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THE SOIL FUNGI COMMUNITIES OF BROWN FOREST PODZOLIC SOILS IN TWO DIFFERENT OAK-HORNBEAM FORESTS OF THE ZWIERZYNIECKI PARK IN BIAŁYSTOK

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A b s t r a c t. The aim of the studies carried out in the natural oak-hornbeam forest *Tilio-Carpinetum typicum* and in the degenerated form in the stage of pinetization *Pinus-Lamniastrum*, was to obtain and compare qualitative-quantitative structures of soil fungi communities in two different oak-hornbeam forests. This degenerated form of oak-hornbeam forest is the result of removing the natural tree population (typical oak-hornbeam forest) and re-afforesting the resultant vacant area with pines. The study plots were located in such a way that the variations of soil fungi communities were affected only by seasonal changes in the vegetation of the degenerated oak-hornbeam forest *Pinus-Lamniastrum*. The soils in both study plots are typical forest grey-brown podzolic soils (Luvisols). The results of mycological studies indicate significant differences between soil fungi communities in both oak-hornbeam forests, although similarities especially in species composition of 15 of the most abundant fungi species were also found. The differences are the result of changes in the floral composition of degenerated oak-hornbeam forest. In the past, when typical oak-hornbeam forest covered whole studied areas, the soil fungi communities were probably almost the same in both plots. The first change could have happened after the removal of the trees; the second, after the re-afforestation of the resulting vacant area with pines. The re-appearance of *Tilio-Carpinetum typicum* in its once occupied habitat causes changes in the soil fungi community in the degenerated oak-hornbeam forest.

K e y w o r d s: typical oak-hornbeam forest, degenerated oak-hornbeam forest, grey-brown, podzolic soil.

INTRODUCTION

The studies were carried out in the natural oak-hornbeam forest *Tilio-Carpinetum typicum* and in the degenerated form in the stage of pinetization *Pinus-Lamniastrum*. Both tree populations were found in the urban forest named the "Zwierzyniecki Park", located in the southern part of the city of Białystok. Typical oak-hornbeam forest *Tilio-Carpinetum typicum* is protected as a nature reserve.

The oak-hornbeam forest *Pinus-Lamniastrum* is located close to the western border of this reserve. This forest is the result of having removed the natural tree population (typical oak-hornbeam forest) some 50 years ago, clear-cutting and reafforestation of the resultant vacant area with pines. The study plots were located in such a way that the qualitative and quantitative variations of soil fungi communities were affected only by seasonal changes in vegetation of the degenerated oak-hornbeam forest.

The aim of the studies was to obtain and compare qualitative-quantitative structures of soil fungi communities in two different oak-hornbeam forests, which occurred in the same type of soil.

MATERIALS AND METHODS

On both permanently signed plots in typical and degenerated oak-hornbeam forest in stage of pinetization soil, plants and soil fungi were studied. The morphological structure of soil was examined in both plots in soil pits with a depth of 200 cm. The physical and chemical properties of soil samples taken from every soil horizon were measured. In the laboratory of the Department of Soil Protection and Land use the following parameters were analysed:

- grain size distribution - areometric analysis by Casagrande in modification by Prószyński;
- soil reaction (pH) - potential method with glass electrode;
- hydrolytic acidity (Hh) - Kappen method;
- exchange acidity of soil - Sokołow method;
- total concentration of P and K was measured after the combustion of samples in sulphuric acid and 30% hydrogen peroxide;
- organic carbon - dichromate method by Tiurin;
- total concentration of nitrogen - spectrophotometric method;
- concentration of exchangeable cations Ca^{2+}, Mg^{2+}, K^{+}, Na^{+} with 1 M CH_3COONH_4 at pH 6.8 as a dislodging solution.

On the basis of analysis results the following parameters were calculated:

- total base exchangeable cations $S = Ca^{2+} + Mg^{2+} + K^{+} + Na^{+}$;
- sorptive capacity of soil $T = Hh + S$;
- proportion of total divalent calcium and magnesium cations and total sodium and potassium monovalent cations:

$$\frac{Ca + Mg}{K + Na}$$

- degree of base soil saturation: $\frac{S}{T}$ 100%;
- carbon and total nitrogen ratio C:N.

Samples of ectohumus were analysed as well.

