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Micromycetes Communities of Soil Fungi Occurring in the Buffer Zones of Selected Agricultural Catchment

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ABSTRACT

The studies of *micromycetes* fungi and physicochemical properties were carried out on the soils of buffer zones of a small watercourse in the agricultural landscape of north-eastern Poland. One of the zones was under a tree which was adjacent to the arable soil, the other one was under a turf located near the grassland. It turned out that the character of vegetation and the way the land was used had an influence on the analyzed soil parameters. Soil under trees was characterized by more diversified structures of fungi communities, it also produced more carbon dioxide and nitrous oxide than soil under turf. This allows us to state that tree-lined buffer zones are more effective in preventing surface water pollution by biogenic compounds displaced from agricultural land compared to the buffer zone under the grassing.

Keywords: *micromycetes* fungi, soils, agricultural catchment

INTRODUCTION

Leaving or creating strips of trees and permanent grassland in the modern agricultural landscape is a purposeful and necessary measure. They create buffer zones (biogeochemical barriers), especially in the vicinity of watercourses. They are an element of landscape which can effectively prevent pollution of rivers and water reservoirs by biogenic compounds transported from agricultural fields with surface runoff and groundwater [Borin, Bigon 2002; Lam et al. 2011; Frątczak et al. 2012]. The barrier slows down the underground and surface runoff and ensures longer contact of water with soil and plant roots. Therefore, physico-chemical and biological processes, including adsorption and immobilisation by microorganisms and vascular plants, which lead to a reduction in the concentration of contaminants, can be effective [Correll 2005; Hefting et al. 2005; Liu et al. 2008].

One of the microorganisms commonly inhabiting the soil are *micromycetes* fungi. They have many functions in the processes of matter and energy circulation in the environment. Among other things, they mineralize the soil on which they grow, transform organic matter, provide nutrients, and contribute to the biodegradation of pollutants. [Paul, Clark 2000; Pociejowska, Selwet 2012]. They also interact with plants, thus significantly affecting their growth and development [Barabasz, Vořišek 2002]. Most of them are saprotrophic organisms [Kwaśna 2014]. *Micromycetes* fungi are undoubtedly the basic link in soil trophic chains and the state of their complexes, i.e. the amount and diversity of species, but also their activity, is a necessary condition for the proper functioning of terrestrial ecosystems [Wierzbicka 2015]. Soil fungi, participating in the decomposition of organic matter, on the one hand shape the physical, chemical and biological properties of soil, and on the other hand depend on the above mentioned properties. Any changes in soil properties contribute to changes in the abundance and activity of these organisms. They also cause changes in the species composition of their communities and biodiversity [Kladivko 2001; Kwaśna 2014].

Therefore, research was undertaken in order to identify and compare *micromycetes* fungi communities inhabiting soils occurring in buffer zones of a small watercourse. Species domination in communities and similarity between communities were also determined. Moreover, the analysis of selected physicochemical properties of soils forming buffer zones, a small watercourse in the agricultural landscape of north-eastern Poland, was performed. The parameters influencing the emission of nitrous oxide and carbon dioxide from soils were pointed out.

MATERIALS AND METHODS

The analysis covered soils from two research points located in the zone near the channel of a small watercourse in North-Eastern Poland. The watercourse is a left-bank tributary of Horodnianka and is located about 1 km from the city of Choroszcz belonging to the Białystok agglomeration. The dominant method of land use is relatively low-intensity agriculture. Arable land is the main use of the catchment area, and cereals and feed maize dominate in the crop structure. Meadows are mowed once and then grazed.

The research points were located at a distance of about 2 m from the water, on both sides of the river (Figure 1). They differed in the vegetation forming a buffer zone and in the soil use above the riverbed. One research point was located under trees and in the vicinity of arable land, the other one was sodden and adjacent to grassland. The analyzed soils are mucky-black soils mounds that are made of clay sands [Systematics of Polish soils 2019].

The soil samples came from a depth of 10–20 cm. In order to perform physicochemical analyzes, they were taken four times: on 2, 7, 13 and 22 November 2016, while microscopic fungal communities were assessed in a sample that was collected on November 7.

