Diversity of saprobic fungi on decaying branch litter of the rubber tree (*Hevea brasiliensis*)

Seephueak P[1*], Phongpaichit S[2], Hyde KD[3] and Petcharat V[4]

[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]Department of Pest Management, Faculty of Natural Resources, Prince of Songkla University, Hat Yai Campus, Songkhla, 90112, Thailand

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The diversity of fungi associated with the degradation of rubber branch litter (*Hevea brasiliensis*) was studied. Samples were collected during four periods in 2010 – January (late rainy season), April (dry season), July (early rainy season) and October (rainy season) in Nakhon Si Thammarat and Songkhla Provinces, southern Thailand. Samples were classified as newly fallen branches, middle stage decaying branches and old decaying fallen branches. Moist chamber, dilution plate and sporocarp survey methodologies were used to detect the fungi. Fungal identification was based on morphological examination under compound and stereo microscopes. In total, 497 species of fungi were identified from the decaying branches, comprising 400 anamorphic taxa, 61 ascomycota, 34 basidiomycota, 1 oomycota and 1 zygomycota. *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Hypoxylon* sp.1, *Hypoxylon* sp.2, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Pestalosphaeria hansenii*, *Schizophyllum commune*, *Torula herbarum* and *Veronaea carlinae* were the dominant species occurring at all stages of decomposition. *Bactrodesmium rahmii*, *Kirschsteiniothelia* sp. and *Lasiodioplodia* cf. *theobromae* were the dominant species occurring during all seasons.

Key words – decomposition – lignicolous fungi – plant litter – rubber tree

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*Corresponding author: Seephueak P – e-mail – spornsil@gmail.com

Introduction

The rubber tree (*Hevea brasiliensis*, Euphorbiaceae) is the main cultivated plant of southern Thailand. A total of 2,019,006 hectares are cultivated in Thailand, yielding 3,051,781 tonnes/year, and of these, 1,699,381 hectares (84.2%) are cultivated in south Thailand (Office of Agricultural Economics 2011). Chemical composition of rubber wood including 77.8% hemicelluloses, 39.7% cellulose and 17.8% lignin (Simatupang & Schmitt 1992). Since the rubber plantations are monoculture, the ecological components differ to the forest in terms of nutrient cycling and soil conservation (Gazia & Chaverri 2010). Dead wood is one of the most important components of ecosystems in rubber plantations, on which many different organisms such as insects, scavengers, bacteria, protozoa and fungi depend (Lonsdale et al. 2008). In addition, dead wood can reduce erosion, increase soil organic matter, store carbon and serve as a reserve of nutrients and water (Boddy & Watkinson 1995).

Fungi are among the major wood-decaying organisms and they play an important role in the nutrient cycle in rubber plantations. The great variability of many characteristics of the dead woody debris seems to be a major factor contributing to fungal biodiversity by creating a wide range of ecological niches. Variety of volumes and diameters of branches, i.e. logs, branches or twigs, and the degree of decomposition tend to favour species-rich fungal communities (Heilmann-Clausen & Christensen 2003, Küffer et al. 2004).

Tree litter can be divided into three categories: leaf litter, branch litter (1–5 cm diameter), logs (≥10 cm diameter). There have been few studies of fungal communities on twig litter or branch litter. Most studies of biodiversity on dead wood focus on course woody debris i.e., wood litter with a minimum diameter of 10 cm (Schiegg 2001). Fine woody debris and very fine woody debris such as branches and twigs are rarely studied. However, significant quantities of dead wood are often found in the form of fine and very fine woody debris (Küffer & Senn-Irlet 2005). Fungal diversity on decaying twig and branch litter of various trees has been previously studied, e.g. *Fraxinus excelsior* (Boddy et al. 1987), *Corylus avellana* (Nordén & Paltto 2001), beech (Küffer et al. 2004), *Picea abies* (Allmér 2005), *Fagus sylvatica*, *Picea abies*, *Abies alba*, *Pinus sylvestris* and *Castanea sativa* (Küffer & Senn-Irlet 2005), *Pinus nigra*, *P. pinaster*, *P. sylvestris* and *P. uncinata* plantation (Zamora et al. 2008), and *Magnolia liliifera* (Kodsueb et al. 2008a).

Our study is the first on fungi associated with branch litter of rubber trees in southern Thailand. In a previous study 447 species of fungi, (comprising 405 anamorphic taxa, 38 ascomycetes, 1 basidiomycete, 1 oomycete and 2 zygomycetes) were discovered on rubber tree leaf litter (Seephueak et al. 2010).

In this paper the focus is on fungi on very fine woody debris and fallen branches (1–5 cm diameter). The purpose of this study was to assess the diversity and distribution of saprobic fungi on rubber branch litter at each stage of decay, namely, newly fallen branches, middle stage and old stage decaying branches, and to evaluate the fungal communities involved in litter decay at each stage.

Methods

Branch samples were collected in January, April, July and October 2010. Based on the degree of decomposition and external appearance each sample was divided into three groups: 1) wood hard and bark present, 2) middle stage decaying branches, with bark absent and the wood softening but still maintaining its structural integrity, and 3) old decaying fallen branches, with branch soft and losing its integrity (Schmit 2005).

Study sites

The study was conducted at two, 25 year old rubber plantations (variety RRIM 600) in Nakhon Si Thammarat and Songkhla Provinces, in southern Thailand. 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 a dry season (February to April) and a rainy season (May to January).

Songkhla Province is located on the eastern coast of southern Thailand, at latitudes 6°17'–7°56'N and longitudes 100°01'–101° 06'E. 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. Total rainfall in 2010 in southern Thailand was 1965.3 mm. and temperatures averaged 28.0°C.

Sampling design

The first collection was made in January, which was late in the rainy season, and the temperature averaged 26.6°C and the rainfall totalled 175.4 mm in Nakhon Si Thammarat Province. In Songkhla Province the temperature was 27.6°C and the rainfall 68.3 mm. The second collection occurred during April, in the dry season when the temperature averaged 29.7°C in Nakhon Si Thammarat Province and 29.8°C in Songkhla Province; no rainfall was recorded. The third collection was in July which is in the early rainy season and had a temperature of 27.9°C in Nakhon Si Thammarat Province and 28.2°C in Songkhla Province. The rainfall was recorded as 115.5 mm in Songkhla Province and 132.0 mm in Nakhon Si Thammarat Province. The fourth collection was in October which is in the rainy season, the

temperature was 27.1°C in Nakhon Si Thammarat and 27.8°C in Songkhla Province. The rainfall was recorded as 272.2 mm in Nakhon Si Thammarat and 399.0 mm in Songkhla Province.

50 m^2 sites were marked out in each rubber plantation and collected 72 branches representing all stages of decay were selected from the litter. They were placed in separate Ziplock plastic bags and taken to the laboratory for treatment within 24 hours.

