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Hyphomycetes in rain water, melting snow and ice

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The investigations performed by direct microscopy method or bait technique (fragments of plants, cellophane, snake skin) using rain water flowing from trees, different types of roofs and melting snow and ice allowed determination of 146 species, including 55 new to Poland. Aero-aquatic species were predominant and only several belonged to typically aquatic *Hyphomycetes*.

Key words: *Hyphomycetes*, freshwater fungi, aero-aquatic fungi.

INTRODUCTION

Fungi of the *Hyphomycetes* demonstrate a great adaptive ability and are thus widely spread in nature. They show a great tolerance to temperature and marked resistance to varied conditions of wet and dry periods.

Analysis of the freshwater *Hyphomycetes* with respect to ecology shows their considerable heterogeneity. Apart from the species, which grow in the aquatic environment the group also includes areo-aquatic and terrestrial--aquatic fungi. The species, which are found in water as conidia and grow in terrestrial conditions, are referred to as the "water-carried fungi".

We decided to supplement our previous studies on the conidial fungi encountered in the open waters of north-eastern Poland (C z e c z u g a and O r ł o w s k a 1993, 1996) with data concerning atypical water forms such as rain water flowing from various trees or roof types, and melting snow and ice. The investigations carried out in such atypical niches as morning dew or water extracted from moss *Sphagnum* and others (C z e c z u g a and O r ł o w s k a 1994, 1995, 1997a, b) encouraged us to perform further studies of *Hyphomycetes* species composition in these and other atypical ecological niches.

MATERIAL AND METHODS

The studies were carried out from May 1992 to September 1994. The rain water draining during a driving rain from 10 coniferous tree species and 10 deciduous tree species was examined. In the coniferous group *Abies concolor* (1), *Juniperus communis* (3), *Picea abies* (6), *Methasequoia glyptostroboides* (5), *Chamaecyparis pisifera cyanoviridis* (2), *Pinus sylvestris* (8), *Pinus strobus* (7), *Juniperus sabina* (4), *Thuja orientalis* (10), *Taxus baccata* (9), and in the deciduous group *Alnus glutinosa* (13), *Betula verrucosa* (14), *Populus nigra* (17), *Buxus sempervirens* (15), *Fraxinus excelsior* (16), *Aesculus hippocastanum* (12), *Acer platanoides* (11), *Quercus robur* (18), *Tilia cordata* (20) and *Salix alba* (19) were examined. Just before the driving rain, a sterilized dish (40 × 30 cm) was situated under a tree of the species examined to collect the required amount of rain water draining from a particular tree.

The rain water draining during a storm from six following roofs: sheet copper (A), sheet zinc (B), red tiled (C), asbestic tiled (D), tar paper (E) and thatched roof (F) was also examined. Just before the storm, a sterilized dish (40 × 30 cm) was situated under a gutter of the roofs examined to collect the required amount of rain water draining from a respective roofs.

The snow was collected from branches (on the height of 1 – 1.5 m) of three gymnosperm tree species in the Knyszyńska Forest (NE Poland): *Pinus sylvestris*, *Picea abies* and *Juniperus communis*. The required amount of snow was shaken from several trees of each species to a sterilized dish (30 – 40 cm) and then transported to the laboratory. The water obtained was filtered trough a gauze to separate tree needles still present in the water. The water obtained was later poured into previously sterilized litre beakers.

The study investigated the ice of stagnant water basins (ponds) and running water bodies (rivers). In January, ice blocks (20 – 25 cm thick) were collected from water basins to sterile containers. Then, in the laboratory they were rinsed with distilled water three times and transferred to sterile dishes to melt. The water formed from the ice collected from each type of water reservoir was distributed to 6 one-litre beakers. Eighteen parameters of this water were determined (Table 1) according to the generally accepted methods (G o l t e r m a n and C l y m o 1969). Temperature in the laboratory was maintained at 1 – 2°C.

For the determinations of the presence of conidia of *Hyphomycetes* species in the rain water, snow water and ice water, the following procedure was employed: one part of each sample of water was examined according to A n d o and T u b a k i (1984a), second part according to C z e c z u g a and O r ł o w s k a (1993) using cellophane and snake exuviae as bait.

The baits were cut into small pieces and boiled several times with the water being changed each time. They were placed in the containers

Table 1

Chemical composition of the water from investigated water bodies (in mg l^{-1}) (n = 5)

