ORIGINAL ARTICLE

Enzyme activity in forest peat soils

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Abstract

The aim of the study was to determine the activity of dehydrogenases and urease in forest peat soils of different fertility. There were selected 23 experimental plots localised in central and northern Poland. The research was conducted on forest fens, transition bogs and raised bogs. The biggest differences in soil physical and chemical properties were detected between fen and raised bog soils while raised bog soils and transition bog soils differed the least. Statistically significant differences between particular subtypes of peat soils were observed for soil pH-H_2O, pH-KCl, C/N ratio as well as the content of organic carbon, nitrogen, calcium and potassium. The highest average dehydrogenase activity in the soil surface level was observed in fen soils, and the lowest – in raised bogs soils. The results obtained on urease activity were similar. Differences in urease activity in the studied soil types were shown. Dehydrogenase activity did not reveal statistically significant diversity. The activity of urease was negatively correlated with the content of carbon, C/N ratio, hydrolytic acidity and moisture. Also the increase in enzymatic activity accompanied by the increase in pH has been observed.

Key words

dehydrogenases, urease, forest soil, peat soils

Introduction

World's peatlands cover 500 million ha, which constitutes 3.8% of the surface of our planet (Paavilainen and Päivänen 1995). In Poland peatlands cover 12547 km^2, and most part of this area is situated within a range of occurrence of fen species. There are more peatlands in the northern part of the country, and they tend to occur less frequently towards the south. In Poland, woodlands on peatland areas cover 1270 km^2 (Tobolski 2000, Ilnicki 2002). Some of the woodlands on peat substrate are integral elements of peatland flora (bog forest, birch bog forest). However, afforestation of many peatland areas, previously drained has been undertaken. In drained peatlands timber increment is considerably higher than in marshy ones, and the use of drained peatlands by woodland initiates numerous processes (e.g. self-consolidation, moorshing, mineralization). Foresters as a rule appraise peat in the perspective of production (Inisheva 2006).

The classification of forest soils in Poland (2000) distinguishes fen soils, raised bog soils and transition bog soils. The process of peat forming takes place at a different pace depending on water conditions. The degree of bog-forming process advancement specifies the peat type. Fens are eu- and mesotrophic kinds of organic soils, conditioned by presence of underground water and depend on alder carr or rush communities. Raised

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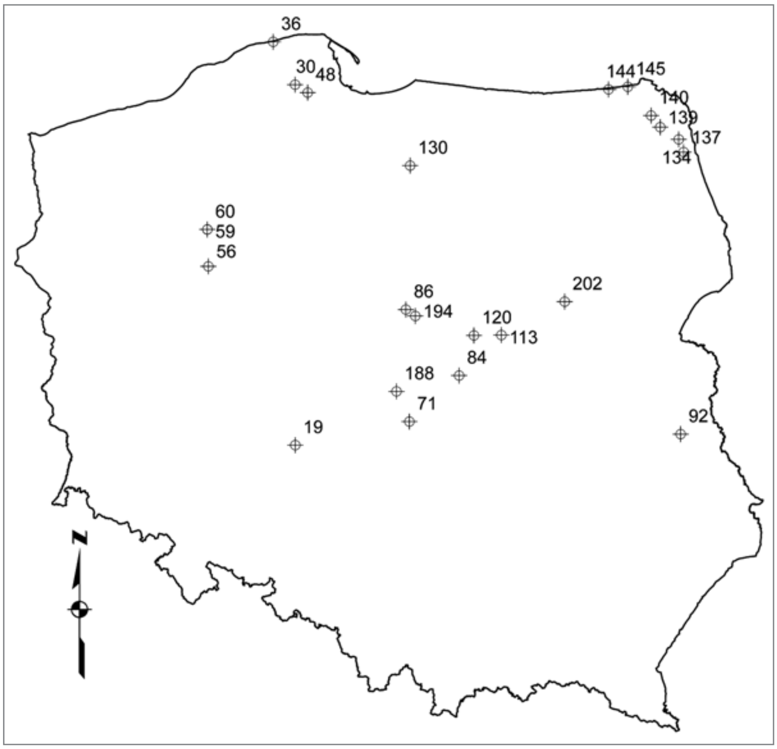

