Fungal spores in rainwater: stemflow, throughfall and gutter conidial assemblages

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Rainwater from live trees and a gutter were collected in Hungary from June 2002 through to January 2003 and analysed for fungal spores. The total number of species was 71. Conidia of 63 species were identified in stemflow and throughfall samples collected from 13 trees. The majority of the species were hyphomycetous and 3 species belonged to coelomycetous anamorphs. The number of species per tree ranged from 5 to 25. The most species were found in a throughfall sample collected from *Taxus baccata* in October. *In situ* sporulation of some corticolous and foliicolous species were observed. Conidia of 25 species were detected in rainwater from a gutter. The definitive majority of the spores, both from trees and a gutter, belonged to the species which are primarily known as terrestrial litter inhabiting fungi. *Camposporium pellucidum, Diplocladiella scalaroides, Lateriramulosa uni-inflata*, *Trinacrium* spp. and *Tripospermum myrti* considered to be rare species in streams, were widely distributed in rainwater from live trees in urban environment. The species and conidial numbers of the common aquatic hyphomycetes in rainwater either from trees or a gutter were low. The exception was *Tetracladium marchalianum* of which conidial number in rainwater in a gutter was much higher than it has ever been observed in stream habitats.

Key words: fungal spores, Ingoldian fungi, stemflow, throughfall.

Introduction

Rainwater passing through the foliage of single trees or the forest canopy is termed as throughfall or stemflow. "Throughfall refers to the precipitation which drips down through the forest canopy and stemflow refers to the precipitation which reaches the ground by running down the boles of trees." (Eaton *et al*., 1973). The role of stemflow and throughfall in nutrient cycling of forest ecosystems has extensively been studied, e.g. (Eaton *et al*., 1973; Falkengren-Grerup, 1989). We know, however, little about fungal spores in rainwater draining from live trees and almost nothing about their role in the forest and litter ecosystems. Aquatic, aero-aquatic and other hyphomycetes in

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natural water bodies, mostly in streams, have extensively been studied since the pioneer work of Ingold (1942), but this is not the case with hyphomycetes in rainwater. In an early study, unusual, mostly unknown conidia were reported from a foam sample collected on the trunk of a beech tree in SW Hungary (Gönczöl, 1976). This foam was formed on the trunk during a summer rainstorm and it was obvious that it had accumulated from rainwater trickling along the tree trunk. In a recent study we analysed fungal species composition of water-filled treeholes in Hungary (Gönczöl and Révay, 2003). Laboratory incubation of leaf and woody substrates collected from these treeholes yielded many growing and sporulating species of hyphomycetes. Some of them (including aquatic hyphomycetes) appeared to be persistent inhabitants in treeholes. It was suspected, however, that some other species, only seen as conidia but not fruiting on the substrates, had entered the treeholes with rainwater. An endophytic or epiphytic origin was also suspected. Water-filled treeholes appear to be an occasional trap rather than a suitable habitat of these fungi.

There are studies suggesting active existence of some aquatic hyphomycetes on live trees. Bandoni (1981) investigated spores in stemflow of several trees in a forested area in British Columbia, Canada and found conidia of some species conventionally treated among aquatic hyphomycetes (e.g. *Gyoerffyella biappendiculata*, *Gy. gemellipara*). *Tripospermum* spp. of which aquatic or terrestrial habit is less known, also occurred in his samples. Japanese workers made extensive studies on hyphomycetes collected in rainwater dripping off trees. Ando and Tubaki (1984a,b) recorded conidia of *Flabellospora* spp., *Articulospora* sp. and many other species with stauroconidia similar in shape to Ingoldian fungi from rainwater collected from intact leaves of trees. They were on the opinion that rain, fog and morning dew are adequate to create an aquatic habitat in a terrestrial condition. By their hypothesis these species "probably live usually on intact leaves as mycelia and can sporulate when leaves are moistened by mist, morning dew or rain. Also, when the leaves fall in aquatic habitats... those fungi may sporulate on them." Moreover they described a number of new species and genera from rainwater, mostly from throughfall, e.g. *Dicranidion fissile, Tricladiella pluvialis, Tripospermum infalcatum, Alatosessilispora bibrachiata, Curucispora ombrogena* (Ando and Tubaki, 1984a,b). Later the term "terrestrial aquatic hyphomycetes" was proposed for the group of these fungi, which was characterised by the staurosporous conidia and the micronematous conidiophores (Ando, 1992).

Recently, Czeczuga and Orlowska (1994, 1999) reported a great number of hyphomycete species found in rainwater from living trees in Poland. Quite a few aquatic hyphomycetes, formerly well known from aquatic habitats, e.g. *Actinosporella megalospora*, *Anguillospora pseudolongissima*, *Clavariopsis brachycladia*, *Lemonniera aquatica* and *Margaritispora aquatica*, were reported (Czeczuga and Orlowska, 1994). Unfortunately few details were given about their collecting and incubation techniques. In another paper Czeczuga and Orlowska (1999) recorded 57 mainly dematiaceous and aero-aquatic hyphomycetes and some noteworthy aquatic hyphomycete species, e.g. *Articulospora prolifera*, *Colispora elongata*, *Pleuropedium tricladioides* and *Sigmoidea prolifera*, in rainwater draining from trees. In this paper they also listed 33 species observed in rainwater from gutters and roofs of several buildings. The occurrence of conidia of aquatic hyphomycete species, such as, *Clavariana aquatica*, *Arbusculina irregularis*, *Colispora elongata* and *Lunulospora curvula*, are also unexpected in these habitats.

The literature data and our preliminary studies suggest that analysis of the spores in rainwater, primarily from live trees, may contribute to our knowledge about biology and distribution of aquatic and other hyphomycetes. Therefore our objectives in this study were: (1) to identify conidia of hyphomycete species in rainwater collected from live trees, mainly in stemflow, and estimate the conidial concentration of some fungal species in some samples; (2) to find and identify spores in rainwater from the gutter of a building; and (3) to study *in situ* sporulation of some fungal species on trees.

Materials and methods

Rainwater samples were occasionally collected from live trees between June 2002 and January 2003. Several trees were selected in Budapest, in streets and in the garden of the Botanical Department of the Museum. Beech trees were sampled in the catchment area of the Morgó stream in the Börzsöny Mountains. The tree species from which the samples were taken and the date of samplings are listed in Table 1. All the deciduous trees sampled for rainwater were at least 20 cm dbh (diameter at breath height) or larger and the evergreen trees with *ca*. 15 cm dbh. Due to rainfall being periodical some of the trees were sampled several times while others could only be sampled less or just on one occasion.

