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Aquatic Hyphomycetes in Detritus, Sediment and Water in the Western Ghat Streams

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ABSTRACT

Most of the investigations on aquatic hyphomycetes in Western Ghats are confined to study their assemblage and diversity in leaf litter, foam and water. The present investigation documented aquatic hyphomycetes in different samples (leaf litter, woody litter, sediment and water) from three perennial streams located at high altitude in the Western Ghats (765-845 m asl). Ten species were common to all samples (*Alatospora acuminata, Anguillospora longissima, Cylindrocarpon* sp., *Flagellospora curvula, F. penicillioides, Isthmotricladia gombakiensis, Lunulospora curvula, L. cymbiformis, Triscelophorus acuminatu* and *T. monosporus*). Five species of them were top conidia producers (*Anguillospora longissima, Flagellospora curvula, F. penicillioides, Lunulospora curvula* and *L. cymbiformis*). Based on per cent conidial contribution, six species could be considered as core-group species (10%) (*A. longissima, F. curvula, F. penicillioides, L. curvula* and *L. cymbiformis*-like sp.). A total of 8, 6, 5 and 2 species each were confined to water, woody litter, leaf litter and sediments, respectively. Those species which selectively occur in specific niche in streams deserve further study. This study recommends the evaluation of different substrates in the streams to understand assemblage and diversity of aquatic hyphomycetes more precisely.

Keywords : Aquatic hyphomycetes, leaf litter, sediments, Western Ghats, species richness, diversity

INTRODUCTION

Aquatic hyphomycetes are polyphyletic group of fungi adapted to streams and rivers, which are mainly involved in the decomposition of submerged plant detritus and energy flow (Webster and Descals, 1981; Bärlocher, 1992). They produce conventional, sigmoid and multiradiate conidia, thus their identification is mainly based on the conidial morphology and ontogeny (Ingold, 1975; Marvanová, 1997; Webster and Descals, 1981; Gulis *et al.*, 2005). There are number of studies which document the historical developments, biogeography and taxonomic studies on aquatic hyphomycetes from 1880 to 2005 (Bärlocher, 1992; Krauss *et al.*, 2011; Duarte *et al.*, 2016).

The Western Ghats of India receives substantial rainfall during south-west monsoon season. Besides litter fall, heavy amount of plant detritus from the forest floor is transferred into the streams. Streams of the Western Ghats of India which are known for the occurrence of up to one-third of the known species of aquatic hyphomycetes (Sridhar, 2009a). Seasonal studies revealed that the post-monsoon (October-January) season is the best period for exploration as 80-90% of the species occur during this period (Chandrashekar *et al.*, 1990; Sridhar *et al.*, 1992; Sridhar and Raviraja, 2001). The majority of the studies in Western Ghats are confined to assess water, leaf litter and foam samples (Sridhar *et al.*, 1992; Rajashekhar and Kaveriappa, 2003). Recently a few studies have been conducted on the colonization of aquatic hyphomycetes on woody litter (Sridhar *et al.*, 2010; Sudheep and Sridhar, 2011;2013a). So far, investigations were carried out in high altitude mountain streams (~900-1300 m asl), mid-altitude streams (~400-700 m asl) and foothill (<350 m asl) streams (Sridhar *et al.*, 1992; Raviraja *et al.*, 1998). Generally, the mid-altitude streams are endowed with highest richness and diversity of aquatic hyphomycetes compared to other locations. The mean species richness is 10.3 in the mountain streams (due to sparse riparian vegetation), attains the highest of 20.1 at mid-altitude (rich in vegetation) and declines to 14.2 (foot-hill locations) possibly due to increased temperature, reduced flow rates and human intervention (Raviraja *et al.*, 1998). It is hypothesized that better conditions prevail in the streams below mountain region of the Western Ghats for aquatic hyphomycetes compared to mountain streams. Thus, the present study focuses on three streams located at an altitude ranging from 765-845 m asl. This study was undertaken during the post-monsoon season and occurrence of aquatic hyphomycetes in leaf litter, woody litter (bark and cambium), sediments and water samples was assessed with several samples spread over the post-monsoon period.