Parameter	Pond		River	
	Fosa	Dojlidy	Biała	Supraśl
Temperature °C	1.0	0.0	2.0	0.5
pH	7.00	7.50	7.31	7.36
O_2	1.82	13.60	7.04	11.88
COD	15.09	9.38	9.02	8.80
CO_2	22.0	4.4	15.4	6.6
Alkalinity in $CaCO_3$ (mval l^{-1})	5.5	3.0	4.7	4.0
$N—NH_3$	0.854	0.280	0.642	0.324
$N—NO_2$	0.008	0.014	0.011	0.012
$N—NO_3$	0.05	0.03	0.05	0.06
PO_4	3.590	0.007	1.504	1.108
Cl	44.0	26.0	40.0	18.0
Total hardness in Ca	79.20	56.88	92.16	68.42
Total hardness in Mg	26.23	13.76	22.34	14.10
SO_4	23.04	38.26	68.70	30.85
Fe	1.05	0.72	0.90	1.02
Dry residue	429.0	224.0	532.0	236.0
Dissolved solids	370.0	117.0	496.0	199.0
Suspended solids	59.0	107.0	36.0	37.0

with investigated water types. During a 1-mo-period, any kind of cluster from a beaker bottom, side walls and the surface film of the water was examined under a light microscope. Identification of respective species was based on morphology and biometric data of conidiophores and conidia, contained in the keys (Nilsson 1964; Dudka 1974; Ingold 1975; Carmichael et al. 1980; Bråthen 1984; Matsushima 1993) and in the works of the authors who were the first to describe a respective species.

RESULTS

We found 146 species belonging to *Hyphomycetes.* Fifty seven taxa were determined in the rain water flowing from 10 coniferous and 10 deciduous tree species, including 17 found in the rain water flowing from both coniferous and deciduous tree species. Sixteen species were found in the water flowing from deciduous trees, while 24 in the water from coniferous trees (Table 2). The rain water flowing from different roof types yielded 33 *Hyphomycetes* taxa (Table 3). We isolated 26 species of fungi imperfecti from the melting snow collected from 3 coniferous trees (*Pinus*, *Picea*, *Juniperus*) in the Knyszyńska Forest (Table 4). A total of 111 taxa belonging to *Hyphomycetes* were found in the ice water from 4 water basins (2 ponds and 2 rivers) during 2 winter seasons (Table 5).

Fifty five *Hyphomycetes* species are new to Poland, including 14 species detected in the rain water flowing from trees, 4 from roofs, 6 in melting snow and 31 in ice water.

The above data indicate that a greater number of conidial fungi occur in melting ice water, compared with the some volume of rain water.

Table 2
Hyphomycetes recorded in the rain water falling from trees

Species of fungi	Species of trees**
Acrodictys bambusicola M.B. Ellis	2,4
Acrodictys elaeidicola M.B. Ellis	2,9,15
Acrodictys similis Hol.-Jech.	10
Actinocladium amazonicum Matsushima	15
Articulospora prolifera Roldan et van der Merve	15
* *Beverwykella cerebriformis* Nawawi et Kuthubuth.	1,6,7,11,16,17,19
Beverwykella pulmonaria (van Beverwijk) Tubaki	2,9,15
Berkleasmium pulchrum Hol.-Jech. et Merc.	5
Blodgettia indica Subramanian	19
* *Brachiosphaera jamaicensis* (Crane et Dumont) Nawawi	5
Canalisporium caribense (Hol.-Jech. et Merc.) Nawawi et Kuthubuth.	2,4,9,10
Canalisporium pulchrum Nawawi et Kuthubuth.	13
Ceratosporium cornutum Matsushima	9,15,17,18
Clathrosporium intricatum Nawawi et Kuthubuth.	1,12,14,17,18,20
Clathrosporium zalewskii van Beverwijk	19
Colispora elongata Marvanová	2,15
Corynespora cubensis Hol.-Jech.	11,17
* *Corynesporella superioramifera* Matsushima	4,5
Curucispora ombrogena Ando et Tubaki	14,16
* *Cylindrocarpon aequatoriale* Matsushima	4
Dactylaria lunata Tzean et Chen	10
Dicranidion fissile Ando et Tubaki	6,11
* *Endophragmiella quadrilocularis* Matsushima	4

Helicoon macrosporum van der Aa et Samson	9
Heliscus lugdunensis Sacc. et Therry	2,6,7,10,11,12,14,16,20
Hyaloscypha lignicola Abdullah et Webster	19
* *Kylindria peruamazonensis* Matsushima	5
Massarina fronsisubmersa Hyde	5
* *Microstella pluvioriensis* Ando et Tubaki	14
Mirandina brevispora Matsushima	17
Mirandina corticola G. Arnaud	8
Ordus tribrachiatus Ando et Tubaki	18,20
* *Paracryptophiale kamaruddinii* Kuthubuth. et Nawawi	4
Pithomyces obscuriseptatus Matsushima	2,4
Pleuropedium tricladioides Marvanová et Iqbal	4,9
Pleurophragmium parvisporum (Preuss) Hol.-Jech.	3
* *Pseudaegerita matsushimae* (Matsushima) Webster	6
Pseudaegerita viridis (Bayl Elliot) Abdullah et Webster	7
Scolecobasidium variabile Barron et Busch	2,9,15
Sigmoidea prolifera (Petersen) Crane	5
Stagonospora macropycnidia Cunnell	3,13
Sterigmatobotrys uniseptata Chang	5,13
Tetracladium maxilliforme (Rostr.) Ing.	2,4
Tetraploa aristata Berk et Br.	18
Titaea clarkeae Ellis et Everh.	1,6,7,11,12,14,16,18,20
Tricellula aquatica Webster	10
Tricellula inaequalis van Beverwijk	4
* *Tricladiella pluvialis* Ando et Tubaki	7,14,16,17,18,20
Trifurcospora irregularis (Matsushima) Ando et Tubaki	1,11,16,20
Tripospermum camelopardus Ing. Dann et McDougall	3,7,8,13
Tripospermum gardneri S. Hughes	19
Tripospermum infalcatum Ando et Tubaki	12
Tripospermum myrti (Lind) S. Hughes	15
* *Tripospermum porosporiferum* Matsushima	15
* *Veromyces manuensis* Matsushima	2
Volucrispora aurantiaca Haskins	2
* *Wiesneriomyces conjunctosporus* Kuthubuth. et Nawawi	8,13

