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CELLULOSE-DECOMPOSING FUNGI IN PEATLANDS OCCUPIED BY INVASIVE MOSS *CAMPYLOPUS INTROFLEXUS*

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Abstract

Repečkienė J., Jukonienė I., Salina O., 2012: Cellulose-decomposing fungi in peatlands occupied by invasive moss *Campylopus introflexus* [Celiuliozę skaidantys grybai durpynuose, kuriuose plinta invazinė samana *Campylopus introflexus*]. – Bot. Lith., 18(**1**): 46–57.

Studies on the abundance and genera composition of cellulose-decomposing fungi in four differently disturbed peatlands occupied by invasive moss *Campylopus introflexus* were carried out in autumn, spring and summer seasons. The abundance of fungi under *C. introflexus* was compared with the abundance of fungal communities under other plants occupying the same habitats (*Polytrichum strictum, Eriophorum angustifolium, Calluna vulgaris)* and bare peat. The serial dilution plate technique was applied for isolation and enumeration of cellulose-decomposing fungi. The large amount of organic matter as well as acidic reaction of peat creates favourable conditions for the development of fungi at the studied sites. The number of cellulose-decomposing fungi depended on the peatland type, prevailing plants and season. The richness of fungal genera (15) was determined under *Campylopus introflexus*. Fungal isolates belonging to the *Penicillium, Trichoderma, Fusarium* genera and the *Zygomycetes* class prevailed.

Keywords: *Campylopus introflexus*, fungi, cellulose decomposition, peatlands.

INTRODUCTION

Microorganisms of soil are sensitive indicators of ecosystem stability, nutrients transformation and cycling in soil and plant productivity. The abundance of microorganisms and their species composition rates may be used to describe the functioning of ecosystem (Croft et al., 2001; Piaulokaitė-Motuzienė & Končius, 2007; Artz et al., 2008). Various physiological groups of bacteria, yeast and fungi are found in peatlands, and their abundance depends on humidity, temperature and availability of nutrients (Semenov et al., 1995; Golovčenko et al., 2010). Fungal enzymes mainly destroy the most abundant organic polymer cellulose. It was found that about 68 % of fungi possess cellulose degrading ability (Jahangeer et al., 2005). Less attention has been given to the study on the dependence of fungal communities on composition of the aboveground moss layer in peatlands (Croft et al., 2001; Andersen et al., 2010). We have not found references about cellulose-decomposing fungal communities in human-disturbed peatlands occupied by invasive moss *Campylopus introflexus*. This expansion can have negative subsequence for natural restoration of plant cover in disturbed peatlands or other damage sites, because they create adverse conditions to the development of grass plants and other organisms.

Soil microorganisms are responsible for litter decomposition and plant species can modify their abundance and community structure (Grayston et al., 1998; Bardget, Walker, 2004; Velichka et al., 2009; Andersen et al., 2010). Plant-induced variation in biomass and activity of microorganisms is caused by variation of labile C input in soil (Groffman et al., 1996; Ayres et al., 2006). The decomposition rate of moss litter is lower than of vascular plants. Mosses contain phenolic compounds, waxes and polymerised lipids mostly than lignin. Due to the chemical composition of mosses residues, they are rather resistant to microbial decomposition (Aerts et al., 1999; Trinder et al., 2008). Environmental factors can influence cellulose decomposition rate. In *Sphagnum* dominated bogs characterized by low rates of plant debris decomposition, acceleration of this process was observed at temperature above 20° C (Pankratov et al., 2011).

Since fungi are the main destructors of plant residues, and fungal species composition varies under different plants, we hypothesized that spreading of cellulose-decomposing fungi under the invasive moss *Campylopus introflexus* might show the biodegradability of its remnants.

The aim of this study was to investigate effect of invasive moss *C. introflexus* cover on community structure of cellulose-degrading fungi able to decompose cellulose-containing plant residues in naturally regenerating disturbed peatlands in Lithuania. We had to ascertain: 1) the abundance of cellulose-decomposing fungi in studied peatlands, 2) richness and diversity of cellulolytic fungal genera under different plants and sampling sites, 3) succession of cellulolytic fungi during the growth season.

MATERIALS AND METHODS

The investigations were carried out in four disturbed peatlands situated in different parts of Lithuania: 1) Palios (Marijampolė dstr.), 2) Mūšos Tyrelis (Joniškis dstr.), 3) Laukėsa (Tauragė dstr.), 4) Šepeta (Kupiškis dstr.). All peatlands have recently been used for peat excavation. Study plots were established in the abandoned areas, where natural layer of vegetation was removed 10–20 years ago. The selected peatlands differed in plant cover: in Mūšos Tyrelis the most abundant was *Calluna vulgaris* (L.) Hull., in Palios peatland dominated *Eriophorum angustifolium* Honck., the study plots in Laukėsa and Šepeta peatlands were covered by various herb species. Bryophyte species *Campylopus introflexus* (Hedw.) Brid. prevailed in all study sites.

Peat samples for microbiological analyses were taken in September 2010, April and June 2011 under various plants: 1) invasive moss *Campylopus introflexus,* 2) common heather *Calluna vulgaris* or common cotton-grass *Eriophorum angustifolium* 3) strict haircap *Polytrichum strictum* Menzies ex Brid. and 4) bare peat. Peat samples were taken from 0–15 cm layer, randomly from five points within circle area (10 m diameter) and a conjugated sample (about 500 g of peat) was prepared. In four study plots, four conjugated peat samples (under various plants and of bare peat) were collected in three seasons (overall 48 peat samples were analysed). The samples of peat were placed in the plastic bags, maintained at 4°C temperature and analysed as soon as possible (ISO 10381-6:2009). Total contents of nitrogen, phosphorus, potassium, organic carbon, soil organic matter and pH_{KCl} were examined using standard methods in air-dry peat.

Cultivable fungi able to decompose cellulose were isolated and enumerated applying the serial dilution plate technique. One ml of each peat sample suspension (in dilution 1:10000) was sown in five replicates on the surface of Haskins-Weston medium containing 0.5 % of carboxymethylcellulose Na salt (Bilaj, 1973). The inoculated plates (in total 240) were incubated at 26° C temperature for 5–7 days and the fungal colonies were counted. The number of fungi was expressed as a colony forming units per gram of dry peat (CFU g^{-1} d. p.) (Carter, 1993).

Fungal genera and species were identified with reference on the basis of their cultural and micromorphological properties (Pitt, 1979; Bissett, 1991; Watanabe, 2002; Samson & Frisvad, 2004; Domsch et al., 2007; Pečiulytė & Bridžiuvienė, 2008). Occurrence rate of various fungal genera was defined as the ratio of the number of peat samples in which a given genus was detected to the total number of analysed samples. Population density was calculated as ratio between isolates number of a given species and total number of isolates (Golovchenko et al., 2002).