Rainwater samples were also collected from the gutter (tin plate) of a building in the garden of our Institute. Close to the building there was a row of trees of *Tilia cordata* and a great amount of the leaf litter had fallen into this gutter.

The following sampling techniques were used: (1) stemflow samples were collected from the deciduous trees with the use of a medical, plastic

Table 1. The tree species investigated for fungi in Hungary.

Serial no.	Tree species	Location	Date
1a	*Chamaecyparis lawsoniana*	Budapest	2 Dec. 2002
1b	*Chamaecyparis lawsoniana*	Budapest	28 Jan. 2003
2	*Fagus sylvatica* 1	Királyrét Börzsöny Mts.	6 Dec. 2002
3	*Fagus sylvatica* 2	Királyrét Börzsöny Mts.	6 Dec. 2002
4	*Fagus sylvatica* 3	Királyrét Börzsöny Mts.	6 Dec. 2002
5a	*Koelreuteria paniculata*	Budapest	12 Aug. 2002
5b	*Koelreuteria paniculata*	Budapest	12 Oct. 2002
5c	*Koelreuteria paniculata*	Budapest	2 Dec. 2002
6	*Morus alba*	Budapest	10 Jun. 2002
7a	*Platanus hybrida*	Budapest	10 Jun. 2002
7b	*Platanus hybrida*	Budapest	4 Nov. 2002
7c	*Platanus hybrida*	Budapest	22 Jan. 2003
8	*Quercus macrocarpa*	Budapest	13 Jul. 2002
9	*Salix matsudana* cv. *tortuosa*	Budapest	2 Dec. 2002
10a	*Sophora japonica* 1	Budapest	8 Aug. 2002
10b	*Sophora japonica* 1	Budapest	24 Sep. 2002
11a	*Sophora japonica* 2	Budapest	12 Aug. 2002
11b	*Sophora japonica* 2	Budapest	2 Dec. 2002
12a	*Taxus baccata*	Budapest	12 Aug. 2002
12b	*Taxus baccata*	Budapest	12 Oct. 2002
13a	*Tilia cordata*	Budapest	10 Jun. 2002
13b	*Tilia cordata*	Budapest	8 Aug. 2002
13c	*Tilia cordata*	Budapest	4 Nov. 2002

syringe (for single use) of 5 ml. Trickling streaks of rainwater were detected on the trunk and the cortex was lightly touched with a syringe and stemflow was slowly sucked up. Depending on the intensity of rain various quantities of water could be collected. During heavy rain when the stemflow was copious the syringe could easily be filled. In such occasions 4 ml of water was sucked in the syringe and 1 ml of FAA (Ingold, 1975) was added for each sample. However, during low intensity rain lesser quantity of water, sometimes 1 or 2 ml, could only be collected. (2) Throughfall samples were collected from the trees of *Chamaecyparis* and *Taxus* because no stemflow appeared on their trunks even during heavy rains. Therefore rainwater on the foliage was shaken down onto a nylon sheet, rough debris was filtered out from the collected water and clean water poured into a glass container. (3) Rainwater samples (50 ml of water, sometimes mixed with some foam) were collected from the spout of the gutter. Some drops of FAA were added to each sample after collection in the field. All of the water samples, when the quantity was enough, were membrane filtered, and the filters were scanned for fungal spores. Water samples of less quantity were settled, one drop of the sediment was mounted on microscope slide and allowed to dry. Lactophenol with cotton blue was added to the dried sediment to prepare semipermanent slide preparations for further studies.

Easily detaching pieces of the cortex of the platan tree, from which the stemflow was sampled, were picked off from the trunk, transported to the laboratory, rinsed with tap water and incubated on wetted filter paper in Petri dishes for three weeks at 15 C. Additionally branchlets of evergreen trees were also moist-incubated in Petri dishes and leaf surfaces investigated microscopically for fungal growing.

Results and discussion

The total number of fungal species encountered in rainwater from trees and the gutter was 71 (Tables 2 and 3). Conidia of 63 species were detected in the stemflow or throughfall samples obtained from the 13 examined trees (Table 2). The majority of the species detected were hyphomycetous anamorphs, which were mostly moniliaceous and 3 species belonged to coelomycetous anamorphs. Species with stauroconidia (Figs. 1-27) occurred in greater number than those of with scolecoconidia (Figs. 28-39). The number of species per tree ranged from 5 to 25. The most species were found in a throughfall sample collected from *Taxus baccata* in October 2002.

The conidia of *Fusarium* species were found in all of the samples. Six other species were also widespread occurring on more than 50% of the trees: *Oncopodiella trigonella* (77%), *Excipularia fusispora* (62%), *Trinacrium* sp. 6 (62%), *Trinacrium* sp. 2, (54%), Unknown sp. 5 (54%), Unknown sp. 9 (54%). However, most species were restricted in distribution, 13 of the 64 species (20%) occurred on two trees, 28 species (44%) were only recovered from a single tree. The numbers of aquatic and aero-aquatic hyphomycetes were generally low.

The conidial abundance of some corticolous species e.g. *Camposporium ontariense*, *Excipularia fusispora*, *Oncopodiella trigonella* was equally high. Despite the wide distribution and great conidial abundance of these species in this study they are generally cited in the literature as rare species.