* were recorded for the first time from Poland; ** see Material and Methods

Table 3
Hyphomycetes found in the rain water falling from six roof types

Species of fungi	Roof type**					
	A	B	C	D	E	F
Acrodictys similis Hol.-Jech.	x					x
Actinospora megalospora Ing.					x	
Angulospora aquatica S. Nilss.		x		x	x	
Arborispora palma Ando			x			
Arbusculina irregularis (Petersen) Marv. et Descals	x		x	x	x	
Beverwykella pulmonaria (van Beverwijk) Tubaki	x		x		x	
Canalisporium caribense (Hol.-Jech. et Merc.) Nawawi et Kuthubuth.	x	x	x	x	x	x
Catenomycopsis rosea Constant.	x		x			
Clavariana aquatica Nawawi	x		x			x
Colispora elongata Marvanová			x			
Corynespora cubensis Hol.-Jech.			x			
Corynesporella superioramifera Matsushima		x		x		
* *Dactylaria lunata* Tzean et Chen						x
Gyoerffyella tricapillata (Ing.) Marvanová			x			
Heliscus lugdunensis Sacc. et Therry	x			x		
Hyaloscypha lingicola Abdul. et Webster	x		x			
* *Hyaloscypha zalewskii* Desc. et Webster						x
Lunulospora curvula Ing.						x
Mirandina corticola G. Arnaud				x		
Neta patuxentica Shearer et Crane			x			
Ordus tribrachiatus Ando et Tubaki	x					
Pithomyces obscuriseptatus Matsushima		x				
* *Scolecobasidium flagelliferum* Matsushima				x		
Speiropsis pedatospora Tubaki	x	x		x	x	
Sporidesmiella hyalosperma (Corda) Kirk	x					
Titaea clarkeae Ellis et Everh.				x	x	
Tricellula aquatica Webster	x					
Tricelulla inaequalis van Beverwijk	x	x			x	
Tricladium procerum Marvanová					x	
Trinacrium subtile Riess			x			x
Tripospermum infalcatum Ando et Tubaki	x					
Veramyces manuensis Matsushima		x		x	x	
* *Wiesneriomyces laurinus* (Tassi) Kirk	x					
Number of species	15	7	12	10	10	7

* were recorded for the first time from Poland; ** see Material and Methods

In the rain water draining from of twenty tree species the presence of 14 species of aero-aquatic fungi was reported as new to Poland (Table 2). We observed the development of *Baverwykella cerebriformis* in the rain water draining from California fir, maple, ash, spruce, Weymouth pine and poplar. The species was reported on leaves submerged in water on Malaysia territory by N a w a w i and K u t h u b u t h e e n (1988). We observed conidia of *Brachiosphaera jamaicensis* in the rain water draining from dawn redwood. For the first time it was isolated by C r a n e and D u m o n t (1975) from decaying wood as *Actinospora jamaicensis* in West Indies. N a w a w i (D e s c a l s et al. 1976) introduced the name *Brachiosphaera jamaicensis*. Some of the hyphomycete species, which appear new to Poland, were first described from the river-basin of the Amazon by M a t s u s h i m a (1993). The growth of such species as *Corynesporella superioramifera*, *Endophragmiella quadrilocularis* and *Tripospermum porosporiferum* was observed by M a t s u s h i m a (1993) on putrescent leaves of latifolious plant in land conditions in the Cuyabeno National Park in Ecuador, while *Veromyces manuensis* on putrescent palm petioles in the Manu National Park in Peru. Such species as *Cylindrocarpon aequatoriale*, *Kylindria peruamazonensis* and *Pithomyces obscuriseptatus* were found on putrescent palm petioles in the Amazon tributaries – the Rio Mamon and the Rio Negro (Peru), and the Rio Yuturi (Equador). *Microstella pluvioriens* was first isolated from the rain water flowing from *Metasequoia glyptostroboides* in Japan by A n d o and T u b a k i (1984b).

