Interactions between several species of macrophytes, zoosporic fungi and fungus-like organisms in different seasons in trophically different water bodies

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Abstract. Excretion into the environment of dissolved organic matter produced during photosynthesis is a characteristic phenomenon for several species of aquatic macrophytes (Wetzel 1969 a, b). Several of these substances are imbibed by heterotrophic microorganisms and may also inhibit the growth of other hydrobionts. An examination of the interactions between macrophytes and aquatic fungi showed that during the growing period (spring, summer and autumn), relationships between these organisms change. At the beginning of the growth period, the number of species of aquatic fungi rose in the presence eight macrophytes; during the summer there was a decrease in the number of fungi observed; while in the autumn (end of the growing season) there was an inhibitive influence of macrophytes on the growth of aquatic fungi, which was higher in eutrophic water. This inhibitive influence depends probably on the storage of any secondary compounds during aging of several macrophytes, which inhibit the growth of several species of fungi and fungus-like organisms.

Key words: fungi, fungus-like organisms, hydrochemistry, interactions, macrophytes, Poland, water bodies

Introduction

In the middle of XXth century it was shown that organic compounds produced during photosynthesis by green algae was secreted extracellularly to the aquatic environment (Tolbert & Zill 1956; Fogg 1971). Later experiments have shown that this phenomenon is characteristic for green algae as well as other taxa: algae (Fogg 1971; Czeczuga *et al.* 1978), cyanobacteria (Carmichael 1992), photosynthesizing bacteria (Czeczuga 1968a, b, 1973; Czeczuga & Grądzki 1973) and for macrophytes (Wetzel 1969a, b). The products of this primary extracellular production include various organic compounds of carbon (Wartanable 1980), free saccharides (Gocke *et al.* 1981), free amino acids (Carlucci *et al.* 1984), polyphenols (Serrano & Guisande 1990), polymeric substances (Hoagland *et al.* 1993) as well as enzymes (Chappell & Goulder 1994), including glucosidase (Corves & Jüttner 2000) and phosphatase (Boavida 2000).

Fungi play a significant role in aquatic ecosystems as a food source for many inverterbrates and in the mineralization of organic matter (Carroll & Wicklow 1999; Wetzel & Likens 2000). We were interested in the interactions between common species of macrophytes and zoosporic aquatic fungi and fungus-like organisms during the growth period in trophically different freshwater reservoirs in north-eastern Poland.

Material and Methods

The study included 8 species of water plants (Table 2) collected in spring (May), summer (July) and autumn (September) 2005 from water bodies of north-eastern Poland. A stem fragment and a few leaves (of submerged shoots in emergent plants) were collected from 3 plants of each species. All fragments were rewashed with distillated water to remove periphyton and fungi from their surfaces. About 200 g fragments of each

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Table 1. Chemical and physical properties of water in particular water bodies

Specyfication	River Biała	River Supraśl	Pond Fosa
Temperature (°C)	17.4	15.1	16.2
pH	7.31	7.52	7.02
O_2 (mg L^{-1})	12.08	11.40	1.84
BOD_5 (mg L^{-1})	4.81	7.21	9.22
COD (mg L^{-1})	9.02	7.00	15.09
CO_2 (mg L^{-1})	15.83	8.82	22.43
Alkalinity in $CaCO_3$ (mval L^{-1})	4.71	4.34	5.76
N-NH_3 (mg L^{-1})	0.642	0.232	0.864
N-NO_2 (mg L^{-1})	0.011	0.008	0.114
N-NO_3 (mg L^{-1})	0.150	0.072	0.252
P-PO_4 (mg L^{-1})	1.504	1.204	3.598
Sulphates (mg L^{-1})	68.11	33.97	23.06
Chlorides (mg L^{-1})	40.02	11.00	45.24
Total hardness (mg Ca L^{-1})	92.16	70.56	79.27
Total hardness (mg Mg L^{-1})	22.34	12.47	26.28
Fe (mg L^{-1})	0.90	0.50	1.06
Dry residue (mg L^{-1})	532.0	166.0	429.0
Dissolved solids (mg L^{-1})	496.0	141.0	370.0
Suspended solids (mg L^{-1})	36.0	15.0	59.0

plant were added to each water sample (in 1L wessel) from each particular water body. The water samples were collected from water reservoirs in three locations:

