Fungal colonization and decomposition of submerged woody litter in River Kali of the Western Ghats, India

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Fungal colonization and decomposition of submerged woody litter (*Terminalia paniculata* and *Anacardium occidentale*) in relation to water and wood chemistry in the Kaiga stream and Kadra Dam of the River Kali were investigated over 12 months. Fungal species richness, diversity and asexual/sexual state ratio on woody litter were higher in the stream than the dam. Woody litter of *Terminalia* supported a higher diversity of fungi as compared to *Anacardium*. Dominant lignicolous fungi were *Annulatascus velatispora, Diplocladiella scalaroides, Massarina australiensis* and an unidentified asexual fungus, while *Lunulospora curvula* and *Triscelophorus acuminatus* were dominant among the Ingoldian fungi. The species richness of lignicolous fungi in submerged woody litter is comparable to naturally deposited woody litter, while the Ingoldian fungi were higher in naturally deposited than submerged woody litter. Organic carbon attained <10% in 12 months, while the nitrogen content was highest within 2 months, which coincided with fungal richness peak. Although species richness of Ingoldian fungi was high within 2 months, the spore output was highest during the 12th month, which coincided with low organic carbon and total phenolics. Cellulase, xylanase and pectinase in woody litter showed two peaks (180 and 300 days) after the peaks of fungal richness (60 and 240 days). The mass loss was higher in *Terminalia* as compared to *Anacardium* and it was faster in the stream than in the dam. The remaining mass of woody litter was positively correlated with organic carbon, nitrogen and phosphorus, while negatively correlated with enzyme production. The mass loss was associated with decreased hardness of woody litter.

Key words – Lignicolous fungi – Ingoldian fungi – Colonization – Wood decomposition – *k* value – Western Ghats

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Introduction

Slow decomposing coarse particulate organic matter (CPOM) especially the woody litter in lotic habitats constitutes the major source of nutrition for the lignicolous fungi (ascomycetes, basidiomycetes and asexual taxa) and aquatic hyphomycetes (Ingoldian fungi) (Shearer et al. 2007; Simonis et al.

2008; Gulis et al. 2009). Extensive studies on the diversity and distribution of fungi on woody litter have been carried out in temperate regions of North America and Europe (see Sudheep and Sridhar 2011). Similar studies have been extended recently in the tropical and subtropical regions of Australia, Brunei, China, India, Malaysia, Seychelles and Thailand. About 550 species of ascomycetes have been reported on various substrates in freshwater habitats (woody litter, 60%; herbaceous litter, 30%; woody + herbaceous litter, 9−10%) (Raja et al. 2009). Up to 405, 320, 90 and 11 species of lignicolous ascomycetes/asexual fungi, Ingoldian fungi, aero-aquatic fungi and basidiomycetes respectively, have been reported from freshwater habitats (Shearer et al. 2007).

The range of mountains of Western Ghats in India extends about 1,600 km (140,000 km^2) along the west coast of India (8º20'–20º40' N and 73º–77º E). This forest range constitutes several habitats (e.g. grasslands, shoals, moist-dry deciduous forests, evergreen forests and scrub jungles) distributed in different altitudes. Out of 5,000 flowering plant species, up to 1,720 species belonging to 54 genera are endemic to the Western Ghats of India. The streams and rivers of the Western Ghats receives a variety of plant substrates (leaves, twigs, wood, bark, flowers and fruits), which constitutes major organic input for colonization of aquatic fungi. Freshwater hyphomycetes (Ingoldian fungi) of the Western Ghats of India have been studied by assessment of water, foam and leaf litter samples (e.g. Sridhar and Kaveriappa 1989, Chandrashekar et al. 1990; Sridhar et al. 1992; Raviraja et al. 1998a, Rajashekhar and Kaveriappa, 2003; Sudheep and Sridhar, 2013). However, studies on fungal diversity on woody litter in freshwater habitats of Western Ghats are meager (e.g. Ramesh and Vijaykumar 2006; Sridhar et al. 2010a, 2010b; Sridhar and Sudheep 2011; Sudheep and Sridhar 2011). In spite of dominance lignicolous fungi (ascomycetes and asexual taxa) on woody litter (Tsui et al. 2003), some studies demonstrated the occurrence of Ingoldian fungi (Shearer and Webster 1991; Sridhar et al. 2010a). Recently, Sridhar et al. (2010b) showed the dominance of Ingoldian fungi in addition to lignicolous fungi on naturally submerged woody litter. There is a gap in our knowledge on the occurrence and dynamics of lignicolous and Ingoldian fungi on woody litter in aquatic habitats of the Western Ghats of India and there seems to be no studies on the pattern of decomposition of woody litter. Therefore, the present study aims to investigate: 1) the pattern of colonization of lignicolous and Ingoldian fungi on submerged woody litter (*Terminalia paniculata* Roth. *Anacardium occidentale* L.) in aquatic habitats with contrasting physicochemical features; 2) the pattern of mass loss of woody litter in relation to water quality, wood chemistry and enzymes. This study was extended up to 12 months in Kaiga stream and Kadra dam of the River Kali of the Western Ghats.

Materials and Methods

Study site

The River Kali originates ~900 m asl in the Western Ghats and flows up to 160 km westwards with two tributaries (Upper Kaneri and Tattihalla) before joining the Arabian Sea near the Karwar. For generation of electricity, four dams have been built across the river (Supa, Bommanahalli, Kodasalli and Kadra). The sampling sites in Kaiga stream (S1, S2 and S3) and Kadra dam (D1, D2 and D3) situated ~35 km east of Karwar adjacent to the Kaiga village (~55−70 m asl; 14°50′−14°51′N, 74°24′−74°27′E). The third order stream Kaiga possesses sandy loam and rocky bottom. The catchment areas of Kadra dam consist of several streamlets passing through the wetlands. Average depth of sampling sites of Kaiga stream during sampling period ranged from 1.4 (S1) to 3.7 m (S3) and in dam sites ranged from 3.7 m (D3) to 13.9 m (D2). The stream and dam locations consist of leaf litter and woody litter of many riparian tree species (e.g. *Artocarpus heterophyllus*, *Ficus benghalensis*, *F. racemosa*, *Syzygium caryophyllatum*, *Terminalia arjuna*, *T. paniculata* and *Xylia xylocarpa*).

Water samples

Water samples were analyzed in five replicates from each sampling sites at bimonthly intervals from June 2009 to June

2010. Water temperature was measured on the sampling site using a mercury thermometer, while the pH and electrical conductivity were assessed by Water Analyzer (Model, 371; Systronics, Gujarat, India). Water samples were fixed on the sampling sites to assess dissolved oxygen by Winkler's method (APHA 1995) in the laboratory.

Wood submersion

Dried and easily breakable branches and twigs of *Terminalia paniculata* and *Anacardium occidentale* were collected during April 2009 from the Kaiga forest. They were cut into pieces (diam., 1 cm; length, 10 cm), air-dried up to two months. Each nylon mesh bag (12 × 12 cm; mesh size, 1 mm) was filled with 15 wood pieces and one wood piece dried at 50°C, pre-weighed and tagged with plastic ring for mass loss determination. A total of 21 bags each of *Terminalia* and *Anacardium* were submerged per site of Kaiga stream (S1, S2, and S3) and Kadra dam (D1, D2 and D3) locations during June 2009. The bags were firmly secured to a nylon rope and they were further tied to lengthy rope, which was fastened to roots or tree trunks. From August 2009 onwards samples were retrieved at bimonthly intervals up to 12 months (June 2010). On each sampling, three bags per site were retrieved to assess fungal colonization, changes chemistry, enzyme profile and mass loss.

Fungal assessment

Wood samples were rinsed in the laboratory to remove the debris. Within 24 hr of sampling, five wood samples from three nylon mesh bag (total fifteen wood samples per site) were incubated separately subjected to damp chamber incubation on the wet sand bed in airtight polythene bags (23 ± 2°C). They were screened once a month up to six months and lignicolous fungi (ascomycetes and asexual taxa) growing on the wood samples were identified using monographs and primary literature (Ellis 1971, 1976; Carmichael et al. 1980; Ellis and Ellis 1987; Cai et al. 2006; Bhat 2010). Bark pieces (if present) or cambium pieces (0.5 × 3 cm) were separated, rinsed in water and four pieces per wood sample were incubated in 150 ml of sterile distilled water in 250 ml Erlenmeyer flasks (bubble chamber incubation). Water with wood pieces in flasks was aerated though Pasteur pipettes by an aquarium pump up to 48 hr (23 ± 2°C). Aerated water was filtered through a Millipore filter (5 µm) and stained with aniline blue in lactophenol (0.1%). Stained filters were cut into half, mounted on microscope slide with lactic acid and the conidia of Ingoldian fungi were identified based on 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).

Wood chemistry

Organic carbon

Walkley and Black's rapid titration method was employed to quantify organic carbon of immersed wood (Jackson 1973). Fifty mg dry wood powder in 500 ml Erlenmeyer flask was mixed with 5 ml 1N potassium dichromate, 15 ml of 90% H_2SO_4 was added after 5 min and digested up to 30 min. Distilled water (100 ml) was added to the digested sample followed by addition of 5 ml 85% orthophosphate and the contents were titrated against 0.5 N ferrous ammonium sulfate using 0.5 ml of diphenylamine indicator.

Nitrogen

The dried wood powder (100 mg) with catalytic mixture (1 g) was digested in concentrated H_2SO_4 (10 ml) in Kjeldahl flask (30 ml capacity) on hot sand bath. On cooling, the contents were transferred to volumetric flask (100 ml capacity), the Kjeldahl flask was rinsed twice with 20 ml distilled water and transferred to the volumetric flask and made up the volume to 100 ml (Chale 1993). The digest (10 ml) was transferred to micro-Kjeldahl distillation flask, NaOH (40%; 10 ml) was added and distilled. The liberated ammonia was collected in boric acid (2%; 10 ml) containing mixed indicator (1 drop) until attaining 25 ml volume and titrated against HCl (0.01N) (APHA 1995).

