Diversity of saprobic fungi on decaying rubber logs (*Hevea brasiliensis*)

P. Seephueak[1]; S. Phongpaichit[2]; K.D. Hyde[3,4] & V. Petcharat[5]

[1] Program in Tropical Agricultural Resource Management, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus, Songkhla, 90112, Thailand.
[2] Department of Microbiology, Faculty of Science, Prince of Songkla University, Hat Yai Campus, Songkhla, 90112, Thailand.
[3] School of Science, Mae Fah Luang University, Chiang Rai 57100, Thailand.
[4] Botany and Microbiology Department, College of Science, King Saud University, Riyadh 1145, Saudi Arabia.
[5] Department of Pest Management, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus, Songkhla, 90112, Thailand.

Seephueak P., Phongpaichit S., Hyde K.D. & Petcharat V. (2011) Diversity of saprobic fungi on decaying rubber logs (*Hevea brasiliensis*). – Sydowia 63 (2): 249–282.

The objective of this research was to study the diversity of fungi associated with the degradation of rubber tree logs (*Hevea brasiliensis*). Samples were collected during four periods in 2010: January (during the late rainy season), April (during the dry season), July (early in the rainy season) and October (during the rainy season) in Nakhon Si Thammarat and Songkhla Provinces, in southern Thailand. Each sample belonged to one of the following of three groups; newly fallen logs, middle stage decaying logs and old decaying fallen logs. Moist chamber, dilution pour-plate and sporocarp survey methodology were used. Fungal identification was based on morphological examination under compound and stereo microscopes. In total 461 species were identified from the decaying logs, comprising 384 anamorphic taxa, 46 ascomycota and 31 basidiomycota. *Bactrodesmium rahmii, Botryodiplodia* sp., *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Paratomenticola lanceolatus* and *Veronaea coprophila* were the dominant species occurring at all stages of decomposition. In addition, *Bactrodesmium rahmii* was the dominant species occurring during all seasons.

Keywords: decomposition, lignicolous fungi, woody litter, rubber tree.

Deadwoodology, the ecology of deadwood, is a research area where wood decay fungi play a major role (Grove 2002). Wood decay fungi are excellent ecosystem engineers, because they directly modulate the availability of resources for other functions in the ecosystem (Moore *et al*. 2004). Coarse wood debris (CWD) is an important structural and functional component of forest ecosystems (Bütler *et al*. 2007). It affects soil development, reduces erosion, and stores carbon, nutrients

[1] Corresponding author: e-mail: spornsil@gmail.com

and water. Coarse wood debris supports a wide diversity of organisms, comprising mammals, birds, insects, mites, nematodes, bryophytes, lichens, fungi, slime moulds and bacteria. Of these, fungi and insects are clearly the most species rich groups (Siitonen 2001), and as the most important agents of wood decay, fungi can be regarded as a key group for the understanding and management of biodiversity associated with decaying wood. Studies on the fungal diversity on plant litter has tended to increase due to the fact that fungi have great potential in industrial and biotechnological applications (Pointing & Hyde 2001, Bills *et al*. 2002).

A number of studies have claimed that large logs are particularly important for fungal biodiversity. Most studies have been on fungi diversity on terrestrial wood in temperate regions such as in coniferous forests (Lambert *et al*. 1980, Sollins *et al*. 1987, Krankina & Harmon 1995, Temnuhin 1996, Yin 1999, Krankina *et al*. 1999, Harmon *et al*. 2000), beech forest (*Fagus* sp.): Heilmann-Clausen and Christensen 2003, 2005) and spruce forests (*Picea* sp.): Bader *et al*. 1995, Bredesen *et al*. 1997, Lindbald 1998, Lumley *et al*. 2000. However, knowledge and interest in fungal diversity on plant litter in tropical regions has grown as these countries develop their scientific research abilities. There have been some studies of lignicolous fungi from terrestrial wood in the tropical regions, i.e. *Avicennia alba* and *A. lanata*: Tan *et al*. 1989, forest: Than-ar-sa, 1998, Sihanonth *et al*. 1998, Chatanon 2001, Inderbitzin & Berbee 2001, Inderbitzin *et al*. 2001, *Magnoliaceae*: Kodsueb 2007, *Dracaena loureiri* and *Pandanus* sp. (Thongkantha *et al*. 2008).

Several studies of the diversity of wood decay fungi have focused on forestry. In this study we focus on the fungal diversity in rubber tree plantations. Rubber wood is a light hardwood of density 450–550 kg/m^3 whose strength characteristics are comparable to those of commercial hardwood of equal density. Rubber wood, however, has no distinct heartwood, it contains a large quantity of starch and is non-durable (Prance 1986). Therefore, rubber wood is readily attacked by wood destroying insects and fungi. Wood decay fungi are central to many ecosystem processes including the recycling of nutrients and the creation of decay wood habitat in rubber plantation ecosystem.

Our study is the first on fungi associated with rubber trees (*H. brasiliensis*) in southern Thailand. There are three categories for studying fungi associated with rubber trees; on leaf litter, on branch litter (1–5 cm diameter) and on wood logs (≥ 10 cm diameter). Fungi on rubber leaf litter in previous studies yielded 493 species of fungi, while 497 species of fungi were identified from the decaying branches. In this paper the focus is on fungi on fallen logs of *H. brasiliensis* (≥ 10 cm diameter). The purpose of this study was to assess the diversity and distribution of saprobic fungi on rubber logs at each stage of decay, namely, newly fallen logs, middle stage decaying logs and old stage

decaying logs, and to evaluate the fungal communities involved in log decay at each stage.

Materials and methods

Log samples were collected at four periods in 2010: January, April, July and October. Each sample which contained variously decayed logs was divided into several log groups based on degree of decomposition and external appearance. The degree of decomposition of log litter belonging to the following three groups were used for fungal isolation: newly fallen logs, i.e. wood hard and bark present, middle stage decaying logs, i.e. bark absent and the wood softening but still maintaining its structural integrity, and old decaying fallen logs, i.e. log soft and losing its integrity (Schmit 2005).

Study sites

The study was conducted at rubber tree plantations comprising *H. brasiliensis* RRIM 600 variety in Nakhon Si Thammarat and Songkhla Provinces, both in southern Thailand. Rainfall varied greatly throughout the year due to the influence of monsoon winds. Nakhon Si Thammarat Province is located in the central southern area with a latitude of approximately 8°47'–9°00' N and longitude range of 99°97'–100°04' E. The province has two seasons: the dry season when the weather is hot and dry and the rainy season. The dry season is in February – April and the rainy season runs from May to January.

Songkhla Province is located on the eastern coast of the southern Thailand, at latitudes 6°17'–7°56' N and longitudes 100°01'–101°06' E. The province has two seasons like Nakhon Si Thammarat, but the dry season is from February to the middle of July. Both areas experience the highest precipitation in November and the highest temperature in May. The total rainfall in 2010 was 2799.40 mm and temperatures averaged about 27.94°C.

Sampling design

Collections of rubber wood logs were made at two sites in a 25-year-old rubber plantation. Three plots were distributed on a grid system of 200 × 200 m and site study was conducted of 50 × 50 m. The decomposition study involved collected of material at four periods in 2010; January, April, July and October.

The first collection was made in January which was late in the rainy season, and the temperature was between 26.6–27.6°C. The rainfall was between 68.3 mm and 175.4 mm. The second collection was made during April, in the dry season ("summer") when the temperature ranged from 27.2–29.8°C and no rainfall was recorded. The third collection was in July which is in the early rainy season and the tem-

perature range was 27.9–28.2ºC and the rainfall was 115.5–132 mm. The fourth collection was in October which is in the rainy season, the temperature range was 27.1–27.8ºC. The rainfall was 272.2–399 mm.

Logs representing all stages of decay were selected from the fallen logs in rubber plantations within 50 m^2 at each of the two sites. Logs of each stage were placed in separate Ziplock plastic bags and taken to the laboratory for treatment within 24 h.

Identification of fungi

Rubber wood logs were selected during each collection trip about 72 dead logs. Samples of each stage were randomly collected and returned to the laboratory where they were each separately incubated in large plastic bags. The fungi were identify, recorded, photographed and fully described if new. Fungi were identified, based on morphological characters, using relevant texts and references (e.g. Ellis 1971, 1976, Barnett & Hunter 1972, Ainsworth *et al*. 1973, Ramirez 1982, Domsch & Gams 1980, Ellis & Ellis 1997, Kubicek & Harman 1998, Kiffer & Morelet 1999, Hyde *et al*. 2000, Tsui & Hyde 2003, Wu & Zhuang, 2005, Cai *et al*. 2006).

Incubation, observation and isolation of fungi

Logs at each stage of decomposition were collected from the two locations. Moist chamber, dilution pour-plate and sporocarp survey were used to study the fungi. In the moist chamber technique, all logs were cut into 5 cm long sections, in diameter ≥10 cm with bark for observation and incubated in moistened plastic boxes at room temperature (28–32 °C). The fungi present on the samples were examined after 24 h of incubation and examined for up to 30 days. The fungal colonies were scraped from the log surface by cellophane tape and mounted on slides using lactophenol as the mounting medium. In the case of the dilution-pour plate method, 10 g samples of log litter were chopped with a sterile knife. The samples were added to 100 ml of sterile water, and spun with a blender for 3 min. From this initial suspension, 1 ml of 1×10^{-3} serial dilution was plate pipetted into each of four replicates on glucose ammonium nitrate agar (GANA) with streptomycin sulfate (300 µg/ml) which cooled to 45 °C and poured into each Petri dish. The plates were incubated at room temperature for 2–3 days and then examined for fungal growth. All fungi colonies were recorded once the fungi had been cultured and identified. For the sporocarp survey, the fruiting bodies visible at the surface were examined. The specimens were photographed, air-dried and kept in 75% ethyl alcohol. All fruiting bodies were deposited in the Herbarium of the Mushroom Museum of the Department of Pest Management, Prince of Songkla University. Identification is based on morphological study involving examination under stereo and compound microscopes.