River Biała, length 9.8 km, a left bank tributary of the Supraśl River flowing through Białystok City;

River Supraśl, length 106.6 km, on the right- bank tributary of the Narew River, flowing through the Knyszyńska Forest;

Pond Fosa, area 2.5 ha, max. depth 1.75 m. Pond with wild ducks and breeding swans as well as crucian carp, used by anglers. The pond is surrounded by meadows with linden and elm.

Water samples for the analysis and the experiments were collected from each reservoir at a depth of 15-30 cm at a distance of 0.5 m from the bank. The water was filtered through a gauze and then poured to containers. Nineteen parameters were determined for physical and chemical characteristics of the water using standard methods (Greenberg *et al.* 1995).

Water samples (800 ml each) were placed in 1000 ml containers. For each plant species from each location, three containers with water from that particular water body were used collected. The fourth container served as a control without aquatic plants. The seeds of buckwheat (*Fagopyrum sagittatum* Gilib.), clover (*Trifolium repens* L.), common vetch (*Vicia sativa* L.), hairy vetch (*V. villosa* Roth.) and snake exuvcae (*Natrix natrix* L.) were used as baits (in containers with plants and controls) in accordance to the general principles of culture (Seymour & Fuller 1987).

All containers were enclosed in Petri dishes with the bed turned upside down to prevent possible airborne contamination in the containers with fungal spores. The containers were stored at 15 ± 2 ^{0}C, with access to daylight resembling natural conditions and following the recommended instructions (Seymour & Fuller 1987). The analyses of water and experiments were carried out in three parallel repetitions.

After one month of exposure, clusters from the containers' bottom and side walls, as well as the surface of baits were examined under a light-microscope. Morphological structures (zoospores, antheridia and oogonia) of aquatic fungi growing in particular containers were recorded. The baits were observed under a microscope every 3-4 days. The size of the fungal structures was measured using light-microscopy at 600×. For determinations of particular species of fungi, the following keys were used: Johson (1956), Waterhouse (1968), Seymour (1970), Batko (1975), Karling (1977), Plaats-Niterink (1981), Dick (1990), Pystina (1998), Watanabe (2002) and of the authors who were the first to describe the respective species. The systematics of straminipilous organisms was used according to Dick (2001), of fungi according to Blackwell *et al.* (2006), and of *Chytridiomycota* according to James *et al.* (2000).

The effect of aquatic plants on the number of aquatic fungal species is presented as a ratio of the number of cases where a species were found in the control (Co) to those in culture with water plants (Pl) (Magurran 1988).

The some results were subjected to statistical analysis (Winer 1997).

Table 2. Aquatic fungi and straminipilous organisms found in water from particular water bodies and different seasons in experiments (b – River Biała, f – Pond Fosa, s – River Supraśl)

