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Original Research

Aqualinderella fermentans Emerson et Weston in Surface Waters of Northeastern Poland

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Abstract

The rare fungus *Aqualinderella fermentans* was recorded from the fruits and seeds of 24 species of plants in nine bodies of water of various trophic states in northeastern Poland. This species was recorded for the first time in Polish waters and for the second time in Europe. Our study shifts the range of *Aqualinderella fermentans* to the north (53°52'N, 22°58'E) from the subtropical and tropical zones where it is known to occur.

Keywords: *Aqualinderella fermentans*, zoosporic fungus, substrata, hydrochemical study

Introduction

Studying the aquatic fungi that grow on various types of fruit in waters of diverse limnological types for the first time in Poland, we found a fungus (*Aqualinderella fermentans*) described as a tropical species in the literature on the subject [l-3]. This species was first reported from South America and the southern part of the USA from stagnant warm waters deprived of oxygen [4]. A few years later this fungus was noted to occur in overheated, swampy reservoirs overgrown with floating plants in tropical Africa (e.g. in Nigeria [5,6]). In these reservoirs, the fungus formed large turfs on juicy fruits that had fallen into the water. It has been emphasized that *Aqualinderella fermentans* is an almost absolute anaerobic species that requires high carbon dioxide concentration in water. It was recently encountered in accumulated rainfall water in Saudi Arabia [7] and in Egypt in the Aswan High Dam Lake [8], the delta of the River Nile [9] and isolated from water and submerged mud polluted with industrial effluents [10], and from the surface water of four Egyptian lakes [11]. At the end of the previous century *Aqualinderella fermentans* was found in Europe for the first time, in Baden Wuertemberg [12]. Our study shifts the range of *Aqualinderella fermentans* to the north from the subtropical and tropical zones where it was known to occur. Moreover, our study provides new data on the environmental conditions and the substrates used by this fungus.

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Material and Methods

Water samples were collected from nine different bodies of water:

- Cypisek Spring, localized in the northern part of Białystok. Limnokrenic type, width 0.41 m, depth 0.17 m, discharge 0.6 1/s. The spring is surrounded by single pine trees, around the spring are cultivated fields. The bed is covered with sand.
- Jaroszówka Spring, localized in the north part of Białystok. Limnokrenic type, width 0.65 m, depth 0.12 m, discharge 2.4 l/s, surrounding without trees. The spring is surrounded by cultivated fields. The bed is covered with sand.
- Biała River, length 9.8 km, a left-bank tributary of the Supraśl River flowing through Białystok City. The samples were collected in the upper course of the Biała, where the water was the least polluted [13].
- Supraśl River, right-bank tributary of the middle part of the Narew river flowing through the Knyszyńska Forest. Length 106.6 km. The samples were collected

Table 1. Chemical properties of water at the sites investigated (n=5).

Parameter	Spring		River		Pond			Lake	
	Cypisek	Jaroszówka	Biała	Supraśl	Akcent	Dojlidy	Fosa	Komosa	Necko
Temperature (°C)	11.0	12.0	18.5	18.0	17.5	19.5	17.0	11.5	10.5
pH	7.78	7.86	7.61	7.88	7.77	7.42	7.61	7.93	7.53
O_2 (mg dm^3)	8.20	9.40	9.60	9.20	2.20	7.80	3.65	12.16	14.86
BOD_5 (mg dm^3)	3.20	5.60	3.60	5.80	1.80	2.50	0.50	4.18	3.91
COD (mg dm^3)	4.30	5.58	10.98	7.84	12.54	12.35	22.97	3.12	5.15
CO_2 (mg dm^3)	15.40	12.20	19.80	11.95	24.20	11.15	18.80	13.20	12.12
Alkalinity in $CaCO_3$ (mval dm^3)	5.20	2.30	5.00	5.10	7.40	3.70	4.50	5.40	3.85
N-NH_3 (mg dm^3)	1.280	0.290	0.590	0.250	3.530	0.280	0.500	0.235	0.320
N-NO_2 (mg dm^3)	0.014	0.020	0.042	0.005	0.012	0.005	0.007	0.021	0.008
N-NO_3 (mg dm^3)	0.080	0.010	0.050	0.070	0.090	0.060	0.900	0.040	0.105
P-PO_4 (mg dm^3)	1.530	2.680	2.160	1.530	12.720	0.120	1.670	0.105	0.080
Sulphates (mg dm^3)	85.54	49.33	32.50	20.16	89.27	30.86	69.08	58.42	21.85
Chlorides (mg dm^3)	38.00	15.00	42.00	36.05	49.15	43.05	52.15	25.05	30.55
Total hardness Ca (mg dm^3)	105.80	110.16	80.64	72.25	137.52	60.48	56.16	113.04	66.96
Total hardness Mg (mg dm^3)	21.07	15.19	27.52	15.91	21.93	11.61	11.50	17.63	21.82
Fe (mg dm^3)	0.700	0.250	0.050	0.650	0.525	0.350	0.450	0.258	0.160
Dry residue (mg dm^3)	473.0	465.0	369.0	242.0	640.0	280.0	444.0	425.0	218.7
Dissolved solids (mg dm^3)	461.0	354.0	360.0	222.0	606.0	261.0	433.0	398.0	181.9
Suspended solids (mg dm^3)	12.0	111.0	9.0	20.0	34.0	19.0	11.0	27.0	36.7