Fig.1. Distribution of sample plots
(19 – Pieczyska Nature Reserve;
30 – Kurze Grzędy Nature Reserve;
36 – Mierzeja Serbska Nature Reserve;
48 – Staniszewskie Błota Nature Reserve;
56 – Źródliska Flinty Nature Reserve;
59, 60 – Kuźnik Nature Reserve;
71 – Wolbórka Nature Reserve;
84 – Kopanicha Nature Reserve;
86 – Kresy Nature Reserve;
92 – Poleski National Park;
113,120 – Kampinos National Park;
130 – Jasne Nature Reserve;
134 – Perkuć Nature Reserve;
137 – Kuriańskie Bagno Nature Reserve;
139, 140 – Wigierski National Park,
144 – Mechacz Wielki Nature Reserve;
145 – Dziki Kąt Nature Reserve;
188 – Grondy nad Lindą Nature Reserve;
194 – Jarząbek Nature Reserve;
202 – Jegiel Nature Reserve)

bogs represent oligotrophic edaphic conditions that are entirely dependent on precipitation water which results in their barrenness. Highly specialised flora – with prevalence of peat mosses of *Sphagnum* genus – is adapted to the strongly acidic substrate and finds here conditions for existance,. Transition bogs are situated between fens and raised bogs. They are weakly oligotrophic and obtain both surface and underground water supply. Flora of transition bogs is formed by peatmoss species of the genus, *Sphagnum* as well sedges and mosses.

Flora, the activity of microorganisms, hydrographical and thermal conditions affect conditions in peat soils. Microorganisms together with flora specify the direction and nature of biochemical processes. Soil enzymes are associated with microorganisms (Burns 1982). Enzymatic activity in soil plays an important role in catalyzing reactions indispensable in life processes of soil microorganisms, decomposition of organic residues, circulation of nutrients as well as forming organic matter and soil structure (Sinsabaugh *et al.* 1994). Peat soils are characteristic of high hydration which can reduce enzymatic activity in soils through changing numbers of microorganisms and an increase in the concentration of such inhibitors as Fe^{2+} (Kang and Freeman 1999).

The objective of this study was to determine dehydrogenase and urease activity in forest peat soils of different fertility. An attempt was made to determine if peat-forming processes affect biological activity of soils expressed by their enzymatic activity and their physical and chemical properties.

Methods

There were selected 23 sample plots, localised in central and northern parts of Poland (Fig.1). The research was carried out on forest peat soils in fens (7 plots), transition bogs (7 plots) and raised bogs (9 plots).

At each sample plot detailed description of soil profile was performed and samples were taken to determine the soil properties. Soil reaction in H_2O and 1M KCl was evaluated with the use of potentiometric method. The following soil parameters were also evaluated: hydrolytic acidity – with the use of Kappen method; exchangeable acidity – according Sokolov method (Ostrowska *et al.* 2001). The N and C content was identified with the use of LECO determinator, with calculation of C/N ratio and the degree of soil saturation with alkaline cations (V%) (Bray-Kurtz method) (Procedure 1995). Soil moisture was determined according to the Kopecky cylinder method (Ostrowska *et al.* 2001).

For determination of enzymatic activity fresh samples of soils were taken which constituted a collective sample of soil from the hole and from 4 spots surrounded this hole. Enzymatic activity was determined at the first genetic level of peat soils (0–20 cm). Dehydrogenase activity was identified with the Lenhard's method according to the procedure of Casidy *et al.* (1964). The activity of dehdrogenases was expressed by triphenyl formazan milligrams (TFF) in 100 g of soil after 24 hours. Urease activity was indicate with the use of Tabatabai and Bremner method (1972) (Alef and Nannipieri 1995), and expressed in µg $N\text{-}NH_4$ per 1 g of soil after 2 hours.

Statistical data analysis was performed using Statistica 8® Software. The differences were assessed with the Kruskal-Wallis test. Relationships between enzyme activities and physic-chemical factors were determined by correlation analysis.

Results

Peats

At 7 sample plots soils were diagnosed as fen soils. They were covered by *Fraxino-Alnetum, Ribo nigri-Alnetum* and *Sphagno girgensohnii-Piceetum* association. The soils showed advanced decomposition of peat and amorphous along with amorphous-fibrous structure. Poor fen soils formed meso- and oligotrophic bog forest associations: *Sphagno girgensohnii-Piceetum, Sphagno squarrosi-Alnetum* and *Vaccinio uliginosi-Betuletum pubescentis, Querco-Piceetum* and *Fraxino-Alnetum*. Amorphous-fibrous structure prevailed in soils.

Raised bog soils formed bog forest habitats with *Vaccinio uliginosi-Pinetum* association. As for the botanical content this kind of soils were raised sphagnum, characterised by poor decomposition of peat and fibrous structure.

