Fungi Associated with Degradation of Rubber Wood Logs and Leaf Litter

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ชื่อวิทยานิพนธ์ เชื้อราย่อยสลายไม้และใบยางพารา

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บทคัดย่อ

วิทยานิพนธ์นี้มีวัตถุประสงค์ เพื่อศึกษาความหลากหลายของเชื้อราที่ย่อยสลายซากใบ กิ่ง และท่อนไม้ยางพารา ในพื้นที่จังหวัดนครศรีธรรมราชและจังหวัดสงขลา โดยการแยกเชื้อราขนาดเล็ก (microfungi) จากเศษซากโดยวิธี dilution plates technique บนอาหาร GANA (glucose ammonium nitrate agar) และบ่มในกล่องให้ความชื้น (moist chamber) และเก็บรวบรวมและจำแนกราขนาดใหญ่ (macrofungi) ที่พบบนดินและเศษซากจากต้นยางพารา เชื้อราที่แยกได้นำมาศึกษาความสามารถในการผลิตเอนไซม์เซลลูเลสและไซแลนเนส และทดสอบความสามารถในการย่อยสลายซากใบยางพาราในห้องปฏิบัติการ

ผลการศึกษาพบเชื้อราจำนวน 503 ชนิด บนซากใบยางพารา ประกอบด้วย anamorphic 461 ชนิด ascomycetes 38 ชนิด zygomycetes 2 ชนิด oomycetes 1 ชนิด และ basidiomycetes 1 ชนิด การทดแทนของราบนซากใบยางพาราที่อยู่บนพื้นที่สวนยางพารามีความหลากหลายแตกต่างกันในระหว่างระดับการย่อยสลายต่างๆ พบเชื้อรา 313 ชนิดบนซากใบใหม่ 326 ชนิด พบบนซากใบเก่าปานกลาง และ 250 ชนิด พบบนซากใบเก่า มีเชื้อราสายพันธุ์เด่น 13 ชนิด (> 10% occurrence) ที่พบทุกระดับของการย่อยสลาย ได้แก่ *Bactrodesmium rahmii, Botryodiplodia* sp., *Cladosporium tenuissimum*, *Hypoxylon* sp.1, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Pestalosphaeria hansenii*, *Pestalotiopsis* sp.1, *Subulispora procurvata*, *Veronaea carlinae*, *V. coprophila* และ *Wiesneriomyces javanicus* ความหลากหลายของเชื้อราขนาดเล็กบนซากใบพบมากที่สุดในฤดูร้อน เชื้อราสายพันธุ์เด่นที่พบได้ทุกฤดู ได้แก่ *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Subulispora procurvata* และ *Veronaea coprophila*

บนซากกิ่งไม้ยางพาราพบเชื้อรา 450 ชนิด ประกอบด้วย anamorphic 400 ชนิด ascomycetes 48 ชนิด oomycetes 1 ชนิด และ zygomycetes 1 ชนิด พบเชื้อราบนซากกิ่งใหม่ 259 ชนิด ซากกิ่งย่อยสลายปานกลาง 276 ชนิด และซากกิ่งเก่า 230 ชนิด เชื้อราสายพันธุ์เด่น 10 ชนิด ที่พบทุกระดับของการย่อยสลาย ได้แก่ *Bactrodesmium rahmii*, *Botryodiplodia* sp.,

Hypoxylon sp.2, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Pestalosphaeria hansenii*, *Torula herbarum* และ *Veronaea carlinae* ความหลากหลายของเชื้อราบนซากกิ่งยางพาราพบมากที่สุดในฤดูร้อน เชื้อราสายพันธุ์เด่น 3 ชนิด ที่พบได้ทุกฤดู ได้แก่ *Bactrodesmium rahmii, Kirschsteiniothelia* sp. และ *Lasiodiplodia* cf. *theobromae* พบเชื้อราจำนวนทั้งหมด 422 ชนิด บนท่อนไม้ยางพารา ประกอบด้วย anamorphic 384 ชนิด และ ascomycetes 38 ชนิด โดยพบบนท่อนไม้ใหม่ 227 ชนิด ท่อนไม้ย่อยสลายปานกลาง 250 ชนิด และท่อนไม้เก่า 219 ชนิด เชื้อราสายพันธุ์เด่น 6 ชนิดที่พบทุกระดับของการย่อยสลาย ได้แก่ *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Paratomenticola lanceolatus* และ *Veronaea coprophila* ความหลากหลายของเชื้อราบนท่อนไม้ยางพาราพบมากที่สุดในฤดูร้อน โดยมีเชื้อราสายพันธุ์เด่นพบได้ทุกฤดู ได้แก่ *Bactrodesmium rahmii* การสำรวจและเก็บตัวอย่างดอกเห็ดที่เจริญบนดิน ซากใบ กิ่ง และท่อนไม้ยางพาราในสวนยางพารา พบดอกเห็ดทั้งหมด 131 ชนิด ประกอบด้วย 42 วงศ์ 66 สกุล เป็นเชื้อราในกลุ่ม basidiomycetes 113 ชนิด และ ascomycetes 18 ชนิด พบดอกเห็ดที่เจริญบนดิน 44 ชนิด บนซากใบ 15 ชนิด ซากกิ่ง 70 ชนิด และท่อนไม้ยางพารา 48 ชนิด ความหลากหลายของดอกเห็ดพบมากที่สุดในระดับกลางของการย่อยสลายและในช่วงต้นฤดูฝน

การศึกษาความสามารถของเชื้อราย่อยสลายซากพืชในการผลิตเอนไซม์ เพื่อย่อยสลายเซลลูโลสและไซแลนในห้องปฏิบัติการ พบเชื้อราจำนวน 26 ชนิด จาก 58 ชนิด มีความสามารถในการผลิตเอนไซม์เซลลูเลสและไซแลนเนส ได้แก่ *Aspergillus carbonarius*, *A. japonicus* var. *aculeatus*, *A. japonicus* var. *japonicus*, *A. kanagawaensis, A. niger, A. parasiticus, A. sclerotiorum*, *A. tamarii*, *Beltrania* sp., *Botryodiplodia* sp., *Cylindrocarpon* sp., *Fusarium redolens*, *Helicostylum piriforme*, *Phyllosticta* sp., *Rhizopus* sp., *Syncephalastrum recemosum*, *T. atroviride*, *T. aureoviride, T. harzianum, T. inhamatum, T. koningii, T. longibrachiatum, T. pseudokoningii*, *T. reesei, T. virens* และ *T. viride* นำเชื้อรา 5 ชนิด ได้แก่ *A. parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *H. piriforme* และ *T. virens* ไปใช้ทดสอบความสามารถในการย่อยสลายเศษซากใบยางพาราในห้องปฏิบัติการ พบว่าเปอร์เซ็นต์น้ำหนักคงเหลือของซากใบในชุดทดลองที่มีเชื้อรา มีค่าระหว่าง 51.89-54.89% ในขณะที่ชุดควบคุม (ไม่มีเชื้อรา) มีค่าน้ำหนักคงเหลือเท่ากับ 60.22% พบความแตกต่างทางสถิติอย่างมีนัยสำคัญยิ่ง ($p<0.01$) ผลการทดลองพบว่าเชื้อรา *T. virens* ทำให้อัตรา

การย่อยสลาย (k value) ของซากใบมีค่าสูงสุด (k=0.0292 d^{-1}) รองลงมาคือ *Cylindrocarpon* sp. (k=0.0289 d^{-1}), *H. piriforme* (k=0.0279 d^{-1}), *A. parasiticus* (k=0.0272 d^{-1}) และ *Beltrania* sp. (k=0.0267 d^{-1}) ในขณะที่ชุดควบคุม มีค่าอัตราการย่อยสลายต่ำสุด (k=0.0225 d^{-1})

จากการศึกษาครั้งนี้พบเชื้อราจำนวนมาก ที่เกี่ยวข้องกับการย่อยสลายของเศษซากต้นยางพารา ชนิดและจำนวนเชื้อราที่พบมีความแตกต่างกัน ขึ้นอยู่กับระดับของการย่อยสลาย ฤดูกาล และชนิดของซาก เชื้อราขนาดเล็ก (microfungi) พบมากที่สุดบนซากใบ กิ่ง และท่อนไม้ยางพาราในระดับกลางของการย่อยสลายและช่วงฤดูร้อน ในขณะที่ราขนาดใหญ่หรือดอกเห็ด (macrofungi) พบมากที่สุดบนซากกิ่ง ท่อนไม้ ดิน และซากใบในช่วงต้นฤดูฝน เชื้อราหลายชนิดที่แยกได้ มีความสามารถในการผลิตเอนไซม์เซลลูเลสและไซแลนเนส ซึ่งสำคัญในกระบวนการย่อยสลายของซากพืช สามารถนำไปประยุกต์เพื่อใช้ประโยชน์ทางการเกษตรได้ในอนาคต

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ABSTRACT

The objective of this thesis was to study the diversity of fungi associated with the degradation of rubber (*Hevea brasiliensis*) leaf litter, branch litter and the tree's wood logs in Nakhon Si Thammarat and Songkhla Provinces. Dilution plates technique on GANA (glucose ammonium nitrate agar) and moist chamber methods were used to study the microfungi. Sporocarp surveys were conducted to study the macrofungi on soil and rubber plant litter. Some of the fungi were studied for cellulolytic and xylanolytic enzyme activities and the ability to degrade rubber leaf litter in laboratory.

A total of 503 fungal species were identified from the rubber leaf litter, comprising 461 anamorphic taxa, 38 ascomycetes, two zygomycetes, one oomycete and one basidiomycete. Fungal succession of *H. brasiliensis* leaf litter on the plantation floor showed variations in fungal composition between the decomposition stages. A total of 313 species were found in newly fallen leaves, 326 species were found in middle stage decaying leaves, and 250 species were found in old decaying fallen leaves. Thirteen taxa of fungi were dominant species (over 10% occurrence) found at all stages of decomposition in both areas comprising, *Bactrodesmium rahmii, Botryodiplodia* sp., *Cladosporium tenuissimum*, *Hypoxylon* sp.1, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Pestalosphaeria hansenii*, *Pestalotiopsis* sp.1, *Subulispora procurvata*, *Veronaea carlinae*, *V. coprophila* and *Wiesneriomyces javanicus*. The highest diversity of microfungi on leaf litter was found in dry season. Four taxa of them were dominant species and found at all seasons comprising, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Subulispora procurvata* and *Veronaea coprophila*.

A total of 450 fungal species were identified from the rubber branch litter, comprising 400 anamorphic fungi, 48 ascomycetes, one oomycete and one zygomycete. A total of 259 species were found in newly fallen branches, 276 species were found in middle stage decaying branches and 230 species were found in old decaying fallen branches. Ten dominant fungal taxa were found in all stages of decomposition in both areas comprising *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Hypoxylon* sp.2, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Pestalosphaeria hansenii*, *Torula herbarum* and *Veronaea carlinae*. The highest diversity of microfungi on branch litter was in dry season. Three taxa of them were dominant species which found at all seasons comprising, *Bactrodesmium rahmii, Kirschsteiniothelia* sp. and *Lasiodiplodia* cf. *theobromae.* A total of 422 species were recorded from the rubber logs, comprising 384 anamorphic taxa and 38 ascomycetes. From these fungi, 227 species were found on newly fallen logs, 250 species on middle stage decaying logs and 219 species on old decaying fallen logs. Six dominant species, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Paratomenticola lanceolatus* and *Veronaea coprophila* were found at all decomposition stages. The highest diversity of microfungi on wood logs was found in dry season. Only one species found during at all seasons was *Bactrodesmium rahmii*. The survey of fruiting bodies appeared on soil surface, leaf litter, branch litter and wood logs were conducted. A total of 131 macrofungal taxa, comprising 42 families 66 genera were identified. Among them, there were 113 taxa belonging to basidiomycetes and 18 taxa to ascomycetes. Forty-four species were found on soil, 15 species found on leaf litter, 70 species found on branch litter and 48 species found on wood logs. The highest diversity of macrofungi was found in the early rainy season and middle stage of decay.

The ability of some leaf litter fungi to produce cellulolytic and xylanolytic enzymes were studied on agar plates. Twenty-six species out of 58 produced both cellulase and xylanase enzymes which were *Aspergillus carbonarius*, *A. japonicus* var. *aculeatus*, *A. japonicus* var. *japonicus*, *A. kanagawaensis, A. niger, A. parasiticus,* *A. sclerotiorum*, *A. tamarii*, *Beltrania* sp., *Botryodiplodia* sp., *Cylindrocarpon* sp., *Fusarium redolens*, *Helicostylum piriforme*, *Phyllosticta* sp., *Rhizopus* sp., *Syncephalastrum recemosum*, *T. atroviride*, *T. aureoviride, T. harzianum, T. inhamatum, T. koningii, T. longibrachiatum, T. pseudokoningii*, *T. reesei, T. virens* and *T. viride*. Five species of fungi, *Aspergillus parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *Helicostylum piriforme* and *Trichoderma virens* were used to studies decomposition rate of rubber leaf litter in laboratory. The percentage of leaf litter that remained at the end of the experiment was 51.89 - 54.89% of the initial mass, whereas in the control the leaf litter remained 60.22%. In this study, *T. virens* treatment showed the highest k value (k=0.0292 d^{-1}), followed by *Cylindrocarpon* sp. (k=0.0289 d^{-1}), *H. piriforme* (k=0.0279 d^{-1}), *A. parasiticus* (k=0.0272 d^{-1}), *Beltrania* sp. (k=0.0267 d^{-1}) and control was the lowest (k=0.0225 d^{-1}).

This study revealed many fungi associated with degradation of rubber plant litter. Fungal communities varied depending on decomposition stages, seasons, and substrates. The highest species of microfungi on leaf litter, branch litter and wood logs were found in the middle stage of decomposition and in the dry season. Whereas, the highest macrofungi were found on branch litter, wood logs, soil and leaf litter in the early rainy season. Many fungi isolated from rubber litter can produce cellulase and xylanase enzymes and had important role in the decomposition process of plant litter. Therefore, these fungi can be applied for agricultural use in the future.

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LIST OF ABBREVIATIONS AND SYMBOLS

CBM	=	Cellulolysis basal medium
CMC	=	Carboxymethyl cellulose
DM	=	Dry mass
GANA	=	Glucose ammonium nitrate agar
MEA	=	Malt extract agar
PDA	=	Potato dextrose agar
XBM	=	Xylanolysis basal medium
^{o}C	=	Degree celsius
cm	=	Centimeter
g	=	Gram
h	=	Hour
k	=	Decomposition constant
kg	=	Kilogram
min	=	Minute
ml	=	Milliliter
mm	=	Millimeter
µl	=	Microliter
t	=	Time
yr	=	Year

CHAPTER 1

INTRODUCTION

1.1 Introduction

Fungi are eukaryote microorganisms which have important roles in the ecological system as decomposer of organic matter, parasites and pathogens on plants and animals, and symbionts with higher plants or algae (Georgieva *et al*., 2005). They constitute the dominant organism groups involved in carbon cycling, primarily in the degradation of organic matter. Critical stages in lignin decomposition are almost exclusively carried out by fungi, and the breakdown of complex biomolecules such as cellulose and tannin in soils is due mostly to fungal enzymatic activity. Fungi mediate plant health and promote growth via mycorrhizal and parasitic associations. They provide a food source for a wide range of invertebrates including collembola, mites and nematodes and gain nutrition in turn from living or dead animals as well as plants. Fungi not only play an integral role in ecosystem processes but also are economically important, as plant and animal pathogens; as a food source; in food spoilage; in biodeterioration (Alexopoulos *et al*., 1996) and they also have a huge potential in the agricultural, biotechnological, pharmaceutical and health care industries (Hyde, 1997).

Saprobic fungi are the most important decomposers of plant material and 75% of the decomposition of various organic substrates are done mainly by different fungal species. No single fungal species is able to use all components of a substrate and it is well established that a succession of different groups of fungi will appear on different substrates (Ananda and Sridhar, 2004; Kannangara and Deshappriya, 2005).

Nowadays, saprobic fungi have been widely studied worldwide. According to their natural habit as decomposer microorganisms, saprobic fungi live on dead remains of other organisms and derive nutrition from that substrate (Alexopoulos *et al*., 1996). Currently, studies on fungal diversity have gradually increased, because of the fact that some fungi have great potential in industrial, biotechnological and agricultural applications (Pointing and Hyde, 2001; Bills *et al*., 2002; Maria *et al*., 2005). Plant litter fungi have key-roles in the ecology of tropical forest. They are the major agents of plant litter decomposition and nutrient cycling. They are capable to decompose major plant components particularly lignin and cellulose and to survive in acid soil while other organic decomposers are unable to do and difficult to survive. The colonization of various fungal species in leaf litter during decomposition process is sequential replaced over time. This replacement or succession may be strongly affected by the nutrient content of the litters and also the competition abilities of each fungus (Bill and Polishook, 1994; Puranong *et al*., 2007).

The abilities of fungi can be divided into three functional groups based on their substrate utilization. Lignocellulose decomposers attack both lignin and carbohydrate in various proportions, resulting in a significant mass loss of litter. Cellulose decomposers preferentially attack carbohydrates with a slight or negligible loss of lignin. Sugar fungi rely on soluble sugars and are unable to dissolve the structural polymers. The decomposing ability was generally higher in mitosporic fungi, basidiomycetes, ascomycetes and zygomycetes.

The rubber tree (*Hevea brasiliensis*) plantation is a monoculture crop. The agro-ecosystem that replaces the natural rainforest is less diverse and much less complex structurally than the original rain forest. Although, rubber plantations which constitute the most widespread agricultural land use, appear superficially similar to a forest, they are less efficient than the native rain forest in terms of nutrient cycling and soil conservation. As pointed out earlier, rubber trees tend to deplete soil nutrients over time. The establishment of rubber plots destabilizes the efficient cycling of nutrients in the natural rain forest ecosystem. This is mainly because single-species tree plantations usually immobilize soil nutrients faster and return less nutrient to the soil through litter fall, mineralization and rain wash than the natural rain forest (Aweto, 2001). A major problem associated with agriculture as pointed out above is the loss of biodiversity.

Saprobic fungi is an essential group of organisms in rubber plantation ecosystem as they are the main decomposers of leaf and wood litter and are responsible for a large part of the hetertrophic respiration (Rayner and Boddy, 1988). Numerous fungal species live as endophytes inside living rubber tree (Gazia and Chaverri, 2010). Plant litter degrading fungi have a range of catabolic enzymes that enable them to utilize litter as an energy and nutrient source (Rayner and Boddy, 1988).

Rubber plant litter (leaf, branch, wood logs) in rubber plantation is extremely diverse and it is not clear whether the decay fungi are specific to each host species comprising that litter. Therefore, it is important to investigate the effects of stage of decomposition on the fungi present. Such a study will establish if there is a sequential succession of fungi during the litter decomposition process and in different seasons.

There have been many studies on fungal diversity in temperate regions, but a few in tropical regions (Kodsueb *et al*., 2007) and this is certainly also true for Thailand. Although information and interest on fungal diversity in tropical regions is increasing, studies on tropical fungi are still under presented. Fungi are an unexplored universe of biodiversity. Eventhough *H. brasiliensis* is of great economical importance, few its associated fungi have been rarely studied (Aráujo *et al*., 2006). This is the first research on the study of fungal diversity associated with leaf, branch and wood logs of rubber tree in Thailand.

1.2 Thesis objectives

1.2.1 To assess the diversity and distribution of saprobic fungi on rubber tree leaf litter, branch litter and wood logs at each stage of decay and in different seasons.

1.2.2 To investigate the mushroom fruiting body growth on soil, leaf litter, branch litter, and wood logs in rubber plantation.

1.2.3 To determine the ability of some fungi associated on rubber leaf litter in degradation of cellulose and xylan.

1.2.4 To determine the mass loss and nutrient changes during decomposition of rubber leaf litter by some cellulolytic and xylanolytic fungi.

1.3 Benefits of this thesis

1.3.1 Knowledge of the ecology and biodiversity of saprobic fungi associated with degradation of rubber plant litter (*Hevea brasiliensis*) in Thailand, which has not been studied before.

1.3.2 Knowledge of some fungi isolated from rubber leaf litter can produce cellulase and xylanase enzymes and had important role in the decomposition process of plant litter.

CHAPTER 2

LITERATURE REVIEW

2.1 Roles and importance of fungi

Fungi play three major roles in the ecosystem. Some fungi are pathogens and attack living plants or animals, causing diseases. Other fungi are mutualistic symbionts and have developed beneficial association with other organisms. Most fungi are saprobes and the principal agents in the ecosystem that decay plant debris, release carbondioxide, and sustain photosynthesis in green plants. It is in this latter role that fungi are the major decaying agents of wood (Zabel and Morrel, 1992). Saprobic (saprophyte) is an organism using dead organic material as food, and commonly causing its decay (Kirk *et al*., 2008). Usually, saprobe is the preferred term for fungi. The most important role of fungal saprobes is as the decomposer of organic matter. Fungi can degrade complex structural material such as plant litter, wood and insect cuticles by producing various enzymes (Tanaka, 1993), these enzymes are excreted into the substrate and the mycelia subsequently take-up digested compounds through their cell wall (De Hoog *et al*., 2000).

Saprobic fungi are the principle decomposers of nonliving plant and animal detritus in the natural environment, thus recycling chemical elements back to the environment in a form other organisms may utilize. Filamentous fungi usually dominate wood and litter decomposition, e.g., for wood in tropical ecosystem termites may predominate, and under waterlogged conditions bacteria may prevail (Rayner and Boddy, 1988). Plant litter residents may include yeasts, bacteria, myxomycetes and invertebrates such as insects, oligochaeta, acria and nematodes. These may influence saprobic fungal community dynamics and consequently affect overall decay rates, either via direct interaction, such as antibiosis or grazing of fungal mycelium or spore, or by indirect interaction through impact on the biotic environment (Rayner and Boddy, 1988). Thus, invertebrate activity, may provide channels for mycelia invasion, and also improve aeration.

Generally, saprobic fungi usually live on dead vegetable matter, as they are the only multi-cellular organisms that can digest cellulose and lignin, the two major components of plant's cell wall in general. The degradative ability of saprobic fungi is very important in ecosystem, especially in rubber plantation as they can decay large or small pieces of organic matter, enhance humus synthesis and bring about nutrient cycling.

Moreover, microfungi are very important in producing secondary metabolites which are very useful in agriculture, medicine and pharmaceutics. Saparrat *et al*. (2002) reported laccase activity in *Tetraploa aristata* isolated from crude oil-polluted organic matter in Santiago river, Buenose Aires, Aegentina. Pericosine A, B and macrosphelide from *Periconia byssoides* isolated from *Aplysia kurodai*, have been proved to be used as antitumour in patient. Kim *et al*. (2004) recorded *Periconia* sp. as a source of bioactive compounds, periconisine A and B which are bacterial inhibitor (Manoch *et al*., 2008b).