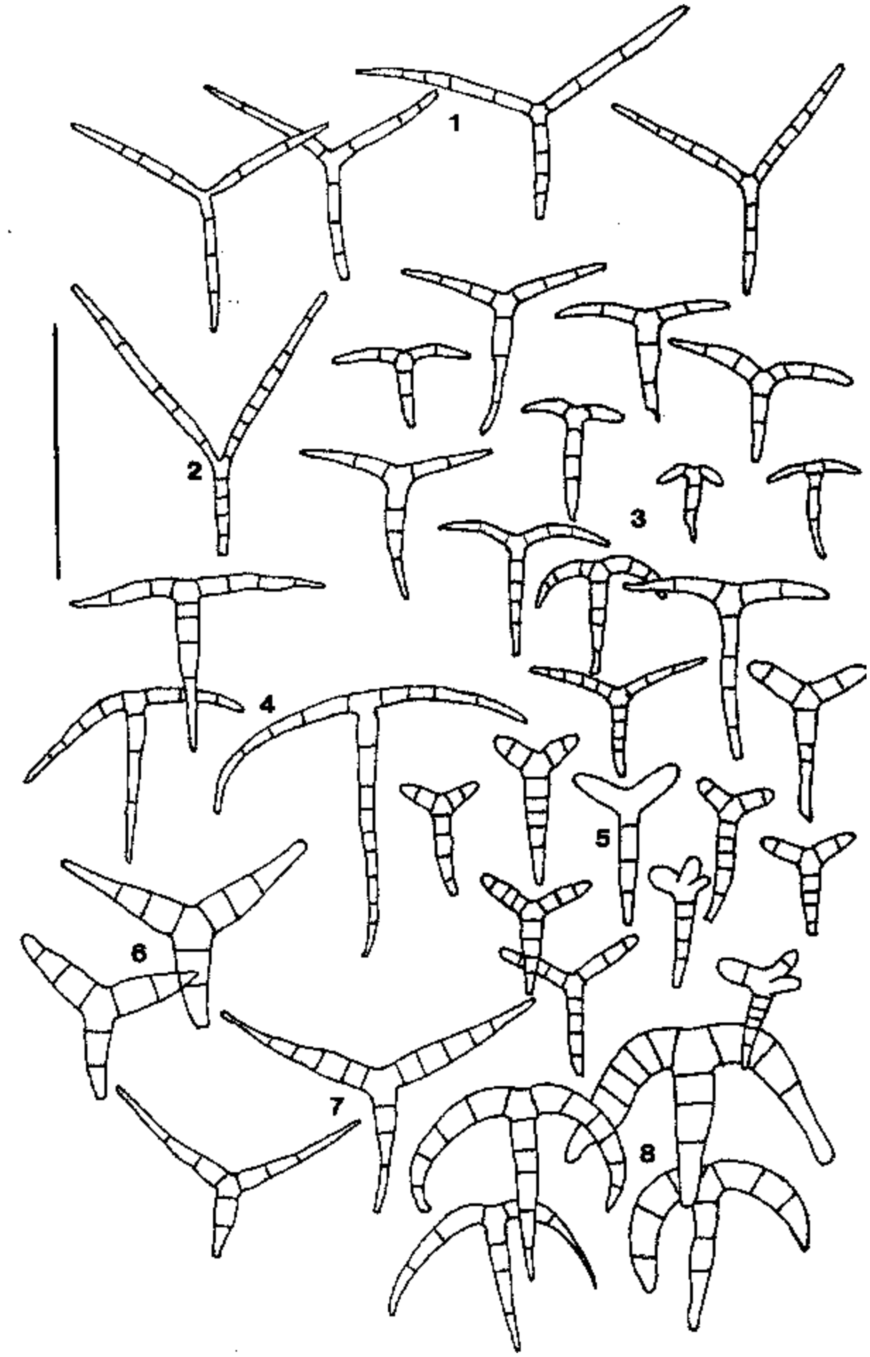
Conidia of four *Camposporium* species occurred during this study (Figs. 40-41, 45-47). Many conidia of *C. cambrense* were seen in all stemflow samples from platan (*Platanus hybrida*) but not in the samples of any other tree species. *Camposporium japonicum* was found in the stemflow from *Tilia cordata* only, while *C. pellucidum* was detected in the throughfall samples from the two evergreen tree species only. *Camposporium ontariense* appeared to be the most widely distributed species: its conidia occurred equally in

Table 2. Fungal species found in rainwater collected from different trees.

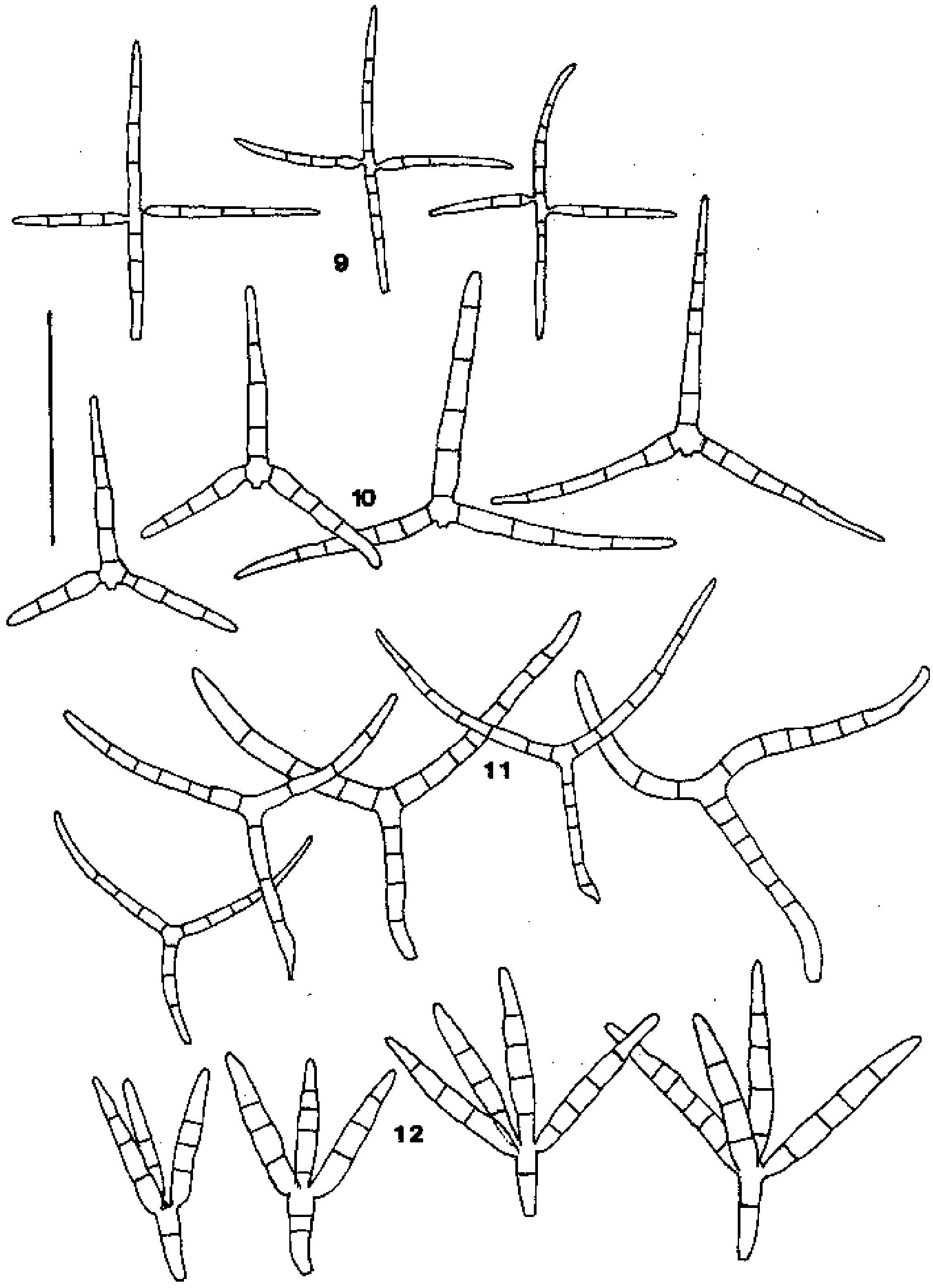
Species	Tree number																						
	1a	**1b**	**2**	**3**	**4**	**5a**	**5b**	**5c**	**6**	**7a**	**7b**	**7c**	**8**	**9**	**10a**	**10b**	**11a**	**11b**	**12a**	**12b**	**13a**	**13b**	**13c**
Alatospora acuminata Ingold			+																				
Arborispora paupera Marvanová & Bärlocher																				+			
Arxiella terrestris Papendorf								+							+					+	+	+	+
Camposporium cambrense Hughes										+	+	+											
Camposporium japonicum Ichinoe																						+	
Camposporium ontariense Matsush.		+				+	+			+	+	+							+				
Camposporium pellucidum (Grove) Hughes		+																		+			
Cercospora sp.						+								+									
Cornutispora sp.											+												
Curucispora ponapensis Matsush.			+																				
Dactylaria sp.	+	+										+											
Dicranidion gracilis Matsush.	+																	+					
Diplocladiella scalaroides Arnaud ex Matsush.											+				+					+	+	+	+
Dwayaangam dichotoma Nawawi					+																		
Dwayaangam yakuensis Matsush.													+										
Dwayaangam sp.																			+	+			
Endophragmiella taxi (M.B. Ellis) Hughes																				+			
Excipularia fusispora (Berk. & Broome) Sacc.						+	+	+			+	+	+	+	+	+	+	+	+	+		+	+
Fusarium spp.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Helicoma sp.						+									+	+	+						
Helicomyces sp.																							+
Isthmotricladia sp.	+						+			+											+		
Lemonniera cornuta Ranzoni			+		+																		
Lemonniera terrestris Tubaki ?			+	+																			
Lateriramulosa uni-inflata Matsush.																	+						
Mirandina corticola Arnaud							+																
Mirandina sp. ?						+		+				+			+	+	+	+	+	+		+	+
Mycocentrospora sp.						+																	
Oncopodiella trigonella (Sacc.) Rifai	+	+				+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+
Pestalotiopsis guepinii (Desm.) Stey	+									+	+	+											
Retiarius bovicornutus Olivier	+									+													
Tetracladium marchalianum de Wild.																			+				
Tetracladium maxilliforme (Rostrup) Ingold																				+			

