Takam.,	1 – 1.5 × Apex dichotomously branched	Pseudoidium1–3
Sambucus racemosa L.	13 August 2013	Jičín	Figure 3U	VP	*Erysiphe vanbruntiana var. sambuci-racemosae* (U. Braun) U. Braun and S. Takam.	1 – 1.5 × Apex d dichotomously branched	-
	8 August 2007	Olomouc—Radíkov	-	MS	*Erysiphe vanbruntiana var. sambuci-racemosae* (U. Braun) U. Braun and S. Takam.	1 – 1.3 × Apex dichotomously branched	Pseudoidium 1–3
	28 October 2006	Lopeník	-	MS	*Erysiphe vanbruntiana var. sambuci-racemosae* (U. Braun) U. Braun and S. Takam.	1 – 1.5 × Apex dichotomously branched Numerous asci	-

Table 1. *Cont.*

Host Species	Date of Collection	Place of Collection	Cross-Referenced With Photos of Symptoms (Figure 2), Chasmothecia (Figure 3)	Leg.	Taxonomic Name of Powdery Mildew Species According to Braun and Cook [2] Unless Otherwise Indicated in Footnotes	Relative Length (Multiples of Chasmothecia Diameter) and Shape of Appendages.	Type of Conidiogenesis/ Number of Distal Cells
Sorbus aucuparia L.	12 August 2013	Jičín	Figure 2BD	BM	*Podosphaera aucupariae* Erikss.	Anamorph only	Euoidium 3–5
Spiraea betulifolia Pall.	3 August 2014	Zlín	-	VP	*Podosphaera spiraeae* (Sawada) U. Braun and S. Takam.	Anamorph only	Euoidium 3–5
Spiraea japonica L.	24 May 2015	Dub n. Moravou	Figure 2BE	VP	*Podosphaera spiraeae* (Sawada) U. Braun and S. Takam.	Anamorph only	Euoidium 3–5
Symphoricarpos albus (L.) S. F. Blake	15 September 2015	Olomouc	Figure 2BF	MA	*Erysiphe symphoricarpi* (Howe) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–3
	25 April 2008	Olomouc -Holice	-	MS	*Erysiphe symphoricarpi* (Howe) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–2
Syringa vulgaris L.	20 July 2019	ZOO Jihlava	-	MM	*Erysiphe syringae* Schwein.	Anamorph only	Pseudoidium 1–3
	20 September 2008	Olomouc	Figure 2BG	BM	*Erysiphe syringae* Schwein.	Anamorph only	Pseudoidium 1–3
	21 October 2006	Vyškov	-	MS	*Erysiphe syringae* Schwein.	0.9 – 1.2 × Apex dichotomously branched	-
Syringa josikaea J.Jacq. ex Rchb.f.	28 September 2011	BG Prague Troja	Figures 2BH and 3S	BM	*Erysiphe syringae* Schwein.	0.7 – 1.5 × Apex dichotomously branched	-
Ulmus minor Mill.	20 September 2018	Olomouc	Figures 2BI and 3V	MM	*Erysiphe ulmi* Cast.	0.6 – 1.4 × Apex circinate	-
Vaccinium myrtillus L.	15 July 2002	Bítouchov	Figure 3AC	MZ	*Podosphaera myrtillina* (C. Schub.) Kunze	2.9 – 3.2 × Apex dichotomously branched	-
Viburnum lantana L.	30 September 2015	Rosarium Olomouc	Figure 2BJ	BM	*Erysiphe hedwigii* (Lev.) U. Braun and S. Takam.	Anamorph only	Pseudoidium 1–3
Viburnum opulus L.	30 September 2015	Rosarium Olomouc	Figure 2BK	BM	*Erysiphe viburni* Schwein.	1.0 – 1.3 × Apex dichotomously branched	-
Vitis amurensis Rupr.	28 September 2011	BG Prague Troja	Figure 2BL	BM	*Erysiphe necator* var. *necator* Schwein.	Anamorph only	Pseudoidium 1–3
Vitis vinifera L.	16 August 2019	Kostelec	-	MM	*Erysiphe necator* var. *necator* Schwein.	Anamorph only	Pseudoidium 1–3
	13 August 2013	Vracov	Figure 2BM,BN and Figure 3L	VP	*Erysiphe necator* var. *necator* Schwein.	1.8 – 4.5 × Apex circinate	Pseudoidium 1–3

Legends: AL—Aleš Lebeda, AV—Abigail Vrbovská, BM—Barbora Mieslerová, BS—Božena Sedláková, MA—Marie Ascherová, MM—Markéta Michutová, MK—Miloslav Kitner, MS—Michaela Sedlářová, MZ—Marie Zeidlerová (Kozáková), PM—Pavel Matušinský, VP—Veronika Petřeková, ZDT—Zuzana Drábková Trojanová.