Plant coverage and floral composition of both oak-hornbeam forests were determined on the basis of two releves.

The soil samples for mycological studies were taken from permanently marked study plots, where the releves were made. The soil plates method by Warcup [13], in modification by Mańka *et al.* [4,7-10], was used in order to render as closely as possible the qualitative and quantitative structures of soil fungi communities. This method allows results closer to reality to be obtained. The Marczewski-Steinhaus formula for similarities of classes [12] was used in order to qualify the similarities of soil fungi communities in both oak-hornbeam forests:

$$S = \frac{w}{a + b - w}$$

S - similarity of two compared soil fungi communities, w - number of fungi species occurring in soil of both oak-horn beam forests, a - number of fungi species in oak-horn beam forests *Tilio-Carpinetum typicum, b* - number of fungi species in oak-horn beam forests *Pinus-Lamniastrum.*

RESULTS

The physical and chemical properties of both soil profiles in typical and degenerated oak-hornbeam forest are indicative of similar processes in these soils. On this basis these soils are distinguished as typical grey-brown podzolic forest soil (forest Luvisols). The nutrient concentration and other analytical properties in the soils described are almost the same (Tables 1 and 2). That is why the differences in qualitative and quantitative structures of soil fungi communities are not a result of the different soil type.

The studies of the phytocenosis shows great similarities in both plant communities. Many features of the typical oak-hornbeam forest are found in the vicarious plant community. This means that in this forest the dynamic processes leading to restoration of natural form of oak-hornbeam forest occur. The regeneration is almost

Table 1. Soil reacion, hydrolytic and exchange acidity, concentration of easily fixated components (phosphorus and nitrogen), organic carbon, total nitrogen and carbon and total nitrogen ratio in soils of oak-hornbeam forest *Tilio-Carpinetum typicum* and oak-hornbeam forest *Pinus-Lamniastrum*

Plant community	Soil genetic horizon	Horizon thickness (cm)	Soil species	Depth of sampling (cm)	pH		Hydrolytic acidity	Exchange acidity		P_2O_5	K_2O	Corg.	N_{tot}	C:N
					H_2O	1 M KCl		Al^{+3}	H^+					
							cmol(+)kg^{-1}			mg/100 g		%		
Tilio-Carpinetum typicum	O	1	vls	0-1						17.95	212.4	0.64	0.16	
	Ah	18	II	15	4.50	3.70	6.17	0.50	0.44	1.05	3.05	0.42	0.09	
	Eet	20	ml	30	4.80	3.70	3.96	1.57	0.12	0	3.05	0.26	0.09	
	Bt	43	ml	52	6.00	4.80	0.91	0.21	0.16	0	9.1			
	Bt		ml	83	6.90	5.80	0.12	0	0.12	16.75	9.6			
	Cca	112	ml	110	7.40	6.90	0.17	0	0.17	0	8.1			
	Cca		ml	144	7.40	6.90	0.08	0	0.08	0.15	9.1			
Pinus-Lamniastrum	O	2		0-2						15.95	110.4			
	Ah	16	vls	13	4.75	3.95	6.08	0.17	0.23	0.55	2.55	0.92	0.15	6.13
	Eet	17	II	30	5.26	4.56	2.08	0.04	0.05	0.01	2.55	0.65	0.08	8.12
	Bt	50	II	42	5.81	4.52	1.29	0	0.11	0	8.1	0.29	0.06	4.81
	Bt		II	95	6.90	5.86	0.07	0	0.07	14.8	5.1			
	Cca	100	II	115	7.53	7.09	0.06	0	0.06	0	3.05			

vls - very loamy sand, II - light loam, ml - medium loam.