For the isolation of *micromycetes* fungi, the method of soil tiles Warcupa (1950) in the modification of Mańka was used [Johnson, Mańka 1961; Mańka 1964; Mańka, Salmanowicz 1987]. In order to determine the species dominance of fungi, the formula proposed by Trojan [1981] and Orphan [1982] was used. The similarity between fungal communities was determined using the Jaccard coefficient [Zak, Willig 2004].

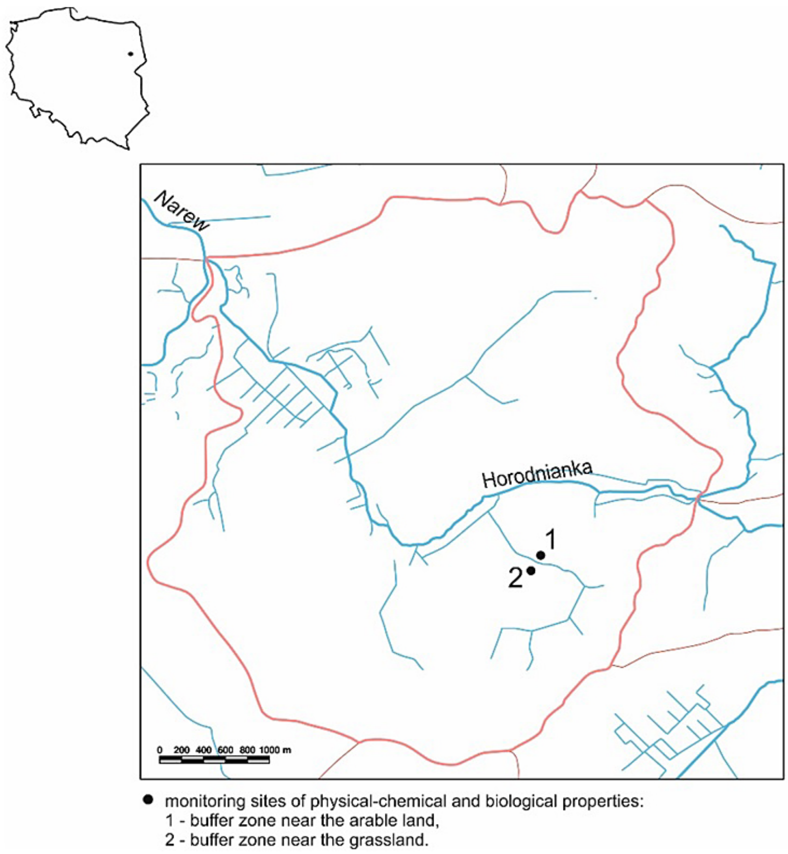

Figure 1. Location of the research points

In the samples, the pH in H_2O was determined, which was measured potentiometrically. The organic carbon (C_{org}) was measured by the catalytic oxidation method, total nitrogen (N_{tot}) was measured by the Kjeldahl method, and nitrate ions were determined spectrophotometrically. The emission of carbon dioxide (CO_2) and nitrous oxide (N_2O) was also determined. Measurements of CO_2 and N_2O emissions were made using the chamber method. The chamber was placed in a frame that was embedded in the soil. Gas samples were taken from the chamber for 1 hour every 15 minutes with gas-tight syringes. The CO_2 and N_2O concentrations were determined in the laboratory using a gas chromatograph. In addition, on soil sampling days, the air temperature and topsoil (at a depth of about 5 cm) and the depth of groundwater retention were measured.

RESULTS

The average temperature of the air and the top soil layer during the tests was about 4°C. The depth of groundwater retention ranged from 50 cm (November 20) to 80 cm (November 2). A total of 141 fungal isolates were obtained from the mycological analysis. They were represented by 37 different species. The fungi community originating from the soil of the buffer zone under the tree planting (marked with symbol 1) had a more diversified quantitative and qualitative structure in comparison with the community obtained from the soil of the buffer zone under the grassland use (marked with symbol 2). From the soil under trees 82 isolates and 29 species were obtained. However, 59 isolates and 25 *micromycetes* species were recorded in the soil under turf (Table 1).

Table 1. The number of isolates and species of fungi obtained from the analyzed soils

Research area	Number of fungal isolates	Number of fungi species
Buffer zone under trees	82	29
Buffer zone under turf	59	25

The similarity between fungal communities was at the level of 41.7%. The common *micromycetes* species, i.e. those occurring simultaneously in both communities, were 7.

