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Correlation between the abundance of cellulolytic fungi and selected soil properties

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The study conducted has revealed that the general abundance of cellulolytic fungi in the soil is significantly correlated only with the phosphorus content. The correlation with specific soil properties was found in the case of the genera *Humicola*, *Penicillium*, *Fusarium* and *Chrysosporium* of the 10 genera of these fungi isolated most often.

Key words: cellulolytic fungi, arable soils, abundance, ecological factors, correlation

INTRODUCTION

Cellulolytic fungi are one of the more important physiological associations responsible for the decomposition and mineralisation of organic residue in the soil. They comprise several genera representing mainly *Ascomycotina* and *Deuteromycotina*. Some genera, such as *Chaetomium*, *Humicola* or *Trichoderma*, are characterised by a high cellulolytic activity; the capacity of others, for instance representatives of *Penicillium* and *Gliocladium*, to decompose cellulose is generally lower. Fungi whose cellulolytic activity is high synthesise a full set of cellulolytic enzymes, including endoglucanases, exoglucanases and cellobiase (β-1.4-glucosidase), and produce special morphological structures that facilitate the destruction of native cellulose substrates (English 1965; Duncan and Eslyn; 1966; Rogalski 1992). Most researchers believe that cellulolytic fungi play the greatest role in decomposing cellulose in acidic soils while bacteria and actinomycetes participate chiefly in this process in neutral or basic soils. The data on the distribution of these micromycetes in the soil have so far been scarce (Domsch and Gams 1970; Griffin 1972; Kjöller and Struwe 1982; Korniłłowicz 1989)

The aim of this article was to expand the knowledge in this area. In particular, the correlation between the abundance of cellulolytic fungi, which occupy arable soils, and some properties of those soils was examined.

MATERIAL AND METHODS

The material examined consisted of soil samples collected in arable soils following plant harvesting. The manner of soil collection and preparation for the examination was described in a recent publication (Korniłłowicz-Kowalska and Bohacz 2002). The study comprised all soils listed in the publication quoted. Tables 1 and 2 present selected physical and chemical properties of the soils. Their more in-depth description was given earlier (Korniłłowicz-Kowalska and Bohacz 2002).

Table 1
Selected physical and chemical properties of the soil examined

No	Soil type	Content (%)				Content mg in 100g of soil	pH_{KCL}
		Floatable fraction (ϕ < 0.02 mm)	Humus	N tot.	$CaCO_3$	P_2O_5	
1	Podsols	10	1.72	0.054	0.00	21.6	4.19
2		15	1.39	0.049	0.00	7.3	3.86
3		9	1.05	0.041	0.08	14.0	4.06
4	Cambisols	21	1.95	0.082	0.00	11.4	4.29
5		52	1.71	0.120	0.00	no data	6.30
6	Chernozems	40	3.93	0.270	0.00	13.3	7.15
7		47	2.28	0.200	0.00	7.8	6.01
8		46	2.69	0.210	0.70	16.8	6.08
9	Phaesols	36	3.95	0.270	4.67	64.5	7.28
10		40	4.80	0.260	14.91	25.0	7.30
11		31	2.91	0.161	0.38	14.0	6.83
12		41	4.01	0.235	2.58	260.0	6.93
13	Fen soils	43	5.89	0.245	0.13	8.4	6.32
14		50	2.52	0.142	1.68	33.5	7.13
15		37	3.93	0.256	3.09	2.7	7.15
16	Limestone soils	20	1.76	0.101	5.06	43.5	7.45
17		21	3.38	0.138	0.84	342.0	7.09

The plate dilution method was used to isolate cellulolytic fungi. The Winogradzki substrate with Whatmann paper 1 as the only source of carbon and energy was used (pH 5.5), and antibiotics inhibiting bacterial growth were added. Plates in which fungal growth occurred were incubated at 26 °C for 14 days. The general abundance of fungi is the mean value of three series, and was expressed in units forming colonies (*colony forming units* f. u.) x kg^{-1} d. m. of the soil.

The generic and species composition of fungi was determined isolating all developed colonies from three plates for a given series of dilutions. The material collected was identified on the basis of micro- and macromorphological properties conducted in microcultures and on plates in keeping with the systematic studies: Ellis (1971), as well as Domsch, Gams and Anderson (1980).