Incubation, observation and isolation of fungi

Moist chamber, dilution-plate and sporocarp surveys were used to study the fungi. In the moist chamber technique, all branches were cut into 5 cm long sections, varying in diameter from 1 to 5 cm for observation and incubated in moistened plastic boxes at room temperature (28–32°C). The fungi present on the samples were examined after 24 hour of incubation and examined daily for up to 7 days. The fungal colonies were lifted from the branch surface by cellophane tape and mounted on slides using lactophenol. For dilution-plate method, 10 g of 4 branch litter were chopped with a sterile knife, and blended for 3 min in 100 mL of sterile water. From this initial suspension, 1 mL of 1×10^{-3} serial dilution was pipetted into each of four replicates of glucose ammonium nitrate agar (GANA) with streptomycin sulfate (300 µg/mL), which was cooled to 45°C, and poured into Petri dishes. The dishes were incubated at room temperature for 2–3 days and then examined for fungal growth. For the sporocarp surveys were collected in 50 m^2 in each rubber plantation, 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 was based on morphology following examination stereo and compound microscopes.

Definition and statistical analyses

Fungal species were recorded as either present or absent from each stage of branch litter decomposition. The number of branches on which a fungal species was found was used to calculate the percentage occurrence of a species in branches of each stage of decomposition and analyzed 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 branch samples on which each fungus was detected/ total number of branch samples examined) × 100%. Fungal taxa with a percentage occurrence equal to or higher than 10% were regarded as a 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 $H = -\Sigma PilnPi$, where Pi is the frequency of fungal species i occurring on specific branch stage or season. Values of the Shannon diversity index for real communities are often found to fall between 1 and 6. Simpson's index $D = 1-\Sigma [n_i/(n_i-1)/N/(N-1)]$, where n_i 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 branches at different stages of decay and in 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 by the three methods used to examine the fungal communities on branch litter. Out of a total of 497 species, 427 fungal taxa (85.9%) were recorded by moist chamber technique, 45 (9.1%) were detected by sporocarp survey and 41 (8.1%) by dilution plate technique. The 497 taxa comprised 400 anamorphic fungi, 61 ascomycota, 34 basidiomycota, 1 oomycota and 1 zygomycota (Table 1).

Fungal succession on *H. brasiliensis* branches on the plantation floor showed differences in fungal composition between the

various decaying branch stages and differences due to variation of season. A total of 266 species were found in newly fallen branches, 302 species were found in middle stage decaying branches and 253 species were found in old decaying fallen branches. In both provinces, it was found that 69 species (40.8%) were overlapping in newly fallen branches, 83 species (42.9%) were overlapping in middle stage decaying branches and 71 species (42.8%) were overlapping in old decaying fallen branches.

The 358 fungal taxa found in Nakhon Si Thammarat Province included 287 anamorphic taxa, 52 ascomycota, 17 basidiomycota, 1 zygomycota and 1 oomycota. One hundred and eighty taxa were recorded from newly fallen branches, 199 from middle stage decaying branches and 175 species were recorded from old decaying fallen branches.

In Songkhla Province, 312 fungal taxa were found including 259 anamorphic taxa, 27 basidiomycota, 25 ascomycota and 1 oomycota. One hundred and fifty-eight taxa were recorded from newly fallen branches, 188 from middle stage decaying branches and 157 taxa from old decaying fallen branches.

Twenty-nine taxa were common to both provinces and to all stages of decomposition: *Acremonium strictum*, *Actinocladium rhodosporum*, *Bactrodesmium rahmii*, *B. spilomeum*, *Botryodiplodia* sp., *Cladosporium tenuissimum*, *Curvularia lunata*, *Dactylaria* sp. 1, *Dactylaria hyalina*, *Diplococcium spicatum*, *Fusarium* sp. 1, *Fusarium* sp. 2, *Hypoxylon* sp. 1, *Hypoxylon* sp. 2, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Penicillium* sp. 1, *Pestalosphaeria hansenii*, *Pseudospiropes obclavatus*, *Schizophyllum commune*, *Speriopsis hyalospora*, *Sporidesmium flagellatum*, *Subulispora procurvata*, *Tetraploa aristata*, *Thyridaria sambucina*, *Torula herbarum* and *Veronaea carlinae*. Fifty-six taxa of fungi were found in all stages of decomposition in Nakhon Si Thammarat Province and 55 in Songkhla Province.

Species richness and the dominant fungi

The dominant fungi on the rubber branch litter, with over 10% occurrence in each stage of decomposition and in each season in Nakhon Si Thammarat and Songkhla provinces are shown in Tables 2 and 3. Anamorphic fungi (400 taxa) were the dominant group, followed by ascomycota (61 taxa), basidiomycota (34 taxa), oomycota (1 taxa) and zygomycota (1 taxa).

The dominant fungi were found in all seasons and at every stage of decomposition. In Nakhon Si Thammarat Province, *Kirschsteiniothelia* sp. and *Lasiodiplodia* cf. *theobromae* were the dominant species occurring on newly fallen branches. Three species, *Kirschsteiniothelia* sp., *Bactrodesmium rahmii* and *Lasiodiplodia* cf. *theobromae* were the dominant species occurring in middle stage decaying. Two species, *Kirschsteiniothelia* sp. and *Lasiodiplodia* cf. *theobromae* were the dominant species occurring in old decaying fallen branches. In Songkhla Province, two species, *Bactrodesmium rahmii* and *Kirschsteiniothelia* sp. were the dominant species occurring on newly fallen branches. Four species, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Kirschsteiniothelia* sp. and *Pestalosphaeria hansenii* were the dominant species occurring in middle stage decaying litter. Two species, *Bactrodesmium rahmii* and *Pyriculariopsis parasitica* were dominant on old fallen branches.

In Nakhon Si Thammarat Province two species, *Kirschsteiniothelia* sp. and *Lasiodiplodia* cf. *theobromae* were the dominant species during the late rainy season. Three species, *Bactrodesmium rahmii*, *Kirschsteiniothelia* sp. and *Nigrospora sphaerica* were the dominant species in the dry season. Two species, *Lasiodiplodia* cf. *theobromae* and *Kirschsteiniothelia* sp. were the dominant species in the early rainy season and rainy season. In Songkhla Province six species, *Bactrodesmium rahmii*, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Torula herbarum* and *Pyriculariopsis parasitica* were the dominant species in late rainy season. Three species, *Bactrodesmium rahmii*, *Kirschsteiniothelia* sp. and *Lasiodiplodia* cf. *theobromae* were the dominant species in the dry season. Two species, *Bactrodesmium rahmii* and *Lasiodiplodia* cf. *theobromae* were the dominant species during the early rainy season and three species, *Botryodiplodia* sp., *Bactrodesmium rahmii* and *Kirschsteiniothelia* sp. were the dominant species during the rainy season.