Table 2 continued.

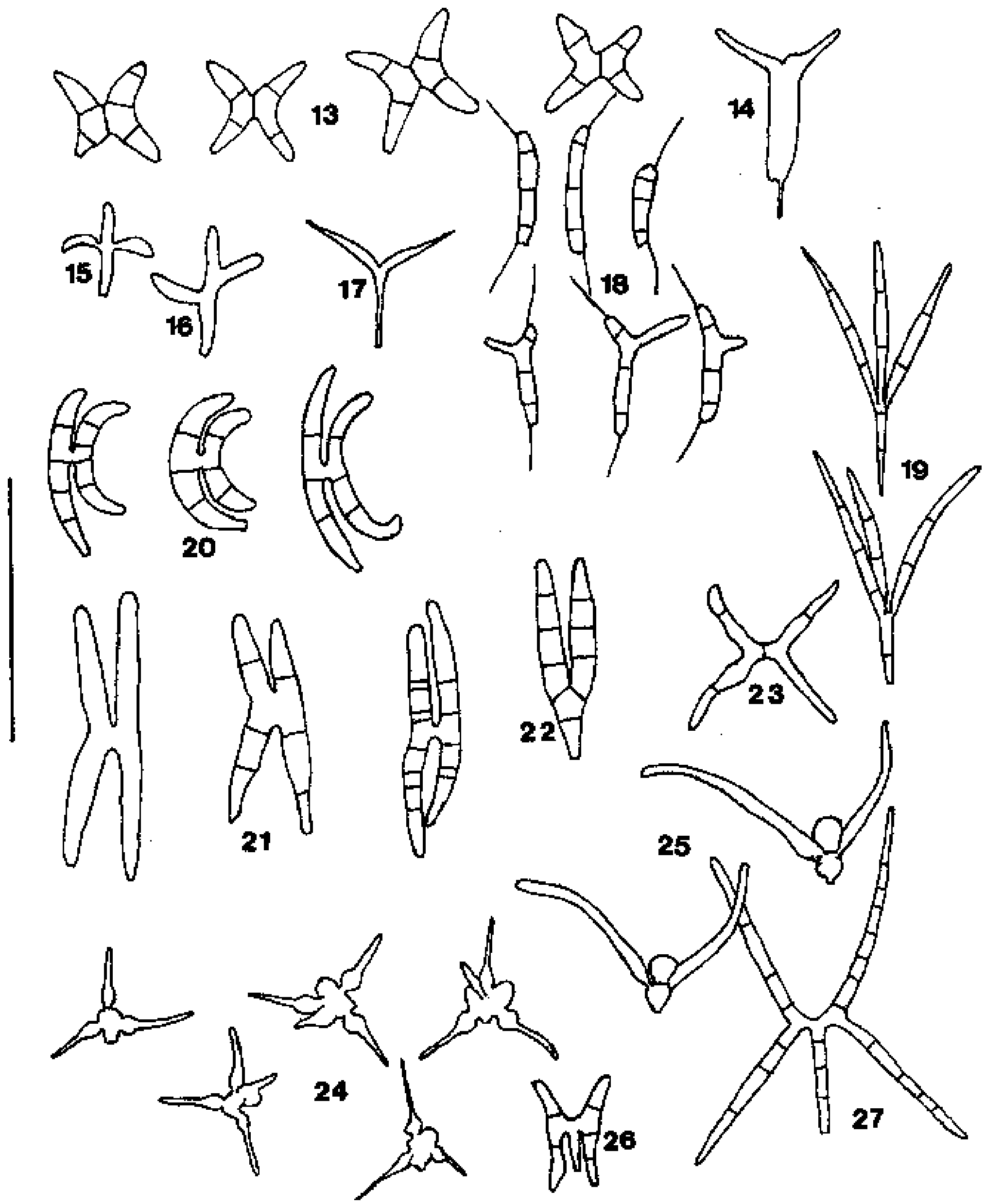
Species	Tree number																						
	1a	1b	2	3	4	5a	5b	5c	6	7a	7b	7c	8	9	10a	10b	11a	11b	12a	12b	13a	13b	13c
Titaea clarkeae Ellis & Everh.													+										
Titaea complexa? Matsush.						+	+										+		+				
Triadelphia heterospora Shearer & Crane															+								
Triadelphia uniseptata (Berk & Br.) P.M. Kirk						+	+	+	+						+	+				+			
Tricellula aquatica Webster										+												+	
Tricladium castaneicola Sutton																				+			+
Tridentaria sp.							+	+							+	+		+					
Trifurcospora irregularis (Matsush.) Ando & Tubaki			+	+	+																		
Trinacrium robustum Tzean & Chen									+	+					+						+		
Trinacrium subtile Riess										+										+	+		
Trinacrium sp. 1																				+			
Trinacrium sp. 2				+			+		+	+	+				+	+			+	+	+		
Trinacrium sp. 3							+				+									+			
Trinacrium sp. 4			+	+	+								+										
Trinacrium sp. 5											+	+	+										
Trinacrium sp. 6			+		+	+	+		+		+	+		+					+	+	+		+
Tripospermum camelopardus Ingold, Dann & McDougall												+							+	+			
Tripospermum myrti (Lind) Hughes	+	+					+			+										+		+	+
Varicosporium elodeae Kegel																				+			
Varicosporium sp.																				+			
Unknown sp. 1	+	+				+	+			+	+											+	+
Unknown sp. 2											+												
Unknown sp. 3							+																
Unknown sp. 4							+																
Unknown sp. 5		+	+				+	+		+	+	+						+		+			+
Unknown sp. 6											+									+			
Unknown sp. 7												+											
Unknown sp. 8			+	+	+		+	+			+	+							+	+			+
Unknown sp. 9			+										+										
Unknown sp. 10													+										