Taxa	Control			Plants		
	Spring	Summer	Autumn	Spring	Summer	Autumn
Fungi						
Blastocladiomycota						
Blastocladiales						
1. *Blastocladiopsis parva* (Whiffen) Sparrow						s
2. *Catenophlyctis variabilis* (Karling) Karling	b	b, f	b, f	b, f	b, f	b, s, f
Chytridiomycota						
Chytridiales						
3. *Blyttiomyces helicus* Sparrow				b		
4. *Chytridium xylophyllum* Cornu				s		
5. *Cladochytrium polystomum* Zopf				f		
6. *Karlingia lacustris* Hassan		f				
7. *Karlingiomyces granulatus* (Karling) Sparrow				f		
8. *K. lobatus* (Karling) Sparrow			b			
9. *Nowakowskiella elegans* (Nowak.) J. Schröt.				b, s, f		
10. *Phlyctochytrium aureliae* Ajello		b	b, f		b	b, f
11. *P. planicorne* G.F. Atk.			s			s
12. *Physoderma maculare* Wallr.				s		
13. *Polyphagus euglenae* (Bail) J. Schröt.	f					
14. *Rhizidium richmondense* Willoughby	f					
15. *Rhizophydium ampullaceum* (Al. Broome) A. Fischer				b		
16. *R. carpophilum* Zopf				s		
17. *R. globosum* (A. Braun) Rabenh.	s					
18. *R. pollinis-pini* (A. Braun) Zopf			b	b ,f		
19. *R. sphaerotheca* Zopf			s			s
Spizellomycetales						
20. *Rhizophlyctis rosea* (de Bary & Woronin) A. Fisch.				b	f	
21. *Rozella achlyae* (Shanor) Batko				b		
22. *R. septigena* Cornu	b			b		
Zygomycota						
Zygomycetales						
23. *Zoophagus insidians* Sommerst.		b	s	s		b, s
Straminipila						
Hyphochytriomycetes						
Myzocytiopsidales						
24. *Syzygangia marchaliana* (De Wild.) M.W. Dick				f		
Hyphochytriales						
25. *Hyphochytrium catenoides* Karling				f		
26. *H. oceanum* Karling		b				
27. *Olpidiopsis achlyae* McLarty	b		b	b		
28. *O. saprolegniae* Cornu	b			b		b
29. *O. varians* Shanor	s					

Table 2. (continued)

Taxa	Control			Plants		
	Spring	Summer	Autumn	Spring	Summer	Autumn
30. *O. vexans* Barrett			b	b		
31. *Olpidium entophytum* A. Braun				f		
32. *O. granulatum* Karling		b				b
33. *O. luxurians* (Tomaschek) A. Fisch.			s			
Peronosporomycetes (Oomycetes)						
Leptomitales						
34. *Apodachlya brachynema* (Hildebr.) Pringsh.	s					
35. *A. pyrifera* Zopf		f			f	b
36. *Leptomitus lacteus* C. Agardh				b, s	s	
Pythiales						
37. *Lagenidium humanum* Karling			s			
38. *L. podbielkowskii* Batko	b			b		
39. *Phytophthora cryptogea* Pathybr. et Laff.			f	f		
40. *P. fragariae* Hickman		b				
41. *P. megasperma* Drechsler				b, f		
42. *P. undulata* (H.E. Petersen) M.W. Dick						b
43. *Pythiogeton utriforme* Minden	b	b		b, s	b, s	
44. *Pythium carolinianum* V.D. Matthews	b, f		b	b, f	f	b
45. *P. debaryanum* R.Hesse	f		f	f		f
46. *P. diacarpum* E.J. Butler		b			b	
47. *P. diclinum* Tokun.		f	f	b	s, f	f
48. *P. graminicola* Subraman.			f			
49. *P. helicandrum* Drechsler		b, f			b, f	
50. *P. inflatum* V.D. Matthews			f	b	b	f
51. *P. middletonii* Sparrow	b	f		b, f	f	s
52. *P. myriotylum* Drechsler	f		b	f	b	b, f
53. *P. oedochilum* Drechsler		f			f	b
54. *P. perniciosum* Serbinow					b	
55. *P. polysporum* Sorokin			s			s
56. *P. rostratum* E.J. Butler	b	s, f	s	b, s	s, f	s
57. *P. splendens* Hans Braun					b	
58. *P. tardicrescens* Vanterp.		b			b	
59. *P. tenue* Gobi			b, f		s	b, f
Saprolegniales						
60. *Achlya americana* Humphrey	b, s			b, s		b
61. *A. androgyna* (W. Archer) T.W. Johnson et R.L. Seym.	s	s		s		
62. *A. apiculata* de Bary					s	b
63. *A. bisexualis* Coker et Couch						s
64. *A. caroliniana* Coker			s	s, f		s
65. *A. colorata* Pringsh.						s
66. *A. conspicua* Coker				b, f		s
67. *A. crenulata* Ziegler					b, s	
68. *A. debaryana* Humphrey	f	b		f	b	