In all forests, fungi fulfil a gange of roles in addition to wood decomposition. Fungi assist in the nutrition of tree through mycorrhizal associations with roots, many species decompose organic matter other than wood in the soil, some live symptomless within leaves as endophytes and may confer on the host such benefits as resistance to disease, drought, and animal browse and minority are pathogenic on plant, animals and other fungi (Buchanan *et al*., 2001). In the tropical forests the mycorrhizal fungi are mainly ectomycorrhizal basidiomycetes that form mushroom and mushroom-like sporocarps (Buchanan *et al*., 2001). Types of fungal interactions in wood decay include the followings (Zabel and Morrel, 1992).

Mutualism

Both organisms benefit for example: *Amylostereum chailleti*, a decay fungus, is vectored by a horntail (*Sirex cyaneus*) during oviposition into the dying sapwood of fire-killed or defoliated balsam fir. The fungus can then invade the wood before the arrival of competing fungi. The horntail larvae benefit by ingesting fungal mycelium and acquiring the cellulose enzyme needed for softening and digestion of the wood.

Commensalism

One is benefited and the other is unaffected. In the later decay stages, many brown-rot fungi release more simple carbon compounds than they use or store. Some secondary scavenger fungi such as *Trichoderma* spp. or *Mucor* spp. invade in the late decay stage and use the excess sugars.

Amensalism

The toxic products of one organism inhibit or retard the growth of another (antibiosis). Prior colonization of logs by *Trichoderma* spp., it has been shown to inhibit subsequent basidiomycota colonization. A microfungus, *Scytalidium* sp. commonly found in seasoning Douglas fir utility poles, is reported to delay the colonization of *Antrodia carbonica* by antibiosis. This antibiotic association has been proposed as a potential biological-control approach to reduce decay development in utility poles.

Parasitism

One organism obtains its nutrition directly from another, and the relationship is general harmful to one. Some fungi are pathogens of other fungi and insects. Some white-rot fungi attack and utilize wood-inhabiting fungi, apparently as a nitrogen source. Such fungi are called mycopathogens and are of special interest as possible biological control agents.

Predation

One organism physically captures and consumes part or all of another. Usually the predator is larger than the prey, but some fungi trap nematodes using hyphal coils and digest them as a food source.

2.2 Fungal decomposer communities

The decomposer fungi were recognized into five behavioural groupings. These groupings take into account three factors; 1) the typical substrates utilized 2) the typical environmental conditions for growth and 3) the interaction with other organism. The behavioural grouping of decomposer fungi and an overlapping sequence are shown in Table 2.1 and Figure 2.1.

Table 2.1 Characteristics of the behavioural groupings of decomposer fungi

Group	Features
1. Pathogens and weak parasites	1. Grow initially by tolerating host resistance factors or other special conditions 2. Generally utilize simple soluble substrates or storage compounds but not structural polymers 3. Generally poor competitors for dead organic matter Examples: *Alternaria* spp. and *Cladosporium* spp.
2. Pioneer saprotrophic fungi	1. Generally utilize simple soluble substrates or storage compounds but not structural polymers 2. Good competitors, with fast growth and short life cycles 3. Cannot defend a resource against subsequent invaders Examples: *Mucor* spp. and *Rhizopus* spp.
3. Polymer degrading fungi	1. Degrade the main structural polymers 2. Have extended growth phase, defending a resource by antibiosis or sequestering mineral nutrient 3. Substrate specialized, and sometimes tolerant of stress factors (extremes of temperature, pH, etc) Examples: *Fusarium* spp. and *Chaetomium* spp.
4. Degraders of recalcitrant compounds	1. Specialized to degrade recalcitrant organic materials and thereby gain access to polymers complexed with them

Table 2.1 (Continued) Characteristics of the behavioural groupings of decomposer fungi

Group	Features
	2. Long growth phase, and defend a resource by antagonism or mutual inhibition 3. Can gain access to mineral nutrients that previous colonizer have exploited Examples: *Mycena* spp. and *Marasmius* spp.1
5. Secondary opportunistic invaders	1. Nutritionally opportunistic: grow on dead remains of other fungi, insect exoskeletons or parasitize other fungi, or grow commensally with polymer-degraders 2. Tolerant of metabolic by-products of other fungi 3. Often antagonistic Examples: *Aspergillus* spp. and *Trichoderma* spp.

Source: Deacon (1997)

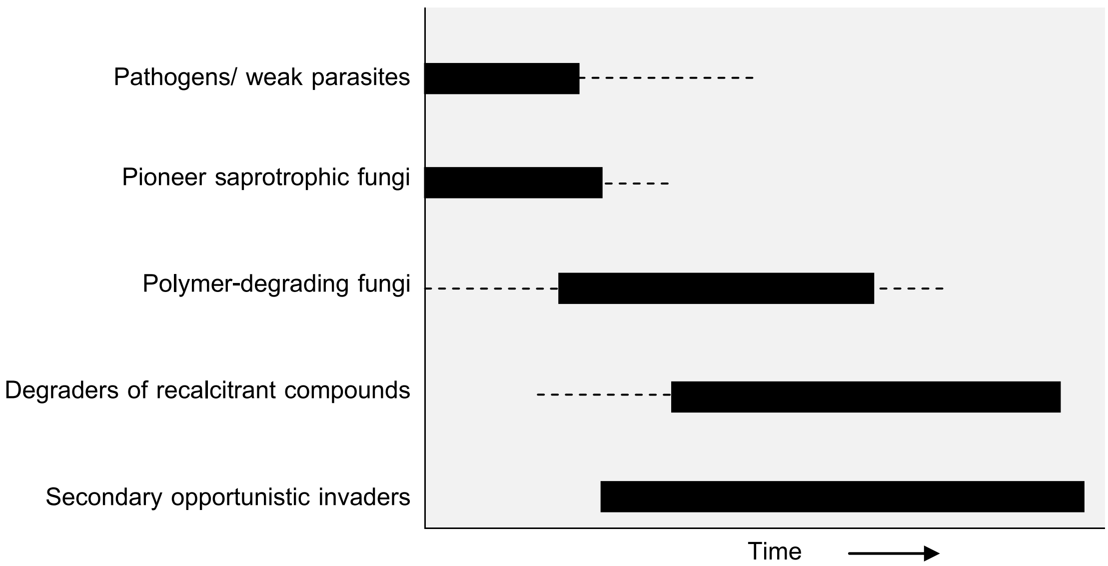


Figure 2.1 Illustration of the overlapping phases of activity of different types of fungi during decomposition of a material. Main stages of activity are shown, but they might extend in some conditions (broken line)

Source: Deacon (1997)

2.3 Fungal succession

Fungal successions mean a time-related change in fungal community structure. A study of the fungal succession is the changes in the structure of fungal communities on various substrates over time (Yanna, 1997). The occurrence of different fungal taxa at different stages of decomposition on decaying materials is serial succession. After fungi colonize on substrate, their presence can be detected by loss in strength and changes in color. Species diversity tends to be richest and number of fungi usually highest during the early stage of colonization than species begin to decline (Dix and Webster, 1995). However, many researchers studied fungal succession and reported that the highest number of species was observed during the middle stage of decomposition (Tan *et al*., 1989; Tiwari *et al*., 1994; Niemelä *et al*., 1995; Renvall, 1995; Linbald, 1998; Yanna *et al*., 2002; Maria and Sridhar, 2004; Kodsueb *et al*., 2008b; Seephueak *et al*., 2010; 2011).

Generally, the fungal communities are classified into three succession stages of decomposition; the pioneer stage, the mature stage and the improverished stage (Kannangara and Deshappriya, 2005). The pioneer communities are typically composed of a large number of different species occurring in low frequency with no obvious dominant species. While mature communities consist of fewer species with one or two obvious dominant species common to all samples at similar stage in the development of the fungal community. The fungal succession on decomposing organic matter rarely followed to this end-point, and investigations of the fungal decay of the refractory remains of plants within soil have been limited. In Thailand numerous substratum successions by saprobic fungi have been described, mostly from plant material above the soil and the pioneer fungi (Wang *et al*., 2008). Studies of fungal leaf litter succession were reported from *Magnolia liliifera*, *Meliosma simplicifolia* and *Pandanus* sp. (Promputtha *et al*., 2002; Kodsueb, 2007; Thongkantha *et al*., 2008). Osono (2005) reported that fungal succession on decomposing *Swida* leaves followed a pattern that the early colonizer *Cladosporium cladosporioides* was regarded as primary saprophytes. Whereas later colonizers such as *Trichoderma hamatum*, *Mucor hiemalis* and *Absidia glauca* might correspond to secondary sugar fungi because they were frequent in stage III when lignin was the dominant constituent of decomposing leaves.

2.4 Fungi and plant litter decomposition

The trees, being deciduous in nature, are a source of substantial quantity of organic matter by way of litter fall. Litter production and nutrient return in natural forests as well as in plantations are very important aspects of nutrient cycling, since a considerable amount of nutrients are returned through litter fall in the form of leaves, twigs, barks, branches, flowers etc. and are available for reabsorption. The sequential process of litter fall, its decomposition and subsequent mineralization are essential in sustaining a dynamic plantation ecosystem. Plant litter dynamics constitute an important aspect of nutrient cycling and energy transfer in ecosystem (Maguire, 1994). It also plays an important role in agroforestry system in cultivated lands (Agarwal, 1980). Decomposition is the progressive dismantling of organic materials into its simplest constituents. In nature, decomposition is mediated mainly by soil micro-organisms, which derive energy and nutrients from the process. It usually occurs not as a single step, but as a cascade. The substrates for decomposition include a wide range of materials, forming a continuum from recently added plant litter to very stable, humified organic matter.

Decomposition can be sub-divided into two processes : primary decomposition, involving the breakdown of fresh litter and secondary decomposition, involving the progressive breakdown of decomposition product. Fresh material, usually plant litter, is converted to altered form with the release of CO_2, NH_4 and other inorganic compounds (Couteaux *et al*., 1995).

The rate of litter decomposition varies widely. Although many factors like temperature, rainfall, pH of the soil, altitude etc affect the decomposition rate, the diverse chemical composition of different litters plays a crucial role in determining the rate of decomposition and nutrient cycling (Dutta *et al*., 2001).

2.4.1 Fungi associated with leaf litter

Saprobic litter fungi contribute substantially to nutrient and carbon cycling processes because fine litter production represents the bulk of the input of biomass to the decomposition system in tropical forest. Resource distribution in time and space strongly influence the activity of litter fungi, as different species have different degrees of resource selectivity, either taxon selectivity or component-selectivity. The resource represents both the substratum and the source of organic nutrients for these fungi, and its durability affects directly mycelia longevity. The fast rate of decomposition of fine litter on the ground in tropical forests necessitates rapid colonization by fungi for capture of resources and subsequently, rapid exit during the colonization of newer resources (Braga-Neto *et al.*, 2008).

The diversity of fungi has been carried out worldwide on various plant substrata such as wood, submerged wood, leaf litter, palms, bamboo and soil (Manoch *et al.*, 2008a). Tropical forests comprise a great variety of tree species that produce high amount of leaf litter. Decomposers are stratified within the forest floor, with some species colonizing only fresh litter and others restricted to soil organic matter. The studies of saprobic fungi on leaf litter and woody litter in several tropical forests were showed in Table 2.2

Each decaying stage of leaf litter has different composition of taxonomic groups. Puranong *et al.* (2007) reported that filamentous fungi associated with the decomposition of *Castanopsis accuminatissina* leaf litter were ascomycetes (54.55%), deuteromycetes (27.27%) and zygomycetes (12.73%) and showed that the initial diversity of fungal taxa from freshly fallen leaves was the highest. Seephueak *et al.* (2010) reported that fungi collected at three periods on rubber leaf litter were including mitosporic (90.60%), ascomycetes (8.50%), zygomycetes (0.45%) and oomycetes (0.22%) and showed that the middle stage of leaf decomposition was the highest.

Several fungi appear to be common on leaf litter including *Beltrania rhombica*, *Beltraniella portoricensis*, *Chaetopsina fulva*, *Hansfordia pulvinata, Hypocrea* spp., *Idriella lunata*, *Selenosporella curvispora* and *Zygosporium echinosporium* (Duong *et al*., 2004). Osono and Takeda (2006) reported the species of fungi frequent by on found initially *Swida controver* leaf litter decomposition including ten ascomycetes (anamorphs) and five zygomycetes. *Phoma* sp.1, *Cladosporium cladosporioides* and *Pestalotiopsis* sp.2 were initially highly frequent and in general decreased over time and thus were regarded as early colonizers. There were 12 fungi that increased in as the decomposition progressed and thus were regarded as late colonizers.

Leaf litter fungi have been used as biological control agent against plant pathogenic fungi in vitro. *Myrothecium verrucaria* and *Ciliochorella* sp. isolated from leaf litter could inhibit growth of *Alternaria alternata*, *Colletotrichum capsici*, *Curvularia lunata* and *Fusarium oxysporum* in vitro (Manoch *et al*., 2008b). Rukachisirikul *et al*. (2005) found that *Beltrania rhombica* on leaf litter from Ton Nga-Chang water fall Songkhla Province produced secondary metabolites which inhibited *Staphylococcus aureus* and *Candida albicans*.

2.4.2 The factors and relative contributions of saprobic fungi on leaf litter

Decomposition of leaf litter is a major source of nutrients in ecosystems. As leaves are broken down by insects and microbial decomposers, organically-bound nutrients are released as free ions to the soil solution which are then available for uptake by plants. Kuers and Simmons (2011) studied rate of decomposition of leaf litter during winter, spring and summer at contrasting sites using the litterbag technique. In most forests the major source of nutrients for trees is the process of decomposition. Decomposition refers to the processes that convert dead organic matter into smaller and simpler compounds. The products of complete decomposition are carbon dioxide, water, and inorganic ions (like ammonium, nitrate, phosphate and sulfate). Decomposition is mainly a biological process carried out by insects, worms, bacteria and fungi both on the soil surface and in the soil.

The rate of decomposition is influenced by many factors. Since decomposition is a biological process carried out primarily by bacteria and fungi, its speed will be affected by temperature and soil moisture. Generally decomposition increases exponentially with temperature; that is, for every 10 degree rise in temperature, decomposition increases by a factor of 2. Nevertheless, leaf decomposition does occur at a low rate during the winter months even under deep snow (Kuers and Simmons, 2009).

Temperature

It is well understood that temperature can have a significant effect on the decomposition of organic resource patches in soil (Swift *et al*., 1979), which is primarily due to the effect of temperature on microbial metabolism and abiotic chemical reactions (Paul and Clark, 1989). Temperature plays a huge role on the speed and item decomposes. The higher the temperature in an area is the faster an object in that area will be decomposed. Heat makes objects decompose more rapidly than they would if they are in a cooler temperature.

Soil moisture

Effects of soil moisture on decomposition are a little more complicated. Decomposition is inhibited in very dry soils because bacteria and fungi dry out. Decomposition is also slow in very wet soils because anaerobic conditions develop in saturated soils. Anaerobic decomposition is less efficient and slower than the aerobic condition. Decomposition proceeds fastest at intermediate water contents (Kuers and Simmons, 2009).

The quality of the leaves

The quality of the leaves as a food source for microbial decomposers is another important factor. Substrate quality has been defined in many different ways - as the nitrogen concentration (N), as the lignin content, and as the C : N ratio. Researchers have found that decomposition of leaf litter can be predicted by the C : N ratio (Taylor and Jones, 1990), by the lignin content (Meentemeyer, 1978), or by the lignin : nitrogen ratio (Melillo *et al*., 1982). Basically, high quality leaves (like nutrient-rich alder leaves) will decompose faster than low quality leaves (like nutrient-poor conifer needles). Many studies have shown striking differences in decomposition rates among species.

Substrate quality

Substrate quality can even vary within a leaf. Berg and co-workers (Berg and Staaf 1980; McClaugherty and Berg, 1987) have shown that in the initial stages (0 to 3 months) of leaf breakdown small soluble carbon molecules, like starches and amino acids, are lost first, leaving behind the more recalcitrant molecules like lignin. Decomposition during this first phase is rapid because these molecules are easy to break down and energy rich. The second stage of decomposition - the breakdown of lignin - is much slower because lignin consists of very large and complex molecules. This rapid initial breakdown followed by a longer period of slow decomposition results in a mass loss curve that resembles an exponential decay curve.

Host preference

Agarics that decompose fallen leaves only rarely show strong host-specificity, and then it is usually for broad classes of hosts such as monocotyledonous versus dicotyledonous plants in the tropics. Specificity occurs slightly and more commonly among fruit-inhabiting agarics, such as those that are specialized on coned of conifers or infructescences of *Magnolia* spp. In contrast, larger ascomycetous fungi in the Xylariaceae (dead man's fingers) are very frequently restricted to fruiting on leaves and fruits of particular host plant genera or families in the tropics. For example, in Puerto Rico it was found that over half of the 13 species of *Xylaria* on leaves and fruits were restricted to a single host plant genus or family (*X. aristata*, *X. axifera*, *X. meliacearum*, *X. phyllocharis* and *X. stromatica* on leaves; *X. worburgii* and *X. palmicola* on fruits were host – specific, whereas *X. apiculata, X. appendiculata*, *X. clusiae*, *X. ianthinovelutina* on leaves and *X. mellisii* and *X. multiplex* on fruits showed no strong preferences) (Lodge, 1997).

2.4.3 Saprobic fungi on decaying wood

Dead wood has been denoted as the most important manageable habitat for biodiversity in forest, supporting a wide diversity of organisms, including birds, mammals, insects, mites, nematodes, bryophytes, lichens, fungi and bacteria. Especially, fungi are the most species rich groups and as the most important agent of wood decay, fungi can be regarded as a key group for the understanding and management of biodiversity associated with decaying wood (Höff *et al*., 2004; Helimann-Clausen and Christensen, 2005).

Wood-inhabiting fungi are among the major wood-decaying organisms involved in the wood decay process and they play an important role in the nutrient cycle in ecosystem. 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 and Christensen 2003; Küffer *et al*., 2004; Küffer and Senn-Irlet, 2005).

Wood decay fungi have key-roles in the ecology of tropical and temperate forests. They are the major agents of wood decomposition and nutrient cycling. Fungi are the principle agent of wood decay in terrestrial habitat and hence. They open up the wood resource for most other organisms living in dead wood (Boddy, 2001). Decay stage appears consistently to be the most important variable for understanding fungal community composition on decaying wood. Tree species, tree size, microclimatic condition, cause of death and the original position of the dead wood in the tree are key variable influencing species. The recycling of these elements by substrate decomposition necessary to maintain soil fertility and health of the forest, is effected primarily by fungi (White, 2004).

Decay fungi destroy the plant's internal supportive or structural components (cellulose, hemicellulose and sometimes lignin). Decay is not visible on the outside of the plant, except where the bark has been cut or injured, when a cavity is present, or when the rot fungi produce reproductive structures. Wood decay makes trees hazardous because trunks and limbs become unable to support their own weight and can fall, especially when stressed by wind, heavy rain, or other conditions. Many wood rot fungi can be identified by the distinctive shape, color, and texture of the fruiting bodies that form on trees. These structures, called conks or brackets, are often located around wounds in bark, at branch scars, or around the root crown. Some decay fungi (such as *Armillaria mellea*) produce typical fleshy mushroom-shaped fruiting bodies at the base of infected trees after a rain in fall or winter. Some fruiting bodies, such as *Armillaria* mushrooms, are annual (for example appearing soon after the beginning of seasonal rains), but most are perennial and grow by adding a new layer each year (Zabel and Morrel, 1992).

Decay fungi often are divided into white rots, brown rots, and soft rots. White rots break down lignin and carbohydrate, and commonly cause rotted wood to feel moist, soft, spongy, or stringy and to appear white or yellow. Brown rots primarily decay the cellulose and hemicellulose (carbohydrates) in wood, leaving behind the brownish wood lignin. Wood affected by brown rot is usually dry and fragile, readily crumbles into cubes because of longitudinal and transverse cracks, and commonly forms a solid column of rot in wood. Brown rot is generally more serious than white rot. Soft rots are caused by both bacteria and fungi. They decay cellulose, hemicellulose, and some lignin, but only in areas directly adjacent to their growth. Soft rots grow more slowly than brown and white rots and usually do not cause extensive structural damage to wood of living trees (Hickman and Perry, 2008).

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 twigs and branches are rarely studied. However, significant quantities of dead wood for fungal growth and fruiting bodies are often found in a high proportion in the form of fine and very fine woody debris (Küffer and Senn-Irlet, 2005). The fungal diversity on decaying twig and branch litter has previously been studied, i.e. *Fraxinus excelsior* (Boddy *et al*., 1987), *Corylus avellana* (Nordén and

Paltto, 2001), beech (Küffer *et al*., 2004), *Picea abies* (Allmér, 2005), *Fagus sylvatica*, *Picea abies*, *Abies alba*, *Pinus sylvestris* and *Castanea sativa* (Küffer and Senn-Irlet, 2005), *Pinus nigra*, *P. pinaster*, *P. sylvestris* and *P. uncinata* plantation (Zamora *et al*., 2008), *Magnolia liliifera* (Kodsueb *et al*., 2008a). However, there have been some studies of lignicolous fungi from terrestrial woody litter 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 and Berbee, 2001; Inderbitzin *et al*., 2001; Kodsueb, 2007), *Dracaena loureiri* and *Pandanus* sp. (Thongkantha *et al*., 2008).

2.4.4 The factors and relative contributions of saprobic fungi on decaying wood

Fungal diversity has received increasing attention during the last decade in part because fungi are used for production of antibiotics, enzymes, food, as agents for biopulping of paper and bioremediation of chemical spill. Although temperate mycotas are relatively better known than tropical ones, fungal diversity is generally thought to be greater in the tropics and subtropics than in a higher latitude, especially among taxonomic groups dominated by decomposers. The reasons of higher diversity at low latitudes are not always clear, but the consensus of mycologists with experience in more than on hemisphere is that host diversity, resource abundance and habitat diversity are important contributing factors. Although decomposers might be expected to exhibit less host-specificity or host – preference than pathogens and beneficial symbionts, the survey suggested that diversity of certain groups of decomposer fungi is strongly related to host diversity (Lodge, 1997; Ferrer and Gilbert, 2003).

Substratum preference

Tropical decomposer fungi are frequently restricted to particular size, classes and types of substrata. For example, an analysis of the data presented in Lodge (1997) shows that almost all decomposer fungi were restricted to one or at most two similar types of substrata at El verde in the Luquillo Mountains of Puerto Rico. Substrata were divided into the following classes; logs (10 cm diameter), branches (> 1 cm to 10 cm), twigs (< 1 cm), leaves (including petioles), roots and soil. Some of these fungi might have appeared to be restricted to particular substrata because they were only collected once or a few times, but they often colonize other types of substrata that were in contact with their own. Of the 705 decomposer fungi, 493 spp. (70%) were restricted to one substratum (246 spp. were only on leaves, 43 in soil,13 on roots, 27 on twigs, 84 on branches and 80 on logs). Another 173 species (25%) were found only on two similar substrata (84 on logs and branches, 34 on branches and twigs, 28 on twigs and leaves, 21 on roots and wood, and 16 in soil and one other substratum). In contrast, only 39 species (5%) were found on three or more substrata (12 on logs, branches and twigs, 15 on branches, twigs and leaves and 12 on soil and two other substrata) (Lodge, 1997).

