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The changes in the number and physiological properties of fungi in lakes differing in trophicity*

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It was demonstrated that the fungi decomposing protein were most abundant in the mesotrophic lake, whereas the fungi decomposing pectin dominated in the eutrophic lake. The accumulation of fungi mineralizing protein in littoral zone (metha- and hypolimnion of pelagial zone) of the mesotrophic lake indicated the increase in the fertility of this reservoir. The frequency of occurrence of physiologically differentiated mycoflora in the lake waters was seasonal and revealed fluctuations in their activity depending on the year of the study. These fluctuations were stronger in the mesotrophic lake.

INTRODUCTION

The basic function of the saprophytic microorganisms occurring in aqueous environment is the decomposition of organic matter. The determination of the total number and physiological activity of these organisms in water and bottom sediments of water reservoirs may supply, according to K o r z e n i e w s k i and K o r z e n i e w s k a (1982) the number index of the organic substance degradation.

The mineralization of the organic matter in water is performed mainly by bacteria, decomposing over 50 % of the resource of this substance in aqueous environment (quoted after D o n d e r s k i, 1983). Aquatic fungi play an important role in the transformation and mineralization of organic compounds in aquaeous environment (S p a r r o w, 1968; B a t k o, 1975; R e i n h e i m e r, 1977). Little is known, however, about the role of non-aquatic micromycetes (the term introduced by Park in 1972) in the transformation of the organic matter in water bodies (M e y e r s et al., 1970; P a r k, 1972, 1974).

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The aim of the present study was the qantitative evaluation of physiological properties of these fungi in the water of two lakes differing in trophicity and the utilization of the basin.

MATERIAL AND METHODS

The object of the study were two lakes (in Mid-Eastern Poland): a mesotrophic Lake – Piaseczno and an eutrophic one – Głębokie, located in Łęczna Włodawa Lake District (Korniłłowicz, 1993 a, b).

Microbiological analyses were carried out in the years 1986-1990 by taking water samples in the following terms: 23-29.04; 27-30.05; 3-11.07; 27-29.09 (Korniłłowicz, 1993 b).

The number of subsequent physiological units of fungi (term agreed upon) was determined by the dilution plating method. In the selection of substrate spectra, the dissemination and their availability in aqueous environment were taken into account.

The fungi which decompose protein were determined with Frazier's method (the gelatine substrate; Rodina, 1968). The number of fungi with amylolytic abilities were evaluated on starch agar by making the zones of substrate hydrolysis visible with Lugol fluid. The number of pectinolytic fungi was determined with Jayasankar and Graham's method (1970), using the pectin from citrus fruits (from Sigma company) and 1% solution of dodecyltrimethylammonium bromide (from Merck firm) to detect the zones of substrate decomposition. The cellulolytic fungi were isolated on the agar nutrient medium of Winogradsky with Whatman's dotting-paper rings. In all the cases streptomycin and chlorocyclin was added to the nutrient medium in the same amounts as to Martin's substrate (1950). The fungi were cultured at 20°C ± 2°C for 5-7 days and in case of cellulolytic fungi for 1-14 days making 3-5 repetitions. The number of fungi counted on the basis of the number of colonies which had grown were given for 1 cm^3 of water.

RESULTS

Proteolytic properties of mycoplankton, were among the most common analysed physiological features. However, fungi with amylo- and cellulolytic abilities rarely occurred in the plankton of lakes (Table 1-3).

It was demonstrated that the waters of the lake with lower trophicity (Piaseczno) had a higher number of fungi decomposing protein on the average by 80 %, than the waters of lake with higher trophicity (Głębokie). The reverse dependence was found in case of mycoflora with pectinolytic abilities (Table 1-2).

The quantitative distribution of the above mentioned physiological units in water was uneven. The fungi hydrolyzing protein gathered more frequently in the littoral zone of both lakes and in metha- and hypolimnion of the mesotrophic Lake Piaseczno. However, the fungi diffusing pectin occurred in the lower eutrophic sublittoral zone Lake Głębokie.