Table 2
Correlation coefficients of the properties of the soils examined

	humus	N tot.	$CaCO_3$	P_2O_5	floatable fraction	pH
humus	1	-	-	-	-	-
N tot.	0.858***	1	-	-	-	-
$CaCO_3$	-	-	1	-	-	-
P_2O_5	-	-	-	1	-	-
floatable fraction	0.482x	0.699**	-	-	1	-
pH	0.612**	0.733***	-	-	0.611**	1

Explanations: (-) – no significance of the correlation coefficient; ˣ - significant correlation coefficient at on the verge of the level of significance $\alpha = 0.05$; * - significant correlation coefficient $\alpha = 0.05$; ** - significant correlation coefficient $\alpha = 0.01$; *** - significant correlation coefficient $\alpha = 0.001$

The statistical method of correlation and the multiple regression analysis were used to calculate the results obtained. The following linear multiple regression models were considered: frequency (fungi) = a + b humus + c floatable fraction + d nitrogen + e $CaCO_3$ + f P_2O_5 + g pH, where: frequency (fungi) – occurrence frequency of a given genus or all cellulolytic fungi in the soil (dependent variables); humus, floatable fraction, nitrogen, $CaCO_3$, P_2O_5 and pH – content of those constituents in the soil (independent variables); a – constant (free term in the regression expression); b, c, d, e, f, g – coefficients for independent variables, determined using least squares with the elimination of the least significant components. Regression models were considered only for those fungi for which a significant correlation between the frequency of occurrence and any physical or chemical soil property examined was found.

RESULTS

The general abundance of cellulolytic fungi in the arable soils examined differed and ranged between ca. 4 mln c. f. u. · kg^{-1} d. m. in the cambisol formed of heavy clay (soil 5) and ca. 200 mln c. f. u. · kg^{-1} d. m. in the limestone soil (rendzina) of the light dusty clay granulometric type (soil 17). Significant quantitative differences in the group of the fungi examined were also recorded within the same soil type. It was particularly noticeable in the case of cambisols and limestone soils where even a 7-fold difference in the number of these microorganisms was recorded (Fig. 1). A statistical calculation of the total frequency of cellulolytic fungi revealed a significant correlation between the development of these fungi and the phosphorus content in the soil (Tab. 3 and 4). A positive correlation coefficient (r), at a high level of significance, and a relatively high determination coefficient (R^2) for both properties prove that the number of cellulolytic fungi in the soil increases as the content of this component increases. The general abundance of cellulolytic fungi did not reveal, however, a significant correlation with any other physical or chemical soil property examined (Tab. 3).

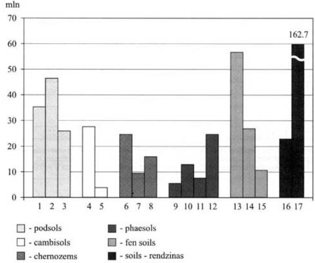

Fig. 1. General abundance of cellulolytic fungi (c. f. u. · kg^{-1} d.m. of soil) in the arable soils examined.

Table 3
Occurrence frequency of selected genera of fungi (%)

Soils	*Aspergillus*	*Chaetomium*	*Chrysosporium*	*Fusarium*	*Gliocladium*	*Humicola*	*Paecilomyces*	*Penicillium*	*Trichoderma*	Other genera
1	0.0	6.9 (2)	0.0	0.0	27.6 (8)	0.0	0.0	34.5 (24)	31.0 (9)	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.6 (63)	7.4 (5)	0.0
3	0.0	0.0	0.0	20.95	0.0	1.9 (2)	0.0	43.8 (46)	17.1 (18)	16.25
4	0.0	0.0	15.4 (8)	1.9 (1)	7.7 (4)	0.0	0.0	17.3 (9)	50.0 (26)	7.7
5	0.0	5.2 (2)	0.0	0.0	23.0 (9)	0.0	0.0	38.5 (15)	33.3 (13)	0.0
6	0.0	31.9 (15)	12.8 (6)	0.0	0.0	0.0	23.4 (11)	12.8 (6)	19.1 (9)	0.0
7	0.0	0.0	0.0	0.0	13.3	0.0	6.7 (2)	33.3 (10)	46.7 (14)	0.0
8	0.0	11.1 (3)	11.1 (3)	0.0	22.2 (6)	0.0	11.1 (3)	0.0	33.3 (9)	11.2
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0(30)	0.0
10	0.0	0.0	0.0	0.0	16.3 (7)	32.55 (14)	13.95 (6)	0.0	18.6 (8)	18.6
11	0.0	0.0	2.6	0.0	17.9 (7)	0.0	0.0	0.0	79.5 (26)	0.0
12	0.0	0.0	0.0	0.0	10.9 (5)	8.7 (4)	8.7 (4)	4.3 (2)	36.95 (17)	30.45
13	0.0	1.5 (1)	51.5 (35)	2.9 (2)	5.9 (4)	0.0	0.0	35.3 (24)	2.9 (2)	0.0
14	15.8 (8)	0.0	0.0	0.0	9.6 (5)	23.0 (12)	0.0	0.0	15.4 (8)	36.6
15	0.0	0.0	0.0	0.0	30.8 (12)	0.0	0.0	15.4 (6)	43.6 (17)	30.2
16	32.7 (18)	0.0	0.0	14.5 (8)	21.8 (12)	0.0	9.09 (5)	0.0	3.6 (2)	18.3
17		0.0	32.25 (10)	12.9 (4)	6.45 (2)	0.0	19.40 (6)	25.8 (8)	3.2 (1)	0.0