In our studies *Paracryptophiale kamaruddinii* occurred only in the rain water draining from savin juniper. It was first isolated by K u t h u b u t h e e n and N a w a w i (1994) from decaying litter submerged in a freshwater stream in Malaysia. *Pseudaegerita matsushimae* was observed in the rain water draining from spruce only. It was first recorded by M a t s u s h i m a (1975) as *Papulaspora viridis* on a decaying *Quercus* sp. leaf, Kumamoto, Japan. A b d u l l a h and W e b s t e r (1983) observed the development of this fungus also in *Quercus* sp. leaf in Scotland, introducing the name *Pseudaegerita matsushimae*. We observed the growth of *Tricladiella pluvialis* in the rain water draining from Weymouth pine, poplar, durmast, lime, ash and birch. It was reported by A n d o and T u b a k i (1984b) in the rain water draining from leaves of *Quercus acutissima* in Japan. This is the second site of this fungus. *Wiesneriomyces conjunctosporus* in our case grew only in the rain water draining from pine and alder. It was first found by K u t h u b u t h e e n and N a w a w i (1994) on decaying submerged leaves in Malaysia.

In the rain water falling from six roof types such species as *Dactylaria lunata*, *Hyaloscypha zalewskii*, *Scolecobasidium flagelliferum* and *Wiesenriomyces laurinus* are new to Poland. We observed *Dactylaria lunata* in the rain water falling from a thatched roof, this fungus was first described from fallen parts of twigs in a recreation forest in Taiwan (T z e a n and C h e n 1991).

Table 4
Hyphomycetes found in snow water

Species of fungi	*Pinus sylvestris*	*Picea abies*	*Juniperus communis*
Acrodictys bambusicola M.B. Ellis	x	x	x
Acrodictys elaeidicola M.B Ellis			x
Anguillospora pseudolongissima Ranzoni		x	x
Arborispora palma Ando			x
Arbusculina irregularis (Petersen) Marv. et Descals		x	
Calcarispora hiemalis Marvanová et Marvan	x	x	
* *Camposporium pellucidum* (Grove) S. Hughes		x	
Canalisporium caribense (Hol.-Jech. et Merc.) Nawawi et Kuthubuth.	x	x	
Canalispora pulchrum (Hol.-Jech. et Merc.) Nawawi et Kuthubuth.			x
Ceratosporium cornutum Matsushima		x	
Clathrosporium intricatum Nawawi et Kuthubuth.			x
Corynesporella simpliphora Matsushima	x	x	
Mirandina corticola G. Arnaud	x	x	x
* *Monodictys peruviana* Matsushima		x	
Mycocentrospora aquatica (Iqbal) Iqbal	x		
Paracryptophiale kamaruddinii Kuthubuth. et Nawawi	x		
Paraepicoccum amazonense Matsushima			x
* *Polystratorictus fusarioideus* Matsushima	x	x	
Pseudaegerita corticalis (Peck) Crane et Schok.			x
* *Sporidesmium moniliforme* Matsushima	x		x
Trifurcospora irregularis (Matsush.) Ando et Tubaki			x
Trinacrium subtile Riess		x	
* *Tripospermum acerinum* (Sydow) Spegazzini	x	x	
Tripospermum myrti (Lind) S. Hughes		x	x
Vargamyces aquaticus (Dudka) Tóth	x	x	
* *Veronaea botryosa* Cif. et Montemartini	x		
Number of species	12	15	12

* were recorded for the first time from Poland

Hyaloscypha zalewskii described in the previous century as *Clathrosphaerina spirifera* (Zalewski 1888). It turned out to be a holomorphic species, in which *Clathrosphaerina zalewskii* (van Beverwijk 1951) and *Hyaloscypha zalewskii* were included (Descals and Webster 1976). We observed the growth of *Hyaloscypha zalewskii* in the rain water falling already from a thatched roof. *Scolecobasidium flagelliferum* were found in the rain water falling from asbestic tiled roof and *Wiesneriomyces laurinus* from a sheet copper roof. *Scolecobasidium flagelliferum* was first described from decaying petiole in the tributary of the Rio Amazonas (Matsushima 1993). *Wiesneriomyces laurinus* was first described from leaves in a stream in Malaysia (Kuthubutheen and Nawawi 1988), while the earlier encountered at several different sites (Kirk 1984), mostly on fallen leaves.

Monodictys peruviana and *Polystratorictus fusarioideus*, new to the Polish mycoflora, were first reported from terrestrial conditions on palm-petolio putrescenti in the valley of the Rio Amazonas by Matsushima (1993). On the same substrate in the water of the Rio Negro and Rio Yalapa another species – *Sporidesmium moniliforme* was found (Matsushima 1993). *Composporium pellucidum* has been long known as a species of terrestrial (Hughes 1951) and aquatic conditions (Tóth 1973; Ingold 1975). Later it was found in Hungary on forest litter (Gönczöl and Révay 1983). Another species new to Poland, *Tripospermum acerinum*, has been already encountered in terrestrial conditions (Ando 1992) and described as *Triposporium acerinum* (Sydow 1902). Later Spegazzini (1918) erected a new genus, *Tripospermum* and created a new combination, *Tripospermum acerinum*. *Verona botryosa* was first described by Ciferri and Montemartini (1957) in Italy, then it was reported as *Sympodina caprophila* by Subramanian and Lodha (1964). Matsushima (1971) called this fungus *Scolecobasidium coprophilum*, although in a monograph on *Hyphomycetes* of the water basin of the Amazon he gave it the name suggested by Ciferri and Montemartini (1957). In the water basin of the Amazon, this fungus was found on fallen palma petioles both in the Rio Negro and Tambopata reserve (Matsushima 1993).

