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CHANGES IN THE MICROBIOLOGICAL ACTIVITY OF HYDROGENIC SOILS AFTER DRAINAGE

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A b s t r a c t. Quantity of some groups of microorganisms and dehydrogenase activity were determined in the top soil layer (0-10 cm) of natural and drained peatland. High soil moisture (85 to 90%) in the natural peatland accounted for the reduction of fungi and cellulolytic microorganisms which can reflect a restricted process of peat mineralization. In late summer (September), peat-muck soils of drained meadows supported rather high numbers of cellulolytic microflora, except for the Modzelówka peatland that was highly decomposed. In the alder peat with high degree of mucking and low moisture content (55-63%), fungi were abundant.

Dehydrogenase activity was the highest (153 to 181 $\mu l\ H_2\ g^{-1}$) in natural peats with high moisture content (80-89%) and the lowest (5-13 $\mu l\ H_2\ g^{-1}$) in alder peats with high degree of mucking. Thus, moisture and degree of peat mucking affect development of microorganisms and dehydrogenase activity causing more or less intense mineralization of organic matter.

K e y w o r d s: microorganisms, dehydrogenase activity, peatland, drainage.

INTRODUCTION

In Poland, there are over 1.5 million ha of peatland, a large part of which is located in the Biebrza and Narew floodplain. Over the last 50-years, thousands of ha of fens were drained and managed mainly as meadows. Peat-forming processes, characteristic of the organic matter accumulation were replaced by peat mucking processes transforming the structure of the organic soil mass into granular or crumbled, typical of muck. The top layer of muck in peat-muck soils developed in drained peatland, overlies peat of various kinds (moss, sedge, or alder peat), with various thickness, important from the point of view of water availability for plants, and also regulates the rhythm of biological processes determining mineralization of organic matter. Depending on peat kind and drainage intensity, hydrogenic soils are subjected to differential transformations [1,9,13,17]. The greatest changes and

transformations are observed in the peat-muck soils derived from highly decomposed peat classified as semi-arid, that can be found on the soils developed from strongly decomposed alder peat [14].

The processes of organic matter transformation in the soil are strongly related to the activity of microorganisms and enzymes they produce [4-6]. Thus, a study was conducted to determine the effect of edaphic conditions in a natural peatland and drained meadow on quantitative changes of micro-organisms and in dehydrogenase activity (enzyme from the oxidoreductase group) in peat soils.

MATERIALS AND METHODS

Quantity of microorganisms and dehydrogenase activity were estimated in the top soil layer (0-10 cm) in a natural peatland and drained peatland managed as meadow, located in the Biebrza floodplain, north-eastern Poland. Wet meadows (Dobarz and Grzędy) are located in the Biebrza National Park on the peat soils derived from moderately decomposed sedge peat. These soils have low density by volume and high porosity close to the full water capacity (Table 1). In spring, they are often flooded for a long time, even until early summer. In summer, the water table is lowered to a depth of 40-60 cm.

The meadows drained in different time periods (from 20 to 120 years ago), are situated on peat-muck soils derived from moss, sedge, or alder peat with various mucking degree. Managed meadows were significantly different in their density and porosity of the top soil layers and the depth of water table (Table 1).

Soil samples for microbiological analyses were taken from wet and drained meadows during the first 10-day periods of July and September 1996. Laboratory determinations included: total number of bacteria by the Bunt and Rovira's method [15] on agar with soil extract. The Martin's culture [12] was used to estimate the number of fungi, nutritive agar for ammonifying bacteria, and the Omeliański's culture for cellulolytic microorganisms. Dehydrogenase activity was assessed by the method of TTC reduction [2].

RESULTS AND DISCUSSION

Microbiological analyses of the soil samples showed quantitative and qualitative differences in the microorganisms, related to the level of water table and peat moisture or type. Early in July, the total number of bacteria was high in the moss peat of the drained meadow at Toczyłowo and also in the sedge peat moderately

Table 1. Characteristics of habitats of the examined sites (after Szuniewicz, Chrzanowski and Kamiński, unpubl.)

