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# FUNGAL DIVERSITY AND SEASONAL SUCCESSION UNDER INVASIVE MOSS *CAMPYLOPUS INTROFLEXUS* AND OTHER PLANTS IN DISTURBED PEATLANDS

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**Abstract**

Repečkienė J., Jukonienė I., Salina O., 2015: Fungal diversity and seasonal succession under invasive moss *Campylopus introflexus* and other plants in disturbed peatlands [Grybų įvairovė ir sezoninė kaita po invazine samana *Campylopus introflexus* ir kitais augalais pažeistose pelkėse]. – Bot. Lith., 21(1): 46–56.

The distribution of invasive moss *Campylopus introflexus* (Hedw.) Brid. may have negative influence on natural restoration of plant cover in peatlands due to the accumulation of heavy decomposing residues and suppression of the growth of microorganisms in peat. Species composition of fungal communities and seasonal succession under mosses *C. introflexus* and *Polytrichum strictum,* vascular plant *Calluna vulgaris* and bare peat were studied in two naturally regenerating disturbed peatlands in Lithuania. Cultivable fungi were isolated from peat and enumerated by applying the serial dilution plate technique. A total of 66 species of fungi ascribed to 21 genera (among these 30 species from 13 genera under moss *C. introflexus*) were identified. Fungus species of the genera *Penicillium*, *Trichoderma, Mortierella* and *Paecilomyces* dominated. The highest diversity of fungal species was found in Laukėsa under *Calluna vulgaris.* Differences in the structure of fungal communities were found in Mūšos Tyrelis in autumn and in Laukėsa in spring. Significant differences in species diversity under various plants were obtained only in summer. The Gleason species diversity index for peat under *C. introflexus* was not very high (1.77–2.58) in different seasons. Fungal species composition under moss *C. introflexus* did not show pronounced characteristic peculiarities compared to other plants and was similar to that in bare peat. The obtained data are important for the prediction of fungal community succession in peatlands and biodegradation level of plant residues.

**Keywords:** *Campylopus introflexus*, fungi, peatlands, seasonal succession.

## INTRODUCTION

Invasive moss *Campylopus introflexus* (Hedw.) Brid., which has native range in Southern hemisphere, was firstly recorded in Europe in 1941 and recently it has been distributed in nearly all countries of Europe (Hassel & Söderström, 2005). From the highly oceanic temperate regions the species spread quickly to more suboceanic or even subcontinental ones; recently it has been found as far northwards as Norway and Sweden and as far eastwards as Poland and Lithuania (Hasse, 2007). In Mediterranean region, *C. introflexus* has been recorded in Azores, Balkans, France, Italy, Madeira, Montenegro, Portugal, Sardinia, Slovenia, single records are known from Canary Islands, Corsica and Turkey (Ros et al., 2013). In Lithuania, *C. introflexus* was first found in 1996 (Jukonienė, 2003). Unlike in Western Europe, where the species occupies mostly seminatural sand communities (Hasse, 2007), in Lithuania, *C. introflexus* most frequently invades disturbed bogs (Jukonienė, 2003). Overall, the overgrowth of deeply drained peat bogs with mosses is a negative phenomenon, because they create adverse conditions for the development of other plants and other organisms. The expansion of invasive moss can have negative impact on natural restoration of plant cover in cutover peatlands or other damaged sites, because its dense carpet blocks the penetration of vascular plants (Equihua & Usher, 1993).

The parameters of microorganism population density and species composition are often used to characterize the functioning of soil ecosystem. Soil microorganisms are directly responsible for the decomposition of plant residues, and fungi are more important than bacteria in this process (Croft et al., 2001; Thorman & Rice, 2007; Artz et al., 2008). Fungi due to their physiological properties are able to take part in the initial stages of moss decomposition (Tsuneda et al., 2001; Grum-Grzhymaylo & Bilanenko, 2010). This explains the great attention given to the study of fungal communities in bogs. Phenolic compounds, lipids, cellulose, lignin existing in moss chemical composition influence the accumulation of heavily decomposing plant residues in soil and suppress the growth of other organisms (Aerts et al., 1999). Negative influence of mosses on the development of wood-decomposing fungi has been reported (Votintseva, 2007). Several aspects of seasonal changes in abundance and fungal species diversity and distribution, influence of biotic and abiotic factors have been studied during last decade (Golovchenko et al., 2010; Andersen & Price, 2012).

There are reports about microbial communities in restored cutover peatlands (Andersen et al., 2010); however there are no data on fungal communities in peat under moss *C. introflexus* growing in human-damaged peatlands. Fungus species richness and amount of colony forming units (CFU) in various peatlands of Lithuania were ascertained during our initial investigations (Repečkienė et al., 2012). In this study, the attention was paid on fungal species occurrence rate, population density of dominant species and their seasonal succession under different plants. Based on the results of our previous investigations, two peatlands – Mūšos Tyrelis (with the largest amount of fungi CFU) and Laukėsa (with the richest fungal species composition) were selected for the current study and analysis.