Table 1 Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota						
Acrophialophora fusispora		2.1				
Anthostomella formosa					8.3	8.3
Astrosphaeriella sp. 1		6.3				
Astrosphaeriella sp. 2				2.1	6.3	
Boerlagiomyces grandisporus		6.3				
Botryosphearia sp.		14.6				
Bulgaria mexicana						4.2
Ceratocystis ulmi			2.1			
Chaetomium sp. 1	2.1					2.1
Chaetomium sp. 2			4.2			
Claussenomyces atrovirens		4.2		2.1	29.2	10.4
Cookeina sulcipes			8.3			
Daldinia escholzii			4.2			
Dothidotthia sp. 1	6.3	2.1		8.3		
Dothidotthia sp. 2	6.3					
Dothiorella sp.	2.1		2.1			
Eupenicillium sp.		2.1				
E. brefeldianum			6.3			
E. javanicum	2.1					
Gaeumannomyces graminis			4.2			
Glomerella cingulata	6.3			2.1	12.5	2.1
Gnomonia creastris	2.1					
Hypocrea pezizoidea		8.3		2.1		
H. rufa	2.1		10.4			
H. splendens	8.3			25.0		
Hypoxylon sp. 1	18.8	18.7	14.6	52.1	50.0	33. 3
Hypoxylon sp. 2	18.8	27.1	22.9	18.8	12.5	25.0
Hypoxylon sp. 3	22.9	6.3	18.8			
Hypoxylon sp. 4	12.5	18.8	10.4			
Hypoxylon sp. 5	6.3	4.2				
Kirschsteiniothelia sp.[1/]	81.3	68.8	45.8	60.4	62.5	50.0
Leptosphaeria blumeri		4.2				
L. cercocarpi		16.7				
L. conoidea	6.3					
L. darkeri						4.2
L. millefolii		8.3				
L. russellii			12.5			
Linocarpon sp.		4.2		10.4	12.5	18.8
Linodochium hyalinum			4.2			
Linospora sp.			4.2		12.5	18.8
Lophiostoma fuckelii			2.1			
Lophodermium sp.					6.3	
Nectria pseudotrichia					2.1	
Orbilia sp.		2.1				
Oxydothis sp.		2.1	4.2	2.1	8.3	
Pestalosphaeria hansenii	18.8	16.8	22.9	25.0	58.3	20.8
Phaeosphaeria sp.		6.3				
Plectosphaerella cucumerina					6.3	
Pleospora sp.		2.1				
Stegopeziza dumeti	2.1					
Thyridaria sambucina	6.3	14.6	2.1	6.3	18.8	18.8
Trematosphaeria pertusa		12.5	8.3	4.2	10.4	6.3

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Typhula ishikariensis		2.1				
Xylaria sp. 1					6.3	
Xylaria sp. 2			2.1			
Xylaria sp. 3		2.1				
Xylaria sp. 4		2.1				
X. caespitulosa			6.3			
X. hypoxylon		8.3		8.3		
X. hypsipoda					8.3	
X. multiplex			4.2			
Basidiomycota						
Aleurodiscus mirabilis		8.3				
A. oakesii					4.2	
Auricularia sp.				4.2	8.3	
A. auricula		8.3	6.3		4.2	
A. fuscosuccinia						4.2
A. polytricha			4.2		8.3	4.2
Claudopus repens					4.2	
Coriolus hirsutus		2.1				
Dacryopinax spathularia		4.2				
Hexagonia apiaria			6.3			
H. tenuis		10.4	6.3	12.5	16.7	16.7
Irpex flavus			4.2			
Lactarius hygrophoides			8.3		8.3	
Lentinus connatus					8.3	
L. similis						4.2
Lenzites elegan		8.3				8.3
Marasmiellus candidus						8.3
Marasmius sp.					4.2	
M. arborescens						8.3
M. conicopapillatua						4.2
M. florideus						4.2
M. micraster						4.2
M. pulcherripes						4.2
M. siccus						4.2
Meruliopsis corium					4.2	2.1
Mycena stylobates			8.3			
Podoscypha nitidula			8.3			
Polyporus retirugis			4.2		2.1	
Pycnoporus lignosus		8.3				
P. sanguineus		8.3			4.2	2.1
Schizophyllum commune	35.4	43.8	75.0	16.7	16.7	43.8
Trametes scabosa		4.2	6.3			4.2
Tremella fuciformis				8.3	8.3	
Xeromphalina campanella						4.2
Anamorphic fungi						
Acarocybe sp.				10.4		
A. deightonii				8.3		
A. formosa	2.1			39.6	33.3	
A. hansfordii	6.3	2.1		20.8		27.1
A. jasminicola		2.1	20.8	8.3	6.3	
Acladium conspersum			4.2			
Acremonium sp.1	4.2		4.2	12.5	14.6	
Acremonium sp.2				2.1		

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Acremonium sp. 3				2.1		
A. butyri[1/]		20.8	10.4			8.3
A. cerealis					22.9	14.6
A. fusidiodes			6.3	6.3	14.6	18.8
A. kiliense[1/]				4.2	29.2	4.2
A. murorum				2.1	2.1	12.5
A. strictum	8.3	2.1	2.1	10.4	4.2	27.1
Acrodictys sp.		4.2			6.3	
A. fuliginosa				10.4		
Acrophialophora fusispora		2.1				
Acrostaurus turneri				6.3	2.1	
Actinocladium rhodosporum	8.3	10.4	33.3	10.4	12.5	14.6
Actinospora megalospora	2.1					
Annellophora dendrographii	4.2					
Anthina sp.	6.3					
Arthinium muelleri				2.1		
Arthrobotryum atrocephalum			20.8			
Arthrocladium caudatum		6.3				
Articulospora tetracladia		2.1	10.4		4.2	4.2
Aspergillus sp.1[1/]	4.2	8.3		4.2	8.3	6.3
Aspergillus sp.2[1/]			2.1			6.3
Aspergillus sp.3[1/]				16.7	16.7	4.2
Aspergillus sp.4[1/]				4.2		
Aspergillus sp.5[1/]		8.3	8.3			
Aspergillus sp.6[1/]						4.2
A. moringae[1/]		4.2				
A. niger[1/]				16.7	8.3	
Asteroma coryli		6.3				
Aureobasidium sp.						2.1
Bactrodesmium sp.					20.8	
B. betulicola				50.0	27.1	2.1
B. pallidum		8.3		25.0	16.7	
B. rahmii	29.2	47.9	79.2	52.1	72.9	47.9
B. spilomeum	8.3	2.1	2.1	68.8	43.8	25.0
Beltraniella pirozynkii					4.2	2.1
Berkleasmium concinnum	8.3	4.2			6.3	
B. cf. *minutissimum*	2.1	2.1			2.1	
Bidenticula cannae			6.3			8.3
Bipolaris sp.	2.1		10.4			
B. australiensis	8.3					
B. biseptata	8.3					
B. cactivora			14.6			
B. dematioidea	2.1					
B. ellisii				12.5	18.8	
B. erythrospila					6.3	
B. heveae	8.3					
B. indica				10.4		
B. phlei	2.1					
B. ravenelii	4.2					4.2
Bispora antennata						8.3
Botryodiplodia sp.	18.8	10.4	20.8	60.4	89.6	35.4
Botryotrichum sp.			2.1			
Brachiosphaera tropicalis	2.1					