New *Hyphomycetes* species, such as *Acrodictys peruamazonensis*, *Cylindrocarpon aequatoriale*, *Fusticeps laevisporus*, *Helminthosporium bigenum*, *Menispora amazonensis* and *Paradactylella peruviana* were first described by Matsushima (1993) from the river basin of the Amazon. *Paradactylella peruviana* was found on petiole in the reserve of Tambopata in Peru, while the other species in the Amazon tributaries, mainly on putrescent palm petioles. *Acrodictys martinii* was first noted in West Indies by Crane and Dumont (1975). Also Matsushima (1993) observed the growth of this fungus on fallen twigs in the Rio Ampiyach. *Taeniolina deightonii* was described by Crane and Schoknecht (1981), when revising *Torula* species collected from *Vismia guineensis* in Sierra Leone by F.C. Deighton. *Pseudospiropes subliferus* has been known since the first half of the previous century as

Table 5

Hyphomycetes found in the water from melting ice

Species of fungi	Pond		River	
	Fosa	Dojlidy	Biała	Supraśl
Acrodictys bambusicola M.B. Ellis	x	x	x	x
Acrodictys elaeidicola M.B. Ellis		x		x
* *Acrodictys martinii* Ceane et Dumont	x	x	x	x
* *Acrodictys peruamazonensis* Matsushima	x			
Actinospora megalospora Ing.		x		
Alatospora acuminata Ing.	x	x		x
Alatosessilispora bibrachiata Ando et Tubaki			x	
Anguillospora crassa Ing.				x
Anguillospora longissima (Sacc. et Syd.) Ing.	x	x	x	x
Anguillospora pseudolongissima Ranz.	x	x		
Angulospora aquatica S. Nilss.	x	x	x	x
Arborispora multisurcularis Ando			x	
Arbusculina fragmentans Marvanová et Descals	x	x	x	x
* *Beltraniella peruamazonica* Matsushina	x	x	x	
* *Blodgettia borneti* Wright		x	x	
Blodgettia indica Subramanian	x			
Calcarispora hiemalis Marvanová et Marvan			x	
Camposporium pellucidum (Grove) S. Hughes	x	x	x	
Canalisporium caribense (Hol.-Jech. et Merc.) Nawawi et Kuthub.		x	x	x
Canalisporium pulchrum (Grove) Hughes			x	
Centrospora aquatica Iqbal	x		x	
Centrospora filiformis (Greath) Petersen			x	
Clavariopsis aquatica de Wild.		x		x
* *Clavariopsis azlanii* Nawawi			x	x
Clavatospora longibrachiata (Ing.) S. Nilss.		x		x
Clavatospora stellata (Ing. et Cox) S. Nilss.			x	
Clavatospora tentacula (Umphlett) S. Nilss.	x	x		x
Clavariana aquatica Nawawi		x		x
Colispora elongata Marvanová	x			x
Condylospora spumigena Nawawi				x
Corynespora cubensis Hol.-Jech.		x	x	

Corynesporella simpliphora Matsushima	x		x	
Corynesporella superioramifera Matsushima	x	x	x	
* *Cylindrocarpon aequatoriale* Matsushima	x	x		x
Dactylella submersa (Ing.) S. Nilss.	x	x		x
Descalsia cruciata Roldan et Honrubia			x	
Dimorphospora foliicola Tubaki	x			
* *Diplocladiella appendiculata* Nawawi	x			x
Flagellospora stricta S. Nilss.				x
* *Fusarium candida* Matsushima		x		x
Fusarium aquaeductum (Radlk. et Rabh.) Lagh.			x	x
* *Fusticeps laevisporus* Matsushima				x
Gyoerffyella myrmecophagiformis Melnik et Dudka			x	x
Helicoon pluriseptatum van Beverwijk				x
* *Helicoma vaccinii* Carris				x
Heliscus lugdunensis Sacc. et Therry	x	x	x	x
* *Heliscus submersus* Hudson		x		
* *Helminthosporium bigenum* Matsushima	x			
* *Isthmolongispora geniculata* Nawawi et Kuthubuth.		x		x
Kontospora halophila Roldan et Honrubia	x			x
* *Lateriramulosa uniinflata* Matsushima				x
Lemonniera aquatica de Wild.	x	x	x	x
* *Lemonniera centrosphaera* Marvanová	x			
Lemonniera filiforme Petersen		x		
Lemonniera terrestris Tubaki		x		x
Lunulospora curvula Ing.	x	x	x	x
Margaritispora aquatica Ing.		x		
* *Menispora amazonensis* Matsushima			x	
Microstella pluvioriens Ando et Tubaki		x		
Mirandina corticola G. Arnaud	x	x	x	x
Monodictys peruviana Matsushima	x	x		
Monotosporella microaquatica (Tubaki) S. Nilss.				x
* *Nectria flavo-lanata* Berkeley et Broome				x
* *Paraarthrocladium amazonense* Matsushima				x
* *Paradactylella peruviana* Matsushima		x	x	
Paraepicoccum amazonense Matsushima		x		

Tab. 5 cont.