The aim of our study was to determine species composition of fungi under moss *C. introflexus* in naturally regenerating disturbed peatlands, ascertain the tendencies of seasonal succession in fungal communities and compare the obtained data with the peculiarities of fungal communities under other plants growing in these peatlands. We addressed the following questions: 1) Does the structure of fungal communities differ in separate peat bogs?; 2) How does fungal species composition and abundance change during the seasons?; 3) Are there any differences in fungal species composition, occurring in peat under the invasive moss compared to other plant species and bare peat?

## MATERIALS AND METHODS

### Site description

The investigations were carried out in two peatlands: Mūšos Tyrelis (northwestern part of Lithuania: 56°20′05″ N, 23°30′59″ E) and Laukėsa (southwestern part of Lithuania: 55°16′69″ N, 22°53′53″ E). The peatlands are located in two different climatic subregions. Mean annual temperature in the subregion, where Laukėsa peatland is located, is +6.7–7 .1°C, annual amount of precipitation – 610 mm. Characteristics of climate of the subregion, where Mūšos Tyrelis peatland is located, are as follows: mean annual temperature – +6.3–6.6°C, annual amount of precipitation – 635 mm (Bukantis, 2013).

Both peatlands are former raised bogs; nowadays they are deeply drained and used for peat extraction. In the study plots, natural layer of vegetation was removed 10–20 years ago and recent plant cover has formed in the process of secondary succession. The vegetation in the studied peatlands is characterized by scarce cover of trees (*Betula pendula* Roth and *Pinus sylvestris* L.) (20%) and shrub layers (30%). The cover of dwarf shrub and herb layers vary in different peatlands: in Mūšos Tyrelis the most abundant were *Calluna vulgaris* (L.) Hull. and *Vaccinium vitis-idaea* L., in Laukėsa – various herb species (e.g. *Calamagrostis epigejos* (L.) Roth, *Agrostis stolonifera* L., *Solidago canadensis* L., *Eriophorum angustifolium* Honck). Bryophyte species *Campylopus introflexus* (Hedw.) Brid. prevailed in both peatlands.

Most of the estimated physico-chemical parameters are characteristic of upland bogs: extremely acid peat (pH 2.8–4.1), low amounts of total phosphorus and potassium (Table 1). The amount of organic matter was close to 90%.

Table 1. Chemical parameters of peat at the studied sites (MT – Mūšos Tyrelis, L – Laukėsa)

| Chemical parameter | Peatland | Sampling site | | |
|---|---|---|---|---|
| | | Under *Campylopus introflexus* | Under *Calluna vulgaris* | Bare peat |
| Total nitrogen, g $kg^{-1}$ | MT | 8 | 10 | 13 |
| | L | 13 | 12 | 12 |
| Total phosphorus, g $kg^{-1}$ | MT | 0.9 | 1 | 0.8 |
| | L | 1 | 0.9 | 0.8 |
| Total potassium, g $kg^{-1}$ | MT | 0.2 | 0.2 | 0.2 |
| | L | 0.3 | 0.2 | 0.3 |
| Organic carbon, % | MT | 47 | 53 | 42 |
| | L | 44 | 44 | 49 |
| Soil organic matter, % | MT | 94 | 93 | 82 |
| | L | 88 | 88 | 84 |
| C: N | MT | 58.8 | 53.0 | 32.3 |
| | L | 33.9 | 36.7 | 40.8 |
| pH | MT | 4.0 | 2.8 | 4.1 |
| | L | 3.7 | 3.9 | 3.7 |

**Isolation of cultivable fungi**

The peat for microbiological analysis was sampled from each site from 0–10 cm layer under various plants: 1) invasive moss *Campylopus introflexus* (Hedw.) Brid., 2) common heather *Calluna vulgaris* (L.) Hull, 3) strict haircap *Polytrichum strictum* Menzies ex Brid., 4) bare peat in September 2010, April and June 2011. Peat samples were taken randomly from five points within circle area (10 m diameter) and a conjugated sample (about 500 g of peat) prepared.

Microscopic fungi from peat were isolated and counted applying the serial dilution plate technique: 5 g of peat was shaken in 95 ml of sterile water for 10 min and 1 ml of peat suspension (dilution 1:10000) was sown in five replications on the surface of malt agar with chloramphenicol (50 mg $l^{-1}$, for bacterium growth inhibition) (Carter, 1993; ISO 10381-6:2009). Czapek, potato-dextrose, Sabouraud CAF and Czapek yeast autolysis agar were used additionally for purification and identification of fungal isolates. Fungal species were identified with reference to their cultural and morphological characteristics using various manuals (Pitt, 1979; Bisset, 1991; Chaverri & Samuels, 2003; Samson & Frisvad, 2004; Jaklitsch et al., 2006; Domsh et al., 2007; Pečiulytė & Bridžiuvienė, 2008).

**Characterization of fungal community**

Occurrence rate (OR) of various fungal species was defined as the ratio of the number of peat samples in which given species was detected to the total number of the analysed samples and expressed in %. Population density (PD) was calculated as ratio between the number of isolates of certain species and the total number of isolates and expressed in % (Golovchenko et al., 2002).