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Brachydesmiella biseptata		2.1		4.2		12.5
B. musifomis					4.2	
Brachyhelicoon xylogenum					2.08	
Brachysporiella gayana	25.0	16.7	2.1		4.2	14.6
B. laxa			8.3			
Brachysporium sp.	10.4				6.3	
B. britanicum				6.3		
B. dingleyae	10.4	6.3	6.3	2.1	6.3	
Camposporium sp.			8.3			
C. antennatum			4.2			
C. cambrense	2.1	2.1	2.1		2.1	2.1
Canalisporium caribense		2.1			18.8	
Cantelabrella musifomis						2.1
Cephaliophora irregularis				2.1		
Ceratosporella deviata			4.2			
C. novae-zelandiae			4.1	6.3	4.2	2.1
Ceratosporium fuscescens			12.5			
Cercospora sp. 1	8.3	6.3	6.3			
Cercospora sp. 2		6.3				
Cercospora sp. 3		6.3				
C. achyranthina		2.1		29.2	10.4	
C. apii	4.2		2.1	29.2	6.3	
C. canescens		12.5				
C. elaedis				4.2		14.6
Ceriospora polygonacearum		4.2			4.2	
Chaetoconidium arachnoideum	2.1					
Chaetopsis grisea					4.2	
Chalara sp.	2.1		4.2		6.3	2.1
C. cylindrosperma					2.1	
C. urceolata			2.1			
Chalaropsis sp.				2.1		
Chrysosporium condensatum	2.1					
Circinotrichum fertile		2.1				
C. poonense	2.1	2.1		10.4	4.2	10.4
Cladosporium sp. 1	12.5				6.3	
Cladosporium sp. 2				4.2		
C. britannicum	4.2	2.1				
C. elatum	10.4		10.4	14.6	10.4	
C. gallicola			6.3	4.2		
C. orchidis				14.6		
C. tenuissimum	2.1	10.4	4.2	22.9	22.9	18.8
Clasterosporium cocoicola	12.5					
C. flagellatum			4.2			
Clavariopsis aquatica	2.1					
C. brachycladia	2.1					
Codinaea sp.						6.3
C. assamica				2.1	14.6	8.3
Colletotrichum sp.[1/]					20.8	6.3
C. gloeosporioides[1/]	2.1		6.3	6.3	16.7	16.7
Cordana pauciseptata			4.2			
Cordella clarkii	4.2	2.1				
Corynespora sp. 1			2.1		2.1	
Corynespora sp. 2						10.4

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Corynespora sp. 3					2.1	10.4
C. cassiicola		6.3	10.4		6.3	2.1
C. novae-zelandiae						2.1
C. proliferata			4.2			
C. trichiliae			6.3		8.3	
Corynesporopsis quereicola			12.5		4.2	
Cryptocoryneum condensatum				2.1	2.1	
Curvularia sp.					4.2	
C. affinis			4.2			
C. deightonii	6.3					
C. lunata[1/]	16.7	4.2	20.8	16.7	22.9	16.7
C. pallescens			2.1			
Cylindrocladium sp.		2.1				
C. parvum[1/]		4.2		25.0		
C. scoparium		8.3	4.2		2.1	
Cylindrocolla urticae			2.1			
Cylindrotrichum sp.		2.1	2.1			
C. oligospermum		8.3			31.3	
Dactylaria sp. 1	14.6	4.2	4.2	6.3	6.3	4.2
Dactylaria sp. 2	2.1	2.1	2.1			14.6
Dactylaria sp. 3	8.3	2.1	6.3			10.4
D. hyalina	4.2	10.4	12.5	8.3	10.4	2.1
D. junci	6.3					
D. purpurella				8.3		
Dactylella sp.		12.5				
D. ellipsospora	10.4	6.3	14.6			2.1
Dendryphion comosum	6.3				10.4	
Dictyoarthrinium sp.						2.1
Dictyosporium sp.	4.2					8.3
D. giganticum				8.3	6.3	
D. heptasporum					6.3	
D. manglietia		2.1	6.3			12.5
Diplocladiella scalaroides		6.3		8.3		8.3
Diplococcium sp. 1	8.3	4.2	25.0			
Diplococcium sp. 2	10.4	18.8		10.4		
D. asperum			4.2			6.3
D. clarkii		2.1				
D. lawrencei		2.1				
D. spicatum	6.3	18.8	25.0	10.4	25.0	16.7
Diplodia sp.[1/]				10.4	6.3	
Discosia artocreas					4.2	
Ellisembia sp.						10.4
E. paravaginata		20.8			18.8	2.1
E. repentioriunda						10.4
E. vaginata			4.2	14.6	12.5	
Ellisiopsis gallesiae					2.1	
Endophragmia sp.			2.1			
E. bisbyi			4.2			
E. boewei				6.3	8.3	10.4
E. brevis				4.2		
E. cesatii				12.5		
E. elliptica				18.8		14.6
E. hyalosperma	31.3			14.6		

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
E. pinicola	6.3					
Endophragmiella sp.	2.1	2.1				
E. boewei	2.1				2.1	
E. lignicola	2.1					
Excipularia narsapurensis	4.2					
Exosporium monanthotaxis					14.6	
E. phyllantheum	25.0					
Fulvia berkhaeyae					10.4	4.2
Fusariella sp.		6.3			8.3	
F. kansensis		6.3	20.8			
F. sarniesis					14.6	4.2
Fusarium sp. 1	2.1	20.8	14.6	12.5	18.8	12.5
Fusarium sp. 2	8.3	8.3	4.2	29.2	6.3	6.3
Fusarium sp. 3	4.2	2.1	8.3	29.2	10.4	
Fusarium sp. 4	4.2	8.3			12.5	
Fusarium sp. 5	6.3	6.3				
Fusarium sp. 6	2.1					
F. aquaeductum					2.1	
F. moniliforme				14.6		
F. oxysporum[1/]	2.1					
F. redolens[1/]						6.3
F. semitectum[1/]		2.1	2.1	4.2		
Fusicladium sp.		2.1				
Gliomastix cerealis					4.2	
G. musicola	4.2				2.1	
Goidanichiella sp.			2.1			
Gyrothrix circinata		2.1		6.3		4.2
G. podosperma			4.2		4.2	
Hansfordia biophila	6.3	4.2			16.7	
H. nebularis	2.1					
H. ovalispora		14.6	14.6			31.3
Harplographium mangiferae		2.1				
Helicomyces sp.		2.1			2.1	4.2
H. roseus			2.1			
Helicosporium aureum					4.2	2.1
H. vegetum			2.1		2.1	
Helminthosporium velutinum	2.1	8.3	10.4			
Henicospora coronata		4.2		4.2		
Hirudinaria macrospora		2.1	2.1		2.1	
Hormiactis sp.		2.1				
H. alba				6.3		
H. candida		4.2				18.8
Humicola grisea					8.3	
Hyalodendron sp.				2.1		
Hyphodiscosia jaipurensis				4.2		8.3
Idriella fertile		6.3				
I. lunata	2.1	4.2			20.8	12.5
Janetia faureae		10.4				
Lasiodiplodia cf. *theobromae*	64.6	58.3	79.2	50.0	45.8	39.6
Lateriramulosa uni-inflata		2.1	2.1		4.2	4.2
Lauriomyces sakaeratensis						2.1
Lemonniera brachycladia	6.3					
Leptodiscella africana	14.6	8.3	4.2		8.3	18.8