Table 2. List of powdery mildew species collected on trees and shrubs in the Czech Republic with their host plants.

Powdery Mildew Genera	Powdery Mildew Species (Host Plants)
Arthrocladiella	*Arthrocladiella mougeotii* (*Lycium barbatum*)
Erysiphe All *E.* sect. *Microsphaera* unless listed as *E.* sect. *Uncinula* (*E.* (*U.*))	*E.* (*U.*) *adunca* var. *adunca* (*Populus tremula*, *Salix caprea; S. daphnoides*, *Salix* × *reichardtii*, *S. purpurea*) *E. alphitoides* (*Quercus faginea*, *Quercus petraea*, *Quercus robur*) ***E.* (*U.*) *arcuata* (*Carpinus betulus*)** *E. azaleae* (*Rhododendron*, *Azalea*) *E. berberidis var. berberidis* (*Berberis vulgaris*, *Mahoberberis* × *neubertii*, *Mahonia aquifolium*) ***E. deutziae* (*Deutzia scabra*)** *E. divaricata* (*Frangula alnus*) *E. elevata* (*Catalpa bignonioides*) *E. euonymi* (*Euonymus europaeus*) ***E. euonymicola* (*Euonymus fortunei*)** ***E.* (*U.*) *flexuosa* (*Aesculus hippocastanum*, *Aesculus* × *carnea*)** *E. grossulariae* (*Ribes uva-crispa*) *E. hedwigii* (*Viburnum lantana*) *E. lonicerae var. loniceae* (*Lonicera periclymenum*); *Erysiphe lonicerae* var. *ehrenbergii* (*Lonicera tatarica*) *E.* (*U.*) *necator* var. *necator* (*Vitis amurensis*, *Vitis vinifera)* *E. ornata* var. *europea* (*Betula pendula*) *E. palczewskii* (*Caragana arborescens*, *Styphnolobium japonicum*) *E. penicillata* (*Alnus glutinosa*) ***E. platani* (*Platanus* × *hispanica*)** *E.* cf. *pseudoacaciae* (*Robinia pseudoacacia*) *E.* (*U.*) *prunastri* (*Prunus insititia*) ***E. symphoricarpi* (*Symphoricarpos albus*)** *E. syringae* (*Ligustrum vulgare*, *Syringa vulgaris*, *Syringa josikaea*) *E. tortilis* (*Cornus mas*, *Cornus sanguinea*) *E.* (*U.*) *ulmi* (*Ulmus minor*) ***E. vanbruntiana var. sambuci-racemosae* (*Sambucus nigra*, *Sambucus racemosa*)** *E. viburni* (*Viburnum opulus*)

Table 2. *Cont.*

Powdery Mildew Genera	Powdery Mildew Species (Host Plants)
Phyllactinia	*Ph. fraxini* (*Fraxinus excelsior*, *Fraxinus ornus*) *Ph. guttata* (*Corylus avelana*, *Corylus maxima*) *Ph. orbicularis* (*Fagus sylvatica*)
Podosphaera All *Po. sect. Podosphaera* unless listed as *Po. sect. Sphaerotheca* (*Po.* (*Sph.*))	***Po. amelanchieris* (*Amelanchier alnifolia, Amelanchier ovalis*)** *Po.* (*Sph.*) *aphanis* (*Rubus* sect. *caesius*) *Po. aucupariae* (*Sorbus aucuparia*) *Po. clandestina var. clandestina* (*Crataegus monogyna*) *Po. leucotricha* (*Malus domestica*) *Po.* (*Sph.*) *mors-uvae* (*Ribes uva-crispa*) *Po. myrtillina* (*Vaccinium myrtillus*) *Po.* (*Sph.*) *pannosa* (*Forsythia* × *intermedia*, *Rosa multiflora*, *R. pendulina*) ***Po.* cf. (*Sph.*) *pruinosa* (*Rhus typhina*)** ***Po.* (*Sph.*) *spiraeae* (*Spiraea betulifolia*,** *S. japonica*) *Po. tridactyla* (*Prunus persica*)
Sawadaea	*S. bicornis* (*Acer negundo*, *A. campestre*, *A. platanoides*, *A. tataricum*) *S. tulasnei* (*Acer platanoides*)

Legend: Species in bold are new records for the Czech Republic.

Table 3. Additional powdery mildews in neighbouring countries compared with Czech survey (this paper).

