

DOI: 10.5586/am.1118

**Publication history**

Received: 2018-04-27

Accepted: 2018-11-20

Published: 2019-06-25

**Handling editor**

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**Authors' contributions**

BJ, JU: research codesigning, conducting experiments, writing the manuscript; PK: contributed to the collection of plant material; WP: contributed to the species determination

**Funding**

This work was founded by the Wrocław University of Environmental and Life Sciences as part of individual research grants (B030/0029/1).

**Competing interests**

WP is the Editor-in-Chief of *Acta Mycologica*; other authors: no competing interests have been declared

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**Citation**

Jacewski B, Urbaniak J, Kwiatkowski P, Pusz W. Microfungal diversity of *Juncus trifidus* L. and *Salix herbacea* L. at isolated locations in the Sudetes and Carpathian Mountains. *Acta Mycol.* 2019;54(1):1118. <https://doi.org/10.5586/am.1118>

**ORIGINAL RESEARCH PAPER**

# Microfungal diversity of *Juncus trifidus* L. and *Salix herbacea* L. at isolated locations in the Sudetes and Carpathian Mountains

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**Abstract**

During cold periods in the Pleistocene Epoch, many plants known as the “relict species” migrated and inhabited new areas. Together with plants, some microfungi also migrated, remaining present on plants and in plant communities. However, the relationship between fungi and the migrating plants (especially host plants) is not well understood. Therefore, we examined the diversity and distribution of microfungi associated with two migratory relict plants in the Sudetes and Carpathian Mountains: *Salix herbacea* L. and *Juncus trifidus* L. In total, we found 17 taxa of fungi that were collected from nine different locations. Nine fungal taxa were collected on *S. herbacea*, and eight taxa on *J. trifidus*. Localities richest of fungi on *S. herbacea* were Mały Śnieżny Kocioł (Karkonosze Mts, Sudetes) and on *J. trifidus*, the Tatra Mts (Carpathian Mts). This work provides new insights into the distribution of fungi inhabiting *S. herbacea* and *J. trifidus* in Poland.

**Keywords**

biodiversity; relict-associated microfungi; mountains; *Juncus*; *Salix*; Central Europe

**Introduction**

The present distribution and genetic structure of organisms are consequences of repeated climatic changes in the Pleistocene during the past several million years. The cold periods in the Pleistocene Epoch caused substantial changes in ecosystems, such as organism extinction, habitat fragmentation, and modified vegetation in the colder areas of Europe, America, and the Arctic [1–4]. These climatic changes were also the primary reason for numerous plant or animal migrations to the southern part of Europe or into warmer localities, in front of glaciers, where they were able to survive unfavorable conditions; once favorable conditions returned, they could migrate back to the northern areas [5–7]. Such organisms, commonly called glacial relicts, were widely distributed when the climate changed in the Holocene Epoch; the changing climate also caused numerous organisms to adapt to the new climatic conditions and reduced their ranges to smaller refugia, mostly in high mountains, where the arctic boreal conditions and cold climate remained. It is possible that together with relict plant species, some microfungal communities migrated and inhabited the relicts in new areas. Although the distributional data from various localities have been published, the occurrence and distribution of microfungi on relict plants is still poorly understood [1,8]. According to Chlebicki and other authors [1,8–15], 35 microfungal species have been found so

far on various parts of *Salix herbacea* shoots, and almost all were collected from small and scarce plant branches, especially from the leaves of a dwarf willow. In general, from the reported 171 fungi taxa occurring on plants from the genus *Juncus* [16], Šandová and Chlebicki as well as other authors listed 32 microfungal species from *J. trifidus* [1,17–21]. Some of these species can inhabit not only *J. trifidus* but also other species from Juncaceae or Cyperaceae. The study presents new data on the distribution of fungal species inhabiting the relict plants *J. trifidus* and *S. herbacea* in the Sudetes and Carpathian Mts. These results could also better our understanding about the coexistence of and mutual relationships among fungi and plants.

## Material and methods

The research was conducted in several locations in the Sudetes and Carpathian Mts ranges in summer 2017 and included specimens of *J. trifidus* and *S. herbacea* (Tab. 1, Tab. 2, Fig. 1). *Salix herbacea* is one of the smallest willows that can survive in harsh high mountains and boreal environments. It is an Arctic-Alpine plant species with an Amphi-Atlantic distribution [22]. It can be found in subarctic North America, Greenland, Iceland, Scotland, and northern Siberia. In Europe, this plant is common in Scandinavia, but also in the Alps and Pyrenees with a few localities in Apennines, Balkan Peninsula, the Sudetes (Karkonosze Mts, Hrubý Jeseník), and in the Carpathian Mountains (Pilsko Mt, Tatra Mts) [23]. Dwarf willow can be found in alpine or subalpine zones on rocks, in rock crevices, snow beds, or in marshes, usually on acid rock substrates, from 1,400 to about 2,200 m a.s.l. The localities of collected samples were marked on the map (Fig. 1) by subscript “Xa”.

According to Hulten [22], *J. trifidus* is Amphi-Atlantic plant, native to boreal regions of Northern Canada, Northeastern United States, Iceland, Greenland, and northern regions of Britain and Siberia. In Europe, it is also common in Scandinavia and present in Pyrenees, Alps, Apennines, and Balkan Peninsula. In Poland, *J. trifidus* occurs in scattered localities in alpine and subalpine zones in the Sudetes (Karkonosze Mts, Śnieżnik Mt, Hrubý Jeseník) and Carpathian Mts (Babia Góra Mt, Tatra Mts) from 1,300 to about 2,200 m a.s.l. [23]. Chlebicki [1] noted that 18 taxa of fungi can be found on different plant species from the family Cyperaceae (genera *Carex*, *Juncus*, and *Luzula*). The localities of collected samples on *J. trifidus* were marked on the map in Fig. 1 by subscript “Xb”.