from the site above the municipal swimming pool at the sluice of an arm of the Supraśl flowing just through the town Supraśl. The sampling site is surrounded by meadows. The bed is muddy [14].

- Pond Akcent, area 0.45 ha, max. depth 1.5 m, localized in the Municipal Park, is habitat of wild ducks and breeding swans. The sampling site is surrounded by single trees. The bed is muddy.
- Pond Dojlidy, localized near Białystok: Area 34.2 ha, max. depth 2.85 m, its south shorest border with coniferous woods and its western part with the town of Białystok. The samples were collected from the western end of this pond, which is used by the inhabitants of the town as a beach.
- Pond Fosa, localized in the Palace Park of Białystok. Area 2.5 ha, max. depth 1.75m Pond with wild ducks and breeding swans as well as crucian carp and tench bred, used by anglers. The pond is surrounded by meadows, with linden (*Tilia cordata* Mill.) and elm (*Ulnus carpinifolia* Gled.) also present.
- Lake Komosa, localized in the Knyszyńska Forest. Area 12.1 ha, max. depth 2.25 m the lake is surrounded by extensive coniferous woods.
- Lake Necko, area 518 ha, max. depth 25 m; the northern shores of the lake adjoin Augustów Forest while the south-western shores border the town of Augustów. For this reason most of the municipal and industrial wastes of the town are drained into the lake. The sampling site was on the eastern side of the lake next to Polish Tourist Country - Lowers' Association Centre; the shore is sandy for 1.5 m.

Geographical localized of the lake Necko - 53°52'N, 22°58'E and other investigated of the water bodies 53°02'N, 23°05'E.

Samples of water were collected along the shore in summer (August 2000) for hydrochemical analysis and to determine the fungal species present. Nineteen parameters were determined in each body of water (Table 1), following generally accepted methods [15].

The water for analysis was poured into three containers for each body of water. Water from each body of water was transferred to three 1.0 litre vessel and added of the substrata as baits (see Table 2) and placed in the laboratory at ambient temperature. Fruits and seeds were used as bait during exposure in the laboratory. The methods of the experiments are described in detail by Fuller and Jaworski [2].

The following procedures for the determination of the presence of fungus species on the baits were employed: during one month of exposure the baits (fruits and seeds)

Table 2. Fruits and seeds used as substrata for isolating *Aqualinderella fermentans* in different bodies of water.