Table 2. (continued)

Taxa	Control			Plants		
	Spring	Summer	Autumn	Spring	Summer	Autumn
69. *A. diffusa* J.V. Harv. ex T.W. Johnson			f			f
70. *A. dubia* Coker				f		s
71. *A. hypogyna* Coker et Pemberton					s	
72. *A. imperfecta* Coker		s				
73. *A. klebsiana* Pieters	b	s	f	s	b, s	f
74. *A. megasperma* Humphrey						s
75. *A. oligocantha* de Bary			s			s
76. *A. orion* Coker et Couch					s	
77. *A. papillosa* Humphrey				s		s
78. *A. polyandra* Hildebr.	b, s, f	b, f	f	b, s, f	b, s, f	b, s, f
79. *A. prolifera* Ness				s		s
80. *A. proliferoides* Coker	f		f	f	b	
81. *A. racemosa* Hildebr.		s	b		s	b
82. *A. radiosa* Maurizio		s			s	
83. *A. rodrigueziana* F.T. Wolf						s
84. *A stellata* de Bary	b	f		b	f	
85. *A. treleaseana* (Humphrey) Kauffman	s	b, s	b, f	b, s	s, f	b, s
86. *Aphanomyces irregularis* W.W. Scott	b, s	b, s, f	b	b, s	b, s, f	b
87. *A. laevis* de Bary	b, f	b, s, f	f	b, s, f	b, s, f	b, f
88. *A. stellatus* de Bary		f			b, f	
89. *Dictyuchus magnusii* Lindst.				s		
90. *D. monosporus* Leitg.	b	s, f		b, s	b	
91. *D. sterilis* Coker		s			b, s	s
92. *Isoachlya monilifera* (de Bary) Kauffman	b		b, f	b	s, f	b, s
93. *I. torulosa* (de Bary) Cejp		f	b	b	s	b
94. *Protoachlya polysporus* (Lindst.) Apinis				b		
95. *Saprolegnia anisospora* de Bary		f	b		s, f	b
96. *S. declina* Humphrey	b			b, s	s, f	f
97. *S. eccentrica* (Coker) R.L. Seym.						s
98. *S. ferax* (Gruith.) Thur.	b, s, f	b, s, f	s, f	b, s, f	b, s, f	b, s, f
99. *S. glomerata* (Tiesenh.) A. Lund		f		b, s	s, f	b, f
100. *S. hypogyna* (Pringsh.)de Bary		s			s	
101. *S. latvica* Apinis	s			s		
102. *S .litoralis* Coker				s	s	b, s, f
103. *S. monoica* Pringsh.		b			b	
104. *S. parasitica* Coker	f			s	b, s	b, f
105. *S. unispora* (Coker et Couch) R.L. Seym.		b			b	
106. *Sommerstorffia spinosa* Arnaudov		f				
107. *Thraustotheca clavata* (de Bary) Humphrey		b, s	b	s, f	b	b, s, f
Plasmodiophoromycetes						
Plasmodiophorales						
108. *Octomyxa brevilegniae* Pend.			b			
109. *Sorodiscus karlingii* Ivimey Cook		s				
110. *Tetramyxa parasitica* K.I. Goebel						

Table 2. (continued)