Species of fungi	Pond		River	
	Fosa	Dojlidy	Biała	Supraśl
* *Phaeodactylium acutisporum* Matsushima		x		
* *Phialogeniculata multiseptata* Matsushima	x			
Piricauda cubensis Hol. Jech. et Merc.		x	x	x
Pithomyces obscuriseptatus Matsushima		x	x	
Polycladium equiseti Ing.		x		
Polystratorictus fusarioideus Matsushima	x	x		x
Pseudaegerita corticalis (Peck) Crane et Schak.			x	x
Pseudaegerita viridis (Bayl Elliot) Abdullah et Webster				x
* *Pseudohansfordia dimorpha* Matsushima	x	x		
* *Pseudospiropes lotorus* Morgan-Jones		x		x
* *Pseudospiropes subliferus* (Corda) M.B. Ellis				x
* *Pyricularia peruamasonica* Matsushima		x		
Retiarius bovicornutus Olivier				x
Scolecobasidium flagelliferum Matsushima	x			
* *Scolecobasidium fusarioideum* Matsushima	x			
* *Scolecosporiella amazonensis* Matsushima	x			
Stachybotris theobromae Hansf.				x
* *Stemphyliomma tambopataense* Matsushima				x
* *Stemphyliomma terricola* Mon. Chary et Ram.	x		x	x
Sterigmatobotris uniseptata Chang			x	x
* *Taeniolina deightonii* Crane et Schaknecht		x		x
Tetrachaetum elegans Ing.				x
Tetracladium marchalianum de Wild.	x	x	x	x
Tetracladium maxilliformis (Rostr.) Ing.	x	x	x	x
Tetracladium setigerum (Grove) Ing.	x	x	x	x
Tricellula aquatica Webster	x	x	x	x
Tricellula inaequalis van Beverwijk		x		
Tricladium angulatum Tubaki		x		x
Tricladium anomalum Ing.			x	
Tricladium gracile Ing.	x		x	
Tricladium marylandicum Crane	x	x		
Tridentaria sp.				x

Trifurcospora irregularis (Matsushima) Ando et Tubaki				x
Trinacrium subtile Riess	x	x	x	x
Tripospermum infalcatum Ando et Tubaki		x		
Tripospermum myrti (Lind) Hughes				x
Tripospermum pes-gallinae Cif. Bat. et Nasum.	x			x
Tripospermum prolongatum Sinclair et Morgan-Jones		x		x
Triscelophorus monosporus Ing.			x	
* *Triscelophorus magnificus* Petersen			x	
Varicosporium delicatum Iqbal			x	x
Varicosporium elodeae Kegel		x		
Veronaea botryosa Cif. et Montemartini		x		
Volucrispora aurantica Haskins		x		
Volucrispora graminea Ing. et al.	x	x	x	x
Number of species	45	55	41	66

* were recorded for the first time from Poland

Helminthosporium subuliferum (Corda 1837 cited from Matsushima 1993). It was included in a number of genera (Hughes 1958), to be finally classified as the genus *Pseudospiropes* (Ellis 1976). *Stemphyliomma terricola* was reported by Manohara Chary and Ramarao (1972) from the soil in India. Both of these fungi were observed by Matsushima (1993) on fallen palm petioles in the reserve of Tamopata. *Nectria flavo-lanata* is known as anamorph of *Actinostilbe* sp. (Matsushima 1993). In our study, it was found in the water from ice collected from the Supraśl river.

Also *Diplocladiella apendiculata* found in the pond Akcent and the Supraśl river is new to Poland. This fungus was first described by Nawawi (1987) from twig fragments immersed in the Gombak river in Malaysia. *Hellicoma vaccinii*, also new to Poland, was first observed by Carris (1989) who found it colonizing a vertical scar on a stem section of *Vaccinium elliotii* collected near the Satilla River, Ware co., Georgia, USA. Its growth was also observed by Matsushima (1993) on decaying palm petioles, the Rio Ampiyacu, a tributary of the Amazon in Loreto, Peru. We found it in the ice collected from the Supraśl river. Also *Lateriramulosa uniinflata* was found in the Supraśl river. This fungus was first described in terrestrial conditions by Matsushima (1971) from decaying banana leaves on the Solomon Islands. It was also encountered in Europe, e.g. in the litoral zone in water among plant debris in a blind branch of the Svratka river, near Brno and in several other watercourses of the region (Marvanová 1973). *Pseudospiropes lotorus* first described by Morgan-Jones (1973) from roots of *Lotus corniculatus* in Alabama, USA, in our study was found in the pond Dojlidy and in the Supraśl river.

DISCUSSION

In our study most fungi grew in the rain water draining from the coniferous trees. This may suggest that the surfaces of certain coniferous trees act as a substratum for a larger number of species than deciduous trees. This phenomenon could be the resultant of several factors specific to the coniferous species, being a more stable habitat for certain *Hyphomycetes*, since they do not lose needles every year, but every few years (with the exception of dawn redwood). It is also known that coniferous species secrete sticky resin, which can arrest wind-carried conidia.