Species domination of individual fungi was diversified. Seven species with the highest turnout – and thus dominance – in the analyzed communities were selected for the analysis of its value (Table 2). The highest domination in both communities was observed in *Pseudogymnoascus roseus* Raillo. In the community inhabiting the soil of buffer zone 1 (under trees) it amounted to 19.5%, while in the community coming from buffer zone 2 (under turf) – 25.5%. The dominance of the remaining species was much lower and was at the level of a few or several percent. Fungi belonging to the genus *Penicillium* also deserve attention. In the analyzed communities they constituted a significant group of organisms, but their species domination was not too high.

The studies on physicochemical properties of the near-surface soil level of the buffer zone near the arable soil (buffer zone 1) and greenfield use (buffer zone 2) show that the average value of individual parameters was similar. The analyzed soils were slightly acidic [Mocek 2015]. The content of organic carbon (C_{org}) and total nitrogen (N_{tot}) in both soils had comparable values, although on November 13th and 22nd in the soil under turf a higher C_{org} content was found in comparison with the soil under tree planting. However, in the soil from the buffer zone with trees the content of nitrates was higher ($N\text{-}NO_3$; Table 3).

The carbon dioxide (CO_2) emission in soil from both research points was about 500–2000 $mg \cdot m^{-2} \cdot d^{-1}$. The emission of nitrous oxide (N_2O) was 0.45–0.80 $mg \cdot m^{-2} \cdot d^{-1}$ in buffer zone 1 and 0.09–0.33 $mg \cdot m^{-2} \cdot d^{-1}$ in buffer zone 2.

Table 2. Species domination of fungi colonizing the soils of the analyzed buffer zones

Fungal species	Species domination [%]	
	1	2
Chrysosporium pannorum (Link) Hughes	8.5	5.1
Fusarium oxysporum Schlecht.	-	5.1
Leptosphaeria coniothyrium (Fuckel) Sacc.	-	13.6
Penicillium brevicompactum Dierckx	6.1	-
Penicillium oxalium Curie and Thom	9.8	6.8
Penicillium raistrickii G. Sm.	-	5.1
Penicillium verucosum var. *cyklopium* (Westling) Samson, Stolk & Hadlok	6.1	-
Pseudogymnoascus roseus Raillo	19.5	25.4

Explanations: 1 – Buffer zone – trees near arable land; 2 – Buffer zone – turf near grassland.

Table 3. Characteristics of selected physico-chemical properties of soils of the zone near the channel during the study period

Date of measurement	pH w H_2O		$C_{org.}$ [%]		$N_{tot.}$ [%]		$N\text{-}NO_3$ [mg·100g^{-1}]	
	1	2	1	2	1	2	1	2
02.11.2016	6.12	6.62	3.52	3.12	0.22	0.22	0.34	0.09
07.11.2016	6.06	6.59	3.40	3.06	0.23	0.23	0.36	0.07
13.11.2016	6.27	5.78	2.73	4.21	0.33	0.37	0.43	0.06
22.11.2016	6.26	6.06	3.14	4.33	0.26	0.27	0.41	0.54

Explanations as in Table 2

CO_2 and N_2O emissions were affected by both air and soil temperature and soil moisture. The emission value of both gases increased with increasing temperature and humidity. However, the emission of N_2O and CO_2 from the buffer zone under trees was higher in comparison with the emission from the buffer zone under turf (Figure 2, 3).

It was also found that CO_2 and N_2O emissions increased along with a decrease in the total nitrogen content in soil (Figure 4).

However, the analyzed soils were characterized by the opposite relationship in the case of total carbon content. CO_2 and N_2O emissions increased along with the increase of carbon content (Figure 5).