The SPSS 16 statistical package was used for all data analysis in this paper.

Differences in mean number of microorganisms between four peatlands and under individual plant species were ascertained by variance analysis (one-way ANOVA) followed by multiple comparisons of means conducted using Tukey's test (HSD). Differences in mean number of microorganisms between samples taken under *Campylopus introflexus* and vascular plant species, *C. introflexus* and *Polytrichum strictum*, *C. introflexus* and bare peat in particular peatland were tested for statistical significance employing the Mann-Whitney U test.

Spearman's rho was used to reveal correlation between the number of cellulolytic fungi and chemical parameters of peat.

All differences were significant at 0.05 probability level.

RESULTS

The number of cellulose-decomposing fungi. The seasonal differences of cellulolytic fungi amount in four studied peatlands were estimated during vegetation period. In autumn (September 2010), the highest amount of fungi able to decompose cellulose was determined in Mūšos Tyrelis – 977–1962 × 10^3 CFU/g d. p., and the lowest – from Šepeta peat – 91–559 × 10^3 CFU/g d. p. (Fig. 1). In spring 2011, the abundance of cellulose degraders decreased. They were the most numerous in Mūšos Tyrelis (318–1073 × 10^3 CFU/g d. p.) and the least numerous in Palios peatland (52–97 × 10^3 CFU/g d. p.). In summer the number of cellulolytic fungi in different

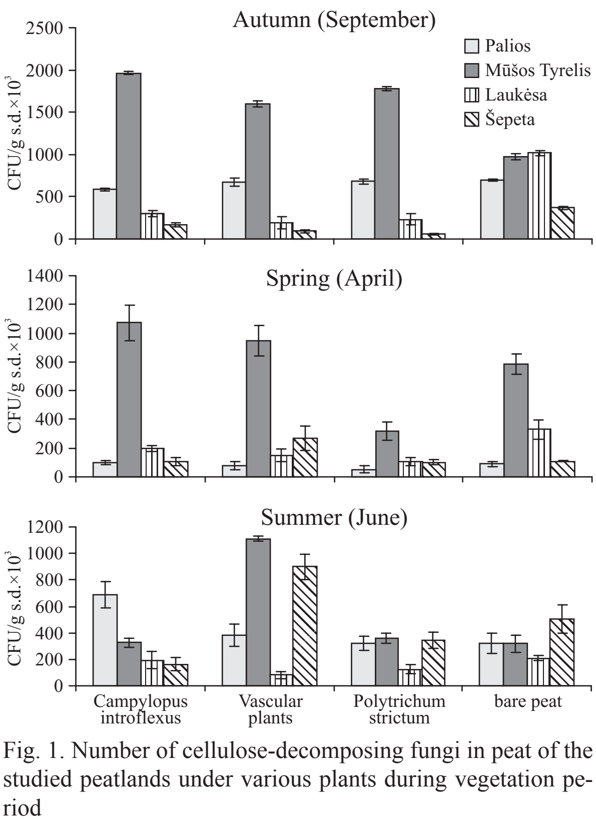

Fig. 1. Number of cellulose-decomposing fungi in peat of the studied peatlands under various plants during vegetation period

peatlands increased and reached 80.76–1111.53 × 10^3 CFU/g d. p. More significant increase in fungi number in the peat from Palios and Šepeta peatlands, and insignificant decrease in some samples from Laukėsa and Mūšos Tyrelis peatlands were estimated.

Abundance of cellulolytic fungi in Mūšos Tyrelis peatland was significantly higher than those in the other peatlands (Table 1).

Table 1. Variations among abundance of cellulolytic fungi in the studied peatlands (Tukey HSD test, different letters show significant differences)

Peatland	Abundace of cellulolytic fungi (Mean ± SD)
Palios	388.5 ± 367.3 a
Mūšos Tyrelis	962.3 ± 582.2 b
Laukėsa	260.9 ± 248.9 a
Šepeta	264.4 ± 242.1 a

The number of CFU of cellulolytic fungi positively correlated with the amount of carbon (Spearman's rho 0.429, $p < 0.05$) and organic matter (Spearman's rho 0.400, $p < 0.05$), while negatively – with the amount of phosphorus (rho -0.504, $p < 0.05$).

The cellulose-decomposing fungi most abundantly were isolated from peat samples collected in Mūšos Tyrelis peatland under invasive moss *Campylopus introflexus*. The number of fungi in this peatland from autumn to summer gradually decreased from 1962 to 325 × 10^3 CFU/g d. p. while in the samples from Palios and Šepeta they were more abundant in summer than in spring and their number exceeded or approximated to highest amounts estimated in autumn. The fewer amounts of cellulolytic fungi under the moss were isolated from Šepeta peat in autumn and summer and from Palios – in spring (Fig. 1).

Mann-Whitney U test showed significant differences between the number of cellulose-decomposing fungi under *C. introflexus* and bare peat in Mūšos Tyrelis and Laukėsa peatlands. In Šepeta significant differences in the number of fungi among all plants and bare peat were calculated (in all cases $p < 0.05$).

Under vascular plants cellulose-decomposing fungi were more abundant in Mūšos Tyrelis peatland as well. Their amount in summer increased as compared to that in spring (except Laukėsa peatland).

Under the moss *Polytrichum strictum* the abundance of this fungal group varied in a similar way as compared to *C. introflexus*. In autumn, their number was 60–1774 × 10^3 CFU/g d. p., in spring, it decreased to 52–318 × 10^3 CFU/g d. p., and in summer – some increase was noticed (reached 126–360 × 10^3 CFU/g d. p.), although autumn level was not reached (except Palios peatland).

Genera composition of cellulose-decomposing fungi. The richness of fungal genera decomposing cellulose differed in various peat samples as well. In total, 1802 isolates belonging to 16 genera were isolated. The richest in genera was Palios (14) and Laukėsa (13) peat, while in Mūšos Tyrelis only nine and Šepeta – seven genera were isolated.

Fungi of the *Penicillium* Link and *Trichoderma* Pers. genera were isolated from almost all samples (Table 2). Sacharolytic fungi from genus *Mortierrela* Coem. were frequent under all plants, except bare peat. More fungal genera with occasional rate (OR) > 30 % were found under the moss *Polytrichum strictum*, and with OR <30 % – under *Campylopus introflexus.*

From the peat under *C. introflexus,* 468 strains of 15 genera were isolated during the investigation period. At the same time from the peat samples under other plants 10–11 genera of cellulose-decomposing fungi were found and the number of their isolates ranged from 379 (under *Polytrichum strictum*) to 497 (under vascular plants).

In autumn, 13 fungal genera, in spring – 12, in summer – 10 were isolated from all studied samples. *Penicillium* genus fungi dominated in autumn, except the peat under *Calluna vulgaris* in Mūšos Tyrelis and under *Polytrichum strictum* in Šepeta, where *Fusarium* Link prevailed, also in Laukėsa bare peat, where the largest part of isolates belonged to the genus *Verticillium* Nees. In spring the population density of *Trichoderma, Fusarium* and *Verticillium* species increased. So, the genera composition varied between the investigated peatlands as well as the seasons.