Table 1

Number of protein (A) and pectin (B) decomposing fungi in 1 cm^3 of water of Lake Piaseczno (at indyvidual sites and dates of investigations)

Year – Months / Station and depth (m)		Litoral zone		Sublitoral zone				Pelagial zone (A)					
								epilimnion		methalimnion		hypolimnion	
		0.5-1		0.5-1		9-10		0.5-1		9		25-30	
		A	B	A	B	A	B	A	B	A	B	A	B
1986	IV	160	26	4	89	70	500	30	650	350	51	670	61
	V	60	530	190	1400	13	400	3	700	60	5850	13	130
	VII	11660	540	230	570	90	150	140	140	6020	220	30	130
	IX	9600	1500	1800	640	740	1490	70	650	500	400	450	370
	mean annual	5370	649	556	675	228	635	61	535	1733	1630	291	173
1987	IV	2	2	2	2	90	160	33	200	190	130	16	20
	V	4	8	5	26	10	1	30	150	8	2	30	3
	VII	15	3	1	1	180	17	90	44	11	11	7	1
	IX	330	40	40	2	30	10	19	30	20	17	90	8
	mean annual	88	13	12	8	78	47	43	106	57	40	36	8
1988	IV	440	0	60	7	233	15	160	30	1233	50	310	67
	V	2400	10	195	1	800	1	63	33	13500	31	166	46
	VII	270	2	170	2	170	3	130	6	270	3	130	1
	IX	168	10	41	1	20	13	63	10	30	7	113	20
	mean annual	820	5	117	3	306	8	104	20	3758	23	180	34
1989	IV	120	30	710	920	540	80	160	1300	250	93	180	67
	V	470	400	890	3310	800	810	140	2080	150	120	450	46
	VII	1000	10	1900	40	1700	190	1900	10	170	40	130	1
	IX	13	3	30	3	270	20	90	6	60	44	60	20
	mean annual	401	111	883	1068	828	275	573	849	158	74	205	34
1990	IV	930	7	10	2	60	38	30	23	50	1	1020	7
	V	150	9	7	1	3	1	113	2	20	4	7000	87
	VII	160	40	30	7	40	70	140	33	120	67	1900	37
	IX	1000	67	40	17	18	16	66	13	190	59	520	160
	mean annual	560	31	22	7	30	31	87	18	95	33	2610	73

Table 2

Number of protein (A) and pectin (B) decomposing fungi in 1 cm^3 of water of Lake Głębokie at indyvidual sites and dates of investigations

Year – Months		Station and depth (m)					
		Litoral zone		Sublitoral zone			
		0.5-1		0.5-1		4.5	
		A	B	A	B	A	B
	IV	10	110	270	220	4	170
	V	570	150	13	100	8	40
1986	VII	560	1100	80	1400	190	800
	IX	500	1700	750	2760	2830	5300
	mean annual	410	765	278	1120	758	1578
	IV	25	1	30	1	3	4
	V	20	4	1	2	30	3
1987	VII	18	29	10	9	204	11
	IX	70	40	280	10	820	3
	mean annual	33	19	80	6	264	5
	IV	310	13	196	70	36	28
	V	166	5	663	53	143	24
1988	VII	130	15	33	1	70	22
	IX	113	30	31	17	–	–
	mean annual	180	16	231	35	83	25
	IV	23	1390	220	980	80	3070
	V	1620	1600	2030	1700	440	3000
1989	VII	1500	10	93	30	1500	6
	IX	30	20	40	10	450	–
	mean annual	793	755	596	680	618	2025
	IV	7030	260	36	40	–	–
	V	37	47	260	11	13	6
1990	VII	30	33	130	33	10	8
	IX	180	3	80	4	120	20
	mean annual	1819	86	127	22	48	11

The mean annual number of fungi showing proteo- and pectinolytic abilities were indicative of significant fluctuations of population density of these microorganisms in the subsequent years of the research. In both lakes the highest number of these fungi was noted in 1986, and 1989 whereas the lowest number of fungi species occurred in 1987-1988 (Table 1-2). The waters of Lake Piaseczno methalimnion were an exception. A higher number of fungi with proteolytic abilities occurred periodically also in 1988. The decrease in the population density of fungi having pectinolytic and, in most cases, proteolytic abilities in the waters of Lake Piaseczno occurred again in 1990.Only the waters of hypolimnion of this reservoir were the next accumulated of fungi hydrolyzing protein (Table 1).