DISCUSSION

The studies conducted in November, which in the conditions of northeastern Poland is the

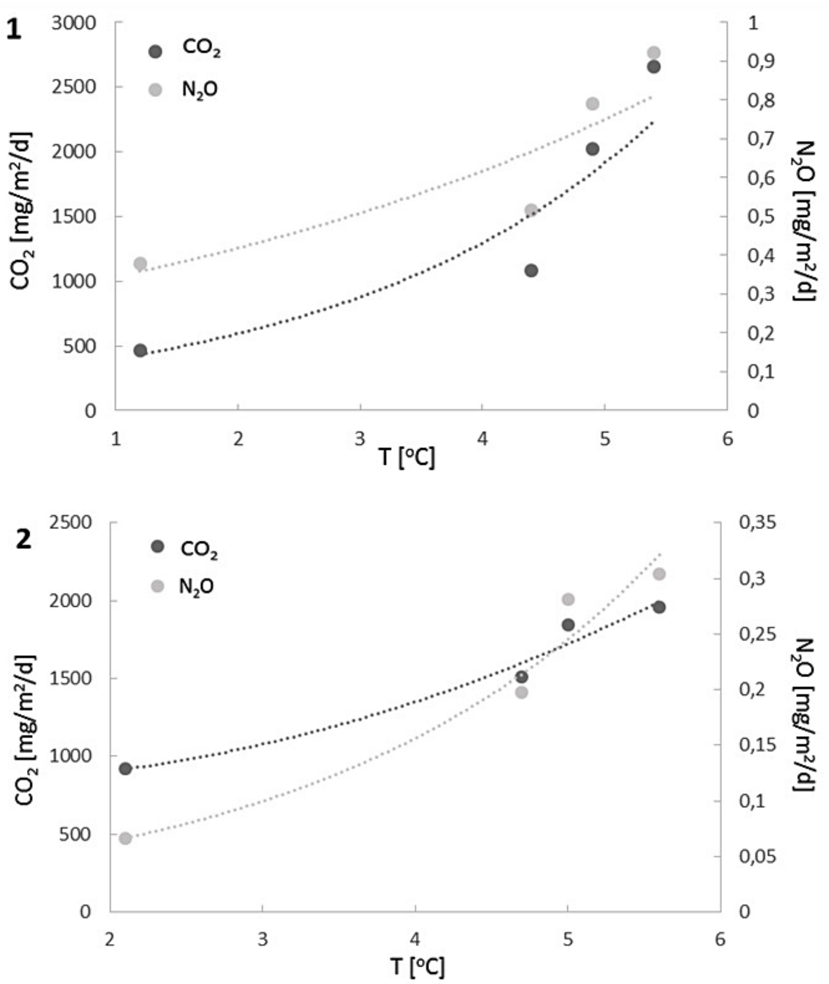

Figure 2. The relationship between the emission of nitrous oxide (N2O) and carbon dioxide(CO2) and the air temperature (T), (1 – buffer zone with trees near the arable land, 2 – buffer zone with turf near grassland)