Effect of plant type on cellulose-decomposing fungi. The fungi of *Penicillium* genus dominated under *Campylopus introflexus* cover in autumn in all peatlands (Table 3). Although nine other species were isolated from the peat, their population density (PD) was low. Only *Trichoderma* in Laukėsa and V*erticillium* in Palios were more abundantly distributed (PD – above 16 %). In spring, the species from six genera were isolated, but their PD was higher. *Verticillium* and *Exophiala* J. W. Carmich. were rather frequent in Palios, *Fusarium* (dominated) – in Mūšos Tyrelis, *Trichoderma* – in Šepeta. In summer, 7 genera were isolated, but only *Fusarium* in Palios and *Trichoderma* in Šepeta were isolated in higher amounts.

During the research period, from the peat under *C. introflexus* as well as from the other samples on the medium with cellulose, *Penicillium* species composed the most part of isolates. Their population density in different peatlands was 28–65.7 %. In Palios and Mūšos Tyrelis peatlands, a significant part (29.4–55.1 %) consisted of the *Fusarium* spp. Link while the strains of genus *Verticillium* were rather

Table 2. The occurrence rate (OR) of cellulose-decomposing fungal genera in peat

Abundance group	Under *Campylopus introflexus*	Under vascular plants	Under *Polytrichum strictum*	In bare peat
Dominant (OR > 60 %)	*Penicillium* *Trichoderma*	*Penicillium* *Trichoderma*	*Penicillium* *Trichoderma*	*Penicillium* *Trichoderma*
Frequent (OR = 30–60 %)	*Mortierella*	*Mortierella* *Fusarium*	*Mortierella* *Verticillium* *Umbelopsis*	*Fusarium* *Verticillium*
Rare (OR = 10–30 %)	*Fusarium* *Verticillium* *Umbelopsis* *Cladosporium* *Aspergillus*	*Verticillium* *Phoma* *Mucor*	*Fusarium* *Paecilomyces* *Aspergillus* *Mucor*	*Umbelopsis* *Acremonium* *Mortierella*
Occasional (OR < 10 %)	*Acremonium* *Phoma* *Paecilomyces* *Exophala* *Oidiodendron* *Aureobasidium* *Scytalidium*	*Scytalidium* *Paecilomyces* *Cladosporium* *Aspergillus*	*Acremonium* *Aureobasidium*	*Exophala* *Mucor*

Table 3. Population density of cellulose-decomposing fungal genera in separate peatlands under *Campylopus introflexus* in different seasons

Peatland	Genera	Population density of genera, %		
		Autumn	Spring	Summer
Palios	*Penicillium*	81	27.3	13.4
	Phoma	14.3	–	–
	Scytalidium	4.8	–	–
	Trichoderma	–	18.2	3.9
	Verticillium	–	27.3	–
	Exophiala	–	27.2	–
	Fusarium	–	–	78.7
	Aspergillus	–	–	1.3
	Cladosporium	–	–	2.7
Mūšos Tyrelis	*Penicillium*	88.9	38	91.6
	Umbelopsis	4	–	9.4
	Verticillium	3	–	–
	Paecilomyces	3	–	–
	Mortierella	1.1	–	–
	Trichoderma	–	4	–
	Fusarium	–	72	
Laukėsa	*Penicillium*	71	13	57.9
	Mortierella	12.9	7	–
	Trichoderma	16.2	–	10.5
	Aureobasidium	12.9	–	–
	Aspergillus	–	–	5.3
	Cladosporium	–	–	5.3
	Acremonium	–	–	21
Šepeta	*Penicillium*	61.1	58.3	50
	Mortierella	5.6	8.4	–
	Trichoderma	11.1	33.3	50
	Verticillium	16.6	–	–
	Oidiodendron	5.6	–	–

frequent in Šepeta (6.5 %). *Trichoderma* spp. made up 1.6–30.4 % and various genera from *Zygomycetes* amounted to 3.3–12.9 % (except Palios) (Fig. 2).

Besides *Penicillium* spp., under *C. introflexus,* the fungi *Fusarium anthophilum* (A. Braun) Wollenw., *F. sporotrichioides* Sherb., *Trichoderma hamatum* (Bonord.) Bainier, *T. virens* (J. H. Mill., Giddens et A. A. Foster) Arx, *Verticillium dahliae* Kleb. were frequently isolated. *Phoma eupyrena* Sacc., *Paecilomyces lilacinus* (Thom) Samson, *Exophiala jeanselmei* (Langeron) McGinniset A. A. Padhye, *Oidiodendron flavum* von Szilvinyi, *Scytalidium lignicola* Pesante and *Cladosporium cladosporioides* (Fresen.) G. A. de Vries were isolated more rarely.

Under vascular plants, eight genera of cellulolytic fungi were isolated in autumn, six in spring and summer. *Penicillium* dominated in three of the studied

Table 4. Population density of cellulose-decomposing fungal genera in separate peatlands under vascular plants in different seasons

Peatland	Genera	Population density of genera, %		
		Autumn	Spring	Summer
Palios (*Eriophorum angustifolium*)	*Penicillium*	82.6	55.6	81.4
	Mortierella	8.7	–	–
	Trichoderma	–	33.3	2.3
	Mucor	–	–	16.3
	Phoma	8.7	11.1	–
Mūšos Tyrelis (*Calluna vulgaris*)	*Penicillium*	10.8	49.5	95.4
	Mortierella	–	–	2.4
	Trichoderma	–	1	1.1
	Fusarium	81.5	49.5	–
	Verticillium	7.7	–	–
	Mucor	–	–	1.1
Laukėsa (*Calluna vulgaris*)	*Penicillium*	90.5	50	55.6
	Mortierella	–	–	11.1
	Trichoderma	–	31.2	11.1
	Scytalidium	3.5	–	–
	Paecilomyces	–	18.8	–
	Aspergillus	–	–	11.1
	Verticillium	9.5	–	–
Šepeta (*Eriophorum angustifolium*)	*Penicillium*	70	87.1	3.5
	Mortierella	20	32	–
	Trichoderma	10	–	4.7
	Fusarium	–	6.5	91.8
	Cladosporium	–	3.2	–

peatlands, while, in Mūšos Tyrelis, *Fusarium* was more abundant in autumn and their PD remained high in spring (Table 4). In spring, the part of *Trichoderma* isolates in Laukėsa and *Mortierella* isolates in Šepeta considerably increased.

Under vascular plants the strains of *Penicillium* genus made up 29.3–65 %, but in Mūšos Tyrelis and Šepeta peatlands, dominated *Fusarium* genus comprising 40.4–63.5 % isolates (Fig. 3).