For species diversity, the Gleason index was calculated: $G = n / \ln (N)$, where $n$ is the number of distinct pathotypes, ln is the common logarithm and $N$ is the number of individuals in a sample. The Sørensen index was used to compare the similarities of fungal species composition between peatlands.

**Statistical analysis**

To ascertain differences of the Gleason indices between sampling plots (peatlands) and species diversity under different vegetation cover, non parametric tests (Mann-Whitney U and Kruskal-Wallis) were used by employing the SPSS 16 statistical package (SPSS, 2007). All differences were significant at 0.05 probability level.

Cluster analyses were performed using the Bray-Curtis coefficient with the Cluster Programme of the Primer package.

## RESULTS

**Fungal species diversity in the investigated peatlands**

During the research, a total of 2040 strains of fungi were isolated from Mūšos Tyrelis (1294 strains) and

Laukėsa peatlands (746 strains). In different seasons, 44 species of fungi belonging to 14 genera were isolated under various plants from Mūšos Tyrelis peatland. Larger number of fungal species were isolated from Laukėsa peatland – 51 species of 20 genera. The largest number of fungi were found in Laukėsa under *Calluna vulgaris,* and the smallest number – at the same site under *Polytrichum strictum* (Table 2).

A total of 66 species of fungi belonging to 21 genera from the order *Zygomycota* and the group of anamorphic fungi were recorded (Table 3). Of the 66 isolated species, *Penicillium* fungi prevailed in both studied peatlands during all seasons (32 species or 48.5% of all records). In the second place according to species diversity, was the genus *Trichoderma* – seven species. Five of these belong to *Pachybasium* section: *T. hamatum* (Bonord.) Bainier*, T. harzianum* Rifai, *T. fertile* Bissett, *T. polysporum* (Link ex Pers.) Rifai, *T. virens* (J.H.Mill., Giddens et A.A.Foster) Arx, whereas *T. viridescens* (A.S. Horne et H.S.Will.) Jaklisch et Samuels belongs to *Trichoderma* and *T. longibrachiatum* Rifai – to *Longibrachiatum* section.

Fungi of the *Mortierella* and *Paecilomyces* genera were widely distributed as well. From the other genera, only 1–2 species were identified.

Some of the isolated fungal species were found in the peat of a particular peatland. For example, *Aureo-*

Table 2. Number of fungal species isolated from the investigated peatlands during seasons

| Peatland | Peat sampling variants | Number of species | | | | |
|---|---|---|---|---|---|---|
| | | Autumn | Spring | Summer | Total | Total |
| Mūšos Tyrelis | *Campylopus introflexus* | 9 | 9 | 12 | 22 | 44 |
| | *Calluna vulgaris* | 9 | 12 | 13 | 23 | |
| | *Polytrichum strictum* | 15 | 12 | 7 | 26 | |
| | Bare peat | 9 | 9 | 8 | 20 | |
| Laukėsa | *Campylopus introflexus* | 14 | 11 | 11 | 24 | 51 |
| | *Calluna vulgaris* | 18 | 7 | 13 | 30 | |
| | *Polytrichum strictum* | 12 | 6 | 8 | 17 | |
| | Bare peat | 17 | 10 | 12 | 26 | |

Table 3. Taxonomic composition of fungal species isolated from Mūšos Tyrelis and Laukėsa peatlands

| Order, group | Genus | Number of species | |
|---|---|---|---|
| | | Mūšos Tyrelis | Laukėsa |
| *Zygomycota* | *Mortierella* Coem. | 4 | 3 |
| | *Umbelopsis* Amos et H.L. Barnett | 2 | 1 |
| | *Mucor* P. Micheli ex Fr. | 1 | 1 |
| | *Zygorynchus* Vuill. | 0 | 1 |
| *Anamorphic fungi* | *Acremonium* Link | 1 | 1 |
| | *Alternaria* Ness | 1 | 1 |
| | *Aspergillus* Link | 1 | 2 |
| | *Aureobasidium* Viala et G. Boyer | 0 | 1 |
| | *Cladosporium* Link | 1 | 1 |
| | *Exophiala* J.W. Carmich. | 0 | 1 |
| | *Fusarium* Link | 0 | 1 |
| | *Oidiodendron* Robak | 2 | 1 |
| | *Paecilomyces* Bainier | 2 | 3 |
| | *Penicillium* Link | 21 | 22 |
| | *Phoma* Sacc. | 1 | 1 |
| | *Scopulariopsis* Bainier | 1 | 1 |
| | *Talaromyces* C.R. Benj. | 0 | 1 |
| | *Trichoderma* Pers. | 5 | 6 |
| | *Trichosporiella* Kamyschko | 0 | 1 |
| | *Verticillium* Nees | 1 | 1 |

*basidium pullulans, Fusarium sporotrichioides, Paecilomyces farinosus, Penicillium digitatum, Penicillium purpurogenum, Phoma eurypena* were isolated only from the peat of Laukėsa. Meantime, *Mortierella alpina, Umbelopsis rammaniana* and some *Penicillium* species (*P. viridicatum* and *P. waksmanii*) were characteristic of Mūšos Tyrelis peatland.