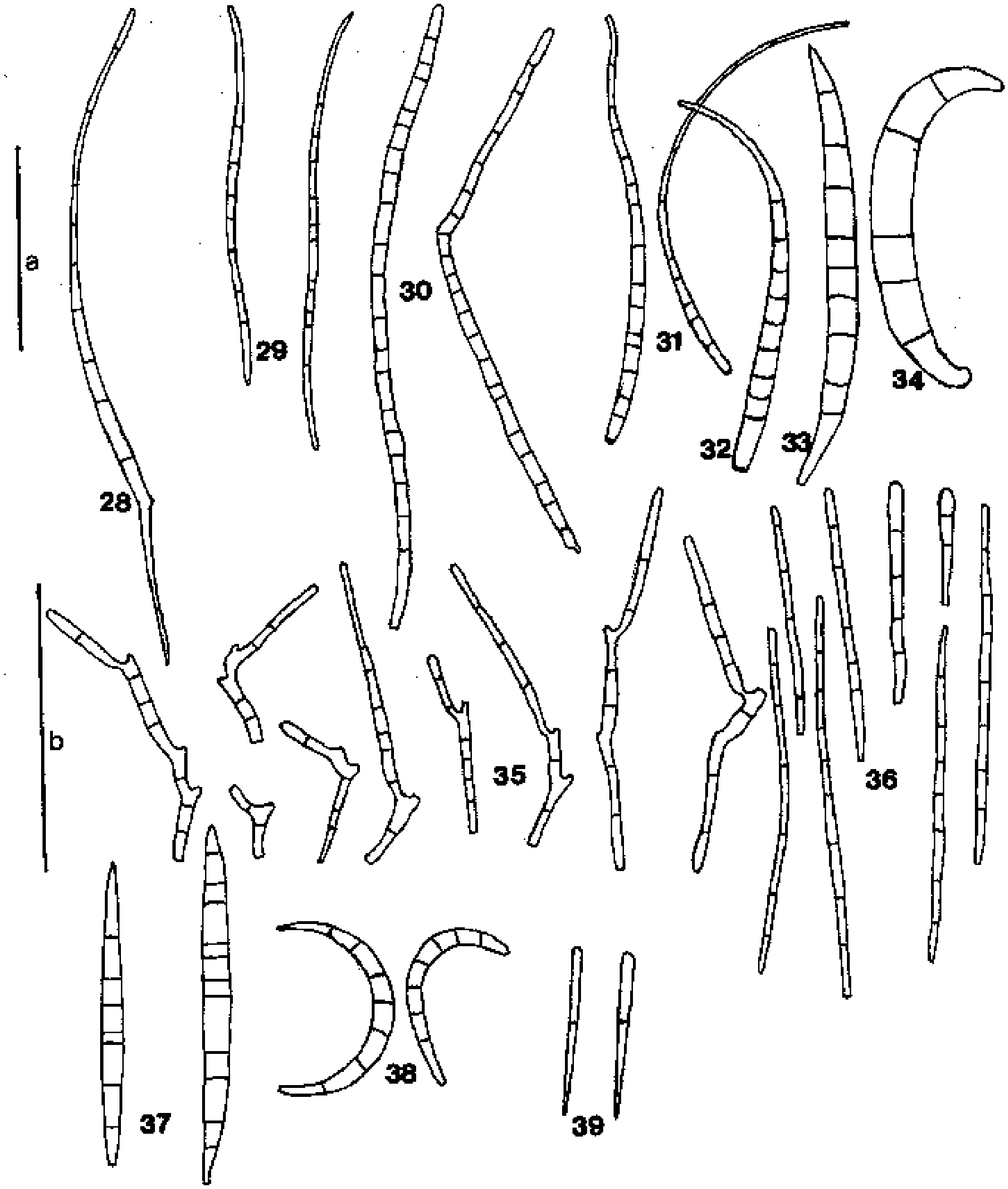
Figs. 1-8. *Trinacrium* species. **1.** *Trinacrium subtile*, **2.** *Trinacrium* sp. 1. **3.** *Trinacrium* sp. 2. **4.** *Trinacrium* sp. 3. **5.** *Trinacrium* sp. 4. **6.** *Trinacrium robustum* **7.** *Trinacrium* sp. 5. **8.** *Trinacrium* sp. 6. Bar = 50 µm.