MATERIALS AND METHODS

Sampling sites

Three perennial streams selected for the study include V'Badaga (12°5'28.51"N, 75°50'24.87"E; 765 m asl), B'Shettigeri (12°8'8.81"N, 75°52'39.31"E; 820 m asl) and Perambadi (12°8'3.23"N, 75°47'55.05"E; 845 m asl). All these streams connect to the River Barapole flowing westwards and empty into the Arabian Sea in Kerala. The first two streams pass through buffer zones of the reserve forest blend with coffee agroforest-paddy fields, while the latter pass through the reserve forest. The catchment areas of these streams receive precipitation ranging between 350 and 650 cm/annum. The major riparian tree species consists of *Artocarpus hirsutus, Bischofia javanica,Canarium strictum, Dimocarpus longan, Dysoxylum malabaricum, Ficus drupacea, F. glomerata, Garcinia gummi-gutta, Holigarna beddomei, H. grahamii, H. nigra, Hydnocarpus pentandra, Legerstroemia microcarpa, Madhuca neriifolia, Mangifera indica, Memecylon umbellatum, Pongamia pinnata, Scleropyrum pentandrum, Terminalia bellirica, Vateria indica* and *Vernonia arborea* (Rani *et al.*, 2011).

Sampling was carried out in three stations of each stream at a distance of 100-150 m. in monthly intervals during the post-monsoon season from November 2013-January, 2014. In each month, three spots per stream were chosen for sample collection.

Edaphic factors

On each sampling, humidity and air temperature were measured using humidity meter (Mextech Digital Thermohygrometer, Mumbai, India; Model #, TM-1; accuracy, ±1%). Water temperature was assessed by glass mercury thermometer. The pH and electrical conductivity of water were assessed at the sampling station (Water Analyzer 371, Systronics, Gujarat, India). Water samples fixed in sampling stations were assessed for dissolved oxygen by the Winkler's method (APHA, 1995).

Samples and processing

Leaf litter

Decomposing leaf litter were collected from each sampling station in sterile polythene bags and brought to the laboratory and processed within 12 hr. After rinsing leaf litter in water, different types of leaves were packed and punched into disks (1.5 cm diam.) using cork-borer. The disks were aerated in bubble chambers to assess the colonization of aquatic hyphomycetes. The leaf disks (5 disks/sample) were incubated in 150 ml of sterile distilled water in 250 ml Erlenmeyer flasks and aerated through Pasteur pipette using an aquarium pump up to 48 hr (23±2ºC). Aerated water was passed through a Millipore filter (diam., 45 mm; porosity, 5 µm) by suction and stained with cotton blue in lactophenol (0.1%). Each stained filter was sliced into half to mount on a microscope slide followed by addition of few drops of lactic acid to scan the filter using high power microscope (Olympus CX 41 RF, Miami FL, USA). The conidia of aquatic hyphomycetes trapped on the filters were identified based on the monographs and primary literature (Ingold, 1975; Carmichael *et al*., 1980;Webster and Descals, 1981; Nawawi, 1985; Marvanová, 1997; Santos-Flores and Betancourt-López, 1997; Gulis *et al*., 2005). Conidia produced in leaf litter were calculated per gram dry mass after drying in an oven at 80ºC for 24 hr.

Woody litter

Decomposing woody litter with and without bark was collected from the streams. Bark was separated if attached to the woody litter, cut into pieces (0.5 x 2.5 cm), rinsed in freshwater and 5-8 pieces were incubated in bubble chambers to generate conidia of colonized aquatic hyphomycetes. The cambium part of woody litter was excised (0.5 x 2.5 x 0.2-0.3 cm) and 5-8 pieces were incubated in bubble chambers to generate conidia. The aerated water was processed to collect the conidia on the filters and scanned as described above.

Sediments

Sediment samples in each location of the stream were scooped by Peterson's grab (Partex Products, Mumbai, India; capacity, 2 kg). Sediments were spread on pack of filter paper to absorb water followed by determination of moisture content gravimetrically. Three hundred milligram wet mass of sediment was inoculated to eight 1.5 cm diam. sterile banyan leaf disks (*Fibus benghalensis*) in 150 ml sterile distilled water in 250 ml capacity Erlenmeyer flasks and shaken on a rotary shaker (125 rpm; 23-25°C) for five days. The shaken leaf disks were rinsed and incubated in bubble chambers as detailed above to generate conidia of aquatic hyphomycetes colonized on leaf disks from the sediments. Dry mass of the inoculated sediment was determined using parallel sediment samples to express conidial release from one gram dry mass of the sediment.