The fungi *Fusarium sporotrihioides, F. oxysporum* Schltdl., *Paecilomyces farinosus* (Holmsk. et Gray) A. H. S. Br. et G. Sm., *Trichoderma longibrachiatum*, *T. virens* were dominant under vascular plants.

From the peat samples collected under moss *Polytrichum strictum,* five genera of cellulolytic fungi were isolated in autumn and spring, whereas seven – in summer. Except Šepeta, where *Fusarium* dominated, in other peatlands, the genus *Penicillium* prevailed in autumn (Table 5). In spring, *Trichoderma* dominated in Palios and reached 100 % PD in Šepeta. In summer, the growth of various genera was

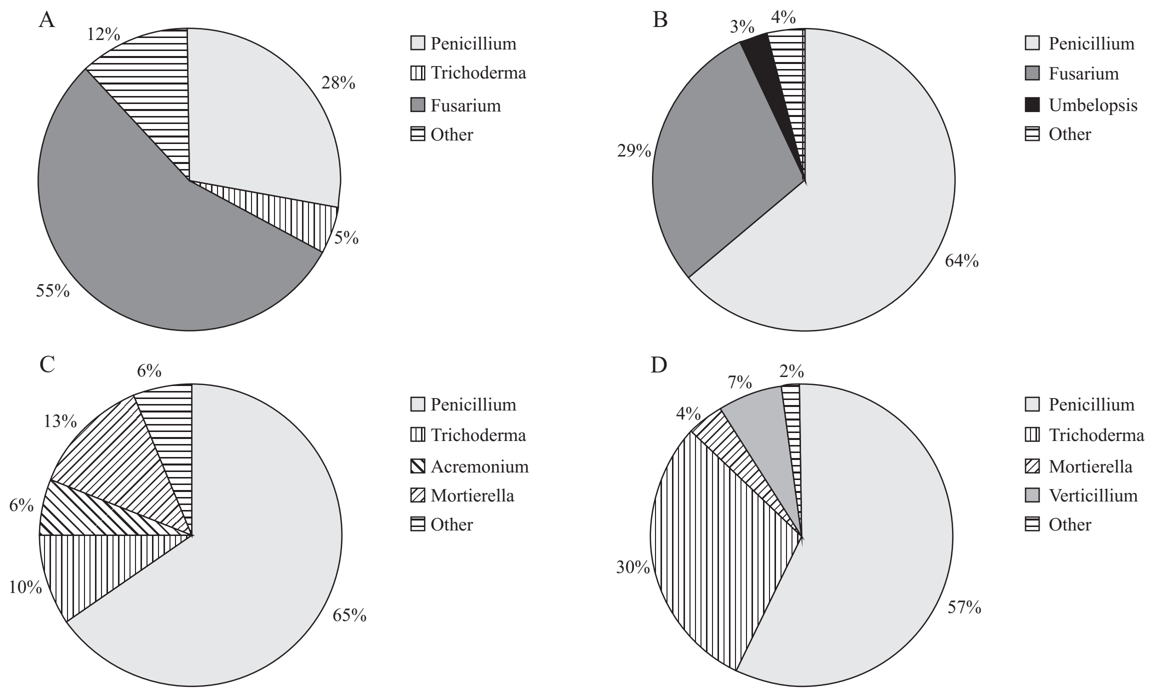

Fig. 2. Distribution of cellulose-decomposing fungal genera (% of the total number of isolates) under *Campylopus introflexus (*A – Palios, B – Mūšos Tyrelis, C – Laukėsa, D – Šepeta peatlands)

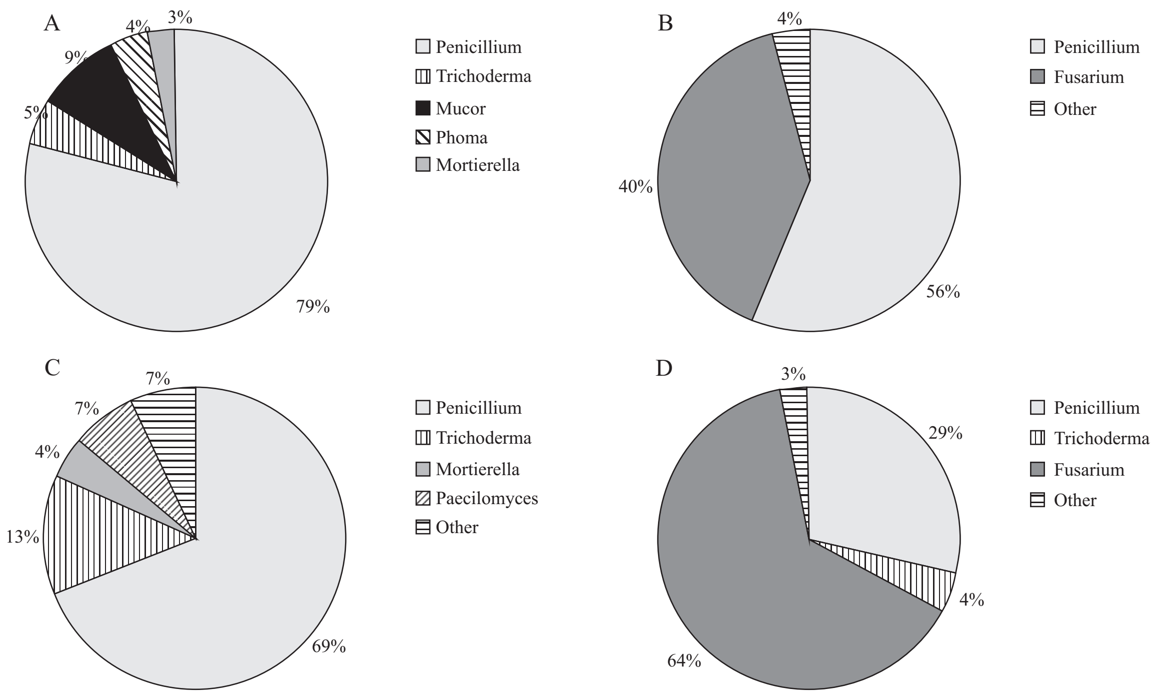

Fig. 3. Distribution of cellulose-decomposing fungal genera (% of the total number of isolates) under vascular plants *(*A – Palios, B – Mūšos Tyrelis, C – Laukėsa, D – Šepeta peatlands)

suppressed by intensive development of the *Penicillium* species except Palios, where the *Fusarium* fungi predominated.