Phosphorus

Phosphorus of dried wood power was measured calorimeterically by vanadomolybdophosphoric acid method (AOAC 2005). The dried wood powder was digested in tri-acid mixture (HNO_3, H_2SO_4 and $HClO_3$; 10:1:4). The digest was made up to 50 ml with *Milli-Q* water. The digest (3 ml) was mixed with vanadate-molybdate reagent (10 ml), mixed thoroughly and made the volume to 50 ml. The absorbance of yellow color developed due to formation of vanadomolybdophosphoric acid was measured after 10 min at 420 nm (UV-VIS Spectrophotometer-118, SYSTRONICS, Ahmedabad, Gujarat, India) using reagent blank as the reference. Known concentrations of KH_2PO_4 served as standard.

Phenolics

The total phenolics of dried wood powder was determined by Rossett et al. (1982). Samples (100 mg) were extracted twice with 50% methanol (5 ml) at 90ºC up to 10 min in centrifuge tubes capped with marble. The pooled extracts were made up to 10 ml, mixed, 0.5 ml was diluted with 0.5 ml distilled water and treated with 2% Na_2CO_3 in 0.1N NaOH (5 ml). After 10 min, Folin-Ciocalteus reagent (0.5 ml) (diluted 1:1 with distilled water) was added and the absorbance was read at 725 nm. Calibration curve was prepared by treating known concentration of tannic acid similar to that of the samples as standard.

Enzyme assay

The freeze-dried (OPERON, OPR-FDB-5003, Korea) wood samples were powdered and enzymes (cellulase, xylanase and pectinase) were estimated colorimetrically (Nelson 1944, Somogyi 1952). Wood powder (100 mg) was wetted with sterile distilled water (25 ml) for 30 min, filtered through Whatman # 1 filter paper, the filtrate (0.5 ml) was mixed with 1 ml each of acetate buffer and substrate (0.5% carboxymethyl cellulose / xylan / polygalacturonic acid) with a drop of toluene to prevent bacterial growth and incubated (1 hr). The samples were boiled in water bath (10 min) for inactivation of enzymes. After attaining the room temperature, Somogy's reagent (1 ml) and Nelson's reagent (0.5 ml) were added. The liberated reducing sugars were estimated spectrophotometrically (620 nm), with D-glucose/D-xylose/D-galacturonic acid as standard. Ten min boiled extract served as blank and the enzyme activity was expressed as µg/ml/hr.

Mass loss

To assess the mass loss, the pre-weighed wood pieces in randomly-sampled litter bags were harvested and rinsed to remove accumulated debris on the surface. The mass loss was determined by comparing initial air-dried mass (100%) before exposure and remaining mass after air-drying, which was corrected by exposure of initial and exposed samples to oven dry mass (100°C, 24 hr). The exponential decay coefficient (*k*) was estimated by linear regression of ln-transformed data.

Data analysis

The frequency of occurrence (*FO %*) and relative abundance (*RA %*) of each fungus on wood samples was determined:

$$FO\ (\%) = [(WC) \div (TW)] \times 100$$

(where, WC is number of wood samples colonized; TW is total woody samples examined).

$$RA\ (\%) = [(FO) \div (TFO] \times 100$$

(where, FO is frequency of occurrence of specific fungus; TFO is total frequency of occurrence of all fungi).

Number of core-group fungi (≥10% frequency of occurrence) among ascomycetes, asexual taxa and Ingoldian fungi in wood samples were documented.

To compare the richness of fungi (ascomycetes, asexual taxa and Ingoldian fungi) in wood samples based on number of isolations and number of samples assessed, the expected number of species was calculated by rarefaction indices (Ludwig and Reynolds 1988). The expected number of species, $E_{(s)}$, in a random sample of *n* isolations taken from a total population of *N* isolations was estimated:

$$E_{(s)} = \sum_{i=1}^{s}\left\{1-\left[\binom{N-n_i}{n}\Big/\binom{N}{n}\right]\right\}$$

(where, n_i is the number of fungal isolations of the *i*th species).

The Shannon's diversity (*H'*) (Magurran, 1988) and Pielou's evenness (*J'*) (Pielou 1975) of ascomycetes, asexual taxa and

Ingoldian fungi in wood samples were calculated:

$$H' = -\sum (p_i \ln p_i)$$

(where, p_i is the proportions of individual that species i contributes to the total number of individuals)

$$J' = (H' \div H'_{max})$$

(where, $H'_{max} = \ln S$)

Ratios of asexual/sexual and lignicolous fungi/Ingoldian fungi were calculated.

Sorensen's similarity coefficient (C_s) (%) of ascomycetes, asexual taxa and Ingoldian fungi in wood samples was calculated based on Chao et al. (2005):

$$C_S\ (\%) = [(2 \times c) \div (a + b)] \times 100$$

(where, a is total number of species in location 1; b is total number of species in location 2; c is number of species common to locations 1 and 2)

Exponential decay coefficient, k, were estimated for decomposition of wood samples based on the exponential decay model proposed by Petersen and Cummins (1974) using MATLAB 6.5:

$$W_t = W_0 e^{-kt}$$

(where W_0 is the percentage of the initial wood mass; W_t is the percentage of wood mass remaining after time t (days) and k is a decay coefficient per day).

The time (days) required for the decomposition of half of the initial wood mass (t_{50}) was determined:

$$t_{50} = \ln 2/k$$

The wood decay coefficient (k) between Kaiga stream vs. Kadra dam was assessed by t-test using Statistica version 8.0 (StatSoft Inc. 2008).

The relationship between wood mass remaining vs. wood chemistry (organic carbon, nitrogen, phosphorus and total phenolics), wood enzymes (cellulose, xylanase and pectinase) and dissolved oxygen was assessed by Pearson's correlation (parameters: P values, two tailed; confidence intervals, 95%) (SPSS 6.0 Windows Student Version 3.5).

Results

Water qualities

Table 1 shows fluctuations in water temperature, pH, salinity and dissolved oxygen in Kaiga stream and Kadra dam at bimonthly intervals. The average temperature (26.9 vs. 32.5°C) and conductivity (54.1 vs. 82.3 µS cm^{-1}) were lower in stream than dam. The pH (pH 8 vs. 7.5) was more alkaline and dissolved oxygen (7.9 vs. 6.9 mg l^{-1}) was high in stream compared to dam.

Fungal colonization, diversity and similarity

Occurrence and relative abundance of lignicolous and Ingoldian fungi on woody litter *Terminalia* and *Anacardium* have been given in Tables 2 and 3, respectively. Among the ascomycetes in *Terminalia*, *Annulatascus velatispora* and *Massarina australiensis* in stream, while *M. austaliensis* and *Savoryella lignicola* in dam. *Massarina australiensis* occurred throughout the sampling period in stream. Asexual species *Diplocladiella scalaroides* and unidentified sp. (brown septate mycelia) dominated in stream as well as dam. They were recovered throughout the sampling period in dam. Among the Ingoldian fungi, *Anguillospora crassa*, *A. longissima*, *Lunulospora curvula*, *Triscelophorus acuminatus*, *T. monosporus* and *T. konajensis* were common and dominant in stream and dam. *Anguillospora longissima*, *L. curvula* and *T. acuminatus* were recovered throughout the year in stream as well as dam, while *Campylospora chaetocladia* was recovered throughout sampling period only in stream.

Among the ascomycetes on *Anacardium*, *Annulatascus velatispora* and *Massarina australiensis* were dominant in stream, while only *M. australiensis* in dam. Asexual species *Periconia* sp., *Pleurothesium recurvatum* and unidentified sp. were dominated in stream, while *Diplocladiella scalaroides* and unidentified sp. in dam. The unidentified sp. was recovered throughout the sampling period in stream. Among the Ingoldian fungi, *Anguillospora longissima*, *Flagellospora curvula*, *Lunulospora curvula*, *Triscelophorus acuminatus* and *T. monosporus* were dominant and common to stream and dam. *Lunulospora curvula* and *T. acuminatus* were found throughout the year in stream as well as dam.

Total fungi were higher in the stream than in the dam in both woody litters (41-43 vs. 31-42 species) (Table 4). Irrespective of