Taxa		Control			Plants		
		Spring	Summer	Autumn	Spring	Summer	Autumn
111. *Woronina asterina* Tokun.				b			
112. *W. polycystis* Cornu		b, f			b		b
Total species		b-20 s-10 f-12	b-19 s-15 f-19	b-18 s-10 f-15	b-34 s-28 f-24	b-26 s-24 f-20	b-27 s-26 f-17
Ratio Control/Plants	b s f				20/34=0.58 10/28=0.36 12/24=0.50	19/26=0.73 15/24=0.63 19/20=0.95	18/27=0.67 10/26=0.38 15/17=0.88

Results

The chemical characteristics of water used in our experiment varied considerably in biogenic compounds (Table1). The most abundant concentrations of nitrogen and phosphates were in water from Fosa Pond, and the lowest amount of these substances was in water from the Supraśl River. It concern also the BOD_5, COD, CO_2 and iron. Water from Supraśl River contained also the lowest levels of COD, CO_2, chlorides, calcium magnesium, iron, dry residue, dissolved solids and suspended solids.

112 species of aquatic fungi on baits were observed (Table 2). The majority of identified species belonged to straminipilous fungi: *Peronosporomycetes* – 74 species, *Chytridiomycota* – 20 species, *Hyphochytriomycetes* – 10 species and 5 species of *Plasmodiophoromycetes* (probably belonging to *Straminipila* or to *Protista*). Four species, *Sorodiscus karlingii, Tetramyxa parasitica, Olpidium luxurians* and *Achlya imperfecta* are new species records for Poland. Several rare species were fouond, namely *Physoderma maculare, Octomyxa brevilegniae, Woronina asterina, Apodachlya punctata* and *Sommerstorffia spinosa* (Czeczuga *et al.* 2007). Of the containers with plants, the lowest number of species of fungi was noted during summer inside the container with *Polygonum amphibium* (9 species) and the highest number of species (24) in the spring inside the containers with *Potamogeton natans* (Table 3). *Catenophlyctis variabilis* and *Achlya polyandra* grew inside all containers with all eight selected plants during all seasons. Inside the control containers, 16 species of fungi grew on baits compared to 37 species inside the containers with plants (Table 4). 59 species of fungi were observed on baits both inside the control containers and in the containers with plants. During the spring inside all containers with plants, with water from all three water bodies, higher number of species of fungi grew than inside the control containers, as shown by mean ratios of Co/Pl which were lower than 1 (Table 5). During summer, lower number of species of fungi were found in containers with plants than inside the control containers. Almost all containers with plants had lower number of species of fungi in autumn than in the control containers. Water from Biała River and Fosa Pond; lower inhibiting influence of plants on fungal growth was observed inside the containers with water from Supraśl River.

Discussion

The phytosaprophyte *Sorodiscus karlingii* (Cooke 1929) represents a new Polish record and was found in the control container with water from Supraśl River during summer. The water from the Supraśl River was comparatively the least abundant in biogenic compounds. A second representative of the *Prostista, Tetramyxa parasitica,* grew in summer in water from Biała River with the plant *Potamogeton natans.* The water from Biała River, in comparison to other two reservoirs, had the highest total hardness (Ca^{2}+ ratio) and the highest ratio of dry residue and dissolved solids. *Tetramyxa parasitica* was described as a parasite of *Ruppia* and *Potamogeton* (Goebel 1884). *Olpidium luxurians* which grew inside the control container with water from the Supraśl River during autumn represented the third new Polish record. It was first described by Tomaschek (1879) in pollen grains.

The influence of macrophytes on the growth of fungi depended on the season. During the spring at the beginning of the growth period, containers with all eight species of plants, in water from all three reservoirs, had a Co/Pl ratio less than 1. This indicates that excreted photosynthetic products stimulate the growth of fungi and fungus-like organisms. During summer, in the middle of the growing season, the Co/Pl ratio increased. This indicates that substances released into the environment by aquatic plants inhibited the growth of several species of fungi. In autumn, at the end of the growing season, all ratios, excluding *Nuphar luteum* with water from the Supraśl River were either above or near to 1. This indicates that substances released by plants did not stimulate the growth of fungi. Furthermore it should be noted that in water from Supraśl River, the inhibitive influence of substances released by macrophytes on species of fungi was lower than in water from two other water bodies. The water from Supraśl River was the least abundant in biogenic compounds in comparison to the other two reservoirs. This synergistic effect has been observed by the effect of macrophytes on bacterioplankton in trophically different water bodies (Czeczuga & Chomutowska 2000).