Log size and shape

The species diversity of wood – inhabiting fungi increases markedly with log size. The large logs simply provide space for more species. Interestingly, complexity is the log size and shape variable which has the strangest effect on total and species richness. The log with one or more bole forks tends to have a larger cumulative log length and bigger surface area compared to a log without forks. Consequently, log length and surface appear to be more important for fungal diversity than diameter (Helimann-Clausen and Christensen, 2003). Large logs are generally more species rich than smaller logs, but differences appear to be mostly qualitative within the range of log size included in the present study. According, two smaller logs appear to be just at valuable for fungal biodiversity as one very big one, as long as the log exceeds 70 cm. and logs with bole forks are more species rich than unfork logs with equal diameter (Ferrer and Gilbert, 2003; Helimann-Clausen and Christensen, 2005).

Microhabitat preference

Lodge (1997) reported that many wood inhabiting ascomycetes had distinct preferences for the state of substratum decay and position relative to the ground, in addition to substratum type and diameter class. Such preferences have also been noted for tropical wood decomposer fungi. Similarly Hedger (1985) showed that, in Ecuador, leaf decomposer basidiomycota fungi from the lower litter required partially decomposed leaves, in contrast to agarics of the upper layer that required freshly fallen leaves. Thus the availability of different microhabitats and substrata in different states of decay are likely to influence the diversity of decomposer fungi in tropical forests (Lodge, 1997).

Rate of wood decay by fungi

The rate of decaying in the tropical forest depends on the combination of fungal species that colonize a particular log activity, type of wood (Buchanan *et al*., 2001; Helimann-Clausen and Christensen, 2003) moisture, temperature, the size of the tree and the decay resistance of the wood (Ódor *et al*., 2006). Fungal activity plays a significant role in the decay of wood in the forest, while hundreds of fungi may be involved with the decay process; only about 50 cause the greatest decay. Once these are present at adequate levels, air temperature becomes a significant influence on fungal activity. Fungi cannot function at air temperatures below 40°F while above 70°F, decay proceeds more rapidly. The length of time to reduce a tree to soil components depends on the size of the tree and type of wood. Heartwood decays more slowly than sapwood (Ódor *et al*., 2006).

Microclimate

Microclimate regimes are crucial for fungal community development in decaying wood. Microclimate conditions have a negative effect on species richness. Soil contact is the only variable which clearly indicates an effect of microclimate on species richness. Microclimate disturbance regime favours a high number of fruiting fungal species on the wood decay. The number of fungi fruiting on wood distributed across several habitat types subject to very different microclimate regimes in the forest (Ódor *et al*., 2006).

2.4.5 Type of wood decaying fungi

The decay process often commences in the standing tree, in attached lower or stressed branches (Rayner and Boddy, 1988). Fungi may gain access either through wounds, tissues following microbial or stress damage or via lenticels or leaf scars. White (2004) studied wood decay fungi in oak and ash and the results indicate that pioneer species such as *Stereum gausapatum*, *Phlebia rufa*, *Phellinus ferreus*, *Exidia glandulosa* and *Vuilleminia comedens* in oak or *Daldinia concentrica*, *Hypoxylon rubiginosum*, and *Peniophora limitata* in ash, can colonize living or recently dead wood. While, secondary invaders such as *Coriolus versicolor*, *Phlebia radiate*, *Stereum hirsutum* and *Peniophora lycii* in oak, and *Radulomyes confluens* in ash, could invade and replace pioneers in already dead or decaying wood.

The majority of wood-decay studies have been concerned with basidiomycetes from early stages of decomposition (White, 2004), and with ascomycetes, moulds, and zygomycetes particularly from later decomposition stage (Rayner and Boddy, 1988; Lumley *et al*., 2000). Nilsson *et al*. (1989) and Höff *et al*. (2004) reported that basidiomycota and ascomycota are the most importance and distribution on wood decay. Wood decaying fungi are classified into 3 groups as:

White-rot fungi

These fungi degrade all the major wood components (cellulose, hemicelluloses and lignin) more or less simultaneously, so that the wood becomes progressively more fragile but remains white as it decays. White rot are caused by the two major root-rot pathogens of trees, *Armillaria mellea* and *Heterobasidiun annosum*, and also by many saprotrophic fungi, including the common colonizer of stumps, *Coriolus versicolor* and the common wood-rot ascomycota *Xylaria hypoxylon* and *X. polymorpha* (Deacon, 2009).

Brown-rot fungi

Brown-rot fungi degrade the cellulose and hemicellulose but leave the lignin more or less intact as a brown framework. Only about 6% of wood decay fungi cause brown rots, and all these fungi are members of the basidiomycota. They include *Serpula lacrymans* (dry-rot fungus) and the common birch polypore, *Piptoporus betulinus* (Deacon, 2009).

Soft-rot fungi

Soft-rot fungi degrade the cellulose and hemicelluloses and some lignin (Robert *et al*., 2000) usually occurs in wood of high water content and high nitrogen content. They are most commonly found in rotting window frames, wet floor boards and fence posts, where nitrogen is recruited from soil or from atmospheric contamination. Some of these fungi are common decomposers of cellulose in soil (e.g. *Chaetomium* sp.) and they are the least specialised of the wood-rot fungi (Robert *et al*., 2000; Deacon, 2009).

Table 2.2 The studies of saprobic fungi on leaf and woody litter in several tropical forests (from 2002-2011)

Plant species	Location	References
Leaf litter		
Anacardium occidentale	Adyar, India	Shanthi and Vittal, 2010a
Artocarpus heterophyllus	Angthong, Thailand	Manoch *et al*., 2008a
Bambusa sp.	Bangkok, Thailand	Manoch *et al*., 2008a
B. tuldoides	Hong Kong	Zhou and Hyde, 2002
Bambusicola sp.	Yunnan, China	Cai *et al*., 2003
Castanopsis accuminatissima	Loei, Thailand	Puranong *et al*., 2007
C. *diversifolia*	Chiang Mai, Thailand	Duong *et al*., 2004; 2008
C. fissa	Mount Nicholson, Hong Kong	Tang *et al*., 2005
Citrus hystrix	Angthong, Thailand	Manoch *et al*., 2008a
Croton poecilanthus	Puerto Rico	Santana *et al*., 2005
Dracaena loureiri	Chiang Mai, Thailand	Thongkantha *et al*., 2008
Elaeocarpus angustifolius	North Queensland, Australia	Paulus and Hyde, 2003
Eleiodoxa conferta	Sirindhorn Peat Swamp Forest, Narathiwat, Thailand	Pinnoi *et al*., 2006
Eugenia malaccensis	Bangkok, Thailand	Manoch *et al*., 2008a
Ficus altissina	Chiang Mai, Thailand	Wang *et al*., 2008
F. pleurocarpa	North Queensland, Australia	Paulus *et al*., 2006
Hevea brasiliensis	Southern, Thailand	Seephueak *et al*., 2010

Table 2.2 (Continued) The studies of saprobic fungi on leaf and woody litter in several tropical forests (from 2002-2011)

Plant species	Location	References
Indocalamus sp.	Shing Mun Country Park, Hong Kong	Shenoy *et al*., 2005
Inga fagifolia	Puerto Rico	Santana *et al*., 2005
Licuala longecalycata	Sirindhorn Peat Swamp Forest, Narathiwat, Thailand	Pinruan *et al*., 2007
Maglielia garrettii	Chiang Mai, Thailand	Kodsueb *et al*., 2006
Magnolia liliifera	Chiang Mai, Thailand	Promputtha *et al*., 2004a; Kodsueb *et al.,* 2008a
Mangrove forest	Nethravathi, Udyavara, India	Ananda and Sridhar, 2004
Manilkara bidentata	Puerto Rico	Santana *et al*., 2005
Michelia baillonii	Chiang Mai, Thailand	Kodsueb *et al*., 2006
M. nilagirica	Hakgala montane forest, Malaysia	Kannangara and Deshappriya, 2005
Musa acuminata	Chiang Mai, Thailand	Photita *et al*., 2003
M. sapientum	Saraburi, Thailand	Manoch *et al*., 2008a
Nenga pumila	Sirindhorn Peat Swamp Forest, Narathiwat, Thailand	Pinnoi *et al*., 2006
Pandanus spp.	Chiang Mai, Thailand	Thongkantha *et al*., 2008
Pavetta indica	Adyar, India	Shanthi and Vittal, 2010b
Phoenix hanceana	Hong Kong	Yanna *et al*., 2002
Phyllanthus distichus	Angthong, Thailand	Manoch *et al*., 2008a
Plumeria acuminata	Bangkok, Thailand	Manoch *et al*., 2008a
Pterocarpus indicus	Angthong, Thailand	Manoch *et al*., 2008a
Quercus rotundifolis	High Atlas, Morocco	Sadaka *et al*., 2003
Rhizophora apiculata	Pattani,Thailand	Sappa-aramdecha, 2002

Table 2.2 (Continued) The studies of saprobic fungi on leaf and woody litter in several tropical forests (from 2002-2011)

Plant species	Location	References
Sapium laurocerasus	Puerto Rico	Santana *et al*., 2005
Semecarpus coriacea	Hakgala montane forest, Malaysia	Kannangara and Deshappriya, 2005
Shorea obtuse	Forest in northern, Thailand	Osono *et al*., 2009
Syzygium cumini	Bangkok, Thailand	Manoch *et al*., 2008a
Woody litter		
Bambusicola sp.	Yunnan, China	Cai *et al*., 2003
Hevea brasiliensis	Southern, Thailand	Seephueak *et al*., 2011
Indocalamus sp.	Shing Mun Country Park, Hong Kong	Shenoy *et al*., 2005
Licuala longecalycata	Narathiwat, Thailand	Pinruan *et al*., 2007
Magnolia liliifera	Chiang Mai, Thailand	Kodsueb *et al*., 2008b
Manglietia garrettii	Chiang Mai, Thailand	Kodsueb *et al*., 2007
Michelia baillonii	Chiang Mai, Thailand	Kodsueb *et al*., 2007
Pennisetum purpureum	Chiang Mai, Thailand	Bhilabutra *et al*., 2010

2.5 Decomposition of plant litter

2.5.1 Nutrient

In forest ecosystems, litter decomposition represents the major pathway for supply of plant nutrients to soil, particularly for tropical rain forests growing in nutrient poor soils with relatively low external nutrient inputs, as similar to rubber plantation. The turnover of bioelements is an important step (Staff and Berg, 1982). Plant litter decomposition is an important process in nutrient cycling within plantation ecosystems. Decomposition processes are mediated by microorganisms that are extremely important for environment maintenance because of their fundamental role on nutrients and organic matter cycling, changing organic matter into inorganic matter and providing nutrients which propitiates energetic balance in ecosystems.

Plant litter is the primary source of food and energy for soil biota and its quality is of critical importance in regulating microbial biomass (Wardle and Lavelle, 1997). Though many biological indicators of soil quality have been proposed (Elliot *et al*., 1996), microbial biomass measurement through substrate induced respiration method is often preferred as it can be applied to a range of soils and due to easiness in its measurement (Webster *et al*., 2001).

The interactive and sequential processes of litter fall, its decomposition and subsequent mineralization are essential in sustaining a dynamic agriculture ecosystem. This is important because the availability of nutrients and plant uptake depends upon the reabsorption and retranslocation of the nutrients before plant litter fall and subsequently on decomposition and mineralization of the organic matter.

The incorporation of plant litter biomass of tree species has been found to be very successful and hence widely adopted for improving the soil nutrient status without much deleterious effect on the physico-chemical properties of the soil. The increase in soil organic carbon content is due to the addition of decomposing plant litter. It could be stated that the decrease in organic carbon content might be due to faster degradation of soil organic carbon as a result of enhanced microbial activity (Flaig, 1984). The stability of soil aggregates, release of essential nutrients for plant growth, maintenance of soil microbial dynamics and biochemical changes in the soil are attributed to the organic matter and organic carbon content of the soil (Paul and Clark, 1989). Palm (1995) reported that nutrient release pattern from organic materials is, in part, determined by their chemical composition or quality. Couteaux *et al*. (1995) suggested that the litter decomposition is controlled by three main factors: climate, litter quality and nature, and abundance of decomposing organisms. They concluded that climate is a dominant factor in areas subjected to unfavourable weather. Litter quality remains important until late decomposition stages through its effect on humus formation.

Litter quality influences the decomposition process of soil organic matter amongst other factors such as activity and variety of decomposer organisms present and the prevailing environmental conditions. However, as litter quality is the factor which is more amenable to management options (Giller and Cadisch, 1997; Krull *et al*., 2003), its assessment in every soil ecosystem is of great importance in maintaining or restoring soil quality. C-to-N ratio is considered as a general index of plant litter quality.

The different carbon compounds present in litter are varying in nature and structure, and cannot be treated as a single entity— total-C, especially when their interaction with decomposer organisms widely differs. For example, decomposition rate is positively correlated with polysaccharides, hemicelluloses and pectin (Swift *et al*., 1979) while negatively correlated with lignins and tannins in litter (Dighton, 1978; Rayner and Boddy, 1988).

Many studies have been carried out on litter decomposition and the dynamics of nutrient release to analyse the effect of climate and litter quality (MacLean and Wein, 1978; Staff and Berg, 1982; Somrithipol, 1997). Aziz (2007) studied role of microorganisms in *Salix* spp. and the results showed that the nutrient concentration of all the nutrients (organic carbon, N, P, K, Ca and Mg) was higher after the litter fall as compared to before litter fall.

Soil organic matter management in arable soils is important as it regulates the physical, chemical and biological properties of soil (Weil and Magdoff,

2004) and is essential to sustain soil quality (Wander, 2004). Plant litter is the major source of soil organic matter in natural as well as many of the cultivated soil systems (Kögel-Knabner, 2002).

Rubber, a tree native of the Amazon forests was introduced to Thailand about a century ago. It is now very widely planted in Thailand. Most of the initial rubber plantations were on forest cleared areas. Rubber plantations are cycled by new trees in about 30 years (Karthikakuttyamma *et al*., 2000). In rubber plantations during the initial 7 to 8 years of cultivation the fields are usually planted with leguminous cover crops and the litter turnover is estimated to be 3-6 tonnes (Mathew *et al*., 1989; Krishnakumar and Potty, 1992). Subsequently rubber leaf litter itself becomes the principal organic matter source in rubber plantations and its turnover is estimated to be about 6 tonnes/ha/year (Krishnakumar and Potty, 1992).

Reports available on the nutrient turnover from leaf litter of rubber, are not detailed (Maharudrappa *et al*., 2000; Amponsah and Meyer, 2000). However, studies on litter quality and comparative assessment of soil biological properties of these ecosystems in rubber are lacking. As organic matter input differs in quality and quantity in these systems, associated microbial activity can be varied.

The decomposition of plant detritus is an important process in ecosystems as it allows the nutrient and carbon cycle to be closed (Lavelle *et al*., 1993). As decomposition and soil organic matter formation are main functions of soil organisms, these ultimately have a crucial role in maintaining soil fertility and plant growth. Soil fauna can improve the growth conditions of plants (Beare *et al*., 1992; Reddy, 1992; Tian *et al*., 1995). Understanding the full decomposition processes would allow to develop management options for agroecosystems that make use of the natural ecological processes to be devised, thus minimizing external inputs. Organic matter is a key to many important soil functions (Martius *et al*., 2001). We also expect that managing the soil fauna will help in halting the alarming degradation of soils in the rubber plantation.

2.5.2 Enzyme

Fungi are very good sources of diverse enzymes that can degrade natural polymeric compounds such as cellulose, pectin and starch. These polysaccharides are widely used in various industries such as food and dairy, pulp and paper, textile, animal feed, pharmaceutics, detergent, cosmetic, and chemical-synthesis processes. Developments of enzyme systems that break down the polysaccharides are needs. There are some reports concerning the biomass of bacteria or fungi and the activity of cellulolytic enzyme on decomposition of leaf litter. (Newell and Hicks, 1982; Fioretto *et al*., 2000; Gautum *et al*., 2011). Tanaka (1993) studied degradation of fungi and reported that cellulolytic and xylanolytic enzymes had relationship between their change and the dynamics of the decomposer microorganisms.

In recent years, attention has turned to the degrading capacity of microorganisms by evaluating their enzyme activities. Microbial species and communities release enzymes into the environment in order to degrade macromolecular and insoluble organic matter prior to cell uptake and metabolism (Burns, 1982). This important property may allow decomposition rates to be related to the enzymes that directly mediate the degradation of the major structural components of plant material and can provide functional information on specific aspects of the microbial community and succession (Sinsabaugh *et al*., 1991). Moreover, the enzymes involved in the degradation of main litter components, such as cellulose, hemicellulose and lignin, and those involved in the cycling of nitrogen, phosphorus and sulphur, are of primary interest in understanding the factors controlling plant litter decomposition. The release of extracellular enzymes is species-dependent and is influenced by temperature, moisture, pH, and quality and quantity of available substrate (Sinsabaugh and Linkins, 1987; Linkins *et al*., 1990).

Cellulose, hemicellulose and lignin are the major components of plant litter. Cellulose and hemicellulose are recalcitrant products added to soil through plant remains and must be transformed into soluble substances prior to microbial assimilation through extracellular enzymes. The microbial degradation of cellulose, hemicellulose and other oligosaccharides may be brought about by those enzymes directly involved in initial chemical breakdown (Swift *et al*., 1979; Burns, 1982).

The importance of microorganisms as agents of the breakdown of plant litter in environments has long been recognized (Tanaka, 1993). Cellulose and xylan, which are typical structural components in the litter as well as lignin, are hydrolyzed by microbially derived extracellular enzymes, cellulases and xylanase. The microorganisms excreting these enzymes, therefore, play an important role in the decomposition process of the plant litter (Tanaka, 1993).

2.6 Rubber tree (*Hevea brasiliensis*)

2.6.1 Morphology

The rubber tree (*Hevea brasiliensis*) is belonging to Euphorbiaceae. It is a deciduous plant, containg 77.8% hemicelluloses, 39.7% cellulose and 17.8% lignin (Simatupang and Schmitt, 1992). The rubber tree is a quick-growing tree, rarely exceeding 25 m in height in plantations, but wild trees of over 40 m have been recorded. Bole usually straight or tapered, branchless for 10 m or more, up to at least 50 cm in diameter, without buttresses; bark surface smooth, hoop marked, grey to pale brown, inner bark pale brown, with abundant white latex; crown conical, branches slender. Root system with a well-developed taproot and far-spreading laterals. Leaves alternate, palmate and each leaf with 3 leaflets. Leaflets elliptic petiolated, with a basal gland, pointed at the tip with lengths varying up to 45 cm; glabrous, with entire margin and pinnate venation. Inflorescence in the form of pyramidal-shaped axillary panicles produced simultaneously with new leaves and arranged in cymose form. Flowers small, greenish-white, dioecious, female flowers usually larger than the male ones. In the female flower, gynoecium composed of 3 united carpels forming a 3-lobed, 3-celled ovary with a single ovule in each cell. Seeds large, ovoid, slightly compressed, shiny, 2.0-3.5 x 1.5-3.0 cm, testa grey or pale brown with irregular dark brown dots, lines and blotches. The testa being derived from the female parent and the seed shape being determined by the pressures of the capsule, it is possible to identify the female parent of any seed by its markings and shape; this is the most reliable method of identifying clonal seed. Seeds weigh 2-4 g. The generic name is derived from a local word in the Amazon, ‘heve’ meaning rubber.

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.

2.6.2 Role and importance of rubber tree

The proliferation of *H. brasiliensis* beyond its wild distribution is extensively due to cultivation (Onokpise, 2004). Today, rubber is primarily produced in large-scale plantations in Southeast Asia and Africa (FAO, 2005). Rubber tree is of major economic importance because its sap-like extract (known as latex) can be collected and is the primary source of natural rubber. Natural rubber has been on important commodity for the past 100 yr. It is synthesized by several plant species belonging to 300 different genera (Kush *et al.*, 1990). Rubber tree produces the best quality and contributes to 90% of the world’s natural rubber and 40% of the rubber world’s consumption.

The rubber tree 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). *H. brasiliensis* is an exotic and deciduous plant (Irvine, 1969) showing maximum litter fall during February-March, with annual litter addition to plantation floor amounting to 7 tonnes/hectares (Jacob, 2000). The litter is not generally removed but persists on the plantation floor through a large part of the year and shows very slow rate of decomposition due to high lignin content. Some phenolic compounds are known to be present in the rubber plant material (Stern, 1967). In the humid tropics, *Hevea* plantations are often considered a sustainable system which, in some cases, might even upgrade the level of soil fertility (Gilot *et al*., 1995).

Since the rubber plantations are monoculture, the ecological components differ to the forest in terms of nutrient cycling and soil conservation (Gazia and Chaverri, 2010). *Hevea* plantations with deciduous litter fall, varieties of weeds, herbs and shrubs at the plantation floor under subtropical conditions provide physical habitat and trophic resource (Onokpise, 2004) for good microorganisms activity. Lonsdale *et al*. (2008) reported that plant litter 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. In addition, rubber plant litter can reduce erosion, increase soil organic matter, store carbon and serve as a reserve of nutrients and water (Boddy and Watkinson, 1995).

2.6.3 Study sites

The study was conducted at rubber plantations, comprising trees of the *H. brasiliensis* RRIM 600 variety, in Nakhon Si Thammarat and Songkhla Provinces, 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 at latitude $8^{\circ}47^{\prime}$-$9^{\circ}00^{\prime}$ N and longitude $99^{\circ}97^{\prime}$-$100^{\circ}04^{\prime}$ E. There are two season in this province: the dry season (many Thais call it “summer” because the weather is hot and dry) and the rainy season. The dry season is in February to April and the rainy season runs from May to January (Nakhon Si Thammarat, 2011). The accumulative rainfall in 2010 was 2747.9 mm. (Thai Meteorological Department, 2011).

Songkhla Province is located on the eastern coast of the southern Thailand at latitudes $6^{\circ}17^{\prime}$-$7^{\circ}56^{\prime}$ N and longitudes $100^{\circ}01^{\prime}$ - $101^{\circ}06^{\prime}$ E. Like Nakhon Si-Thammarat, the province has two seasons, but the dry season is from February to the middle of July (Songkhla, 2011). The accumulative rainfall in 2010 was 2850.9 mm. (Thai Meteorological Department, 2011). Both areas experience the highest rainfall and precipitation in November and highest temperature in May. The temperature and the rain fall recorded in 2010 were shown in Table 2.3.