The occurrence rate of dominant species in both peatlands was calculated. The species with OR higher than 16.6% are presented in Table 4. Species with OR ≥ 30.0% were considered to be frequent and OR ≥ 60.0% – dominant. *Mortierella hyalina*, *Penicillium lividum*, *P. montanense*, *P. roquefortii*, *Trichoderma hamatum* and *Umbelopsis isabellina* were isolated frequently in both studied peatlands. In Mūšos Tyrelis peatland, *Mucor hiemalis*, *Oidiodendron flavum*, *Penicillium thomii*, *P. waksmanii* and *Trichoderma virens*, and in Laukėsa, *Paecilomyces carneus*, *P. farinosus*, *Penicillium chrysogenum*, *P. purpurogenum* and *Verticillium* sp. were recorded as frequent or dominant species.

## Fungal species succession during seasons

Table 4. Fungal species isolated from Mūšos Tyrelis and Laukėsa peatlands with occurrence rate ≥ 16.6%

| Fungal species | Occurrence rate, % | |
|---|---|---|
| | Mūšos Tyrelis | Laukėsa |
| *Acremonium charticola* (Lindau) W. Gams | 8.3 | 16.6 |
| *Aureobasidium pullulans* (de Bary) G. Arnaud | 0 | 16.6 |
| *Aspergillus niger* Tiegh. | 16.6 | 8.3 |
| *Cladosporium cladosporioides* (Fresen.) G.A. de Vries | 25.0 | 16.6 |
| *Fusarium sporotrichioides* Sherb. | 0 | 16.6 |
| *Mortierella alpina* Peyronel | 16.6 | 0 |
| *Mortierella hyalina* (Harz) W. Gams | 41.6 | 58.3 |
| *Mortierella minutissima* Tiegh. | 16.6 | 25.0 |
| *Mortierella polycephala* Coem. | 16.6 | 8.3 |
| *Mucor hiemalis* Wehmer | 50.0 | 16.6 |
| *Oidiodendron flavum* von Szilvinyi | 33.3 | 25.0 |
| *Paecilomyces carneus* (Duché et R. Heim) A.H.S.Br. et G.Sm. | 8.3 | 33.3 |
| *Paecilomyces farinosus* (Holmsk. et Gray) A.H.S.Br. et G.Sm. | 0 | 41.6 |
| *Paecilomyces variotii* Bainier | 25.0 | 16.6 |
| *Penicillium chrysogenum* Thom | 16.6 | 91.6 |
| *Penicillium crustosum* Thom | 16.6 | 0 |
| *Penicillium digitatum* (Pers.) Sacc. | 0 | 16.6 |
| *Penicillium janthinellum* Biourge | 8.3 | 25.0 |
| *Penicillium lividum* M.Chr. et Backus | 58.3 | 66.6 |
| *Penicillium melinii* Thom | 16.6 | 0 |
| *Penicillium montanense* M.Chr. et Backus | 50.0 | 50.0 |
| *Penicillium purpurogenum* Stoll | 0 | 33.3 |
| *Penicillium roquefortii* Thom | 50.0 | 66.6 |
| *Penicillium spinulosum* Thom | 16.6 | 25.0 |
| *Penicillium thomii* Maire | 50.0 | 8.3 |
| *Penicillium viridicatum* Westling | 25.0 | 0 |
| *Penicillium waksmanii* K.M. Zalessky | 41.6 | 0 |
| *Phoma eurypena* Sacc. | 0 | 16.6 |
| *Trichoderma hamatum* (Bonord.) Bainier | 50.0 | 75.0 |
| *Trichoderma harzianum* Rifai | 25.0 | 8.3 |
| *Trichoderma virens* (J.H.Mill., Giddens et A.A.Foster) Arx | 33.3 | 25.0 |
| *Umbelopsis isabellina* (Oudem.) W. Gams | 58.3 | 33.3 |
| *Umbelopsis rammaniana* (A. Möller) W. Gams | 25.0 | 0 |
| *Verticillium* sp. | 16.6 | 33.3 |
| *Mycelia sterilia* | 75.0 | 58.3 |

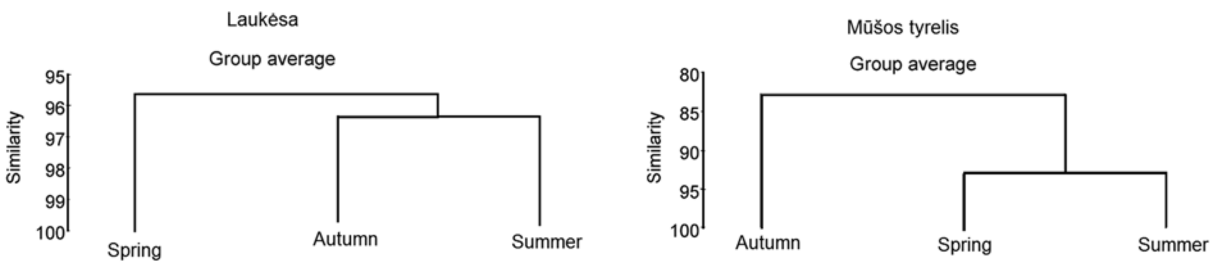


Fig. 1. Dendrogram of the Bray-Curtis index cluster analysis showing similarity between fungal species composition in different vegetation seasons

The analysis of species seasonal diversity showed differences in the structure of fungal communities in Mūšos Tyrelis peatland in autumn and in Laukėsa peatland in spring compared to other seasons (Fig. 1).