Tab. 1. Characteristics of peat soils

Parameter	Fen peat soils		Transition bog		Raised bog peat soils		Kruskal–Wallis p-value
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	
Dehydrogenase activity mg TFF/100g^{-1}/24h^{-1}	85.71	82.90	46.62	43.99	41.89	29.02	0.7849
Urease activity µg N-NH4/1g^{-1}/2h^{-1}	5.02	3.28	0.71	0.32	0.61	0.51	0.0033
Organic C	30.94	12.94	43.12	3.33	42.28	5.68	0.0071
Total N	1.95	0.87	1.79	0.43	1.29	0.45	0.0270
C/N	15.80	2.68	25.45	7.21	35.63	11.17	0.0016
pH in H_2O	5.88	0.56	4.10	0.40	3.67	0.25	0.0003
pH in KCl	5.32	0.56	3.19	0.44	2.74	0.20	0.0002
Hydrolytic acidity	27.20	20.34	126.70	32.04	137.99	20.77	0.0008
Ca	1494.64	785.26	487.97	268.51	241.01	145.47	0.0038
K	13.00	8.07	20.55	10.78	30.67	14.39	0.0219
Mg	59.80	55.84	33.54	11.44	28.71	9.71	0.6591
Na	5.23	5.12	10.29	9.45	8.89	3.26	0.1011
P	8.03	2.87	10.32	6.49	11.98	4.89	0.3360
Moisture	75.57	19.92	80.57	7.06	84.22	5.01	0.1626
Exchangeable acidity	0.52	0.29	6.40	4.52	17.47	6.92	0.0002
Exchangeable aluminum	0.40	0.21	4.54	3.38	10.34	5.81	0.0008

Physical and chemical properties

Surface levels of raised bog soils indicated the lowest pH (average pH in H_2O was 3.67 and pH in KCl was 2.74) and the highest C/N ratio amounting to 35.63. The highest pH in surface levels was observed in fen soils (average pH in H_2O: 5.88, pH in KCl: 5.32), in which C/N ratio amounted to 15.80. In transition bog soils the average pH in H_2O amounted to 4.10 and pH in KCl was 3.19 (Tab. 1). Statistically significant differences between particular subtypes of peat soils were found in: pH-H_2O and pH-KCl, C/N ratio and the content of organic carbon, nitrogen, calcium and potassium. The biggest differences in physical and chemical properties were observed between fen soils and raised bog soils, and the least between raised bog soils and transition bog soils. The average moisture was highest in raised bog soils (84.22%), and lowest in fen soils (75.57%).

Enzymatic activity

Dehydrogenase and urease activity varied within the studied soils (Tab.1). The highest average dehydrogenase activity in soil surface level was noted in fen soils (85.71 mg TFF/100g^{-1}/24h^{-1}), and lowest in raised bog soils (41.89 mg TFF/100g^{-1}/24h^{-1}). The results on urease activity were similar: from 5.02 µg N-NH4/1g^{-1}/2h^{-1} in fen soils through 0.71 µg N-NH4/1g^{-1}/2h^{-1} in transition bog soils to 0.61 µg N-NH4/1g^{-1}/2h^{-1} in raised bog soils. Statistically significant differences in urease activity between particular soil subtypes were observed (Tab.1). Dehydrogenase activity did not reveal statistically significant diversity. Relations between enzymatic activity and physical and chemical properties of soils are presented in Table 2. Urease activity correlated positively with: pH -H_2O and pH-KCl and Ca content, whereas it correlated negatively with: C content, C/N ratio, hydrolytic acidity, moisture, exchangeable acidity and Al content. Urease activity increased with an increase of soil pH and Ca content. (Tab. 2). Dehydrogenase activity correlated positively with pH-H_2O and pH-KCl, Ca, Mg, Na content, and correlated negatively with hydrolytic acidity. On the whole no correlation between dehydrogenase and urease activity and the content of N, K and P was found. Dehydrogenase activity did not correlate with C content and C/N ratio. An increase in soil pH as well as Ca and Mg content were accompanied by an increase of dehydrogenase activity.