The most frequently encountered fungus in the rain water draining from twenty tree species during a driving rain was *Heliscus lugdunensis* and *Titaea clarkeae*. *Heliscus lugdunensis* was noted in northeastern Poland in water of the Supraśl river (C z e c z u g a and O r ł o w s k a 1993), and even in a micropool, temporarily made of melting terrestrial snow (C z e c z u g a 1992); and in the water of *Sphagnum* (C z e c z u g a and O r ł o w s k a 1997b). Earlier this fungus was also found in water conditions in France (M o r e a u and M o r e a u 1949). The history of the description of this species is of great interest due to, among other things, the environmental factors-dependent dimorphism of its conidia (D u d k a 1985). *Heliscus lugdunensis* was first described in the previous century as a terrestrial fungus from the pine bark in Italy (S a c c a r d o 1880). I n g o l d (1942), when distinguishing the aquatic *Hyphomycetes* group, described the aquatic species *Heliscus aquaticus* as having much in common with the Saccardo's *H. lugdunensis* and *H. aquaticus* and suggested that they were one and the same species *H. lugdunensis* (I n g o l d and C o x 1957). In extra-aquatic conditions, *Heliscus lugdunensis* was, apart from the pine bark, also found in the forest bedding (S a n d e r s and W e b s t e r 1978) and soil roots of the alder (F i s h e r et al. 1991). Also *Titaea clarkeae* was first described in the previous century (E l l i s and E v e r h a r t 1891). This fungus was found on *Dichaena quercina* (naw known as *Polymorphum quercinum*) and on *Quercus ilicifolia*, at Vineland, N.J., U.S.A. S u t t o n (1984) observed the type material of the fungus, and described and illustrated it in detail. However A n d o and K a w a m o t o 1986) isolated this fungus from rain water on intact leaves of *Carpinus tschonoskii* in Tokyo. We also found this species in the water of petmoss in northeastern Poland (C z e c z u g a and O r ł o w s k a 1997b).

Only two species, *Canalisporium caribense* and *Mirandina corticola* were found to grow in the water collected from tree, roof, snow and ice. *Canalisporium caribense* belong to the so called lignicolous group, first described in terrestrial conditions in Cuba (H o l u b o v á - J e c h o v á and M e r c a d o 1984). We have already found this species in morning dew drops on meadow grass (C z e c z u g a and O r ł o w s k a 1997a), in 13 springs of 20 investigated in the Knyszyńska Forest (C z e c z u g a and

Orłowska 1996). *Mirandina corticola* was first described also in terrestrial conditions by Arnaud (1952). The Gönczöl and Révay (1983) found it in the sediment of several litterleaf samples in Hungary. In northeastern Poland, *Mirandina corticola* was encountered in the water of several springs of the Knyszyńska Forest (Czeczuga and Orłowska 1996), in small forest lakes called suchary in the Augustowska Forest (Czeczuga 1995) and coastal water of some lakes in the Suwałki District (Czeczuga et al. 1997).

The present study reveals that certain *Hyphomycetes* species can grow on the roofs of buildings covered with different material both in rural and urban areas. The fungi, some of which have other habitats (e.g., tree leaves), and their conidia were arrested to roofs after they had come here with wind. A substrate for most of these species is an organic matter filling up roof unevenness. Short-lasting morning damp and rainwater may help in sporification (Tubaki et al. 1985). It can be assumed that not only conidia but also mycelia of these fungi are able to survive dry weather periods. This supposition is substantiated by the data obtained in recent years by Sridhar and Kaveriappa (1988). It was found that aquatic fungi growing on *Coffea arabica* and *Hovea brasiliensis* leaves collected from the water of a small stream and then kept in the laboratory under dry conditions for 360 d, continued to grow on being returned to a water environment. These were aquatic fungi of the *Hyphomyces* genus. The data provide evidence of the mechanisms of adaptation of aquatic fungi to their existence in waters, which during the year periodically dry up. In such cases as soon as the water returns, the fungi begin to develop. Most *Hyphomycetes* species were found to develop in rainwater samples from sheet copper, the fewest from sheet zinc and thatch roof, which is difficult to interpret explicitly. It may be associated with the size and unevenness degree of roof surface (it can facilitate the arrest of organic matter and conidia). Among the roofs examined sheet copper was the largest and most uneven surface, which was connected with the roof construction, and sheet zinc was the smoothest, while the thatched roof was the smallest. The texture of each roof may be associated also as one factor, which affects the difference in number and flora of inhabiting fungi in each roof. Thus, the number of species found is probably a resultant of all these factors.