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Mariannaea elegans			4.2			
Microthyrium fagi				18.8		
Monacrosporium sp. 1	6.3	6.3	6.3		2.1	
Monacrosporium sp. 2		2.1				
Mycoleptodiscus indicus			6.3	4.2		
Mycovellosiella solani-torvi			2.1			
Myrothecium roridum			6.3			
Myxocyclus sp.			2.1			
Nawawia filiformis			6.3			
Nematoctonus sp.			2.1			
Nigrospora sphaerica	22.9	20.8	14.6	22.9	27.1	25.0
Paecilomyces sp.			8.3		12.5	
P. lilacinus[1/]	2.1	2.1	8.3	8.3	12.5	
Panchanania jaipurensis		8.3			12.5	4.2
Parapleurotheciopsis sp.	18.8	18.8		8.3		
Parasympodiella podocarpi	6.3	10.4			4.2	20.8
Paratomenticola lanceolatus	16.7	27.1	25.0	31.3	35.4	27.1
Paratrichoconis chinensis		4.2	6.3		27.1	
P. polygonecearum		4.2				
Penicillium sp. 1[1/]	6.3	2.1	14.6	31.3	35.4	18.8
Penicillium sp. 2[1/]	4.2	2.1		6.3	25.0	16.7
Penicillium sp. 3[1/]	4.2	2.1		6.3		12.5
Penicillium sp. 4[1/]		10.4				
Periconia byssoides	2.1					
P. cambrensis		2.1				
P. jabalpurensis			4.2			
P. lateralis	2.2					2.2
P. tirupatiensis					6.3	
Periconiella cyatheae	8.3					
Pestalotiopsis sp. 1	14.6	8.3		8.3	14.6	10.4
Pestalotiopsis sp. 2	14.6	2.1			16.7	
Pestalotiopsis sp. 3		2.1				
P. disseminata[1/]	6.3		10.4	4.2		
P. hansenii	10.4					
P. sydowiana[1/]	14.6					
Phaeodactylium alpiniae		6.3	12.5			
Phaeoisariopsis cercosporioides				25.0		
Phaeoramularia marmorata				25.0	22.9	
P. oldenlandiae				8.3		
Phialocephala bactrospora					4.2	
Phoma sp.[1/]	2.1			2.1	8.3	
Phomopsis sp.[1/]			8.3	8.3		
Phyllosticta sp.[1/]			6.3			
Piricauda pseudarthiae					6.3	
Pithomyces graminicola	12.5					
Pleurophragmium actum			10.4		18.8	8.3
Pleurotheciopsis pusilla	4.2					
Polymorphum sp.		2.1				
Pseudobotrytis terrestris		16.7	27.1			
Pseudocercospora pterocauli	6.3					
Pseudodiplodia sp.		10.4				
Pseudospiropes hughesii		12.5	10.4	6.3		10.4
P. obclavatus	12.5	4.2	10.4	12.5	18.8	33.3

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
P. roussetianus						4.2
P. subuliferus					16.7	
Pyriculariopsis sp.						6.3
P. parasitica	18.8			37.5	62.5	47.9
Rhinocladiella sp. 1		10.4	18.8	4.2		14.6
Rhinocladiella sp. 2				4.2	8.3	
Rhinocladiella sp. 3					4.2	
Rhinocladiella sp. 4					4.2	
Saccardaea atra					6.3	
Schizotrichum lobeliae	4.2					
Scolecobasidiella sp.		4.2				
S. avellanea		6.3	6.3	4.2	2.1	29.2
Scolecobasidium acanthacearum	4.2		4.2	4.2		2.1
S. anellii				2.1		
S. compactum	21	8.3	10.4			10.4
S. dendroides		2.1				
S. salinum	10.4	6.3		10.4		
Scytalidium lignicola	4.2					
Septonema fasciculare		6.3	12.5	12.5	39.6	25.0
Sirosporium stylidii				2.1		
Spadicoides bina						10.4
S. obovata	10.4					
Spegazzinia sp.				2.1		
S. deightonii		8.3				
S. parkeri	2.1			2.1		
S. sundara		2.1	2.1			
Speriopsis hyalospora	2.1	2.1	4.2	4.2	18.8	10.4
Spondylocladiella sp.				6.3		
S. botrytioides	2.1	2.1		12.5		10.4
Sporidesmium sp. 1	2.1					
Sporidesmium sp. 2		2.1				
Sporidesmium sp. 3		14.6				
S. australiense	2.1		4.2			12.5
S. bambusicola	2.1		6.3		14.6	
S. cambrense		12.5				
S. coronatum		10.4				
S. dioscoreae		6.3		20.8		
S. ehrenbergii						25.0
S. ellisii						8.3
S. flagellatum	20.8	20.8	6.3	8.3	54.2	22.9
S. ghanaense	14.6		8.3			
S. harknesii	8.3	16.7	14.6		4.2	10.4
S. hormiscioides				12.5		
S. jasminicola	4.2			12.5		20.8
S. larvatum		6.3	6.3			
S. leptosporum	8.3	2.1			25.0	
S. longirostratum	6.3	10.4	8.3			8.3
S. njalaense					8.3	
S. nodipes	10.4	10.4	2.1		18.8	16.7
S. parvum			10.4			
S. penzigii		14.6	31.3			
S. rubi	2.1	20.8	29.2	20.8		
S. socium				10.4		

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. subulatum	8.3	12.5				
S. tenuisporum	4.2					
S. uvariicola	2.1					
S. zambiense			25.0			
Sporoschisma uniseptatum	2.1			10.4	6.3	
Sporoschismopis sp. 1		12.5	6.3	16.7	27.1	27.1
Sporoschismopis sp. 2				16.7	6.3	
Stachybotrys oenanthes	8.3					
S. parvispora					2.1	
S. sanserieriae	16.7					
Staphylotrichum sp.						8.3
S. coccosporum	2.1					8.3
Stenella pithecellobii	12.5		8.3	6.3	29.2	4.2
Stigmina sp. 1					6.3	
Stigmina sp. 2					8.3	
S. celata	12.5	4.2				
S. combreticola						4.2
S. crotonicola	6.3					
S. hartigiana					10.4	10.4
S. kranzii	8.3					
S. mangiferae			2.1			
S. murrayae		16.7				
S. obtecta					6.3	
S. phaeocarpa					4.2	
S. rauvalfiae	2.1		6.3	20.8	20.8	
S. sudanensis	25.0				4.17	
Subulispora sp.			4.2	2.1		
S. britannica			10.4			
S. procurvata	2.1	4.2	8. 3	25.0	14.6	12.5
Sympodiella sp.					4.2	
Taeniolella breviuscula		14.6			20.8	
Tetracrium amphibium	4.2	8.3	6.3			
Tetraploa aristata	4.2	25.0	10.4	4.2	12.5	8.3
T. ellisii	16.7					
Tetraposporium sp.						4.2
T. asterinearum	4.2	8.3	10.4			2.1
Tetratosperma sp.	8.3					
Thyrsidina sp.	10.4					
Torula sp.				14.6		
T. herbarum	47.9	31.3	14.6	37.5	31.3	29.2
Tretospora sp. 1		2.1				
Tretospora sp. 2	2.1	8.3	2.1			
Trichoderma sp. 1[1/]	4.2	8.3		10.4		18.8
Trichoderma sp. 2[1/]	6.3	2.1		10.4		
Trichoderma sp. 3[1/]	6.3	2.1		10.4	12.5	
Trichoderma sp. 4[1/]	4.2			10.4		16.7
Trichoderma sp. 5[1/]	4.2			12.5	12.5	
Trichoderma sp. 6[1/]	4.2			12.5		
T. atroviride[1/]	4.2	10.4	6.3	10.4		18.8
T. citrinoviride[1/]				2.1		
T. disseminatum	4.2					
T. hamatum[1/]		4.2	4.2			
T. harzianum[1/]		10.4	6.3	6.3	8.3	20.8