The annual fluctuation in the number of fungi decomposing protein and pectin were stronger in the mesotrophic lake than in the eutrophic one (Table 1-2). However, the number of fungi decomposing starch and cellulose did not change distinctly and was maintained on a very low level during the whole period (Tab. 3). In the investigated lakes the fungi occurred seasonally (Fig. 1-2).

Table 3

Mean annual number of starch (A) and cellulose (B) decomposing fungi in 1 cm^3 of water of Lake Piaseczno and Głębokie

PIASECZNO														
Station –	Litoral zone		Sublitoral zone				Pelagial zone					
Depth (m)	0.5-1		0.5-1		9-10		epilimnion 0.5-1		methalimnion 9		hypolimnion 25-30	
Year	A	B	A	B	A	B	A	B	A	B	A	B
1986	28	37	32	17	9	11	4	12	6	16	12	33
1987	2	11	2	2	5	24	30	67	4	7	13	9
1988	1	9	1	1	1	9	2	3	15	2	15	10
1989	1	3	1	1	1	30	1	2	2	13	1	30
1990	5	4	1	3	4	20	5	8	5	8	12	21

GŁĘBOKIE						
Station – Depth (m)						
Year	Litoral zone		Sublitoral zone			
	0.5-1		0.5-1		4.5	
	A	B	A	B	A	B
1986	270	240	400	450	800	80
1987	12	16	1	2	2	2
1988	12	7	1	1	2	9
1989	1	7	1	3	2	3
1990	9	13	6	90	130	10

The dynamics of the seasonal quantitative changes of proteolytic mycoflora in Lake Piaseczno were associated with the horizontal and vertical stratification of the reservoir. In the coastal zone (mainly 0.5-1 m) the stimulation of the growth of these microorganisms occurred in July and was maintained untli September. At the same time in the surface water of sublittoral zone and pelagial, a slight increase in the number of fungi decomposing protein was noted. In the interlake profile of Lake Piaseczno the increase in the number of fungi decomposing protein occurred in May and was higher in metha- and hypolimnion than in epilimnion (Fig. 1 A). In May the maximum number of plankton pectinolytic fungi occurred in Lake Piaseczno. The minimum number of these micromycetes occurred in April and July. The renewed slight increase in the number of fungi splitting pectin was noted in September (Fig. 1B).

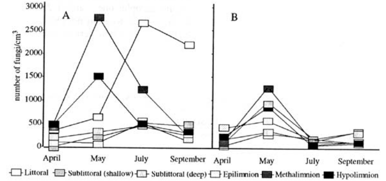

Fig. 1. Seasonal changes in the number of protein (A) and pectin (B) decomposing fungi in the water of Lake Piaseczno (mean values for 5 years)

depth (m): littoral zone – 0.5; shallow sublittoral zone – 0.5-1; deep sublittoral zone – 9-10; epilimnion – 0.5-1; methalimnion – 9; hypolimnion – 25-30

The seasonal changes in the number of the examined units of fungi in Lake Głębokie were distinctly weaker than in Lake Piaseczno (Fig. 2). The growth of fungi decomposing protein and pectin was more perceptible in early autumn and sometimes spring. The highest fluctuations in the density of these fungi population were noted in the littoral (proteolytic fungi) and deeper sublittoral (pectinolytic fungi) zones.

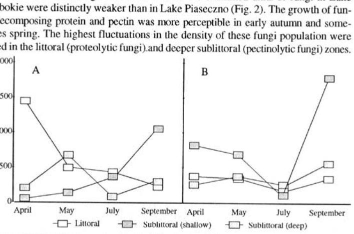

Fig. 2. Seasonal changes in the number of protein (A) and pectin (B) decomposing fungi in the water of Lake Głębokie (mean values for 5 years)

depth (m): littoral zone – 0.5-1; shallow sublittoral zone – 0.5-1; deep sublittoral zone – 4.5

DISCUSSION

In spite of the fact that the waters of Lake Piaseczno and Głębokie differed in the degree of trophicity, they were inhabited by similar, in respect of physiological properties, fungi. The differences in the physiological units of planktonic fungi of both lakes had a quantitative character.