Explanations: () – number of isolates

An examination of the taxonomic composition of the isolates of cellulolytic fungi yielded 59 species in 20 genera of mainly fungi imperfecti (*Deuteromycotina*). The genera *Chaetomium* and *Thielavia* represented cellulolytic ascomycetes (*Ascomycotina*). Altogether 830 isolates were identified; 30 of them were identified only up to the genus (mainly *Penicillium*), and 6 did not develop fruit-bodies. *Trichoderma* (214 strains) and *Penicillium* (214 strains) were the genera isolated most frequently. Although less numerous, fungi of the following genera were also common: *Gliocladium* (88 strains), *Chrysosporium* (63 strains), *Fusarium* (37 strains), *Paeciliomyces* (37 strains), *Humicola* (32 strains), *Aspergillus* (26 strains), *Chaetomium* (23 strains) and *Acremonium* (23 strains). Other genera of cellulolytic fungi were isolated rarely or sporadically (1-17 strains) (Tab. 3).

The distribution of the majority of the genera of the examined fungi in the soil was not uniform. Fungi of the genus *Trichoderma* were the exception and occupied all soil environments examined, although their frequency of occurrence varied. Cellulolytic strains of the genus *Gliocladium* and *Penicillium* also occurred in the majority of the soils. Fungi of those genera were usually not recorded in podsols (*Gliocladium*), as well as phaesols and fen soils (*Penicillium*). The other genera recorded occurred in 2 to 7 of the arable soils examined. *Fusarium* occurred chiefly in podsols; *Chaetomium* and *Paeciliomyces* – chernozems and some phaesols; the genus *Humicola* was isolated from chernozems and fen soils most often, while *Chrysosporium* occupied fen soil number 13 to the greatest extent (Tab. 3).

The statistical calculation of the occurrence frequency of the most common genera of fungi (Tab. 4) showed that a significant correlation between their development and the soil properties examined existed only in the case of four of them (*Humicola*, *Penicillium*, *Fusarium*, *Chrysosporium*) – Tab. 4, 5.

Table 4

Correlation coefficients (r) between the general abundance of cellulolytic fungi and the frequency of selected genera and properties of the soils examined

Fungi	Soil properties					
	Content					pH
	humus	N tot.	$CaCO_3$	P_2O_5	Floatable fraction	
Total number	-	-	-	0.708**	-	-
Aspergillus	-	-	-	-	-	-
Chaetomium	-	-	-	-	-	-
Chrysosporium	0.527*	-	-	-	-	-
Fusarium	-	-	-	-	-0.559*	-
Gliocladium	-	-	-	-	-	-
Humicola	-	-	0.740***	-	-	-
Paecilomyces	-	-	-	-	-	-
Penicillium	-	-0.536*	-	-	-	-0.715**
Trichoderma	-	-	-	-	-	-

Explanations: (-) – no significant correlation coefficient; * - significant correlation coefficient $\alpha = 0.05$; ** - significant correlation coefficient $\alpha = 0.01$; *** - significant correlation coefficient $\alpha = 0.001$

The occurrence of cellulolytic strains of *Humicola* depended significantly on the level of $CaCO_3$ in the soil, as indicated by very high correlation coefficients (Tab. 4) and high determination coefficients (Tab. 5). They prove that the number of *Humicola* occurrences increases as the content of this fraction goes up. Thus, these fungi occupied phaesols, fen soils and limestone soils, characterised by a significant $CaCO_3$ content and, consequently, by the basic pH of the soil (Tab. 1 and 3).