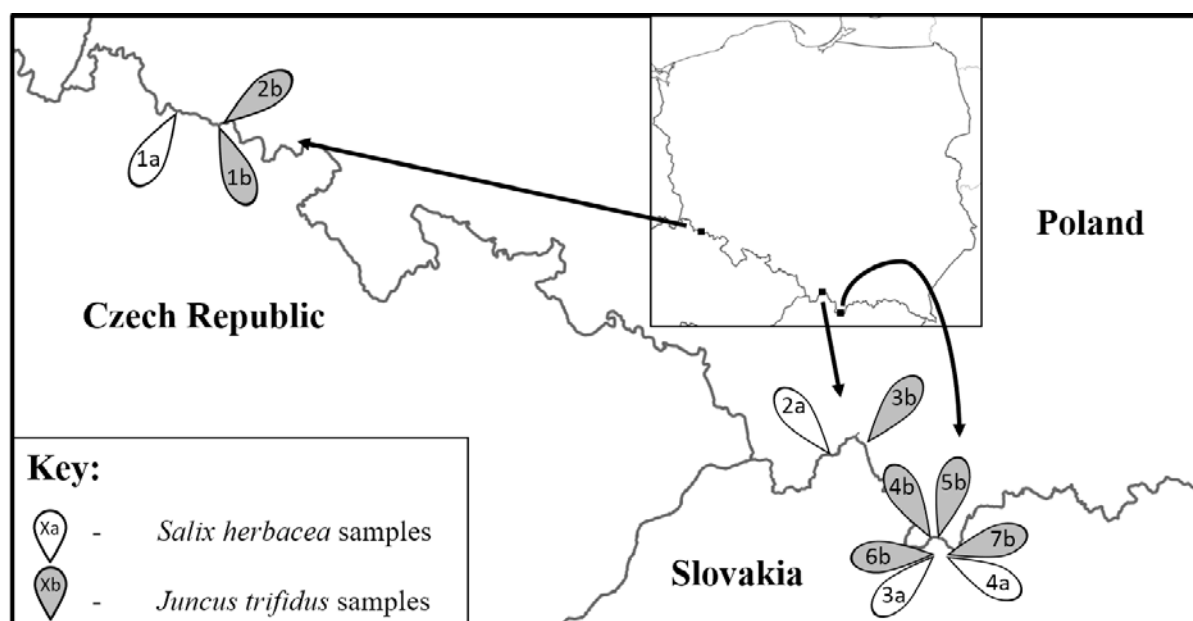
The occurrence of fungi on stems, leaves, inflorescences, fruits, bracts, and bracteoles has been analyzed. Plant parts were taken to the laboratory and after being immersed in a disinfectant, they were placed on standard PDA medium in Petri dishes. After growth, fungi were identified using a light microscope (ZeissAxiophot, Carl Zeiss, Jena, Germany) at a magnification of 400×. For some morphological structures, i.e.,

**Tab. 1** Locations of studied *S. herbacea* populations.

No.	Location	Altitude (m)	Coordinates	Comments
<b>Karkonosze Mts</b>				
1a	Mały Śnieżny Kocioł	1,477	50°46'46.38" N 15°33'23.41" E	Small patch above couloir
<b>Beskid Mts</b>				
2a	Pilsko Mt	1,492	49°31'41.16" N 19°18'46.85" E	At the top, plants on rock walls
<b>Tatra Mts</b>				
3a	Nižné Wahlenbergovo pleso	1,805	49°8'52.77" N 20°1'50.5" E	On the rocks
4a	Furkotský štít	1,772	49°8'47.21" N 20°1'45.5" E	On the rocks

**Tab. 2** Locations of studied *J. trifidus* populations.

No.	Location	Altitude (m)	Coordinates	Comments
<b>Karkonosze Mts</b>				
1b	Śnieżka Mt	1,537	50°44'12.01" N 15°44'34.97" E	Commonly on the ground and rocks
2b	Czarny Grzbiet	1,419	50°44'27.78" N 15°45'5.76" E	Close to Śnieżka Mt
<b>Babia Góra massif</b>				
3b	Diablak	1,692	49°34'26.21" N 19°32'0.72" E	Commonly on the ground
<b>Tatra Mts</b>				
4b	Chuda Turnia	2,027	49°14'2.06" N 19°54'56.92" E	On the ground and rocks
5b	Ciemniak Mt	2,050	49°13'49.88" N 19°54'11.89" E	On the ground and rocks
6b	Nižné Wahlenbergovo pleso	1,894	49°9'5.81" N 20°1'43.98" E	Commonly on the ground and rocks
7b	Furkotský štít	1,781	49°8'48.93" N 20°1'42.68" E	Commonly on the rocks

**Fig. 1** Locations of collected samples.

ornamentation, a magnification of 1,000× with immersion oil was used. All samples were collected, and the species were determined by Brayan Jacewski. Fungi species were identified using specialized bibliography [24–29]. Taxonomic nomenclature of fungi follows that used in the Index Fungorum [30], and plant names were given according to Mirek et al. [31]. In a few cases, molecular methods were used for species determination. The fungal DNA was extracted using a common Doyle and Doyle [32] method of nucleic acid extraction with CTAB. ITS rDNA regions were used for species determination with the primer pairs ITS1F and ITS4 [33]. The detailed procedure of PCR reaction and temperature parameters were the same as those described by Pusż and Urbaniak [8]. Sequencing, postreaction purification, and reading were performed by a sequencing service (Genomed S.A., Warsaw, Poland), using an ABI377XL Automated DNA Sequencer (Applied Biosystems, Carlsbad, CA, USA). The sequences were

**Tab. 3** Fungi collected on *S. herbacea*.

<b>Mały Śnieżny Kocioł</b>
<i>Alternaria alternata</i>
<i>Alternaria infectoria</i>
<i>Aspergillus brasiliensis</i>
<i>Ceuthospora</i> spp.
<i>Cladosporium allicinum</i>
<i>Melampsora arctica</i>
<i>Penicillium notatum</i>
<b>Pilsko Mt</b>
<i>Alternaria alternata</i>
<i>Alternaria infectoria</i>
<i>Ceuthospora</i> spp.
<i>Cladosporium allicinum</i>
<i>Penicillium notatum</i>
<i>Pestalotiopsis</i> spp.
<i>Truncatella angustata</i>
<b>Niżné Wahlenbergovo pleso</b>
<i>Alternaria alternata</i>
<i>Penicillium notatum</i>
<b>Furkotský štít</b>
<i>Alternaria alternata</i>
<i>Cladosporium allicinum</i>
<i>Penicillium notatum</i>

analyzed with FinchTV [34] and MEGA 5.0 [35]. Species determinations were verified using BLAST software [36]. Collected samples were deposited in the Herbarium of the Museum of Natural History in Wrocław (WRSŁ) with numbers from JBr-2017-0001 to JBr-2017-0038 (Tab. 4).

## Results

In this study, 17 taxa of fungi were collected from nine localities: eight taxa on *S. herbacea* and eight on *J. trifidus*. All detected microfungal species associated with the two glacial relicts are presented in Tab. 3 and Tab. 4. Current results were also compared with previously published data (Tab. 5, Tab. 6). The localities richest in fungi on *S. herbacea* were Mały Śnieżny Kocioł (Karkonosze Mts, Sudetes) and on *J. trifidus*, the Tatra Mts (Carpathian Mts). Detailed descriptions of all the findings are given below.

### Fungi collected on *S. herbacea*

#### Ascomycota

##### *Alternaria alternata* (Fr.) Keissl.

**Description.** Conidiophores  $50 \times 3\text{--}6\ \mu\text{m}$  pale brown to olive brown, forming bushy heads consisting of 4–8 conidial chains. Conidia  $20\text{--}63 \times 9\text{--}18\ \mu\text{m}$ , obclavate, with short conical beak at the tip, pale brown to light brown. GenBank accession numbers: MH118270, MH118271.

**Habitat.** Dead leaves, petioles.

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0001), at the top of Pilsko Mt (Beskid Mts, August 30, 2017; JBr-2017-0008), near Niżné Wahlenbergovo pleso (Tatra Mts, September 2, 2017; JBr-2017-0015), Furkotský štít (Tatra Mts, September 2, 2017; JBr-2017-0017).