Water body		Substrata	Number of plants
Spring	Cypisek	*Juniperus phoenicea* Nakai, *Limonium multiforme* Pignatti, *Opuntia leucotricha* De Candolle, *Solanum tuberosum* L.	4
	Jaroszówka	*Crataegus azarolus* Borkh, *Juniperus oxycedrus* var. *macrocarpa* (Sibth et Sm.) Ball, *Juniperus phoenicea* Nakai	3
River	Biała	*Malus* x *purpurea* Rehd.	1
	Supraśl	*Asparagus officinalis* L., *Cucurbita pepo* L. convar. *giromontiina* Greb., *Sorbus maderensis* (Lowe) Dode	3
Pond	Akcent	*Pyracantha crenulata* M. Roem, *Rhamnus alaternus* Miller	2
	Dojlidy	*Hyoscyamus niger* L. var. *pallidus*	1
	Fosa	*Berberis thunbergii* C.P. Thunberg, *Cotoneaster henryana* (Schn.) Rehd et Wils, *Crataegus oxyacantha* L., *Lonicera periclymenum* Hantz, *Mahonia aquifolium* Nutt., *Parthenocissus vitacea* Hitchc., *Rosa pomifera* Herrm., *Sorbus hybrida* L.	8
Lake	Komosa	*Berberis thunbergii* C.P. Thunberg, *Mahonia aquifolium* Nutt., *Rosa moyesii* Hemsl. et Wils., *Sambucus nigra* L.	4
	Necko	*Sorbus aucuparia* L.	1

were examined under a light microscope (once or twice a week) and the presence of the mycelium of aquatic fungi growing on the baits was noted. Identyfication of *Aqualinderella fermentans* was based on morphology and biometric data of thallus, zoosporangium, zoospores, oogonium and oospore (Fig. 1) described by Emerson and Weston [4].

Results

The hydrochemical analysis of water samples collected from the studied aquatic reservoirs showed substantial differences. Oxygen content in water ranged from 2.2 (Akcent Pond) to 14.86 mg/dm^3 (Lake Necko), while carbon dioxide varied within 11.15 (Dojlidy Pond) - 24.2 mg/dm^3 (Akcent Pond). Water oxidability was the lowest in Lake Komosa (3.12) and highest in Fosa Pond (22.97 mg/dm^3). The lowest content of nitrogen (all three forms) was observed in Lake Komosa and of phosphates in Lake Necko, while their highest concentrations were noted in Akcent. Akcent water was also most abundant in sulphates, their content being the lowest in the Supraśl. The least abundant in chlorides was Jaroszówka, Fosa being the richest. Necko and the Supraśl had the smallest amounts of dry residue and substances dissolved in water. Akcent was the most abundant in these parameters (Table 1).

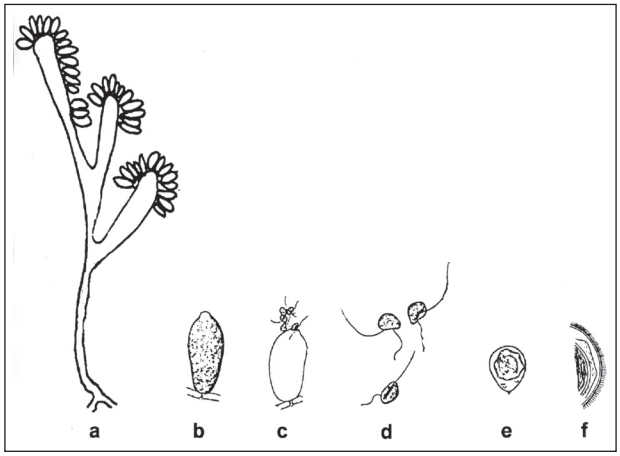

Fig. 1. *Aqualinderella fermentans*.
a - Maturing thallus with developing zoosporangia; b - Mature zoosporangium with apical discharge papilla; c - Empty sporangium with a few zoospores; d - Zoospores with laterally inserted whiplash flagellum (longer) and tinsel flagellum (shorter); e - A detached oogonium with spiny outer wall, basal cellulin apiculus; f - Portion of wall of mature oospore and oogonium to show spines on the latter.

In the present study *Aqualinderella fermentans* was found to grow on fruits in the water of all the four limnological types of aquatic reservoirs (Table 2). In Biała, Dojlidy and Necko it was observed only on one type of fruit. In Fosa this fungus was noted on the fruits of eight plant species.