Characteristics	Sites					
	Natural peatlands		Drained peatlands			
	Dobarz	Grzędy	Toczyłowo		Biebrza	Modzelówka
	(D)	(G)	(Tm)	(Tt)	(ZD)	(M)
Origin of peat	tall sedge	tall sedge	moss-sedge	tall sedge	alder	tall sedge
Years after drainage			20	20	45	120
Ground water level (cm): July	0	16	32	36	82	44
September	45	35	52	58	75	90
Moisture (%): July	89.4	80.0	74.6	81.6	54.7	75.7
September	70.2	79.6	61.5	82.6	62.8	71.5
Bulk density (g cm^{-3})	0.176	0.148	0.202	0.308	0.280	0.371
Hay crop (q ha^{-1})	24	20	80	45	52	38

decomposed in the wet meadow at Grzędy, with the top soil moisture of about 75 to 80%. High soil moisture (89%) in the wet meadow at Dobarz during the same time period, and too low soil moisture (55%) noted in the alder peat (Biebrza) in the managed meadow, limited the growth of bacteria (Fig. 1). In early September, at Dobarz, water table markedly dropped (to a depth of 45 cm), and also the moisture of the top soil layer was reduced (to 70%). At the same time, the highest number of bacteria was noted. During the same period, a similar number of bacteria was also recorded from the drained meadow on moss peat at Toczyłowo at a much higher moisture content (82%). The lowest variation in the number of bacteria was observed in the heavily transformed peat-muck soil (Modzelówka), in the meadow drained 120 years ago, with small variation in soil moisture (71.5 to 75.5%).

The fungi growth in the peat-muck soil depends on the degree of mucking and peat moisture content. Abundance of fungi in sedge peats from wet meadows and also in less decomposed peats from the drained meadows at Toczyłowo was markedly lower (Fig. 1) than in the alder peat (Biebrza) with high degree of mucking and low moisture content (55 to 63%).

When a spring flood ended, a rapid growth of ammonifying bacteria was observed in the top peat layer of wet meadows early in July (Fig. 1), which may be indicative of intensified ammonification processes in these soils. In drained meadows, a substantial increase of these microorganisms at the beginning of July was observed only in the moss peat weakly decomposed at Toczyłowo. The number of