The storage of many different organic substances, including algicidal hydrolysable polyphenols (Gross 2000), during growth is characteristic for phanerogams (Hegnauer 1962-1973; Gibbs 1974). Polyphenols occur in probably

Table 3. Aquatic fungi and straminipilous organisms found in containers with particular plant species in different seasons

Species of plants	Seasons	Fungi and straminipilous organisms (see Table 2)	Number of species	Only in containers with one plant species
Nuphar luteum (L.) Sm.	Spring	2,4,9,12,18,24,28,39,43,44,51,61,68,78,85,89,92,93,94	19	2,78
	Summer	2,20,49,50,52,54,56,57,58,62,68,71,78,85,86,88,91,98,104,107	20	
	Autumn	2,10,23,28,42,45,52,63,65,73,77,78,79,96,98,99,102,104,107,112	20	
Phragmites australis (Cav.) Trin. ex Steud.	Spring	2,15,18,20,24,27,30,43,51,77,78,80,85,86,87,93,94,98,102	19	2,78,86 87,98
	Summer	2,10,20,43,47,49,54,78,80,81,86,87,90,95,96,98,99,105	18	
	Autumn	2,23,45,50,59,64,77,78,85,87,92,93,98,102,107	15	
Polygonum amphibium L.	Spring	2,4,5,16,23,27,28,30,35,41,44,50,51,78,84,87,94,96,98,99,107,112	22	2,44 78,98
	Summer	2,44,78,86,90,92,95,98,102	9	
	Autumn	1,2,10,28,44,51,52,53,55,63,69,78,81,87,98,99,104	17	
Potamogeton natans L.	Spring	2,4,7,9,20,25,27,28,30,36,38,44,48,51,56,60,64,66,78,79,85,87,96,98	24	2,78 87,98
	Summer	2,43,47,53,62,67,78,82,86,87,90,98,99,105,107,110	16	
	Autumn	2,23,28,52,56,60,78,87,95,98,102,104,107	13	
Sagittaria sagittifolia L.	Spring	2,4,9,28,30,51,52,56,60,73,78,80,87,90,96,98,99,104,107,112	20	2,56,78 87,98,104
	Summer	2,35,47,49,56,67,76,78,85,86,87,98,99,103,104,105	16	
	Autumn	2,44,45,50,56,60,64,78,85,86,87,91,92,93,97,98,102,104,107,111	20	
Schoenoplectus lacustris (L.) Palla	Spring	2,15,18,27,30,36,41,43,45,51,78,80,84,85,86,87,93,94,98	19	2,78
	Summer	2,10,35,47,49,51,59,73,78,86,88,90,91,92,95,98,99,102	18	
	Autumn	2,19,23,42,52,56,59,62,77,78,81,87,104	13	
Stratiotes aloides L.	Spring	2,3,4,9,21,22,47,51,60,64,68,70,78,86,87,90,92,96,98,99,101,112	22	2,78,92
	Summer	2,36,43,46,50,56,67,78,86,87,88,92,93,95,98,100	16	
	Autumn	2,10,23,35,47,64,74,77,78,79,81,83,85,86,92,93,95,98,107,112	20	
Typha latifolia L.	Spring	2,9,15,20,24,30,31,43,44,45,50,56,78,85,86,87,92,94,98	19	2,78
	Summer	2,46,47,49,73,78,84,86,88,90,92,96,98,104	14	
	Autumn	2,10,11,32,53,59,66,70,78,87,99,107	12	