Some differences in fungal population density of more frequently isolated species in different seasons under various plants were observed in the studied peatlands (Table 5). The highest PD of *Penicilium lividum* population was determined in autumn and in spring, whereas of *Mortierella hyalina* and *Penicillium montanense* – in spring and in summer in both studied peatlands. Quite high PD of *Penicillium thomii* and *P. waksmanii* populations was recorded only in Mūšos Tyrelis peatland in summer. In Laukėsa peatland, *Penicillium chrysogenum* was dominant; it showed high density of the population during a year in all studied variants. *P. roquefortii* was dominant in autumn and spring, while *Trichoderma hamatum* – in spring and summer in the same peatland.

Significant differences in seasonal distribution of other fungal species characterized by high PD were not obtained. The species were isolated in different seasons under various plants and in different peatlands (for example, *P. janthinellum*, *P. spinulosum*, *Trichoderma harzianum*, *T. virens*).

The Kruskal Wallis test showed significant differences in species diversity under various plants in summer (Chi-square = 17.643, df = 3, $p = 0.001$); no differences were found in autumn and in spring ($p > 0.05$).

**Fungal species diversity under different plants**

During all seasons, in both peatlands, 551 fungal strains were isolated under moss *Campylopus introflexus*, 535 – under heather *Calluna vulgaris*, 401 – under moss *Polytrichum strictum* and 553 fungal strains – in bare peat.

A total of 30 fungal species ascribed to 13 genera were recorded in both peatlands under *Campylopus introflexus.* In Mūšos Tyrelis peatland, from the peat under the moss, fungi *Penicillium lividum*, *P. montanense*, *P. waksmanii* and *Umbelopsis isabellina* were isolated more frequently (Table 5). In Laukėsa, *Mortierella hyalina*, *Penicillium chrysogenum*, *P. lividum*, *P. roquefortii* dominated. P. *chrysogenum was* constantly found under other plants and in the bare peat as well.

During all investigation seasons, under native moss *Polytrichum strictum*, high density of *Mortierella hyalina* and *Umbelopsis isabellina* populations was observed in Mūšos Tyrelis. Distribution of *Oidiodendron flavum* was observed only under this moss. In autumn, *Trichoderma* fungi distributed abundantly and limited the growth of *Penicillium* and other fungal species in both studied peatlands.

The greatest species diversity and high density was determined under *Calluna vulgaris.* Together with constantly found *Penicillium* spp. (*P. lividum*, *P. chrysogenum*, etc.), high density of *Mortierella hyalina* and *Mucor hiemalis* populations was reported in Mūšos Tyrelis, and of *Trichoderma* spp. – in Laukėsa peatland.

In bare peat, *Trichoderma virens* made up the most part of isolates in autumn, while in different seasons, eight *Penicillium* species dominated.

Cluster analysis of fungal species similarities under different plants showed that in both studied peatlands, the species composition under *Campylopus introflexus* was similar to that in bare peat (Fig. 2.).

To characterize and compare species diversity of fungal communities in peat under various plants in different seasons, the Gleason index was calculated (Fig. 3). The greatest species diversity in Mūšos

Table 5. Seasonal changes in population density of more frequently isolated fungal species under different plants in the studied peatlands, %. Abbreviations: *Ci* – *Campylopus introflexus*; *Cv* – *Calluna vulgaris*; *Ps* – *Polytrichum strictum*; *Bp* – bare peat)