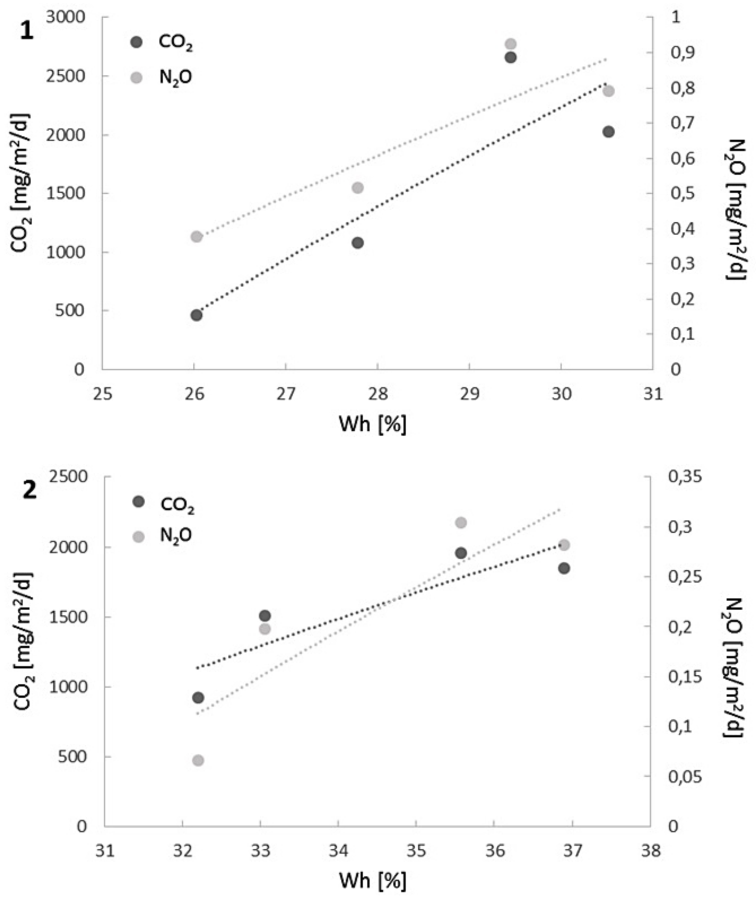

Figure 3. The relationship between the emission of carbon dioxide(CO_2) and nitrous oxide (N_2O) and the soil moisture (Wh), (1 – buffer zone with trees near the arable land, 2 – buffer zone with turf near grassland)

month ending the vegetation period [Tomczyk, Szyga-Pluta 2016], showed that the processes taking place in the soils of the buffer zone under trees were dynamic. This conclusion is based, inter alia, on carbon dioxide and nitrous oxide emissions that are associated with microbial activity [Paul, Clark 2000; Błaszczyk 2010; Frączek 2010; Turbiak, Miatkowski 2010; Traczewska 2011; Mocek 2015]. The studies showed that with the increase of organic carbon content in soils, the emission of CO_2 and N_2O increased. At the same time, high total and species abundance of *micromycetes* communities was noted. This is undoubtedly related to the fact that soil microorganisms develop intensively in habitats rich in dead organic matter and mineralize it [Paul, Clark 2000; Błaszczyk 2010].

It was also shown that CO_2 and N_2O emissions increased with the decrease in the content of nitrogen compounds in the soil. These results, in turn, confirm the observations that the decomposition of organic compounds (rich in nitrogen) is accompanied by active microbiological processes, which result in the production of CO_2. Denitrification is also more efficient in habitats rich in biogenic elements, including nitrogen [Paul, Clark 2000; Błaszczyk 2010; Frączek 2010; Traczewska 2011; Moccek 2015]. Therefore, under such conditions the number of communities and their species diversity was relatively high. *Micromycetes* fungi colonizing the soil are one of the groups of microorganisms that may use different nitrogen compounds [Kalbarczyk 2012].

It was found that fungi communities, which came from soils with similar typological development and comparable physicochemical properties differing in vegetation, had different quantitative and qualitative structures. The fungi community originating from the buffer zone soil under a tree planting near the arable land was characterized by a higher number of isolates and a richer species composition. This diversity is undoubtedly due to the fact that the biological breakdown of organic matter carried out by fungi depends not only on climatic factors, soil properties, soil fertility, pH, oxidative