Table 2.3 The temperature and rain fall average during January-December 2010 in Nakhon Si Thammarat and Songkhla Provinces

Month	Nakhon Si Thammarat		Songkhla	
	Temperature (^{o}C) (Mean)	Rain fall (mm)	Temperature (^{o}C) (Mean)	Rain fall (mm)
January	26.6	175.4	27.6	68.3
February	27.2	7.1	28.3	1.3
March	27.9	79.4	28.9	22.5
April	29.7	-	29.8	-
May	29.7	123.2	30.1	18.1
June	28.6	175.4	28.8	184.5
July	27.9	132.0	28.2	115.5
August	28.0	128.9	28.6	98.6
September	27.5	109.2	27.8	307.6
October	27.1	272.2	27.8	399.0
November	25.7	1043.3	26.6	825.3
December	25.8	479.7	26.2	706.6

Source: Thai Meteorological Department (2011)

CHAPTER 3

FUNGI ASSOCIATED WITH LEAF LITTER OF RUBBER TREE (*HEVEA BRASILIENSIS*)

3.1 Introduction

Leaf litter fungal communities play a key role in the ecology of a tropical forest. They are the major agents of leaf decomposition and nutrient cycling. It is now well established that the decomposition of plant litter on the soil surface is brought about by a variety of microorganisms, including fungi, bacteria, protozoan and actinomycetes (Shanthi and Vittal, 2010a). Fungi are regarded as efficient decomposer of organic matter, especially plant litter.

Decomposition of organic substrates is mainly carried out by various fungal groups. No single fungal species is capable of using all the components of a substrate and a succession of different fungal groups will be involved. (Ananda and Sridhar, 2004; Kannangara and Deshappriya, 2005). Decomposition rate of leaf litter is regulated by biotic factors, such as microorganisms and larger soil fauna (Omkar *et al*., 1993; Paulus *et al*., 2006), and abiotic factors, such as climate, microclimate and nutrient properties of leaf litter. Climate factors, such as rainfall, temperature and humidity, are unhelpful in predicting the decomposition rates of the various types of leaf litter and mobilization of nutrient (Braga-Neto *et al*., 2008). Duong *et al*. (2006) reported that the plant leaf litter from specific hosts has different chemical contents, which may influence the fungi growing on it.

There have been a number of studies on fungal communities occurring on leaf litter in both temperate and tropical regions. However, there are few studies on fungal communities occurring on leaf litter in tropical forests and, to the best of our knowledge, our study is the first on fungal diversity associated with rubber leaf litter in southern Thailand. Nevertheless, some studies have been carried in northern Thailand; for example, on the fungi associated with *Maglielia garrettii* (Promputtha *et al*., 2002), fungi on the leaf litter of *Magnolia liliifera* (Promputtha *et al*., 2004a; Kodsueb *et al*., 2008a), fungi on *Eleiodoxa conferta* (Pinnoi *et al*., 2003; Pinruan *et al*., 2007), fungi on *Dracacna loureiri* and *Pandanus* spp. (Thongkantha *et al*., 2008), fungi on fallen leaves of *Ficus* spp. (Wang *et al*., 2008), fungi on *Castanopsis diversifolia* (Duong *et al.,* 2008) or fungi on *Shorea obtuse* (Osono *et al*., 2009).

The rubber tree (*H. brasiliensis*) is an economically important plant species in southern Thailand. It is a deciduous perennial tree with a major annual leaf shedding during December, leaf flush in January and flowering in February. Under rubber trees were abound in decomposted rubber leaves. Thailand's rubber plantations have been poorly investigated. No data on fungal communities associated with rubber plantation ecosystem, leaf litter is a major contributor to nutrient cycling path ways; however, little is known about fungal diversity on this host. Despite its high leaf litter production and its utility in decomposting, no systematic attempts have been made to investigate the fungal diversity associated with leaf litter of this plant.

The purpose of this study was to assess the diversity and distribution of saprobic fungi on rubber leaf litter at each stage of decay, namely newly fallen leaves, middle stage decaying leaves and old decaying fallen leaves, and to evaluate the fungal communities involved in litter decay at each stage.

3.2 Materials and Methods

3.2.1 Leaf samples

Leaf samples were collected four times in 2010; January, April, July and October. Each sample, which contained variously decayed leaves, was divided into several leaf groups based on external appearance and the degree of decomposition. Leaf litter belonging to the following three groups were used for fungal isolation; newly fallen leaves, i.e. relatively undecomposed, middle stage decaying leaves which were partly discoloured, i.e. slightly decomposed, and old decaying fallen leaves which were highly discolored, i.e. decomposed leaf litter (Tokumasu, 1990).

3.2.2 Sampling design

Rubber leaf litter was collected at two sites in a 25-year-old rubber plantation in Nakhon Si Thammarat and Songkhla Provinces. Three plots were distributed on a grid system of 200 x 200 m and the site study was conducted at 30 subplots of 50 x 50 m. In the decomposition study, materials were collected four times 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 and 27.6^{o}C. Rainfall was recorded at between 68.3 and 175.4 mm. The second collection occurred during April, in the dry season (“summer”) when the temperatures ranged form 29.7-29.8^{o}C and no rainfall was recorded. The third collection was in July which is in the early rainy season with the temperature range of 27.9-28.2^{o}C and rainfall was recorded as being between 115.5 - 132.0 mm. The fourth collection was in October which is in the rainy season with temperature range between 27.1-27.8^{o}C. The rainfall was 272.2-399.0 mm.

Leaves representing all stages of decay were selected from the litter from within 1 m^2 quadrants at each site. Leaves of each stage were placed in separate

Ziplock plastic bags and taken to the laboratory for isolation within 24 h (Polishook *et al*., 1996).

3.2.3 Incubation, observation and data analyses

Four sets of fallen leaf litter at each stage were collected from the two locations and isolation, moist chamber and dilution plate methods were used to study the fungi. In the moist chamber technique, all leaves were cut into 5 x 5 cm pieces and incubated in moistened Petri dishes at room temperature (28-32^{o}C). After a 24-h incubation, the fungal colonies were scraped from the leaf surface with cellophane tape and mounted on slides using lactophenol as the mounting medium. Fungi isolated by dilution pour-plate methods were cultured on glucose ammonium nitrate agar (GANA). Identification was based on morphological examination under stereo and compound microscopes (Manoch *et al*., 2008a).

3.2.4 Definition and statistical analyses

Fungal species were recorded as either present or absent from each stage of litter decomposition. The number of leaves on which a fungal species was found was designated as the occurrence of a fungus and was used to calculate the percentage occurrence of a species on leaves of each stage using the following formula (Pinruan *et al*., 2007; Kodsueb *et al*., 2007; 2008a; Duong *et al*., 2008). % occurrence of taxon A = (number of leaf samples on which each fungus was detected/ total number of leaf samples examined) x 100%. Fungal taxa with a percentage occurrence equal to or higher than 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 index (H) and Simpson's index (D).

The Shannon-Wiener index $H = -\Sigma Pi \ln Pi$, where Pi is the frequency of fungal species i occurring at a specific leaf stage or season. Values of H for real communities are often fall between 1 and 6.

Simpson's index $D = 1 - O[n_i / (n_i - 1) / N / (N - 1)]$, where n_i is the number of individuals of species i and N = total number of species in the community. Values of D range between 0 and 1.

Sorensen's similarity index (S) was applied to compare the similarity of species on leaves of different stages and seasons : $S = 2c/(a+b)$, where a is the number of species in stage or season A, b is the number of species at stage or season B and c is the number of species in both stages or seasons. Similarity is expressed with values between 0 (no similarity) and 1 (absolute similarity) (Wang *et al.*, 2008).

3.3 Results

3.3.1 Fungal taxonomic composition

Examination of decaying leaves of *H. brasiliensis* RRIM 600 variety at three stage of decomposition yielded 503 fungal taxa, comprising 461 anamorphic taxa, 38 ascomycetes, two zygomycetes, one oomycete and one basidiomycete (Table 3.1).

Fungal succession of *H. brasiliensis* leaf litter on the plantation floor showed variations in fungal composition between the decomposition stages. A total of 313 species were found in newly fallen leaves, 326 species were found in middle stage decaying leaves, and 250 species were found in old decaying fallen leaves. In both areas, it was shown that 88 species (43.56%) overlapped in newly fallen leaves, 121 species (54.02%) in middle stage decaying leaves and 88 species (52.21%) were overlapping in old decay fallen leaves.

In Nakhon Si Thammarat Province, 376 fungal taxa were found, including 348 anamorphic, 26 ascomycetes one basidiomycete and one zygomycete. A total of 212 taxa were recorded on newly fallen leaves, 239 taxa on middle stage decaying leaves and 176 taxa from old decaying fallen leaves.

The 324 fungal taxa found in Songkhla Province included 296 anamorphic taxa, 24 ascomycetes, two zygomycetes, one oomycete and one basidiomycete. A total of 192 taxa were recorded from newly fallen leaves, 209 from middle stage decaying leaves and 162 species were recorded from old decaying fallen leaves.

Sixty-one taxa were common to both provinces and to all stages of decomposition, including *Acremonium cerealis, Aspergillus* sp.1, *Aspergillus* sp.2, *A. japonicus* var. *aculeatus, A. japonicus* var. *japonicus, A. kanagawaensis, A. sojae, A. tamarii, Bactrodesmium rahmii, Beltrania* sp., *Botryodiplodia* sp., *Cladosporium tenuissimum, Curvularia lunata*, *C. pallescens*, *Cylindrocarpon* sp., *Dactylaria* sp.1, *Dactylaria* sp.2, *D. hyalina*, *Eupenicillium* sp., *Fusarium redolens, Hansfordia pulvinata*, *Helicostylum piriforme*, *Helminthosporium heveae*, *Hypoxylon* sp.1, *Hypoxylon* sp.2, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica, Paecilomyces* sp., *P. variota, Penicillium* sp.1, *Penicillium* sp.2, *Penicillium* sp.4, *Penicillium* sp.5, *Penicillium* sp.6, *P. canescens*, *P. citrinum*, *P. griseofulvum*, *P. miioluteum*, *P. simplicissium*, *Pestalotiopsis* sp.1, *Pestalotiopsis* sp.2, *P. guepini*, *Pestalosphaeria hansenii, Rhizopus* sp., *Speiropsis hyalospora*, *Subulispora procurvata*, *Syncephalastrum recemosum, Torula herbarum*, *Trichoderma atroviride*, *T. aureoviride*, *T. harzianum*, *T. inhamatum*, *T. longibrachiatum*, *T. pseudokoningii*, *T. reesei*, *Wiesneriomyces javanicus, Veronaea carlinae*, *V. coprophila, Zygosporium echinosporium* and *Z. gibbum*. Eighty-three taxa of fungi were found at all stages of decomposition in Nakhon Si Thammarat Province. In addition, 80 taxa of fungi were found at all stages of decomposition in Songkhla Province.

3.3.2 Species richness and dominant fungi

Thirteen taxa of dominant species (over 10% occurrence) were found at all stages of decomposition in both areas comprising, *Bactrodesmium rahmii, Botryodiplodia* sp., *Cladosporium tenuissimum*, *Hypoxylon* sp.1, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Pestalosphaeria hansenii*, *Pestalotiopsis* sp.1, *Subulispora procurvata*, *Veronaea carlinae*, *V. coprophila* and *Wiesneriomyces javanicus*.

Twenty-six species, *Bactrodesmium rahmii*, *B. spilomeum*, *Botryodiplodia* sp., *Cladosporium tenuissimum*, *Colletotrichum gloeosporioides*, *Dactylaria* sp.1, *Dactylaria* sp.2, *Hansfordia pulvinata*, *Hypoxylon* sp.1, *Hypoxylon* sp.2, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica, Penicillium* sp.1, *Pestalosphaeria hansenii, Pestalotiopsis disseminata,* *Pestalotiopsis* sp.1, *Pestalotiopsis* sp.3, *Scolecobasidiella avellanea*, *Subulispora procurvata*, *Torula herbarum*, *Veronaea carlinae*, *V. coprophila*, *Wiesneriomyces javanicus*, *Zygosporium gibbum* and *Z. masonii* were the dominant species occurring on newly fallen leaves in both areas.

Thirty-one species, *Aspergillus* sp.1, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Chaetopsina fulva*, *Cladosporium tenuissimum, Codinaea* sp.1, *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Cylindrocladium scoparium*, *Dactylaria* sp.1, *D. hyalina*, *Hansfordia pulvinata*, *Henicospora coronata*, *Hypoxylon* sp.1, *Idriella lunata, Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Linospora* sp., *Nigrospora sphaerica, Panchanania jaipurensis*, *Pestalosphaeria hansenii*, *Pestalotiopsis* sp.1, *P. disseminata*, *Speiropsis hyalospora*, *Subulispora procurvata*, *Thyridaria sambucina, Torula herbarum*, *Triscelophorus panapensis, Veronaea carlinae*, *V. coprophila* and *Wiesneriomyces javanicus* were dominant species occurring in middle stage decaying leaves in both areas.

Twenty-two species, *Acticulospora tetracladia, Bactrodesmium rahmii, Botryodiplodia* sp.*,* *Cladosporium tenuissimum*, *Curvularia lunata*, *Dactylaria* sp.2*, D. hyalina, Henicospora coronata, Hypoxylon* sp.1*, Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Leptodiscella africana, Nigrospora sphaerica, Panchanania jaipurensis, Pestalosphaeria hansenii, Pestalotiopsis* sp.1*, Subulispora procurvata, Thyridaria sambucina, Triscelophorus acuminatus, Veronaea carlinae, V. coprophila* and *Wiesneriomyces javanicus* were dominant species occurring in old decaying fallen leaves in both areas.

The dominant fungi on the rubber leaf litter, with over 10% occurrence at each stage of decomposition, are shown in Table 3.2.

Table 3.1 Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota						
Amerosporium sp.		2.08				
Aquaticheirospora lignicola		2.08				
Astrosphaeriella sp.	12.50					
Broomella acuta	4.17					
Ceratocystis ulmi		4.17				
Ceratohorum uncinatum		4.17				
Ceratosporella deviate		2.08				
Chaetomium sp.			2.08			
Claussenomyces prasinulus					2.08	
Cucurbitaria elongata				10.42		6.25
Dothidotthia sp.1				8.33	6.25	
Dothidotthia sp.2	8.33				2.08	
Dothiorella sp.					2.08	
Eupenicillum sp.[1/]	8.33	8.33	8.33	8.33	8.33	8.33
Gaeumannomyces graminis				4.17		
Glomerella cingulata	2.08	31.25	8.33		2.08	
Gnomonia amoena	2.08					
G. fragariae			12.50			
Hypoxylon sp.1	18.75	31.25	25.00	37.50	16.67	14.58
Hypoxylon sp.2	12.50	10.42	8.33	14.58	6.25	8.33
Hypoxylon sp.3				6.25	10.42	4.17
Hypoxylon sp.4					4.17	
H. cohaerens	8.33	16.67			4.17	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Kirschsteiniothelia sp.[1/]	39.58	58.33	43.75	52.08	60.42	62.50
Leptosphaeria blumeri					2.08	
L. darkeri	2.08	6.25			4.17	6.25
Linocarpon sp.		2.08	12.50		6.25	
Linospora sp.	8.33	35.42	8.33		16.67	
Lophiostoma semiliberum						2.08
L. viridarium				2.08		
Nectria ventricosa		10.42				
Oedothea vismiae				14.58		
Pestalosphaeria hansenii	27.08	43.75	27.08	10.42	35.42	14.58
Talaromyces flavus[1/]	8.32					
Thyridaria sambucina		14.59	18.76	4.17	29.17	41.67
Trematosphaeria pertusa				4.17	4.17	
Xylaria sp.		6.25				
X. hypoxylon		10.42				
Basidiomycota						
Marasmius sp.			16.67			8.33
Mitosporic fungi						
Acarocybe deightonii	8.33					
A. formosa				2.08		
A. hansfordii		4.17				
Acremonium sp.1		2.08				
A. alternatum				2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
A. butyri	6.25	2.08	8.33			
A. cerealis[1/]	8.33	8.33	8.33	8.33	8.33	8.33
A. fusidioides		2.08	6.25	2.08	4.17	
A. kiliense[1/]		2.08		10.42	4.17	
A. murorum		4.17				
A. strictum		2.08		2.08		
Acrodictys sacchari					4.17	
Acrostaurus turneri						6.25
Acticulospora tetracladia	10.42	20.83	22.92		6.25	25.00
Actinocladium rhodosporum			2.08			
Alternaria sp.[1/]	2.08	2.08				
A. pluriseptata			4.17			4.17
A. radicina			8.33			
Anguillospora sp.	2.08					
Annellophora solani					10.42	
Annellophroagmia sp.			12.50			
Aposphaeria peizizoides	35.42	12.50				
Arnoldiomyces sp.					6.25	
Arthrinium meulleri				8.33		
Arthrobotryum atrocephalum				2.08	16.67	
Aspergillus sp.1[1/]	8.33	10.41	4.17	12.50	12.50	8.33
Aspergillus sp.2	8.33	8.33	10.42	4.17	4.17	4.17
Aspergillus sp.3			4.17	4.17		4.17

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
*A. aculeatus*1/	2.08		2.08			
*A. carbonarius*1/	2.08				2.08	2.08
*A. caespitosus*1/		2.08		2.08		
*A. flavus*1/				2.08	2.08	
*A. japonicus*1/		2.08		10.41		
A. japonicus var. *aculeatus*1/	8.33	8.33	8.33	8.33	8.33	8.33
A. japonicus var. *japonicus*1/	8.33	8.33	8.33	8.33	8.33	8.33
*A. kanagawaensis*1/	8.33	8.33	8.33	8.33	8.33	8.33
*A. niger*1/		2.08		4.17		2.08
*A. parasiticus*1/	2.08				2.08	
*A. pulverulentus*1/		2.08		4.17		
*A. puniceus*1/	2.08				2.08	2.08
A. restrictus	2.08		8.33		2.08	
*A. sclerotiorum*1/		2.08	6.25	2.08		
*A. sojae*1/	8.33	8.33	8.33	8.33	8.33	8.33
*A. tamarii*1/	8.33	8.33	8.33	8.33	8.33	8.33
*A. sydowii*1/		2.08	2.08	2.08	4.16	
*A. terreus*1/				4.17	2.08	
Bacillispora aquatica						6.25
Bactrodesmium sp.1					2.08	
B. betulicola	2.08			2.08		
B. longisporum	2.08					
B. myrtii				4.17		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
B. pallidum			4.17		4.17	
B. rahmii	10.41	37.50	41.67	18.75	37.50	16.67
B. spilomeum	10.42	4.17		18.75		16.67
Balladynopsis vanderystii	6.25					
Beltrania sp.[1/]	8.33	8.33	8.33	8.33	8.33	8.33
B. rhombica						2.08
B. santapaui			6.25			
Beltraniella sp.[1/]				4.17		
B. fertilis[1/]					4.17	10.42
B. humicola					4.17	
B. odinae						2.08
B. pini						2.08
B. pirozynskii[1/]					2.08	2.08
Berkleasmium cf. *minutissimum*		2.08		2.08	4.17	
B. macropus	6.25					
Bidenticula cannae				2.08		
Bipolaris sp.1	12.50	6.25			4.17	
Bipolaris sp.2	8.33	2.08				
Bipolaris sp.3	6.25					
B. ellisii[1/]					2.08	
B. heveae	4.17			10.42	2.08	
B. antennata						2.08
Bisporostilbella sp.		4.17				

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Botryodiplodia sp.[1/]	54.17	25.00	16.67	12.50	37.50	35.42
Botryotrichum sp.				2.08		
B. piluliferum[1/]						2.08
Brachydesmiella biseptata		2.08	10.42	2.08	12.50	6.25
Cacumisporium sp.				12.50		
Calospora patanoides		14.58				
Camarosporium salicinum			2.08			
C. rosae	6.25					
Camposporium sp.		2.08				8.33
C. antennatum	4.17	2.08				16.67
C. cambrense	12.50	4.17		6.25	12.50	4.17
C. laundonii						2.08
Canalispora pallidum	4.17					
Canalisporium caribense			6.25			
C. exiguum					2.08	
C. pallidum			2.08	2.08	8.33	
Cercospora sp.1	8.33	2.08		12.50	2.08	
Cercospora sp.2		8.33				
Cercospora sp.3	6.25					
Cercospora sp.4	6.25					
Cercospora sp.5		4.17				
C. apii		8.33				
C. chevalieri			4.17			

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
C. fusimaculans		10.42				
C. opuli	2.08					
C. vaginae	2.08					
Ceriospora polygonacearum	2.08					
Chaetochalara sp.	12.50					
Chaetopsina fulva		20.83			16.67	
Chalara sp.	4.17	2.08	6.25			
C. cylindrosperma				2.08		
C. elegans					6.25	
Chalariopsis sp.		4.17				
Chryseidea sp.						4.17
Chrysosporium pannorum		4.17				
Chuppia sarcinifera		2.08				
Circinotrichum fertile	4.17	4.17				
C. maculiforme	6.25		2.08		6.25	2.08
C. poonense		4.17		8.33		8.33
Cladosporium sp.1[1/]	2.08			6.25	6.25	6.25
Cladosporium sp.2			8.33	4.17	12.50	
Cladosporium sp.3					4.17	
C. acaciicola				8.33		
C. balladyner			2.08			
C. britannicum[1/]	2.08	4.17	4.17	4.17		
C. cladosporioides					8.33	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
C. elatum				20.83		
C. fulvum	20.83	43.75	20.83			
C. gallicola	6.25		4.17		2.08	
C. nigrelum				2.08		
C. orchidearum					14.58	
C. orchidis	25.00	27.08	4.17			
C. oxysporum				16.67	18.75	2.08
C. psoraleae[1/]			2.08			
C. staurophorum						2.08
C. tenuissimum[1/]	33.33	12.50	16.67	31.25	12.50	10.42
C. uredinicola		2.08				4.17
Clavariopsis aquatica	4.17					
Codinaea sp.1	6.25	12.50	4.17		14.58	
Codinaea sp.2		8.33			2.08	
Codinaea sp.3	6.25	2.08	2.08			
C. assamica	14.58	2.08				2.08
C. britannica		4.17			12.50	
C. fertilis	10.42	4.17	6.25		4.17	16.67
C. hughesii		2.08			4.17	4.17
Colletotrichum sp.1[1/]		10.42			6.25	
Colletotrichum sp.2	20.83	6.25				
Colletotrichum sp.3	8.33					
C. dematum	4.17			8.33		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
C. gloeosporioides	22.92	10.42		56.25	29.17	8.33
Conioscypha sp.				2.08		
Coronospora novae-zelandiae			4.17			
Corynespora sp.1		4.17				
C. cassiicola		10.42	6.25		2.08	
C. trichiliae				2.08		
C. quereicola			20.83			
Coryneum sp.	6.25					
C. elevatum			2.08			
Curvularia sp.				8.33	4.17	
C. affinis				2.08		
C. deightonii						4.17
C. geniculata			2.08	8.33		2.08
C. lunata	6.25	39.59	12.50	4.17	14.58	10.42
C. pallescens	6.25	2.08	8.33	12.50	12.50	8.33
C. peniseti					2.08	
C. senegalensis		2.08				
C. uncinata				2.08	2.08	
Cylindrocarpon sp.[1/]	8.33	8.33	8.33	8.33	8.33	8.33
C. didymum[1/]				6.25		
Cylindrocladium sp.1			6.25			
Cylindrocladium sp.2	6.25	2.08				
C. parvum[1/]		10.42	22.92	8.33	4.17	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
C. scoparium	18.75	10.42		4.17	12.50	20.83
Cylindrotrichum oligospermum					8.33	
Cytosporina sp.		2.08				
Dactylaria sp.1	18.75	16.67	8.33	35.42	16.67	10.42
Dactylaria sp.2	16.67	8.33	16.67	12.50	10.42	12.50
Dactylaria sp.3		6.25	4.17		6.25	
D. hyalina	2.08	16.67	25.00	6.25	12.50	12.50
D. junci	6.25	8.33		25.00	8.33	41.67
D. obtriangularia			8.33			
Dactylella ellipsospora			4.17			2.08
D. obtriongularia			2.08			
Dendrospora erecta		6.25				
Dendryphiopsis atra	6.25					
Dichomera prunicola		6.25				
Dictyosporium sp.		2.08			2.08	
D. elegans	4.17			8.33		
D. heptasporum					2.08	
D. manglietiae	6.25		6.25			2.08
Diplococcium sp.	14.58					
D. asperum					10.42	
D. pallidum					6.25	
D. spicatum				6.25	35.42	
Diplocladiella scalarioides				2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Diplodia sp.	8.33	14.58		6.25		
D. melaena				8.33		2.08
D. zeae			35.42			
Diplodina sp.		12.50				
Diplorhinotrichum candidulum	2.08					
Discosia artocreas						6.25
D. maculicila	4.17					
Elletevera parasitica		10.42				
Ellisembia paravaginata	8.33					
E. vaginata	6.25	25.00		2.08		8.33
Ellisiopsis sp.			2.08		4.17	22.92
E. gallessiae				16.67	14.58	
Endophragmia sp.1					4.17	
Endophragmia sp.2					4.17	
E. bisbyi	8.33				6.25	
E. elliptica						2.08
E. hyalosperma		2.08				
E. parva		8.33				16.67
Endophragmiella theobromae		2.08		6.25		
Ephelis borealis			10.42			
Exosporium phyllantheum		18.75				
Fasariella sp.			10.42	12.50	10.42	
Fibulocoela sp.	10.42					