| Species of fungi under different plants and bare peat | | Population density, % | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mūšos Tyrelis | | | Laukėsa | | |
| | | Autumn | Spring | Summer | Autumn | Spring | Summer |
| *Mortierella hyalina* | *Ci* | 0 | 0 | 0 | + | 11.1 | 0 |
| | *Ps* | + | 14.2 | 10.6 | 0 | 0 | 0 |
| | *Cv* | 0 | 17.9 | + | + | 0 | 12.2 |
| *Mucor hiemalis* | *Cv* | 33.3 | + | + | 0 | 0 | 0 |
| *Oidiodendron flavum* | *Ps* | 0 | 10.9 | + | 0 | 0 | 0 |
| *Penicillium chrysogenum* | *Ci* | + | 0 | 0 | 12.5 | 17.6 | 25.8 |
| | *Ps* | 0 | 0 | 0 | 18.9 | 11.8 | 17.6 |
| | *Cv* | 26.6 | 0 | 0 | 22.2 | + | 16.3 |
| | *Bp* | 0 | 0 | 0 | 13.8 | + | 17.0 |
| *P. crustosum* | Cv | 10.6 | 0 | + | 0 | 0 | 0 |
| *P. digitatum* | *Cv* | 0 | 0 | 0 | 11.1 | 0 | 0 |
| | *Bp* | 0 | 0 | 0 | 10.3 | + | 0 |
| *P. glabrum* | *Ci* | + | 0 | 0 | 0 | 11.0 | 0 |
| *P. janthinellum* | *Cv* | 0 | 0 | 0 | 0 | 0 | 24.4 |
| | *Bp* | 23.0 | 0 | 0 | 0 | 0 | 28.9 |
| *P. lividum* | *Ci* | 68.2 | 33.0 | 0 | 17.9 | 17.6 | 0 |
| | *Ps* | 0 | + | 0 | 15.1 | 23.5 | 0 |
| | *Cv* | 13.3 | 15.9 | + | 12.9 | + | 0 |
| | *Bp* | + | 43.4 | 0 | + | 23.7 | 0 |
| *P. montanense* | *Ci* | + | 15.8 | 28.5 | 0 | + | + |
| | *Ps* | 0 | 0 | 15.9 | 0 | 0 | 23.5 |
| | *Bp* | 0 | 0 | + | 0 | 14.8 | 0 |
| *P. purpurogenum* | *Ci* | 0 | 0 | 0 | + | 0 | 19.3 |
| *P. roquefortii* | *Ci* | 0 | 0 | 0 | 21.5 | 13.2 | 0 |
| | *Bp* | 0 | 16.8 | + | 13.8 | + | 10.2 |
| *P. spinulosum* | *Cv* | 0 | 13.8 | 0 | 11.1 | 0 | 0 |
| | *Ps* | 0 | 15.6 | 0 | + | 0 | 0 |
| *P. thomii* | *Cv* | 0 | 0 | 16.6 | 0 | 0 | 0 |
| | *Ps* | + | + | 17.0 | 0 | 0 | 0 |
| | *Bp* | 0 | 0 | 20.8 | 0 | 0 | 0 |
| *P. waksmanii* | *Ci* | 0 | 0 | 24.7 | 0 | 0 | 0 |
| | *Ps* | + | + | 42.4 | 0 | 0 | 0 |
| | *Cv* | 0 | 0 | 33.3 | 0 | 0 | 0 |
| | *Bp* | 0 | 0 | 45.5 | 0 | 0 | 0 |
| *Talaromyces luteus* | *Cv* | 0 | 0 | 0 | 0 | 10.7 | 0 |
| *Trichoderma hamatum* | *Ci* | 0 | 0 | 0 | + | + | 11.3 |
| | *Ps* | 0 | 0 | 0 | 0 | 47.0 | 36.7 |
| | *Cv* | 0 | 0 | 0 | 0 | 26.9 | 12.2 |
| *T. harzianum* | *Cv* | 0 | 0 | 0 | 0 | 21.5 | 0 |
| | *Ps* | 22.8 | 0 | 0 | 0 | 0 | 0 |
| | *Bp* | 11.5 | 0 | 0 | 0 | 0 | 0 |
| *T. longibrachiatum* | *Cv* | 0 | 0 | 0 | 0 | 21.5 | 0 |
| *T. viridescens* | *Ps* | + | 0 | 0 | 11.3 | 0 | 0 |
| *T. virens* | *Ci* | 0 | 0 | 0 | + | 0 | 11.3 |
| | *Ps* | 13.7 | 0 | 0 | 0 | 0 | 0 |
| | *Bp* | 32.2 | 0 | 0 | 0 | 14.8 | 6.8 |
| *Umbelopsis isabellina* | *Ci* | 0 | 15.8 | + | + | 0 | 0 |
| | *Ps* | + | 10.9 | + | 0 | 0 | 0 |
| | *Bp* | 0 | 0 | + | 0 | 0 | 10.2 |

Note: (+) – population density < 10.0; (0) – not isolated. Abbreviations: *Ci* – *Campylopus introflexus*; *Cv* – *Calluna vulgaris*; *Ps* – *Polytrichum strictum*; *Bp* – bare peat

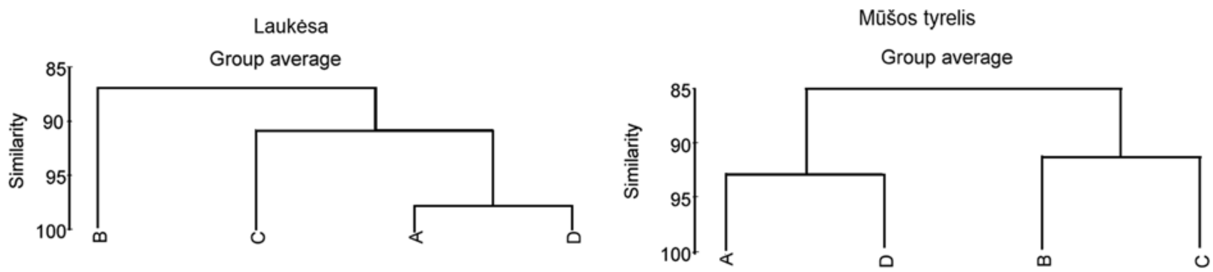


Fig. 2. Dendrogram of the Bray-Curtis index cluster analysis showing similarity between fungal community under different plants (A – *Campylopus introflexus*; B – *Calluna vulgaris*; C – *Polytrichum strictum*; D – bare peat)