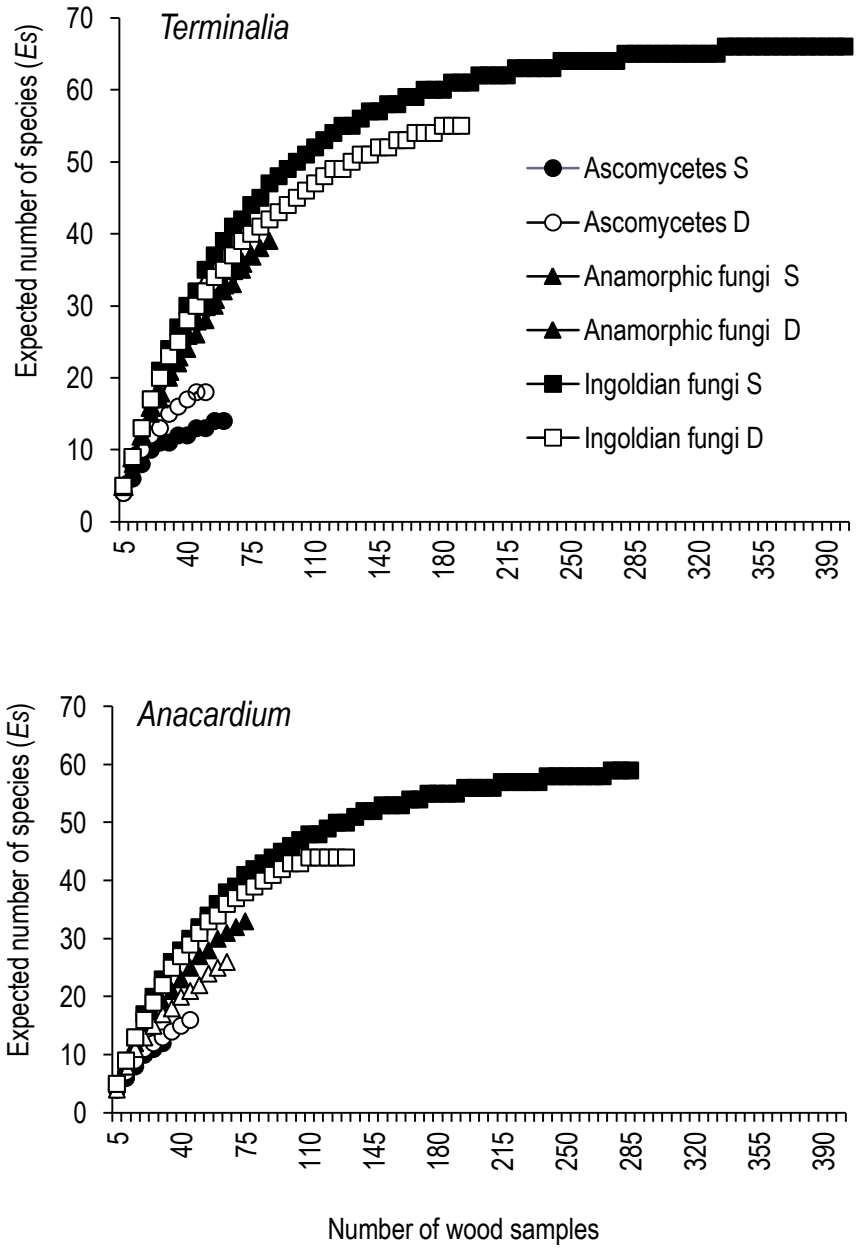

Fig. 1 – Expected number of species in immersed woody litter in Kaiga stream (S) and Kadra dam (D).

locations, *Terminalia* possesses more fungi than *Anacardium* (42-43 vs. 31-41 species). Irrespective of locations and woody litter, the richness of lignicolous fungi was higher than Ingoldian fungi (21-26 vs. 14-17 species). The core-group fungi (≥10% frequency of occurrence) were higher in stream than dam location (17 vs. 8-10 species). The expected number of species out 30 random wood samples based on rarefaction indices was higher in *Terminalia* than *Anacardium* (56 vs. 52-54 species). The expected number of species of Ingoldian fungi was highest on both woody litters and locations (Fig. 1). Overall, *Terminalia* possesses higher species richness and extended species richness curve than *Anacardium*. Total fungi were higher in *Terminalia* than *Anacardium* in stream and dam up to six months and thereafter no definite trend was seen except for total species was highest in *Terminalia* of dam by the end of 12 months (Fig. 2). The trend in species richness in lignicolous and Ingoldian fungi was more or less followed similar pattern of total fungi.

Table 1 Physical and chemical properties of Kaiga stream and Kadra dam (in parenthesis) (n=5, mean±SD).

		Temperature (°C)	pH	Conductivity (µS cm^{-1})	Dissolved oxygen (mg l^{-1})
2009	June	31.0 (35.5)	8.3 (7.4)	56.16 (80.58)	7.14 (6.64)
	August	25.5 (33.0)	8.0 (7.7)	41.46 (86.74)	8.22 (7.06)
	October	25.0 (29.0)	8.5 (8.2)	44.60 (99.66)	8.16 (7.58)
	December	26.0 (30.0)	8.1 (7.5)	72.22 (73.58)	8.24 (6.74)
2010	February	30.0 (35.0)	7.2 (7.3)	62.76 (70.80)	7.54 (7.00)
	April	25.0 (33.0)	8.0 (7.4)	43.34 (78.52)	7.92 (6.86)
	June	26.0 (32.0)	7.9 (7.3)	58.28 (86.16)	7.86 (6.72)
Average		26.9 (32.5)	8.0 (7.5)	54.12 (82.29)	7.87 (6.94)
Range		25.0-31.0 (29.0-35.5)	7.2-8.5 (7.3-8.2)	41.46-72.22 (70.80-99.66)	7.14-8.24 (6.64-7.58)

During the peak period, the conidial output of Ingoldian fungi was highest in stream *Terminalia* and least in dam *Anacardium* at the end of 12 months.

The Shannon diversity of ascomycetes in both woody litters was higher in dam (2.459 and 2.180) than stream (1.334 and 1.739). The diversity of asexual species in both woody litters was higher in stream (2.524 and 3.541) than dam (3.156 and 2.660). The diversity of Ingoldian fungi in woody litters was also higher in stream (3.721 and 3.699) than dam (3.447 and 3.417). The asexual/sexual ratio was higher in stream compared to dam (4.9-6.2 vs. 3.4-3.7), while it was reverse for the ratio of lignicolous/Ingoldian fungi (1.41-1.53 vs. 1.50-1.63). The Sorenson's similarity of ascomycetes was highest between *Terminalia* in dam with that of *Anacardium* in dam (94.1%), while it was least between *Terminalia* in stream vs. *Anacardium* in dam (57.1%) (Table 5). The similarity of asexual taxa was highest between *Terminalia* in stream vs. *Terminalia* in dam (72.2%), while least between *Terminalia* vs. *Anacardium* in dam (53.3%). The similarity of Ingoldian fungi was highest between *Terminalia* in stream vs. *Terminalia* in dam (97%) and also between *Terminalia* in dam vs. *Anacardium* in stream (97%), while least between *Terminalia* vs. *Anacardium* in dam (80%).

Changes in wood chemistry and enzymes

The initial organic carbon was higher in *Terminalia* than *Anacardium* and decreased fast in *Terminalia* (Fig. 3). The nitrogen in wood showed two peaks during 60 or 180 days and decreased more quickly in dam *Terminalia*. Overall nitrogen content was lowest in all samples during 360 days (<10%). The initial phosphorus of *Terminalia* was higher than *Anacardium* and it decreased steadily by attaining the lowest concentration in 360 days. The initial quantity of total phenolics was higher in *Terminalia* than *Anacardium* and decreased sharply within two months followed by steady decrease.

Cellulase, xylanase and pectinase showed increasing trend until 300 days and decreased thereafter (Fig. 4). The initial concentration of enzymes was higher in *Terminalia* than *Anacardium* and the enzymes showed two distinct peaks during 180 and 300 days. Overall, cellulase showed the highest peak compared to xylanase and pectinase.

Extent of wood mass loss

The rate of mass loss in time series for two woody litters is presented in Fig. 5. The mass loss of both woody litters in two locations was about 20% within 60 days. Subsequently the mass loss was steady in *Anacardium*, while sharply dropped in *Terminalia* in stream than dam by attaining the lowest mass in 360 days. The initial hardness was higher in *Anacardium* than *Terminalia* and the mass loss as well as loss of hardness was almost coincided. The mass loss of *Terminalia* between stream and dam was significantly differed ($P<0.001$), so also in *Anacardium* ($P<0.001$). However, the loss of hardness of *Terminalia* was significantly differed between stream and dam ($P<0.01$) than *Anacardium* ($P>0.05$). Visual observation revealed that *Terminalia* bark degraded about 50% within six months in both the locations, while the bark

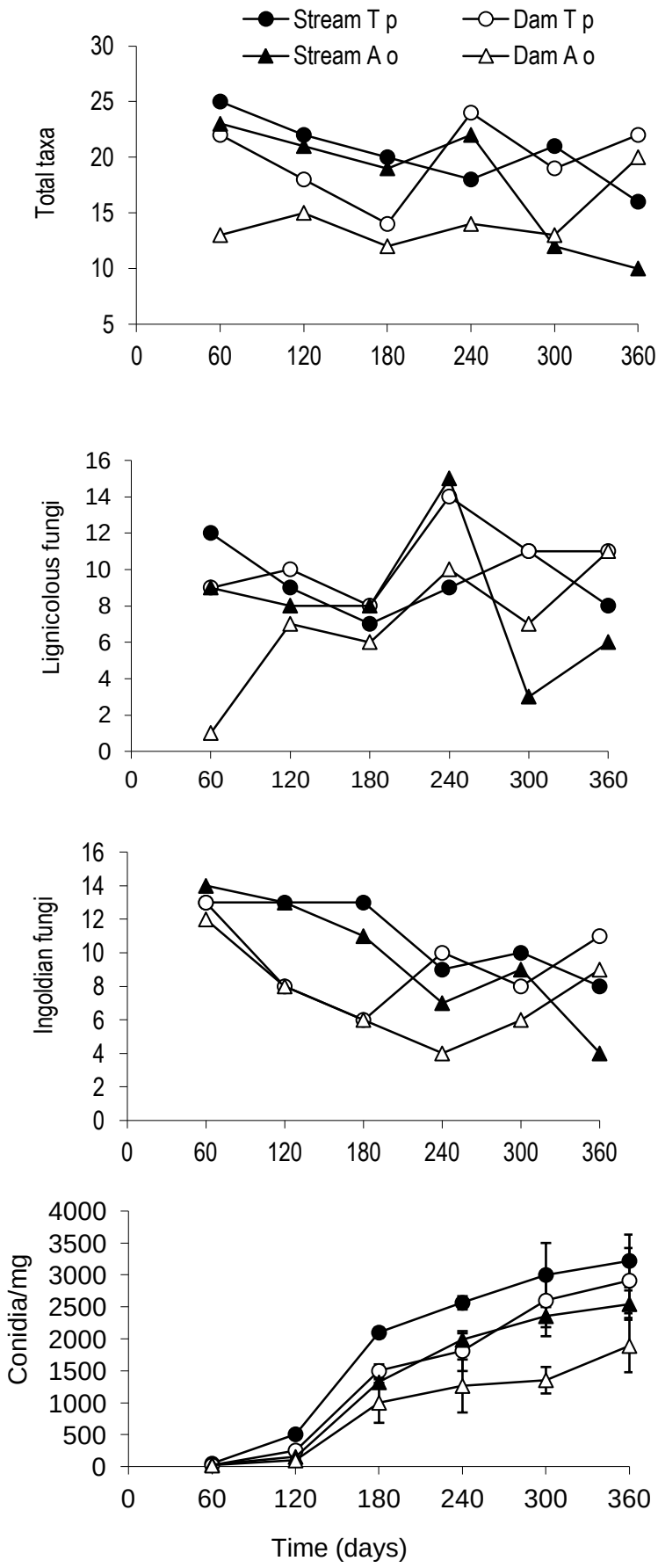

Fig. 2 – Species richness of fungi and conidial output of Ingoldian fungi in submerged wood *Terminalia* (Tp) and *Anacardium* (Ao) in Kaiga stream and Kadra Dam.