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Fulvia sp.		6.25				
F. berkheyae				16.67	8.33	
Fusarium sp.1			10.42	37.50	12.50	4.17
Fusarium sp.2			6.25	12.50	12.50	4.17
Fusarium sp.3	33.33	6.25		8.33	14.58	
Fusarium sp.4	10.42	12.50		6.25		
Fusarium sp.5	12.50	14.58				
Fusarium sp.6	6.25	10.42				
Fusarium sp.7	6.25	4.17				
Fusarium sp.8		29.17				
F. moniliforme	4.17					
F. oxysporum[1/]	6.25	2.08				
F. redolens[1/]	8.33	8.33	8.33	8.33	8.33	8.33
F. semitectum[1/]	20.83			2.08		
Fusicladium sp.				2.08		
Fusoma rubricosa		10.42				
Genicularia cystospora	10.42					
Griphoshaeria corticola			2.08			
Grophium putredinis						2.08
Gyrothrix podosperma	2.08	6.25	4.17		12.50	2.08
G. circinata		4.17		4.17	8.33	12.50
Hansfordia ovalispora						2.08
H. pulvinata	16.67	18.75	2.08	14.58	27.08	4.17

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Haplariopsis fagicola				2.08		
Haplographium mangiferae	2.08	8.33			2.08	
Harknessia sp.	2.08					
Harphographium sp.	8.33	2.08				
Harposporium sp.		4.16				
Helicorhoidion botryoideum				10.42		
Helicosporium aureum		2.08	2.08	2.08		6.25
*Helicostylum piriforme*1/	8.33	8.33	8.33	8.33	8.33	8.33
Helminthosporium sp.	6.25	2.08	2.08		8.33	
*H. heveae*1/	8.33	8.33		8.33	8.33	
Hendersonia sp.		22.92				
Hyphodiscosia jaipurensis			6.25			
Idriella sp.1			18.75	2.08		4.17
Idriella sp.2		8.33				
I. fertile		4.17	6.25		12.50	2.08
I. lunata	25.00	27.08	10.42	10.42	18.75	
Kellermannia yaccaegena	8.33					
Kramasamuha sp.	2.08		2.08			8.33
Lasiodiplodia cf. *theobromae*	29.17	39.58	33.33	29.17	60.42	29.17
Lateriramulosa uni-inflata	6.25					
Leptodiscella sp.						6.25
L. africana	6.25	20.83	16.67		4.17	14.58
Massariothea sp.						4.17

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Menispora sp.	6.25	10.42			4.17	2.08
Menisporopsis profusa	2.08	2.08				
M. theobromae	12.50	12.50				
Microsporium sp.		6.25				
Mitteriela ziziphina				2.08		
Monacrosporium sp.1	2.08					6.25
Monacrosporium sp.2			4.17			2.08
Monacrosporium sp.3		6.25				
Monochaetia sp.	25.00	8.33				
Monodictys glauca		10.42				
Moorella speciosa						2.08
Murogenella terricola			6.25			
Mycoleptodiscus indicus						2.08
Mycovellosiella solani-torvi		2.08		8.33	2.08	
Myrothecium roridum				2.08		
Mystrosporiella litseae					2.08	4.17
Neottiosporella sp.						10.42
Nigrospora sphaerica	45.83	47.92	33.33	35.42	43.75	22.92
Paecilomyces sp.[1/]	8.33	2.08	4.17	12.50	12.50	4.17
P. varioti[1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. lanceolatus				4.17		2.08
Panchanania jaipurensis		20.83	35.42		12.50	45.83
Paranospora novae-zelandiae			12.50			

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Parasympodiella podocarpi	4.17					2.08
Paratomenticola lanceolatus						4.17
Penicillifer pulcher				2.08		
Penicillium sp.1	22.92	20.83	10.42	14.58	6.25	2.08
Penicillium sp.2	6.25	12.50	6.25	6.25	6.25	4.17
Penicillium sp.3	4.17		6.25	10.42	6.25	8.33
Penicillium sp.4[1/]	8.33	8.33	8.33	8.33	8.33	8.33
Penicillium sp.5[1/]	8.33	8.33	8.33	8.33	8.33	8.33
Penicillium sp.6[1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. canescens[1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. chrysogenum[1/]				2.08		4.17
P. citrinum[1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. griseofulvum[1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. janthinellum[1/]		6.25				
P. miczynskii[1/]				4.17		
P. minioluteum [1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. rolfsii				4.17		4.17
P. rubrum[1/]	8.33		4.17			
P. simplicissium[1/]	8.33	8.33	8.33	8.33	8.33	8.33
Pestalotia sp.		8.33	4.17			2.08
Pestalotiopsis sp.1	20.83	18.75	10.42	16.67	12.50	16.67
Pestalotiopsis sp.2	12.50	4.17	8.33	4.17	10.42	6.25
Pestalotiopsis sp.3	10.42	4.17		12.50		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Pestalotiopsis sp.4	2.08					
P. disseminata[1/]	12.50	16.67	22.92	10.42	12.50	
P. guepini[1/]	8.33	8.33	8.33	8.33	8.33	8.33
P. sydowia[1/]		2.08	10.42			
Peyronellaea sp.	2.08					
Phaeoisaria sparsa	10.42	2.08				
Phaeoisariopsis sp.		6.25				
P. cercosporioides					6.25	2.08
Phaeoramularia capsicicola				2.08		
P. oldenlandiae			2.08			4.17
Phaeosphaeria sp.						6.25
Phoma sp.[1/]	4.17			8.33		
Phomopsis sp.[1/]	8.33	8.33			2.08	
Phyllosticta sp.		10.42				2.08
Pilulina nigrospora			2.08			
Pithomyces graminicola	2.08					
Pleurophragmium acutum	14.58			8.33	14.58	
P. simplex					4.17	
Pleurotheciopsis pusilla				2.08	2.08	6.25
Polyschema sp.		8.33				
Pseudobeltrania penzigii					2.08	
Pseudogliomastix sp.			10.42			
Pseudospiropes hughesii		10.42			8.33	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
P. obclavatus					4.17	
Pseudorobillarda sp.					2.08	
Pteroconium intermedium	4.17					
Pucciniopsis sp.		14.58				
Pyriculariopsis parasitica		2.08			6.25	
Raffaelea sp.					4.17	
Ramularia tulasnea	10.42					
Rhexoampullifer sp.	2.08					
Rhinocladiella sp.		2.08		4.17	6.25	12.50
Rhombostilbella rosae			2.08			
Robillarda phragmitis				2.08	6.25	
Sarcopodium tortuosum		6.25				
Scolecobasidiella avellanea[1/]	16.67	2.08		20.83	4.17	47.92
Scolecobasidium acanthacearum				4.17		4.17
S. compactum		16.67	18.75	2.08	4.17	
S. dendroides		2.08	4.17		4.17	
S. salinum			4.17	4.17	4.17	
Selenosporella sp.	2.08		4.17			
Septocylindrium aromaticum			14.58			
Setocyta ruborum				8.33		
Seynesiella sp.1	6.25					
Sirosporium antenniforme	12.50					
Spegazzinia deightonii	4.17		2.08	2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. lobulata	2.08			4.17		
S. sundara				2.08		
Speiropsis hyalospora	4.17	29.17	6.25	10.42	31.25	22.92
S. pedatospora			6.25			16.67
Spermospora avenae	4.17					
S. subulata		4.17				
Spiropes sp.				2.08		
S. capensis		14.58	6.25			
S. effusus		6.25				
S. fumosus			6.25			
S. japonicus		6.25				
S. penicillium		10.42				
Spondylocladiella botrytioides	14.58	4.17	6.25		4.17	
Sporidesmium sp.1		10.42			4.17	
Sporidesmium sp.2		4.17				
Sporidesmium sp.3		4.17				
Sporidesmium sp.4		4.17				
Sporidesmium sp.5	8.33					
S. aburiense		2.08				
S. baccharidis	2.08		16.67			
S. bambusae	10.42					
S. bambusicola			6.25			
S. dioscoeae		4.17	4.17			

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. flagellatum			8.33	2.08		2.08
S. harknesii				6.25	4.17	2.08
S. japonicus			10.42			
S. jasminicola	2.08	4.17	4.17			
S. leptosporum	4.17	6.25	6.25			
S. longirostratum		8.33				
S. nodipes			4.17	4.17	2.08	
S. pallidum					4.17	
S. rubi	6.25	4.17	6.25	12.50	4.17	
S. socium					4.17	
S. uvariicola			2.08			
Sporoschisma uniseptatum					10.42	
Sporoschismopsis sp.	4.17			4.17	6.25	2.08
Sporothrix schenckii				8.33		
Stachybotrys sp.	2.08	6.25			2.08	
S. sansevieriae		6.25				
Stenella liabicola		8.33			6.25	
S. pithecellobii	27.08	14.58	6.25	2.08	8.33	
Stigmina sp.		2.08				
S. combreticola	8.33		6.25			
S. hartigiana					4.17	2.08
S. kranzii		2.08				
S. murrayae			2.08			

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. obtecta		2.08	2.08			
Stilbospora sp.	2.08					
Stilbum sp.[1/]	4.17					
Strumella coryneoidea			6.25			
Subulispora sp.	16.67		2.08			
S. britannica					4.17	
S. procurvata	10.42	41.67	45.83	25.00	45.83	62.50
Syncephalastrum recemosum[1/]	8.33	8.33	8.33	8.33	8.33	8.33
Taeniolella scripta		8.33			4.17	
Taeniolina centaurii		2.08				
Taeniolina sp.				8.34		
Tetraploa aristata	22.92	50.00	14.58		4.17	8.33
Tetraposporium sp.1		2.08		2.08		
Tetraposporium sp.2		2.08	2.08	2.08	2.08	2.08
Tiarosporella sp.				2.08		
Torula sp.	29.17		12.50		4.17	
T. herbarum	25.00	43.75	18.75	33.33	18.75	2.08
Toxosporiums sp.		8.33				
Tretospora sp.	10.42				2.08	
Triadelphia heterospora	4.17	4.17				
Trichoderma sp.1		6.25		6.25	12.50	4.17
Trichoderma sp.2				4.17	6.25	
T. atroviride[1/]	8.33	8.33	8.33	8.33	8.33	8.33

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
T. aureoviride[1/]	8.33	8.33	8.33	8.33	8.33	8.33
T. hamatum[1/]			6.25	2.08	2.08	
T. harzianum[1/]	8.33	8.33	16.67	12.50	4.17	4.17
T. inhamatum[1/]	8.33	8.33	8.33	8.33	8.33	8.33
T. koningii[1/]	6.25					
T. longibrachiatum[1/]	8.33	8.33	8.33	8.33	8.33	8.33
T. parceramosum[1/]		4.17		4.17	2.08	
T. pseudokoningii[1/]	8.33	8.33	8.33	8.33	8.33	8.33
T. reesei[1/]	8.33	8.33	8.33	8.33	8.33	8.33
T. virens[1/]		6.25		4.17	2.08	
T. viride[1/]				4.17	2.08	
Trichodochium disseminatum	6.25	10.42				
Trichothecium roseum				8.33		
Tricladium angulatum						2.08
T. castaneicola	8.33	4.17			10.42	18.75
T. fuscum	4.17				2.08	2.08
Trimmatostrona betulinum					2.08	
Triscelophorus acerinum	4.17					
T. acuminatus	2.08	8.33	25.00		4.17	47.92
T. monoporus		4.17	8.33			2.08
T. panapensis	12.50	29.17	33.33		12.50	
Trisulcosporium acerinum				6.25		
Truncatella sp.	2.08					

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Tubercularia vulgaris		2.08				
Varicosporium eladeae	4.17					
Veronaea sp.		4.17				
V. botryosa	2.08					
V. carlinae[1/]	20.83	25.00	22.92	47.92	37.50	41.67
V. coprophila	33.33	72.92	54.17	18.75	52.08	39.58
V. musae				10.42		
Verticillium sp.	4.17	2.08				
V. dahliae				4.17		
Vulutella fructi	4.17					
Wiesneriomyces javanicus	12.50	31.25	18.75	12.50	16.67	16.67
Zanclospora sp.		8.33				
Z. brevispora				2.08		
Zygosporium deightonii					4.17	2.08
Z. echinosporum	8.33	2.08	2.08	2.08	6.25	2.08
Z. gibbum	12.50	6.25	6.25	12.50	18.75	2.08
Z. majus					4.17	4.17
Z. masonii	14.58	14.58	4.17	12.50	4.17	
Z. oscheoides	2.08					
Oomycota						
Phytophthora sp.				4.17		
Zygomycota						
Mortierella polycephala					2.08	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Rhizopus sp.[1/]	8.33	8.33	8.33	8.33	8.33	8.33
Total number of species recorded at each stage	**212**	**239**	**176**	**192**	**209**	**162**

Note: [1/] Isolated from dilution plates

* Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

Table 3.2 Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
Newly fallen leaves	*Acticulospora tetracladia*	*Acremonium kiliense*
	Aposphaeria peizizoides	*Aspergillus* sp.1
	Astrosphaeriella sp.	*A. japonicus*
	Bactrodesmium rahmii	*Bactrodesmium rahmii*
	B. spilomeum	*B. spilomeum*
	Bipolaris sp.1	*Bipolaris haveae*
	Botryodiplodia sp.	*Botryodiplodia* sp.
	Camposporium cambrense	*Cacumisporium* sp.
	Chaetochalara sp.	*Cercospora* sp.1
	Cladosporium fulvum	*Cladosporium elatum*
	C. orchidis	*C. oxysporum*
	C. tenuissimum	*C. tenuissimum*
	Codinaea assamica	*Colletotrichum gloeosporioides*
	C. fertilis	*Cucurbitaria elongata*
	Colletotrichum sp.2	*Curvularia pallescens*
	C. gloeosporioides	*Dactylaria* sp.1
	Cylindrocladium scoparium	*Dactylaria* sp.2
	Dactylaria sp.1	*D. junci*
	Dactylaria sp.2	*Ellisiopsis gallessiae*
	Fusarium sp.3	*Fasariella* sp.
	Fusarium sp.4	*Fulvia berkheyae*
	Fusarium sp.5	*Fusarium* sp.1
	F. semitectum	*Fusarium* sp.2

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	Genicularia cystospora	*Hansfordia pulvinata*
	Hansfordia pulvinata	*Helicorhoidion botryoideum*
	Hypoxylon sp.1	*Hypoxylon* sp.1
	Hypoxylon sp.2	*Hypoxylon* sp.2
	Kirschsteiniothelia sp.	*Kirschsteiniothelia* sp.
	Lasiodiplodia cf. *theobromae*	*Lasiodiplodia* cf. *theobromae*
	Menisporopsis theobromae	*Nigrospora sphaerica*
	Monochaetia sp.	*Oedothea vismiae*
	Nigrospora sphaerica	*Penicillium* sp.1
	Penicillium sp.1	*P. canescens*
	Pestalosphaeria hansenii	*Pestalosphaeria hansenii*
	Pestalotiopsis sp.1	*Pestalotiopsis* sp.1
	Pestalotiopsis sp.2	*Pestalotiopsis* sp.3
	Pestalotiopsis sp.3	*P. disseminata*
	P. disseminata	*Scolecobasidiella avellanea*
	Phaeoisaria sparsa	*Speiropsis hyalospora*
	Pleurophragmium acutum	*Sporidesmium rubi*
	Ramularia tulasnea	*Subulispora procurvata*
	Scolecobasidiella avellanea	*Torula herbarum*
	Sirosporium antenniforme	*Trichoderma harzianum*
	Spondylocladiella botrytioides	*Veronaea carlinae*
	Sporidesmium bambusae	*V. coprophila*
	Stenella pithecellobii	*V. musae*

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	Subulispora sp.	*Wiesneriomyces javanicus*
	S. procurvata	*Zygosporium gibbum*
	Tetraploa aristata	*Z. masonii*
	Torula sp.	
	T. herbarum	
	Tretospora sp.	
	Triscelophorus panapensis	
	Veronaea carlinae	
	V. coprophila	
	Wiesneriomyces javanicus	
	Zygosporium gibbum	
	Z. masonii	
Middle stage decaying leaves	*Acticulospora tetracladia*	*Annellophora solani*
	Aposphaeria peizizoides	*Arthrobotryum atrocephalum*
	Aspergillus sp.1	*Aspergillus* sp.1
	Bactrodesmium rahmii	*Bactrodesmium rahmii*
	Botryodiplodia sp.	*Botryodiplodia* sp.
	Calospora patanoides	*Brachydesmiella biseptata*
	Chaetopsina fulva	*Camposporium cambrense*
	Cladosporium fulvum	*Chaetopsina fulva*
	C. orchidis	*Cladosporium* sp.2
	C. tenuissimum	*C. orchidearum*
	Codinaea sp.1	*C. oxysporum*

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	Colletotrichum sp.1	*Cladosporium tenuissimum*
	C. gloeosporioides	*Codinaea* sp.1
	Corynespora cassiicola	*C. britannica*
	Curvularia lunata	*Colletotrichum gloeosporioides*
	Cylindrocladium parvum	*Curvularia lunata*
	C. scoparium	*C. pallescens*
	Dactylaria sp.1	*Cylindrocladium scoparium*
	D. hyalina	*Dactylaria* sp.1
	Diplodia sp.	*Dactylaria* sp.2
	Diplodina sp.	*D. hyalina*
	Elletevera parasitica	*Ellisiops gallessiae*
	Ellisembia vaginata	*Fraseriella* sp.
	Exosporium phyllantheum	*Fusarium* sp.1
	Fusarium sp.4	*Fusarium* sp.2
	Fusarium sp.5	*Fusarium* sp.3
	Fusarium sp.6	*Gyrothrix podosperma*
	Fusarium sp.8	*Hansfordia pulvinata*
	Fusoma rubricosa	*Henicospora coronata*
	Glomerella cingulata	*Hypoxylon* sp.1
	Hansfordia pulvinata	*Hypoxylon* sp.3
	Hendersonia sp.	*Idriella fertile*
	Hendersonula sp.	*I. lunata*
	Henicospora coronata	*Kirschsteiniothelia* sp.

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	Hypoxylon sp.1	*Lasiodiplodia* cf. *theobromae*
	Hypoxylon sp.2	*Linospora* sp.
	H. cohaerens	*Nigrospora sphaerica*
	Idriella lunata	*Oedothea vismiae*
	Kirschsteiniothelia sp.	*Panchanania jaipurensis*
	Lasiodiplodia cf. *theobromae*	*Pestalosphaeria hansenii*
	Leptodiscella africana	*Pestalotiopsis* sp.1
	Linospora sp.	*Pestalotiopsis* sp.2
	Menispora sp.	*P. disseminata*
	Menisporopsis theobromae	*Pleurophragmium acutum*
	Monodictys glauca	*Speiropsis hyalospora*
	Nectria ventricosa	*Sporoschisma uniseptatum*
	Nigrospora sphaerica	*Subulispora procurvata*
	Panchanania jaipurensis	*Thyridaria sambucina*
	Penicillium sp.1	*Torula herbarum*
	P. citrinum	*Trichoderma longibrachiatum*
	Pestalosphaeria hansenii	*Tricladium castaneicola*
	Pestalotiopsis sp.1	*Triscelophorus panapensis*
	P. disseminata	*Veronaea carlinae*
	Phyllosticta sp.	*V. coprophila*
	Pseudospiropes hughesii	*Wiesneriomyces javanicus*
	Pucciniopsis sp.	*Zygosporium gibbum*
	Scolecobasidium compactum	

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	Speiropsis hyalospora	
	Spiropes capensis	
	S. penicillium	
	Sporidesmium sp.1	
	Stenella pithecellobii	
	Subulispora procurvata	
	Tetraploa aristata	
	Thyridaria sambucina	
	Torula herbarum	
	Trichoderchium disseminatum	
	Triscelophorus panapensis	
	Veronaea carlinae	
	V. coprophila	
	Wiesneriomyces javanicus	
	Xylaria hypoxylon	
	Zygosporium masonii	
Old decaying fallen leaves	*Acticulospora tetracladia*	*Acticulospora tetracladia*
	Annellophroagmia sp.	*Aspergillus* sp.1
	Aspergillus sp.2	*Bactrodesmium rahmii*
	Bactrodesmium rahmii	*B. spilomeum*
	Botryodiplodia sp.	*Botryodiplodia* sp.
	Brachydesmiella biseptata	*Camposporium antennatum*
	Cladosporium fulvum	*Cladosporium tenuissimum*

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	C. tenuissimum	*Codinaea fertilis*
	Corynesporopsis quereicola	*Curvularia lunata*
	Curvularia lunata	*Cylindrocladium scoparium*
	Cylindrocladium parvum	*Dactylaria* sp.1
	Dactylaria sp.2	*Dactylaria* sp.2
	D. hyalina	*D. hyalina*
	Diplodia zeae	*D. junci*
	Ephelis borealis	*Ellisiopsis* sp.
	Fusarium sp.1	*Endophragmia hyalosperma*
	Gnomonia fragariae	*Gyrothrix circinata*
	Hendersonia celtifolia	*Henicospora coronata*
	Henicospora coronata	*Hypoxylon* sp.1
	Hypoxylon sp.1	*Kirschsteiniothelia* sp.
	Idriella sp.1	*Lasiodiplodia* cf. *theobromae*
	I. lunata	*Leptodiscella africana*
	Kirschsteiniothelia sp.	*Neottiosporella* sp.
	Lasiodiplodia cf. *theobromae*	*Nigrospora sphaerica*
	Leptodiscella africana	*Panchanania jaipurensis*
	Linocarpon sp.	*Pestalosphaeria hansenii*
	Marasmius sp.	*Pestalotiopsis* sp.1
	Nigrospora sphaerica	*Pestalotiopsis* sp.3
	Panchanania jaipurensis	*Rhinocladiella* sp.
	Paranospora novae-zelandiae	*Scolecobasidiella avellanea*

Table 3.2 (Continued) Dominant fungi found on rubber leaf litter with over 10% occurrence at each stage

Decomposition stage	Location	
	Nakhon Si Thammarat	Songkhla
	Penicillium sp.1	*Speiropsis hyalospora*
	Pestalosphaeria hansenii	*S. pedatospora*
	Pestalotiopsis sp.1	*Subulispora procurvata*
	P. disseminata	*Thyridaria sambucina*
	P. sydowia	*Tricladium castaneicola*
	Pseudogliomastix sp.	*Triscelophorus acuminatus*
	Scolecobasidium compactum	*Veronaea carlinae*
	Septocylindrium aromaticum	*V. coprophila*
	Sporidesmium baccharidis	*Wiesneriomyces javanicus*
	S. japonicus	
	Subulispora procurvata	
	Tetraploa aristata	
	Thyridaria sambucina	
	Torula sp.	
	Trichoderma harzianum	
	Triscelophorus acuminatus	
	T. panapensis	
	Veronaea carlinae	
	V. coprophila	
	Wiesneriomyces javanicus	

3.3.3 Fungal diversity and abundance of fungi

The fungal taxa at different stages of leaf decay were distinct. The number of taxa in newly fallen and middle stage decaying leaves tended to be higher than on old decaying fallen leaves. The number of taxa found on newly fallen leaves and middle stage decaying leaves in Nakhon Si Thammarat Province was 212 and 239 taxa, respectively, whereas, the number of taxa found on the old decaying fallen leaves was 176. The results obtained in Songkhla Province corresponded to the results from Nakhon Si Thammarat. In Songkhla Province, 192 and 209 taxa were found on newly fallen and middle stage decaying leaves, respectively, whereas, 162 taxa were found on old decaying fallen leaves (Table 3.3).