As we have already mentioned, the occurrence of phycomycetes in the snow water collected from the ground was studied by many mycologists (Kobayasi and Fukushima 1952; Tubaki 1960; Nilsson 1964; Czeczuga 1992). A comparison of data reported by these authors with our present findings indicates that significant differences occur in the species composition. While the snow water obtained from the ground contents species, which are normally found in water bodies, the samples of the snow water collected from coniferous trees show a predominance of the so-called aero-aquatic hyphomycetes. Among the 26 species found in the snow water from coniferous trees only a few belong to the group of aquatic hyphomycetes. How could one explain the presence of hyphomycetes conidia in the snow collected from coniferous tree branches? It seems that conidia of the hyphomycetes species present in the air and carried by the wind fall on coniferous tree needles and branches, attracted by sticky resin, before the trees get covered with snow, i.e. in autumn. The snow, shaken off to dishes, contains conidia. They are also present in the snow water, initiating mycelia, which in turn produce new conidia in laboratory conditions.

Water in the pond Fosa is more trophic than in the pond Dojlidy. Similarly, water of the Biała river, compared to the Supraśl is trophically more abundant (Table 1). This could explain the differences in the number of species found in the respective ponds and rivers. The ice water collected from the pond Dojlidy contained more species than the water in the pond Fosa. Also, the ice water from the Supraśl river had more species than the Biała river. Furthermore, the largest number of *Hyphomycetes* species in the Supraśl river may be associated with the fact that this river flows through the Knyszyńska Forest, while the Biała river through the town of Białystok. In the case of ponds, the Fosa is situated in the very centre of Białystok, while the Dojlidy on the town periphery. According to F a b r e (1996), afforestation has an effect on the number of *Hyphomycetes* fungi of the particular watercourse. The occurrence of *Hyphomycetes* spores in ice explains sudden appearance of fungi in sulphur hydrogen stagnant water bodies observed in our studies following ice cover melting. In ice-covered basins, a sudden increase is noted in sulphur hydrogen content in the whole water space. This causes death of all living organisms. We did not manage to culture any *Hyphomycetes* species, even with the use of different baits, in water samples collected from such water bodies. However, a few days after the ice cover had melted, both aero-aquatic and typically aquatic species appeared in water samples. The presence of aero-aquatic *Hyphomycetes* could be easily explained by air movements (wild-blown spores). However, sudden appearance of typically aquatic *Hyphomycetes* species seemed strange. The present study throws some light on the problem. The spores found in ice are isolated from a pernicious effect of sulphur hydrogen, allowing their growth after ice melting. At the present state of knowledge of the biology of aquatic fungi the occurrence of certain rare fungus species in ice-melting water still remains unexplained. This refers not only conidial, but also zoosporic fungi (C z e c z u g a et al. 1999). Our long-term studies on zoosporic and conidial fungi carried out in the same water basins from which ice was collected as well as in other reservoirs of northeastern Poland in different seasons of the year, using the same methods and baits, have not revealed the presence of these aquatic fungus species. They were found only in the ice-melting water collected from these basins. Moreover, the number of species observed in the adequate volume of ice-melting water is significantly larger than in the same volume of water collected from the same basin not only in winter but in any other season of the year. This may be associated with water properties during freezing and particularly with surface tension, being the highest at water temp. of 0°. According to Ruttner (1962), a specific biotop is formed in the zone of the highest surface tension, with a specific accumulation of organisms, called neuston. As water temperature decreases, the increasing surface tension of the upper layer seems to attract various forms of neuston-forming aquatic fungi from the lower layers. Thus, their highest condensation occurs in the layer of water, which turns into ice. This assumption needs to be confirmed.

According to the keys of aquatic *Hyphomycetes* (Nilsson 1964; Ingold 1975; Carmichael et al. 1980; Bråthen 1984; Dudka 1985) 146 species found in the study included all three species of the genus *Anguillospora*, *Angulospora aquatica*, *Centrospora aquatica*, *Clavariopsis aquatica*, *Dactylella submersa*, *Heliscus lugdunensis*, *Lemonniera aquatica*, *Lunulospora curvula*, *Mycocentrospora aquatica*, *Palycladium equiseti*, *Tetrachaetum elegans*, 4 species of the genus *Tetracladium* and *Tricladium* and *Tricellula aquatica*. Most species were found in melting snow water. The fewest fungi were encountered in the rain water from trees. Most of these species have been found under fallen leaves in forest basins, in river valleys or at a certain distance from water basins (Fisher et al. 1991). This would suggest that typical aero-aquatic species can be found in open waters, while aquatic species in terrestrial conditions. The division into aero-aquatic and aquatic *Hyphomycetes* is relative, as in both cases water (as morning dew, raindrop or snow) is necessary to form conidia.

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Hyphomycetes w wodzie deszczowej oraz w wodzie z topniejącego śniegu i lodu

Streszczenie

Przeprowadzone badania w warunkach laboratoryjnych metodą bezpośredniego mikroskopowania oraz metodą przynęt (resztki roślinne, celofan i wylinka węża) w wodzie deszczowej spływającej z drzew, z dachów o różnym pokryciu oraz w stopniałym śniegu i lodzie pozwoliły ustalić obecność 146 gatunków grzybów klasy *Hyphomycetes*, w tym 55 nowych dla Polski.

Wśród oznaczonych grzybów dominowały tak zwane gatunki powietrzno-wodne, a tylko kilkanaście należało do typowo wodnych.