Under moss *Polytrichum strictum,* the *Penicillium* spp. fungi made up 41–77 % of all isolated strains in different peatlands (Fig. 4). In Palios

Table 5. Population density of cellulose-decomposing fungal genera in separate peatlands under *Polytrichum strictum* in different seasons

Peatland	Genera	Population density of genera, %		
		Autumn	Spring	Summer
Palios	*Penicillium*	83.8	33.3	16.7
	Paecilomyces	2.7	–	–
	Trichoderma	5.4	66.7	16.7
	Verticillium	8.1	–	–
	Fusarium	–	–	63.8
	Aspergillus	–	–	2.8
Mūšos Tyrelis	*Penicillium*	82.3	54.3	87.6
	Paecilomyces	2.7	2.8	–
	Trichoderma	–	2.8	3.1
	Verticillium	10.1	11.5	–
	Mucor	5.4	–	3.1
	Mortierella	–	8.6	6.2
	Acremonium	–	14.3	–
	Umbelopsis	5.4	5.7	3.1
	Fusarium	2.7	–	–
Laukėsa	*Penicillium*	72	58.4	76.9
	Aspergillus	8	–	–
	Trichoderma	8	16.7	23.1
	Verticillium	8	–	–
	Mortierella	–	8.3	–
	Umbelopsis	–	8.3	–
	Aureobasidium	–	8.3	–
Šepeta	*Penicillium*	16.9	–	94.3
	Mortierella	1.7	–	–
	Trichoderma	3.4	100	5.7
	Verticillium	12.9	–	–
	Fusarium	51	–	–

peat, *Fusarium* (29 %), and in Šepeta – *Verticillium* (41.3 %) were widely distributed as well.

The fungi *Fusarium anthophilum* (A. Braun) Wollenw., *F. oxysporum*, *F. sporotrichioides, Verticillium* sp., *Trichoderma hamatum. T. harzianum* Rifai, *Paecilomyces farinosus* under *P. strictum* dominated somewhat rarely *Acremonium murorum* (Corda) W. Gams, and *Oidiodendron flavum* were isolated.

It should be noted that in bare peat high population density of *Fusarium* (Palios and Šepeta in summer) and *Verticillium* (Laukėsa in autumn) was estimated (Table 6).

In the peat of Mūšos Tyrelis *Trichoderma* fungi distribution under various plants was very low (0.8–1.6 %). Only in bare peat they were obtained slightly more abundantly – 4.1 % (Fig. 5). In this variant, species *Mucor hiemalis* Wehmer, *Mortierella hyalina* (Harz) W. Gams, *M. alpina* Peyronel, *Umbelopsis vinacea* (Dixon-Stev.) Arx dominated. *Fusarium oxysporum*, *Trichoderma virens, Verticillium album* (Preuss.) Pidopl., *V. dahliae* Kleb. were isolated as well.

Table 6. Population density of cellulose-decomposing fungal genera in samples of bare peat from separate peatlands in different seasons

Peatland	Genera	Population density of genera, %		
		Autumn	Spring	Summer
Palios	*Penicillium*	64.7	50	30.3
	Acremonium	–	20	–
	Trichoderma	–	10	3
	Verticillium	2.9	–	3
	Umbelopsis	–	10	–
	Fusarium	–	10	60.7
	Aspergillus	–	–	3
Mūšos Tyrelis	*Penicillium*	76.9	92.1	93.5
	Mucor	2.6	–	–
	Trichoderma	15.4	–	–
	Verticillium	5.1	–	–
	Umbelopsis	–	3.9	6.5
	Mortierella	–	2.6	–
	Acremonium	–	1.3	–
Laukėsa	*Penicillium*	22	94.4	75
	Trichoderma	1.2	2.8	20
	Verticillium	72	–	–
	Mortierella	–	–	5
	Exophiala	–	2.8	–
	Fusarium	4.8	–	–
Šepeta	*Penicillium*	97.4	18.8	18.6
	Trichoderma	2.6	81.2	7
	Fusarium	–	–	74.4

DISCUSSION

Microorganisms degrade complex organic polymers: cellulose, hemicellulose and lignin up to intermediate products of humic acids. The role of fungi on plant residues decomposition is very important in acid peat, where development of bacteria is complicated. Fungi are able to destruct organic residues to soluble hydrocarbons, which are available for the nutrition of other microorganisms and plants (Piaulokaitė-Motuzienė & Končius, 2007). The greatest amount of cellulose-decomposing fungi from the studied peatlands was isolated in autumn, while the least – in spring. Similar results about seasonal

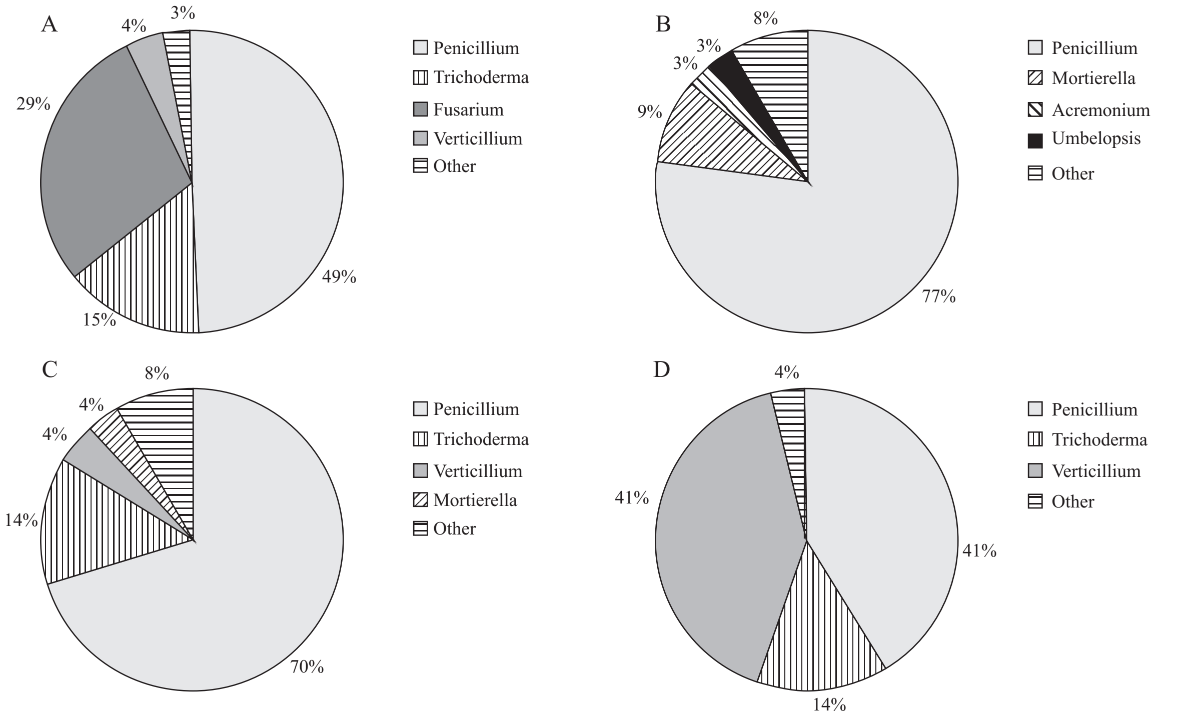

Fig. 4. Distribution of cellulose-decomposing fungal genera (%) under *Polytrichum strictum (*A – Palios, B – Mūšos Tyrelis, C – Laukėsa, D – Šepeta peatlands)