It was demonstrated that the number of fungi able to decompose protein in the water of the above mentioned lakes was almost identical (on the average 500-900 in cm^3) to the number of proteolytic bacteria (300-800 cells/cm^3) noted in the over-fertile waters of the Lake Łętowo (northern Poland) by Korzeniewski and Korzeniewska (1982). Hence, the mycoplankton together with bacterioplankton, takes part in protein degradation in water bodies. The changes in the number of mycoplankton may be indicative of the eutrophic changes in lakes. The increase in the number of proteolytic microorganisms in aqueous ecosystems testifies to the intensification of inorganic N liberation (Korzeniewski, Korzeniewska, 1982), as the one of the eutrophicating factors (Kajak, 1979).

The increase in the number of proteolytic fungi in the waters of lower trophicity (Lake Piaseczno) resulted from the increase in the fertility of this reservoir. Such an effect was most probably caused by the increased inflow of organic matter, resulting from the increased development of phytoplankton in Lake Piaseczno (Czernaś, Krupa, Wojciechowski, 1992, 1993). In addition a high, especially from the peat area, underground transport of protein sunstances to the littoral zone of this lake was noted (Górniak, Misztal, 1991). Apart from the autochtonic organic matter the organic substance of soil origin is probably, a significant factor stimulating the development of mycoflora decomposing protein, especially in the littoral zone.

The present results indicated that the littoral and deeper pelgial comprising the waters of metha- and hypolimnion of Lake Piaseczno were most subjected to extreme fertilization, due to nitrogen accumulation. A high density of fungi decomposing protein occurred there. Intensively developing nannoplankton might be an abundant source of organic N. In its zone (methalimnion) both maximal primary production was noted (Czernaś – unpubl. data) as well as the accumulation of rotifers and crustaceans (Radwan, Popiołek, 1989). Moreover the highest number of saprophytic mycoflora hydrolyzing protein occurred. In the mesotrophic plankton of Lake Piaseczno the fungi with proteolytic properties occurred more often than the pectinolytic ones. In the Lake Głębokie the pectinolytic micromycetes were more abundant (on the average over 500 in 1 cm^3 of water). The source of pectin in Lake Głębokie was net plankton as well as undoubtedly macrophytes dwelling in a wide strip in littoral zone. According to Wojciechowski (1987), the above mentioned plant communities constitute the main mass of organic matter of eutrophic lakes. In spite of the limited growth of vascular plants in Lake Piaseczno, the concentration of pectins also increased, periodically, due to the increase in the number and proportion *Chlorophyceae* (Czernaś, Krupa, Wojciechowski, 1993).

It was also demostrated that these changes were accompanied by an increase in the number of pectinolytic micromycetes. The above observations indicate that the mycoplankton of both lakes may play a role in the degradation of pectin substances present in the water.

It is strilung that a small number of fungi hydrolysing starch – a substrate more frequent in water than pectin (R e i n h e i m e r, 1977), was noted. It was very probable that this phenomenon was caused by the feed competition (nutrients) with the amylolytic bacteria abundantly inhabiting the waters of both lakes (F u r c z a k, 1988). According to D o n d e r s k i (1983), the amylolytic bacteria are the most abundant group among the oxygen heterotrophic bacteria decomposing complex carbohydrates in water.

However, the relatively low occurrence of cellulolytic fungi in the plankton of Lake Piaseczno and Głębokie may be associated with a low availability of this substrate for planktonic fungi. F u r c z a k (1988), reported a low number of cellulolytic bacteria in the water of the examined lakes. Under the conditions of organic residue sedimentation in water bodies it seems that the metabolisation of cellulose (a substrate which is more slowly decomposed than other carbohydrates) takes place first of all in the sediments. This could also be confirmed by the results obtained by the author (K o r n i ł ł o w i c z, 1993 c).