**Comments.** Common fungus causing leaf spots, blights, and other symptoms on many dicotyledonous plants. Ubiquitous species that usually disperses in the air [15].

##### *Alternaria infectoria* E. G. Simmons

**Description.** Colonies pale grey to silvery with white and fluffy aerial mycelia. Conidiophores  $11\text{--}21\ \mu\text{m}$  long. Conidia  $20\text{--}27.5 \times 7.5\text{--}16\ \mu\text{m}$ , obclavate, in long or short chains, predominantly without longitudinal septa. GenBank accession number: MH118273.

**Habitat.** Dead leaves and petioles.

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0002), on the top of Pilsko Mt (Beskid Żywiecki, August 30, 2017; JBr-2017-0009).

**Comments.** Species from the Pleosporales order, ubiquitous, saprotrophic species which could be associated with seeds [37]. It was identified, for example, in Australia on *Tanacetum cinerariifolium* Trevir. leaves and dead flower stems (causing small black spots), and in the UK on *Triticum aestivum* L. [38,39].

##### *Aspergillus brasiliensis* Varga, Frisvad & Samson

**Description.** Conidiophores  $900\text{--}1,200\ \mu\text{m}$  long, unbranched, enlarged at the tip, forming swollen vesicles. Stipes hyaline. Conidia globose to sub-globose,  $3.5\text{--}5\ \mu\text{m}$  in diam., dark brown to black.

**Tab. 4** Fungi collected on *J. trifidus*.

<b>Śnieżka Mt</b>
<i>Arthrinium cuspidatum</i>
<i>Cladosporium herbarum</i>
<i>Phomatospora dinemasporium</i>
<b>Czarny Grzbiet</b>
<i>Arthrinium cuspidatum</i>
<i>Botrytis cinerea</i>
<i>Cladosporium herbarum</i>
<i>Periconia atra</i>
<b>Diablak</b>
<i>Botrytis cinerea</i>
<i>Periconia atra</i>
<i>Unguicularia costata</i>
<b>Chuda Turnia</b>
<i>Botrytis cinerea</i>
<i>Cladosporium herbarum</i>
<i>Periconia atra</i>
<i>Phaeosphaeria vagans</i>
<b>Ciemniak Mt</b>
<i>Cladosporium herbarum</i>
<i>Nimbomollisia eriophori</i>
<b>Nižné Wahlenbergovo pleso</b>
<i>Cladosporium herbarum</i>
<i>Unguicularia costata</i>
<b>Furkotský štít</b>
<i>Phaeosphaeria vagans</i>

**Habitat.** Dead leaves and petioles placed on PDA medium.

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0003).

**Comments.** Cosmopolitan, saprobic species, widespread in the environment.

*Ceuthospora* sp.

**Description.** Colonies black, leathery, rounded or oval 0.5 mm in diam., with one locule. Conidia 12–16 × 2–4 µm, subcylindrical, hyaline, with funnel-shaped apical appendages.

**Habitat.** Bottom side of dead leaves.

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0004), at the top of Pilsko Mt (Beskid Żywiecki, August 30, 2017; JBr-2017-0010).

**Comments.** Widespread fungal genus, usually causing leaf spots. Sutton [29] listed its occurrence in association with dicotyledonous plants. Many species of this genus are plant pathogens, i.e., *C. lauri* and *C. innumera* parasitize *Eucalyptus* leaves [40], and *C. phaeocomes* parasitizes holly leaves [41].

*Cladosporium allicinum* (Fr.) Bensch, U. Braun & Crous

**Description.** Colonies olivaceous to dark brown, powdery. Conidiophores 30–200 µm long, 3–6 µm wide, unbranched, light brown, with characteristic, long secondary ramoconidia. Conidia ovoid to lemon-shaped 4–6 × 3 µm, unicellular, pale to dark brown with dark hila, forming chains at the end of conidiophores, with prominent ornamentation [34]. GenBank accession number: MH118272.

**Habitat.** Dead leaves and petioles.

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0005), at the top of Pilsko Mt (Beskid Mts, August 30, 2017; JBr-2017-0011), Furkotský štít (Tatra Mts, September 2, 2017; JBr-2017-0018).

**Comments.** Species distributed worldwide, but not commonly isolated. Present on leaves and fruits of dicotyledons as a secondary saprotrophic infection on decaying parts [24]. In Germany, this species was isolated from various samples, including leaves of *Robinia pseudoacacia* L., *Acer campestre* L., and *Alnus glutinosa* (L.) Gaertn. [42].

*Penicillium notatum* Westling

**Description.** Colonies: at first yellow-green changing into dark green, velvety, subtle floccose. Conidiophores 250–500 µm, mononematous, two to three branches, hyaline. Metulae cylindrical with three–six flask-shaped phialides. Conidia globose to subglobose, hyaline, 3–4 µm in diam.

**Habitat.** Dead leaves and petioles placed on PDA medium.

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0007), at the top of Pilsko Mt (Beskid Mts, August 30, 2017; JBr-2017-0012), near Nižné Wahlenbergovo pleso (Tatra Mts, September 2, 2017; JBr-2017-0016), Furkotský štít (Tatra Mts, September 2, 2017; JBr-2017-0019).

**Comments.** Species common worldwide, inhabiting moist soils; spores present in the air. There are two other species of *Penicillium* genus associated with *S. herbacea*: *P. citrinum*, which was reported in the Apennines and on Surtsey island, and *P. palitans*,

which was collected also on Surtsey island [9,43]. All mentioned species likely belong to different sections: *P. notatum* belongs to the *Chrysogena* section, wherein colonies of species are characterized by having a velvety texture and producing penicillin (majority). *Penicillium citrinum* is assigned to sect. *Citrina*. The majority of species found in this section form symmetrical biverticillate conidiophores with flask-shaped phialides and small conidia. *Penicillium palitans* belongs to sect. *Fasciculata* with most species having granulose or fasciculate colony texture [44–46].

***Pestalotiopsis* sp.**

**Description.** Conidiomata acervular. Conidiophores  $10\text{--}15 \times 2 \mu\text{m}$ , hyaline, cylindrical. Conidia  $25 \times 6 \mu\text{m}$ , four–six-celled; pigmentation can be affected by environmental conditions.

**Habitat.** Twigs.

**Collected material.** Pilsko Mt (Beskid Mts, August 30, 2017; JBr-2017-0013).

**Comments.** Species of the genus *Pestalotiopsis* are common plant pathogens, which are not highly host-specific. They are often isolated as endophytes or as saprobes [47,48]. They may also cause grey blight disease of *Persea* spp. [49]. Most species are distinguished by conidia size, as well as by the length and the number of apical appendages [29].

***Truncatella angustata* (Pers.) S. Hughes**

**Description.** Conidiomata acervular. Conidia four-celled,  $16\text{--}19 \times 7\text{--}9 \mu\text{m}$ , slightly curved, with two dark brown, median cells, with two hyaline apical appendages.