Water samples

One hundred ml of water sample from each sampling location was filtered on the spot through Millipore filters (50 ml/filter), which were processed as described above, subsequently scored the conidia and expressed conidia/100 ml water sample.

Data analysis

Conidial output of aquatic hyphomycetes from leaf litter, bark, cambium, sediment and water were expressed in per cent contribution of each species. Total species and average species in each stream were documented. Similarly, conidial output per gram of leaf litter, bark, cambium and sediment were calculated. Water samples were treated separately as species and conidia were scored per 100 ml.

The Simpson and Shannon diversities (Magurran, 1988) of aquatic hyphomycetes in leaf litter, bark, cambium, sediment and water samples were calculated based on the conidial output by different aquatic hyphomycetes. Expected number of species of aquatic hyphomycetes in pooled data (leaf litter, bark, cambium, sediment and water) from three streams was assessed by rarefaction indices (Ludwig and Reynolds, 1988).

RESULTS

Edaphic features

There was no wide fluctuation in edaphic factors during the study period in three streams (**Table 1**). Humidity was higher in V'Badaga as compared to the other streams (64.9 vs. 63.1-63.2%). Air as well as water temperatures were least in Perambadi than in other streams. Water pH, conductivity and dissolved oxygen were ranged between 6.7 and 7.1, 44.5 and 64.1 µS/cm and 6.1 and 7.2 mg/l, respectively.

Species richness

The present study yielded 36species of aquatic hyphomycetes in three streams. The species richness was highest in water

Table 1. Physical and chemical properties of three Western Ghat streams (n=9, mean±SD)(range in parenthesis).

	V'Badaga	B'Shettigeri	Perambadi
Air			
Humidity (%)	64.9 ±7.9 (55–74)	63.2±7.1 (53–70)	63.1±9.8 (54–78)
Temperature (°C)	25.6±0.9 (24.8–27.3)	25.3±1.9 (23–28.3)	23.6±2.6 (20.3–27.1)
Water			
Temperature (°C)	24.8±1.8 (23–27.3)	24.6±1.9 (22–26.5)	23.9±2.6 (20.5–27.5)
pH	6.9±0.4 (6.3–7.7)	7.1±0.6 (6.5–8.04)	6.7±0.3 (6.2–7.3)
Conductivity (µS/cm)	44.5±13.6 (33.7–75.4)	64.1±20.2 (47.9–98.1)	45.3±12.1 (33.2–70.9)
Dissolved oxygen (mg/l)	7.2±0.8 (6.5–8.2)	6.7±0.5 (6.0–7.6)	6.1±0.9 (3.8–6.8)

samples (19 species) compared to woody litter (18 species), leaf litter (17 species) and sediment (13 species). The number of species found in leaf litter, cambium and water was highest in V'Badaga (11, 9 and 13 species, respectively) (**Fig. 1**). It was least in leaf litter, cambium and water in Perambadi (8, 7 and 9 species, respectively). Bark consists of 10 species each in all streams, while sediment consists of 9 species each in V'Badaga and Perambadi and 7 species in B'Shettigeri. The average species per sample was highest in leaf litter in all three streams. The average species was highest in cambium and sediment in V'Badaga. Bark and water samples consist of the highest average species in B'Shettigeri.