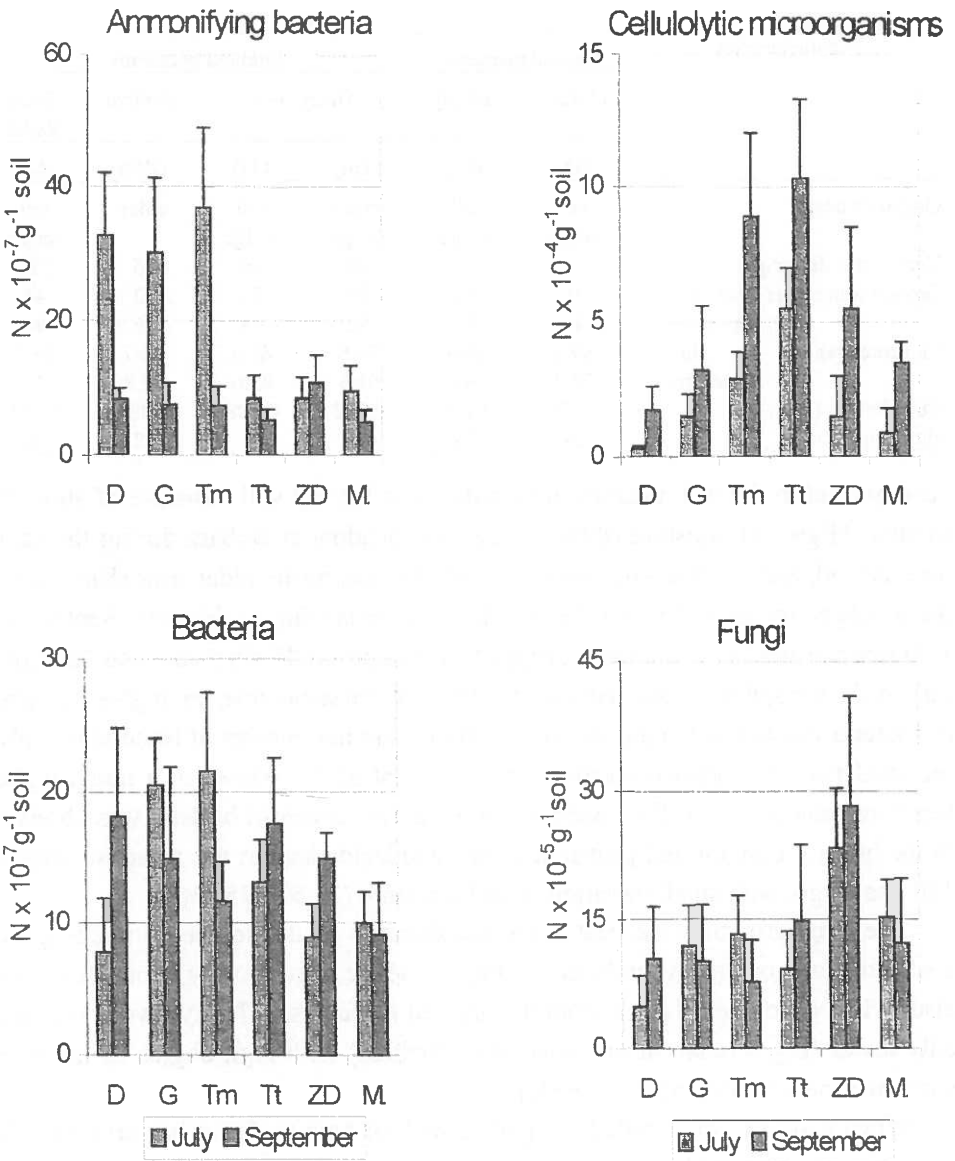

Fig. 1. Microflora abundance of natural and drained peatlands.

ammonifying bacteria markedly declined over summer, and in September it was similar to other studied soils.

The soils of wet meadows are characterised by low quantities of cellulolytic microflora (Fig. 1), which may be indicative of limited mineralization of organic matter in these peats. In contrast, peat soils with low degree of mucking in the drained meadows supported rather high numbers of cellulolytic microflora in September.

Dehydrogenase activity (enzyme of the oxidoreductases group) was the highest in the peat soils with high moisture (80 to 89%) in wet meadows at the beginning of July (Fig. 2). In the peat-muck soils of drained meadows, dehydrogenase activity was low, first of all in the alder peat (Biebrza), with low moisture content (55 to 63%). Peat draining to reduce water content and to improve the aeration of the upper peat layers, reduced dehydrogenase activity, a sensitive biological index of the farming effects on the soil.

Differences in the moisture content in the upper horizons of hydrogenic soils due to various levels of water table and precipitation, affect the rate of organic matter mineralization. This is closely related to the activity of microorganisms, as in dry and highly decomposed peats, number of bacteria and cellulotytic microorganisms is reduced. Also the rate of cellulose decomposition was lower, and dehydrogenase activity dropped (Table 2).

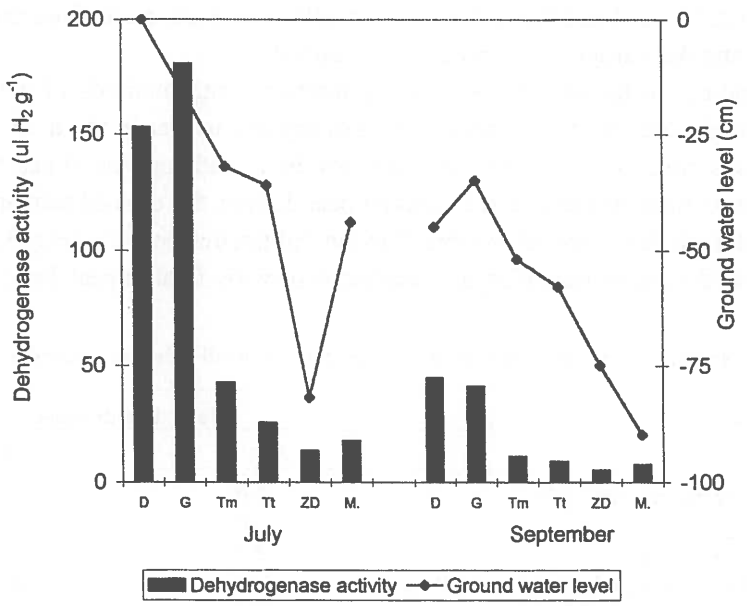

Fig. 2. Dehydrogenase activity and ground water level in peat-muck soil.