Table 5
Determination coefficients (R^2) for the genera of fungi with significant correlation between frequency of occurrence and soil properties

Fungi	Soil properties					
	Content					pH
	Humus	N tot.	$CaCO_3$	P_2O_5	Floatable fraction	
Total number	-	-	-	0.465**	-	-
Chrysosporium	0.673***	0.673**	0.673**	-	-	-
Fusarium	-	-	-	-	0.258*	-
Humicola	-	-	0.510**	-	-	-
Penicillium	-	-	-	-	-	0.502*

Explanations: * - level of model significance $\alpha = 0.05$; ** - level of model significance $\alpha = 0.01$; *** - level of model significance $\alpha = 0.001$

The occurrence of cellulolytic strains of *Penicillium* in the soils examined was conditioned by the pH value and nitrogen content. Negative correlation coefficients between these properties (Tab. 4) are indicative of a decrease in the number of these fungi as the pH and the N content in the soil increases. By the same token, the data obtained demonstrate that those fungi prefer acidic soils, which was reflected (Tab. 4) by a significant number of these fungi in podsols (pH 3.86 – 4.19), cambisols (pH 4.29 – 6.30) and some chernozems (pH~6). The importance of the soil pH for the distribution of cellulolytic strains of *Penicillium* was corroborated by the multiple regression analysis (Tab. 5). The method used eliminated nitrogen as a factor that directly influences the development of these fungi. The reduction of the model to pH only resulted from a stronger correlation between the abundance of *Penicillium* and the soil pH than that between its abundance and the nitrogen content, while both chemical properties remained correlated with each other (Tab. 2).

The distribution of cellulolytic strains of *Fusarium* was negatively correlated with the level of the floatable fraction in the soil (Tab. 4), which proves that the occurrence frequency of the representatives of this genus decreases as the content of the granulometric fraction with Ø < 0.02 mm increases. A greater number of *Fusarium* in light soils (podsols) than that in heavy soils (cambisols formed of heavy clay) was a reflection of it (Tab. 4). The values of the determination coefficients obtained, although not very high, supported these findings (Tab. 5).

The number of cellulolytic fungi of the genus *Chrysosporium*, represented by one species, *Ch. pannorum*, was positively, although not strongly, correlated with the level of soil humus. Therefore, these fungi were accumulated in fen soils, characterised by the highest (5.89%) level of this fraction of all soils examined (Tab. 1, Tab. 3). The multiple regression analysis provided more data on the factors that influence the occurrence of active cellulolytic strains of *Chrysosporium*. It shows that the growth of the genus in the soil is also determined by the nitrogen content and the $CaCO_3$ content (Tab. 5). The values obtained prove that, at a set humus content, the number of cellulolytic *Chrysosporium* goes down as the amount of nitrogen and $CaCO_3$ goes up. The number of the other genera of fungi with cellulolytic capacity, listed in Tab. 4, was not significantly correlated with any of the physical or chemical soil properties examined (Tab. 4).

On the level of populations, the cellulolytic fungi isolated were most frequently represented by: *Trichoderma viride* (137 strains), *Gliocladim roseum* (66), *Chrysosporium pannorum* (63), *Penicillium canescens* (30), *P. decumbens* (30), *Humicola fuscoatra* (26), *Trichoderma harzianum* (24), *T. koningii* (24), *Paecilomyces lilacinus* (22), *Penicillium purpurogenum* (22). Other species were few (between 1 and 20 isolates) – Tab. 6.