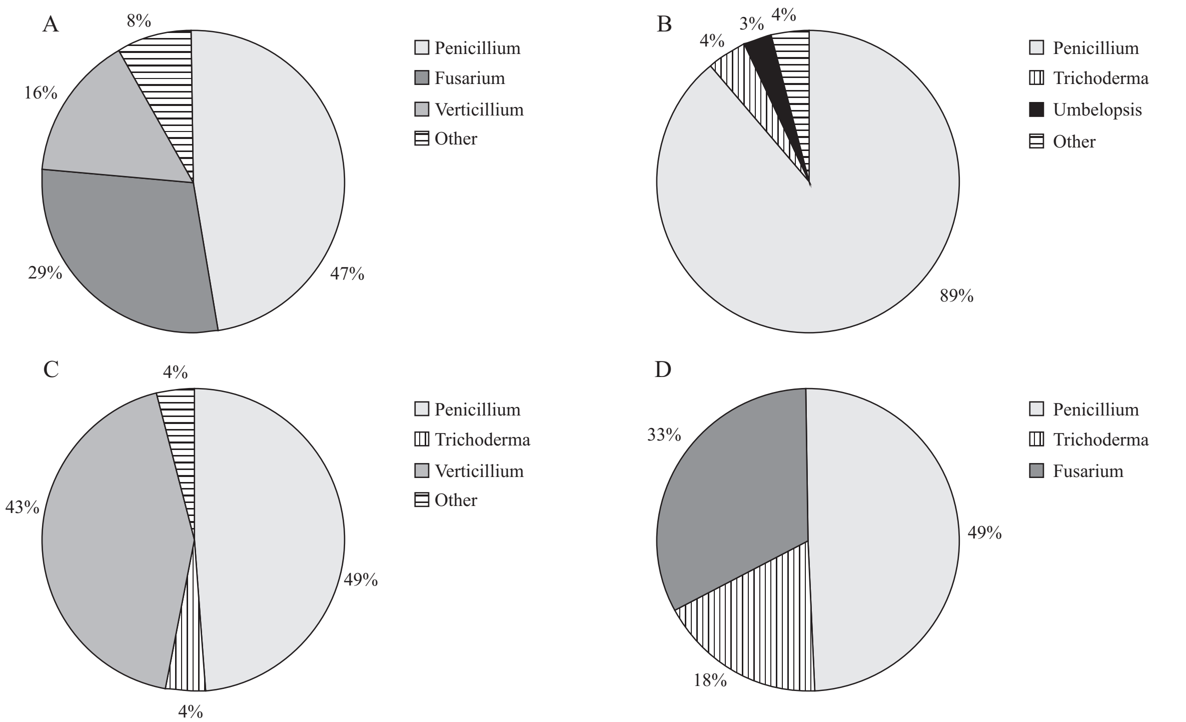

Fig. 5. Distribution of cellulose-decomposing fungal genera (%) in bare peat (A – Palios, B – Mūšos Tyrelis, C – Laukėsa, D – Šepeta peatlands)

distribution of microorganisms and their decomposition potential have been reported in various articles (Golovchenko et al., 2002; Andersen et al., 2010). These results show that higher number of fungi in the peat is correlated with higher carbon and organic matter content that increase at the end of growth season.

In the peat under moss *Campylopus introflexus,* the number of cellulose-decomposing fungi differed in separate peatlands and varied in different vegetation seasons. Despite the limitation of the serial dilution plate technique applied in this study it may be stated that in the most cases invasive moss *C. introflexus* had insignificant influence on the number of fungal CFU in the peat.

The richness of fungal genera decomposing cellulose differed in various peatlands and under different plants. The wide distribution of fast-growing and abundantly sporulating *Trichoderma* in spring or *Penicillium* in autumn and summer suppressed the growth of other fungal species. Furthermore, in variants with the highest fungal CFU amounts the least species diversity was estimated. The similar contrasts of total abundance and the number of fungal genera have been reported by other authors (Pečiulytė & Dirginčiūtė-Volodkienė, 2009).

Fungi of the *Penicillium*, *Trichoderma* and *Mortierrela* genera prevailed in the studied peat samples. Fungal genera with occasional rate > 30 % were more abundant under the moss *Polytrichum strictum* than under other plants. Under *Campylopus introflexus* fast-growing *Fusarium* and *Verticillium* were isolated more rarely than under other plants and in bare peat; even so seven occasional genera were found. Fungi of slow-growing genera, of which phenoloxidase activity is characteristic (*Cladosporium, Oidiodendron, Scytalidium, Exophiala* and others), were found rather rarely (< 10 %), though their role in natural polymers decomposition is very important. It has been reported that in upper layer of peat the abundance of dark-pigmented fungi varies from 0 % in spring to 34 % in autumn. *Oidiodendron* species isolated from decomposing *Sphagnum* are known to show phenoloxidase activity (Golovchenko et al., 2002; Thormann et al., 2002).

The greatest amount of isolates and genera were found in the peat under *Campylopus introflexus* as compared with other plants or bare peat. These data coincided with the spreading tendency of other cultivable fungi isolated on malt agar from peat samples in separate peatlands and under different plants (data not presented). Consequently, the invasive moss does not have negative effect on the distribution of fungi.

In autumn, under *Campylopus introflexus,* the fungi of the *Penicillium, Trichoderma* and V*erticillium* genera dominated. In spring, the species from *Penicillium*, *Verticillium, Exophiala*, *Fusarium* and *Trichoderma* genera were isolated more frequently. In this season the destruction of plant remnants starts, therefore, in many peat samples the number of *Trichoderma* fungi increased. Fungi of this genus are known as active decomposers of organic matter and improvers of soil structure. They participate in the decomposition of lignin-cellulose complex (Grum-Grzymaylo & Bilanenko, 2010).

During the research period, *Penicillium* species composed the most part of isolates under all plants. These species are ubiquitous saprothrophs and produce wide spectrum of metabolites. They are not the main degraders of recalcitrant plant residues, therefore, several species (*P. digitatum* (Fresen.) G. A. de Vries*, P. lividum* Westling and *P. spinulosum* Thom, which were very frequently isolated in our experiment, are able to decompose cellulose (Domsh et al., 2007).