In accordance with the author's previous opinion (K o r n i ł ł o w i c z, 1993 b), the changes in the intensity of the development and the photosynthetic activity of phytoplankton were accepted as the most important factors determining the annual and seasonal fluctuations of the physiological activity of mycoplankton. It appeared that in Lake Piaseczno (in Lake Głębokie this analysis was not carried out), the dynamics of changes in the primary production and biomass of phytoplankton was convergent (the increase in the years 1986 and 1989) with fluctuations in the level of the number of fungi decomposing pectin, and often also protein. Climatic factors**, such as rainfalls, could also have a significant effect on the fluctuation of the number of these fungi. It may be assumed that during vegetative seasons with high amounts of rainfall, i.e., 1986, a significant number of geophilic fungi penetrated into the waters of lakes together with rain and runoff contributing to the increase in the number of these microorganisms. The results of C o l l i n s and W i l l o u g h b y (1962) support this suggestion since they point out to the enrichment of water reservoirs with allochtonic mycoflora after rainfalls.

Because of the more stable trophic and thermal conditions of eutrophic lakes (cited after D o n d e r s k i, 1983), the annual and seasonal variations in the number of "physiological units" of the mycoplankton in Lake Głębokie were significantly lower than in Lake Piaseczno.

The seasonal changes in the physiological activity of planktonic micromycetes of the both lakes were reflected in the changes of the total number of these fungi (K o r n i ł ł o w i c z, 1993 b). The maximum number of fungi occurred in spring and

** Examined by group led by Prof. dr. J. K o ł o d z i e j from the Deptartm. of Agrometeor. of Acad. Agricult. in Lublin.

in early autumn (eutrophic lakes), while the lowest numbers of fungi was recorded a the beginning of summer. It was also demostrated that the increase in the number of pectinolytic fungi in the plankton of Lake Piaseczno in spring was convergent with the occurrence of green algae in this reservoir (Czernaś, Krupa, Wojciechwski, 1993) which are the main source of pectins in mesotrophic lakes. The increase in the number of proteolytic fungi in metha- and hypolimnion of this reservoir in spring was probably caused by the intensified increase of phytoplankton (Szember et al., 1989) and the zooplankton accumulated in these environments (Radwan, Popiołek, 1989). The maximum increase in the number of proteolytic fungi dwelling in the waters of the littoral zone of Lake Piaseczno in the period of the summer stagnation was accompanied by an accumulation of organic N of soil origin (Misztal, Smal, Górniak, 1989). This confirms the role of allochtonic organic substance in eutrophication of this lake.

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Zmiany liczebności i „zespołów fizjologicznych" grzybów w jeziorach o zróżnicowanej trofii

Streszczenie

W latach 1986-1990 przeprowadzono badania liczebności wybranych „zespołów fizjologicznych": grzybów w wodzie dwóch jezior Pojezierza Łęczyńsko-Włodawskiego: mezotroficznym i eutroficznym.

Wykazano, że wody j. mezotroficznego (podlegającego presji antropogenicznej) charakteryzowały się wyższą liczebnością grzybów rozkładających białko niż grzybów rozszczepiających pektynę. W toni wodnej j. eutroficznego obserwowano odwrotne zjawisko. W obu zbiornikach rzadko pojawiały się grzyby rozkładające skrobię i celulozę.

Stwierdzono, że proteolitycznie uzdolnione mikromycetes nagromadzały się głównie w litoralu obu jezior oraz metha- i hypolimnionie j. mezotroficznego. Grzyby o właściwościach pektynolitycznych najobficiej pojawiały się w wodach dolnego sublitoralu j. eutroficznego. Wyniki wskazały na znaczne wahania aktywności fizjologicznej mikoplanktonu w zależności od roku i miesiąca prowadzonych badań. Maksimum liczebności proteo- i pektynolitycznych grzybów występowało na ogół wiosną, minimum – wczesnym latem. Wyraźnie odwrotną tendencję przejawiały grzyby zasiedlające wody litoralu j. mezotroficznego. Wahania aktywności fizjologicznej mikoflory były na ogół silniejsze w zbiorniku mezotroficznym.