Definition and statistical analyses

Fungal species were recorded as either present or absent from each stage of log decomposition. The number of logs on which fungal species was found was designated as the occurrence of a fungus and was used to calculate the percentage occurrence of a fungal species in logs of each stage of decay, subject to study using the following formula (Pinruan *et al*. 2007, Kodsueb *et al*. 2007, 2008a, 2008b, Duong *et al*. 2008). Percentage occurrence of taxon A = (number of log samples on which each fungus was detected/ total number of log samples examined) × 100%. Fungal taxa with a percentage occurrence equal to or higher 10% are regarded as one of the dominant species. Fungal species diversity at each stage of degradation and each season was calculated using Shannon-Wiener's index (*H*) and Simpson's index (D).

The Shannon-Wiener's index $H = -\Sigma Pi \ln Pi$, Where Pi is the frequency of fungal species i occurring on specific log stage or season. Values of the Shannon diversity index for real communities are often found to fall between 1 and 6. Simpson's index $D = 1-\Sigma [ni/ (ni-1) / N/ (N-1)]$, where ni is the number of individuals of species 1 and N = total number of species in community. The values of this index range between 0 and 1.

Sorensen's similarity index (*S*) was applied to compare the similarity of species on logs of different stages and different seasons: $S = 2c/(a+b)$, where *a* is the number of species at stage or season A and *b* is the number of species at stage or season B and *c* is the number of species found during both stages or seasons. Similarity is expressed with values between 0 (no similarity) and 1 (absolute similarity).

Results

Fungal taxonomic composition

There were clear differences in the species composition and richness detected in the three methods used to examine the fungal communities on rubber logs. Out of a total of 461 species recorded, 407 fungal taxa (88.09%) were found by moist chamber technique, 40 fungal taxa (8.66%) were detected with sporocarp survey and 19 fungal taxa (4.67%) from using the dilution pour-plate technique. Examination of decaying logs of *H. brasiliensis* RRIM 600 variety at three stages of decomposition yielded 461 fungal taxa, comprising 384 anamorphic taxa, 46 ascomycota and 31 basidiomycota (Tab. 1).

The fungal community and its changes during the three analogous decomposition stages (newly fallen logs, middle stage decaying logs and old decaying fallen logs) were studied. Fungal succession on *H. brasiliensis* logs on the plantation floor i.e. in the fallen logs showed differences in fungal composition between the various decaying log stages and differences due to variation of season.

A total of 231 species were found in newly fallen logs, 287 species were found in middle stage decaying logs and 230 species were found in old decaying fallen logs. In both areas, it was found that 51 species (35.79%) were overlapping in newly fallen logs, 85 species (46.68%) were overlapping in middle stage decaying logs and 53 species (37.59%) were overlapping in old decaying fallen logs.

The 304 fungal taxa were found in Nakhon Si Thammarat Province included 255 anamorphic taxa, 35 ascomycota, 14 basidiomycota. One hundred and thirty-eight taxa were recorded from newly fallen logs, 174 from middle stage decaying logs and 136 species were recorded from old decaying fallen logs.

In Songkhla Province, 305 fungal taxa were found including 255 anamorphic taxa, 23 basidiomycota, 27 ascomycota. One hundred and fourty-seven taxa were recorded from newly fallen logs, 189 from middle stage decaying logs and 146 taxa from old decaying fallen logs. The list of taxa from each stage and their dominant fungi with over 10% occurrences is shown in Tab 1.

Tab. 1. Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Ascomycota						
Anthostomella formosa	2.08		4.17			
Astrosphaeriella sp.						6.25
Bulgaria maxicana			2.08			
Chaetomium sp.			2.08			
Claussenomyces atrovirens	16.67				2.08	
Cookeina tricholoma			4.17			
Daldinia escholizii		2.08	2.08			
Dothidotthia sp.1				10.42	6.25	10.42
Dothidotthia sp.2				8.33		
Eupenicillium sp.					2.08	
Gaeumannomyces graminis			2.08			2.08
Geastrum mirabile					4.17	
Glomerella cingulata		4.17			2.08	
Hyphodiscosia sp.		6.25				
Hypocrea pezizoidea	2.08	4.17				
Hypocrea rufa					6.25	
Hypocrea splendens		2.08	2.08	2.08		
Hypoderma sp.		2.08				
Hypomyces sp.						2.08

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Hypoxylon sp.1	43.75	29.17	31.25	6.25	8.33	25.00
Hypoxylon sp.2	20.83	25.00	8.33	10.42	8.33	4.17
Hypoxylon sp.3	16.67	31.25	6.25	4.17	2.08	
Hypoxylon sp.4	8.33	14.58	10.42	8.33	8.33	
Hypoxylon sp.5	2.08	14.58				
Hypoxylon sp.6		8.33				
Hypoxylon cohaerens	22.92	12.50			31.25	27.08
Hysterium pulicare		4.17				
Kirschsteiniothelia sp.	47.92	22.92	43.75	35.42	47.92	25.00
Leptosphaeria blumeri			4.17			
Leptosphaeria darkeri		2.08				
Linocarpon sp.	8.33		2.08			
Linodochium hyalinum			2.08			
Linospora sp.		4.17	2.08	4.17	6.25	8.33
Lophiostoma fuckelii		14.58				
Lophiostoma viridarium		2.08			2.08	
Nectria ventricosa			2.08			
Oedothea vismiae				12.50		
Oxydothis sp.				2.08		
Pestalosphaeria hansenii		14.58	4.17	20.83	4.17	18.75
Phaeosphaeria sp.				8.33		
Thyridaria sambucina	18.75		20.83	22.92		8.33
Trematosphaeria pertusa		2.08		2.08	6.25	4.17
Xylaria sp.1	12.50					
Xylaria arbuscula		8.33			2.08	
Xylaria cubensis					4.17	
Xylaria multiplex		2.08				
Basidiomycota						
Aleuria aurantia			2.08			
Auricularia auricula					4.17	4.17
Auricularia polytricha					4.17	
Collybia peronata					2.08	
Coriolopsis polyzona		4.17				
Corious hirsutus					2.08	
Fomitopsis feei		2.08				
Ganoderma sp.		4.17				
Heterobasidion annosum					6.25	

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Hexagonia tenuis	6.25	4.17	10.42	2.08	8.32	8.32
Lactarius hygrophorides					2.08	
Lentinus squarrosulus					4.17	
Lenzites elegan		4.17	2.08		2.08	2.08
Marasmius aurantioferrugineus					2.08	
Marasmius pellucidus					2.08	
Marasmius pulcherripes					2.08	
Marasmius siccus					2.08	
Meruliopsis corium		4.17			4.17	10.42
Microporus affinis					4.17	
Polyporus sp.1		2.08		2.08		
Polyporus sp.2		2.08				
Polyporus elegans		4.17				
Pycnoporus sanguineus		4.17				
Rigidoporus microporus		4.17	2.08			
Schizophyllum commune	8.32	12.50	6.17	8.32	10.41	14.58
Trametes flavida					6.25	
Trametes fuciformis					4.17	
Trametes modesta				2.08	2.08	
Trametes scabosa	2.08	2.08		4.17	6.25	
Trametes sp.					2.08	
Xeromphalina campanella					2.08	4.17
Mitosporic fungi						
Acarocybe formosa				35.42	14.58	6.25
Acarocybe hansfordii				18.75	8.33	8.33
Acarocybella jasminicola				8.33		
Acladium curtisii	4.17					
Acremoniula sp.				2.08		
Acremoniula fagi	4.17	2.08				
Acremonium sp.1	8.33		2.08			
Acremonium sp.2	2.08					
Acremonium sp.3				6.25	20.83	6.25
Acremonium alternatum					6.25	
Acremonium butyri		12.50		16.67	8.33	4.17
Acremonium cerealis	8.33	12.50				
Acremonium fusidioides	2.08	16.67	10.42	10.42	16.67	
Acremonium kiliense	8.33	6.25		16.67	6.25	12.50

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Acremonium murorum					8.33	
Acremonium rutilum	14.58		4.17			
Acremonium strictum		6.25	12.50		12.50	
Actinocladium rhodosporum	4.17	10.42	14.58		14.58	8.33
Alternaria dennisii		2.08				
Alternaria tenissimum		4.17				
Annellophora solani	18.75	37.50				
Annellophorella ziziphi			2.08			
Aplosporella sp.			16.67			
Arthobotrys oligospora						4.17
Arthrinium sp.					8.33	6.25
Arthrinium muelleri	2.08				2.08	
Arthrinum paeospermum			2.08			
Articulospora tetracladia	8.33		2.08			
Aspergillus sp.1*	4.17	4.17	4.17	18.75	12.50	8.33
Aspergillus sp.2	4.17	4.17	4.17	10.42	6.25	16.67
Aspergillus sp.3*	4.17	4.17	4.17	8.33	4.17	
Aspergillus sp.4*	2.08	2.08	2.08	4.17	12.50	
Aspergillus sp.5	2.08		2.08			
Aspergillus sp.6	2.08		2.08			
Aspergillus japonigum				14.58		
Aspergillus niger				8.33		
Bachysporium masonii		18.75				
Bactrodesmiella masonii		2.08		6.25	4.17	
Bactrodesmium pallidum		25.00		4.17	4.17	18.75
Bactrodesmium betulicola				50.00		12.50
Bactrodesmium longisporum		6.25				
Bactrodesmium masonii						14.58
Bactrodesmium rahmii	87.50	77.08	41.67	45.83	58.33	41.67
Bactrodesmium spilomeum		31.25	20.83	50.00	45.83	16.67
Bactrodesmium traversianum	25.00	10.42				
Bahusakala cookei						12.50
Beltraniella fertilis					4.17	8.33
Beltraniella odinae						2.08
Berkleasmium cf. *minutissimum*					6.25	14.58
Berkleasmium concinnum					8.33	8.33
Berkleasmium grandisporus					6.25	