Table 2 Number of occurrences (out of 15 wood), frequency of occurrence (FO %) and relative abundance (RA %) of lignicolous and Ingoldian fungi on immersed woody litter of *Terminalia paniculata* in Kaiga stream and Kadra dam (in parenthesis).

Taxon	2009			2010			FO (%)	RA (%)
	Aug.	Oct.	Dec.	Feb.	Apr.	June		
Ascomycetes								
Massarina australiensis K.D. Hyde	8 (3)	9 (6)	11 (7)	4 (8)	4	9	50 (26.7)	8 (6.7)
Annulatascus velatispora K.D. Hyde	–	–	3	10	2	7 (2)	24.4 (2.2)	3.9 (0.6)
Savoryella lignicola E.B.G. Jones & R.A. Eaton	–	–	–	(1)	(6)	(6)	(14.4)	(3.6)
Torrentispora fibrosa K.D. Hyde, Wai H. Ho, E.B.G. Jones, K.M. Tsui & S.W. Wong	1	(1)	–	(1)	1 (3)	–	2.2 (5.6)	0.4 (1.4)
Leptosphaeria typharum (Desm.) P. Karst.	–	–	(2)	–	(3)	–	(5.6)	(1.4)
Massarina sp.	1 (1)	–	–	–	(1)	(1)	1.1 (3.3)	0.2 (0.8)
Nectria byssicola Berk. & Broome	(1)	–	–	1	–	–	1.1 (1.1)	0.2 (0.3)
Halosarpheia heteroguttulata S.W. Wong, K.D. Hyde and E.B.G. Jones	–	–	–	(1)	–	(1)	(2.2)	(0.6)
Phaeosphaeria sp.	–	–	–	(2)	–	–	(2.2)	(0.6)
Aniptodera sp.	–	1	–	–	–	–	1.1	0.2
Asexual taxa								
Diplocladiella scalaroides G. Arnaud	10 (2)	1 (3)	4 (6)	2 (10)	(5)	3 (15)	22.2 (45.6)	3.5 (11.5)
Unidentified sp. (brown septate mycelia)	1 (1)	5 (3)	(1)	6 (4)	(1)	5 (3)	18.9 (14.4)	3 (3.6)
Dreshlera sp.	3 (1)	2 (1)	(1)	(2)	–	–	5.6 (5.6)	0.9 (1.4)
Bactrodesmium sp.	–	–	–	2 (4)	1 (2)	(1)	3.3 (7.8)	0.5 (2.0)
Sporoschisma saccardoi E.W. Mason & S. Hughes	–	2 (1)	1 (3)	1	(1)	–	4.4 (5.6)	0.7 (1.4)
Acrogenospora sphaerocephala (Berk. & Broome) M.B. Ellis	2 (1)	(1)	3	(1)	–	–	5.6 (3.3)	0.9 (0.8)
Stemphyliomma sp.	–	–	–	(3)	2 (3)	–	2.2 (6.7)	0.4 (1.7)
Pleurothecium recurvatum (Morgan) Höhn.	1	(2)	(1)	–	2	(1)	3.3 (4.4)	0.5 (1.1)
Tretospora sp.	–	2 (1)	–	(1)	1	1	4.4 (2.2)	0.7 (0.6)
Cancellidium sp.	–	–	–	1	2	1	(5.6)	(1.4)
Helicomyces sp.	1	–	–	–	2 (1)	(1)	3.3 (2.2)	0.5 (0.6)
Alternaria sp.	–	–	–	–	4	–	4.4	0.7
Brachysporiella pulchra (Subram.) S. Hughes	–	1	–	1	(1)	–	2.2 (1.1)	0.4 (0.3)
Curvularia lunata (Wakker) Boedijn	(1)	1	1	–	–	–	2.2 (1.1)	0.4 (0.3)
Cacumisporium sigmoideum Mercado & R.F. Castañeda	–	(1)	–	–	–	1 (1)	1.1 (2.2)	0.2 (0.6)
Curvularia sp.	–	–	(1)	–	–	(2)	(3.3)	0.2 (0.8)
Trichocladium nypae K.D. Hyde & Goh	(1)	–	–	(1)	–	–	(2.2)	(0.6)
Curvularia trifolii (Kauffman) Boedijn	1	–	–	–	–	–	1.1	0.2
Dictyosporium hepatosporum (Garov.) Damon	1	–	–	–	–	–	1.1	0.2
Diplocladiella aquatic O.H.K. Lee, Goh & K.D. Hyde	1	–	–	–	–	–	1.1	0.2
Periconia sp.	–	–	–	–	1	–	1.1	0.2
Sporoschisma uniseptatum Bhat & W.B. Kendr	–	–	1	–	–	–	1.1	0.2
Coelomycete sp.	–	–	–	(1)	–	–	(1.1)	(0.3)
Ingoldian fungi								
Lunulospora curvula Ingold	12 (10)	8 (6)	11 (7)	10 (5)	9 (8)	7 (8)	63.3 (48.9)	10.1 (12.3)
Triscelophorus acuminatus Nawawi	14 (10)	11 (5)	5 (6)	8 (6)	7 (5)	8 (3)	58.9 (38.9)	9.4 (9.8)
Anguillospora longissima (Sacc. & P. Syd.) Ingold	9 (3)	12 (7)	8 (5)	6 (3)	8 (3)	5 (2)	53.3 (25.6)	8.5 (6.4)
Cylinodrocarpon sp.	10 (3)	7 (2)	5	9	–	3 (1)	37.8 (6.7)	6 (1.7)
Triscelophorus monosporus Ingold	11 (3)	8 (7)	5 (2)	(5)	9	(6)	36.7 (26.7)	5.9 (6.7)
Anguillospora crassa Ingold	8 (3)	9	5 (1)	5 (2)	(5)	(1)	30 (13.3)	4.8 (3.3)
Campylospora chaetocladia Ranzoni	2 (1)	5	7	6 (3)	5 (1)	3	31.1 (5.6)	5 (1.4)
Dimorphospora foliicola Tubaki	5 (1)	7	6	3	(4)	5	30 (5.6)	4.8 (1.4)

Flagellospora curvula Ingold	9 (2)	8	6	(2)	(1)	2	27.8 (5.6)	4.4 (1.4)
Flagellospora penicillioides Ingold	2 (5)	9 (2)	5	–	8	(2)	26.7 (9)	4.3 (2.3)
Triscelophorus konajensis K.R. Sridhar & Kaver.	9 (2)	5 (2)	–	4	3	(5)	23.3 (10)	3.7 (2.5)
Clavariana aquatica Nawawi	–	3	2	(1)	4	(2)	10 (3.3)	1.6 (0.8)
Flabellospora crassa Alas.	3 (2)	–	2	–	(4)	1	6.7 (6.7)	1.1 (1.7)
Lunulospora sp.	–	–	2 (4)	(1)	4	(1)	6.7 (6.7)	1.1 (1.7)
Lunulospora cymbiformis K. Miura	–	–	–	5 (1)	2	(3)	7.8 (4.4)	1.2 (1.1)
Helicomyces roesus Link	5 (2)	(1)	–	–	–	–	5.6 (3.3)	0.9 (0.8)
Nawawia filiformis (Nawawi) Marvanová	–	2	–	–	–	–	2.2	0.4

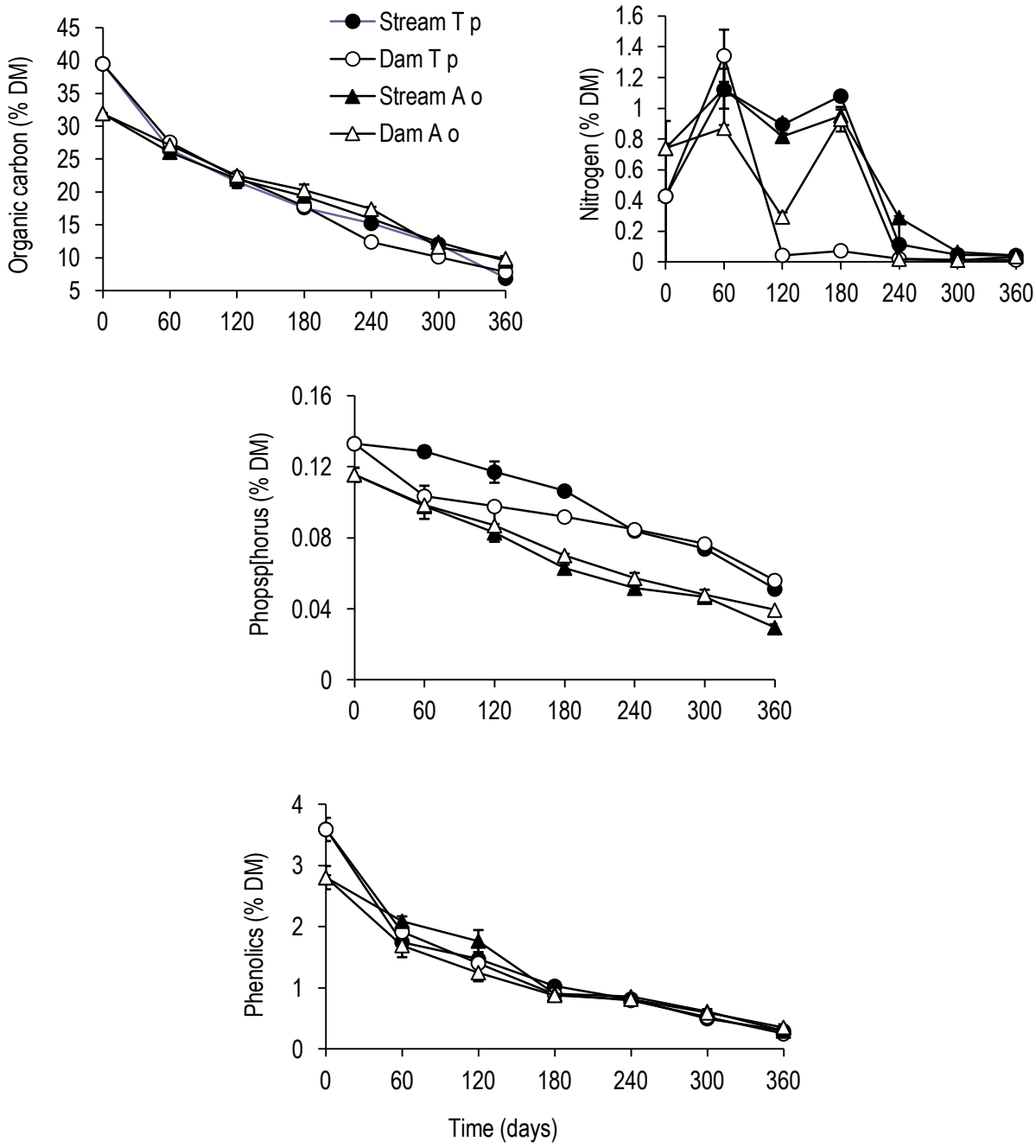

Fig. 3 – Changes in chemistry of *Terminalia* (Tp) and *Anacardium* (Ao) wood immersed in Kaiga stream and Kadra dam.