As shown in the present study, water samples taken from sites of all the aquatic reservoirs contained relatively large amounts of dissolved oxygen and carbon dioxide. *Aqualinderella fermentans* was found to grow on baits in all the reservoirs studied. Its development was observed on 24 fruits, including juicy fruits (*Malus x purpurea, Sambucus nigra*), dry fruits (*Juniperus* species) and even seeds (*Hyoscyamus niger*). In the Biała, this fungus was noted only on fruits of *Malus x purpurea*, in Dojlidy on seeds of *Hyoscyamus niger*, in Necko on fruits of *Sorbus aucuparia*, while in Komosa and in Fosa on as many as four and eight plant species, respectively. It should be emphasized that the water in Fosa was poor in dissolved oxygen (2.65 mg/dm^3) and abundant in carbon dioxide (18.80 mg/dm^3).

Discussion

Akcent water had the lowest oxygen content and the highest carbon dioxide concentration, but the fungus was found to grow only on two plant species there. This would suggest not only that the contents of oxygen and carbon dioxide affect the occurrence of this fungus, but also some other chemical factors. In the case of pond Fosa this different factor turned out to suspended solids. Suspended solids this bacterioplankton examples of influence of inhibitory this environmental factor be well-known on development [16] and periphyton overgrown macrophytes [17]. They in different reservoirs can then be different factors, depending probably on the chemical weight of water of a given reservoir. In comparison to Fosa, water in Akcent had higher BOD_5, alkalinity, concentrations of ammonia, nitrates, phosphates, calcium, magnesium and sulphates, greater amounts of dry residue, dissolved and suspended solids.

Aqualinderella fermentans is considered to be a facultative anaerobe that is fermentative [18,19]. As reported by various authors, *Aqualinderella fermentans* growing as pustules covered with other microbial growth have been obtained from stagnant water on fleshy fruit baits [20]; their natural habitat may therefore be low in oxygen and high in carbon dioxide [18]. As shown in the study on rudimentary mitochondria using an electron microscope, only sparse, double-membraned vesicles were observed in both aerobically and anaerobically grown *Aqualinderella fermentans*. No cytochromes were detected in *Aqualinderella fermentans* grown in a medium, in a stationary air-containing culture [20].

In our study, aquatic reservoirs from which water samples were taken for analysis can be divided into two limnological groups: running waters (the two springs and two rivers; lotic environment) and stagnant waters (ponds and lakes; lenitic environment). The literature on the subject has emphasized that *Aqualinderella fermentans* inhabits stagnant waters [1-5,18]. In our study, it was observed in the Supraśl on 3 plants, in the Biała only on the apple *Malus x purpurea*, while in the two springs on 3 plants. These springs flow through allotment gardens intensively fertilized and therefore they show a high concentration of these biogenes. The spring water was also abundant in dry residue (465-473 mg/dm^3). Worthy of note is that *Aqualinderella fermentans* was isolated in high, low and rare frequency of occurrence in the Nile system, Egypt, by El-Hissy and Khallil [9] and El-Hissy et al. [8].

It should be assumed that in laboratory conditions baits kept in beakers containing water from the respective reservoirs were subject to decay, thus causing a decrease in dissolved oxygen content and an increase in carbon dioxide. Thus, the environmental conditions in the beakers were gradually becoming more and more favourable for the growth of *Aqualinderella fermentans*.

In this context is the study of El-Hissy and Oberwinkler [12], who found *Aqualinderella fermentans* in natural surface waters in Baden Wuertemberg (Germany) is of interest. The authors used sesame seeds as baits to investigate the occurrence of phycomycetes in water samples collected from 26 water reservoirs (rivers, small and large lakes, canals and ponds) and found three cases of this fungus (unfortunately, the authors did not define the type of the aquatic reservoir). Water temperature during the study ranged from 9-23.3°C (July-September 1996), content of oxygen dissolved in water being 5.20-15.40 mg/dm^3 and of organic matter 3.26-67.24 mg/dm^3.

The results of many years of mycological studies [21] indicate that most aquatic fungus species, both conidial and zoosporic, including *Aqualinderella fermentans*, are cosmopolitan, showing a limited range due to ecological factors rather than geographic, and therefore can be found in water at different latitudes.

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