**Habitat.** Dead petioles.

**Collected material.** Pilsko Mt (Beskid Mts, August 30, 2017; JBr-2017-0014).

**Comments.** Cosmopolitan species that is usually found on leaf spots on different genera of Ericaceae, Oleaceae, Rosaceae, and Salicaceae. The species was identified on *Malus domestica* Borkh. in the Netherlands, on *Rosa canina* L. in Kazakhstan, and on blueberry twigs (*Vaccinium* spp.) [50–52].

**Basidiomycota**

***Melampsora arctica* Rostr.**

**Description.** Uredinia intense yellow to pale orange, circular, mainly epiphyllous, pulverulent. Urediniospores globose,  $15\text{--}20 \times 17\text{--}25 \mu\text{m}$ . Paraphyses  $50\text{--}60 \mu\text{m}$  long, intermixed with urediniospores, colourless wall,  $5\text{--}7 \mu\text{m}$  thick at the base and  $3\text{--}5 \mu\text{m}$  thick at the top, rarely verrucose.

**Habitat.** Leaves (dead and alive).

**Collected material.** Above Mały Śnieżny Kocioł (Karkonosze Mts, July 20, 2017; JBr-2017-0006).

**Comments.** The data on the distribution of *M. arctica* summarized by Chlebicki [1] indicate that this species is relatively often found on *S. herbacea*. It was reported in both Polish and Slovakian parts of the Tatra Mountains [53]. *Melampsora arctica* is considered as an Arctic-Alpine species, and it was also noticed on other *Salix* species, e.g., *S. lapponum* or *S. hastata*, growing in Arctic-Alpine areas and in cold climates. This confirms the older data concerning the occurrence of *M. arctica* in the Alps, Scandinavia, Greenland, and North America [10,54].



Fungi collected on *J. trifidus*

### Ascomycota

*Arthrinium cuspidatum* (Cooke & Harkn.) Tranzschel

**Description.** Colonies black. Conidiophores 20–25 µm long, hyaline, with dark septa. Conidia 13–15 × 8–10 µm, one-celled, curved, brown, double-horned.

**Habitat.** Dead stems and leaves.

**Collected material.** Śnieżka Mt (Karkonosze Mts, July 20, 2017; JBr-2017-0020); Czarny Grzbiet (Karkonosze Mts, July 20, 2017; JBr-2017-0023).

**Comments.** This species was previously reported to inhabit *Juncus* and *Carex* species in the Eastern Alps, North America, and Scandinavia, and was collected in the Tatra and Karkonosze Mts [1]. In Scandinavia, the species was noted in Abisko Östra. Šandová [17,18] found *A. cuspidatum* on *J. trifidus* in the Czech Republic in Šumava, Karkonosze, and Hrubý Jeseník Mts. In the Czech Republic, this species seems to be common on *Juncus* spp. in subalpine and alpine belts [1,17,20].

*Botrytis cinerea* Pers.

**Description.** Conidiophores 1,500–2,000 × 15–20 µm, brown, highly branched. Conidia 10–16 × 6–9 µm, obovoid to ellipsoid, pale brown.

**Habitat.** All above-ground parts of a studied plant.

**Collected material.** Czarny Grzbiet; host growing on rocks (Karkonosze Mts, July 20, 2017; JBr-2017-0024); Diablak; host growing on rocks (Babia Góra massif, September 1, 2017; JBr-2017-0027); Chuda Turnia, *Junco trifidi-Festucetum airoidis* plant community (Tatra Mts, September 1, 2017; JBr-2017-0030).

**Comments.** Cosmopolitan, necrotrophic species, mostly growing on living and dead dicotyledonous plants. Most notable hosts are wine grapes and strawberry fruits. Brown lesions develop on twigs, slowly causing withering by breaching the plant cuticle and producing a wide range of metabolites [55]. Šandová [18] found *B. cinerea* in the Czech Republic in several mountain ranges: Šumava, Karkonosze Mts, Králický Sněžník, and Hrubý Jeseník Mts, suggesting that *B. cinerea* is not especially common on *J. trifidus*, but more frequently on other *Juncus* species.

*Cladosporium herbarum* (Pers.) Link

**Description.** Conidiophores 80–120 µm, long brown, erect. Conidia 6–10 × 3–5 µm, in branching chains, elliptical to cylindrical, thick walled, dark brown, no- or one-septate.

**Habitat.** Dead stems, leaves, and bracts.

**Collected material.** Śnieżka Mt (Karkonosze Mts, July 20, 2017; JBr-2017-0021); Czarny Grzbiet (Karkonosze Mts, July 20, 2017; JBr-2017-0025); Chuda Turnia (Tatra Mts, September 1, 2017; JBr-2017-0031); Ciemniak Mt (Tatra Mts, September 1, 2017; JBr-2017-0034); Nižné Wahlenbergovo pleso (Tatra Mts, September 2, 2017; JBr-2017-0036).

**Comments.** Cosmopolitan species, growing on many species of plants [19]. From *J. trifidus*, *C. herbarum* was reported in the Czech Republic [17,56].

*Phomatospora dinemasporium* J. Webster

**Description.** Conidiomata acervular, black, up to 200 µm in diam., superficial, densely setose. Setae up to 220 µm long, dark. Conidiophores 25 × 2 µm, hyaline. Conidia 9–11 × 1–2 µm, cylindrical.

**Habitat.** Dead leaves and bracts.

**Collected material.** Śnieżka Mt (Karkonosze Mts, July 20, 2017; JBr-2017-0022).

**Comments.** Common saprobic species, growing on plants from Poaceae and Juncaceae [57]. The species was found on leaves of *Populus tremula* L. in Germany, and on blades of *Secale cereale* L. [58].

***Nimbomollisia eriophori*** (L. A. Kirchn.) Nannf.

**Description.** Apothecia turbinate to discoid, sessile, 250–400 µm in diam., light brownish. Excipulum textura globosa, cells 10 µm at base, brown at flanks, light brown at the base and edge. Asci 70–80 × 12–15 µm, clavate. Spores 15 × 5 µm, fusiform, with a thin gelatinous coat. Paraphyses cylindrical, branched, segmented, with circinate tips.

**Habitat.** Dead stems.

**Collected material.** Ciemniak Mt (Tatra Mts, September 1, 2017; JBr-2017-0035).

**Comments.** Common saprobic species growing on various species of Cyperaceae and Juncaceae. Previously, this species was identified by Šandová on *J. trifidus* [18] and *J. filiformis* [59]. Müller and Défago [60] found this species on *Eriophorum angustifolium* Honck., *E. scheuchzeri* Hoppe and *Carex fusca* Bell et al.

***Periconia atra*** Corda

**Description.** Conidiophores 250–300 × 3–5 µm, brown, with a swollen apex. Conidia 5–10 µm in diam, brown, rounded.

**Habitat.** Dead stems, leaves, and bracts.

**Collected material.** Czarny Grzbiet (Karkonosze Mts, July 20, 2017; JBr-2017-0026) Diablak (Babia Góra massif, September 1, 2017; JBr-2017-0028) Chuda Turnia (Tatra Mts, September 1, 2017; JBr-2017-0032).