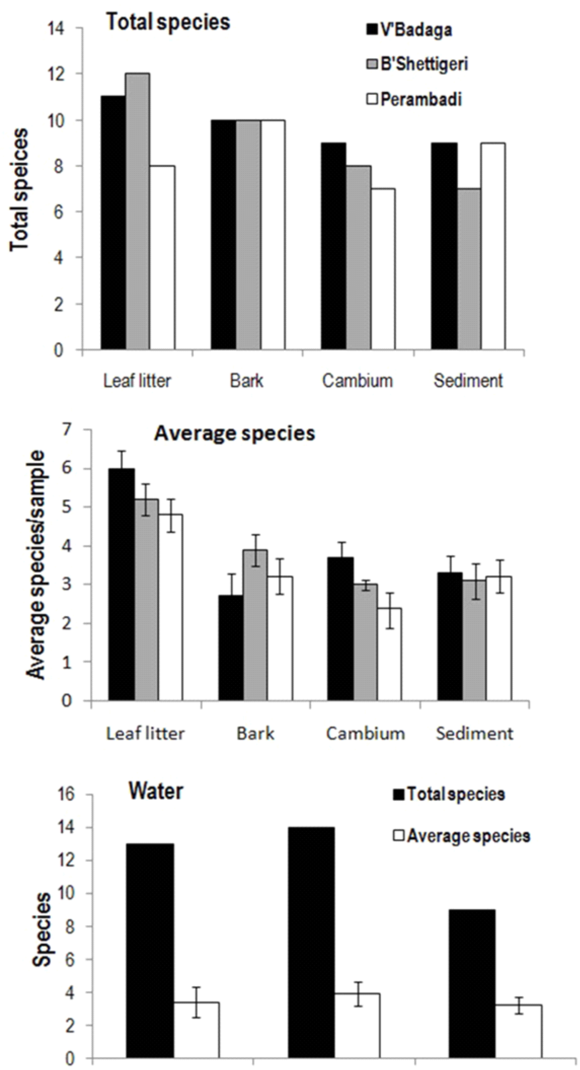

Fig. 1 Variation in total species (in 9 samples) and average species (n=9, mean±SE) of aquatic hyphomycetes in leaf litter, bark, cambium, sediment and water samples in three Western Ghat streams.

Conidial richness

The overall conidial richness was highest in leaf litter of all streams, while it was lowest in water samples (**Fig. 2**). Conidial richness in sediments was next to leaf litter followed by bark, cambium and water. Among the top five species in

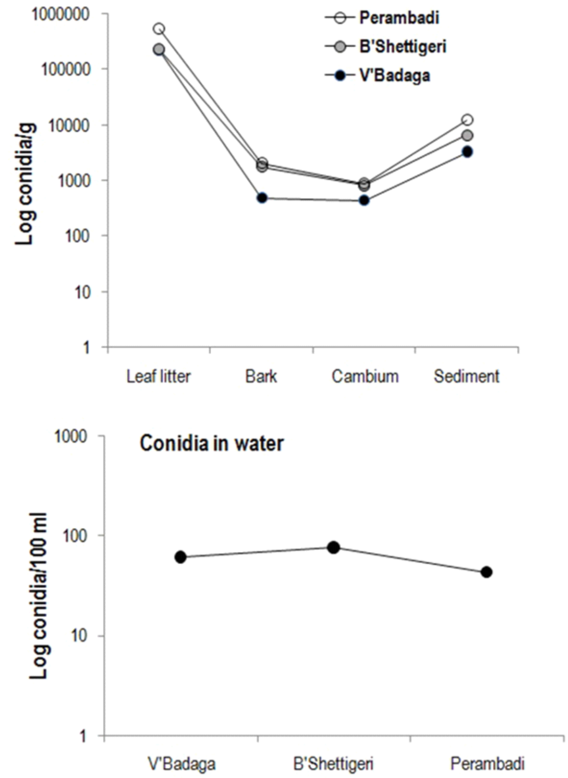

Fig. 2 Variation in conidial output (in leaf litter, bark, cambium and sediment) and drift conidia of aquatic hyphomycetes in water samples in three Western Ghat streams.

per cent conidial contribution in pooled samples of three streams, *Anguillospora longissima*, *Flagellospora penicillioides*, *Lunulospora curvula* and *L. cymbiformis* were common to leaf litter, woody litter, sediment and water samples (**Table 2-5**). *Flagellospora curvula* was also among the top five conidial producers in woody litter, sediment and water samples, while *Triscelophorus monosporus* was one among the top five conidial producers only in leaf litter.

Table 2. Per cent contribution of aquatic hyphomycetes in leaf litter in three Western Ghat streams (based on nine samples: three samples each in three months).

	V'Badaga	B'Shettigeri	Perambadi
Flagellospora curvula Ingold	24.1	53.4	55.6
Lunulospora cymbiformis K. Miura	75.4	0.6	29.3
Lunulospora curvula Ingold	0.1	40.9	13.7
Triscelophorus monosporus Ingold	–	1.8	–
Anguillospora longissima (Sacc. & P.Syd.) Ingold	0.3	1.6	0.1
Flagellospora penicillioides Ingold	0.1	1.4	0.1
Anguillospora crassa Ingold	<0.01	0.02	1.1
Cylindrocarpon sp.	0.03	0.2	0.2
Triscelophorus sp.	0.1	–	–
Tripospermum myrti (Lind) Hughes	–	0.04	–
Triscelophorus acuminatus Nawawi	–	0.04	–
Tripospermum sp.	–	0.02	–
Triscelophorus konajensis K.R. Sridhar & Kaver.	–	0.01	–
Actinospora megalospora Ingold	<0.01	–	–
Alatospora acuminata Ingold	<0.01	–	–
Clavariana aquatica Nawawi	–	–	<0.01
Unidentified (sigmoid conidia)	<0.01	–	–
Total species	11	12	8

Table 3. Per cent contribution of aquatic hyphomycetes in woody litter of three Western Ghat streams (based on nine samples: three samples each in three months).