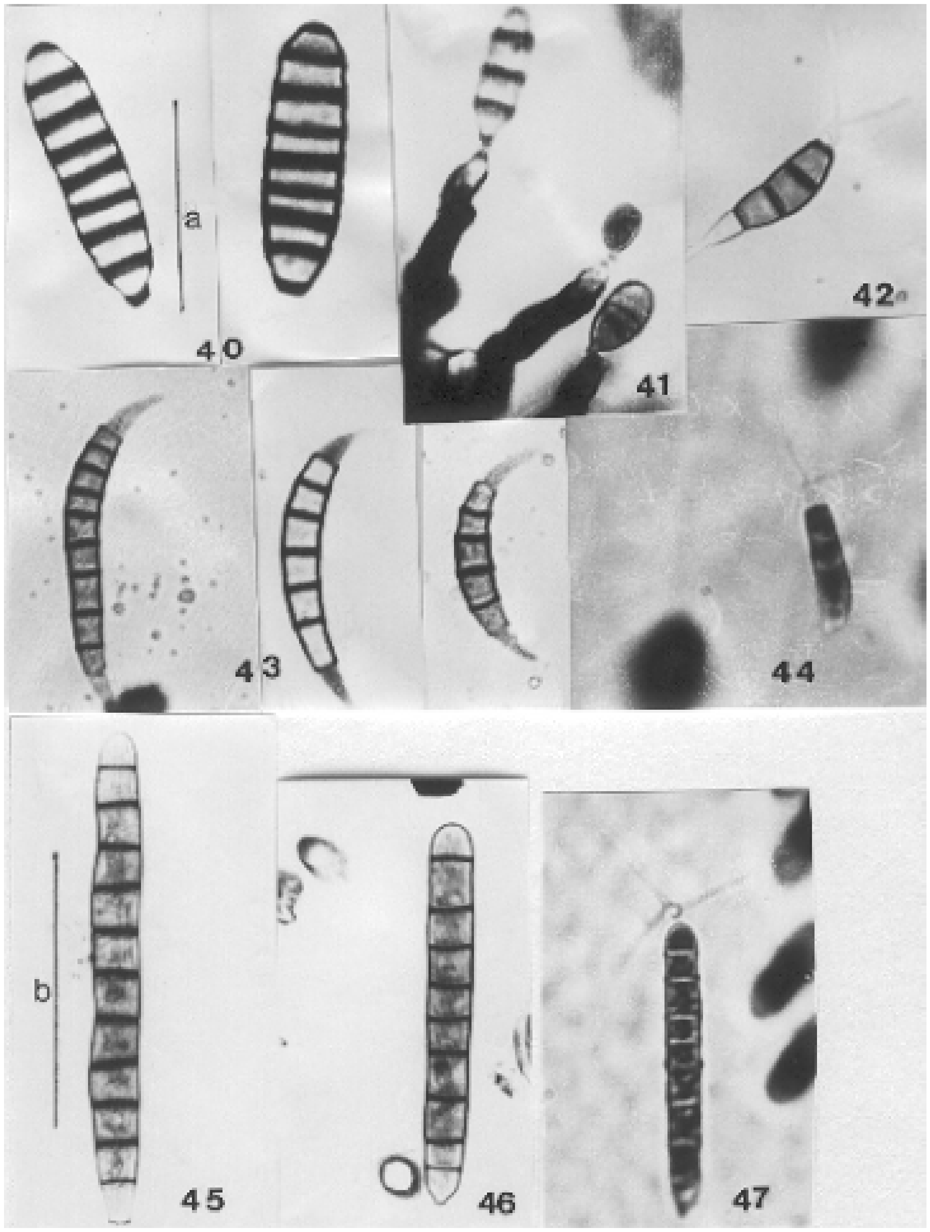
Figs. 9-12. Stauroconidia from rainwater. **9.** *Arborispora paupera*. **10.** *Trifurcospora irregularis*. **11.** *Retiarius bovicornutus*. **12.** *Tridentaria* sp. Bar = 50 µm.



Figs. 13-27. Various conidia from rainwater. **13.** Unknown sp. 1. **14.** *Cornutispora* sp. **15.** Unknown sp. 2. **16.** Unknown sp. 3. **17.** Unknown sp. 4. **18.** *Discosia* sp. **19.** *Isthmotricladia laeensis*. **20-21.** Unknown sp. 5. **22.** *Dicranidion gracilis*. **23.** *Curucispora ponapensis*. **24.** *Titaea complexa*. **25.** *Titaea clarkeae*. **26.** *Dwayaangam yakuensis*. **27.** *Dwayaangam* sp. Bar = 50 µm.



Figs. 28-39. Scolecoconidia in rainwater. **28.** *Mycocentrospora* sp. **29.** *Mirandina* sp. **30.** Unknown sp. 6. **31.** *Cercospora* sp. **32.** Unknown sp. 11. **33.** Unknown sp. 7. **34.** Unknown sp. 8. **35-36.** *Dactylaria* sp. **37.** Unknown sp. 9. **38.** Unknown sp. 10. **39.** *Dactylaria obtriangularia*. Bars = 50 µm, Figs. 28-34 with scale a and Figs. 35-39 with scale b.



Figs. 40-47. Various conidia from rainwater. **40-41.** *Camposporium ontariense*, conidia and conidiophores with conidia. **42.** *Pestalotiopsis guepinii.* **43.** *Excipularia fusispora*. **44.** *Bartalinia robillardoides*. **45.** *Camposporium pellucidum*. **46.** *Camposporium cambrense*. **47.** *Camposporium japonicum*. Bars: a =30 µm, b = 60 µm, Figs. 40, 42-44 with scale a and Figs. 41, 45-47 with scale b.

stemflow samples from deciduous and throughfall samples from evergreen tree species. The incubation of pieces of the cortex from the trunk of platan yielded abundant sporulation of *C. cambrense* and *C. ontariense*.

The conidia of *Excipularia fusispora* were readily recognized due to their falcate conidia with characteristic terminal, hyaline cells (Fig. 43). We found the conidia in almost all of the stemflow samples, sometimes in great abundance. Small portions of the conidiomata with developing conidia have also been several times observed in stemflow samples collected during heavy rains. It is interesting that, while we found this species being widely distributed on the trees sampled, it has been known as a rare fungus which "has not been reported from Britain since its description (Berkeley and Broome, 1859) and has only rarely been collected elsewhere in Europe" (Spooner and Kirk, 1982).

Oncopodiella trigonella was also one of the most widely distributed species found on almost all trees except beech. Its conidia were seen usually in great numbers suggesting that this fungus may be a dominant corticolous species. We have found little data about the distribution of *O. trigonella* in the literature. It was published by Kirk (1983) as a rare species in the British Isles represented by four collections on rotten wood. It was collected on cracked bark of *Fumana procumbens* in several localities of Hungary (Révay, 1995).

The conidia of the species of *Tripospermum*, *Trinacrium* and of Unknown sp. 5 occurred most frequently amongst the stauroconidia.