**Comments.** Common saprobic species growing on dead leaves of various species of Cyperaceae, Juncaceae, and Poaceae [19]. The species was identified on *Carex pendula* Huds., *C. riparia* Curtis, *Juncus* sp. [61–63], and *J. trifidus* [18].

***Phaeosphaeria vagans*** (Niessl) O. E. Erikss.

**Description.** Pycnidia 200–250 × 400–450 µm in diam., dark brown to black, ellipsoidal. Asci 135 × 20 µm, cylindrical. Ascospores 20–24 × 8–9 µm, six-celled, slightly curved.

**Habitat.** Dead stems.

**Collected material.** Chuda Turnia (Tatra Mts, September 1, 2017; JBr-2017-0033); Furkotský štít (Tatra Mts, September 1, 2017; JBr-2017-0038).

**Comments.** Common saprobic species growing on dead stems of species from Poaceae, Cyperaceae, and Juncaceae [17]. The species was found on dried grass culms in British Columbia (Canada) by Ceska and Ceska [64], and on plants from *Agrostis*, *Calamagrostis*, *Festuca*, and *Lolium* [65].

***Unguicularia costata*** (Boud.) Dennis



**Description.** Apothecia 150–200 µm in diam., 150 µm high, pale white, urn-shaped, sessile, superficial. Ascospores  $9\text{--}13 \times 2\text{--}2.5$  µm, straight, hyaline.

**Habitat.** Dead stems.

**Collected material.** Diablak (Babia Góra massif, September 1, 2017; JBr-2017-0029); Niżné Wahlenbergovo pleso (Tatra Mts, September 2, 2017; JBr-2017-0037).

**Comments.** The rarest of the identified species. Growing on dicotyledonous plants. Not common on *J. trifidus* [17]. This species was identified on *J. effusus* L. in the Czech Republic [66].

## Discussion

No fungal species exclusive to *S. herbacea* were found during this study. The occurrence of *Melampsora arctica*, the truly Arctic-Alpine species, above Mały Śnieżny Kocioł (Karkonosze Mts) confirmed the subarctic characteristic of *S. herbacea* and geographical connections of disjunctive localities that link the Alps, Carpathian Mts, Scandinavia, and Greenland (Tab. 5). *Melampsora arctica* has been also found in the Tatra Mts. (Carpathian Mts) by Chlebicki [1]. During this study, the presence of *Alternaria infectoria* (Mały Śnieżny Kocioł, Pilsko Mt) and *Cladosporium allicinum* (Mały Śnieżny Kocioł, Pilsko Mt, Furkotský štít) was noted for the first time on *S. herbacea*. The occurrence of *Alternaria alternata* – a species previously noted on *S. herbacea* in the Karkonosze Mts only by Pusz and Urbaniak [8] – has been confirmed in other dwarf willow populations (Mały Śnieżny Kocioł), as well as in new locations (Pilsko Mt, Furkotský štít, Niżné Wahlenbergovo pleso). Similarly, the occurrence of *Aspergillus brasiliensis* and *Ceuthospora* sp. in different locations in the Karkonosze Mts has been confirmed. *Ceuthospora* sp. has been observed for the first time in the Beskid Mts (Pilsko Mt) [8]. The *Penicillium notatum* previously reported in the Apennines and Karkonosze Mts was again collected in Karkonosze Mts, and also found in the Tatra and Beskid mountains [8,9]. The species in the *Pestalotiopsis* genus and *Truncatella angustata*, both previously reported on *S. herbacea* only in the Karkonosze Mts, were reported in the Pilsko Mt (Beskids Mts) [8].

Among the numerous fungal species inhabiting *J. trifidus*, some (i.e., *Lophodermium juncinum* and *Naeviella paradoxa*) were noted to exist exclusively on *J. trifidus* [1,18], whereas other species such as *Arthrinium cuspidatum*, *Ascochyta junci*, or *Leptosphaeria sepalorum* strictly inhabit various *Juncus* species, not only *J. trifidus* [17]. However, the occurrence of the mentioned oligophagous fungi species was not confirmed in the present study. *Lophodermium juncinum* has not been reported in Poland so far, with the closest known locations in the Eastern Alps (Tab. 6). *Naeviella paradoxa* has been noted in the Polish mountains (Karkonosze and Tatra Mts) only by Chlebicki [1]. The occurrence of *Arthrinium cuspidatum*, *Botrytis cinerea*, and *Cladosporium herbarum* has been confirmed in the locations studied in the Karkonosze Mts [17]. *Botrytis cinerea* was noted in the Tatra Mts and Babia Góra massif for the first time. The new, uncharted locations of *Nimbomollisia eriophori* and *Phaeosphaeria vagans* were found on *J. trifidus* in the Tatra Mts, and in the case of *Periconia atra*, also at Pilsko Mt.

In summary, the total number of fungi noticed during our research, as well as reported in previously on *S. herbacea* is 56, and on *J. trifidus* 98 species. In the case of *S. herbacea*, the most fungi-rich localities were the mountain ranges of the Karkonosze, Tatra, and Apennines Mts. Certainly, this species is connected with small, but quite numerous and widespread communities of *S. herbacea* especially in the Tatra Mts. The past 150 years of exploration of the Karkonosze Mts have also contributed to the relatively thorough knowledge of mountain mycobiota [21]. Likewise, the relatively broad knowledge of fungal biota associated with *J. trifidus* in the Karkonosze Mts may be the result of recent intensive, multiyear research. It is also fostered by the extensive *J. trifidus* populations. This subalpine species often covers areas that stretch for several kilometers of mountains peaks. It can be concluded that the mycobiota of both studied plant relicts seems to be highly diverse. However, according to results of Pusz and Urbaniak [8], detailed analyses