Table 3 Number of occurrences (out of 15 wood), frequency of occurrence (FO %) and relative abundance (RA %) of lignicolous and Ingoldian fungi on immersed woody litter of *Anacardium occidentale* in Kaiga stream and Kadra dam (in parenthesis).

	2009			2010			FO (%)	RA (%)
	Aug.	Oct.	Dec.	Feb.	Apr.	June		
Ascomycetes								
Massarina australiensis K.D. Hyde	9 (12)	5 (5)	2 (7)	4 (6)	(1)	2	24.4 (34.4)	5.1 (12.3)
Annulatascus velatispora K.D. Hyde	–	–	1	1	–	9	12.2	2.6
Leptosphaeria typharum (Desm.) P. Karst.	1	–	–	1 (1)	(4)	–	2.2 (5.6)	0.5 (2.0)
Savoryella lignicola E.B.G. Jones & R.A. Eaton	–	–	–	–	(3)	(3)	(6.7)	(2.4)
Halosarpheia heteroguttulata S.W. Wong, K.D. Hyde and E.B.G. Jones	–	1	–	(1)	–	(2)	1.1 (3.3)	0.2 (1.2)
Torrentispora fibrosa K.D. Hyde, Wai H. Ho, E.B.G. Jones, K.M. Tsui & S.W. Wong	–	–	–	1 (2)	–	(1)	1.1 (3.3)	0.2 (1.2)
Massarina sp.	–	–	–	–	(2)	(2)	(4.4)	(1.6)
Phaeosphaeria sp.	–	–	–	–	(3)	–	(3.3)	(1.2)
Nectria byssicola Berk. & Broome	–	(1)	–	1	–	–	1.1 (1.1)	0.2 (0.4)
Aniptodera sp.	1	–	–	–	–	–	1.1	0.2
Asexual taxa								
Unidentified sp. (brown septate mycelia)	2	4 (2)	5 (2)	2 (8)	1 (2)	9 (5)	25.6 (21.1)	5.4 (7.6)
Diplocladiella scalaroides G. Arnaud	3	(2)	(8)	(9)	–	1 (9)	4.4 (31.1)	0.9 (11.2)
Periconia sp.	–	–	5	11 (1)	–	–	17.8 (1.1)	3.7 (0.4)
Pleurothecium recurvatum (Morgan) Höhn.	–	1 (1)	–	5 (1)	–	4 (2)	11.1 (4.4)	2.3 (1.6)
Staphylotrychum sp.	–	–	–	3 (1)	(1)	(4)	3.3 (6.7)	0.7 (2.4)
Dreshlera sp.	2	(1)	–	1 (1)	–	(2)	3.3 (4.4)	0.7 (1.6)
Acrogenospora sphaerocephala (Berk. & Broome) M.B. Ellis	–	–	2 (1)	1	2	–	5.6 (1.1)	1.2 (0.4)
Brachysporiella pulchra (Subram.) S. Hughes	–	4	(1)	1	–	–	5.6 (1.1)	1.2 (0.4)
Stemphyliomma sp.	–	–	–	(1)	(1)	(4)	(6.7)	(2.4)
Cacumisporium sp.	1	2	–	–	–	(1)	3.3 (1.1)	0.7 (0.4)
Cancellidium sp.	–	–	1	1	1	–	3.3	0.7
Tretospora sp.	–	1	1	–	–	1	3.3	0.7
Cacumisporium sigmoideum Mercado & R.F. Castañeda	–	1	1	–	–	–	2.2	0.5
Curvularia intermediata	2	–	–	–	–	–	2.2	0.5
Chloridium reniforme Matsush.	–	–	–	2	–	–	2.2	0.5
Gliocladium sp.	–	–	–	2	–	–	2.2	0.5
Alternaria alternate (Fr.) Keissl.	1	–	–	–	–	–	1.1	0.2
Curvularia trifolii (Kauffman) Boedijn	–	–	–	1	–	–	1.1	0.2
Alternaria sp.	–	–	(1)	–	–	–	(1.1)	(0.4)
Helicomyces roseus Link	–	–	–	–	–	(1)	(1.1)	(0.4)
Sporoschisma saccardoi E.W. Mason & S. Hughes	–	(1)	–	–	–	–	(1.1)	(0.4)
Ingoldian fungi								
Lunulospora curvula Ingold	15 (5)	11 (2)	11 (1)	9 (3)	5 (7)	8 (3)	65.9 (23.3)	13.8 (8.4)
Triscelophorus acuminatus Nawawi	11 (3)	9 (2)	8 (3)	5 (8)	2 (1)	6 (2)	45.6 (21.1)	9.6 (7.6)
Flagellospora curvula Ingold	8 (3)	6 (8)	4 (2)	(3)	8	(2)	28.9 (20.0)	6.1 (7.2)
Anguillospora longissima (Sacc. & P. Syd.) Ingold	8 (3)	11 (2)	5 (1)	(5)	7	(2)	34.4 (14.4)	7.2 (5.2)
Lunulospora cymbiformis K. Miura	9 (2)	5 (1)	2	5	3 (1)	–	26.7 (4.4)	5.6 (1.6)
Triscelophorus monosporus Ingold	5 (2)	5 (4)	2 (3)	–	1	(2)	14.4 (12.2)	3.0 (4.4)
Campylospora chaetocladia Ranzoni	–	6	4	7	–	–	18.9	4.0
Cylinodrocarpon sp.	5 (3)	4	2	–	(2)	(3)	12.2 (8.9)	2.6 (3.2)
Dimorphospora foliicola Tubaki	2 (5)	3	7	2	–	–	15.6 (5.6)	3.3 (2.0)
Triscelophorus konajensis K.R. Sridhar & Kaver.	8 (2)	3	–	2	1	(2)	15.6 (4.4)	3.3 (1.6)
Anguillospora crassa Ingold	5 (1)	2	5	–	(1)	(3)	13.3 (5.6)	2.8 (2.0)
Flabellospora crassa Alas.	2 (1)	5 (2)	(4)	–	–	–	7.8 (7.8)	1.6 (2.8)
Lunulospora sp.	–	5	1	–	4	–	11.1	2.3
Helicomyces sp.	4 (2)	–	–	–	2	(3)	6.7 (5.6)	1.4 (2.0)
Clavariana aquatica Nawawi	–	–	–	2	(1)	6	8.9 (1.1)	1.9 (0.4)
Flagellospora penicillioides Ingold	1	2	–	–		3	6.7	1.4
Nawawia filiformis (Nawawi) Marvanová	3	(1)	–	–	–		3.3 (1.1)	0.7 (0.4)