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Berkleasmium leonense					2.08	
Bidenticula cannae		6.25		4.17	2.08	
Bipolaris sp.1		6.25	10.42	8.33		4.17
Bipolaris sp.2				6.25		
Bipolaris australiensis		10.42				
Bipolaris biseptata					6.25	
Bipolaris cactivora				8.33		6.25
Bipolaris frumentacei		6.25				
Bipolaris indica					4.17	
Bipolaris japonica					2.08	
Bipolaris miyakei				4.17		
Bipolaris ravenelii	8.33					8.33
Bipolaris rostrata	4.17					
Bipolaris sacchari				4.17		
Bispora antennata	6.25			4.17		
Bispora catenula				2.08		
Botryodiplodia sp.	39.58	47.92	14.58	56.25	35.42	25.00
Botryodiplodia bisbyi			10.42			
Brachydesmiella biseptata			8.33	4.17	4.17	16.67
Brachyhelicoon xylogenum		2.08				
Brachysporiella gayana		2.08	4.17	10.42	4.17	
Brachysporiella laxa						2.08
Brachysporiella turbinata	2.08					6.25
Brachysporium bloxami					4.17	
Brachysporium nigrum				4.17		
Calospora patanoides		4.17	8.33		4.17	
Camarosporium rosea						12.50
Camposporium antennatum			2.08	6.25		
Camposporium cambrense	2.08	14.58	6.25			2.08
Canalisporium caribense					6.25	4.17
Cantelabrella musifomis						2.08
Capnobotrys neesii			8.33			
Ceratosporella deviata	8.33		2.08			
Ceratosporella novae-zalandiae	4.17					
Cercospora sp.	8.33			4.17	4.17	
Cercospora elaeidis		4.17	10.42	14.58		
Cercospora justiciicola		8.33				

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Cercospora malayensis	2.08					
Chaetochalara bulbosa					2.08	
Chalara sp.	4.17				6.25	
Chalara elegans		4.17			2.08	
Chalaropsis sp.						
Chloridiella sp.	6.25	4.17				
Chuppia sarcinidera						6.25
Circinotrichum maculiforme				6.25		
Cirrenalia pseudomacrocephala						4.17
Cladosporium sp.1			14.58		6.25	
Cladosporium sp.2		12.50			12.50	
Cladosporium sp.3		6.25				
Cladosporium sp.4		6.25				
Cladosporium acaciicola				8.33		
Cladosporium balladynae			2.08			
Cladosporium britannicum		2.08				
Cladosporium diaphanum				2.08		
*Cladosporium elatum**		6.25		10.42	12.50	
Cladosporium fulvum	6.25					
Cladosporium gynoxidicola	8.33					
Cladosporium orchidis	6.25		2.08			
*Cladosporium psoraleae**					2.08	
Cladosporium taurophorum			2.08			
Cladosporium tenuissimum	4.17	16.67	4.17	18.75	10.42	25.00
Clasterosporium cocoicola		16.67				
Clasterosporium pistaciae						10.42
Colletotrichum sp.*				4.17		
Colletotrichum gloeosporioides		2.08				
Codinaea sp.1	6.25					6.25
Codinaea hughesii	4.17					
Cordana pauciseptata						4.17
Coronospora dendrocalami						4.17
Corynespora sp.		4.17				
Corynespora combreti		8.33				
Corynespora foveolata	4.17	25.00				
Corynespora kamatii			18.75			
Corynespora trichiliae			6.25			

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Corynesporopsis quereicola	8.33					
Curvularia sp.				6.25		2.08
Curvularia affinis					4.17	
Curvularia eragrostidis					4.17	
Curvularia geniculata	2.08			2.08		
Curvularia inaequalis			14.58			
*Curvularia lunata**	12.50	6.25	2.08	8.33		14.58
Curvularia pallescens			4.17	4.17	10.42	
Curvularia trifolii						2.08
Cylindocladium sp.					4.17	
Cylindrotrichum oligospermum			4.17		2.08	
Dactylaria sp.1		12.50	6.25	6.25	12.50	20.83
Dactylaria sp.2		12.50	6.25	12.50	2.08	2.08
Dactylaria hyalina	14.58	2.08	4.17	8.33	4.17	6.25
Dactylaria junci	6.25			4.17	4.17	8.33
Dactylella sp.						6.25
Dactylella aquatica		4.17	4.17			8.33
Dactylella ellipsospora	4.17	2.08	2.08			4.17
Dendryphiopsis arbuscula			25.00			
Dictyosporium sp.				2.08		6.25
Dictyosporium elegans						6.25
Dictyosporium giganticum				2.08		
Dictyosporium manglieliae	12.50			10.42	8.33	12.50
Diplococcium sp.1	12.50					
Diploccocium clarkii					16.67	
Diploccocium spicatum	14.58	10.42	10.42	2.08		2.08
Diplodia sp.		12.50				
Diplodina macrospora		4.17				
Domingoella leonensis		8.33	4.17	12.50	4.17	6.25
Duosporium cyperi		6.25				
Ellisembia paravaginata	4.17					6.25
Ellisembia vaginata	4.17			10.42	6.25	8.33
Ellisiopsis gallesiae					2.08	2.08
Endophragmia bisbyi				8.33		
Endophragmia boewei					6.25	
Endophragmia brevis	20.83					
Endophragmia cesatii					6.25	

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Endophragmia elliptica				2.08		
Endophragmia hyalosperma			4.17			
Endophragmiella sp.						8.33
Endophragmiella cambrensis				4.17		
Entomosporium sp.		2.08				
Excipularia narsapurensis			18.75			
Exosporiella fungorum					2.08	
Exosporium sp.						4.17
Exosporium ramosum		6.25				20.83
Fulvia berkheyae				2.08	4.17	4.17
Fusariella sp.		6.25	10.42			
Fusariella concinna				8.33		
Fusariella sarniensis		12.50				
Fusarium sp.1	6.25	8.33	6.25	6.25	10.42	8.33
Fusarium sp.2		8.33	10.42		8.33	6.25
Fusarium sp.3			10.42		2.08	22.92
Fusarium chlamydosporum				8.33		
Fusarium moniliforme				4.17	2.08	6.25
*Fusarium oxysporum**		8.32		12.50		
Fusarium semitectum			2.08		6.25	
Gliomastix murorum			2.08			
Gliomastix vegetum					6.25	
Gonatophragmium mangiferae				2.08		
Graphium calicioides	8.33					
Handsfordia nebularis			12.50			
Handsfordia biophila					2.08	4.17
Handsfordia ovalispora					6.25	4.17
Helicoma dennisii						2.08
Helicoma mulleri		2.08				
Helicomyces roseum		2.08		8.33	6.25	
Helicomyces scandens	4.17					
Helicoon auratum			2.08			
Helicosporium sp.	2.08					
Helicosporium aureum		2.08	6.25	2.08		
Helicosporium elatum			2.08			
Helicosporium vegetum					10.42	4.17
Helicostylum piriforme		2.08				

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Helminthosporium acaciae		8.33				
Helminthosporium velutinum		6.25				
Hemibeltrania cinnamomi					4.17	
Hemicorynespora deightonii			2.08			
Hemicorynespora mitrata						4.17
Henicospora coronata		6.25			8.33	4.17
Heteroconium solaninum					20.83	
Hirudinaria macrospora					2.08	
Hormiactis candida				8.33		8.33
Humicola grisea	2.08		4.17		2.08	
Hyphodiscosia jaipurensis			8.33			6.25
Idriella lunata		18.75				4.17
Janetia euphorbiae		2.08				
Lasiodiplodia cf. *theobromae*	37.50	60.42	22.92	35.42	50.00	33.33
Leptodiscella africana				2.08	6.25	6.25
Macrodiplodiopsis sp.			14.58			
Megalodochium elaedis		8.33				
Menispora sp.			2.08	2.08		
Menispora manitobaensis	2.08	10.42	2.08			
Molowia basicola						2.08
Monacrosporium sp.			4.17			
Monacrosporium psychrophilum			8.33			
Monilia sp.			2.08	2.08		
Moorella speciosa						4.17
Mycoleptodiscus indicus				6.25		
Myrothecium roridum					4.17	
Nawawia filiformis			4.17			
Nigrospora sphaerica	18.75	6.25	25.00	25.00	29.17	18.75
Paecilomyces sp.*	8.33			6.25	8.34	4.17
Paecilomyces lilancinus			2.08			
Panchanania jaipurensis					6.25	
Parapleurotheciopsis sp.			2.08			
Parapyricularia musea		4.17	10.42			
Parasympodiella podocarpi	4.17				2.08	6.25
Paratomenticola lanceolatus	18.75	22.92	50.00	18.75	14.58	14.58
Paratrichoconis chinensis	6.25	16.67	14.58			8.33
Penicillium sp.1*	6.25	8.33		27.08	25.00	10.42

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Penicillium sp.2	2.08	2.08		6.25	20.83	12.50
Penicillium sp.3	8.33	8.33		16.67	16.67	
Penicillium sp.4		4.17		6.25	14.58	
Penicillium sp.5	4.17	6.25		10.42	6.25	
Penicillium sp.6					10.42	
Periconia sp.	4.17			10.42	6.25	
Pestalotiopsis sp.1*	8.33	6.25	10.42	6.25	4.17	4.17
Pestalotiopsis sp.2*	8.33		4.17			6.24
*Pestalotiopsis disseminata**	6.25				4.17	
Pestalotiopsis sydowiana			4.17			
Phaeoisaria sparsa		2.08				2.08
Phaeoisariopsis cercosporioides				8.33	16.67	6.25
Phaeoramularia leeae						20.83
Phaeoramularia marmorata			10.42	37.50	58.33	8.33
Phialophora bubakii					4.17	
Phoma sp.		4.17				
Phomopsis sp.			4.17			
Pithomyces graminicola	6.25					
Pleurophragmium acutum	12.50	8.33	18.75			
Pleurophragmium simplex				8.33		
Pleurophragmium tritici			2.08			
Pleurotheciopsis pusilla				6.25		
Polyscytalina grisea					8.33	
Pseudobeltrania cedrelae	4.17				4.17	
Pseudobeltrania macrospora	8.33					
Pseudobotrytis terrestris	8.33					6.25
Pseudocercospora terminaliae	2.08					
Pseudocerospora helleri	2.08					
Pseudospiropes sp.					4.17	
Pseudospiropes hughesii		2.08		12.50	18.75	14.58
Pseudospiropes obclavatus		16.67		4.17		
Pyriculariopsis parasitica				27.08	27.08	
Rhinocladiella sp.		6.25			6.25	4.17
Saccardaea atra					6.25	
Schizotrichum lobeliae				2.08		
Scolecobasidiella avellanea	12.50	10.42	35.42	10.42	18.75	4.17
Scolecobasidium acanthacearum		12.50				