**Tab. 5** Fungi species reported on *S. herbacea* based on own observations and literature data.

Species	Locality										References	
	Apennine Mts	Karkonosze Mts	Tatra Mts	Beskid Mts	Alps	Khibiny Mts	Greenland	Rila Mts	Retezat Mts	Chornohora Mts		Rodna Mts
<i>Acremonium murorum</i> (Corda) W. Gams	×											[9]
<i>Alternaria alternata</i> (Fr.) Keissl.	×	×	*	*								[8,9]
<i>Alternaria infectoria</i> E. G. Simmons		*		*								
<i>Aspergillus brasiliensis</i> Varga, Frisvad & Samson		×										[8]
<i>Ceuthospora</i> spp.		×		*								[8]
<i>Cladosporium allicinum</i> (Fr.) Bensch, U. Braun & Crous		*	*	*								
<i>Cladosporium cladosporioides</i> (Fresen.) G. A. de Vries	×	×										[8,9]
<i>Cladosporium oxysporum</i> Berk. & M. A. Curtis	×											[9]
<i>Colletotrichum</i> spp.		×										[8]
<i>Botrytis cinerea</i> Pers.	×	×										[8,9]
<i>Epicoccum nigrum</i> Link	×											[9]
<i>Gibberella avenacea</i> R. J. Cook		×										[8]
<i>Gibberella baccata</i> (Wallr.) Sacc.		×										[8]
<i>Gibberella intricans</i> Wollenw.		×										[8]
<i>Lecanicillium lecanii</i> (Zimm.) Zare & W. Gams	×											[9]
<i>Lecanicillium longisporum</i> (Petch) Zare & W. Gams	×											[9]
<i>Linospora arctica</i> P. Karst.					×							[14]
<i>Melampsora arctica</i> Rostr.		*	×		×		×					[1]
<i>Melampsora epitea</i> Thüm.								×	×			[11,12]
<i>Mucor hiemalis</i> Wehmer	×											[9]
<i>Mycosphaerella maculicola</i> (G. Winter) Tomilin										×		[1]
<i>Mycosphaerella salicicola</i> (Fuckel) Johanson ex Oudem.							×					[10]
<i>Penicillium citrinum</i> Thom	×	×										[8,9]
<i>Penicillium notatum</i> Westling	×	×	*	*								[8,9]
<i>Pestalotia</i> spp.	×											[9]
<i>Pestalotiopsis</i> spp.		×		*								[8]
<i>Phleospora</i> sp.			×									[1]
<i>Phoma leveillei</i> Boerema & G. J. Bollen		×										[8]
<i>Pleuroceras insulare</i> (Johanson) M. Monod					×							[14]
<i>Pleuroceras groenlandicum</i> (Rostr.) M. E. Barr												[13]
<i>Rhytisma salicinum</i> (Pers.) Fr.		×	×					×			×	[1,11,67]
<i>Strasseria geniculata</i> (Berk. & Broome) Höhn.										×		[1]
<i>Truncatella angustata</i> (Pers.) S. Hughes		×		*								[8]
<i>Venturia subcutanea</i> Dearn.			×			×	×					[1,10]

× – species reported in literature;

\* – species collected during this study.

**Tab. 6** Fungi species reported on *J. trifidus* based on own observations and literature data.

Species	Locality										References
	Šumava Mts	Karkonosze Mts	Králický Sněžník	Hrubý Jeseník Mts	Ural Mts	Tatra Mts	Eastern Alps	Babia Góra massif	Chornohora Mts	Abisko region	
<i>Arthrinium cuspidatum</i> (Cooke & Harkn.) Tranzschel	×	×	×	×		×	×				[1,17,18]
<i>Arthrinium arundinis</i> (Corda) Dyko & B. Sutton					×	×					[19]
<i>Ascochyta caricicola</i> Melnik						×					[1]
<i>Ascochyta junci</i> (Oudem.) Melnik		×		×							[17]
<i>Aureobasidium pullulans</i> (de Bary & Löwen-thal) G. Arnaud						×					[19]
<i>Botrytis cinerea</i> Pers.	×	×	×	×		*		*			[18]
<i>Cistella fugiens</i> (W. Phillips) Matheis					×		×				[1,21]
<i>Cladosporium herbarum</i> (Pers.) Link	×	×	×	×		×					[18,19]
<i>Diplonaevia emergens</i> (P. Karst.) B. Hein		×							×		[1]
<i>Epicoccum nigrum</i> Link	×	×		×							[18]
<i>Hysteronaevia minutissima</i> (Rehm) Nannf.	×						×		×		[1,18,21]
<i>Hysteropezizella diminuens</i> (P. Karst.) Nannf.	×	×	×	×			×			×	[1,18,21]
<i>Lachnum calycioides</i> (Rehm) Rehm	×	×	×	×	×	×	×		×	×	[1,18,21]
<i>Lachnum diminutum</i> (Roberge ex Desm.) Rehm		×									[17]
<i>Lachnum roseum</i> (Rehm) Rehm	×						×				[1,18]
<i>Leptosphaeria sepalorum</i> (Vleugel) Lind					×		×			×	[1]
<i>Lophodermium juncinum</i> (Jaap) Terrier							×				[1]
<i>Mycosphaerella perexigua</i> (P. Karst.) Johanson	×	×	×	×						×	[1,18]
<i>Naeviella paradoxa</i> (Rehm) Clem.		×				×	×				[1,18]
<i>Nimbomollisia eriophori</i> (L. A. Kirchn.) Nannf.	×	×	×	×		*					[17,18]
<i>Penicillium expansum</i> Link						×					[19]
<i>Periconia atra</i> Corda	×	×	×			*		*			[18]
<i>Phaeosphaeria juncicola</i> (Rehm ex G. Winter) L. Holm					×		×		×		[1,21]
<i>Phaeosphaeria vagans</i> (Niessl) O. E. Erikss.				×		*					[17]
<i>Phialocephala</i> sp.				×							[17]
<i>Phomatospora dinemasporium</i> J. Webster	×	×	×	×			×		×		[1,18,21]
<i>Pseudoseptoria</i> sp.	×	×		×							[17]
<i>Pycnothyrium junci</i> Grove	×			×							[17]
<i>Septoria chanousiana</i> Ferraris		×									[17]
<i>Stagonospora junciseda</i> (Sacc.) Mussat	×										[17]
<i>Stagonospora caricinella</i> Brunaud		×						×			[1]
<i>Unguicularia costata</i> (Boud.) Dennis				×		*		*			[17]

× – fungi reported in literature data;

\* – fungi collected during this study.

still provide new data on the species diversity and the biogeography of fungal species, which justifies the need for further research in this direction.