Powdery Mildew Genus	Slovakia ([21], Pastirčáková and Co-Workers)	Poland ([27,34])	Hungary [29]	Germany/Bavaria [28]
Arthrocladiella	-	-	-	-
Erysiphe	*E.* (*M.*) *friesii* *E.* (*M.*) *magnusii* *E.* (*M.*) *cotini* *E.* (*M.*) *magnifica*	*E.* (*M.*) *friesii*	*E.* (*M.*) *friesii* *E.* (*M.*) *sparsa*	*E.* (*M.*) *friesii*
Phyllactinia	*Ph. mali* *Ph. roboris*	*Ph. berberidis* *Ph. mali* *Ph. roboris*	*Ph. mali* *Ph. roboris*	*Ph. berberidis* *Ph. betulae* *Ph. carpini* *Ph. corni* *Ph. mali* *Ph. marissalii* *Ph. populi*
Podosphaera	-	-	-	*Po.* (*Sph.*) *niessleri*
Sawadaea	-	-	-	-

3.1. Sawadaea and Arthrocladiella

In our survey we distinguished two *Sawadaea* taxa on *Acer* as the now well-defined species of *S. bicornis* and *S. tulasnei.* These two taxa were described by Klika [14] by the older names of *Uncinula aceris* and its var. *tulasnei*. In our collections, the sexual state was not always present with *S. bicornis*, but in these cases it was identified on the basis of symptoms. These species were confirmed in the four nearby countries, apart from Poland that recorded only *S. tulasnei* [27]. In Slovakia *S. bicornis* was more frequent [21].

Arthrocladiella on *Lycium* was recorded by Klika [14] as *Microsphaera mougeotii*. It recently occurs in the Czech Republic and surrounding countries [21,27–29].

3.2. Phyllactinia Species

Only three *Phyllactinia* species were found in our survey, namely *Ph. guttata*, *Ph. fraxini* and *Ph. orbicularis*, on respectively, *Corylus*, *Fraxinus* and *Fagus*. The differences with our neighbours, see Table 3, show that Slovakia [21] had two additional species, *Ph. mali* and *Ph. roboris*, but not *Ph. orbicularis.* Hungary [29] had exactly the same results as Slovakia. Poland [27] recorded an additional three species, *Ph. berberidis*, *Ph. mali* and *Ph. roboris*, but not *Ph. fraxini* or *Ph. orbicularis*. A very different situation was found in Bavaria [28], which had seven additional species namely: *Ph. berberidis*, *Ph. betulae*, *Ph. carpini*, *Ph. corni*, *Ph. mali*, *Ph. marissalii* and *Ph. populi.*

3.3. Erysiphe Species

This group gave rise to most problems in identification, in particular, those genera involving recent name changes. In our survey 27 species of *Erysiphe* were recorded on trees. Klika [14] described the following genera that are now mostly classed as *Erysiphe* emend; four *Uncinula* spp. (one of them *Sawadaea* on *Acer*), 4 *Microsphaera* spp. (one now *Arthrocladiella* on *Lycium*) and 2 *Trichocladia* spp. Compared with Klika [14], some additional recordings of powdery mildew species (including invasive ones) were detected. Indeed, it is an interesting fact that during the last few decades several new powdery mildew species were described in Europe, frequently due to their introduction from Asia or America. This is well illustrated with *Erysiphe* species whose hosts, origins and present locations are listed below. New records for the Czech Republic are in bold:

E. (*M.*) *azaleae* on *Rhododendron*; North American origin, first described in England from the 1990s; see Inman et al. [35] and later in Bavaria [28], Czech Republic [15], Poland [36], Slovakia [37].

E.* (*M.*) *deutziae on *Deutzia*; Asiatic origin, first described in Europe in 2000 [38], and later in Bavaria [28], Czech Republic (current article), Poland [38].

E. (*M.*) *elevata* on *Catalpa;* North American origin, first described in Europe (Hungary) in 2002 [39], and later in Bavaria [28], both in Czech Republic and Poland [20], Slovakia [25].

E.* (*M.*) *euonymicola on *Euonymus fortunei*; Asiatic origin, introduced to the Europe at the beginning of the 20th century; Bavaria [28], Czech Republic (current article), Poland [40].

E. (*M.*) *palczewskii* on *Caragana*; Asiatic origin, in Europe since the 1990s; see Lebeda et al. [18] for the Czech Republic, also in Bavaria [28], Hungary [41], Poland [27] and Slovakia [21].

E.* (*M.*) *platani on *Platanus*; North American origin, in Europe from 1960s [22]; later in Bavaria [28], Czech Republic (recent article), Hungary [42], Poland [43] and Slovakia [22].