Associations of cellulolytic fungi that occupied limestone soils were characterised by the greatest generic and species diversity (12 genera and 23 species), while cellulolytic fungi in cambisols – the smallest (7 and 11, respectively). It should be noted that strains of *Trichoderma*, as well as *Gliocladium* and *Penicillium*, occurred sporadically in limestone soils and in some fen soils. Less common fungal species that yield dark pigmentation, such as *Aspergillus erytrocephalus*, *A. ustus*, *Oidiodendron cerealis*, *Doratomyces microsporus* and *Acremonium murorum*, occurred in those soils more often (Tab. 6). An accumulation of representatives of fungi with dark pigmentation, i.e. *Humicola grisea*, *H. insolens*, *Stachybotrys atra*, *A. murorum*, was also recorded in some phaesols (Tab. 7). What those soils had in common was also a small number of fungi of the genus *Trichoderma*, *Trichoderma viride* in particular (Tab. 6). Furthermore, a low occurrence frequency of *Trichoderma viride* is some phaesols and chernozems was accompanied by a more numerous occurrence of such *Trichoderma* species as *T. polysporum*, *T. piluliferum*, *T. harzianum*, *T. koningii* and *T. hamatum*. On the other hand, in phaesol number 9, characterised by a very strong growth of *T. viride* (97% of all cellulolytic fungi), the occurrence of other species of *Trichoderma* was recorded sporadically. A similar phenomenon was noticed also in the other soils examined in which populations of *Trichoderma* spp occurred. Conversely, populations of *Chaetomium* spp. and *Paeciliomyces* ssp. benefited from the occurrence of each other, which was particularly conspicuous in the chernozems examined (Tab. 6).

DISCUSSION

The studies conducted show that the soils with a high nutrient content and availability, well buffered and oxygenated, offer the most favourable conditions for the development of cellulolytic fungi. Cellulolytic fungi develop most weakly in heavy soils, which should be accounted for by a high level of the floatable fraction, which impedes oxygen diffusion and consequently hinders the growth of these microorganisms. While great differences in the general abundance of fungi occupying the same or diverse soil types were undoubtedly induced by edaphic factors, agrotechnical ones, such as the system of cultivation, types of plants cultivated,

Table 6

Occurrence frequency of various species of cellulolytic fungi in arable soils

N°	Species	Soils																
		podsols			cambisols		chernozems			phaesols				fen soils			limestone soils	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	*Acremonium murorum* (Corda) W. Gams				4*						2				11			
2.	*A. strictum* W. Gams			1														
3.	*Acremonium* sp.												5					
4.	*Aspergillus erytrocephalus* Berk. et Curt.														1		6	
5.	*A. fumigatus* Fres.																3	
6.	*A. ustus* (Bain.) Thom et Church														7		9	
7.	*Chaetomium funeti* (Fuckel) Sacc.	3					3						8				2	
8.	*Ch. globosum* Kunze ex Steud.					2	8		2									
9.	*Ch. spirale* Zopf						4		1					1				
10.	*Chrysosporium pannorum* (Link) Hughes				8		6		3			1		35				10
11.	*Cladosporium cladosporioides* (Fres.) de Vries																2	
12.	*Doratomyces microsporus* (Sacc.) Morton et G. Sm.															4	4	
13.	*Fusarium culmorum* (W. G. Sm.) Sacc.													1				
14.	*F. equiseti* (Corda) Sacc.													1				
15.	*F. oxysporum* Schlecht. emend. Sny. et Hans.			8	1													
16.	*F. redolens* Wollenw.																8	4
17.	*F. solani* (Mart.) Sacc.			14														
18.	*Gilmaniella humicola* Barron																2	
19.	*Gliocladium catenulatum* Gilm. et Abbott			1	4			1			3						4	
20.	*G. roseum* Bain.	8				9		3	5		4	5	5	4	5	12	4	2
21.	*G. virens* Miller, Giddens et Foster								1			2					4	
22.	*Humicola fuscoatra* Traaen										8			6	12			
23.	*H. grisea* Traaen			2							2		4	4				
24.	*H. insolens* Cooney et Emerson										3							
25.	*Myrothecium verrucaria* (Alb. et Schw.) Ditm. ex Steudel																3	
26.	*Oidiodendron cerealis* (Thüm.) Barron																1	
27.	*Paecilomyces carneus* (Duché et Heim) A. H. S. Brown et G. Sm.						9											
28.	*P. marquandii* (Massee) Hughes										2							
29.	*P. lilacinus* (Thom) Samson						2	2	3		4		4				4	3
30.	*P. variotii* Bain.																1	3
31.	*Penicillium aculeatum* Raper et Fennell			4														
32.	*P. canescens* Sopp			27			3											

Tab. 6 cont.