Table 2. The concentration of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, total alkalis, sorptive capacity, proportion of total divalent cations and total monovalent cations, and the degree of base soil saturation in oak-hornbeam forest *Tilio-Carpinetum typicum* and oak-hornbeam forest *Pinus-Lamniastrum*

Plant community	Soil genetic horizon	Horizon thickness (cm)	Soil species	Depth of sampling (cm)	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	S	T	$\frac{Ca+Mg}{K+Na}$	V
					cmol(+)kg^{-1}							
Tilio-Carpinetum typicum	O	1		0-1	3.97	2.19	0.61	0.10				
	Ah	18	vls	15	1.64	0.89	0.15	0.03	2.58	8.75	14.06	0.30
	Eet	20	II	30	3.61	0.79	0.07	0.05	4.52	8.48	36.67	0.53
	Bt	43	ml	52	13.91	2.96	0.24	0.15	16.54	17.45	41.41	0.95
			ml	83	15.61	3.47	0.23	0.21	35.13	35.25	57.82	0.90
	Cca	112	ml	110	41.44	0.16	0.19	0.22	42.01	42.18	108.78	0.99
			ml	144	83.97	3.85	0.23	0.25	88.30	88.38	182.96	0.99
Pinus-Lamniastrum	O	2		0-2	4.93	1.42	0.39	0.08				
	Ah	16	vls	13	1.90	1.48	0.16	0.01	3.44	9.52	52.00	0.36
	Eet	17	II	30	4.75	1.28	0.05	0.05	6.13	8.21	60.03	0.75
	Bt	50	II	42	17.41	1.66	0.19	0.07	19.33	20.62	73.35	0.94
			II	95	13.35	1.28	0.17	0.12	14.92	14.99	50.45	0.99
	Cca	100	II	115	72.54	2.41	0.15	0.21	75.31	75.37	208.19	0.99

vls - very loamy sand, II - light loam, ml - medium loam, S-total alkalis, T-sorptive capacity, V-degree of base soil saturation.

finished in the ground flora of the forest, whereas the undergrowth and the tree population is still undergoing transformation.

The method of soil plates were used in mycological studies. Soil samples were taken in spring and autumn from 1993 to 1996. As a result of these studies, 4000 isolates of soil fungi were obtained, including 1892 isolates form soil taken from oak-hornbeam forest *Tilio-Carpinetum typicum* and 2108 isolates from soil taken from oak-hornbeam forest *Pinus-Lamniastum*. These isolates were representative of 94 soil fungi species. On each date of isolation and from every plot under examination, dozens of soil fungi species were found. A maximum of 40 soil fungi species was isolated during one study season, although several species were represented by few isolates (1- 9). Such a low number of isolates indicates the insignificant ecological part of these species in the community.

The most abundant soil fungi species in soils of both typical oak-hornbeam forest and degenerated oak-hornbeam forest are: *Absidia spinosa, Chrysosporium merdarium*, *Ch. pannorum*, *Humicola fuscoatra, H. grisea, Mortierella minutissima*, *M. vinacea, Penicillium brevicompactum, P. daleae*, *P. janczewskii*, *Trichoderma koningii* and *Trichoderma viride.* Although the domination of the aforementioned species in both populations is different, only *Chrysosporium merdarium, Penicillium brevicompactum* and *Trichoderma koningii* play a similar part in both of the communities described, however the other soil fungi communities play various parts (Table 3).

The percentage variation coefficient, which amounts from 26% to 48% (Table 4) was obtained by the comparison of both soil fungi communities using the Marczewski-Steinhaus formula for the similarity of classes. The lowest coefficients around 30% were obtained during the comparison of soil fungi communities in the 1993 study season and the highest values almost 50%, were calculated in 1994. The similarity of both oak-hornbeam forests was around 40% in the rest of the study seasons.

The results obtained by the Marczewski-Steinhaus formula indicate the qualitative similarities in the soil fungi communities compared. This formula permits the assessment of the level of similarity between the floral composition of communities (qualitative structure), but the abundance of species (quantitative structure) is omitted. This problem was resolved by using the statistical computer programme SYNTAX 5.01 and the percentage distance coefficient.

The percentage distance coefficient for both analysed soil fungi communities obtained the value 0.67 which means 67%. It was observed that the higher the value of this coefficient is calculated, the smaller is the similarity between the communities.

The soil fungi communities obtained from the soil of the oak-hornbeam forest *Tilio-Carpinetum typicum* in 1995 and 1996 were the most similar. The similarity was above 50% and the percentage distance coefficient was 0.48. The similar soil fungi communities were also obtained from soil of oak-hornbeam forest *Pinus-Lamniastrum* in 1994 and 1995. The coefficient amounts to 0.52.