E.* (*M.*) cf. *pseudoacaciae on *Robinia pseudoacacia*; European (Ukrainian) origin, Bavaria [28] (unclear finding), Czech Republic (current article).

E. (*M.*) *syringae-japonicae* on *Syringa*; Asiatic origin, in Europe since the 1990s [44]; later in Poland [45].

E.* (*M.*) *symphoricarpi on *Symphoricarpos*; North American origin, in Hungary since the 1980s; see Kiss et al. [46], and later in Czech Republic (current article), Poland [47] and Slovakia [21].

E.* (*M.*) *vanbruntiana* var. *sambuci-racemosae on *Sambucus*; Asiatic origin, introduced to Europe; see Braun and Cook [2], and later in Bavaria [28], Czech Republic (current article), Poland [48].

E.* (*U.*) *arcuata on *Carpinus betulus*; European origin, recently in Bavaria [28], Czech Republic (current article), Poland [40], Slovakia [24].

E.* (*U.*) *flexuosa on *Aesculus;* North American species first described in Europe by Ale-Agha et al. [49]; later in Bavaria [28], Czech Republic (current article), Hungary [29], Poland [50], Slovakia [26].

E.* (*U.*) *ulmi* on *Ulmus minor; European origin; Czech Republic (current article), Hungary (as *E. clandestina* [29]), Germany (as *E. clandestina* [51]), Slovakia (as *U. clandestina* [21]).

All of these except *E.* (*M.*) *syringae-japonicae* were confirmed in our study, while Klika [14] did not mention any of them. However, most of the *Erysiphe* spp on trees and shrubs were shared with our neighbouring countries. On the other hand, there were several differences. For instance, *E.* (*M.*) *friesii* was present on *Rhamnus* in all four neighbours as indicated in Table 3. It is highly probable that this species occurs within the area of our republic, and its non-reporting is only due to a lack of examination of the host. In Slovakia there were three other species not recorded in our survey, namely: *E.* (*M.*) *magnusii* on *Lonicera*, *E.* (*M.*) *cotini* on *Cotinus* [21] and *E. (M.) magnifica* on *Magnolia* [23]; Hungary had the addition of *E.* (*M.*) *sparsa* on *Viburnum* [29], and Poland added *E.* (*M.*) *hypophylla* on *Quercus* [27].

3.4. Podosphaera Species

We recorded the following 11 species of *Podosphaera*; all were sect. *Podosphaera* unless stated as sect. *Sphaerotheca* (*Sph.*) and those in bold were new records for the Czech Republic: ***Podosphaera amelanchieris*** on *Amelanchier* (not confirmed in Slovakia, Hungary, Poland), *Po.* (*Sph.*) *aphanis* on *Rubus*, *Po. aucupariae* on *Sorbus*, *Po. clandestina* on *Crataegus*, *Po. leucotricha* on *Malus*, *Po.* (*Sph.*) *mors-uvae* on *Ribes*, *Po. myrtillina* on *Vaccinium*, *Po.* (*Sph.*) *pannosa* on *Rosa*, ***Podosphaera* (*Sph.*) *pruinosa*** on *Rhus typhina* (not confirmed in Slovakia, Poland, Hungary and Bavaria), ***Podosphaera* (*Sph.*) *spiraeae*** on *Spiraea* (not confirmed in Hungary, Slovakia), *Po. tridactyla* on *Prunus*. In Bavaria *Po.* (*Sph.*) *niesslii* on *Sorbus* was the only additional *Podosphaera* sp. not recorded in our country [28].

4. Discussion

This was the first detailed study since Klika's monograph [14], that was focussed on the spectrum of powdery mildew species on a selected group of plants in the Czech Republic. Questions had logically arisen as to whether the spectrum had changed and if so, how it had changed, and what were the reasons for the change.

By comparing our results with Klika's monograph [14], it is clear that most of the powdery mildew species on trees and shrubs in our country have occurred here for a long time. Although Klika [14] did not distinguish *Sawadaea*, *Arthrocladiella* and other genera, this does not mean that these have not occurred previously in our country. This can be due to the historical changes in the taxonomy of powdery mildews, e.g., *Arthrocladiella* being recorded by the old name of *Microsphaera mougeotii*. Braun [9] placed it in *Erysiphe*, which was later divided into the three aforementioned genera: *Erysiphe*, *Golovinomyces* and *Arthrocladiella*. Now *Arthrocladiella* is a monotypic genus containing a single species (*A. mougeotii*), with *Lycium* (Solanaceae) as the sole host genus.