Table 2. Comparison of microorganisms abundance, enzymes activity and cellulose decomposition rate in moist and arid hemic soils

Characteristics	Arid meadows	Moist meadows
Soil moisture (%)	50.8	69.0
Number of microorganisms:		
Bacteria (10^{-7} g^{-1})	9.8	14.9
Actinomycetes (10^{-6} g^{-1})	6.2	6.3
Fungi (10^{-5} g^{-1})	27.1	24.3
Cellulolytic microorganisms (10^{-4} g^{-1})	3.7	6.1
Soils enzymes:		
Dehydrogenase activity (μl H_2 g^{-1})	6.5	21.7
Urease activity (ppm NH_4-N)	0.0	34.3
Cellulose decomposition rate (mg g^{-1} day^{-1})	10.6	14.3

Dehydration and management (mainly as meadows) of peatland accounts for deep changes in the edaphic conditions. In the first period after drainage, there is a slow growth of microorganisms and soil fauna that takes part in the mineralization of organic matter [3,8,10,16]. In the first year after drainage of the peatland at Lipniki, with high precipitation (420 mm) over the growing season, a moderate growth of microorganisms and high dehydrogenase activity were noted in the top layer of sedge peat (Table 3). In the fifth year after drainage, when rainfall rate was lower (235 mm) and the soil was seasonally overdried, microflora growth was intensive and dehydrogenase activity was reduced.

Depending on the peat kind, draining intensity, and methods of aeration adjustment and water regime, mineralization of organic matter in the drained hydrogenic soils is more or less rapid which accounts for a steady decline of peat thickness. As a result of mineralization and increasing peat density, the drained peatland surface declines at a rate from several to more than ten millimetres per year (Fig. 3). As a result of rapid decomposition of organic matter, especially in alder peat, large amount of

Table 3. Number of microorganism and enzymatic activity in tall sedge peat after drainage

Characteristics	Years after drainage	
	1	5
Ammonifying bacteria (10^{-7} g^{-1})	3.0	22.5
Fungi (10^{-5} g^{-1})	7.0	21.7
Actinomycetes (10^{-6} g^{-1})	3.7	13.4
Microorganisms utilizing mineral nitrogen (10^{-7} g^{-1})	14.6	38.9
Dehydrogenase activity (μl H_2 g^{-1})	30.4	14.6
Urease activity (ppm NH_4-N)	56.4	50.1

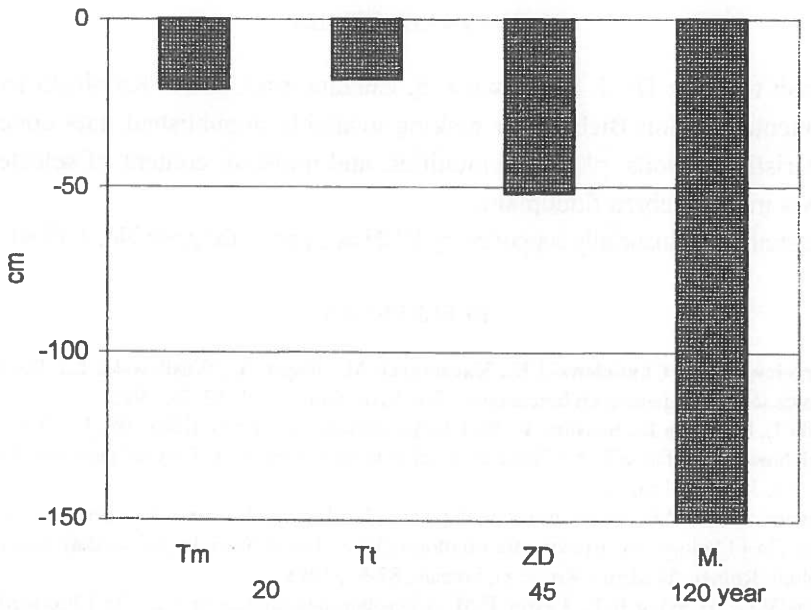

Fig. 3. Decline (cm) of the surface peat meadows after drainage (after Szuniewicz, unpubl.).

mineral nitrogen is released [7,11,18,19]. Part of this nitrogen, not used by plants, percolates to ground waters and contributes to river eutrophication.

CONCLUSIONS

Peat decomposition in hydrogenic soils occurs mostly due to the activity of microorganisms and saprophagous fauna. Mineratlization rate of organic matter in the natural and drained peatland can differ, depending on the water table depth, temperature, and moisture content of the upper soil horizon, as well as kind and degree of peat mucking. Excessive moisture, as well as overdrying of the top layer of peat soils are the main factors responsible for the reduction in the number and activity of microorganisms. In natural peatland, transformation of organic matter is rather limited because at a high water table, the soil is too wet for the growth of microorganisms. In drained peatlands, abundance of fungi and cellulolytic microflora can increase and dehydrogenase activity can decrease because water table is lower and the moisture content of the top soil layer is reduced.

Rapid mucking of hydrogenic soils and reduction in meadow productivity in drained peatland requires in-depth studies to restore some wetlands in Poland, and search for effective methods of preventing the progress of soil degradation.

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