The analysis of data with computer programme SYNTAX 5.01 indicates that the soil fungi communities of both oak-hornbeam forests belong to two different qualitative units The soil fungi community of oak-hornbeam forest *Pinus-Lamniastrum* is forming as a qualitatively new community, whose structure and functions are different from the soil fungi community of the typical oak-hornbeam forest.

Table 3. The evaluation of species domination in soil fungi communities in oak-hornbeam forests *Tilio-Carpinetum typicum* and *Pinus-Lamniastrum*

Chosen fungi species - components of community	Species domination (%)	
	Tilio-Carpinetum typicum	*Pinus-Lamniastrum*
Absidia spinosa	4.49	1.61
Chrysosporium merdarium	11.73	12.95
Chrysosporium pannorum	4.70	9.677
Gliomastix murorum	0.37	2.47
Humicola fuscoatra	3.49	1.71
Humicola grisea	0.37	4.51
Mortierella minutissima	8.72	10.15
Mortierella vinacea	14.00	1.14
Penicillium aurantiogriseum	0.48	2.37
Penicillium aurantiogriseum	6.36	6.74
Peicillium brevicompactum	15.06	10.82
Penicillium janczewskii	5.92	8.25
Trichoderma koningii	2.48	2.61
Trichoderma viride	4.86	1.33

Table 4. The evaluation of similarities in soil fungi communities in oak-hornbeam forests *Tilio-Carpinetum typicum* and *Pinus-Lamniastrum*

Isolation year	Similarity of communities (%)	
	spring	autumn
1993	26.1	33.3
1994	48.7	46.7
1995	43.1	43.2
1996	37.5	40.9

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The computer programme SYNTAX 5.01 permits the differences and similarities between the structures of soil fungi communities in relation to the season of the sampling to be found. Differences in soil fungi communities relating to the spring or autumn sampling were not found.

The differences in the qualitative and quantitative structures of soil fungi communities of the natural oak-hornbeam forest *Tilio-Carpinetum typicum* and in the degenerated form in the stage of pinetization *Pinus-Lamniastrum* are the results of changes in the floral composition of *Pinus-Lamniastrum*. In the past, when typical oak-hornbeam forest covered the whole of the studied area, the soil fungi communities were probably almost the same on both plots. The first change could have happened after removing trees, the second, after re-afforestation of the cleared area with pines. This re-introduction of *Tilio-Carpinetum typicum* to its former habitat, causes changes in the soil fungi community in the degenerated oak-hornbeam forest.

DISCUSSION

The oak-hornbeam forests are one of the most frequently changed forest communities, because of the wide possibilities for their economic use. The forms of oak-hornbeam forests tree populations were exploited variously; amongst other things, the re-afforestation of most cleared areas with pines resulted in the creation of new, vicarious plant communities in various stages [3] or forms [11] of degeneration. This type of management caused great losses to the oak-hornbeam forest environment. However, the growth and health of the plant community is related to living organisms like soil fungi. Czerwiński [2] in the community *Pinus-Lamniastrum* observed the dynamic processes leading to the recreation of the primary, natural form of oak-hornbeam forest. Caused by pinetization changes in the trees, humus and soil environment influence the soil fungi, because there are strong connections between the formation of the soil fungi communities and the floral composition of the forest community [1]. In studies of the microorganism communities of forest soil, it is very important to find the closest relation between the microorganism communities studied and the well defined plant communities and the mechanical, physical and

chemical properties of the soil, because this permits the comparison of the results of investigations carried out on different occasions and at different locations on account of the close relation between the microorganism communities of the soil environment and soil properties and plants [5].

CONCLUSIONS

1. Although similarities between the soil fungi communities of the oak-hornbeam forest *Tilio-Carpinetum typicum* and the degenerated form of the oak-hornbeam forest at the stage of pinetization *Pinus-Lamniastrum* were observed, especially in the species composition of 15 of the most abundant fungi species, these two soil fungi communities show different properties.

2. The soil fungi community of the degenerated oak-hornbeam forest follows changes in plant composition and forms at a different specific level in relation to the soil fungi community in the typical oak-hornbeam forest.

3. Changes in the microbiological soil environment of degenerated oak-hornbeam forest have advantageous influences on the regeneration process of the typical oak-hornbeam forest as opposed to those of the oak-hornbeam forest *Pinus-Lamniastrum*.

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