## References

1. Chlebicki A. Biogeographic relationships between fungi and selected glacial relict plants. Łódź: Polish Botanical Society; 2002. (Monographiae Botanicae; vol 90). <https://doi.org/10.5586/mb.2002.001>
2. Hewitt GM. Some genetic consequences of ice ages, and their role in divergence and speciation. *Biol J Linn Soc Lond.* 1996;58:247–276. <https://doi.org/10.1006/bijl.1996.0035>
3. Hewitt GM. Genetic consequences of climatic oscillations in the Quaternary. *Philos Trans R Soc Lond B.* 2004;359:183–195. <https://doi.org/10.1098/rstb.2003.1388>
4. Taberlet P, Fumagalli L, Wust-Saucy AG, Cosson JF. Comparative phylogeography and postglacial colonization routes in Europe. *Mol Ecol.* 2002;7:453–464. <https://doi.org/10.1046/j.1365-294x.1998.00289.x>
5. Ronikier M, Cieślak E, Korbecka G. High genetic differentiation in the alpine plant *Campanula alpina* Jacq. (Campanulaceae): evidence for glacial survival in several Carpathian regions and long-term isolation between the Carpathians and the Alps. *Mol Ecol.* 2008;17:1763–1775. <https://doi.org/10.1111/j.1365-294X.2008.03664.x>
6. Slovák M, Kučera J, Turis P, Zozomová-Lihová J. Multiple glacial refugia and postglacial colonization routes inferred for a woodland geophyte, *Cyclamen purpurascens*: patterns concordant with the Pleistocene history of broadleaved and coniferous tree species. *Biol J Linn Soc Lond.* 2012;105:741–760. <https://doi.org/10.1111/j.1095-8312.2011.01826.x>
7. Urbaniak J, Kwiatkowski P, Ronikier M. Postglacial history and current population genetic diversity of a central-European forest plant *Hacquetia epipactis*. *Preslia.* 2018;90:39–57. <https://doi.org/10.23855/preslia.2018.039>
8. Pusz W, Urbaniak J. Foliar diseases of willows (*Salix* spp.) in selected locations of the Karkonosze Mts (the Giant Mts). *Eur J Plant Pathol.* 2017;148:45–51. <https://doi.org/10.1007/s10658-016-1067-7>
9. Long O, Longa C, Luisa P, Tosi S. Conidial fungi from *Salix herbacea* leaf litter and their growth temperature preferences. *Boletín Micológico.* 2018;20:91–95.
10. Barr MEB. Northern Pyrenomycetes. I, Canadian Eastern Arctic. Montreal: Institut botanique de l'Université de Montréal; 1959.
11. Denchev CM. Bulgarian Uredinales. *Mycotaxon.* 1995;55:405–465.
12. Mycobank. Specimen record #94273 n.d. [Internet]. 2019 [cited 2018 Jun 14]. Available from: <http://www.mycobank.org/BioloMICS.aspx?Table=Mycobank%20specimens&Rec=94273&Fields=All>
13. Mycobank. Specimen record #65307 n.d. [Internet]. 2019 [cited 2018 Jun 14]. Available from: <http://www.mycobank.org/BioloMICS.aspx?Table=Mycobank%20specimens&Rec=65307&Fields=All>
14. Monod M. Monographie taxonomique des Gnomoniaceae. Horn: Berger; 1983.
15. Pusz W. Plants' healthiness assessment as part of the environmental monitoring of protected mountainous area in the example of Karkonosze (Giant) Mts. (SW Poland). *Environ Monit Assess.* 2016;188:544. <https://doi.org/10.1007/s10661-016-5551-5>
16. Farr DF, Bills GF, Chamuris GP, Rossman AY. Fungi on plants and plant products in the United States. St. Paul, MN; 1989. (Contributions from the U.S. National Fungus Collections; vol 5).
17. Šandová M, Chlebicki A. Fungi on *Juncus trifidus* in the Czech Republic (II) with taxonomical notes to some species. *Czech Mycol.* 2004;56:203–221.
18. Šandová M. Fungi on *Juncus trifidus* in the Czech Republic. I. *Czech Mycol.* 2004;56:63–84.
19. Chlebicki A. Some endophytes of *Juncus trifidus* from Tatra Mts. in Poland. *Acta Mycol.* 2009;44:11–17. <https://doi.org/10.5586/am.2009.003>
20. Scheuer C. Some important corrections to the ascomycetes recorded on Cyperaceae and Juncaceae from the Eastern Alps by Scheuer (1988). *Mycotaxon.* 1999;73:33–44.

21. Scheuer C. Ascomyceten auf Cyperaceen und Juncaceen im Ostalpenraum. *Bibl Mycol.* 1988;123:1–274.
22. Hulten E. Phytogeographical connections of the North Atlantic. In: Löve Å, Löve D, editors. *North Atlantic biota and their history: a symposium held at the University of Iceland, Reykjavík under the auspices of the University of Iceland and the Museum of Natural History; 1962 Jul; Reykjavík, Iceland.* Oxford: Pergamon Press; 1963. p. 45–72. <https://doi.org/10.5962/bhl.title.10237>
23. Meusel H, Jäger E, Weinert E, editors. *Vergleichende Chorologie der zentraleuropäischen Flora.* Jena: G. Fischer; 1965.
24. Bensch K, Braun U, Groenewald JZ, Crous PW. The genus *Cladosporium*. *Stud Mycol.* 2012;72:1–401. <https://doi.org/10.3114/sim0003>
25. Henderson DM. *The rust fungi of the British Isles: a guide to identification.* Kew: British Mycological Society; 2004.
26. Brandenburger W. *Parasitische Pilze an Gefäßpflanzen in Europa.* Stuttgart: Spektrum Akademischer Verlag; 1985.
27. Raper KB, Thom C. *A manual of the penicillia.* New York, NY: Hefner Publishing Company; 1968.
28. Ellis MB, Ellis JP. *Microfungi on land plants: an identification handbook.* New York, NY: Macmillan; 1985.
29. Sutton BC. *The Coelomycetes. Fungi imperfecti with pycnidia, acervuli and stromata.* Kew: Commonwealth Mycological Institute; 1980.
30. Index Fungorum [Internet]. 2019 [cited 2018 Oct 31]. Available from: <http://www.indexfungorum.org/names/Names.asp>
31. Mirek Z, Piękos-Mirkowa H, Zajac A, Zajac M, editors. *Flowering plants and pteridophytes of Poland: a checklist.* Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2002. (Biodiversity of Poland; vol 1).
32. Doyle J, Doyle J. A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochemical Bulletin.* 1987;19:11–15.
33. White T, Bruns T, Lee S, Taylor J. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis M, Gelfand D, Shinsky J, White T, editors. *PCR protocols: a guide to methods and applications.* San Diego, CA: Academic Press; 1990. p. 315–322.
34. Patterson J, Chamberlain B, Thayer D. FinchTV ver. 1.4 [Software]. Seattle, WA: Geospiza Inc.; 2012 [cited 2017 Dec 2]. Available from: <https://digitalworldbiology.com/FinchTV>
35. Tamura K, Peterson D, Peterson N, Stecher G, Nei M, Kumar S. MEGA5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Mol Biol Evol.* 2011;28:2731–2739. <https://doi.org/10.1093/molbev/msr121>
36. National Center for Biotechnology Information, U.S. National Library of Medicine. BLAST: Basic Local Alignment Search Tool [Internet]. 2017 [cited 2018 Apr 19]. Available from: <https://blast.ncbi.nlm.nih.gov/Blast.cgi>
37. Silva BMA, Prados-Rosales R, Espadas-Moreno J, Wolf JM, Luque-Garcia JL, Gonçalves T, et al. Characterization of *Alternaria infectoria* extracellular vesicles. *Med Mycol.* 2014;52:202–210. <https://doi.org/10.1093/mmy/myt003>
38. Moslemi A, Ades PK, Groom T, Nicolas ME, Taylor PWJ. *Alternaria infectoria* and *Stemphylium herbarum*, two new pathogens of pyrethrum (*Tanacetum cinerariifolium*) in Australia. *Australas Plant Pathol.* 2017;46:91–101. <https://doi.org/10.1007/s13313-016-0463-y>
39. Woudenberg JHC, Groenewald JZ, Binder M, Crous PW. *Alternaria* redefined. *Stud Mycol.* 2013;75:171–212. <https://doi.org/10.3114/sim0015>
40. Park RF, Keane PJ, Wingfield MJ, Crous PW. Fungal diseases of eucalypt foliage. In: Keane PJ, Kile GA, Podger FD, Brown BN, editors. *Diseases and pathogens of eucalypts.* Collingwood: CSIRO Publishing; 2000. p. 153–239.
41. Henslow JS, Skepper E. *Flora of Suffolk: a catalogue of the plants (indigenous or naturalized) found in a wild state in the county of Suffolk.* Cambridge: Cambridge University Press; 2013. (Cambridge Library Collection – Botany and Horticulture). <https://doi.org/10.1017/CBO9781139506892>
42. Bensch K, Groenewald JZ, Braun U, Dijksterhuis J, de Jesús Yáñez-Morales M, Crous PW.