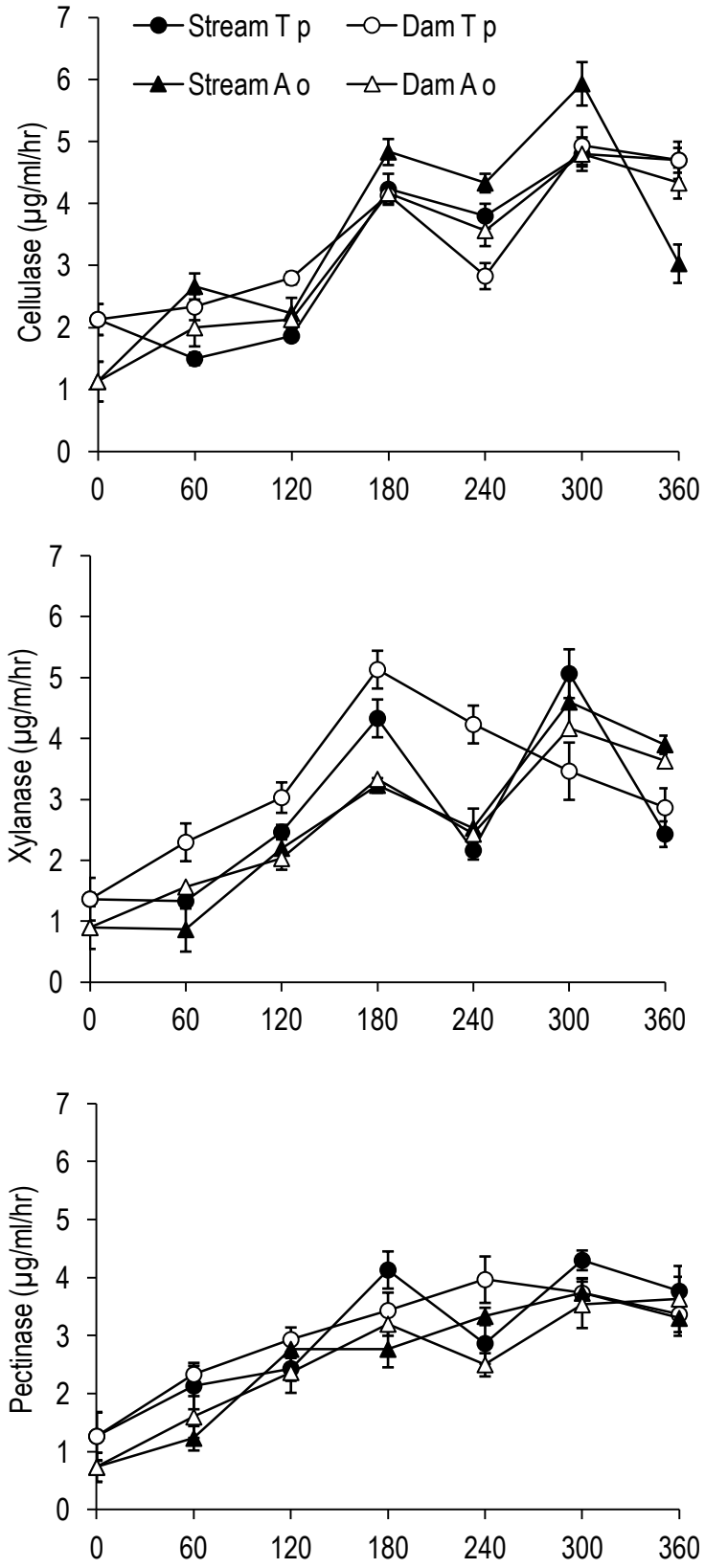

Fig 4 – Enzyme profile of *Terminalia* (Tp) and *Anacardium* (Ao) woody litter immersed in Kaiga stream and Kadra dam.

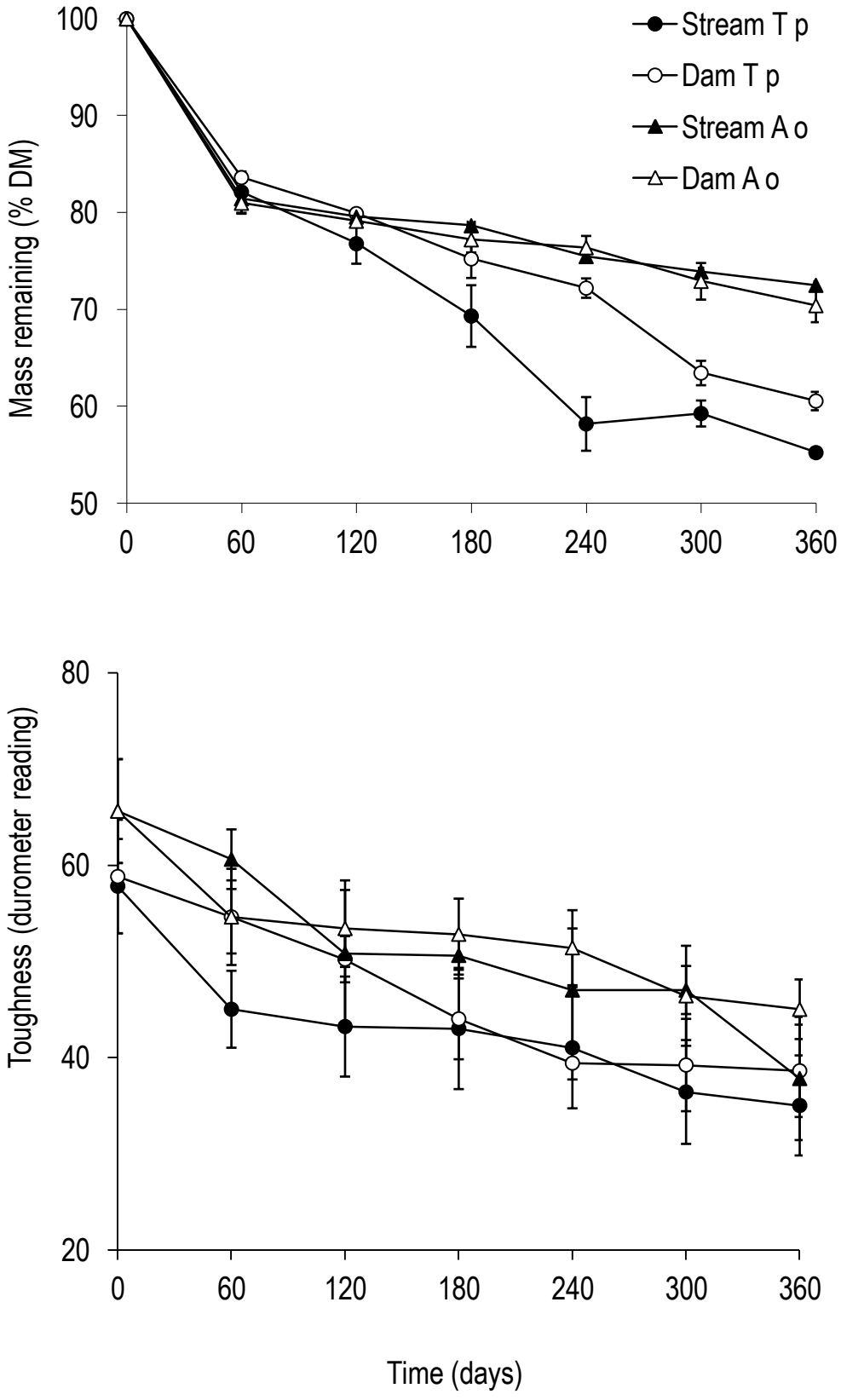

Fig. 5 – Mass loss and toughness loss of *Terminalia* (Tp) and *Anacardium* (Ao) wood immersed in Kaiga stream and Kadra dam.

of *Anacardium* was persistent till the last sampling on 12th month although the wood has considerably softened and the core was eroded (Fig. 6). The mass of *Terminalia* wood decreased faster (t_{50}, 403-525 days) than *Anacaridum* (t_{50}, 832-886 days) (Table 6). The daily exponential decay coefficient, *k*, was varied between 0.0235 (*Anacardium* of stream) and 0.0516 (*Terminalia* of stream).

Table 7 gives the correlation coefficients between remaining mass of woody litter against the changes in woody litter chemistry and dissolved oxygen in water. The mass *Terminalia* in both locations was positively correlated with organic carbon ($P<0.01$), nitrogen ($P<0.05$), phosphorus ($P<0.01$) and total phenolics ($P<0.01$), while it was negatively correlated with cellulase (stream, $P<0.05$; dam, $P<0.01$), xylanase ($P<0.05$) and pectinase ($P<0.01$). The total phenolics of *Terminalia* litter in both locations was positively correlated with organic carbon ($P<0.01$), nitrogen (dam, $P<0.05$), phosphorus ($P<0.01$), while it was negatively correlated (except dissolved oxygen in dam) with cellulase ($P<0.01$), xylanase ($P<0.01$), pectinase ($P<0.01$) and dissolved oxygen (stream, $P<0.05$). The remaining mass of *Anacardium* in both locations was positively correlated with organic carbon ($P<0.01$), nitrogen (stream, $P<0.05$; dam, $P<0.01$), phosphorus ($P<0.01$) and total phenolics ($P<0.01$), while negatively correlated with cellulase (stream, $P<0.05$; dam, $P<0.01$), xylanase ($P<0.01$), pectinase (stream, $P<0.05$; dam, $P<0.01$) and dissolved oxygen (stream, $P<0.01$). The total phenolics of *Anacardium* in both locations (except for dissolved oxygen in dam) was negatively correlated with cellulase ($P<0.01$), xylanase ($P<0.01$) and pectinase (dam, $P<0.01$) and dissolved oxygen.

Discussion

The mean water temperature during survey was higher in Kadra dam than Kaiga stream (26.9 vs. 32.5°C). The average water temperature of dam is equivalent or comparable to earlier studies in discharge site of Kali River (range, 27.5-31°C) (Sridhar et al. 2010a), River Kollur (30°C) (Raviraja et al. 1998a) and the River Nethravathi (31.1-32.4 vs. 31.1°C) (Raviraja et al. 1998b) of the Western Ghats. Increase in water temperature results in decrease of species richness as well as conidial output of Ingoldian fungi (Sridhar et al. 2010a). Considering the species richness as 100% on incubation of field sampled leaf litter at 24-28°C, the loss of species richness was up to 33, 67 and 87% in bubble chamber incubation at 31, 33 and 36°C, respectively (Sridhar et al. 2010b). The sporulation decreased up to 12.5, 79 and 95% in bubble chamber incubation 31, 33 and 36°C, respectively. Increased temperature in thermal springs of the Western Ghats also showed similar trend in decrease of species richness and conidial output (Chandrashekar et al. 1991; Rajashekhar and Kaveriappa 1996). This clearly shows that elevation of temperature severely influences the species richness and reproduction of Ingoldian fungi.

The pH of stream and dam locations during survey was alkaline (range, 7.2-8.5) and comparable to other locations such as Kali River (543 m asl, pH, 7.8; 235 m asl, pH 7.45; 222 m asl, pH 7.3; 80 m asl, pH 7.21-7.24) (Rajashekhar and Kaveriappa 2003; Madoddi et al. 2009; Sridhar et al. 2010a), streams of Sampaje (500 m asl, pH 7.1-7.4; 510 m asl, pH 7.2) (Raviraja et al. 1996), Bagamandala (560 m asl, pH 7.2), Agumbe (960 m asl, pH 7.2; 970 m asl, pH 7.4) and Shivpura (460 m asl, pH 7.3) (Sridhar et al. 2010a). The pH of stream and dam locations is comparable to most of the 21 lotic habitats of the Western Ghats (7.2-8.5 vs. 7.2-8.8) (Rajashekhar and Kaveriappa 2003). According to Suberkropp (2001), the pH or alkalinity of the water seems to influence the richness of fungi. However, the combined data of 16 streams in France, Germany and Switzerland showed a significant negative correlation between species richness and pH (Wood-Eggenschwiler and Baerlocher 1983; Bärlocher 1987). The dissolved oxygen during survey in Kadra dam was lower than Kaiga stream (6.6-7.6 vs. 7.1-8.2 mg l^{-1}). Its concentration in Kaiga stream is comparable to other Western Ghat rivers (8-8.3 vs. 7.5-8.1 mg l^{-1}) (Maddodi et al. 2009). The Western Ghat lotic habitats showed positive correlation of species richness against increased dissolved oxygen (Rajashekhar and Kaveriappa 2003).