Under *Campylopus introflexus* in Palios and Mūšos Tyrelis peatlands, a significant part consisted of the *Fusarium* spp., which on the one hand has the ability to decompose plant residues containing cellulose, but on the other hand may be the agents of plant diseases (Domsch et al., 2007). It must be noted that under invasive moss, although rarely, *Phoma eupyrena* Sacc., *Paecilomyces lilacinus* (Thom) Samson, *Exophiala jeanselmei* (Langeron) McGinnis et A. A. Padhye, *Oidiodendron flavum* von Szilvinyi were isolated. These species are very important in degradation of plant biopolymers. *Scytalidium lignicola* Pesante and *Cladosporium cladosporioides* (Fresen.) G. A. de Vries were isolated only under this moss in autumn. Large amounts of slow growing and complex compounds decomposing fungi have been found in the peat by other researchers (Golovčenko et al., 2002). The increase of carbon in soil stimulates the activity and abundance of initial colonizers (r- strategists) decomposing plant residues. At the same time species able to destroy recalcitrant components of organic matter (K-strategists) are suppressed (Blagodatskaja et al., 2007). Presumably the residues of *Campylopus introflexus* have more compounds recalcitrant to microbial decomposition, therefore, more fungal species belonging to K-strategists take part in their biodegradation.

Fungi from the *Penicillium* or *Fusarium* (Mūšos Tyrelis) genera under vascular plants were more abundant in autumn. In spring, the part of *Trichoderma* (Laukėsa) and *Mortierella* (Šepeta) considerably increased. Yan et al. (2008) reports that pioneer species (*Eriophorum vaginatum*, *Er. angustifolium* and *Calluna vulgaris*) alter the functional response of microbial community of a previously cutover peatland. In rhizosphere of vascular plants compounds with low molecular weight (sugars, amino and organic acids) are easily available to fungi. Fungi of the *Zygomycetes* class are known as rapid decomposers of simple carbohydrates (Kubicek & Druzhinina, 2007). It may be noted that the studied vascular plants had different root system and produced different metabolites, therefore some variations in fungal genera composition was observed. For example, under *Eriophorum angustifolium* fungi from the *Zygomycetes* class were obtained more rarely than under *Calluna vulgaris*.

From the peat under another moss *Polytrichum strictum,* 11 genera of cellulolytic fungi were isolated. The *Penicillium* genus fungi prevailed in autumn, except Šepeta, where *Fusarium* dominated. In spring, *Trichoderma* dominated in Palios and Šepeta. Cellulolytic activity is characteristic of isolated species, and this shows active decomposition of residues at these sites. In summer, the growth of various genera was suppressed by intensive development of the *Penicillium* species except Palios, where the *Fusarium* fungi predominated. The greater part of isolates of the *Trichoderma* genus fungi in comparison with peat under vascular plants (except Mūšos Tyrelis peatland) was found.

The organic residues (twigs, leaves, etc.) occur in bare peat; therefore the same fungal genera as under various plants were isolated from this variant. Species of the *Zygomycetes* class able to destruct easily decomposing compounds were isolated rather frequently. Species from the *Fusarium, Trichoderma* and *Verticillium* genera, known as cellulose destructors, were isolated as well.

Although the richness of fungal genera under *Polytrichum strictum* in the most cases was greater than under *Campylopus introflexus* (especially in autumn period), under the last-mentioned moss more genera from *Dematiaceae* (1 and 7, respectively) were isolated. The high enzymatic activity (especially phenoloxydase and laccase, which take part in the destruction of lignin-cellulose complex) is characteristic of fungi containing melanin pigment in their cells (Thormann et al., 2002; Currah & Davey, 2006).

It can be predicted that moss residues are more recalcitrant for degradation than residues of vascular plants *Eriophorum angustifolium* or *Calluna vulgaris*, but some adapted fungal species, especially from dematiaceous fungi were able to carry out this process intensively. Similar results were obtained by other authors, when moss *Sphagnum* sp. showed the lowest rates of decomposition in comparison with vascular plants (Bragazza et al., 2007; Trinder, et al., 2008).

Based on lower cellulolytic activity in variants with higher species diversity (Semenov et al., 1995) it may be concluded that fungal community in peat with low nutrient content are not able to ensure fast degradation of plant remnants. The degradation of invasive moss *Campylopus introflexus* residues and microorganisms participating at the various stages of this process should be the objective of further investigations.

CONCLUSIONS

This study for the first time revealed the tendencies of distribution of cellulose-decomposing fungi under *Campylopus introflexus* in disturbed peatlands. The number of fungi able to decompose cellulose in peat samples from different peatlands ranged from 51.77 to 1962.5 thou. CFU/g d. p. Their abundance correlated with the amount of total carbon and organic matter in the peat. The greatest numbers of cellulolytic fungi were isolated in autumn and the least – in summer time.

Under invasive moss *C. introflexus*, the amount of cellulose-decomposing fungi varied similarly as under other plants. In total, 16 genera of fungi decomposing cellulose were isolated. The genera *Penicillium*, *Trichoderma*, *Fusarium*, *Verticillium* and the species of *Zygomycetes* predominated. Under the moss *C. introflexus*, the greatest diversity of fungal species (15 genera) was estimated.

The residues of *C. introflexus* in comparison with other studied plants are more recalcitrant to microbial decomposition. This decision is confirmed by the fact that fungal species with phenoloxidase activity important in lignin-cellulose complex biodegradation (*Cladosporium cladosporioides*, *Oidiodendron flavum*, *Scytalidium lignicola*) are widely spread in the peat under the moss.

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REFERENCES

Aerts R., Verhoeven J. T. A., Whigham D. F., 1999: Plant-mediated controls of nutrient cycling in temperate fens and bogs. – Ecology, 80(7): 2170–2181.

Andersen R., Grasset L., Thormann M. N., Rochefort L., Francez A.-J., 2010: Changes in microbial community structure and function following *Sphagnum* peatland restoration. – Soil Biology & Biochemistry, 42: 291–301.

Artz R. R. E., Chapman S. J., Siegenthaler A., Mitchell E. A. D., Buther A., Bortoluzzi E., Gilbert D., Yli-Petais M., Vasander H., Francez A.-J., 2008: Functional microbial diversity in regenerating cutover peatlands responds to vegetation succession. – Journal of Applied Ecology, 45(6): 1799–1809.

Ayres E., Dromph K. M., Bardgett R. D., 2006: Do plant species encourage soil biota that specialise in the rapid decomposition of their litter? – Soil Biology & Biochemistry, 38: 183–186.

Bardgett R. D., Walker L. R., 2004: Impact of coloniser plant species on the development of decomposer microbial communities following deglaciation. – Soil Biology & Biochemistry, 36: 555–559.

Bilaj V. J. (ed.), 1973: Metody eksperimental‘noj mikologii. – Kiev.

Bissett J., 1991: A revision of the genus *Trichoderma*. (III). Section *Pachybasium*. – Canadian Journal of Botanics, 69: 2373–2417.

Blagodatskaja E. V., Blagodatsky S. A., Anderson T.-H., Kuzyakov Y., 2007: Priming effects in Chernozem induced by glucose and N in relation to microbial growth strategies. – Applied Soil Ecology, 37: 95–105.