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Scolecobasidium arenarium	12.50					
Scolecobasidium compactum	8.33					20.83
Scolecobasidium salinum				18.75		2.08
Scutellinia scutellata	4.17					
Septonema fasciculare	4.17	6.25	14.58		18.75	12.50
Septonema secedens				12.50		
Sirosporium antenniforme				4.17		
Sirosporium carissae					4.17	
Sirosporium mori						6.25
Spadicoides afzeliae					27.08	
Spegazzinia lobulata						18.75
Spegazzinia sundara			2.08			
Spiropes sp.						8.33
Spiropes capensis		4.17				
Speiropsis hyalospora	4.17				6.25	2.08
Speiropsis pecatospora	29.17					
Spondylocladiella botrytioides	14.58			10.42		8.33
Sporidesmium sp.1	4.17	16.67				
Sporidesmium sp.2					6.25	
Sporidesmium australiense	6.25	6.25				
Sporidesmium bambusicola	2.08					
Sporidesmium bonarii		25.00				
Sporidesmium cladii	12.50					
Sporidesmium dioscoreae				25.00		
Sporidesmium ehrenbergii				14.58	12.50	
Sporidesmium flagellatum	66.67	27.08	66.67	6.25	16.67	25.00
Sporidesmium folliculatum		6.25				
Sporidesmium fusiforme	8.33					
Sporidesmium ghanaense				8.33		
Sporidesmium harknessii	39.58	22.92	33.33			
Sporidesmium hormiscioides	10.42					
Sporidesmium jaipurensis			6.25			
Sporidesmium jasminicola		14.58		10.42	18.75	12.50
Sporidesmium larvatum		22.92	16.67			
Sporidesmium leptosporum			14.58			20.83
Sporidesmium longirostratum	35.42			8.33		6.25
Sporidesmium obclavatum		14.58				

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Sporidesmium paludosum		2.08				
Sporidesmium penzigii	20.83	14.58				8.33
Sporidesmium raphiae						6.25
Sporidesmium rubi		10.42			8.33	
Sporidesmium socium						2.08
Sporoschisma uniseptatum	10.42	2.08				2.08
Sporoschismopsis sp.1		8.33			10.41	
Sporoschismopsis sp.2				41.67	22.92	
Staphylotrichum sp.				10.42		
Staphylotrichum coccosporum			10.42		4.17	
Stemphyliomma valparadisiacum		4.17				
Stenella pithecellobii			6.25	2.08	8.33	
Stigmina celata					4.17	2.08
Stigmina crotonicola		6.25				
Stigmina fici	6.25					
Stigmina hartigiana		6.25	8.33			
Stigmina kranzii	8.33					
Stigmina murrayae		6.25				
Stigmina rauvolfiae	6.25					
Stigmina sapii					4.17	
Stigmina thermopsidis		8.33				
Stigmina triumfettae	8.33					
Subulispora sp.					6.25	
Subulispora procurvuta	8.33					4.17
Sympodiella acicola		6.25				
Taeniolella alta				4.17		
Taeniolella breviuscula		25.00		6.25		
Taeniolella exilis				8.33		
Taeniolella sp.	10.42					
Taeniolella scripta		18.75	20.83		6.25	
Teratosperma singulare					2.08	
Tetracrium amphibium		2.08	8.33			
Tetraploa aristata	8.33	8.33	6.25	4.17	8.33	
Tetraposporium asterinearum		4.17	4.17			2.08
Tetraposporium sp.	4.17	4.17	2.08		6.25	12.50
Tomenticola trematis						14.58
Torula sp.	6.25			6.25	10.42	

Tab. 1 (Continued). Occurence (%) of fungi on rubber logs at different stage of composition collected from Nakhon Si Thammarat and Songkhla Provinces.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
Torula ellisii					6.25	4.17
Torula herbarum	12.50	4.17	39.58	25.00	20.83	16.67
Triadelphia heterospora		4.17				6.25
Triadelphia inquinans					2.08	
Trichoderma sp.1*	4.17	14.58	16.67	4.17	10.42	
Trichoderma sp.2		8.33		8.33	12.50	
Trichoderma sp.3		10.42		8.33	8.33	
*Trichoderma atroviride**	14.58	12.50	14.58	4.17	8.33	14.58
*Trichoderma aureoviride**	16.67	8.33	14.58	4.17	2.08	
*Trichoderma hamatum**				4.17	12.50	
*Trichoderma harzianum**	10.42	27.08	8.33	8.33	2.08	14.58
*Trichoderma virens**	8.33			4.17	8.33	
*Trichoderma viride**		8.33	2.08		2.08	8.33
Trichothecium sp.		10.42				
Tricladium sp.				2.08	8.33	
Tricladium fuscum	4.17		2.08		2.08	
Tridentaria implicans		2.08				
Trimmatostroma betulinum			6.25	2.08		
Trimmatostroma salicis				2.08		
Tripospermum myrti			8.33	2.08	8.33	8.33
Triscelophorus panapensis					4.17	8.33
Trochophora simplex	4.17					
Tubercularia vulgaris	8.33					
Ulocladium alternariae					4.17	
Veronaea apiculata			4.17			
Veronaea carlinae	14.58	8.33	16.67	4.17	16.67	18.75
Veronaea coprophila	22.92	12.50	14.58	10.42	14.58	12.50
Veronaea musae			12.50	2.08		2.08
Veronaea parvispora	4.17	6.25				
Verticillium dahliae					6.25	
Virgaria nigra				4.17		12.50
Wiesneriomyces javanicus	6.25	2.08	6.25		4.17	
Xenosporium indicum		4.17				4.17
Xenosporium larvale	4.17					
Ypsilonia sp.				2.08		
Zanclospora novae-zelandiae				4.17	4.17	
Zygosporium gibbum	8.33	2.08				
Total number of species recorded at each stage	**138.00**	**174.00**	**136.00**	**147.00**	**189.00**	**146.00**

* Isolated from dilution pour-plate.

Twenty-three taxa were common to both provinces and to all stages of decomposition including, *Aspergillus* sp.1, *Aspergillus* sp.2, *Bactrodesmium rahmii, Botryodiplodia* sp., *Cladosporium tenuissimum, Dactylaria hyalina, Fusarium* sp.1, *Hexagonia tenuis, Hypoxylon* sp.1, *Hypoxylon* sp.2*, Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Pestalotiopsis* sp.1, *Schizophyllum commune, Scolecobasidiella avellanea, Sporidesmium flagellatum, Torula herbarum, Trichoderma atroviride, T. harzianum, Veronaea coprophila* and *Veronaea carlinae*. Fourty-three taxa were found in all stages of decomposition in Nakhon Si Thammarat Province. In addition, 52 taxa were found at all stages of decomposition in Songkhla Province.

Species richness and the dominant fungi

The taxa and their percentage occurrence are listed in Table 1. Anamorphic fungi (384 taxa) were the dominant group, followed by ascomycota (46 taxa) and basidiomycota (31 taxa). Six species, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Paratomenticola lanceolatus* and *Veronaea coprophila* were dominant fungi found at all decomposition stages. The dominant fungi on the rubber logs, with over 10% occurrence at each stage of decomposition and in each season in Nakhon Si Thammarat and Songkhla provinces are shown in Tab. 2 and 3.

The number of dominant taxon during the late rainy season, dry season, early rainy season and rainy season in Nakhon Si Thammarat Province was 18, 15, 14 and 7 taxa respectively (Tab. 2). In addition, the result obtained in Songkhla Province corresponded to the results from Nakhon Si Thammarat province. In Songkhla Province, 18, 13, 7 and 6 taxa were found on late rainy season, dry season, early rainy season and rainy season. respectively (Tab. 3).

In this study, nine taxa were common species in Nakhon Si Thammarat Province found all season and to all stages of decomposition including, *Bactrodesmium rahmii, Hypoxylon* sp.1, *Hypoxylon* sp.4, *Lasiodiplodia* cf. *theobremae*, *Kirschstheniothelia* sp., *Sporidesmium flagellatum*, *Sporidesmium harknessii*, *Trichoderma harzianum*, *Trichoderma* sp.1. In addition, 6 taxa were common species in Songkhla Province found in all seasons and at all stages of decomposition including, *Bactrodesmium rahmii*, *Bactrodesmium spilomeum*, *Botryodiplodia* sp., *Kirschsteiniothelia* sp., *Penicillium* sp.1 and *Torula herbarum*. Finally, *Bactrodesmium rahmii* and *Kirschsteiniothelia* sp. were common to both provinces. One species, *Bactrodesmium rahmii* was dominant species in all seasons and at all stages of wood log decomposition.