Table 3.3 Diversity indices of saprobic fungi on leaf 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*	212	0.9907	4.8376	192	0.9871	4.5871
Middle*	239	0.9909	4.8388	209	0.9881	4.7149
Old*	176	0.9883	4.6287	162	0.9821	4.3210

Note: *Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

The similarity in fungal communities associated with rubber leaf litter at each stage of decomposition was closest in newly fallen and middle stage decaying leaves. Newly fallen and old decaying fallen leaves were least similar. Middle stage decaying and old decaying fallen leaves showed slightly less similarity than the newly fallen versus middle stage decaying leaves (Table 3.4).

Table 3.4 Sorensen's similarity indices of fungi on leaf litter of rubber (*Hevea brasiliensis*) at different stages of decomposition

Decomposition stage	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
New*		0.5138	0.4185		0.4827	0.4229
Middle*			0.4355			0.4533
Old*						

Note: *Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

3.3.4 Fungal communities in different seasons

The number of fungal taxa found in each collecting site during the different seasons is shown in Table 3.5. In Nakhon Si Thammarat Province, 367 taxa were recorded from the dry season followed by 345, 294 and 262 taxa from the late rainy season, early rainy season and rainy season, repectively. These results are similar to the results from Songkhla Province, 317 fungal taxa were recorded in dry season followed by 282, 229 and 204 taxa from late rainy season, early rainy season and rainy season, respectively. The similarity of fungi associated with rubber leaf litter during the different seasons was also investigated. The highest similarity was found during the late rainy season and the dry season (56.58% in Nakhon Si Thammarat Province, 43.12% in Songkhla Province) (Table 3.6).

The dominant species found during the different seasons in Nakhon Si Thammarat and Songkhla Provinces are shown in Table 3.7 and 3.8. One species, *Veronaea coprophila* was the dominant species found at all seasons in Nakhon Si Thammarat Province. In addition, three species, *Kirschsteiniothelia* sp., *Subulispora procurvata* and *Veronaea coprophila* were the dominant species found during every season in Songkhla Province.

Table 3.5 Diversity indices of saprobic fungi on leaf litter of rubber (*Hevea brasiliensis*) 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	Index
	New*	Middle*	Old*		D	H
Nakhon Si Thammarat						
Late rainy season	123	126	96	345	0.9962	5.5289
Dry season	125	136	106	367	0.9966	5.5532
Early rainy season	104	107	83	294	0.9946	5.2551
Rainy season	84	102	76	262	0.9944	5.1405
Songkhla						
Late rainy season	100	113	69	282	0.9952	5.2856
Dry season	107	122	88	317	0.9959	5.4129
Early rainy season	77	90	62	229	0.9934	5.0141
Rainy season	63	88	53	204	0.9924	4.8647

Note: *Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

Table 3.6 Sorensen's similarity indices of fungi associated with leaf litter of rubber (*Hevea brasiliensis*) versus seasons: late rainy season (January), dry season (April), early rainy season (July) and rainy season (October)

Season	Location							
	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		0.5658	0.4351	0.4167		0.4312	0.4035	0.4131
Dry season			0.4235	0.4398			0.4174	0.3656
Early rainy season				0.4158				0.4086
Rainy season								

Table 3.7 Dominant fungi (over 10% occurrence) on leaf 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	*Aposphaeria peizizoides* (20.83)	*Aposphaeria peizizoides* (10.42)	*Diplodia zeae* (10.42)
(January)	*Botryodiplodia* sp. (25.00)	*Cladosporium fulvum* (14.58)	*Veronaea coprophila* (12.50)
	Fusarium sp.3 (14.58)	*Idriella lunata* (12.50)	
	Menisporopsis theobromae (10.42)	*Linospora* sp. (14.54)	
	Monochaetia sp. (16.67)	*Speiropsis hyalospora* (12.50)	
		Veronaea coprophila (18.75)	
		Wiesneriomyces javanicus (10.42)	
Dry Season	*Aposphaeria peizizoides* (10.42)	*Cladosporium fulvum* (29.17)	*Cladosporium fulvum* (20.83)
(April)	*Botryodiplodia* sp. (14.58)	*C. orchidis* (18.75)	*Corynespora quereicola* (10.42)
	Cladosporium orchidis (22.92)	*Curvularia lunata* (20.83)	*Dactylaria* sp.2 (10.42)
	C. fulvum (16.67)	*Ellisembia vaginata* (10.42)	*Diplodia zeae* (10.42)
	Fusarium sp.3 (10.42)	*Hypoxylon* sp.1 (10.42)	*Idriella* sp.1 (12.42)
	Hansfordia pulvinata (10.42)	*Hansfordia pulvinata* (12.50)	*Pestalotiopsis disseminata* (10.42)
	Idriella lunata (12.50)	*Hendersonula* sp. (10.42)	*Pestalosphaeria hansenii* (12.50)

Table 3.7 (Continued) Dominant fungi (over 10% occurrence) on leaf litter of rubber (*Hevea brasiliensis*) at each stage of decomposition and each season in Nakhon Si Thammarat Province

Season	Decomposition stage		
	New*	Middle*	Old*
	Kirschsteiniothelia sp. (12.50)	*Kirschsteiniothelia* sp. (16.67)	*Subulispora procurvata* (14.58)
	Nigrospora sphaerica (12.50)	*Nigrospora sphaerica* (20.83)	*Veronaea coprophila* (20.83)
	Penicillium sp.1 (14.58)	*Pestalosphaeria hansenii* (10.42)	
	Tetraploa aristata (10.42)	*Penicillium* sp.1 (12.58)	
	Veronaea coprophila (12.50)	*Penicillium* sp.2 (10.42)	
	Zygosporium gibbum (12.50)	*Tetraploa aristata* (16.67)	
	Z. masonii (12.50)	*Torula herbarum* (14.58)	
		Veronaea coprophila (20.83)	
Early Rainy Season	*Botryodiplodia* sp. (10.42)	*Articulospora tetracladia* (12.50)	*Bactrodesmium rahmii* (25.00)
(July)	*Cladosporium tenuissimum* (18.75)	*Bactrodesmium rahmii* (25.00)	*Diplodia zeae* (10.42)
	Colletotrichum sp.2 (12.50)	*Cladosporium tenuissimum* (10.42)	*Henicospora coronata* (14.58)
	Fusarium semitectum (12.50)	*Curvularia lunata* (12.50)	*Lasiodiplodia* cf. *theobromae* (20.83)
	Idriella lunata (12.50)	*Fusarium* sp.8 (10.42)	*Kirschsteiniothelia* sp.(18.75)

Table 3.7 (Continued) Dominant fungi (over 10% occurrence) on leaf litter of rubber (*Hevea brasiliensis*) at each stage of decomposition and each season in Nakhon Si Thammarat Province

Season	Decomposition stage		
	New*	Middle*	Old*
	Kirschsteiniothelia sp. (14.58)	*Glomerella cingulata* (14.58)	*Nigrospora sphaerica* (16.67)
	Lasiodiplodia cf. *theobromae* (10.42)	*Kirschsteiniothelia* sp.(18.75)	*Panchanania jaipurensis* (18.75)
	Speiropsis hyalospora (10.42)	*Lasiodiplodia* cf. *theobromae* (14.58)	*Subulispora procurvata* (18.75)
	Torula sp. (16.67)	*Nigrospora sphaerica* (10.42)	*Tetraploa aristata* (10.42)
	T. herbarum (10.42)	*Panchanania jaipurensis* (12.50)	*Torula herbarum* (10.42)
	Veronaea carlinae (10.42)	*Pestalosphaeria hansenii* (12.50)	*Triscelophorus panapensis* (25.00)
	V. coprophila (10.42)	*Scolecobasidium compactum* (12.42)	*Veronaea carlinae* (10.42)
		Subulispora procurvata (20.83)	*V. coprophila* (12.50)
		Torula herbarum (16.67)	
		Triscelophorus panapensis (16.67)	
		Veronaea carlinae (12.42)	
		V. coprophila (20.83)	
		Xylaria hypoxylon ((10.42)	
		Wiesneriomyces javanicus (12.50)	

Table 3.7 (Continued) Dominant fungi (over 10% occurrence) on leaf litter of rubber (*Hevea brasiliensis*) at each stage of decomposition and each season in Nakhon Si Thammarat Province

Season	Decomposition stage		
	New*	Middle*	Old*
Rainy season	*Dactylaria* sp.1 (10.42)	*Glomerella cingulata* (10.42)	*Articulospora tetracladia* (14.58)
(October)	*Lasiodiplodia* cf. *theobromae* (10.42)	*Kirschsteiniothelia* sp. (22.92)	*Hypoxylon* sp.1 (12.50)
	Nigrospora sphaerica (20.83)	*Lasiodiplodia* cf. *theobromae* (12.50)	*Kirschsteiniothelia* sp. (14.58)
	Pestalosphaeria hansenii (14.58)	*Nigrospora sphaerica* (20.83)	*Pestalotiopsis disseminate* (10.42)
	Scolecobasidiella avellanea (10.42)	*Pestalosphaeria hansenii* (18.75)	*Subulispora procurvata* (10.42)
	Stenella pithecellobii (12.50)	*Subulispora procurvata* (12.50)	*Triscelophorus acaminatus* (22.92)
	Torula herbarum (14.58)	*Tetraploa aristata* (10.42)	
		Torula herbarum (12.50)	
		Veronaea coprophila (12.50)	

Note: *Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

Table 3.8 Dominant fungi (over 10% occurrence) on leaf 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	*Colletotrichum gloeosporioides* (10.42)	*Arthobrotryum atrocephalum* (10.42)	*Acticulospora tetracladia* (14.58)
(January)	*Dactylaria* sp.1 (12.50)	*Colletotrichum gloeosporioides* (10.42)	*Codinaea fertilis* (10.42)
	D. junci (10.42)	*Ellisiopsis gallessiae* (10.42)	*Cylindrocladium scoparium* (12.50)
	Ellisiopsis gallessiae (12.50)	*Kirschsteiniothelia* sp. (10.42)	*Henicospora coronata* (12.50)
	Fusarium sp.1 (20.83)	*Lasiodiplodia* cf. *theobromae* (16.67)	*Kirschsteiniothelia* sp. (18.75)
	Hypoxylon sp.1 (10.42)	*Pestalosphaeria hansenii* (12.50)	*Panchanania jaipurensis* (14.54)
	Subulispora procurvata (12.50)	*Veronaea coprophila* (14.58)	*Scolecobasidiella avellanea* (14.58)
	Veronaea carlinae (18.75)		*Subulispora procurvata* (10.42)
	Zygosporium gibbum (10.42)		*Thyridaria sambucina* (10.42)
			Tricladium castaneicola (10.42)
			Tricelophorus acuminatus (20.83)
			Veronaea carlinae (25.00)
			V. coprophila (14.58)
			Wiesneriomyces javanicus (10.42)

Table 3.8 (Continued) Dominant fungi (over 10% occurrence) on leaf litter of rubber (*Hevea brasiliensis*) at each stage of decomposition and each season in Songkhla Province

Season	Decomposition stage		
	New*	Middle*	Old*
Dry season	*Cladosporium tenuissimum* (16.67)	*Diplococcium spicatum* (20.83)	*Cladosporium tenuissimum* (10.42)
(April)	*Fusarium* sp.1 (10.42)	*Hansfordia pulvinata* (18.75)	*Lasiodiplodia* cf. *theobromae* (16.67)
	Kirschsteiniothelia sp.(10.42)	*Kirschsteiniothelia* sp. (16.67)	*Scolecobasidiella avellanea* (18.75)
	Lasiodiplodia cf. *theobromae* (10.42)	*Lasiodiplodia* cf. *theobromae* (14.58)	*Subulispora procurvata* (10.42)
	Oedothea vismiae (10.42)	*Nigrospora sphaerica* (16.67)	*Veronaea carlinae* (10.42)
	Veronaea carlinae (14.58)	*Pestalosphaeria hansenii* (10.42)	*V. coprophila* (10.42)
		Veronaea carlinae (14.58)	
		V. coprophila (10.42)	
		Zygosporium gibbum (14.58)	
Early rainy season	*Bactrodesmium spilomeum* (14.58)	*Botryodiplodia* sp. (20.83)	*Bactrodesmium rahmii* (10.42)
(July)	*Cladosporium oxysporum* (12.50)	*Bactrodesmium rahmii* (20.83)	*Botryodiplodia* sp. (12.50)
	Colletotrichum gloeosporioides (18.75)	*Kirschsteiniothelia* sp. (12.50)	*Dactylaria junci* (10.42)
	Nigrospora sphaerica (12.50)	*Lasiodiplodia* cf. *theobromae* (20.83)	*Kirschsteiniothelia* sp. (16.67)
	Kirschsteiniothelia sp. (16.67)	*Nigrospora sphaerica* (16.67)	*Nigrospora sphaerica* (12.50)

Table 3.8 (Continued) Dominant fungi (over 10% occurrence) on leaf litter of rubber (*Hevea brasiliensis*) at each stage of decomposition and each season in Songkhla Province

Season	Decomposition stage		
	New*	Middle*	Old*
	Torula herbarum (16.67)	*Subulispora procurvata* (18.75)	*Panchanania jaipurensis* (10.42)
	Veronaea carlinae (12.50)	*Thyridaria sambucina* (12.50)	*Subulispora procurvata* (16.67)
		Veronaea carlinae (12.50)	*Thyridaria sambucina* (12.50)
		V. coprophila (12.50)	*Triscelophorus acuminatus* (10.42)
Rainy season	*Bactrodesmium rahmii* (10.42)	*Kirschsteiniothelia* sp. (20.83)	*Botryodiplodia* sp. (20.83)
(October)	*Colletotrichum gloeosporioides* (18.75)	*Subulispora procurvata* (12.50)	*Dactylaria junci* (14.58)
	Hypoxylon sp.1 (14.58)	*Thyridaria sambucina* (14.58)	*Henicospora coronata* (14.58)
	Kirschsteiniothelia sp. (16.67)		*Kirschsteiniothelia* sp. (18.75)
	Nigrospora sphaerica (10.42)		*Panjanania jaipurensis* (10.42)
	Torula herbarum (12.50)		*Scolecobasidium avellanea* (10.42)
			Subulispora procurvata (18.75)
			Thyridaria sambucina (12.50)
			Veronaea coprophila (10.42)

Note: *Newly fallen leaves, middle stage decaying leaves, old decaying fallan leaves

3.4 Discussion

3.4.1 Fungal diversity and colonization

This is the first report of fungal communities associated on rubber leaf litter decay in Thailand. Fungal community structure and its changes during the three analogous decomposition stages (newly fallen leaves, middle stage decaying leaves and old decaying fallen leaves) were studied.

Differences in fungal communities occur during the fungal succession on decaying *H. brasiliensis* leaves. In the newly fallen leaves (313 taxa) and middle stage decaying leaves (326 taxa) the number of species tends to be higher than fungi associated with the old decaying fallen leaves (250 taxa). Some fungi, such as *Bactrodesmium betulicola, Colletotrichum dematum, Dictyosporium elegans*, *Bipolaris heveae*, *Spegazzina lobulata* and *Talaromyces flavus* were recorded only from the samples of newly fallen leaves, suggesting that they may be carried over from the phyllophane. Their occurrence on the surfaces of green foliage has been reported previously (Subramanian and Vittal, 1980) and they are primary saprobes, which are ever-present inhabitants of aerial plant surfaces (Shanthi and Vittal, 2010a). Some species of fungi were recorded only on the middle stage decaying leaves; for example, *Chaetopsina fulva, Codinaea* sp.2, *C. britannica, Dictyosporium* sp., *Hypoxylon cohaerens, Pseudospiropes hughesii, Pyriculariopsis parasitica, Sporidesmium* sp.1, *Stenella liabicola* and *Taeniolella scripta*. Finally, some fungi such as *Alternaria pluriseptata*, *Dactylella ellipsospora* and *Marasmius* sp. were recorded only from the old decaying fallen leaf stage.

Kannangara and Deshappriya (2005) reported that the differences in resource quality such as nitrogen, and the presence of inhibitory tannin concentrations involved in decay, are important. According to Bill and Polishook (1994) and Puranong *et al*. (2007), colonization of leaf litter by various fungal species during decomposition is a sequential process with sequential replacement over time. Replacement or succession may be strongly affected by the nutrient levels of the litter and/or between fungi. Substrate quality can even vary within a leaf.

Berg and Staaf (1980) and McClaugherty and Berg (1987) have shown that, in the initial stages (0 to 3 months) of leaf breakdown, small soluble carbon-based molecules, such as starch and amino acids, are lost, leaving behind more recalcitrant molecules, such as lignin. Decomposition during this first phase is rapid because these small, soluble carbon-based molecules are energy rich and easily broken down, which allows the greater fungal growth associated with this stage. Fungal colonization of a substrate results in a loss in strength and changes in color. Species diversity tends to be richest and number of fungi usually highest during the early and middle stages of colonization; then the number of species begins to decline.

Fungal communities are classified into three successive decomposition stages: the pioneer stage, mature stage and the impoverished stage (Kannangara and Deshappriya, 2005; Osono, 2005). Pioneer communities are typically composed of a large number of different species occurring at low frequency with no obvious dominant species. Mature fungal communities consist of fewer species with one or two obviously dominant species common to all samples at a similar stage in the development of the fungal community. Distinct succession of fungal communities has been recorded based on the replacement of microfungi at each stage. Factors regulating leaf litter decomposition include resource composition, i.e. chemical and physical composition, temperature and aeration during the decomposition process. Succession studies are unclear as to which factor has the greater influence over decomposition rate and fungal diversity (Kannangara and Deshappriya, 2005; Osono, 2005; Shanthi and Vittal, 2010b). Promputtha *et al*. (2002) have recorded fungal succession on the leaves of *Magnolia garrettii*. Other studies have included bamboo (Zhou and Hyde, 2002), *Sphagnum fuscum*, *Carex aquatilis* and *Salix planifolia* (Thorman *et al*., 2003), *Quercus rotundifolis* (Sadaka *et al*., 2003), *Swida controversa* (Osono, 2005), *Castanopsis fissa* (Tang *et al*., 2005), *Castanopsis diversifolia* (Duong *et al*., 2008) and *Shorea obtuse* (Osono *et al*., 2009).

3.4.2 Seasonal effects on the fungal community

Seasonality is one factor that is believed to affect the fungal community. Studies on the diversity of fungi in leaf litter suggest that the communities vary according to the seasons (Kennedy *et al*., 2006). Nevertheless, it is unclear how the seasons affect fungal communities. As the presence or absence of aquatic hyphomycetes is regulated primarily by season, one can assume that this cause and effect chain operates via temperature (Nikolcheva and Bârlocher, 2005).

In this study, samples collected in the dry season (April) tends to be richer in species and have a higher Shannon diversity index than the samples collected in the early or late rainy season. Kodsueb *et al*. (2007) studied the diversity of saprobic fungi on Magnoliaceae litter and reported that samples collected in the dry season had greater species richness than samples collected in the wet season, which suggest a humidity factor. Rayner and Todd (1979) found 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 leaf litter, with high moisture and low aeration during the wettest period. High humidity is needed for the germination and dispersal of fungi (Pinnoi *et al*., 2006); consequently, fungal communities from wet season samples (which have higher humidity) are more diverse.

Our results have shown that fungal communities during the dry season are more diverse (Rayner and Todd, 1979). Thus, many factors affect the changes in community structure, for instance, the microclimate of the growing area, biological interaction within leaf litter, or substrate, microhabitat preference and host preferences (Lodge, 1997).

CHAPTER 4

DIVERSITY OF SAPROBIC FUNGI ON DECAYING BRANCH LITTER OF THE RUBBER TREE (*HEVEA BRASILIENSIS*)

4.1 Introduction

The rubber tree (*H. 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 southern Thailand (Office of Agricultural Economics, 2011). Chemical composition of rubber wood includes 77.8% hemicelluloses, 39.7% cellulose and 17.8% lignin (Simatupang and Schmitt, 1992). Since the rubber plantations are monoculture, the ecological components differ to the forest in terms of nutrient cycling and soil conservation (Gazia and 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 and 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 and Christensen, 2003; Küffer *et al*., 2004). Tree litter can be divided into three categories: leaf litter, branch litter (1-5 cm diameter) and logs ($\geq$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 coarse 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 and 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 and Paltto, 2001), beech (Küffer *et al*., 2004), *Picea abies* (Allmér, 2005), *Fagus sylvatica*, *Picea abies*, *Abies alba*, *Pinus sylvestris* and *Castanea sativa* (Küffer and 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, two zygomycetes, one basidiomycete and one oomycete) were discovered on rubber tree leaf litter in three periods (Seephueak *et al*., 2010). In addition, the fungal diversity on rubber leaf litter in four periods (Chapter 3) was found 503 species (comprising 461 anamorphic taxa, 38 ascomycetes, two zygomycetes, one basidiomycete and one oomycete).