Conidia belonging to different species of *Tripospermum* were regularly seen in almost all stemflow and throughfall samples. *Tripospermum myrti* (and possibly *Tr. camelopardus*) are good examples of the species which are able to grow and sporulate on leaf surface of live trees. We observed dense mycelial growth together with abundant sporulation of *Tripospermum* spp. on the leaves of *Taxus baccata* and *Chamaecyparis lawsoniana* in different seasons of the year, even in February when the weather was dry and very cold (-15 to -20 C). Tubaki *et al*. (1985) observed that morning dew was an important factor in stimulating the sporulation of *Tripospermum* spp. and possibly of other leaf-inhabiting fungi. They concluded that most species of the genus were obviously foliicolous rather than aquatic and their habitat could be considered as alternating between "terrestrial" and "aquatic". However, we know little about the "habitat-change" of *Tripospermum* spp.: i.e. what happens to the conidia and/or substrates colonized by these fungi when they are fallen from live plants into aquatic habitats.

The abundance of conidia of *Trinacrium* spp. in stemflow has already been observed during our study on treehole fungal communities (Gönczöl and Révay, 2003). In this study a great variety in shapes and sizes of the conidia of *Trinacrium* spp. was seen in stemflow samples. We believe that these conidia can be grouped in eight forms, i.e. they may belong to eight species, as illustrated in Figs. 1-8. The highest species richness (six forms), sometimes together with high conidial numbers, was observed in stemflow samples from platan (*Platanus hybrida*). On the contrary no conidia of *Trinacrium* spp. were found in any of the throughfall samples from *Chamaecyparis*, while five of the eight forms occurred in the throughfall samples from *Taxus*. The unidentified conidial forms illustrated in Figs. 3 and 8 proved to be the most widely distributed during our investigation. Conidia very similar in shape and size to those in Fig. 8 were seen in rainwater drops shaken off tree leaves in the Canary Islands by Descals (pers. comm.).

The conidial forms illustrated in Figs. 20-21were found in the majority of stemflow samples. These conidia have not previously been seen in any terrestrial or aquatic habitats in Hungary. Two types of these conidia occurred: one of them with arcuated branches seen as a "double C" (Fig. 20) and the other one with rigid, more or less straight branches, often seen as a "capital K" (Fig. 21). The two forms may belong to the same genus but they probably represent different species. The two forms appeared with closely similar frequencies and their abundances were also noticeably high in some samples. A conidium found in foam in New Zealand was somewhat similar in its shape and size to the conidial form of "capital K" (Aimer and Segedin, 1985, Fig. 6 Q). An identical form as "double C" was recorded and illustrated also from rainwater by Bandoni (1981, Fig. 2 f, g). The conidium illustrated by Santos-Flores and Betancourt-López (1997, Fig. 186) also strongly resembles to form of "double C", but the well visible isthmus connecting the two conidial parts, seems to be less clear. The conidia of the species of *Ypsilonia* (Nag Raj, 1977) bear some resemblance to those of ours. All the known species of *Ypsilonia* occur on dead scale insects and our conidia observed in rainwater from trees may also derive from such animal substrates.

The conidia of *Titaea complexa* (Fig. 24) were identified with some doubt. We were unable to make suitable photomicrographs or drawings of the very complicated structure of the conidial body and its branches. The species epithet "complexa" probably also implies to the extreme complexity of this conidium. We observed many conidia in our samples, sometimes dozens of conidia occurred in one drop of stemflow and we believed that our identification was correct. We have also seen the conidia of this fungus in water samples from a beech treehole and listed as *Titaea* sp. (Gönczöl and Révay, 2003). Undoubtedly, the conidia of the same fungus were found in a stemflow sample and illustrated in Gönczöl (1976, Plate III. Figs. 3-4).

An enormous quantity of thin, mostly straight, hyaline conidia (Fig. 36) together with rachis-like and/or sympodially growing fungal elements, probably detached conidiophores (Fig. 35) were seen in the throughfall samples from *Chamaecyparis* and, in less quantity, in stemflow samples from platan in December and January. Intact, green branchlets of this *Chamaecyparis* were collected and tiny parts of the leaves were prepared for direct microscopic examination. Extended mycelial growth with densely growing conidiophores and attached conidia on them could be observed on the leaf epidermis. The morphology of the fungus is close to that of several species described in *Dactylaria*. The conidia of our fungus were very similar to those of *Dactylaria congregata* de Hoog (1985), but the conidiophores of the two species differed somewhat from each other.

Three specimens of beech (*Fagus sylvatica*) and two specimens of sophora (*Sophora japonica*) were sampled. Some common species such as, *Excipularia fusispora* and *Oncopodiella trigonella*, were absent on beech trees, while some other species occurred only on them. *Trifurcospora irregularis* (Fig. 10), a species of which conidia were formerly found in a beech treehole, occurred in the stemflow samples from all of the beech trees. An average of 17 conidia per four ml of stemflow was found. On contrary to this relatively abundant occurrence of these conidia on beech no conidia occurred in the samples from any other tree. Further examinations need to be assessed if this fungal species preferably inhabits this tree species. Three conidia of *Dwayaangam dichotoma*, a species also observed earlier in a beech treehole, occurred in two of the stemflow samples from beech trees. Five conidia resembling those of *Lemonniera cornuta* were seen in the samples from beech.

Conidia of *Tridentaria* sp. (Fig. 12) were found in five stemflow samples from August to December. Relatively high numbers of conidia were seen in the stemflow samples collected from both specimens of *Sophora japonica*. The conidia described and illustrated by Descals (1997) as *Tridentaria* sp. and those of *Tr. subuliphora* Matsushima (1989) were equally considered for comparison. Descals illustrated conidia with typical acute apices of the branches, while our conidia even more similar to those of *Tr. subuliphora* with branches with rounded apices. Also we have taken into account *Tr. implicans* a species capturing and subsisting on weakened nematodes (Drechsler, 1940). Conidia of *Tr. implicans* were described with one septum in the main body which also appeared in the majority of our conidia. Nevertheless, conidia alone were insufficient for the correct identification of this species. The possibility that these conidia may come from nematodes living in decaying materials on live trees also has to be taken into account.

The rainwater outflow from the gutter yielded a total of 26 fungal species (Table 3). Precipitation differed distinctly in 2002 and 2003. In 2002 there was a normal, rainy summer, whereas 2003 had an extremely dry summer.

Table 3. Fungal species found in rainwater from the gutter.