Table 4 Species richness, diversity and fungal ratio in woody litter in Kaiga stream and Kadra dam.

	Terminalia paniculata		*Anacardium occidentale*	
	Stream	**Dam**	**Stream**	**Dam**
Species richness				
Ascomycetes	6	9	7	8
Asexual taxa	20	17	17	13
Ingoldian fungi	17	16	17	14
Total fungi	43	42	41	35
Number of core-group fungi				
Ascomycetes	3	2	2	1
Asexual taxa	2	2	3	2
Ingoldian fungi	12	6	12	5
Total core group fungi	27	10	17	8
Expected number of species, $E_{(30)}$*				
Ascomycetes	11	13	12	13
Asexual taxa	21	20	19	17
Ingoldian fungi	24	23	23	22
Shannon diversity (Pielou's evenness)				
Ascomycetes	1.344 (0.520)	2.459 (0.776)	1.739 (0.619)	2.180 (0.727)
Asexual taxa	3.524 (0.830)	3.156 (0.772)	3.451 (0.844)	2.660 (0.719)
Ingoldian fungi	3.721 (0.910)	3.447 (0.862)	3.699 (0.905)	3.417 (0.898)
Ratio				
Anamorph/teleomorph	6.2	3.7	4.9	3.4
Lignicolous/Ingoldian	1.53	1.63	1.41	1.50

Note: *Out of isolations from 30 random wood samples

Table 5 Sorensen's similarity index (%) of lignicolous fungi and Ingoldian fungi (in parenthesis) on woody litter in Kaiga stream and Kadra dam (TS, *Terminalia* stream; TD, *Terminalia* dam; AS, *Anacardium* stream; AD, *Anacardium* dam).

Ascomycetes				**Asexual taxa**				**Ingoldian fungi**			
	TD	AS	AD		TD	AS	AD		TD	AS	AD
TS	66.7	76.9	57.1	TS	72.2	55.6	62.5	TS	97.0	94.1	83.9
	TD	87.5	94.1		TD	58.8	53.3		TD	97.0	80.0
		AS	66.7			AS	60.0			AS	90.3

Table 6 Statistics of wood mass loss rates (k, daily exponential decay rate; R^2, coefficient of determination; t_{50}, estimated time in days for 50% mass loss).

Wood	**Location**	***k***	***R²***	***t₅₀***
Terminalia paniculata	Kaiga stream	0.0516[a]	0.933	403
	Kadra dam	0.0396[b]**	0.955	525
Anacardium occidentale	Kaiga stream	0.0235[a]	0.730	886
	Kadra dam	0.0250[a]	0.748	832

k between locations with different letters indicate significant difference (t-test, $p<0.01$)

Wood-Eggenschwiler and Bärlocher (1983) indicated that factors such as temperature, water flow and competition among fungi are responsible for variation in species richness.

Among the dominant lignicolous fungi in the present study, *Massarina australiensis* was also dominant on naturally deposited woody litter in the Western Ghats streams (Sridhar et al., 2010a; Sudheep and Sridhar 2011). Among the Ingoldian fungi, *Anguillospora longissima, Flagellospora curvula* and *Lunulospora curvula* were most dominant on the natural woody litter of the Western Ghat streams (Sridhar et al. 2010b). However, the dominant Ingoldian fungi like *A. longissima, F. curvula, L. curvula, Triscelophorus acuminatus* and *T. monosporus* were also common in natural woody litter in Kaiga stream as well as Kadra dam (Sudheep and Sridhar 2011). Thus, the species richness of lignicolous fungi in the present study is comparable to natural woody litter sampled from Kaiga stream and Kadra dam, while the species richness of Ingoldian fungi is higher than natural woody litter (Sudheep and Sridhar 2011).

Within 12 months, the organic carbon of the woody litter decreased to below 10%. In 60 days, the nitrogen content of the woody litter was elevated and coincided with the first peak of the species richness. The species richness was also coincided with sharp decrease of total phenolics within two months. However, although species richness of Ingoldian fungi was high in 60 days, the spore output was lowest, which attained a peak in 12 months coinciding with the loss of organic carbon as well as total phenolics. It depicts that the spore output by Ingoldian fungi depends on loss of inhibitory compounds and increase in softness of the woody litter. Besides, the persistent woody litter serves as the stable refuge for growth, sporulation and dissemination of Ingoldian fungi. The pattern of loss of total phenolics in *Terminalia* and *Anacardium* woody litter is comparable similar to submerged *Avicennia officinalis* and *Rhizophora mucronata* woody litter in Udyavara mangroves of the west coast of India (Maria et al. 2006). The nitrogen enrichment was also similar to that of immersed mangrove woody litter, however, its peak was within 60 days in Kaiga stream and Kadra dam, while it was during 120 days in mangroves. The extracellular enzymes (cellulase, xylanase and pectinase) in woody litter showed two peaks during 180 and 300 days, which followed the peaks of total fungal richness (first peak, 60 days; second peak, 240 days).

Based on daily decay coefficient (*k*), the woody litter used in the present study belonged to fast decomposing category (Petersen and Cummins 1974). The rate of mass loss was higher in *Terminalia* than in *Anacardium*. *Terminalia* showed faster degradation in stream than in dam location. However, the mass loss of *Anacardium* was slightly higher in dam compared to stream. Studies are not available to compare the mass loss of woody litter in lotic habitats of the Western Ghats. However, the mass loss of mangrove woody litter (*Avicennia* and *Rhizophora*) was slower (Maria et al. 2006) compared to *Terminalia* and *Anacardium* woody litter. The mass of woody litter in the present study was positively correlated with organic carbon, nitrogen and phosphorus, while negatively correlated with enzymes (cellulase, xylanase and pectinase) of woody litter. Similarly, the mass loss resulted in decrease in hardness of woody litters.

Conclusions

It is a necessity to rapidly evaluate the biodiversity especially in tropics in view of the extent of habitat destruction, value of biota possessing bioactive compounds, restoration and preservation of natural habitats. Being recalcitrant substrate, woody litter is ideal to evaluate pristine nature of aquatic habitats to understand fungal colonization, mass loss and changes in chemistry on long-term basis. Adaptation of different techniques in evaluation of fungi assumes importance in biodiversity studies. To understand the structural and functional attributes of fungi on woody litter in natural habitats, it is necessary to simulate the natural conditions of the habitats in laboratory microcosms. Such simulations are useful to follow the relationship between human interference on the availability of suitable substrates,

Table 7 Pearson correlation coefficients between wood mass remaining vs. wood chemistry, enzymes and dissolved oxygen in Kaiga stream and Kadra dam (in parenthesis).

Terminalia paniculata	**Organic carbon**	**Nitrogen**	**Phosphorus**	**Total phenolics**	**Cellulase**	**Xylanase**	**Pectinase**	**Dissolved oxygen**
Mass remaining	0.971** (0.984**)	0.468* (0.462*)	0.889** (0.972**)	0.956** (0.945**)	-0.508* (-0.837**)	-0.526* (-0.545*)	-0.786** (-0.713**)	-0.305 (0.073)
	Organic carbon	0.396 (0.534*)	0.899** (0.959**)	0.981** (0.955**)	-0.509* (-0.797**)	-0.554** (-0.627**)	-0.838** (-0.746**)	-0.401 (0.070)
		Nitrogen	0.689** (0.422)	0.292 (0.484*)	-0.024 (-0.502*)	-0.166 (-0.481*)	-0.226 (-0.308)	0.494* (0.147)
			Phosphorus	0.820** (0.917**)	-0.420 (-0.811**)	-0.441* (-0.471*)	-0.731** (-.0700**)	-0.016 (0.089)
				Total phenolics	-0.561** (-0.754**)	-0.569** (-0.649**)	-0.826** (-0.647**)	-0.512* (0.010)
					Cellulase	0.261 (0.456*)	0.523* (0.386)	0.350 (-0.366)
						Xylanase	0.842** (0.218)	0.373 (0.076)
							Pectinase	0.404 (0.199)
Anacardium occidentale	Organic carbon	Nitrogen	Phosphorus	Total phenolics	Cellulase	Xylanase	Pectinase	Dissolved oxygen
Mass remaining	0.885** (0.877**)	0.463* (0.549**)	0.850** (0.863**)	0.882** (0.961**)	-0.505* (-0.809**)	-0.725** (-0.806**)	-0.525* (-0.862**)	-0.571** (-0.105)
	Organic carbon	0.780** (0.759**)	0.984** (0.980**)	0.974** (0.935**)	-0.510* (-0.910**)	-0.899** (-0.899**)	-0.378 (-0.901**)	-0.262 (0.150)
		Nitrogen	0.767** (0.722**)	0.686** (0.611**)	-0.215 (-0.504*)	-0.727** (-0.499*)	-0.200 (-0.517*)	0.332 (-0.089)
			Phosphorus	0.981** (0.931**)	-0.476* (-0.919**)	-0.879** (-0.889**)	-0.326 (-0.869**)	-0.227 (0.209)
				Total phenolics	-0.560** (-0.892**)	-0.892** (-0.860**)	-0.376 (-0.921**)	-0.305 (0.011)
					Cellulase	0.733** (0.939**)	0.252 (0.917**)	0.477* (-0.281)
						Xylanase	0.235 (0.869**)	0.232 (-0.256)
							Pectinase	0.233 (-0.082)

*, Correlation is significant at the 0.05 level (2-tailed)
**, Correlation is significant at the 0.01 level (2-tailed)

Fig. 6 – The pattern of decomposition of woody litter of *Terminalia paniculata* (Tp) and *Anacardium occidentale* (Ao): Comparison of woody litter of *T. paniculata* before immersion (a), after 6 months (stream, c; dam, e) and 12 months (stream, g; dam, i); Comparison of woody litter of *A. occidentale* before immersion (b), after 6 months (stream, d; dam, f) and 12 months (stream, h; dam, j).

impact of edaphic factors, accumulation of fungal biomass, extent of fungal reproduction and fungal dissemination in natural habitats. Further detailed studies on fungal colonization in relation to woody litter decomposition in aquatic habitats of the Western Ghats of India are warranted.