- Common but different: the expanding realm of *Cladosporium*. *Stud Mycol.* 2015;82:23–74. <https://doi.org/10.1016/j.simyco.2015.10.001>
43. Eyjólfsson G. Investigation of the fungi of Surtsey 2008. *Surtsey Research.* 2009;12:105–111.
  44. Houbraken J, Samson RA. Phylogeny of *Penicillium* and the segregation of Trichocomaceae into three families. *Stud Mycol.* 2011;70:1–51. <https://doi.org/10.3114/sim.2011.70.01>
  45. Houbraken J, Frisvad JC, Samson RA. Taxonomy of *Penicillium* section *Citrina*. *Stud Mycol.* 2011;70:53–138. <https://doi.org/10.3114/sim.2011.70.02>
  46. Visagie CM, Houbraken J, Frisvad JC, Hong SB, Klaassen CHW, Perrone G, et al. Identification and nomenclature of the genus *Penicillium*. *Stud Mycol.* 2014;78:343–371. <https://doi.org/10.1016/j.simyco.2014.09.001>
  47. Liu AR, Chen SC, Wu SY, Xu T, Guo L, Jeewon R, et al. Cultural studies coupled with DNA based sequence analyses and its implication on pigmentation as a phylogenetic marker in *Pestalotiopsis* taxonomy. *Mol Phylogenet Evol.* 2010;57:528–535. <https://doi.org/10.1016/j.ympev.2010.07.017>
  48. Hu H, Jeewon R, Zhou D, Zhou T, Hyde K. Phylogenetic diversity of endophytic *Pestalotiopsis* species in *Pinus armandii* and *Ribes* spp.: evidence from rDNA and  $\beta$ -tubulin gene phylogenies. *Fungal Divers.* 2007;24:1–22.
  49. Valencia AL, Torres R, Latorre BA. First report of *Pestalotiopsis clavispora* and *Pestalotiopsis* spp. causing postharvest stem end rot of avocado in Chile. *Plant Dis.* 2011;95:492–492. <https://doi.org/10.1094/PDIS-11-10-0844>
  50. Wenneker M, Pham KTK, Boekhoudt LC, de Boer FA, van Leeuwen PJ, Hollinger TC, et al. First report of *Truncatella angustata* causing postharvest rot on ‘Topaz’ apples in the Netherlands. *Plant Dis.* 2016;101:508–508. <https://doi.org/10.1094/PDIS-09-16-1374-PDN>
  51. Eken C, Spanbayev A, Tulegenova Z, Abiev S. First report of *Truncatella angustata* causing leaf spot on *Rosa canina* in Kazakhstan. *Australas Plant Dis Notes.* 2009;4:44–45.
  52. Espinoza JG, Briceño EX, Keith LM, Latorre BA. Canker and twig dieback of blueberry caused by *Pestalotiopsis* spp. and a *Truncatella* sp. in Chile. *Plant Dis.* 2008;92:1407–1414. <https://doi.org/10.1094/PDIS-92-10-1407>
  53. Mułenko W, Kozłowska M, Sałata B. Microfungi of the Tatra National Park. A checklist. Cracow: W. Szafer Institute of Botany, Polish Academy of Sciences; 2004.
  54. Watling R. Larger Arctic-Alpine fungi in Scotland. In: Laursen GA, Ammirati JF, Redhead SA, editors. *Arctic and Alpine mycology II*. Boston, MA: Springer; 1987. p. 17–45. (Environmental Science Research; vol 34). [https://doi.org/10.1007/978-1-4757-1939-0\\_3](https://doi.org/10.1007/978-1-4757-1939-0_3)
  55. Collado I, Aleu J, Hernández-Galán R, Duran-Patron R. Botrytis species: an intriguing source of metabolites with a wide range of biological activities. Structure, chemistry and bioactivity of metabolites isolated from *Botrytis* species. *Curr Org Chem.* 2000;4:1261–1286. <https://doi.org/10.2174/1385272003375815>
  56. Bettucci L, Alonso R, Tiscornia S. Endophytic mycobiota of healthy twigs and the assemblage of species associated with twig lesions of *Eucalyptus globulus* and *E. grandis* in Uruguay. *Mycol Res.* 1999;103:468–472. <https://doi.org/10.1017/S0953756298007205>
  57. van Ryckegem G, Verbeken A. Fungal diversity and community structure on *Phragmites australis* (Poaceae) along a salinity gradient in the Scheldt estuary (Belgium). *Nova Hedwigia.* 2005;80(1–2):173–197. <https://doi.org/10.1127/0029-5035/2005/0080-0173>
  58. Crous PW, Verkley GJM, Christensen M, Castañeda-Ruiz RF, Groenewald JZ. How important are conidial appendages? *Persoonia.* 2012;28:126–37. <https://doi.org/10.3767/003158512X652624>
  59. Šandová M. Contribution to the knowledge of herbicolous Ascomycetes and mitosporic fungi in the Sumava Mountains (Czech Republic). *Fritschiana.* 2003;42:59–66.
  60. Müller E, Defago G. *Beloniella* (Sacc.) Boud. und *Dibeloniella* Nannf., zwei wenig bekannte Discomycetengattungen. *Sydowia.* 1967;20:157–168.
  61. Keißler K. Mykologische Mitteilungen. I. Nr. 1–30. *Annalen des Naturhistorischen Museums in Wien.* 1922;35:1–35.
  62. Jaap O. Weitere Beiträge zur Pilzflora von Triglitz in der Prignitz. *Verhandlungen des Botanischen Vereins der Provinz Brandenburg.* 1922;64:8–60.



63. Fell JW, Hunter IL. Fungi associated with the decomposition of the black rush, *Juncus roemerianus*, in South Florida. *Mycologia*. 1979;71:322–342.  
<https://doi.org/10.2307/3759156>
64. Ceska O, Ceska A. Observation 134698: *Phaeosphaeria vagans* (Niessl) O. E. Erikss. [Internet]. 2013 [cited 2018 Apr 19]. Available from: [http://mushroomobserver.org/observer/show\\_observation/134698](http://mushroomobserver.org/observer/show_observation/134698)
65. Webster J. *Graminicolous pyrenomycetes*. V. Conidial states of *Leptosphaeria michotii*, *L. microscopica*, *Pleospora vagans* and the perfect state of *Dinemasporium graminum*. *Transactions of the British Mycological Society*. 1955;38:347–365.  
[https://doi.org/10.1016/S0007-1536\(55\)80038-1](https://doi.org/10.1016/S0007-1536(55)80038-1)
66. Svrček M. New or less known Discomycetes. XIV. *Czech Mycol*. 1986;40:203–207.
67. Mycobank. Specimen record #105812 n.d. [Internet]. 2019 [cited 2018 Jun 14]. Available from: <http://www.mycobank.org/BioMICS.aspx?Table=Mycobank%20specimens&Rec=105812&Fields=All>