	V'Badaga		B'Shettigeri		Perambadi	
	Bark	Cambium	Bark	Cambium	Bark	Cambium
Flagellospora penicillioides Ingold	81.0	18.8	71.2	40.1	78.2	39.9
Flagellospora curvula Ingold	12.3	45.9	22.5	53.6	5.1	28.9
Lunulospora cymbiformis-like (septate)	0.1	17.2	–	–	–	–
Anguillospora longissima (Sacc. & P. Syd.) Ingold	2.9	1.5	2.1	1.9	3.3	19.0
Lunulospora curvula Ingold	0.1	12.6	0.2	0.3	0.5	–
Anguillospora crassa Ingold	0.2	–	0.1	1.1	3.1	7.2
Cylindrocarpon sp.	0.7	3.2	0.2	1.9	7.0	1.2
Clavariana aquatica Nawawi	2.0	–	3.5	0.7	–	–
Lunulospora cymbiformis K. Miura	–	–	0.1	0.3	–	2.6
Campylospora sp.	–	–	–	–	–	1.2
Triscelophorus acuminatus Nawawi	–	–	–	–	1.2	–
Triscelophorus monosporus Ingold	–	0.4	–	–	0.5	–
Tetracladium marchalianum De Wild.	0.6	–	–	–	–	–
Trisulcosporium sp.	–	–	–	–	0.5	–
Unidentified sp. 1 (tetraradiate conidia	–	0.3	–	–		–
Triscelophorus konajensis K.R. Sridhar & Kaver.	0.1		–	–	0.5	–
Clavatospora tentacula Sv. Nilsson	–	–	0.1	–	–	–
Unidentified sp.2 (tetraradiate conidia)	–	–	0.1	–		–
Total species	10	9	10	8	10	7

Table 4. Per cent contribution of aquatic hyphomycetes in sediments of three Western Ghat streams (based on nine samples: three samples each in three months).

	V'Badaga	B'Shettigeri	Perambadi
Flagellospora penicillioides Ingold	59.9	99.3	98.5
Lunulospora curvula Ingold	39.6	0.1	0.1
Flagellospora curvula Ingold	0.2	0.1	1.2
Anguillosporalongissima (Sacc. & P. Syd.) Ingold	0.1	0.4	0.1
Lunulospora cymbiformis K. Miura	0.3	0.05	–
Cylindrocarpon sp.	0.02	0.1	0.1
Alatospora acuminata Ingold	–	0.02	0.01
Lunulospora cymbiformis-like (septate)	–	–	0.02
Tricladium sp.	0.02	–	–
Dendrospora sp.	0.01	–	–
Isthmotricladia gombakiensis Nawawi	0.01	–	–
Triscelophorus acuminatus Nawawi	–	–	0.01
Triscelophorus monosporus Ingold	–	–	0.01
Total species	9	7	9

Table 5. Per cent contribution of aquatic hyphomycetes in water samples of three Western Ghat streams (based on nine samples: three samples each in three months).

	V'Badaga	B'Shettigeri	Perambadi
Lunulospora cymbiformis K. Miura	52.6	26.7	45.4
Lunulospora curvula Ingold	15.3	27.9	22.7
Flagellospora curvula Ingold	11.0	25.6	11.3
Anguillospora longissima (Sacc. & P.Syd.) Ingold	7.3	6.4	4.1
Flagellospora penicillioides Ingold	5.8	1.8	2.1
Isthmotricladia gombakiensis Nawawi	–	–	3.1
Triscelophorus acuminatus Nawawi	1.5	0.6	7.2
Triscelophorus monosporus Ingold	–	2.9	3.1
Flagellospora sp.	1.5	2.3	–
Campylospora parvula Kuzuha	1.5	–	–
Cylindrocarpon sp.	–	1.7	1.0
Lunulospora sp.	–	1.2	–
Campylospora filicladia Nawawi	0.7	1.2	–
Lunulospora cymbiformis-like (septate)	0.7	–	–
Speiropsis pedatospora Tubaki	0.7	–	–
Unidentified sp. (triradiate conidia)	0.7	–	–
Alatospora acuminata Ingold	0.7	0.6	–
Subulispora sp.	–	0.6	–
Tridentaria sp.	–	0.6	–
Total species	13	14	9