Tab. 2. Dominant fungi found on rubber logs with over 10% of occurrence at each stage of decomposition and each season in Nakhon Si Thammarat Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
Late rainy season	*Bactrodesmium rahmii*	*Annellophora solani*	*Aplosporella* sp.
	Botryodiplodia sp.	*Bactrodesmium rahmii*	*Hypoxylon* sp.1
	Hypoxylon sp.1	*Botryodiplodia* sp.	*Lasiodiplodia* cf. *theobromae*
	Sporidesmium flagellatum	*Cladosporium tenuissimum*	*Paratomenticola lanceolatus*
	Sporidesmium longirostratum	*Clasterosporium cocoicola*	*Pleuophragmium acutum*
	Veronaea coprophila	*Corynespora foveolata*	*Scolecobasidiella avellanea*
		Hypoxylon sp.1	*Sporidesmium flagellatum*
		Lasiodiplodia cf. *theobromae*	*Torula herbarum*
Dry season	*Bactrodesmium rahmii*	*Annellophorella ziziphi*	*Kirschsteiniothelia* sp.
	Botryodiplodia sp.	*Bactrodesmium rahmii*	*Paratrichoconis chinensis*
	Curvularia lunata	*Bactrodesmium spilomeum*	*Sporidesmium flagellatum*
	Diploccocium spicatum	*Botryodiplodia* sp.	*Torula herbarum*
	Hypoxylon sp.1	*Hypoxylon* sp.1	
	Kirschsteiniothelia sp.	*Hypoxylon* sp.3	
	Lasiodiplodia cf. *theobromae*	*Lasiodiplodia* cf. *theobromae*	
	Sporidesmium flagellatum	*Pestalosphaeria hansenii*	
	Sporidesmium harknessii		
Early rainy season	*Bactrodesmium rahmii*	*Acremonium fusidioides*	*Bactrodesmium rahmii*
	Lasiodiplodia cf. *theobromae*	*Bactrodesmium rahmii*	*Nigrospora sphaerica*
	Nigrospora sphaerica	*Bactrodesmium spilomeum*	*Paratomenticola lanceolatus*

Tab. 2 (Continued). Dominant fungi found on rubber logs with over 10% of occurrence at each stage of decomposition and each season in Nakhon Si Thammarat Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
	Sporidesmium harknessii	*Botryodiplodia* sp.	*Scolecobasidiella avellanea*
	Sporidesmium longirostratum	*Lasiodiplodia* cf. *theobromae*	*Sporidesmium harknessii*
		Paratomenticola lanceolatus	*Sporidesmium leptosporum*
		Scolecobasidium acanthacearum	
		Sporidesmium larvatum	
Rainy season	*Bactrodesmium rahmii*	*Bactrodesmium rahmii*	*Bactrodesmium rahmii*
	Kirschsteiniothelia sp.	*Sporidesmium flagellatum*	*Hypoxylon* sp.1
	Sporidesmium flagellatum		*Kirschsteiniothelia* sp.
	Sporidesmium harknessii		*Paratomenticola lanceolatus*
			Sporidesmium flagellatum
			Thyridaria sambucina

* Newly fallen logs, middle stage decaying logs and old decaying fallen logs.

Tab. 3. Dominant fungi found on rubber logs with over 10% of occurrence at each state of decomposition and each season in Songkhla Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
Late rainy season	*Acarocybe formosa*	*Bactrodesmium rahmii*	*Bactrodesmium rahmii*
	Acarocybe hansfordii	*Bactrodesmium spilomeum*	
	Bactrodesmium betulicola	*Diploccocium clarkii*	
	Bactrodesmium rahmii	*Hypoxylon cohaerens*	
	Bactrodesmium spilomeum	*Kirschsteiniothelia* sp.	
	Botryodiplodia sp.	*Lasiodiplodia* cf. *theobromae*	
	Kirschsteiniothelia sp.	*Phaeoramularia marmorata*	
	Lasiodiplodia cf. *theobromae*	*Pseudospiropes hughesii*	
	Pestalosphaeria hansenii	*Sclecobasidiella avellanea*	
	Phaeoramularia hansenii	*Spadicoides afzeliae*	
	Staphylotrichum sp.	*Torula herbarum*	
Dry season	*Aspergillus* sp.1	*Bactrodesmium rahmii*	*Bactrodesmium rahmii*
	Bactrodesmium rahmii	*Bactrodesmium spilomeum*	
	Cladosporium tenuissimum	*Hypoxylon cohaerens*	
	Nigrospora sphaerica	*Kirschsteiniothelia* sp.	
	Penicillium sp.1	*Lasiodiplodia* cf. *theobromae*	
	Sporoschismopsis sp.2	*Nigrospora sphaerica*	
		Penicillium sp.1	
		Phaeoramularia marmorata	
		Spadicoides afzeliae	

Tab. 3 (Continued). Dominant fungi found on rubber logs with over 10% of occurrence at each state of decomposition and each season in Songkhla Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
Early rainy season	*Acremonium butyri*	*Bactrodesmium rahmii*	*Bactrodesmium rahmii*
	Bactrodesmium rahmii	*Bactrodesmium spilomeum*	
	Bactrodesmium spilomeum		
	Botryodiplodia sp.		
	Pyriculariopsis parasitica		
	Sporoschismopsis sp.2		
	Torula herbarum		
Rainy season	*Bactrodesmium betulicola*	*Bactrodesmium rahmii*	
	Botryodiplodia sp.	*Botryodiplodia* sp.	
	Kirschsteiniothelia sp.	*Phaeroramularia marmorata*	
		Sporoschismopsis sp.2	

* Newly fallen logs, middle stage decaying logs and old decaying fallen logs.

Fungal diversity and abundance of fungi

Communities of fungal taxa at different stages of decay of rubber logs were distinct. The number of taxa recorded from middle stage decaying logs tended to be higher than on new and old decaying fallen logs. The number of taxa found on middle stage decaying logs in Nakhon Si Thammarat were 174 taxa, 138 taxa found on the newly fallen logs and 136 taxa found on the old decaying fallen logs. The result obtained in Songkhla Province corresponded to the results from Nakhon Si Thammarat province. In Songkhla Province, 189 taxa were found on the middle stage decaying logs, 147 taxa were found on newly fallen logs and 146 taxa were found on the old decaying fallen logs (Tab. 4).

The similarity of fungal communities associated with rubber logs at each different stage of decay were the most similar during the middle and old stage (44.37% in Nakhon Si Thammarat Province, 48.96% in Songkhla Province). The newly fallen logs and the old decaying fallen logs were the least similar (39.27% in Nakhon Si Thammarat Province, 44.37% in Songkhla Province) (Tab. 5).

Fungal communities in different seasons

The results for the fungal taxa found in Nakhon Si Thammarat Province were that 275 taxa were recorded during the dry season, 260, 257 and 206 taxa during the late rainy season, early rainy season, and rainy season, respectively (Tab. 6).

For the fungal taxa that were found in Songkhla Province, the results are similar to the results from Nakhon Si Thammarat Province. Two hundred and ninety-seven fungal taxa were recorded in the dry season, 291, 280 and 223 taxa were recorded during the late rainy season, early rainy season and rainy season, respectively (Tab. 6).

The similarity of fungi associated with rubber logs during the different seasons was investigated. The most similar were during the early rainy season and during the dry season (50.09% in Nakhon Si Thammarat Province, 43.67% in Songkhla Province) and during the late

Tab. 4. Diversity indices of saprobic fungi on rubber logs at different stage of decomposition.

Decomposition stage	Location					
	Nakhon Si Thammarat			Songkhla		
	No. of species	Index (D)	Index (H)	No. of species	Index (D)	Index (H)
New*	138	0.9846	4.4530	147	0.9873	4.6982
Middle*	174	0.9887	4.4743	189	0.9886	4.7887
Old*	136	0.9845	4.4502	146	0.9804	4.6294

* Newly fallen logs, middle stage decaying logs and old decaying fallen logs.

rainy season and during the rainy season were the least similar fungi (34.76% in Nakhon Si Thammarat Province, 37.74% in Songkhla Province) (Tab. 7).

Tab. 5. Indices of similarity of fungi associated with different stages of decomposition.

	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
New*		0.4038	0.3927		0.4762	0.4437
Middle*			0.4437			0.4896
Old*						

* Newly fallen logs, middle stage decaying logs and old decaying fallen logs.

Tab. 6. Diversity indices of saprobic fungi on rubber logs in the late rainy season: January, dry season: April, early rainy season: July and rainy season: October.

Location/season	No. of fungi (species)			Total	Index (D)	Index (H)
	New*	Middle*	Old*			
Nakhon Si Thammarat						
Late rainy season	85	103	72	260	0.9961	5.4206
Dry season	88	107	80	275	0.9963	5.4385
Early rainy season	77	104	76	257	0.9956	5.1241
Rainy season	62	85	59	206	0.9954	5.0339
Songkhla						
Late rainy season	96	99	96	291	0.9955	5.3208
Dry season	99	103	95	297	0.9958	5.3753
Early rainy season	86	108	86	280	0.9952	5.2820
Rainy season	72	91	60	223	0.9939	5.0318

* Newly fallen logs, middle stage decaying logs and old decaying fallen logs.

Tab. 7. Indices of similarity of fungi associated with rubber logs versus season, late rainy season: January, dry season: April, early rainy season: July and rainy season: October.

Season	Nakhon Si Thammarat				Songkhla			
	Late rainy season	Dry season	Early rainy season	Rainy season	Late rainy season	Dry season	Early rainy season	Rainy season
Late rainy season	0.4925	0.3946	0.3476		0.4354	0.4028	0.3774	
Dry season		0.5009	0.4033			0.4367	0.4307	
Early rainy season			0.4147				0.4414	
Rainy season								

Discussion

Fungal diversity and colonization

This study represents one of the small number of studies to investigate the fungi occurring on decaying terrestrial wood logs in tropical regions and is the first study to address fungal diversity on *H. brasiliensis* wood logs in Thailand. Studies of fungi on terrestrial wood began in 1902 (Schumacher 1982). Recently studies of fungi on woody plant debris include those of Sihanonth *et al.* (1998), Chatanon (2001), Promputtha *et al.* (2004) and Kodsueb (2007) However, information of terrestrial lignicolous fungi is still poorly understood and need further study. Most studies fungi on decaying wood have been on unidentified terrestrial wood. This study focused on the fungal diversity on terrestrial rubber wood logs (≥10 cm diameter).