Tab. 2. Correlation between physico-chemical soil properties and enzyme activity

Parameter	Organic C	Total N	C/N	pH in H_2O	pH in KCl	Hydrolytic acidity	Exchangeable acidity	Exchangeable aluminum	Ca	K	Mg	Na	P	Moisture
Urease activity µg N-NH4/1g^{-1}/2h^{-1}	−0.57**	0.26	−0.55**	0.77*	0.79*	−0.78*	−0.50*	−0.50*	0.61**	−0.24	0.28	−0.19	−0.18	−0.55**
Dehydrogenase activity mg TFF/100g^{-1}/24h^{-1}	−0.06	0.39	−0.28	0.50***	0.51***	−0.45***	−0.33	−0.37	0.54**	−0.26	0.62**	0.45***	0.23	0.12

*** – significant at α=0.001; ** - significant at α=0.01; * - significant at α=0.05

Discussion

Literature data (Dick 1984) point out that among soil physical and chemical properties the strongest connections with enzymatic activity are indicated by organic C and N contents and the features of soil sorption complex. Bielińska *et al.* (2003) showed high enzymatic activity in bog soils. This was associated by the authors with the content of organic C, total N and P. In the present study high negative correlation between urease activity and the content of organic C as well as C/N ratio was established. This results from the fact that urease catalyzes hydrolysis of urea to carbon dioxide and ammonia. Urease in soil is closely connected with organic matter (Alef and Nannipieri 1995, Chakrabarti *et al.* 2004). Differentiation of urease activity in the studied peat types was found which can be associated with statistically significant differentiation in the content of C and N. Differentiation of the contents of organic C and total N in the examined soils results from different botanical composition of partly decayed vegetation matter. Warner and Asada (2006) define biological diversity of peat soils as differentiation of plant species occurring in them (perennial plants, ferns, residues of trees, lichens and mosses). Maciak (1995) underlines the influence of increasing moorshing process as well as the degree of peat decay on intensity of mineralization of organic matter mineralization and reduction of C/N ratio value.

The increase of enzymatic activity with the increase of pH was observed in dehydrogenase as well as urease activity. Activity and longevity of enzymes in soil is affected by its pH (Trasar-Cepeda and Gil-Sotres 1987). Brzezińska *et al.* (2001) observed maximum dehydrogenase activity at pH 6.6–7.2. Optimum pH for urease amounts to 6–7 (Bremner and Mulvaney 1978). In this study the highest activity of both dehydrogenases and urease was observed in fen soils where pH was close to optimal, and the average pH value amounted to 5.88. In transition bog soils the enzymatic activity was lower as in these soils there are formed durable humic acids with lower pH – below 4 (Bielińska *et al.* 2003). According to Frankenberger and Johanson (1982), the weakening of enzymatic activity in soil with the increase of soil acidity is the effect of destroying ion and hydrogen bonds in enzyme active centre. Maciak (1995) points out a possibility of acidifying peat-moorsh soils which results from: mineralization of organic compounds, release of nitrogen and formation of nitrate forms of this element In this study statistically significant differences in the content of Ca in the studied peat soils were indicated. The content of Ca was positively correlated with the activity of dehydrogenase and urease. According to Okołowicz and Sowa (1997) peat soils are characteristic of the high content of Ca at clearly acidic soil reaction as well as small amounts of Fe, Al and Mn.

Tate and Terry (1980) studied dehydrogenase activity and microbiological biomass in histosols. The authors found correlation between enzymatic activity and soil moisture, and concluded that moisture could be a limiting factor for microbiological activity. Dehydrogenase activity is related to quantitative changes in microorganism populations, It is also determined by chemical composition of fresh litter which provides substrates to soil microflora. Similar results were obtained in own research where dehydrogenase activity was highest in fen peat soils where mean moisture was lowest. This was also observed for urease activity which then was correlated negatively with soil moisture. According to Efremov and Ovchinnikow (2008) in peat soils the enzymatic activity depends on humidity conditions. In dehydrated peatland conditions there is variable nutrient distribution. (Westman and Laiho 2003).

In the present study conspicuous differences were observed in soil biological, physical and chemical properties between fen and raised bog soils. Not significant differences were observed for peat soils in transition bogs and raised bog soils. In a view of the genesis of transition bog soils, they are just a stage in peatland development and probably do not present long-lasting accumulative systems (Tobolski 2000).

Conclusions

- The biggest differences in soil physical and chemical properties were observed between fen and raised bog soils, and the least – between raised bog and transition bog soils.
- Enzymatic activity varied between the studied soils. Statistically significant differences in urease activity was observed between particular soil subtypes. Dehydrogenase activity did not reveal statistically significant diversity.
- Dehydrogenase as well as urease activities increased with the increase of soil pH.

– Statistically significant differences in Ca content were observed. Dehydrogenase as well as urease activities were positively correlated with Ca content.

Acknowledgments

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