Diversity

Simpson and Shannon diversities in leaf litter, woody litter, sediment and water revealed almost same pattern (**Fig. 3**). The diversity was highest in water samples in all streams. Next to water samples was cambium in V'Badaga and Perambadi streams which showed almost equal diversity. Leaf litter showed the highest diversity in Perambadi as was observed in the sediments of V'Badaga.

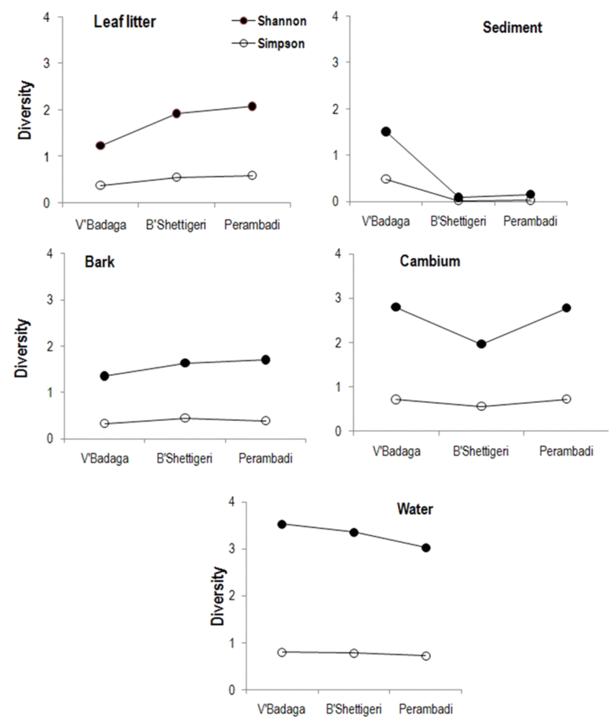

Fig. 3 Variation in Shannon and Simpson diversities of aquatic hyphomycetes in leaf litter, bark, cambium, sediment and water samples in three Western Ghat streams.

Rarefaction

Expected number of species in pooled samples of streams (27 samples each of leaf litter, bark, cambium, sediment and water) revealed interesting results (**Fig. 4**). The expected number of species out of 70 random samples of leaf litter, bark, cambium and sediment was 26, while it was 25 in water samples. The curve was extended attaining plateau in leaf litter with highest of 27 species, the trend of curve was similar in sediments. The curves in bark, cambium and water showed increasing trend, but truncated between 70 and 90 random samples with 26-27 species.

DISCUSSION

Aquatic hyphomycetes are not obligately confined to the aquatic conditions in streams. They occur beyond stream habitats like stream slopes, canopy of riparian vegetation and tree holes (Bärlocher, 1992; Sridhar, 2009a; b; Ghate and Sridhar, 2015; Chauvet *et al.*, 2016). Within the streams, they are active in leaf litter, woody litter, sediments and hyporheic