The fungal diversity on decaying logs of *H. brasiliensis* involved the identification of 461 species. The present study demonstrated a rich fungal diversity compared to that previously reported for fungi on decaying terrestrial wood logs. For instance, Huhndorf & Lodge (1997) found 157 taxa; Crites & Dale (1998): 19 taxa; Nordén & Paltto (2001): 140 taxa; Schmit (2005): 207 taxa; Küffer *et al.* (2008): 59 taxa; Ódor *et al.* (2006): 161 taxa and Iršėnaitė & Kutorga (2006): 203 taxa. In addition, when compared to the fungi on submerged wood; Tan *et al.* (1989) were found 20 taxa; Ho (1998): 222 taxa; Tsui (1999): 300 taxa; Sivichai *et al.* (2002): 58 taxa; Ho *et al.* (2002): 155 taxa; Maria & Shidhar (2004): 37 taxa and Van Ryckegem & Verbeken (2005): 46 taxa. The number of species recorded here is much larger.

Microfungi growing in decomposing plant debris are mostly vegetative or asexual (anamorph) reproducing states of ascomycetes. Three hundred and eighty four anamorphic fungi were recorded, comprising 226 taxa found on middle stage decaying logs, 206 taxa found on newly fallen logs and 199 taxa found in old decaying fallen logs. Fourty-six ascomycota were recorded including, 23 taxa found on newly fallen logs, 29 taxa found in middle stage decaying logs and 24 taxa found in old decaying fallen logs. Fourty-six basidiomycota were recorded, comprising 4 taxa found on newly fallen logs, 30 taxa found in middle stage decaying logs and 8 taxa found in old decaying fallen logs In this study anamorphic fungi were the dominant group and this is also in agreement with previous studies. Kodsueb *et al.* (2008) studied fungi on woody litter of *Magnolia liliifera* and *Michelia baillonii* and identified 239 fungal taxa comprising 143 anamorphic fungi, 92 ascomycetes and four basidiomycetes.

The fungal community structure and changes during three analogous decomposition stages (newly fallen logs, middle stage decaying logs and old decaying fallen logs) were studied. The results are similar to those found while investigating fungi on rubber leaf liter (Seep-

hueak *et al*. 2010) and branch litter (Seephueak *et al*. 2011) in previous studies, except that number of taxa on leaf and branch litter was higher than on logs. Boddy (1986) and Kodsueb *et al*. (2008a) reported that the higher diversity of fungi on woody litter may result from the longer decomposition period of wood when compared with that of leaves and woody litter (Küffer *et al*., 2008). Fungi have competitive abilities; they can grow successfully on wood along side other taxa or may dominate (Shearer 1992, Fryar *et al*. 2004). Generally, the composition of wood is quite different from other plant litter (i.e. leaves), with woody litter having high lignocellulose content and low nitrogen content so that few groups of fungi process the required enzymatic capabilities to digest wood (Singh 1982, Zare-Mairan & Shearer 1988, Abdullah & Taj-Aldee 1989, Wong *et al*. 1998, Bucher *et al*. 2004). However, the factors that rule certain saprobes to occur regularly or uniquely on a host are poorly understood (Zhou & Hyde 2001).

This is similar to the succession studies on rubber wood logs as according to Küffer *et al*. (2008), Schmit (2005), Heilmann-Clausen & Christensen (2003) studies fungi succession on wood logs showed that three distinct succession communities; the pioneer communities, mature communities and impoverished communities. The number of fungal species was highest during the mature community of wood decomposition than during either the pioneer community and the impoverished community, when the diversity and number of taxa decrease. Heilmann-Clausen & Christensen (2003) explained that, logs in intermediate stages of decay are most species rich and support the highest number species. Moreover, complex logs which have branches or twigs are more species rich than unforked logs with equal diameter (Heilmann-Clausen & Christensen 2003).

In this study, three methodologies were use to study fungal diversity on fallen rubber logs; a moist chamber technique, a dilution pourplate technique and a sporocarp survey. Four hundred and seven fungal taxa were recorded from the moist chamber technique, 40 taxa recorded by sporocarp survey and 19 taxa recorded from dilution pourplate. In this study, the moist chamber is one of the best techniques for revealing fungi on fallen logs according to previous studies (Huhndorf & Lodge 1997, Crites & Dale 1998, Kodsueb 2007).

Diameter and decomposition stage

Previous studies defined three woody debris categories: coarse woody debris, CWD (≥ 10 cm diameter), fine woody debris, FWD (5–9 cm diameter) and the very fine woody debris, VFWD (<5 cm diameter) (Küffer *et al*. 2008). However, in the present study, fungal diversity on woody rubber tree, the category limits are confined to wood logs (≥10 cm diameter). The assumption is the large woody debris and small woody debris support different fungal communities. In previous

studies, 497 fungal taxa were recorded on branch litter, while 461 taxa were found on wood logs. The importance of very small branches for fungal growth and fruiting were hitherto largely underestimated. They may have been simply overlooked or not taken into consideration. They have a low potential as a nutrient source for fungi and in addition an unfavorable surface-volume ratio, i.e. rather large surface, but minor nutrient content. On the other hand, one might argue that these rather large surfaces are more easily colonized by fungal species avoiding competition with other, more competitive species, since these small braches are only colonized by one single species at a time. (Küffer *et al*. 2008).

Kruys & Jonsson (1999) studied spruce logs with diameter < 10 cm and the fungal diversity species on these logs was greater than on logs with diameter > 10 cm, which is in accordance with our results. Similarly, Schiegg (2001), studied beech limbs (diameter < 10 cm) in comparison to beech trunks (diameter > 20 cm) and the species diversity decreased with decreasing wood size. Thus this seems to be a general phenomenon, which can be explained by considering two simple factors. Firstly, small diameter logs have a larger surface to volume area and may hence support more fungal sporocarps (or attract more insects) per volume unit, as compared to larger diameter logs (Kruys & Jonsson 1999). Secondly, the small diameter of coarse woody debris involves many more individual wood pieces per unit volume as compared to large diameter coarse woody debris. Thus, assemblages of small coarse woody debris will tend to have higher species density per volume unit. This is due to the stochastic nature of the colonization processes and occurs as long as the wood-inhabiting organisms are able to live in the smaller volumes in the small coarse woody debris (Heilmann-Clausen & Christensen 2003). However, the importance of large logs for maintenance of a defined set of specialised species is largely recognized (Heilmann-Clausen & Christensen 2004).

Decomposition rate of substrate

Rubber wood is a light hardwood, whose strength characteristics are comparable to those of commercial hardwoods of equal density. Rubber wood, however, has no distinct heartwood, and contains a large quantity of starch and is non-durable. Therefore, rubber wood is readily attacked by wood destroying insects and fungi. There is evidence, however, the rubber wood contains chitinases which protects if against fungal decay (Collinge *et al*. 1993, Bokma *et al*. 2000, Bokma *et al*. 2002).

Sap stain fungi, of which blue stain fungi are the most serious, attack rubber wood within a day of felling (Prance 1986). A common blue stain fungus is *Botryodiplodia* sp. occurring together with surface moulds, *Aspergillus* sp. and *Penicillium* sp. Blue stain fungi cause con-

siderable loss of strength in rubber wood. According to the present study, *Botryodiplodia* sp. was dominant and found at all decomposition stages. Besides, wood-rotting fungi i.e. *Lenzites elegan* and *Ganoderma* sp. were found on wood logs and rapidly destroy rubber wood.

The time taken for the decomposition of wood logs varies in different regions (Kane *et al*. 2002, Yanna *et al*. 2002, Tang *et al*. 2005). That the rate of decomposition of wood logs in temperate rain forest is slower than in other regions (Osono & Takeda 2001). The decomposition rate of plant substrates in the tropical rain forest is generally more rapid (Tang *et al*. 2005). The number of fungi obtained from several studies appears to vary dependant on the host species and the period of decomposition. Decomposition of woody litter differs between different species and age (Kodsueb *et al*. 2008a). For example, beech logs in Denmark took from 10 to more than 28 years to completely decay on the forest floor (Lange 1992). Woody litter of *Magnolia liliifera* took about 29 months for decaying (Kodsueb *et al*. 2008b). In the present study *H. brasiliensis* wood logs took about 24 months. Young wood samples decay markedly faster than the mature wood, while fewer fungi are obtained from young wood samples than from mature wood (Kodsueb *et al*. 2008b). The slowness of decaying of litter means a longer period of colonization and this may lead to the higher number of fungi being recovered during the present succession study.

Many factors however, can affect changes in the communities of fungi, such as physical and chemical properties of trees (Kodsueb *et al*. 2008a): type of wood, size, and age (Boddy & Watkinson 1995, Lodge 1997), macroclimate, microclimate and biological interaction within woody substrate effects of endophytes growing on living wood and leaf litter fungi that may thrive in wood it is dead.

Seasonality is one factor that is believed to affect the fungal community. Studies of the diversity of the fungi on plant litter usually suggest that the communities of fungi vary accord to the season (Kenney *et al*. 2006). In this study, the diversity of fungi that were recorded during the dry season tends to be greater in species richness and had a higher Shannon diversity index than the samples collected in wet season. The studied according to Rayner & Todd (1979), Kodsueb *et al*. (2007) and Seephueak *et al*. (2010) reported that there was a greater variety and number of fungi during the dry season. Nikolcheva & Bärlocher (2005) concluded that the presence or absence of aquatic hyphomycetes is regulated primarily by season and one can assume that this cause and effect chain operates through temperature. This may be due to an unsuitable ratio between moisture content and aeration of woody litter with extremely high moisture and low aeration during the wettest period. Another possible reason for this might be differences in humidity which vary within wet and dry seasons. Nevertheless, there is no evidence to clarify how the seasons affect communities.