Table 1 (Continued) Occurrences (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
T. virens[1/]		6.3				
T. viride[1/]				4.2	10.4	
Tricladium sp.	4.2	8.3	4.2	2.1		
T. fuscum	2.1	10.4				
Tridentaria sp.			4.2			
T. implicans	2.1	14.6	4.2			
Tripospermum myrtii	14.6				8.3	
Triscelophorus acuminatus	2.1	2.1	2.1	2.1		2.1
T. monosporus				4.2	6.3	
T. panapensis		4.2			14.6	8.3
Uniseta sp.				4.2		
Venturia crataegi	6.3		4.2			
Veronaea sp.					10.4	
V. apiculata		16.7	8.3			
V. botryosa				4.17		20.8
V. carlinae	14.6	20.8	16.7	25.0	18.8	25.0
V. coprophila	18.8	39.6		20.8	54.2	25.0
V. musae		4.2	8.3	2.1	14.6	6.3
Wiesneriomyces javanicus		6.4			12.5	12.5
Zygosporium gibbum					4.2	
Z. minus	4.2					
Oomycota						
Phytophthora sp.	2.1			8.3		
Zygomycota						
Rhizopus sp.[1/]	2.1	4.2				
Total number of species recorded at each stage	**180**	**199**	**175**	**158**	**188**	**157**

Note: *Newly fallen branches, middle stage decaying branches, old decaying fallen branches. [1/]Isolated from dilution plates.

Fungal diversity and abundance of fungi

Communities of fungal taxa at different stages of decay of rubber branches were distinct. The number of taxa on middle stage decaying branches tended to be higher than new and old decaying fallen branches. The number of taxa found on middle stage decaying branches in Nakhon Si Thammarat was 199 taxa, 180 taxa were found on newly fallen branches and 175 taxa on old decaying fallen branches.

In Songkhla Province, 188 taxa were found on the middle stage decaying branches, 158 taxa on newly fallen branches and 157 taxa on the old decaying fallen branches (Table 4). The similarity of fungal communities associated with rubber branch litter at different decay stages were most similar during the middle and old stage decaying (47.9% in Nakhon Si Thammarat Province, 47.5% in Songkhla Province). The newly fallen branches and the old decaying fallen branches were the least similar (39.4% in Nakhon Si Thammarat Province, 44.2% in Songkhla Province) (Table 5).

Fungal communities in different seasons

In Nakhon Si Thammarat Province 299 taxa were recorded in the dry season, while 258, 245 and 215 taxa were recorded from the early rainy season, late rainy season, and rainy season, respectively (Table 6). In Songkhla Province 308 fungal taxa were recorded in dry season, 305, 298 and 232 taxa were recorded from early rainy season, late rainy season and rainy season, respectively (Table 6).

Four species, *Bactrodesmium rahmii*, *Lasiodiplodia* cf. *theobromae*, *Kirschsteiniothelia* sp. and *Schizophyllum commune* were the dominant species during all seasons in Nakhon Si Thammarat Province. Seven species, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Hypoxylon* sp.1, *Pestalosphaeria*

Table 2 Dominant fungi (over 10% occurrence) on branch litter of rubber (*Hevea brasiliensis*), at each stage of decomposition and each season in Nakhon Si Thammarat Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
Late rainy season (January)	*Torula herbarum* *Kirschsteiniothelia* sp. *Lasiodiplodia* cf. *theobromae*	*Sporidesmium penzigii* *Kirschsteiniothelia* sp. *Lasiodiplodia* cf. *theobromae* *Bactrodesmium rahmii* *Schizophyllum commune*	*Bactrodesmium rahmii* *Hypoxylon* sp.2 *Lasiodiplodia* cf. *theobromae* *Kirschsteiniothelia* sp. *Rhinocladiella* sp. *Arthobotryum atrocephalum* *Psuedobotrytis terrestris* *Dactylella ellipsospora*
Dry season (April)	*Kirschsteiniothelia* sp. *Lasiodiplodia* cf. *theobromae* *Torula herbarum* *Bactrodesmium rahmii* *Nigrospora sphaerica* *Diplococcium* sp.2	*Diplococcium* sp.2 *Kirschsteiniothelia* sp. *Lasiodiplodia* cf. *theobromae* *Veronaea carlinae* *Cercospora canescens* *Nigrospora sphaerica* *Stigmina murrayae* *Bactrodesmium rahmii* *Sporidesmium rubi* *Tetraploa aristata* *Tricladium fuscum* *Veronaea coprophila*	*Bactrodesmium rahmii* *Lasiodiplodia* cf. *theobromae* *Sporidesmium rubi* *Nigrospora sphaerica* *Paratomenticola lanceolatus* *Veronaea carlinae* *Acticulospora rhodosporum* *Sporidesmium zambiense* *Fusarium* sp.1 *Kirschsteiniothelia* sp. *Sporidesmium penzigii*
Early rainy season (July)	*Kirschsteiniothelia* sp. *Botryodiplodia* sp. *Nigrospora sphaerica* *Lasiodiplodia* cf. *theobromae* *Paratomenticola lanceolatus* *Pestalotiopsis sydowiana* *Endophragmia hyalosperma* *Schizophyllum commune*	*Kirschsteiniothelia* sp. *Lasiodiplodia* cf. *theobromae* *Bactrodesmium rahmii* *Paratomenticola lanceolatus* *Schizophyllum commune* *Trichoderma harzianum* *Veronaea coprophila* *Actinocladium rhodosporum*	*Actinocladium rhodosporum* *Lasiodiplodia* cf. *theobromae* *Kirschsteiniothelia* sp. *Pestalosphaeria hansenii*
Rainy Season (October)	*Kirschsteiniothelia* sp. *Lasiodiplodia* cf. *theobromae* *Curvularia lunata* *Torula herbarum*	*Lasiodiplodia* cf. *theobromae* *Kirschsteiniothelia* sp. *Torula herbarum* *Veronaea coprophila* *Schizophyllum commune* *Bactrodesmium rahmii*	*Lasiodiplodia* cf. *theobromae* *Bactrodesmium rahmii* *Kirschsteiniothelia* sp. *Curvularia lunata* *Sporidesmium penzigii*

Note: *Newly fallen branches, middle stage decaying branches, old decaying fallen branches.