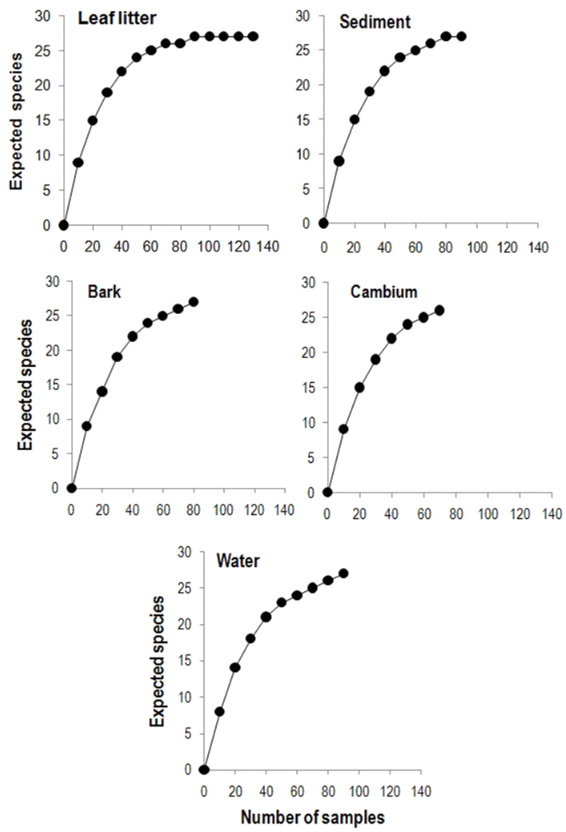

Fig. 4 Variation in expected number of species based on rarefaction index in pooled leaf litter, bark, cambium, sediment and water samples of three Western Ghat streams.

zones (Bärlocher, 1992; Krauss *et al.*, 2011; Sudheep and Sridhar, 2012; Chauvet *et al.*, 2016).

Leaf litter

Generally, leaf litter is the most abundant organic matter available for colonization of aquatic hyphomycetes in the streams. However, they decompose faster than woody litter, thus aquatic hyphomycetes have to depend on alternate substrates for their survival and dissemination. Although leaf litter has been studied earlier for occurrence of aquatic hyphomycetes in the Western Ghats, a few studies evaluated the conidial output by bubble chamber incubation (e.g. Sudheep and Sridhar, 2013a,b). Leaf litter showed the highest conidial output than other substrates and endowed with 17 species. Rarefaction curve of species showed saturation in leaf litter compared to other samples of streams studied. *Flagellospora curvula*, *Lunulospora curvula* and *L. cymbiformis* were the dominant species. These species were also dominant in the leaf litter of Kaiga stream of the Western Ghats (Sudheep and Sridhar, 2013a). Five species found exclusively on leaf litter were *Actinosprora megalospora*, *Trypospermum myrti*, *Tripospermum* sp., *Triscelophorus* sp. and an unidentified sp. with sigmoid conidia (**Table 6**).

Woody litter

Unlike leaf litter, woody litter is long lasting in the streams

Table 6. Occurrence of aquatic hyphomycetes in leaf litter, woody litter, sediment and water samples in three streams of the Western Ghats.

	Leaf	Wood	Sediment	Water
Alatospora acuminata Ingold	+	+	+	+
Anguillospora longissima (Sacc. & P. Syd.) Ingold	+	+	+	+
Cylindrocarpon sp.	+	+	+	+
Flagellospora curvula Ingold	+	+	+	+
F. penicillioides Ingold	+	+	+	+
Isthmotricladia gombakiensis Nawawi			+	+
Lunulospora curvula Ingold	+	+	+	+
L. cymbiformis K. Miura	+	+	+	+
Triscelophorus acuminatus Nawawi	+	+	+	+
T. monosporus Ingold	+	+	+	+
Anguillospora crassa Ingold	+	+	–	–
Clavariana aquatica	+	+	–	–
Triscelophorus konajensis K.R. Sridhar & Kaver.	+	+	–	–
Lunulospora cymbiformis-like (septate)	–	–	+	+
Actinosprora megalospora Ingold	+		–	–
Trypospermum myrti (Lind) Hughes	+	–	–	–
Tripospermum sp.	+	–	–	–
Triscelophorus sp.	+	–	–	–
Unidentified sp. (sigmoid conidia)	+		–	–
Campylospora sp.	–	+	–	–
Clavatospora tentacula Sv. Nilsson	–	+	–	–
Tetracladiumm archalianum De Wild.	–	+	–	–
Trisulcosporium sp.	–	+	–	–
Unidentified sp. 1 (tetraradiate spore)	–	+	–	–
Unidentified sp. 2 (tetraradiate spore)	–	+	–	–
Dendrospora sp.	–	–	+	–
Tricladium sp.	–	–	+	–
Campylospora filicladia Nawawi	–	–	–	+
C. parvula Kuzuha	–	–	–	+
Flagellospora sp.	–	–	–	+
Lunulospora sp.	–	–	–	+
Speiropsis pedatospora Tubaki	–	–	–	+
Subulispora sp.	–	–	–	+
Tridentaria sp.	–	–	–	+
Unidentified sp. (triradiate conidia)	–	–	–	+
Total species	17	18	13	19