Tyrelis peatland was observed under *Polytrichum strictum* in autumn and in spring; therefore, in summer it decreased approximately twofold. Under *Campylopus introflexus*, the converse tendency was observed – the Gleason index from the lowest in autumn (1.77) gradually increased and reached 2.58 in summer. These tendencies were similar to species diversity dynamics under *Calluna vulgaris.*

In Laukėsa, the greatest species diversity was found in autumn in all studied variants. The Gleason index ranged from 3.02 under *Polytrichum strictum* to 5.04 in the bare peat. Under *Campylopus introflexus*, the Gleason index in autumn was lower than in the bare peat or under *Calluna vulgaris,* but higher than under other moss *Polytrichum strictum*. In spring, species diversity significantly decreased, especially under *Calluna vulgaris* and bare peat. Though the amount of isolated species in summer increased, their diversity persisted at lower level than in autumn. Under *Campylopus introflexus*, the Gleason index in spring was higher than in other variants, but in summer exceeded only the diversity in the peat under *Polytrichum strictum*.

The Mann Whitney U test showed significant differences between the Gleason indices in both peatlands during all seasons (in all cases $p < 0.05$).

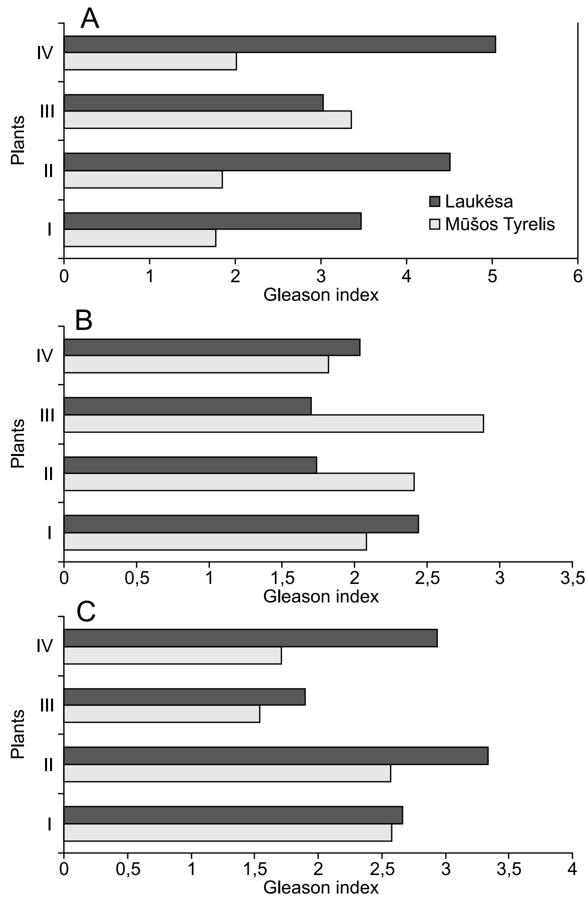


Fig. 3. Fungal species diversity (Gleason index) in the peat under: I – *Campylopus introflexus*; II – *Calluna vulgaris*; III – *Polytrichum strictum;* IV – bare peat, in autumn (A), spring (B) and summer (C)

## DISCUSSION

The peat under moss and vascular plants in Mūšos Tyrelis differed in lower amount of nitrogen and lower C:N ratio compared to Laukėsa. In Laukėsa, conversely a higher amount of C was estimated in the bare peat. Consequently, depending on higher amount of nutrients and, may be, to milder climate, a larger number of fungal species were isolated from Laukėsa peatland compared to Mūšos Tyrelis.

It should be noted that almost all identified fungal species coincided with the species from the taxonomic list, in which the data on fungi distribution in peatlands from various countries are summarized (Thorman, 2006; Thorman & Rice, 2007). This list should be supplemented by the species of the genus *Trichoderma* (*T. virens*, *T. hamatum*, *T. viridescens*, *T. longibrachiatum* and *T. fertile*), for the first time found during our investigations and not mentioned in the previous reports.

High population density was not always characteristic of fungal species with high rate of occurrence, and, conversely, species, which distribution was limited and related to several plants or season, were able to develop abundantly. For example, PD of *Penicillium glabrum*, *Talaromyces luteus*, *Trichoderma longibrachiatum* and *T. viridescens* in different peat samples was > 10%, however, its OR < 16.6% in different peatlands. At the same time rather frequent spiecies *Cladosporium cladosporioides*, *Mortierella minutissima*, *Paecilomyces farinosus* and some others were not characteristic of different plants in separate seasons. Due to abundant sporulation, the *Penicillium* species very often showed high density. On the other hand, fast growing species of *Trichoderma* may suppress the growth of other fungi in many cases. This tendency was well expressed in spring and summer periods, when the amount of these fungi increased in Laukėsa.