Table 3 Dominant fungi (over 10% occurrence) on branch litter of rubber (*Hevea brasiliensis*), at each stage of decomposition and each season in Songkhla Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
Late rainy season (January)	*Bactrodesmium spilomeum* *Botryodiplodia* sp. *Paratomenticola lanceolatus* *Kirschsteiniothelia* sp. *Torula herbarum* *Hypoxylon* sp.1 *Pyriculariopsis parasitica* *Bactrodesmium betulicola* *Bactrodesmium rahmii* *Nigrospora sphaerica* *Veronaea coprophila*	*Botryodiplodia* sp. *Pyriculariopsis parasitica* *Kirschsteiniothelia* sp. *Bactrodesmium rahmii* *Bactrodesmium spilomeum* *Hansfordia biophila* *Pseudospiropes obclavatus* *Thyridaria sambucina* *Torula herbarum* *Veronaea coprophila* *Lasiodiplodia* cf. *theobromae* *Paratomenticola lanceolatus* *Pestalosphaeria hansenii* *Hypoxylon* sp.1 *Wiesneriomyces javanicus* *Nigrospora sphaerica* *Acarocybe formosa* *Colletotrichum* sp. *Bipolaris ellisii*	*Parasympodiella podocapi* *Bactrodesmium rahmii* *Lasiodiplodia* cf. *theobromae* *Penicillium* sp.2 *Pyriculariopsis parasitica* *Torula herbarum* *Kirschsteiniothelia* sp. *Nigrospora sphaerica*
Dry season (April)	*Lasiodiplodia* cf. *theobromae* *Acarocybe formosa* *Hypoxylon* sp.1 *Kirschsteiniothelia* sp. *Subulispora procuvata* *Bactrodesmium betulicola* *Bactrodesmium rahmii* *Sporidesmium rubi* *Cylindrocladium parvum* *Trichoderma viride*	*Botryodiplodia* sp. *Hypoxylon* sp.1 *Septonema fasciculare* *Bactrodesmium rahmii* *Kirschsteiniothelia* sp. *Pestalosphaeria hansenii* *Veronaea coprophila* *Sporidesmium flagellatum* *Cylindrotrichum oligospermum* *Lasiodiplodia* cf. *theobromae* *Subulispora procuvata* *Triscelophorus panapensis* *Canalisporium caribense*	*Kirschsteiniothelia* sp. *Septonema fasciculare* *Bactrodesmium rahmii* *Lasiodiplodia* cf. *theobromae* *Pyriculariopsis parasitica* *Hypoxylon* sp.2 *Acarocybe hansfordii* *Acremonium strictum* *Endophragmia elliptica*
Early rainy season (July)	*Cercospora apii* *Bactrodesmium spilomeum*	*Bactrodesmium rahmii* *Botryodiplodia* sp.	*Veronaea carlinae* *Bactrodesmium rahmii*

Table 3 (Continued) Dominant fungi (over 10% occurrence) on branch litter of rubber (*Hevea brasiliensis*), at each stage of decomposition and each season in Songkhla Province.

Season	Decomposition stage		
	New*	**Middle***	**Old***
	Penicillium sp.1	*Cladosporium tenussimum*	*Hypoxylon* sp.1
	Veronaea carlinae	*Curvularia lunata*	*Lasiodiplodia* cf. *theobromae*
	Bactrodesmium betulicola	*Kirschsteiniothelia* sp.	*Nigrospora sphaerica*
	Bactrodesmium rahmii	*Lasiodiplodia* cf. *theobromae*	*Penicillium* sp.3
	Kirschsteiniothelia sp.	*Pestalosphaeria hansenii*	*Pyriculariopsis parasitica*
	Fusarium sp.2	*Pseudospiropes obculavatus*	*Pestalosphaeria hansenii*
	Fusarium sp.3	*Pyriculariopsis parasitica*	*Scolecobasidiella avellanea*
	Aspergillus niger	*Sporidesmium flagellatum*	*Schizophyllum commune*
	Cladosporium tenuissimum	*Torula herbarum*	*Torula herbarum*
	Botryodiplodia sp.	*Veronaea coprophila*	*Cladosporium tenussimum*
	Sporoschismopsis sp.1	*Cylindrotichum oligospermum*	
	Lasiodiplodia cf. *theobromae*	*Penicillium* sp.1	
		Speriopsis hyalospora	
		Acarocybe formosa	
		Bactrodesmium spilomeum	
		Hypoxylon sp.1	
Rainy season (October)	*Botryodiplodia* sp.	*Botryodiplodia* sp.	*Botryodiplodia* sp.
	Bactrodesmium spilomeum	*Sporidesmium flagellatum*	*Hypoxylon* sp.1
	Hypoxylon sp.1	*Pyriculariopsis parasitica*	*Kirschsteiniothelia* sp.
	Bactrodesmium rahmii	*Bactrodesmium rahmii*	*Sporidesmium flagellatum*
	Kirschsteiniothelia sp.	*Acremonium kiliense*	*Pyriculariopsis parasitica*
	Pseudospiropes obculavatus	*Penicillium* sp.1	*Trichoderma* sp.3
		Pestalosphaeria hansenii	*Bactrodesmium rahmii*
		Kirschsteiniothelia sp.	*Schizophyllum commune*
		Sporoschismopsis sp.1	*Veronaea carlinae*
		Bactrodesmium spilomeum	
		Nigrospora sphaerica	
		Penicillium sp.2	
		Stenella pithecellobii	

Note: *Newly fallen branches, middle stage decaying branches, old decaying fallen branches.

Table 4 Diversity indices of saprobic fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Decomposition stage	Location					
	Nakhon Si Thammarat			Songkhla		
	No. of species	Index (*D*)	Index (*H*)	No. of species	Index (*D*)	Index (*H*)
New*	180	0.9881	4.7493	158	0.9989	4.6605
Middle*	199	0.9887	4.7743	188	0.9993	5.8676
Old*	175	0.9843	4.6303	157	0.9897	3.6951

Note: *Newly fallen branches, middle stage decaying branches and old decaying fallen branches.

Table 5 Sorensen's similarity index of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition.

Decomposition stage	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
New*		0.4767	0.3943		0.4611	0.4422
Middle*			0.4797			0.4745
Old*						

Note: *Newly fallen branches, middle stage decaying branches and old decaying fallen branches.

Table 6 Diversity indices of saprobic fungi on branch litter of rubber (*Hevea brasiliensis*) in different seasons.

Location/season	No. of fungi (species)			Total	Index (*D*)	Index (*H*)
	New*	Middle*	Old*			
Nakhon Si Thammarat						
Late rainy season	78	90	77	245	0.9921	5.1176
Dry season	97	109	93	299	0.9945	5.3319
Early rainy season	84	96	78	258	0.9915	5.1147
Rainy season	69	76	70	215	0.9887	4.8880
Songkhla						
Late rainy season	93	112	93	298	0.9987	4.9816
Dry season	101	121	86	308	0.9991	5.4072
Early rainy season	96	114	95	305	0.9988	5.3087
Rainy season	76	83	73	232	0.9931	4.0587

Note: *Newly fallen branches, middle stage decaying branches and old decaying fallen branches.

hansenii and *Pyriculariopsis parasitica* were the dominant species during each season in Songkhla Province.

The similarity of fungi associated with rubber branch litter during the different seasons was investigated. The most similar were during the early rainy season and during the dry season (40.4% in Nakhon Si Thammarat Province, 49.1% in Songkhla Province) and during the late rainy season and during the rainy season were the least similar (30.1% in Nakhon Si Thammarat Province, 37.1% in Songkhla Province) (Table 7).

Discussion

Fungal recorded from branch litter

The advantages of using more than one technique to study the fungi was highlighted by Shanchi & Vittal (2010). The moist chamber is one of the best techniques for revealing fungi on small branches. Some fungi were discovered by the dilution plate method but are more easily detected by the moist chamber method. For instance, *Kirschsteiniothelia* sp. was detected mainly by means of the moist chamber technique, and was rare when using the dilution plate technique. The presence of several other fungi was revealed by only a limited range of techniques (Shanchi & Vittal 2010). The dilution plate has been used by several workers (Tokumasu 1980, Shirouzu et al. 2009). The reason for using this technique is to establish if any fungi were missed by direct observation or moist chamber techniques (Shanchi & Vittal 2010). Fungal fruiting bodies are environmentally influenced and may vary between years and among different species. Thus, sporocarp inventories are recommended to be repeatedly taken during a season and over several years to gain a more comprehensive idea of the fungal communities present (Huhndorf et al. 2004).