and serve as suitable substrate for colonization of aquatic hyphomycetes (Shearer, 1992; Sridhar *et al*., 2010; Sudheep and Sridhar, 2013b). Comparatively, woody litter has been least studied for occurrence of aquatic hyphomycetes in the Western Ghat streams (e.g. Sridhar *et al.*, 2010).The conidial output from the woody litter was not as high as leaf litter and sediments. Woody litter showed an increasing trend of rarefaction curve indicating occurrence of more species on increasing the sample number. Overall, woody litter consists of 18 species and *Anguillospora longissima*, *Flagellospora curvula* and *F. penicillioides* were dominant. These species were also dominant on woody litter in other streams of the Western Ghats (Sridhar *et al*., 2010; Sudheep and Sridhar, 2013b). Among the aquatic hyphomycetes recorded, six species were confined only to woody litter (*Campylospora* sp., *Clavatospora tentacula*, *Tetracladium marchalianum*, *Trisulcosporium* sp., unidentified sp. 1 with tetraradiate conidia and unidentified sp. 2 with tetraradiate conidia).

Sediment

Although sediments in streams serve as sink for minerals and pollutants, aquatic hyphomycetes occur in sediments as mycelial prapagules or conidia. Sediment analysis for occurrence of aquatic hyphomycetes in the Western Ghats is fairly recent (e.g. Sudheep and Sridhar, 2012).The conidial output from sediments was the second highest after leaf litter. As seen in woody litter, rarefaction curve of sediment samples showed increasing trend. Overall, sediments consist of 13 species and *Flagellospora penicillioides* and *Lunulospora* *curvula* were the dominant species. Among them *L. Curvula* was also dominant in sediments of Kaiga stream of the Western Ghats (Sudheep and Sridhar, 2012). Two species which were confined only to sediments include *Dendrospora* sp. and *Tricladium* sp.

Water

Conidial concentration in the water column of streams represents their active role of aquatic hyphomycetes in organic matter decomposition. Quantitative studies on the occurrence of aquatic hyphomycetes in water samples in the Western Ghats are meagre. The diversity of aquatic hyphomycetes was highest in water samples in three streams studied. Similar to woody litter and sediments, the rarefaction curve showed an increasing trend against the number of samples assessed. Water samples of three streams in the present study consist of highest number of 19 species of which *Flagellospora curvula, Lunulospora curvula* and *L. cymbiformis* were dominant. A highest number of eight species was confined to water samples (*Campylospora filicladia, C. parvula, Flagellospora* sp., *Lunulospora* sp., *Speiropsis pedatospora, Subulispora* sp., *Tridentaria* sp. and an unidentified triradiate conidial sp.).

Species richness and diversity

Species richness and diversity in the streams studied were neither too low like mountain streams and nor too high as in the mid-altitude streams of the Western Ghats (Sridhar *et al.*, 1992; Raviraja *et al*., 1998). Ten species were common to all samples studied (*Alatospora acuminata, Anguillospora longissima, Cylindrocarpon* sp., *Flagellospora curvula, F. penicillioides, Isthmotricladia gombakiensis, Lunulospora curvula, L. cymbiformis,Triscelophorus acuminatus* and *T. monosporus)* (see **Table 6**). Five of them are the top conidial producers *(A. longissima, F. curvula, F. penicillioides, L. curvula* and *L. cymbiformis*). Based on the per cent conidial contribution, six species have been considered as core-group species (*A. longissima, F. curvula, F. penicillioides, L. curvula* and *L. cymbiformis* and *L. cymbiformis*-like sp.). A total of 8, 6, 5 and 2 species were confined only to water, woody litter, leaf litter and sediments, respectively (see **Table 6**) and these species seem to be selective in their niches in the streams. The present study advocates evaluating different substrates in the streams to follow the diversity of aquatic hyphomycetes. There is a need to evaluate the whole Western Ghat lotic habitats for diversity and ecological functions of aquatic hyphomycetes.

CONCLUSIONS

Human interference certainly influences the percentage of aquatic hyphomycetes in the Western Ghats (e.g. pollutants and clear channelling). No major studies have been performed on the impact of pollutants on aquatic hyphomycetes and their functions in this region. There are several gaps, which warrant conventional and molecular approaches. Clearly, more critical observations are required especially in different aquatic habitats of the Western Ghats to answer many questions. It is necessary to enforce an integrated approach for the whole Western Ghat with a view to map the aquatic hyphomycetes as vast number of streamlets flow in different biomes throughout this region at different altitudinal ranges.

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