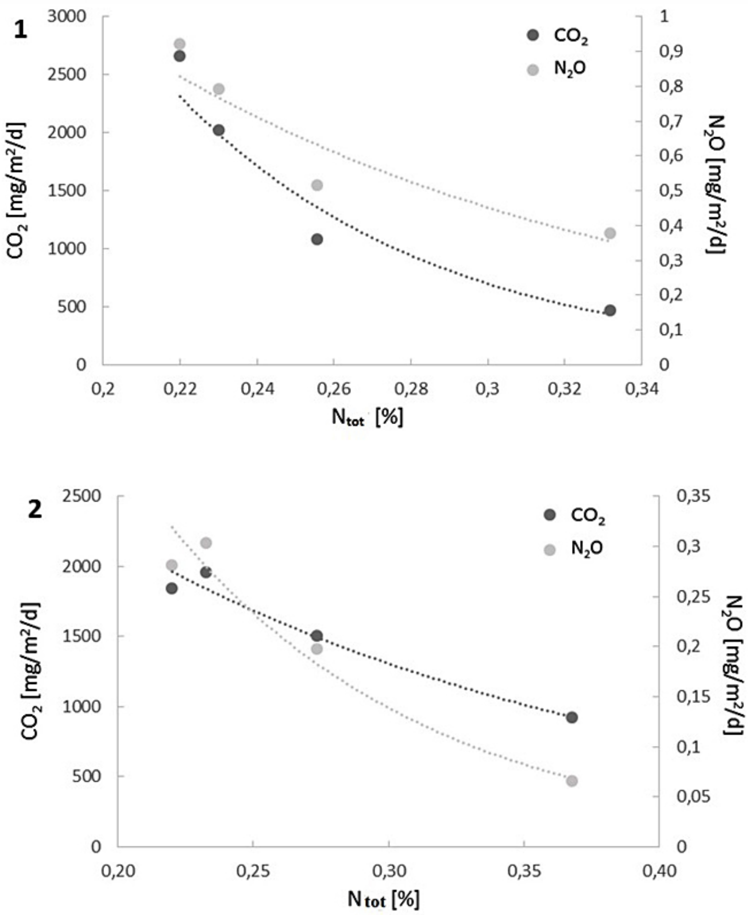

Figure 4. The relationship between the emission of carbon dioxide(CO_2) and nitrous oxide (N_2O) and total nitrogen (N_{tot}) in soil, (1 – buffer zone with trees near the arable land, 2 – buffer zone with turf near grassland)

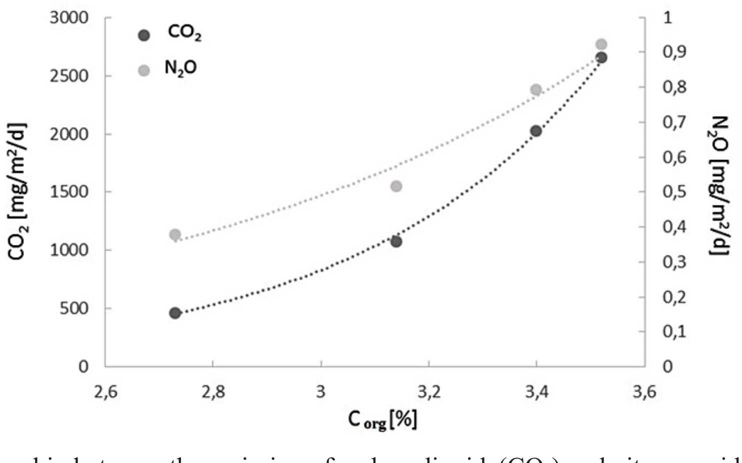

Figure 5. The relationship between the emission of carbon dioxide(CO_2) and nitrous oxide (N_2O) and organic carbon (C_{org}) in soil, on the example of the buffer zone created by tree plantings next to arable land

potential, but also on the system of use, agrotechnical treatments and species forming plant cover [Paul, Clark 2000; Barabasz, Vořišek 2002; Kamiński, Chrzanowski 2007; Błaszczyk 2010; Kwaśna 2014; Mocek 2015]. Thus, it was shown that the diversity of plant cover affects the variety of *micromycetes* fungi communities.

At the same time, it was found that the analyzed communities, despite clear differences, had common features. The similarity between them exceeded 40%. *Pseudogymnoascus roseus* Raillo had the highest species domination in both communities. This indicates the important role of this species in the processes taking place in the analyzed soils. It seems that *Penicillium* genus fungi are also important. In the course of the study different species of the genus were isolated. However, the dominance of *Penicillium* species was not high.

CONCLUSIONS

On the basis of the conducted research, it was found that the *micromycetes* fungi communities of the analyzed soils of two buffer zones differing in their vegetation and use of the neighboring area, despite some similarities, differed in their quantitative and qualitative structures. The community obtained from the buffer zone soil under trees had a more numerous quantitative composition and a richer qualitative structure in comparison with the community inhabiting the soil under turf. The character of vegetation and the way of land use influence the physicochemical properties and microbiological activity of buffer zones of agricultural catchment areas. The soil of the buffer zone under trees near the arable soil produced more carbon dioxide and nitrous oxide than the soil of the buffer zone under turf near grassland. This was also related to its higher microbiological activity. It allows to state that the buffer zones under shelter more effectively prevent surface water pollution by biogenic compounds displaced from the agricultural land area in comparison with the buffer zone under turf. *Pseudogymnoascus roseus* Raillo was the species with the highest species domination in the analyzed soils. This indicates the important role of this species in the processes in the soil environment of the discussed buffer zones. Fungi of the genus *Penicillium* also played an important role.

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