In this chapter 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 fallen branches, and to evaluate the fungal communities involved in litter decay at each stage.

4.2 Materials and 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).

4.2.1 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 Province and 27.8°C in Songkhla Province. The rainfall was recorded as 272.2 mm in Nakhon Si Thammarat Province and 399.0 mm in Songkhla Province. 50 m^2 sites were marked out in each rubber plantation and 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 h.

4.2.2 Incubation, observation and isolation of fungi

Moist chamber and dilution-plate techniques 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.

4.2.3 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) x 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 $H = -\sum P_i \ln P_i$, 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–Σ [ni/(ni–1)/N/(N–1)], where ni is the number of individuals of species 1 and N = total number of species in community. 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 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).

4.3 Results

4.3.1 Fungal taxonomic composition

There were clear differences in the species composition and richness detected by the two methods used to examine the fungal communities on branch litter. Out of a total of 450 species, 409 fungal taxa (90.89%) were recorded by moist chamber technique and 41 (9.11%) were detected by dilution plate technique. The 450 taxa comprised 400 anamorphic fungi, 48 ascomycetes, one oomycete and one zygomycete (Table 4.1).

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 259 species were found in newly fallen branches, 276 species in middle stage decaying branches and 230 species in old decaying fallen branches. In both provinces, it was found that 69 species (41.95%) were overlapping in newly fallen branches, 79 species (44.26%) were overlapping in middle stage decaying branches and 65 species (43.92%) were overlapping in old decaying fallen branches. The 331 fungal taxa found in Nakhon Si Thammarat Province included 287 anamorphic taxa, 42 ascomycetes, one zygomycete and one oomycete. One hundred and seventy-eight taxa were recorded from newly fallen branches, 185 from middle stage decaying branches and 158 species were recorded from old decaying fallen branches. In Songkhla Province, 279 fungal taxa were found including 259 anamorphic taxa, 19 ascomycetes and one oomycete. One hundred and fifty-one taxa were recorded from newly fallen branches, 172 from middle stage decaying branches and 138 taxa from old decaying fallen branches.

Twenty-eight 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, *D. 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*, *Speiropsis hyalospora*, *Sporidesmium flagellatum*, *Subulispora procurvata*, *Tetraploa aristata*, *Thyridaria sambucina*, *Torula herbarum* and *Veronaea carlinae*. Fifty-four taxa of fungi were found in all stages of decomposition in Nakhon Si Thammarat Province and 53 in Songkhla Province.

4.3.2 Species richness and 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 4.2 and 4.3. Anamorphic fungi (400 taxa) were the dominant group, followed by ascomycetes (48 taxa), oomycetes (1 taxon) and zygomycetes (1 taxon). Ten dominant fungal taxa were found in all stages of decomposition in both areas comprising *Hypoxylon* sp.2, *Kirschsteiniothelia* sp., *Pestalosphaeria hansenii*, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Lasiodiplodia* cf. *theobromea*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Torula herbarum* and *Veronaea carlinae*.

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 decaying 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.

4.3.3 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 Province was 185 taxa, 178 taxa were found on newly fallen branches and 158 taxa on old decaying fallen branches. In Songkhla Province, 172 taxa were found on the middle stage decaying branches, 151 taxa on newly fallen branches and 138 taxa on the old decaying fallen branches (Table 4.4).

The similarity of fungal communities associated with rubber branch litter at different decay stages was most similar during the middle and old stage decaying (48.98% in Nakhon Si Thammarat Province, 51.61% in Songkhla Province). The newly fallen branches and the old decaying fallen branches were the least similar (40.12% in Nakhon Si Thammarat Province, 49.31% in Songkhla Province) (Table 4.5).

4.3.4 Fungal communities in different seasons

In Nakhon Si Thammarat Province 289 taxa were recorded in the dry season, while 242, 238 and 193 taxa were recorded from the early rainy season, late rainy season, and rainy season, respectively (Table 4.6). In Songkhla Province 299 fungal taxa were recorded in dry season, 294, 288 and 211 taxa were recorded from early rainy season, late rainy season and rainy season, respectively (Table 4.6). Three species, *Bactrodesmium rahmii*, *Lasiodiplodia* cf. *theobromae* and *Kirschsteiniothelia* sp. were the dominant species during at all seasons in Nakhon Si Thammarat Province. Seven species, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Hypoxylon* sp.1, *Pestalosphaeria hansenii* and *Pyriculariopsis parasitica* were the dominant species during all seasons in Songkhla Province.

The similarity of fungi associated with rubber branch litter during the different seasons was investigated. The most similar fungi were found during the early rainy season and during the dry season (43.69% in Nakhon Si Thammarat Province, 50.00% in Songkhla Province) and during the late rainy season and during the rainy season were the least similar (33.08% in Nakhon Si Thammarat Province, 39.76% in Songkhla Province) (Table 4.7).

Table 4.1 Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota						
Acrophialophora fusispora		2.08				
Anthostomella formosa					8.33	8.33
Astrosphaeriella sp.1		6.25				
Astrosphaeriella sp.2				2.08	6.25	
Boerlagiomyces grandisporus		6.25				
Botryosphearia sp.		14.58				
Ceratocystis ulmi			2.08			
Chaetomium sp.1	2.08					2.08
Chaetomium sp.2			4.17			
Claussenomyces atrovirens		4.17		2.08	29.17	10.42
Dothidotthia sp.1	6.25	2.08		8.33		
Dothidotthia sp.2	6.25					
Dothiorella sp.	2.08		2.08			
Eupenicillium sp.		2.08				
E. brefeldianum			6.25			
E. javanicum	2.08					
Gaeumannomyces graminis			4.17			
Glomerella cingulata	6.25			2.08	12.50	2.08
Gnomonia creastris	2.08					
Hypocrea rufa	2.08		10.42			
Hypoxylon sp.1	18.75	18.74	14.58	52.08	50.00	33.33

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Hypoxylon sp.2	18.75	27.08	22.92	18.75	12.50	25.00
Hypoxylon sp.3	22.92	6.25	18.75			
Hypoxylon sp.4	12.50	18.75	10.42			
Hypoxylon sp.5	6.25	4.17				
Kirschsteiniothelia sp. [1/]	81.25	68.75	45.83	60.42	62.50	50.00
Leptosphaeria blumeri		4.17				
L. cercocarpi		16.67				
L. conoidea	6.25					
L. darkeri						4.17
L. millefolii		8.33				
L. russellii			12.50			
Linocarpon sp.1		4.17		10.42	12.50	18.75
Linodochium hyalinum			4.17			
Linospora sp.			4.17		12.50	18.75
Lophiostoma fuckelii			2.08			
Lophodermium sp.					6.25	
Orbilia sp.		2.08				
Oxydothis sp.		2.08	4.17	2.08	8.33	
Pestalosphaeria hansenii	18.75	16.67	22.92	25.00	58.33	20.83
Phaeosphaeria sp.		6.25				
Plectosphaerella cucumerina					6.25	
Pleospora sp.		2.08				
Stegopeziza dumeti	2.08					

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Thematosphaeria pertusa		12.50	8.33	4.17	10.42	6.25
Thyridaria sambucina	6.25	14.58	2.08	6.25	18.75	18.75
Typhula ishikariensis		2.08				
Xylaria sp.1					6.25	
Mitosporic fungi						
Acarocybe sp.1				10.42		
A. deightonii				8.33		
A. formosa	2.08			39.58	33.33	
A. hansfordii	6.25	2.08		20.83		27.08
Acarocybella jasminicola		2.08	20.83	8.33	6.25	
Acladium conspersum			4.17			
Acremonium sp.1	4.17		4.17	12.50	14.58	
Acremonium sp.2				2.08		
Acremonium sp.3				2.08		
A. butyri[1/]		20.83	10.42			8.33
A. cerealis					22.92	14.58
A. fusidiodes			6.25	6.25	14.58	18.75
A. kiliense[1/]				4.17	29.17	4.17
A. murorum				2.08	2.08	12.50
A. strictum	8.33	2.08	2.08	10.42	4.17	27.08
Acrodictys sp.		4.17			6.25	
A. fuliginosa				10.42		
Acrostaurus turneri				6.25	2.08	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Actinocladium rhodosporum	8.33	10.42	33.33	10.42	12.50	14.58
Actinospora megalospora	2.08					
Annellophora dendrographii	4.17					
Anthina sp.	6.25					
Arthinium muelleri				2.08		
Arthobotryum atrocephalum			20.83			
Arthrocladium caudatum		6.25				
Articulospora tetracladia		2.08	10.42		4.17	4.17
Aspergillus sp.1[1/]	4.17	8.33		4.17	8.33	6.25
Aspergillus sp.2[1/]			2.08			6.25
Aspergillus sp.3[1/]				16.67	16.67	4.17
Aspergillus sp.4[1/]				4.17		
Aspergillus sp.5[1/]		8.33	8.33			
Aspergillus sp.6[1/]						4.17
A. niger[1/]				16.67	8.33	
Asperisporium moringae[1/]		4.17				
Asteroma coryli		6.25				
Aureobasidium sp.						2.08
Bactrodesmium sp.					20.83	
B. rahmii	29.17	47.92	79.17	50.00	72.92	47.92
B. betulicola				50.00	27.08	2.08
B. pallidum		8.33		25.00	16.67	
B. spilomeum	8.33	2.08	2.08	68.75	43.75	25.00

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Beltraniella pirozynkii					4.17	2.08
Berkleasmium cf. *minutissimum*	2.08	2.08			2.08	
B. concinnum	8.33	4.17			6.25	
Bidenticula cannae			6.25			8.33
Bipolaris sp.1	2.08		10.42			
B. australiensis	8.33					
B. biseptata	8.33					
B. cactivora			14.58			
B. dematioidea	2.08					
B. ellisii				12.50	18.75	
B. erythrospila					6.25	
B. heveae	8.33					
B. indica				10.42		
B. phlei	2.08					
B. ravenelii	4.17					4.17
Bispora antennata						8.33
Botryodiplodia sp.	18.75	10.42	20.83	60.42	89.58	35.42
Botryotrichum sp.			2.08			
Brachiosphaera tropicalis	2.08					
Brachydesmiella biseptata				4.17		12.50
B. musifomis		2.08			4.17	
Brachyhelicoon xylogenum					2.08	
Brachysporiella gayana	25.00	16.67	2.08		4.17	14.58

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
B. laxa			8.33			
Brachysporium sp.	10.42				6.25	
B. britannicum				6.25		
B. dingleyae	10.42	6.25	6.25	2.08	6.25	
Camposporium sp.			8.33			
C. antennatum			4.17			
C. cambrense	2.08	2.08	2.08		2.08	2.08
Canalisporium caribense		2.08			18.75	
Cantelabrella musifomis						2.08
Cephaliophora irregularia				2.08		
Ceratosporella deviata			4.17			
C. novae-zelandiae			4.17	6.25	4.17	2.08
Ceratosporium fuscescens			12.50			
Cercospora sp.1	8.33	6.25	6.25			
Cercospora sp.2		6.25				
Cercospora sp.3		6.25				
C. achyranthina		2.08		29.17	10.42	
C. apii	4.17		2.08	29.17	6.25	
C. canescens		12.50				
C. elaedis				4.17		14.58
Ceriospora polygonacearum		4.17			4.17	
Chaetoconidium arachnoideum	2.08					
Chaetopsis grisea					4.17	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Chalara sp.	2.08		4.17		6.25	2.08
C. cylindrosperma					2.08	
C. urceolata			2.08			
Chalaropsis sp.				2.08		
Chrysosporium condensatum	2.08					
Circinotrichum fertile		2.08				
C. poonense	2.08	2.08		10.42	4.17	10.42
Cladosporium sp.1	12.50				6.25	
Cladosporium sp.2				4.17		
C. britannicum	4.17	2.08				
C. elatum	10.42		10.42	14.58	10.42	
C. gallicola			6.25	4.17		
C. orchidis				14.58		
C. tenuissimum	2.08	10.42	4.17	22.92	22.92	18.75
Clasterosporium cocoicola	12.50					
C. flagellatum			4.17			
Clavariopsis aquatica	2.08					
C. brachycladia	2.08					
Codinaea sp.						6.25
C. assamica				2.08	14.58	8.33
Colletotrichum sp.[1/]					20.83	6.25
C. gloeosporioides[1/]	2.08		6.25	6.25	16.67	16.67
Cordana pauciseptata			4.17			

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Cordella clarkii	4.17	2.08				
Corynespora sp.1			2.08		2.08	
Corynespora sp.2						10.42
Corynespora sp.3					2.08	10.42
C. cassiicola		6.25	10.42		6.25	2.08
C. novae-zelandiae						2.08
C. proliferata			4.17			
C. trichiliae			6.25		8.33	
Corynesporopsis quereicola			12.50		4.17	
Crytocoryneum condensatum				2.08	2.08	
Curvularia sp.					4.17	
C. affinis			4.17			
C. deightonii	6.25					
C. lunata[1/]	16.67	4.17	20.83	16.67	22.92	16.67
C. pallescens			2.08			
Cylindrocladium sp.1		2.08				
C. parvum[1/]		4.17		25.00		
C. scoparium		8.33	4.17		2.08	
Cylindrocolla urticae			2.08			
Cylindrotrichum sp.		2.08	2.08			
C. oligospermum		8.33			31.25	
Dactylaria sp.1	14.58	4.17	4.17	6.25	6.25	4.17
Dactylaria sp.2	2.08	2.08	2.08			14.58

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Dactylaria sp.3	8.33	2.08	6.25			10.42
D. hyalina	4.17	10.42	12.50	8.33	10.42	2.08
D. junci	6.25					
D. purpurella				8.33		
Dactylella sp.		12.50				
D. ellipsospora	10.42	6.25	14.58			2.08
Dendeyphion comosum	6.25				10.42	
Dictyoarthrinium sp.						2.08
Dictyosporium sp.1	4.17					8.33
D. giganticum				8.33	6.25	
D. heptasporum					6.25	
D. manglietiae		2.08	6.25			12.50
Diplocladiella scalaroides		6.25		8.33		8.33
Diplococcium sp.1	8.33	4.17	25			
Diplococcium sp.2	10.42	18.75		10.42		
D. asperum		4.17				6.25
D. clarkii		2.08				
D. lawrencei		2.08				
D. spicatum	6.25	18.75	25.00	10.42	25.00	16.67
Diplodia sp. 1/				10.42	6.25	
Discosia artocreas					4.17	
Ellisembia sp.						10.42
E. paravaginata		20.83			18.75	2.08

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
E. repentioriunda						10.42
E. vaginata			4.17	14.58	12.50	
Ellisiosis gallesiae					2.08	
Endophragmia sp.			2.08			
E. bisbyi			4.17			
E. boewei				6.25	8.33	10.42
E. brevis				4.17		
E. cesatii				12.50		
E. elliptica				18.75		14.58
E. hyalosperma	31.25			14.58		
E. pinicola	6.25					
Endophragmella sp.	2.08	2.08				
E. boewei	2.08				2.08	
E. lignicola	2.08					
Excipularia narsapurensis	4.17					
Exosporium monanthotaxis					14.58	
E. phyllantheum	25.00					
Fulvia berkhaeyae					10.42	4.17
Fasariella sp.		6.25			8.33	
Fusariella kansensis		6.25	20.83			
F. sarniesis					14.58	4.17
Fusarium sp.1	2.08	20.83	14.58	12.50	18.75	12.50
Fusarium sp.2	8.33	8.33	4.17	29.17	6.25	6.25

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Fusarium sp.3	4.17	2.08	4.17	29.17	10.42	
Fusarium sp.4	4.17	8.33			12.50	
Fusarium sp.5	6.25	6.25				
Fusarium sp.6	2.08					
F. aquaeductuum					2.08	
F. moniliforme				14.58		
F. oxysporum[1/]	2.08					
F. redolens[1/]						6.25
F. semitectum[1/]		2.08	2.08	4.17		
Fusicladium sp.		2.08				
Gliomastix cerealis					4.17	
G. musicola	4.17				2.08	
Goidanichiella sp.			2.08			
Gyrothrix circinata		2.08		6.25		4.17
G. podosperma			4.17		4.17	
Hansfordia biophila	6.25	4.17			16.67	
H. nebularis	2.08					
H. ovalispora		14.58	14.58			31.25
Haplographium mangiferae		2.08				
Helicomyces sp.		2.08			2.08	4.17
H. roseus			2.08			
Helicosporium aureum					4.17	2.08
H. vegetum			2.08		2.08	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Helminthosporium velutinum	2.08	8.33	10.42			
Henicospora coronata		4.17		4.17		
Hirudinaria macrospora		2.08	2.08		2.08	
Hormiactis sp.1		2.08				
H. alba				6.25		
H. candida		4.17				18.75
Humicola grisea					8.33	
Hyalodendron sp.				2.08		
Hyphodiscosia jaipurensis				4.17		8.33
Idriella fertile		6.25				
I. lunata	2.08	4.17			20.83	12.50
Janetia faureae		10.42				
Lasiodiplodia cf. *theobromae*	64.58	58.33	79.17	50.00	45.83	39.58
Lateriramulosa uni-inflata		2.08	2.08		4.17	4.17
Lauriomyces sakaeratensis						2.08
Lemonniera brachycladia	6.25					
Leptodiscella africana	14.58	8.33	4.17		8.33	18.75
Mariannaea elegans			4.17			
Microthyrium fagi				18.75		
Monacrosporium sp.1	6.25	6.25	6.25		2.08	
Monacrosporium sp.2		2.08				
Mycoleptodiscus indicus			6.25	4.17		
Mycovellosiella solani-torvi			2.08			

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Myrothecium roridum			6.25			
Myxocyclus sp.			2.08			
Nawawia filiformis			6.25			
Nematoctonus sp.			2.08			
Nigrospora sphaerica	22.92	20.83	14.58	22.92	27.08	25.00
Paecilomyces sp.			8.33		12.50	
P. lilacinus[1/]	2.08	2.08	8.33	8.33	12.50	
Panchanania jaipurensis		8.33			12.50	4.17
Parapleurotheciopsis sp.	18.75	18.75		8.33		
Parasympodiella podacarpi	6.25	10.42			4.17	20.83
Paratomenticola lanceolatus	16.67	33.33	25.00	31.25	27.08	27.08
Paratrichoconis chinensis		4.17	6.25		27.08	
P. polygonecearum		4.17				
Penicillium sp.1[1/]	6.25	2.08	14.58	31.25	35.42	18.75
Penicillium sp.2[1/]	4.17	2.08		6.25	25.00	16.67
Penicillium sp.3[1/]	4.17	2.08		6.25		12.50
Penicillum sp.4[1/]		10.42				
Periconia byssoides	2.08					
P. cambrensis		2.08				
P. jabalpurensis			4.17			
P. lateralis	2.08					2.08
P. tirupatiensis					6.25	
Periconiella cyatheae	8.33					

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Pestalotiopsis sp.1	14.58	8.33		8.33	14.58	10.42
Pestalotiopsis sp.2	14.58	2.08			16.67	
Pestalotiopsis sp.3		2.08				
P. disseminata[1/]	6.25		10.42	4.17		
P. hansenii	10.42					
P. sydowiana[1/]	14.58					
Phaeodactylium alpiniae		6.25	12.50			
Phaeoisariopsis cercosporioides				25.00		
Phaeoramularia marmorata				25.00	22.92	
P. oldenlandiae				8.33		
Phialocephala bactrospora					4.17	
Phoma sp.[1/]	2.08			2.08	8.33	
Phomosis sp.[1/]			8.33	8.33		
Phyllosticta sp.[1/]			6.25			
Piricauda pseudarthiae					6.25	
Pithomyces graminicola	12.50					
Pleurophragmium acutum			10.42		18.75	8.33
Pleurotheciopsis pusilla	4.17					
Polymorphum sp.		2.08				
Pseudobotrytis terrestris		16.67	27.08			
Pseudocercospora pterocauli	6.25					
Pseudodiplodia sp.		10.42				
Pseudospiropes hughesii		12.50	10.42	6.25		10.42

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
P. obclavatus	12.50	4.17	10.42	12.50	18.75	33.33
P. roussetianus						4.17
P. subuliferus					16.67	
Pyriculariopsis sp.						6.25
P. parasitica	18.75			37.50	62.50	47.92
Rhinocladiella sp.1		10.42	18.75	4.17		14.58
Rhinocladiella sp.2				4.17	8.33	
Rhinocladiella sp.3					4.17	
Rhinocladiella sp.4					4.17	
Saccardaea atra					6.25	
Schizotrichum lobeliae	4.17					
Scolecobasidiella sp.		4.17				
S. avellanea		6.25	6.25	4.17	2.08	29.17
Scolecobasidium acanthacearum	4.17		4.17	4.17		2.08
S. anellii				2.08		
S. compactum	2.08	8.33	10.42			10.42
S. dendroides		2.08				
S. salinum	10.42	6.25		10.42		
Scytalidium lignicola	4.17					
Septonema fasciculare		6.25	12.50	12.50	39.58	25.00
Sirosporium stylidii				2.08		
Spadicoides bina						10.42
S. obovata	10.42					

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Spegazzinia sp.				2.08		
S. deightonii		8.33				
S. parkeri	2.08			2.08		
S. sundara		2.08	2.08			
Speiropsis hyalospora	2.08	2.08	4.17	4.17	18.75	10.42
Spondylocladiella sp.				6.25		
S. botrytioides	2.08	2.08		12.50		10.42
Sporidesmium sp.1	2.08					
Sporidesmium sp.2		2.08				
Sporidesmium sp.3		14.58				
S. australiense	2.08		4.17			12.50
S. bambusicola	2.08		6.25		14.58	
S. cambrense		12.50				
S. coronatum		10.42				
S. dioscoreae		6.25		20.83		
S. ehrenbergii						25.00
S. ellisii						8.33
S. flagellatum	20.83	20.83	6.25	8.33	54.17	22.92
S. ghanaense	14.58		8.33			
S. harknesii	8.33	16.67	14.58		4.17	10.42
S. hormiscioides				12.50		
S. jasminicola	4.17			12.50		20.83
S. larvatum		6.25	6.25			