Bragazza L., Siffi C., Iacumin P., Gerdol R., 2007: Mass loss and nutrient release during litter decay in peatland: The role of microbial adaptability to litter chemistry. – Soil Biology & Biochemistry, 39(1): 257–267.

Carter M. R. (ed.), 1993: Soil sampling and methods of analysis. – London, Tokyo.

Croft M., Rochefort L., Beauchamp Ch. J., 2001: Vacuum-extraction of peatlands disturbs bacterial population and microbial biomass carbon. – Applied Soil Ecology, 18: 1–12.

Currah R. S., Davey M. L., 2006: Interaction between mosses *Bryophyta* and fungi. – Canadian Journal of Botany, 84(10): 1509–1519.

Domsh K. H., Gams W., Anderson T.-H., 2007: *Compendium of soil fungi* (Second Edition, taxonomically revised by W. Gams). – Eching.

Golovchenko A. V., Semenova T. A., Polyakova A. V., Inisheva L. I., 2002: The Structure of the Micromycete Complexes of Oligotrophic Peat Deposits in the Southern Taiga Subzone of West Siberia. – Microbiology, 71: 575–581.

Golovchenko A. V., Dobrovolskaja T. G., Semenova T. A., Bogdanova O. Yu., Kucharenko O., 2010: The temperature influence on the structure of microbial communities of bog peatland (model experiment). – Vestnik TGPU, 3(93): 92–100.

Grayston S. J., Wang S., Campbell C. D., Edwards A. C., 1998: Selective influence of plant species on microbial diversity in the rhizosphere. – Soil Biology & Biochemistry, 30(3): 369–378.

Groffman P. M., Eagan P., Sullivan W. M., Lemunyon J. L., 1996: Grass species and soil type effects on microbial biomass and activity. – Plant and Soil, 183: 61–67.

Grum-Grzhymaylo O. A., Bilanenko E. N., 2010: Microfungi as a Component of Bogs Ecosystems. – Mikologija i Fitopatologija, 44(6): 485–496.

ISO 10381-6, 2009: Soil quality – Sampling – Part 6: Guidance on the collection, handling and storage of soil under aerobic conditions for the assessment of microbiological processes, biomass and diversity in the laboratory.

Jahangeer S., Khan N., Jahangeer S., Sohail M., Shahzad S., Ahmad a., Ahmed-Khan S., 2005: Screening and characterization of fungal cellulases isolated from the native environmental source. – Pakistan Journal of Botany, 37: 739–748.

Kubicek C. P., Druzhinina I. S., 2007: Environmental and Microbial Relationships. – Springer. 350.

Pankratov T. A., Ivanova A. O., Dedysh S. N., Liesack W., 2011: Bacterial populations and environmental factors controlling cellulose degradation in an acidic *Sphagnum* peat. – Environmental Microbiology, 13(7): 1800–1814.

Pečiulytė D., Bridžiuvienė D., 2008: Lietuvos grybai. II. Skurdeniečiai (*Mortierellales*) ir Pelėsiečiai (*Mucorales*). [Fungi of Lithuania. II *Mortierellales* and *Mucorales*]. – Vilnius.

Pečiulytė D., Dirginčiūtė-Volodkienė V., 2009: Effect of long-term industrial pollution on micro-organisms in soil of deciduous forests situated along a pollution gradient next to a fertilizer factory. 2. Abundance and diversity of soil fungi. – Ekologija, 55(2): 133–141.

Piaulokaitė-Motuzienė L., Končius D., 2007: Azotą transformuojančių mikroorganizmų paplitimas esant skirtingoms aplinkos sąlygoms. – Žemės Ūkio Mokslai, 14(3): 19–26.

Pitt J. I., 1979: The genus *Penicillium* and its teleomorphic states *Eupenicillium* and *Talaromyces.* – London, New York.

Samson R. A., Frisvad J. C., 2004: *Penicillium* subgenus *Penicillium:* new taxonomic schemes, mycotoxins and other extrolites. – Studies in Mycology, 49: 1–253.

Semenov A. M., Nizovtseva D. V., Panikov N. S., 1995: Influence of temperature and mineral supply on cellulase activity and micromycete development in samples of peat from upper bog. – Mikrobiologiya, 64(1): 97–103.

Thormann M. N., 2006: Diversity and function of fungi in peatlands: A carbon cycling perspective. – Canadian Journal of Soil Science, 86: 281–293.

Thormann M. N., Currah R. S., Bayley S. E., 2002: The relative ability of fungi from *Sphagnum fuscum* to decompose selected carbon substrates. – Canadian Journal of Microbiology, 48(3): 204–211.

Trinder C. J., Johnson D., Artz R. R. E., 2008: Litter type, but not plant cover, regulates initial litter decomposition and fungal community structure in a recolonising cutover peatland. – Soil Biology & Biochemistry, 41: 651–655.

Velička R., Rimkevičienė M., Kriaučiūnienė Z., Pupalienė R., Salina O., 2009: The effect of cellulose-degrading micro-organisms on the biodestruction of crop residues in the soil. – Zemdirbyste-Agriculture, 96(1): 113–126.

Watanabe T., 2002: Pictorial atlas of soil and seed fungi: morphologies of cultured fungi and key to species. Second edition. – London–New York–Washington.

Yan W., Artz R. R. E., Johnson D., 2008: Species-specific effects of plants colonizing cutover peatlands on patterns of carbon source utilization by soil microorganisms. – Soil Biology and Biochemistry, 40(2): 544–549.

CELIULIOZĘ SKAIDANTYS GRYBAI DURPYNUOSE, KURIUOSE PLINTA INVAZINĖ SAMANA *CAMPYLOPUS INTROFLEXUS*

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Santrauka

Ištirtas mikromicetų, sugebančių skaidyti celiuliozę paplitimas po invazinėmis samanomis *Campylopus introflexus* 4 durpynuose rudens, pavasario ir vasaros mėnesiais. Mikromicetų gausumas ir bendrijų sudėtis po šiomis samanomis palyginta su jų paplitimu po kitais durpynuose vyraujančiais augalais (*Polytrichum strictum*, *Eriophorum angustifolium*, *Calluna vulgaris*) bei durpžemyje be augmenijos. Celiuliozę skaidantys grybai išskirti naudojant suspensijos praskiedimų metodą. Nustatyta, kad tirtose durpėse didelis organinės medžiagos kiekis ir rūgšti reakcija sudaro palankias sąlygas mikromicetams vystytis. Celiuliozę skaidančių mikromicetų gausumas ir rūšių sudėtis labiausiai priklausė nuo durpynų, taip pat skyrėsi po skirtingais augalais ir atskirais mėnesiais. Didžiausia jų įvairovė nustatyta po *C. introflexus* – 15 genčių. Per visą tyrimo laikotarpį dominavo *Penicillium*, *Trichoderma*, *Fusarium* genčių ir *Zygomycetes* klasės grybai.