Table 4. Aquatic fungi and straminipilous organisms found in particular containers

Specification	**Aquatic fungi and straminipilous organisms** (see Table 2)	**Number of species**
Only control	6,8,13,14,17,26,29,33,34,37,40,72,106,108,109,111	16*
Only with plants	1,3,4,5,7,9,12,15,16,20,21,24,25,31,36,41,42,48,54,57,62,63,65,66,67,70,71, 74,76,77,79,83,89,94,97,102,110	37*
Control and with plants	2,10,11,18,19,22,23,27,28,30,32,35,38,39,43,44,45,46,47,49,50,51,52,53,55, 56,58,59,60,61,64,68,69,73,75,78,80,81,82,84,85,86,87,88,90,91,92,93,95,96, 98,99,100,101,103,104,105,107,112	59*

*Asterisks indicate differences significant at the ≤ 0.05 level.

Table 5. Mean ratio (Co/Pl) in particular water bodies and in different seasons

Species of plants	**Spring**			**Summer**			**Autumn**		
	River Biała	**River Supraśl**	**Pond Fosa**	**River Biała**	**River Supraśl**	**Pond Fosa**	**River Biała**	**River Supraśl**	**Pond Fosa**
1. *Nuphar luteum* (L.) Sm.	0.55	0.75	0.88	0.67	0.75	0.75	1.33	0.75	1.11
2. *Phragmites australis* (Cav.) Trin.. ex Steud.	0.73	0.25	0.50	1.50	0.67	1.00	2.00	1.00	1.67
3. *Polygonum amphibium* L.	0.50	0.67	0.57	1.50	1.33	1.00	1.45	1.00	1.67
4. *Potamogeton natans* L.	0.63	0.33	0.40	0.60	0.67	1.33	1.23	1.00	1.43
5. *Sagittaria sagittifolia* L.	0.70	0.33	0.75	1.00	1.50	1.00	1.14	1.00	1.67
6. *Schoenoplectus lacustris* (L.) Palla	0.67	0.20	0.75	1.33	0.50	1.50	1.60	1.50	2.50
7. *Stratiotes aloides* L.	0.70	0.33	0.25	1.67	0.50	0.60	1.60	1.00	2.50
8. *Typha latifolia* L.	0.75	0.33	0.75	0.67	0.67	1.25	1.60	1.00	1.25

all species of macrophytes (Maksimov *et al.* 2002). Aquatic macrophytes are known to release different chemical substances into their aquatic environment (Wetzel 1969a, b). These substances may stimulate or inhibit the growth of bacteria and algae (Fitzgerald 1969; Su *et al.* 1973; Wium-Andersen *et al.* 1982; Duarte *et al.* 1988; Czeczuga & Chomutowska 2000). Our experiment shows that interactions between selected species of macrophytes and fungi and fungus-like organisms depend on the season. *Woronina asterina* which was observed inside the control container with water from Biała River and represents a new record for Poland. It was first described by Tokunaga (1933) as a parasite belonging to *Achlya.* Among 112 identified species of fungi, the majority grew inside the containers with selected plants. There was a greater diversity of fungi inside containers with plants, as shown by data in Table 4. A similar phenomenon was observed during an examination of the influence of plants on the growth of fungi (Czeczuga *et al.* 2005). The highest number of species of fungi (24) grew in spring inside the containers with *P. natans*; the lowest number of species were found in the summer inside the containers with *Polygonum amphibium* (9 species). Some species, for example *Catenophlyctis variabilis* and *Achlya polyandra,* occured inside the continers with plants during every season.

In water of north-eastern Poland the most frequent representative of the *Plasmodiophorales* was *Woronina polycystis* (Czeczuga *et al.* 2005). It was first described by Cornu (1872) as a parasite of fungus-like organisms belonging to *Achlya, Isoachlya* and *Saprolegnia* genera.

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