The identification of fungi in this study is based on morphological characters and use of reference text and in most cases species are named because they are similar to species described in books and references. In several cases species identification was not possible and we identified taxa to genus level only. We acknowledge that several of the species we name are species complexes e.g. *Colletotrichum gloeosporioides* (Hyde *et al*. 2009, Phoulivong *et al*. 2010), however the account reveals the present of 461 distinct fungal taxa which are named as accurately as possible. As more and more verified and type taxa are deposited in GenBank, future studies should be able to use molecular data to accurately identify taxa and provide more details on the diversity of fungi on rubber logs. It would also be interesting to use direct sequencing of total DNA such as rDNA-ITS (Pinruan *et al*. 2010, Xie *et al*. 2010, Curlevski 2010) to estimate species numbers.

Acknowledgments

The authors would like to acknowledge the financial support provided by the Graduate School of Prince of Songkla University and by Rajamangala University of Technology Srivijaya.

References

Abdullah S.K., Taj-Aldee S.J. (1989). Extracellular enzymatic activity of aquatic and aeroaquatic condial fungi.*Hydrobiologia* **174**: 217–223.

Ainsworth G.C., Sparrow F.K. Sussman A.S. 1973. *The Fungi*. Academic Press. London.

Bader, P., Jansson, S. Jonsson, B.G. (1995). Wood-inhabiting fungi and substratum decline in selectivelyboreal spruce forests. *Biological Conservation* **72**: 355–362.

Barnett H.L. Hunter B.B. (1972). *Illustrated genera of imperfect fungi*. Burgess Publishing Company,Minnesota.

Bredesen B., Haugan R., Aanderaa R., Lindblad I., Økland B., Røsok, Ø. (1997). Wood- inhabiting fungi as indicators of continuity in spruce forests in eastern Norway. *Blyttia* **54**: 131–140.

Bills G., Dombrowski A., Peláez F., Polishook J. and An Z. (2002). *Recent and Future Discoveries ofPharmacologically Active Metabolites from Tropical Fungi*. In: *Tropical Mycology*, Vol.II *Micromycetes*(eds. Watling R., Frankland J. C., Ainsworth A.M., Isaac S., Robinson C.H.) CABI Publishing, Wallingford, UK: 165–194.

Boddy L. (1986). Wood as a venue for fungal activity: study of decomposition processes and communitydynamics. *Proceeding of IV International Symposium on Microbial Biology*: 394–400.

Boddy L. Watkinson S.C. (1995). Wood decomposition, higher fungi, and their role in nutrient redistribution.*Canadian Journal of Botany* **73**: 1377–1383.

Bokma E., Barends T., Terwisscha van Scheltinga A.C., Dijkstra B.W., Beintema J.J. (2000). Enzyme kinetics of hevamine, a chitinase from the rubber tree *Hevea brasiliensis*. *Federation of European Biochemical Societies Letters* **478**: 119–122.

Bokma E., Rozeboom H.J., Sibbald M., Dijkstra B.W., Beintema J.J. (2002). Expression and Characterization ofsite mutants of hevamine, a chitinase from the

rubber tree *Hevea brasiliensis*. *European Journal of Biochemistry* **269**: 893–901.
Bucher V.V.C., Hyde K.D., Pointing S.B., Reddy C.A. (2004). Production of wood decay enzymes, mass logs and lignin solubilization in wood by marine ascomycetes and their anamorphs. *Fungal Diversity* **15**: 1–14.
Bütler R., Patty L., Le Bayon R.C., Guenat C. and Schlaepfer R. (2007). Log decay of *Picea abies* in the Swiss Jura Mountains of central Europe. *Journal Forest Ecology and Management* **242**: 791–799.
Cai L., Hyde K.D., Tsui C.K.M. (2006). Genera of freshwater fungi. *Fungi Diversity Research Series* **17**: 275–324.
Chatanon L. (2001). *Biodiversity of ascomycetous fungi at Huai-Kha Khaeng Wildlife Sanctuary*. M.S. thesis. Kasetsart University, Thailand.
Collinge D.B., Kragh K.M., Mikkelsen J.D., Nielsen K.K., Rasmussen U. and Vad K. (1993). Plant chitinase. *Plant Journal* **3**: 31–40.
Crites S., Dale M.R.T. (1998). Diversity and abundance of bryophytes, lichens, and fungi in relation to woody substrate and successional stage in aspen mixed wood boreal forest. *Canadian Journal of Botany* **76**: 641–651.
Curlevski N.J.A., Xu Z.H., Anderson I.C., Cairney J.W.G. (2010). Diversity of soil and rhizosphere fungi under *Araucaria bidwillii* (Bunya pine) at an Australian tropical montane rainforest site. *Fungal Diversity* **40**: 12–22.
Domsch K.H., Gams W. (1980). *Compendium of soil fungi*. Academic Press. San Francisco, London. Duong L.M., McKenzie E.H.C., Lumyong S. and Hyde K.D. (2008). Fungal succession on senescent leavesof *Castanopsis diversifolia* in Doi Suthep-Pui National Park, Thailand. *Fungal Diversity* **30**: 23–36.
Eaton J.M., Lawrence D. (2006). Woody debris stocks and fluxes during succession in a dry tropical forest. *Journal Forest Ecology and Management* **232**: 46–55.
Ellis M.B. (1971). *Dematiaceous Hyphomycetes*. Commonwealth Mycologial Institute, Kew.
Ellis M.B. (1976). *More Dematiaceous Hyphomycetes*. Commonwealth Mycological Institute, Kew.
Ellis M.B., Ellis J.P. (1997). *Microfungi on Land Plants*. The Richmond Publishing, England.
Fryar S.C., Davies J., Booth W., Hyde K.D., Hodgkiss J.J. (2004). Succession of fungi on dead and live wood in brackish in Brunei. *Mycologia* **96**: 219–225.
Grove S.J. (2002). Saproxylic insect ecology and the subtainable management of forest. *Annual Review of Ecology, Evolution, and Systematics* **33**: 1–23.
Harmon L. Knudsen H. (2000). *Nordic Macromycetes Ascomycetes*. Vol. 1 Nordsvamp, Copenhagen, Denmark. Heilmann-Clausen J., Christensen M. (2003). Fungal diversity on decaying beech logs- implication for sustainable forestry. *Biodiversity and Conservation* **12**: 953–973.
Heilmann-Clausen J., Christensen M. (2004). Does size matter? on the importance of various dead wood fraction for fungal diversity in danish beech forests. *Journal Forest Ecology and Management* **201**: 105–117.
Heilmann-Clausen J., Christensen M. (2005). Wood-inhabition macrofungi on danish beech forest-conflicting diversity patterns and their implications in a conservation perspective. *Journal Biological Conservation* **122**: 633–642.
Ho W.H. (1998). *Biodiversity, ecological and ultrastructural observations of fungi on wood submerged in tropical streams*. Ph.D. thesis. The University of Hong Kong. Hong Kong.
Ho W.H., Yanna, Hyde K.D., Hodgkiss I.J. (2002). Seasonality and sequential occurrence of fungi on wood submerged in Toi Po Kau Forest Stream, Hong Kong. *Fungal Diversity* **8**: 21–43.
Huhndorf S.M., Lodge D.J. (1997). Host specificity among wood-inhabiting pyrenomycetes (fungi, ascomycetes) in a wet tropical forest in Puerto Rico. *Tropical Ecology* **38**: 307–315.

Hyde K.D., Taylor J.E., Frohlich J. (2000). Genera of ascomycetes from palms. *Fungal Diversity Research Series* **2**: 1–247.

Hyde K.D., Cai L., McKenzie E.H.C., Yang Y.L., Zhang J.Z., Prihastuti H. (2009). *Colletotrichum*: a catalogue of confusion. *Fungal Diversity* **39**: 1–17.

Inderbitzin P., Berbee M.L. (2001). *Lollipopaia minuta* from Thailand, a new genus and species of the Diaporthales (ascomycetes, fungi) based on morphological and molecular data. *Canadian Journal of Botany* **79**: 1099–1106.

Inderbitzin P., Landvik S., Abdel-Wahab M.A., Berbee M.L. (2001). Aliquandostipitaceae, a new family for two new tropical ascomycetes with unusually wide hyphae and dimorphic ascomata. *American Journal of Botany* **88**: 52–61.

Iršėnaitė R., Kutorga E. (2006). Diversity of fungi on decaying common oak coarse. *Ekologija* **4**: 22–30.

Kane D.F., Tam W.Y., Jones E.B.G. (2002). *Fungi colonizing and sporulation on submerged wood in the River Severn, UK*. In: *Fungal Succession* (eds. Hyde K.D., Jones E.B.G.) *Fungal Diversity* **10**: 45–55.

Kenney N., Brodie E., Connolly J., Clipson N. (2006). Seasonal influences on fungal community structure in unimproved and improved upland grassland soils. *Canadian Journal Microbiology* **52**: 689–694.

Kiffer E., Morelet M. (1999). *The Deuteromycetes*. Science Publishers, USA.

Kodsueb R. (2007). *Biodiversity of saprobic fungi on woody litter*. Ph.D. thesis. Chiang Mai University, Thailand.

Kodsueb R., McKenzie E.H.C., Ho W.H., Hyde K.D., Lumyong P., Lumyong S. (2007). New anamorphic fungi from decaying wood litter of *Michelia baillonii* (Magnoliaceae) in northern Thailand. *Crytogamie Mycologie* **28**: 237–245.

Kodsueb R., McKenzie E.H.C., Lumyoung S. Hyde K.D. (2008a). Diversity of saprobic fungi on *Magnoliaceae*. *Fungal Diversity* **30**: 37–53.

Kodsueb R., McKenzie E.H.C., Lamyong S., Hyde K.D. (2008b). Fungal succession on woody litter of *Magnolia liliifera* (Magnoliaceae). *Fungal Diversity* **30**: 55–72.

Krankina O.N., Harmon M.E. (1995). Dynamics of dead wood carbon pool in northwestern Russian boreal forest. *Water Air and Soil Pollution* 227–238.