33.	*P. chrysogenum* Thom				7													
34.	*P. corylophilum* Dierckx					12								5				1
35.	*P. cyclopium* Westling		2	7														
36.	*P. decumbens* Thom	6	22													2		
37.	*P. nigricans* Bain. ex Thom					3	1											3
38.	*P. purpurescens* (Sopp) n. Camb.	8	21	1														
39.	*P. purpurogenum* Stoll												2	19				1
40.	*P. restrictum* Gilman et Abbott			7														
41.	*P. rubrum* Stoll								1									
42.	*P. rugulosum* Thom						1											
43.	*P. spinulosum* Thom		18															
44.	*P. verrucosum* Dierckx															4		
45.	*Penicillium* sp.	10			2		1	10										3
46.	*Sesquicilium candelabrum* (Bonord.) W. Gams								1									
47.	*Stachybotrys chartarum* (Ehrenb. ex Link) Hughes										5							
48.	*Thielavia heterothallica* Klopotek														2			
49.	*Trichocladium asperum* Harz			14														
50.	*Trichoderma hamatum* (Bonord.) Bain.		5	1							6							1
51.	*T. harzianum* Rifai	2		9	1	2		6	1			1		2				
52.	*T. koningii* Oudem							8		3		12			1			
53.	*T. piluliferum* J. Webster et Rifai						1											
54.	*T. polysporum* (Link ex Pers.) Rifai						8					11						
55.	*T. viride* Pers. ex Gray	7		8	25	11			7	27	2	2	17	2	8	17	4	
56.	*Trichoderma* sp.								1									
57.	*Verticillium catenulatum* (Kamyschko ex Barron et Orions) W. Gams			2														
58.	*V. lecanii* (Zimm.) Viégas										2							
59.	*V. nigrescens* Pethybr.						1								2			
60.	*V. psalliotae* Treschow																4	
61.	*V. tenerum* (Ness ex Pers.) Link												3					
62.	Mitosporic fungi								6									
	Total	44	68	106	52	39	48	30	32	30	43	34	48	80	49	39	65	31

Explanations: * - number of strains

fertilisation, could also contribute to this effect. Those factors, however, were not considered in this study.

Among all physical and chemical properties examined only the phosphorus content showed a significant correlation with the general abundance of cellulolytic fungi. A high demand of cellulolytic fungi for this nutrient is probably caused by the synthesis of great amounts of phospho-derivatives of glucose and other phosphorilisied intermediate products generated in the process of cellulose hydrolysis by fungi (Griffin 1972).

Only four genera of the 10 genera isolated most often, i.e. *Humicola, Penicillium, Fusarium* and *Chaetomium*, were correlated with specific soil properties.

The distribution of the population of *Humicola* was positively correlated with the $CaCO_3$ content in the soil. The greatest numbers of these fungi were recorded in chernozems, fen soils and limestone soils rich in this compound. The dependence between the occurrence frequency of *Humicola* representatives and the amount of $CaCO_3$ in the soil should be put down to alkaliphilous preference of these fungi (quoted after Domsch, Gams and Anderson 1980). As is known, soils with a much lower $CaCO_3$ content belong to basic soils. The results of other studies (Korniłłowicz 1993) also reveal the stimulation of the development of *Humicola* representatives in a basic environment. Those studies showed that the frequency of occurrence of *Humicola* rose as ammonia, a factor that alkalises the environment, was released into the soil.

The selective influence of pH could also be discerned in the case of cellulolytic representatives of *Penicillium*. In contrast to the *Humicola* populations, *Penicillium* populations were accumulated in acidic soils, podsols in particular. On the other hand, *Penicillium* representatives occupied basic soils, especially phaesols, only to a small degree. In the light of the data (Domsch, Gams and Anderson 1980) on the possible growth of *Penicillium* in a wider range of soil pH (pH 3.0 – 8.0), it may be suspected that the phenomenon observed was also influenced by other factors, such as competition with other cellulolytic fungi. It was noticed that the soils in which cellulolytic strains of *Penicillium* occurred more frequently were characterised by a low frequency of cellulolytic representatives of *Trichoderma*, and vice versa. Soils with a low frequency of *Penicillium* were characterised by a high frequency of *Trichoderma*. As soils with a high number of *Penicillium* comprised chiefly podsols, it may be assumed that this genus prefers mainly soils in which water retention is poor and which are susceptible to overdrying. Fungi of the genus *Penicillium* are characterised by a low coefficient of water activity (a_w), which equals 0.65 (Moss 1987). Fungi of the genus *Trichoderma*, on the other hand, are a more effective coloniser of soils which are well moisturised as their coefficient is high a_w=0.98 (Domsch, Gams and Anderson 1980). Thus, this genus prefers phaesols which belong to hydrogenic soils.