Fungal diversity and colonization

This is the first report on fungal communities on decaying rubber branch litter in Thailand. The results are similar to those found while investigating fungi on rubber leaf litter in a previous study (Seephueak et al. 2010), except that the number of taxa on decaying rubber branch litter is higher than on leaf litter. The higher diversity of fungi on woody litter may result from the longer decomposition period of wood (Kodsueb et al. 2008b) when compared with that of leaves. Wood decays slowly because of its recalcitrant properties (Boddy 1986). Fungi have competitive abilities; they can grow successfully on wood alongside other taxa or may dominate (Shearer 1992, Fryar et al. 2004). Wong et al (1998) reported that generally the composition of wood is quite different from leaves, the 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, 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). Many factors can affect changes in the communities of fungi, for instance, the microclimate of the growth site and biological interaction within woody substrate, effects of endophytes growing in living wood and leaf litter fungi that may develop in wood after it is dead (Rayner & Boddy 1988).

Kodsueb et al (2008b) studied fungal succession on wood of *Magnolia liliifera* by three-dimensional correspondence analysis and showed that 163 taxa were identified in three distinct succession communities; the pioneer communities, mature communities and impoverished communities. The number of fungal species was highest during the mature community (113 taxa) of wood decomposition than pioneer community (65 taxa) and in the impoverished community, the diversity and number of taxa declined (21 taxa). In this study, there were differences between the fungal communities associated on decaying branches of *H. brasiliensis*. In the middle stage decaying branches the number of species tended to be higher than on newly fallen branches or on old decaying fallen branches.

The fungal diversity on decaying branches of *H. brasiliensis* involved the identification of 497 species, which is high when compared with other studies of fungi on branch litter. For instance, Allmér (2005) found 58 taxa fungi on Norway spruce, and Kodsueb et al (2008a) found 239 fungi on Magnoliaceae. The present study demonstrated a rich fungal diversity compared to that previously reported for fungi on decaying branch litter (Nordén &

Table 7 Sorensen's similarity index of fungi associated with branch litter of rubber (*Hevea brasiliensis*) versus seasons.

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		0.3917	0.3831	0.3011		0.4250	0.4374	0.3707
Dry season			0.4043	0.3583			0.4912	0.3992
Early rainy season				0.3792				0.4202
Rainy season								

Paltto 2001, Küffer et al. 2004, Küffer & Senn-Irlet 2005, Zamora et al. 2008).

The importance of very small branches for fungal growth and fruiting was previously largely underestimated. This substrate has a low potential as a nutrient source for fungi and in addition has an unfavorable surface-volume ratio, i.e. a rather large surface area, but only 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 small branches are only colonized by one single species at a time (Küffer et al. 2008). Rubber is a deciduous tree. In the rubber plantation ecosystem plant litter is a major contributor to the nutrient cycling pathway in which a large amount of nutrients are returned to the plantation floor (Kush et al. 1990). Küffer et al (2008) explained the regression tree analysis for fungi from coniferous and deciduous trees. The similarity within the fungal species inhabiting deciduous tree species is higher than within the fungal species inhabiting conifer tree species. Fungal species growing on coniferous wood have had more time to evolve into a larger variety of types, when compared to fungal species growing on broadleaf tree wood litter, simply due to the greater evolutionary age of coniferous trees (Küffer et al. 2008).

Fungal communities at different decay stages

Fungal communities were determined from three successive decomposition stages: the pioneer stage, the mature stage and the impoverished stage in previous succession studies (Kannangara & Deshappriya 2005, Osono 2005, Paulus et al. 2006, Duong et al. 2008, Thongkantha et al. 2008, Kodsueb et al. 2008b, Seephueak et al. 2010). In this study the fungal communities are also classified into three stages of decay. In the mature stage of decay the number of fungi tends to be higher than at any other stage according to Tan et al (1989) and Maria & Sridhar (2004). Kodsueb et al (2008a) reported that the highest number of species was observed during the mature stage of wood decomposition. Fungal succession studies by Tawari et al (1994) and Yanna et al (2002) found that the number of species of fungi was at a maximum during the mature stage of decomposition of palm fronds and pineapple leaves. This is in accordance with the results from several observations on Norway spruce wood (Niemelä et al. 1995, Renvall 1995, Linbald 1998).

Anamorphic fungi were the dominant group and this is also in agreement with previous studies (Hyde et al. 2001, Zhou & Hyde 2002, Kodsueb et al. 2008a). Wood samples are almost completely decayed by the impoverished stage of decomposition so that few species of fungi were present. Basidiomycete species are believed to dominate ascomycetes during the later stage of the decomposition of wood (Duong et al. 2008) since they can synthesize the enzymes required to degrade complex polymers such as lignin (McClaugherty & Berg 1987, Deacon 1997).

Decomposition rate of substrate and number of fungi

The factors that influence whether a certain saprobe occurs regularly or uniquely on a host are poorly understood (Zhou & Hyde 2001). Generally, different plant species have different chemical compositions and this may affect the microbial communities and biomass

(Boddy & Watkinson 1995, Mille-Lindblom et al 2006). Zhou & Hyde (2001) reported that many fungi are host-specific or exhibit host-recurrence.

The time taken for the decomposition of plant litter varies in different regions (Kane et al. 2002, Yanna et al. 2002, Tang et al. 2005). The rate of decomposition of plant litter in temperate regions is slower than in other regions (Osono & Takeda 2001), while decomposition rate in the tropics is generally more rapid (Tang et al. 2005). The number of fungi obtained from several succession studies appears to be dependant on the host species and the period of decomposition (depending on the litter type). 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 to decay (Kodsueb et al. 2008b). In the present study *H. brasiliensis* branch litter took at least 12 months to completely decay and it took about 6 months for degradation of rubber leaf litter to be completed (Seephueak et al. 2010). 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 such as the composition of litter components, the type of wood, size of wood and environmental factors such as humidity and temperature may result in different rates of wood decomposition and higher or lower fungal diversity (Boddy & Watkinson 1995, Lodge 1997).

The effect of season on the fungal communities

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 according to the season (Kenney et al. 2006). 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 (Nikolcheva & Bärlocher 2005). Nevertheless, there is no data to clarify how the seasons affect communities.

In this study, the diversity of fungi during the dry season (April) tended to be greater in richness of species and had a higher Shannon diversity index than the samples collected in wet season (early rainy season, rainy season and the late rainy season). Kodsueb (2007) studied the diversity of saprobic fungi on *Magnoliaceae* wood and reported that samples collected in a dry season have a greater species richness than samples collected in a wet season. Rayner & Todd (1979) showed that there was a greater variety and number of fungi during the dry season. 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 varies within wet and dry seasons. Since humidity is needed for the germination and dispersal of fungal propagules, it follows that the fungal communities of wet season samples, which exhibit higher humidity, are believed to be more diverse (Pinnoi et al. 2006).

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