The situation with *Sawadaea* is similar, being recorded as *Uncinula aceris* in older literature [14]. Later, the name *Sawadaea* was introduced [52], and its status was proven by molecular sequence analysis [7].

Concerning *Phyllactinia*, there is also the problem of older publications having a very wide definition of some species, e.g., *Ph. guttata* (= *Ph. corylea*) has a wide host range in Klika's monograph [14]. At the end of the last century, *Ph. guttata* was recognized as a species complex, consisting of several biological species [3]. Then, based on a phylogenetic study by Takamatsu et al. [53], Braun and Cook [2] confined *Ph. guttata* to *Corylus* hosts and accepted separate species on single hosts, e.g., the *Phyllactinia* spp. *alnicola*, *betulae* and *carpini* that they said were present in all or almost all Europe. Indeed, *Ph. betulae* and *Ph. carpini* were found in Bavaria [28], but *Ph. alnicola* was not found in our part of Europe. We all did, however, find the genuine *Ph. guttata* on *Corylus* spp. Species of *Phyllactinia* probably prefer much colder regions. For instance, in Wales, Chater and Woods [54] recorded 12 *Phyllactinia* species. Although Scholler et al. [55] had described how *P. fraxinicola* on *Fraxinus* was introduced into Europe from Eastern Asia, neither this nor any other recently introduced species of *Phyllactinia* were recorded in our four country surveys.

As explained above, earlier workers recognised the sections of *Podosphaera* (sects *Podosphaera* and *Sphaerotheca*) as full genera. For instance, on trees and shrubs in the Czech Republic, Klika [14] described two *Sphaerotheca* and three *Podosphaera* species whilst Slovakia [21] had four *Sphaerotheca* and four *Podosphaera* species. By comparison with Klika's survey [14], the probably newly occurring species in our republic were: *Po. amelanchieris*, *Po.* (*Sph.*) *pruinosa* and *Po.* (*Sph.*) *spiraeae* and they were also found in Bavaria by Bresinsky [28]. The discrepancy with Klika's list is not surprising, because the hosts (respectively *Amelanchier*, *Rhus* and *Spiraea*) are grown here as ornamentals, and would not have been present in Klika's time. All three species are missing in both the Hungarian [29], and Polish check-lists [27]. Later however, Piątek [34] confirmed *Po. spiraeae* in Poland.

The most complicated situation is with the genus *Erysiphe.* As mentioned above, the previous genera *Microsphaera* and *Uncinula* were recently made part of the genus *Erysiphe*; while another problem is the ever-narrowing definitions of particular species. On trees Klika [14] described four *Uncinula* spp. (one of them is now *Sawadaea* on *Acer*), 4 *Microsphaera* spp. (one is now *Arthrocladiella* on *Lycium*) and 2 *Trichocladia* spp. (now *Erysiphe* spp.).

A complicated situation arises when more than one powdery mildew species can infect one host plant. This is the case with *Salix* (with *E. adunca* and *E. capreae*), *Quercus* (with *E. alphitoides* and *E. hypophylla*), *Acer* (with *S. bicornis* and *S. tulasnei*), *Catalpa* (with *Erysiphe catalpae*, *E. elevata* and *Neoerysiphe galeopsidis*), *Cornus* (with *Erysiphe pulchra* and *E. tortilis*) and *Syringa* (with *E. syringae* and *E. syringae-japonicae*). Accurate and experienced interpretations of microscopical, as well as molecular analyses, are needed to fully appreciate the results of the valuable research on these species. For instance, the powdery mildews of *Erysiphe* genus on legumes represent one of the taxonomically most complicated groups within this genus as highlighted by the revision of Braun et al. [56].

5. Conclusions

Despite the problems with the naming of powdery mildews on so wide a range of host species, our study both confirmed previously described species and revealed some new records for our country, i.e., *Podosphaera* (sect. *Po.*) *amelanchieris* on *Amelanchier*, *Po.* (sect. *Po.*) *pruinosa* on *Rhus typhina*,

Po. (sect. *Sph.*) *spiraeae* on *Spiraea*, *E.* (*U.*) *arcuata* on *Carpinus*, *E.* (*M.*) *deutziae* on *Deutzia*, *E.* (*M.*) *euonymicola* on *Euonymus fortunei*, *E.* (*U.*) *flexuosa* on *Aesculus*, *E.* (*M.*) *platani* on *Platanus*, *E.* (*M.*) *symphoricarpi* on *Symphoricarpos*, *E.* (*M.*) *vanbruntiana* var. *sambuci-racemosae* on *Sambucus racemosa* and *E.* (*U.*) *ulmi* on *Ulmus minor.*

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