More research is needed to elucidate which exactly species among dominants are the most active degraders of plant, including *Campylopus introflexus,* residues. Most of the isolated *Penicillium* species produce enzymes necessary for the decomposition of lignin, cellulose and other complex substances and distinguish by high physiological activity (Samson & Frisvad, 2004; Domsch et al., 2007). The cellulolytic and chitinolytic enzymes produced by *Trichoderma* allow competing successfully with other microorganisms for nutrients and colonizing substrata in a short time. More than 40 various physiologically active substances, besides enzymes, are produced by *Trichoderma* (Ghisalberti & Sivasithamparam, 1991; Chaverri & Samuels, 2003). The wide spectrum of produced antibiotics ensures competitive ability of these fungi in peat communities. As it was mentioned above, higher amount of N found under plants in Laukėsa peatland allows to suppose that *Trichoderma* fungi actively participate in the plant residues decomposition.

Isolated fungi from the genera *Mortierella, Umbelopsis*, *Oidiodendron* are also often referred as decomposers of residues in peatlands (Grum-Grzhymaylo & Bilanenko, 2010).

The significant differences between species diversity in both peatlands during all seasons were estimated. It has been reported that seasonal succession of fungal species is not characteristic of raised bogs, because the destruction of plant residues runs rather slowly (Golovchenko et al., 2010). In our investigations, the succession of fungi during vegetation period was rather well expressed. It may be caused by direct human impact – drainage of the peatlands. Lowered water levels with the consequent increase in oxygen availability in the surface soil may be assumed to result in accelerated rates of organic matter decomposition (Laiho, 2006).

The calculated Sørensen similarity coefficient was equal to 0.55, when full taxonomical lists of fungal species isolated during all seasons under all plants and from bare peat were compared. It showed that the studied fungal communities had more than half of common species in their composition.

Species composition under *Campylopus introflexus* was similar to that in bare peat in both studied peatlands (as shown in Fig. 2). The numbers of fungal strains isolated from bare peat under *C. introflexus* and *Calluna vulgaris* were similar, while under *Polytrichum strictum* it was the lowest. Some researchers state that plant cover does not affect fungal community structure and litter decomposition in cutover peatlands (Trinder et al., 2008). We suppose that variations in fungal communities under different plants are associated with the degradation level of plant residues in the examined peatlands.

The obtained data show that more stable and less sensitive to environmental factors fungal communities have formed in Laukėsa peatland. More similarities in community structure between seasons and plants were observed compared to Mūšos Tyrelis peatland. It may be predicated that plants had no evident influence on the structure of fungal communities. In most cases it also depended on vegetation season and peat peculiarities.

It may be concluded that the analysis of fungi abundance and species composition under invasive moss *C. introflexus* did not show pronounced peculiarities specific only to these communities. All variations noticed in these communities were similar to the common tendencies of variations found in the peat of particular peatland under other plants. The main factors (amount of nitrogen, C:N ratio) affecting the distribution and species diversity in peat under *C. introflexus* were the same as the factors under other plants. The similarities of community of fungi in bare peat and under *C. introflexus* indirectly indicate the low destruction level of moss residues. It is presumable that with the increasing of habitat area in time the impact of metabolites and residues of *C. introflexus* on fungal communities should increase. The obtained data are important for the further monitoring of fungal communities structure in peatlands and should help to predict changes in the functioning of peatland ecosystem.

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## GRYBŲ ĮVAIROVĖ IR SEZONINĖ KAITA PO INVAZINE SAMANA *CAMPYLOPUS INTROFLEXUS* IR KITAIS AUGALAIS PAŽEISTOSE PELKĖSE

**Jūratė REPEČKIENĖ, Ilona JUKONIENĖ, Olga SALINA**

### Santrauka

Invazinės samanos *Campylopus introflexus* paplitimas gali neigiamai veikti pelkių natūralios augalinės dangos atsikūrimą dėl sunkiai skaidomų liekanų kaupimosi ir mikroorganizmų vystymosi slopinimo durpėse. Tirta grybų rūšių sudėtis ir jų sezoninė kaita po samanomis *C. introflexus* ir *Polytrichum strictum,* induočiais augalais *Calluna vulgaris* ir plikose durpėse dviejose pažeistose pelkėse Lietuvoje. Grybai buvo išskirti iš durpių suspensijų praskiedimo metodu, suskaičiuotos išaugusios kolonijos ir jie identifikuoti. Iš viso identifikuota 66 grybų rūšys iš 21 genties (tarp jų 30 rūšių iš 13 genčių buvo rasta po samana *C. introflexus*). Vyravo grybai iš *Penicillium*, *Trichoderm, Mortierella* ir *Paecilomyces* genčių. Didžiausia grybų rūšių įvairovė nustatyta Laukėsoje po *Calluna vulgaris.* Grybų bendrijų skirtumai nustatyti rudenį Laukėsos ir pavasarį Mūšos Tyrelio pelkėse. Ženklūs rūšių įvairovės skirtumai po skirtingais augalais buvo nustatyti tik vasarą. Gleasono rūšių įvairovės indeksas durpėse po *C. introflexus* nebuvo labai aukštas (1.77–2.58) visų sezonų metu. Grybų rūšių įvairovė po samana *C. introflexus* nerodė aiškiai išreikštų savitumų ir buvo panaši į grybų bendriją durpėse be augalų. Gauti duomenys yra svarbūs vertinant mikroskopinių grybų rūšių kaitą pelkėse ir augalinių liekanų biodestrukcijos aktyvumą.