Krankina O.N., Harmon M.E., Griazkin A.V. (1999). Nutrient stores and dynamics of woody detritus in a boreal forest: modeling potential implication at stand level. *Canadian Journal Forest Research* **29**: 20–32.

Kruys N., Jonsson B.G. (1999). Fine woody debris is important of species richness on logs in managed boreal spruce forest of northern Sweden. *Canadian Journal Forest Research* **29**: 1295–1299.

Kubicek C.P., Harman G.E. (1998). *Trichoderma and Gliocladium*. Volume I. Taylor and Francis, UK.

Küffer N., Senn-Irlet B. (2005). Diversity and ecology of wood-inhabiting apphyllophoroid basidiomycetes on fallen woody debris in various forest types in Switzerland. *Mycological Progress* **4**: 77–86.

Küffer N., Gillet F., Senn-Irlet B., Aragno M., Job D. (2008). Ecological determinant of fungal diversity on dead wood in European forests. *Fungal Diversity* **30**: 83–95.

Lambert R.L., Lang G.E., Reiners W.A. (1980). Loss of mass and chemical change in decaying boles of a subalpine balsam fir forest. *Ecology* **61**: 1460–1473.

Lange M. (1992). Sequence of macromycetes on decaying beech logs. *Persoonia* **14**: 449–456.

Lindbald J. (1998). Wood-inhabiting fungi on fallen logs of *Norway spruce*: relations to forest management and substrate quality. *Nordic Journal of Botany* **18**: 243–255.

Lodge D.J. (1997). Factors related to diversity of decomposer fungi in tropical forests. *Biodiversity and Conservation* **6**: 681–688.

Lumley T.C., Abbott S.P., Currah R.S. (2000). Microscopic ascomycetes isolated from rotting wood in the boreal forest. *Mycotoxon* **74**: 395–414.

Maria G.L., Sridhar K.R. (2004). Fungal colonization of immersed wood in mangroves of the southwest coast of India. *Canadian Journal of Botany* **82**: 1409–1418.

Moore J.C., Berlow E.L., Coleman D.C., De Ruiter P.C., Dong Q., Hastings A., Johnson N.C., McCann K.S., Melville K., Morin P.J., Nadelhoffer K., Rosemond A.D., Post D.M., Sabo J.L., Scow K.M., Vanni M.J., Wall D.H. (2004). Detritus, trophic dynamics and biodiversity. *Ecological Letters* **7**: 584–600.

Nikolcheva L.G., Bärlocher F. (2005). Seasonal and substrate preferences of fungi colonizing leaves in streams: traditional versus molecular evidence. *Applied and environmental microbiology* **7**: 270–280.

Nordén B., Paltto H. (2001). Wood-decay fungi in hazel wood: species richness correlated to stand age and dead wood features. *Journal Biological Conservation* **101**: 1–8.

Ódor P., Heilman-Clausen J., Christensen M., Aude E., Van Dort K.W., Piltaver A., Siller, I., Veerkamp M.T., Walleyn R., Standovar T., Van Hees A.F.M., Kosec J., Matocec N., Kraigher H., Grebenc T. (2006). Diversity of dead wood inhibiting fungi and bryophytes in semi-nutral beech forest in Europe. *Journal Biological and Conservation* **131**: 58–71.

Osono T., Takeda H. (2001). Organic chemical and nutrient dynamics in decomposing beech leaf litter in relation to fungal in growth and succession during 3-year decomposition processes in a cool temperate deciduous forest in Japan. *Ecological Research* **16**: 649–670.

Phoulivong S., Cai L., Chen H., McKenzie E.H.C., Abdelsalam K., Chukeatirote E., Hyde K.D. 2010. *Colletotrichum gloeosporioides* is not a common pathogen on tropical fruits. *Fungal Diversity* **44**: 33–43.

Pinruan U., Hyde K.D., Lumyong S., McKenzie E.H.C., Jones E.B.G. (2007). Occurrence of fungi on tissues of the peat swamp palm *Licuala longicalycata*. *Fungal Diversity* **25**: 157–173.

Pinruan U., Rungjindamai N., Choeyklin R., Lumyong S., Hyde K.D., Jones E.B.G. 2010. Occurrence and diversity of basidiomycetous endophytes from the oil palm, *Elaeis guineensis* in Thailand. *Fungal Diversity* **41**: 71–88.

Pointing S.B., Hyde K.D. (2001). Bio-explotation of filamentous fungi. *Fungal Diversity Research Series* 6: 1–467.

Prance G.T. (1986). Preservation of timber in the tropics. *Brittonia* **38**: 101–188.

Promputtha I., Lumyong S., Lumyong P., McKenzie E.H.C., Hyde K.D. (2004). Fungal saprobes on dead leaves of *Magnolia liliifera* (*Magnoliaceae*) in Thailand. *Crytogamie Mycologie* **25**: 315–321.

Ramirez C. (1982). *Manual and Atlas of the Penicillia*. Elsevier Biomedical Press. New York, Oxford.

Rayner A.D.M., Todd N.K. (1979). Population and community structure and dynamics of fungi in decaying wood. *Journal Botanical Research* **7**: 333–420.

Schiegg K. (2001). Saproxylic insect diversity of beech: limbs are richer than trunks. *Journal Forest Ecology and Management* **149**: 295–304.

Schmit J.P. (2005). Species richness of tropical wood-inhabiting macrofungi provides support for species-energy theory. *Mycologia* **97**: 751–761.

Schumacher T. (1982). Ascomycetes from northern Thailand. *Nordic Journal of Botany* **2**: 257–263.

Seephueak P., Petcharat P., Phongpaichit S. (2010). Fungi associated with degrading leaf litter of para rubber (*Hevea brasiliensis*). *Mycology* 1: 213–227.

Seephueak P., Phongpaichit S., Hyde K. D. & Petcharat P. (2011). Diversity of saprobic fungi on decaying branch litter of the rubber tree (*Hevea brasiliensis*). *Mycosphere* **2**: 307–330.

Shearer C.A. (1992). The role of wood debris. In: The Ecology of Aquatic Hyphomycetes. (ed Bärlocher F.) Ecological Studies 94. Springer-Verlag, Berlin: 77–98.
Sihanonth P., Thienhirun S., Whalley A.J.S. (1998). Entonaema in Thailand. *Mycological Research* **102**: 458–460.
Siitonen J. (2001). Forest management, coarse woody debris and saproxylic organisms: fennoscandian boreal forests as an example. *Ecological Bulletin* **49**: 11–41.
Singh N. (1982). Cellulose decomposition by some tropical aquatic hyphomycetes. *Transactions British Mycological Society* **79**: 560–561.
Sivichai S., Jones E.B.G., Ht-Jone N.L. (2002). Fungal colonization of wood in a freshwater stream at Tod Ta Phu, Khao Yao National Park, Thailand. *Fungal Diversity* **10**: 113–129.
Sollins P., Cline S.P., Verhoeven T., Sachs D., Spycher G. (1978). Patterns of log decay in old-growth douglas-fir forest. *Canadian Journal of Forest Research* **17**: 1585–1595.
Tan-ar-sa, A. (1998). *Diversity of sac fungi in the class discomycetes in Doi Suthep-Pui National Park*. M.S. thesis. Chiang Mai University, Thailand.
Tan T.K., Leong W.F., Jones E.B.G. (1989). Succession of fungi on wood of *Avicennia alba* and *A. lanata* in Singapore. *Canadian Journal of Botany* **67**: 2687–2691.
Tang A.M.C., Jeewon R., Hyde K.D. (2005). Succession of microfungal communities on decaying leaves of *Castanopsis fissa*. *Canadian Journal of Microbiology* **51**: 967–974.
Temnuhin V.B. (1996). Preliminary quantitative estimation of wood decomposition by fungi in a Russian temperate pine forest. *Journal Forest Ecology and Management* **81**: 249–257.
Thongkantha S., Lumyong S., McKenzie E.H.C., Hyde K.D. (2008). Fungal saprobed and pathogens occurrence on tissues of *Dracaena loureiri* and *Pandanus* spp. *Fungal Diversity* **30**: 149–179.
Tsui C.K.M. (1999). *Biodiversity and longitudinal distribution of fungi on submerged wood, with reference to human disturbance*. Ph.D. thesis. The University of Hong Kong. Hong Kong.
Tsui C.K.M., Hyde K.D. 2003. Freshwater Mycology. *Fungal Diversity Research Series* **10**: 1–350.
Van Ryckegem G., Verbeken A. (2005). Fungal ecology and succession on *Phragmites australis* in a brackish tidal marsh. I. Leaf sheaths. *Fungal Diversity* **19**: 157–187.
Wong M.K.M., Goh T.K., Hodgkiss I.J., Hyde K.D, Ranghoo V.M., Tsui C.K.M., Ho W.H., Wong W.S.W., Yuen T. (1998). Role of fungi in freshwater ecosystem. *Biodiversity and Conservation* **7**: 1187–1206.
Wu W.P., Zhuang W. (2005). *Sporidesmium*, *Endophragmiella* and related genera from China. *Fungal Diversity Research Series* **15**: 1–351.
Xie L., Zhang J.Z., Cai L., Hyde K.D. (2010). Biology of *Colletotrichum horii*, the causal agent of persimmon anthracnose. *Mycology* **1**: 242–253.
Yanna, Ho W.H., Hyde K.D. (2002). Fungal succession on fronds of *Phoenix hanceana* in Hong Kong. *Fungal Diversity* **10**: 185–211.
Yin X. (1999). The decay of forest woody debris: numerical modeling and implications based on some 300 data cases from north America. *Oecologia* 81–98.
Zare-Mairan H., Shearer C.A. (1988). Extracellular enzyme production and cell wall degradation by freshwater lignicolous fungi. *Mycologia* **80**: 365–375.
Zhou D., Hyde K.D. (2001). Host-specificity, host-exclusivity, and host-recurrence in saprobic fungi. *Mycological Research* **105**: 1449–1457.

(Manuscript accepted 29 November 2011; Corresponding Editor: M. Kirchmair)