Populations of *Trichoderma* and *Fusarium* also occurred in soil environments whose properties differed. Cellulolytic strains of *F. solani* occurred only in soils in which the frequency of *T. viride* was very low. The results of other studies also reveal a strong opposition between populations of *T. viride* and *F. solani* in the soil (Joffe 1966; Korniłłowicz 1991/1992, 1993). The antagonism between these two species is brought about by mycoparasitism of *T. viride*, resulting primarily from the secretion of mycolytic enzymes, i.e. β-1.3-glucanase and chitinase (Chet and Baker 1981; Elad et al. 1981, 1982). The opposition between the populations of *T. viride* and *F. solani* was most probably also responsible for the negative correlation between the occurrence of *F. solani* and the content of the floatable fraction in the soil, noticed in this study. It was reflected in the accumulation of *F. solani* representatives in light soils (podsols), characterised by a small number of *T. viride* populations at the same time.

In contrast to fungi of the genus *Fusarium* which occupy light soils with a low content of the floatable fraction, populations of cellulolytic representatives of *Chrysosporium* (*Ch. pannorum*) colonised soils with a high content of the floatable fraction and humus. The occurrence of this species was particularly strongly correlated with the amount of $CaCO_3$ and N in the soil. The affinity of *Ch. pannorum* with soils rich in $CaCO_3$, similarly to *Humicola*, is brought about by the species' preference for neutral and weakly basic environments (Williams and Pugh 1974 after Domsch, Gams and Anderson 1980). The stimulating influence of nitrogen should, on the other hand, be attributed to the cellulolytic activity of *Ch. pannorum*. As Park (1976 a, b) reports, the amount of nitrogen in the soil is the main factor that determines the decomposition of cellulose by the species.

In the light of the results obtained in this study, it seems that the occurrence and distribution of cellulolytic fungi in the soil should be explored in greater depth to include the soil type, as well as a more diverse edaphic factors and microbiocenotic relationships.

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Korelacja pomiędzy obfitością grzybów celulolitycznych a wybranymi właściwościami gleby

Streszczenie

W pracy przedstawiono wyniki badań dotyczące liczebności i składu rodzajowego grzybów celulolitycznych w glebach uprawnych różniących się właściwościami fizycznymi i chemicznymi.

Badaniami objęto 17 gleb sklasyfikowanych w 6 typach: bielicowe, brunatne, czarnoziemy, czarne ziemie, mady i rędziny.

Zastosowana analiza korelacji i regresji wykazała istotną zależność ogólnej liczebności grzybów celulolitycznych jedynie do zawartości fosforu w glebie ($r = 0,708$ przy $\alpha = 0,01$; $R^2 = 0,465$ przy $\alpha = 0,01$). Liczebność, przeważającej części, powszechnie spotykanych w badanych glebach rodzajów grzybów celulolitycznych m. in. *Trichoderma, Gliocladium, Paeciliomyces* i *Chaetomium*, nie była istotnie skorelowana z określonymi cechami gleby. Korelacja ta zaznaczyła się tylko w odniesieniu do liczebności celulolitycznych szczepów *Humicola, Penicillium, Fusarium* i *Chrysosporium.* Najbardziej istotną i dodatnią współzależność otrzymano między wystepowaniem *Humicola* i zawartością $CaCO_3$ w glebie ($r = 0,740$, $\alpha = 0,001$; $R^2 = 0,510$ przy $\alpha = 0,01$). Słabszą i ujemną korelację stwierdzono między liczebnością *Penicillium* i poziomem pH gleby ($r = -0,715$, $\alpha = 0,01$; $R^2 = 0,520$ przy $\alpha = 0,05$). Wzrost w glebie celulolitycznych szczepów *Chrysosporium*, reprezentowanych jedynie przez *Ch. pannorum*, był w największym stopniu uwarunkowany poziomem próchnicy ($R^2 = 0,637$ przy $\alpha = 0,001$). Występowanie celulolitycznych szczepów *Fusarium* było natomiast istotnie skorelowane z poziomem części spławialnych. Otrzymany współczynnik korelacji był jednak niski ($r = 0,258$, $\alpha = 0,05$).