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References

AOAC. 1990 – Official Methods of Analysis (15th Edition). Association of Official

Analytical Chemists, Washington DC.

APHA. 1995 – Standard Methods in Examination of Water and Waste Water (19th Edition). American Public Health Association, Washington DC.

Bärlocher F. 1987 – Aquatic hyphomycete spora in 10 streams of New Brunswick and Nova Scotia. Canadian Journal of Botany 65, 76–79.

Bhat DJ. 2010 – Fascinating Microfungi (Hyphomycetes) of Western Ghats - India. Broadway Publishers, Goa.

Cai L, Hyde KD, Tsui CKM. 2006 – Genera of Freshwater Fungi. Fungal Diversity Research Series # 18, Fungal Diversity Press, Hong Kong.

Carmichael JW, Kendrick WB, Conners IL, Sigler L. 1980 – Genera of Hyphomycetes. The University of Alberta Press, Edmonton, Canada.

Chale FMM. 1993 – Degradation of mangrove leaf litter under aerobic conditions. Hydrobiologia 257, 177–183.

Chandrashekar KR, Sridhar KR Kaveriappa KM. 1990 – Periodicity of water-borne hyphomycetes in two streams of Western Ghat Forests (India). Acta Hydrochimica et Hydrobiologica 18, 187–204.

Chandrashekar KR, Sridhar KR, Kaveriappa KM. 1991 – Aquatic hyphomycetes of a sulphur spring. Hydrobiologia 218, 151–156.

Chao A, Chazdon RL, Colwell RK, Shen T-J. 2005 – A new statistical approach for assessing similarity of species composition with incidence and abundance data. Ecology Letters 8, 148–159.

Ellis MB. 1971 – Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew.

Ellis MB. 1976 – More Dematiaceous Hyphomycetes. Commonwealth Mycological Institute, Kew.

Ellis MB, Ellis JP. 1987 – Microfungi on Land Plants: An Identification Handbook. Croom Helm, London.

Gulis V, Marvanová L, Descals E. 2005 – An illustrated key to the common temperate species of aquatic hyphomycetes. In: Methods to Study Litter Decomposition: A Practical Guide (eds MAS Graça, F Bärlocher, MO Gessner), Kluwer Academic Publishers, The Netherlands, 153–167.

Gulis V, Kuehn KA, Suberkropp K. 2009 – Fungi. In: Encyclopaedia of Inland Waters (Volume 3) (ed Likens GE), Elsevier, Oxford, UK, 233–243.

Ingold CT. 1975 – An Illustrated Guide to Aquatic and Waterborne Hyphomycetes (Fungi Imperfecti). Ambleside-Cumbria, Freshwater Biological Association Scientific Publication # 30, UK.

Jackson ML. 1973 – Soil Chemical Analysis. Prentice-Hall International, USA.

Ludwig JA, Reynolds JF. 1988 – Statistical Ecology: A Primer on Methods and Computing. Wiley, New York.

Maddodi ND, Raviraja NS, Rajashekhar M. 2009 – Diversity of aquatic hyphomycetes of the Western Ghat rivers. In: Frontiers of Fungal Ecology, Diversity and Metabolites (ed Sridahr KR). IK International Publishing House Pvt. Ltd., New Delhi, 17–27.

Magurran AE. 1988 – Ecological Diversity and its Measurement. Princeton University Press, New Jersey.

Maria GL, Sridhar KR, Bärlocher F. 2006 – Decomposition of dead twigs of *Avicennia officinalis* and *Rhizophora mucronata* in a mangrove in southwest India. Botanica Marina 49, 450-455.

Marvanová L. 1997 – Freshwater hyphomycetes: A survey with remarks on tropical taxa. In: Tropical Mycology (eds KK Janardhanan, C Rajendran, K Natarajan, DL Hawksworth). Science Publishers, New York, 169–226.

Nawawi A. 1985 – Aquatic hyphomycetes and other water-borne fungi from Malaysia. Malaysian Nature Journal 39, 75–134.

Nelson N. 1944 – A photometric adaptation of the Somogyi method for the determination of glucose. Journal of Biological Chemistry 152, 375–380.

Petersen RC, Cummins KW. 1974 – Leaf processing in woodland stream. Freshwater Biology 4, 343–368.

Pielou FD. 1975 – Ecological Diversity. Wiley InterScience, New York.

Raja HA, Schmit JP, Shearer CA. 2009 – Latitudinal, habitat and substrate distribution patterns of freshwater ascomycetes

in the Florida Peninsula. Biodiversity and Conservation 18, 419–455.

Rajashekhar M, Kaveriappa KM. 1996 – Studies on the aquatic hyphomycets of a sulphur spring in the Western Ghats, India. Microbial Ecology 32, 73–80.

Rajashekhar M, Kaveriappa KM. 2003 – Diversity of aquatic hyphomycetes in the aquatic ecosystems of the Western Ghats of India. Hydrobiologia 501, 167–177.

Ramesh Ch, Vijaykumar S. 2006 – Observation on water-borne fungi of Uttara Kannada region. In: Recent Mycological Researches (ed Sati SC), IK International Publishing House Pvt Ltd, New Delhi, 61–76.

Raviraja NS, Sridhar KR, Bärlocher F. 1996 – Breakdown of introduced and native leaves in two Indian streams. International Revew Gesamten Hydrobiologie 81, 529–539.

Raviraja NS, Sridhar KR, Bärlocher F. 1998a – Fungal species richness in Western Ghat streams, (Southern India); is it related to pH, temperature or altitude? Fungal Diversity 1, 179–191.

Raviraja NS, Sridhar KR, Bärlocher F. 1998b – Breakdown of *Ficus* and *Eucalyptus* leaves in an organically polluted river in India: fungal diversity and ecological functions. Freshwater Biology 39, 537–545.

Rosset J, Bärlocher F, Oertli JJ. 1982 – Decomposition of conifer needles and deciduous leaves in two Black Forest and two Swiss Jura streams. International Revew Gesamten Hydrobiologie 67, 695–711.

Santos-Flores C, Betancourt-López C. 1997 – Aquatic and Water-Borne Hyphomycetes (Deuteromycotina) in Streams of Puerto Rico. University of Puerto Rico, Puerto Rico, Caribbean Journal of Science Special Publication # 2.

Shearer CA, Webster J. 1991 – Aquatic hyphomycete communities in the River Teign. IV. Twig colonization. Mycological Research 95, 413–420.

Shearer CA, Descals E, Kohlmeyer B, Kohlmeyer J, Marvanová L, Padgett D, Porter D, Raja HA, Schmit JP, Thorton HA, Voglymayr H. 2007 – Fungal biodiversity in aquatic habitats. Biodiversity and Conservation 16, 49–67.

Simonis JL, Raja HA, Shearer CA. 2008 – Extracellular enzymes and soft rot decay: Are ascomycetes important degraders in fresh water? Fungal Diversity 31, 135–146.

Somogyi M. 1952 – Notes on sugar determination. Journal of Biological Chemistry 195: 19–23.

Sridhar KR, Kaveriappa KM. 1989 – Observations on aquatic hyphomycetes of the Western Ghat streams. Nova Hedwigia 49, 455–467.

Sridhar KR, Sudheep NM. 2011 – The spatial distribution of fungi on decomposing woody litter in a freshwater stream, Western Ghats, India. Microb Ecol 61, 635-645.

Sridhar KR, Chandrashekar KR, Kaveriappa KM. 1992 – Research on the Indian Subcontinent. In: The Ecology of Aquatic Hyphomycetes (Ed Bärlocher F). Springer-Verlag, Berlin, 182–211.

Sridhar KR, Karamchand KS, Hyde KD. 2010a – Wood-inhabiting filamentous fungi in 12 high altitude streams of the Western Ghats by damp incubation and bubble chamber incubation. Mycoscience 51, 104–115.

Sridhar KR, Arun AB, Maria GL, Madhyastha MN. 2010b – Diversity of fungi on submerged leaf and woody litter in River Kali, Southwest India. Environmental Research Journal 5, 701–714.

StatSoft Inc. 2008 – Statistica, Version 8. StatSoft, Tulsa, Oklahoma, USA.

Suberkropp K. 2001 – Fungal growth, production, and sporulation during leaf decomposition in two streams. Appl Environ Microbiol 67, 5063–5068.

Sudheep NM, Sridhar KR. 2011 – Diversity of lignicolous and Ingoldian fungi on woody litter in River Kali (Western Ghats, India). Mycology 2, 98-108.

Sudheep NM, Sridhar KR. 2013 – Colonization and diversity of aquatic hyphomycetes in relation to decomposition of submerged leaf litter in River Kali (Western Ghats, India). Mycosphere 4, (in press).

Tsui CKM, Hyde KD, Hodgkiss IJ. 2003 – Methods for investigating the

biodiversity and distribution of freshwater ascomycetes and anamorphic fungi on submerged wood. In: Fungal Diversity Research Series # 10 - Freshwater Mycology (eds Tsui CKM, Hyde KD). Hong Kong University Press, Hong Kong, 195–209.

Webster J, Descals E. 1981 – Morphology, distribution and ecology of conidial fungi in freshwater habitats. In: Biology of Conidial Fungi (Volume 1) (eds GT Cole, B Kendrick), Academic Press Inc, New York, 295–355.

Wood-Eggenschwiler S, Bärlocher 1983 – Aquatic hyphomycetes in sixteen streams in France, Germany and Switzerland. Transactions of the British Mycological Society 81, 371–379.