Species	Jun. 2002	Aug. 2002	Jun. 2003	Aug. 2003
Arxiella terrestris Papendorf	+	+	+	+
Bartalinia robillardoides Tassi	+	+		+
Camposporium japonicum Ichinoe	+	+	+	+
Dactylaria obtriangularia Matsush.		+		
Diplocladiella scalaroides Arnaud ex Matsush.	+	+	+	+
Discosia sp.	+	+		+
Fusarium sp.	+	+	+	+
Helicomyces sp.	+	+	+	+
Isthmolongispora ampulliformis (Tubaki) de Hoog & Hennebert	+		+	
Isthmotricladia laeensis Matsush.	+	+		+
Lateriramulosa uni-inflata Matsush.	+	+	+	
Mirandina sp.			+	+
Oncopodiella trigonella (Sacc.) Rifai	+			
Tetracladium marchalianum de Wild.	+	+		
Tetracladium maxilliforme (Rostrup) Ingold		+		
Tetracladium setigerum (Grove) Ingold	+	+	+	+
Tricellula aquatica Webster	+	+	+	+
Tricellula aurantiaca (Haskins) Arx	+			
Tricladium castaneicola Sutton			+	
Tricladium sp.			+	
Trinacrium sp. 2	+	+		+
Trinacrium sp. 5	+			
Tripospermum myrti (Lind) Hughes	+	+	+	+
Varicosporium elodeae Kegel			+	
Unknown sp. 1	+	+		
Unknown sp. 11	+	+		

Consequently the condition of the substrates in the gutter differed in the two years. During the summer of 2002 the plant litter in the gutter was often and repeatedly wet, sometimes submerged, however, it was permanently dry and only rarely wetted in 2003. The species and conidial numbers in the rainwater samples distinctly differed in the two years which reflected the important role of the water in this artificial environment.

In both years the common species were *Arxiella terrestris*, *Camposporium japonicum, Diplocladiella scalaroides, Helicomyces* sp. and *Tripospermum myrti*. Moreover, two coleomycetous species with conidia bearing appendages, *Bartalinia robillardoides* (Fig. 44) and *Discosia* sp. (Fig. 18), were also observed with great abundance. Conidial numbers of *Tetracladium marchalianum* and *Tetracladium setigerum* differed markedly in the samples of the rainy and dry year. While the conidial numbers of *T.*

marchalianum were very high (*ca*. 400 conidia in 20 ml of rainwater) in the samples in 2002, no conidia were seen in the samples in 2003. At the same time the conidia of *T. setigerum*, although with lower numbers, have been recorded in both years. The steady sporulation of *T. setigerum* in slightly wet or even in dry condition and the disappearance of *T. marchalianum* under the same condition may result from the difference in the water requirements of these two species. *Tetracladium marchalianum* and *T. setigerum* are well known, conventionally accepted as true aquatic species. Conidia of *T. marchalianum* or *T. setigerum* were not found in the rainwater samples from *Tilia cordata* and any other trees standing nearby. Therefore we do not believe that the living leaves and/or any other part of the trees had previously been colonised by these species before they get into the gutter. Nevertheless the theory that some fungi can establish themselves on living, senescent or even dead plant parts have to be further studied. This building is in the centre of the town very far from any natural water body. The same question which was posed in the case of aquatic hyphomycetes in treeholes arises: how do these species get into this gutter and colonise substrates there?

The gutter on a building filled with leaves and other plant substrates and occasionally slowly flowing rainwater can be considered as an artificial tiny brook or may also be similar to the water filled treeholes (Gönczöl and Révay, 2003). Czeczuga and Orlowska (1999) reported a great variety of aquatic and other hyphomycetes in rainwater from "different types of roofs". They considered that the main substrates of these fungi were the organic materials trapped by "roof unevenness" which, however, appears to be a less plausible hypothesis of the development of these fungi.

Conclusions

1. The conidia of some species formerly detected in treehole water (e.g. *Dwayaangam dichotoma, Trifurcospora irregularis*) were repeatedly found in stemflow from beech trees. This suggested that these species probably entered treehole with rainwater. This was especially notable in *Tr. irregularis* as numerous conidia were present in all of the samples from beech trees.

2. We found that conidial numbers in stemflow or throughfall may occasionally be very high: hundreds or even thousands of conidia occurred in some ml of rainwater. Depending on the intensity of rainfall some 100 litres of stemflow can be produced, even from not very large trees during a 2-3-cm rainstorm (Likens and Eaton, 1970). Consequently, an enormous quantity of the spores may be transported in this way to the soil and litter or even to streams. What happens to these spores after they arrived in terrestrial or

submerged litter and how this spore input affects the species composition of the hyphomycetes in these habitats is not known.

3. The present study provided little evidence of active existence of aquatic hyphomycetes on live trees. Quite a few species, however, e.g. *Camposporium pellucidum*, *Diplocladiella scalaroides, Lateriramulosa uni-inflata, Trinacrium* spp., *Tripospermum myrti*, of which conidia are regularly found in stream habitats, usually as rare species, proved to be widely distributed fungi in rainwater from live trees even in a polluted urban environment. Their common occurrence in the phyllosphere indicates that they probably do not belong to the true aquatic fungi.

4. The growth habits of the fungi of which conidia were recovered in a rainwater sample, on live trees in most cases are not known. *Pestalotiopsis guepinii* is generally restricted to live or recently killed wood (Bills and Polishook, 1991). The majority of the species discussed in this study are known as plant litter inhabiting species. We found, however, that some of them may occur on the trunk, and possibly on other parts of the trees. Although we have collected them from live trees it became evident that, for example, *Camposporium cambrense* and *C. ontariense* grew and sporulated heavily on the cortex of platan. *Arxiella terrestris*, *C. japonicum, C. pellucidum*, *Diplocladiella scalaroides*, *Endophragmiella taxi*, *Excipularia fusispora*, *Oncopodiella trigonella*, *Triadelphia heterospora* and *T. uniseptata* which are primarily known as wood or leaf litter inhabiting species may also live on and come from dead parts of the live trees. The term "litter" is conventionally used for dead plant material deposited on the ground or in various water bodies. The results in this study, together with other observations, suggest that many of the litter inhabiting fungi may colonize their substrates earlier than those are fallen to the ground. Carroll (1981) also discussed, mainly in Douglas fir canopy, the role of "canopy fungi or arboreal aquatic hyphomycetes in the decomposition of litter lodged in the canopy". In his opinion "such fungi constituted a guild of arboreal aquatic hyphomycetes which may function in canopies much as classical Ingoldian aquatic hyphomycetes function in streams". The abundance of the conidia and the richness of the species in rainwater from trees, observed during this study, indicate that these fungi may have an important role in the canopies. This phenomenon requires much further study because we know much less about hyphomycetes decomposing litter in the canopy than those which act in aquatic or terrestrial habitats (litter on the ground).

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