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. leptosporum	8.33	2.08			25.00	
S. longirostratum	6.25	10.42	8.33			8.33
S. njalaense					8.33	
S. nodipes	10.42	10.42	2.08		18.75	16.67
S. parvum			10.42			
S. penzigii		14.58	31.25			
S. rubi	2.08	20.83	29.17	20.83		
S. socium				10.42		
S. subulatum	8.33	14.58				
S. tenuisporum	4.17					
S. uvariicola	2.08					
S. zambiense			25.00			
Sporoschismopis sp.1		12.50	6.25	16.67	27.08	27.08
Sporoschismopsis sp.2				16.67	6.25	
S. uniseptatum	2.08			10.42	6.25	
Stachybotrys oenanthes	8.33					
S. parvispora					2.08	
S. sanserieriae	16.67					
Staphylotrichum sp.						8.33
S. coccosporum	2.08					8.33
Stenella pithecellobii	12.50		8.33	6.25	29.17	4.17
Stigmina sp.1					6.25	
Stigmina sp.2					8.33	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. celata	12.50	4.17				
S. combreticola						4.17
S. crotonicola	6.25					
S. hartigiana					10.42	10.42
S. kranzii	8.33					
S. mangiferae			2.08			
S. murrayae		16.67				
S. obtecta					6.25	
S. phaeocarpa					4.17	
S. rauvalfiae	2.08		6.25	20.83	20.83	
S. sudanensis	25.00				4.17	
Subulispora sp.			4.17	2.08		
S. britannica			10.42			
S. procurvata	2.08	4.17	8.33	25.00	14.58	12.50
Sympodiella sp.					4.17	
Taeniolella breviuscula		14.58			20.83	
Tetracrium amphibium	4.17	8.33	6.25			
Tetraploa aristata	4.17	25.00	10.42	4.17	12.50	8.33
T. ellisii	16.67					
Tetraposporium sp.						4.17
T. asterinearum	4.17	8.33	10.42			2.08
Tetratosperma sp.	8.33					
Thyrsidina sp.	10.42					

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Torula sp.1				14.58		
T. herbarum	47.92	31.25	14.58	37.50	31.25	29.17
Tretospora sp.1		2.08				
Tretospora sp. 2	2.08	8.33	2.08			
Trichoderma sp.1[1/]	4.17	8.33		10.42		18.75
Trichoderma sp.2[1/]	6.25			10.42		
Trichoderma sp.3[1/]	6.25	2.08		10.42	12.50	
Trichoderma sp.4[1/]	4.17	2.08		10.42		16.67
Trichoderma sp.5[1/]	4.17			12.50	12.50	
Trichoderma sp.6[1/]	4.17			12.50		
T. atroviride[1/]	4.17	10.42	6.25	10.42		18.75
T. citrinoviride[1/]				2.08		
T. hamatum[1/]		4.17	4.17			
T. inhamatum		2.08				
T. harzianum[1/]		10.42	6.25	6.25	8.33	20.83
T. virens[1/]		6.25				
T. viride[1/]				4.17	10.42	
Trichodochium disseminatum	4.17					
Tricladium sp.	4.17	8.33	4.17	2.08		
T. fuscum	2.08	10.42				
Tridentaria sp.			4.17			
T. implicans	2.08	14.58	4.17			
Tripospermum myrtii	14.58				8.33	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) at different stages of decomposition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Triscelophorus acuminatus	2.08	2.08	2.08	2.08		2.08
T. monosporus				4.17	6.25	
T. panapensis		4.17			14.58	8.33
Uniseta sp.				4.17		
Venturia crataegi	6.25		4.17			
Veronaea sp.					10.42	
V. apiculata		16.67	8.33			
V. botryosa				4.17		20.83
V. carlinae	14.58	20.83	16.67	25.00	18.75	25.00
V. coprophila	18.75	39.58		20.83	54.17	25.00
V. musae		4.17	8.33	2.08	14.58	6.25
Wiesneriomyces javanicus		6.33			12.50	12.50
Zygosporium gibbum					4.17	
Z. minus	4.17					
Oomycota						
Phytophthora sp.	2.08			8.33		
Zygomycota						
Rhizopus sp.[1/]	2.08	4.17				
Total number of species recorded at each stage	**178**	**185**	**158**	**151**	**172**	**138**

Note: [1/] Isolated from dilution plates

* Newly fallen branches, middle stage decaying branches, old decaying fallen branches

Table 4.2 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	*Kirschsteiniothelia* sp. (14.58)	*Bactrodesmium rahmii* (10.42)	*Arthobotryum atrocephalum* (10.42)
(January)	*Lasiodiplodia* cf. *theobromae* (10.42)	*Kirschsteiniothelia* sp. (12.50)	*Bactrodesmium rahmii* (22.92)
	Torula herbarum (16.67)	*Lasiodiplodia* cf. *theobromae* (10.42)	*Dactylella ellipsospora* (10.42)
		Sporidesmium penzigii (14.58)	*Hypoxylon* sp.2 (16.67)
			Kirschsteiniothelia sp. (12.50)
			Lasiodiplodia cf. *theobromae* (10.67)
			Psuedobotrytis terrestris (10.42)
			Rhinocladiella sp. (12.50)
Dry season	*Bactrodesmium rahmii* (12.50)	*Bactrodesmium rahmii* (12.50)	*Acticulospora rhodosporum* (14.58)
(April)	*Diplococcium* sp.2 (10.42)	*Cercospora canescens* (12.50)	*Bactrodesmium rahmii* (25.00)
	Kirschsteiniothelia sp. (20.83)	*Diplococcium* sp.2 (18.75)	*Fusarium* sp.1 (10.42)
	Lasiodiplodia cf. *theobromae* (20.83)	*Kirschsteiniothelia* sp. (18.75)	*Kirschsteiniothelia* sp. (10.42)

Table 4.2 (Continued) 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*
	Nigrospora sphaerica (10.42)	*Lasiodiplodia* cf. *theobromae* (14.58)	*Lasiodiplodia* cf. *theobromae* (22.92)
	Torula herbarum (18.75)	*Nigrospora sphaerica* (18.75)	*Nigrospora sphaerica* (14.58)
		Stigmina murrayae (16.67)	*Paratomenticola lanceolatus* (14.58)
		Sporidesmium rubi (12.50)	*Sporidesmium penzigii* (10.42)
		Tetraploa aristata (12.50)	*S. rubi* (22.95)
		Tricladium fuscum (10.42)	*S. zambiense* (12.95)
		Veronaea carlinae (14.58)	*Veronaea carlinae* (14.58)
		V. coprophila (10.42)	
Early rainy season	*Botryodiplodia* sp. (14.58)	*Actinocladium rhodosporum* (10.42)	*Actinocladium rhodosporum* (18.75)
(July)	*Endophragmia hyalosperma* (10.42)	*Bactrodesmium rahmii* (12.50)	*Lasiodiplodia* cf. *theobromae* (14.58)
	Kirschsteiniothelia sp. (25.00)	*Kirschsteiniothelia* sp. (18.75)	*Kirschsteiniothelia* sp. (10.42)
	Lasiodiplodia cf. *theobromae* (12.50)	*Lasiodiplodia* cf. *theobromae* (14.58)	*Pestalosphaeria hansenii* (10.42)

Table 4.2 (Continued) 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*
	Nigrospora sphaerica (12.50)	*Paratomenticola lanceolatus* (12.50)	
	Paratomenticola lanceolatus (12.50)	*Trichoderma harzianum* (10.42)	
	Pestalotiopsis sydowiana (10.42)	*Veronaea coprophila* (10.42)	
Rainy Season	*Curvularia lunata* (10.42)	*Bactrodesmium rahmii* (12.50)	*Bactrodesmium rahmii* (22.92)
(October)	*Kirschsteiniothelia* sp. (20.83)	*Kirschsteiniothelia* sp. (18.75)	*Curvularia lunata* (14.58)
	Lasiodiplodia cf. *theobromae* (20.83)	*Lasiodiplodia* cf. *theobromae* (18.75)	*Kirschsteiniothelia* sp. (16.67)
	Torula herbarum (10.42)	*Torula herbarum* (16.67)	*Lasiodiplodia* cf. *theobromae* (25.00)
		Veronaea coprophila (18.58)	*Sporidesmium penzigii* (12.50)

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

Table 4.3 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	*Bactrodesmium betulicola* (12.50)	*Acarocybe formosa* (10.42)	*Bactrodesmium rahmii* (12.50)
(January)	*B. rahmii* (12.50)	*Bactrodesmium rahmii* (16.67)	*Cornespora* sp.3 (10.42)
	B. spilomeum (20.83)	*B. spilomeum* (16.67)	*Kirschsteiniothelia* sp. (10.42)
	Botryodiplodia sp. (20.83)	*Bipolaris ellisii* (16.67)	*Lasiodiplodia* cf. *theobromae* (12.50)
	Hypoxylon sp.1 (14.58)	*Botryodiplodia* sp. (22.92)	*Nigrospora sphaerica* (10.42)
	Kirschsteiniothelia sp. (18.75)	*Colletotrichum* sp. (10.42)	*Parasympodiella podocapi* (16.67)
	Nigrospora sphaerica (10.42)	*Hansfordia biophila* (10.42)	*Penicillium* sp.2 (12.50)
	Paratomenticola lanceolatus (18.75)	*Hypoxylon* sp.1 (12.50)	*Pyriculariopsis parasitica* (12.50)
	Pyriculariopsis parasitica (14.58)	*Kirschsteiniothelia* sp. (18.75)	*Torula herbarum* (12.50)
	Torula herbarum (16.67)	*Lasiodiplodia* cf. *theobromae* (12.50)	
	Veronaea coprophila (10.42)	*Nigrospora sphaerica* (10.42)	
		Paratomenticola lanceolatus (12.50)	
		Pestalosphaeria hansenii (12.50)	

Table 4.3 (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*
		Pseudospiropes obclavatus (14.58)	
		Pyriculariopsis parasitica (22.92)	
		Thyridaria sambucina (14.58)	
		Torula herbarum (14.58)	
		Veronaea coprophila (14.58)	
		Wiesneriomyces javanicus (12.50)	
Dry season	*Acarocybe formosa* (16.67)	*Bactrodesmium rahmii* (14.50)	*Acarocybe hansfordii* (10.42)
(April)	*Bactrodesmium betulicola* (12.50)	*Canalisporium caribense* (18.75)	*Acremonium strictum* (10.42)
	B. rahmii (12.50)	*Kirschsteiniothelia* sp. (10.42)	*Bactrodesmium rahmii* (12.50)
	Cylindrocladium parvum (10.42)	*Lasiodiplodia* cf. *theobromae* (10.42)	*Botryodiplodia* sp. (10.42)
	Cylindrotrichum oligospermum (10.42)	*Pestalosphaeria hansenii* (14.58)	*Endophragmia elliptica* (10.42)
	Hypoxylon sp.1 (14.58)	*Septonema fasciculare* (16.67)	*Kirschsteiniothelia* sp. (14.58)

Table 4.3 (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*
	Kirschsteiniothelia sp. (14.58)	*Sporidesmium flagellatum* (12.50)	*Hypoxylon* sp.2 (10.42)
	Lasiodiplodia cf. *theobromae* (25.00)	*Subulispora procuvata* (10.42)	*Lasiodiplodia* cf. *theobromae* (12.50)
	Sporidesmium rubi (12.50)	*Triscelophorus panapensis* (10.42)	*Pyriculariopsis parasitica* (12.50)
	Subulispora procuvata (14.58)	*Veronaea coprophila* (14.58)	*Septonema fasciculare* (14.58)
Early rainy season	*Aspergillus niger* (14.58)	*Acarocybe formosa* (10.42)	*Bactrodesmium rahmii* (12.50)
(July)	*Bactrodesmium betulicola* (16.67)	*Bactrodesmium rahmii* (25.00)	*Cladosporium tenuissimum* (10.42)
	B. rahmii (16.67)	*B. spilomeum* (10.42)	*Hypoxylon* sp.1 (12.50)
	B. spilomeum (25.00)	*Botryodiplodia* sp. (22.92)	*Kirschsteiniothelia* sp. (12.50)
	Botryodiplodia sp. (10.42)	*Curvularia lunata* (16.67)	*Lasiodiplodia* cf. *theobromae* (12.50)
	Cercospora apii (10.42)	*Cylindrotrichum oligospermum* (12.50)	*Nigrospora sphaerica* (12.50)
	Cladosporium tenuissimum (14.58)	*Cladosporium tenuissimum* (16.67)	*Penicillium* sp.3 (12.50)

Table 4.3 (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*
	Fusarium sp.2 (14.58)	*Hypoxylon* sp.1 (10.42)	*Pestalosphaeria hansenii* (12.50)
	Kirschsteiniothelia sp. (16.67)	*Kirschsteiniothelia* sp. (16.67)	*Pyriculariopsis parasitica* (12.50)
	Lasiodiplodia cf. *theobromae* (10.42)	*Lasiodiplodia* cf. *theobromae* (16.67)	*Scolecobasidiella avellanea* (12.50)
	Penicillium sp.1 (20.83)	*Penicillium* sp.1 (12.50)	*Torula herbarum* (10.42)
	Sporoschismopsis sp.1 (10.42)	*Pestalosphaeria hansenii* (16.67)	*Veronaea carlinae* (14.58)
	Veronaea carlinae (20.83)	*Pyriculariopsis parasitica* (16.67)	
		Speiropsis hyalospora (12.50)	
		Sporidesmium flagellatum (16.67)	
		Torula herbarum (16.67)	
		Veronaea coprophila (16.67)	
Rainy season	*Bactrodesmium rahmii* (10.42)	*Acremonium kiliense* (14.58)	*Bactrodesmium rahmii* (10.42)
(October)	*B. spilomeum* (14.58)	*Bactrodesmium rahmii* (16.67)	*Botryodiplodia* sp. (16.67)

Table 4.3 (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*
	Botryodiplodia sp. (20.83)	*B. spilomeum* (10.42)	*Hypoxylon* sp.1 (12.50)
	Hypoxylon sp.1 (14.58)	*Botryodiplodia* sp. (25.00)	*Kirschsteiniothelia* sp. (12.50)
	Kirschsteiniothelia sp. (10.42)	*Kirschsteiniothelia* sp. (12.50)	*Pyriculariopsis parasitica* (10.42)
	Pseudospiropes obculavatus (10.42)	*Nigrospora sphaerica* (10.42)	*Sporidesmium flagellatum* (12.50)
	Trichoderma sp.3 (12.50)	*Penicillium* sp.1 (14.58)	*Veronaea carlinae* (10.42)
		Penicillium sp.2 (10.42)	
		Pestalosphaeria hansenii (14.58)	
		Pyriculariopsis parasitica (16.67)	
		Sporidesmium flagellatum (18.75)	
		Sporoschismopsis sp.1 (12.50)	
		Stenella pithecellobii (10.42)	

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

Table 4.4 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*	178	0.9876	4.7256	151	0.9893	4.6684
Middle*	185	0.9885	4.7282	172	0.9896	4.7911
Old*	158	0.9871	4.6689	138	0.9892	4.3857

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

Table 4.5 Sorensen's similarity indices 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*		0.4654	0.4012		0.5031	0.4931
Middle*			0.4898			0.5161
Old*						

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

Table 4.6 Diversity indices of saprobic fungi on branch litter of rubber (*Hevea brasiliensis*) 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	Index
	New*	Middle*	Old*		D	H
Nakhon Si Thammarat						
Late rainy season	77	85	76	238	0.9955	5.2694
Dry season	97	104	88	289	0.9957	5.2816
Early rainy season	83	90	69	242	0.9955	5.2816
Rainy season	68	71	54	193	0.9839	5.0482
Songkhla						
Late rainy season	91	109	88	288	0.9961	5.4481
Dry season	101	110	88	299	0.9962	5.5510
Early rainy season	94	108	92	294	0.9958	5.4435
Rainy season	74	75	62	211	0.9945	5.1247

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

Table 4.7 Sorensen's similarity indices of fungi associated with branch litter of rubber (*Hevea brasiliensis*) versus seasons: 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		0.4111	0.4033	0.3308		0.4252	0.4589	0.3976
Dry season			0.4369	0.4199			0.5000	0.4240
Early rainy season				0.4312				0.4286
Rainy season								

4.4 Discussion

4.4.1 Fungal recorded from branch litter

The advantages of using more than one technique to study the fungi were highlighted by Shanthi and Vittal (2010a). 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 (Shanthi and Vittal, 2010a). 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 (Shanthi and Vittal, 2010a). 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 fungi communities present (Huhndorf *et al*., 2004). In this study, all fruiting bodies were found on branch litter are shown in Chapter 6.

4.4.2 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 slightly higher than on leaf litter. Five hundred and eighteen taxa (503 microfungi and 15 macrofungi) were found on leaf litter, whereas 520 taxa (450 microfungi and 70 macrofungi) were found on branch 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 and Shearer, 1988; Abdullah and 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 and 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 and 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 higher 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 450 species, which is high when compared with other studies of fungi on branch litter. For instance, Allmér (2005) found 58 taxa of 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 and Paltto, 2001; Küffer *et al*., 2004; Küffer and 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).

4.4.3 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 and Deshappriya, 2005; Osono, 2005; Paulus *et al*., 2006; Duong *et al*., 2008; Thongkantha *et al*., 2008; Kodsueb *et al*., 2008b; Seephueak *et al*., 2011). 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 (Tan *et al*., 1989; Maria and 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 and 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. Basidiomycetes 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 and Berg, 1987; Deacon, 1997).

4.4.4 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 and Hyde, 2001). Generally, different plant species have different chemical compositions and this may affect the microbial communities and biomass (Boddy and Watkinson, 1995; Mille-Lindblom *et al*., 2006). Zhou and 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 and 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 dependent 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 and Watkinson, 1995; Lodge, 1997).

4.4.5 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 (Kennedy *et al*., 2006). Nikolcheva and 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 and 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 the 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 and 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).

CHAPTER 5

DIVERSITY OF SAPROBIC FUNGI ON DECAYING RUBBER LOGS (*HEVEA BRASILIENSIS*)

5.1 Introduction

Deadwoodology, the ecology of deadwood, is a research area where wood decay fungi play a major role (Grove, 2002; Glaseser and Smith, 2010). 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 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 and 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 fungal diversity on terrestrial wood in temperate regions such as in coniferous forests (Lambert *et al*., 1980; Sollins *et al*., 1987; Krankina and Harmon, 1995; Temnuhin, 1996; Yin, 1999; Krankina *et al*., 1999; Harmon and Knudsen, 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 up 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 and 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.

In this chapter the focus is on fungi on fallen logs of *H. brasiliensis* ($\geq$ 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 decaying fallen logs, and to evaluate the fungal communities involved in log decay at each stage.

5.2 Materials and Methods

Log samples were collected at four periods in 2010: January, April, July and October. Each sample was classified based on degree of decomposition and external appearance. The 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).

5.2.1 Sampling design

Collections of rubber wood logs were made at two sites in a 25-year-old rubber plantation in Nakhon Si Thammarat and Songkhla Provinces. Three plots were distributed on a grid system of 200 × 200 m and site study was conducted of 50 x 50 m. The decomposition study involved collection 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 26.6-27.6ºC. The rainfall was between 68.3 mm and 175.4 mm. The second collection was made during April, in the dry season when the temperature ranged from 29.7-29.8ºC and no rainfall was recorded. The third collection was in July which is in the early rainy season and the temperature range was 27.9-28.2ºC and the rainfall was 115.5-132.0 mm. The fourth collection was in October which is in the rainy season, the temperature range was 27.1-27.8ºC. The rainfall was 272.2-399.0 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.

5.2.2 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 identified, 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 and Hunter, 1972; Ainsworth *et al*., 1973; Ramirez, 1982; Domsch and Gams, 1980; Ellis and Ellis, 1997; Kubicek and Harman, 1998; Kiffer and Morelet, 1999; Hyde *et al*., 2000; Tsui and Hyde, 2003; Wu and Zhuang, 2005; Cai *et al*., 2006).

5.2.3 Incubation, observation and isolation of fungi

Logs at each stage of decomposition were collected from the two locations. Moist chamber and dilution pour-plate techniques were used to study the fungi. In the moist chamber technique, all logs were cut into 5 cm long sections, in diameter $\geq$ 10 cm with bark for observation and incubated in moistened plastic boxes at room temperature (28-32^{o}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 x 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^{o}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. Identification is based on morphological study involving examination under stereo and compound microscopes. For the sporocarp survey, the fruiting bodies visible at the surface were examined and the results are shown in Chapter 6.

5.2.4 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) x 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 = $-\sum$PilnPi, 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 fall between 1 and 6. Simpson's index D = 1 - $\sum[n_i/ (n_i - 1) / N/ (N - 1)]$, where n_i is the number of individuals of species 1 and N = total number of species in community. 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).

5.3 Results

5.3.1 Taxonomic composition

There were clear differences in the species composition and richness detected in the two methods used to examine the fungal communities on rubber logs. Out of a total of 422 species recorded, 403 fungal taxa (95.50%) were found by moist chamber technique and 19 fungal taxa (4.50%) from using the dilution plate technique. Examination of decaying logs of *H. brasiliensis* RRIM 600 variety at three stages of decomposition yielded 422 fungal taxa, comprising 384 anamorphic taxa and 38 ascomycetes (Table 5.1).

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 227 species were found in newly fallen logs, 250 species in middle stage decaying logs and 219 species in old decaying fallen logs. In both areas, it was found that 47 species (34.18%) were overlapping in newly fallen logs, 70 species (43.75%) were overlapping in middle stage decaying logs and 50 species (37.45%) were overlapping in old decaying fallen logs.

The 284 fungal taxa found in Nakhon Si Thammarat Province included 255 anamorphic taxa and 29 ascomycetes. One hundred and thirty-three taxa were recorded from newly fallen logs, 157 from middle stage decaying logs and 128 species from old decaying fallen logs.

In Songkhla Province, 278 fungal taxa were found including 255 anamorphic taxa and 23 ascomycetes. One hundred and forty-two taxa were recorded from newly fallen logs, 163 from middle stage decaying logs and 140 taxa from old decaying fallen logs. The list of taxa from each stage and their dominant fungi with over 10% occurrences is shown in Table 5.1.

Twenty-one 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, *Hypoxylon* sp.1, *Hypoxylon* sp.2*, Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Pestalotiopsis* sp.1, *Scolecobasidiella avellanea, Sporidesmium flagellatum, Torula herbarum, Trichoderma atroviride, T. harzianum, Veronaea coprophila* and *V. carlinae.* Fourty-one taxa were found in all stages of decomposition in Nakhon Si Thammarat Province. In addition, 50 taxa were found at all stages of decomposition in Songkhla Province.

5.3.2 Species richness and dominant fungi

The taxa and their percentage occurrence are listed in Table 5.1. Anamorphic fungi (384 taxa) were the dominant group, followed by ascomycetes (38 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 Tables 5.2 and 5.3.

The number of dominant taxa 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 (Table 5.2). 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 (Table 5.3).

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

5.3.3 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 was found on middle stage decaying logs in Nakhon Si Thammarat Province was 157 taxa, 133 taxa were found on the newly fallen logs and 128 taxa were 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, 163 taxa were found on the middle stage decaying logs, 142 taxa were found on newly fallen logs and 140 taxa were found on the old decaying fallen logs (Table 5.4).

The similarity of fungal communities associated with rubber logs at each different stage of decay was the most similar during the middle and old stage (44.21% in Nakhon Si Thammarat Province, 50.17% in Songkhla Province). The newly fallen logs and the old decaying fallen logs were the least similar (39.69% in Nakhon Si Thammarat Province, 44.52% in Songkhla Province) (Table 5.5).

4.3.4 Fungal communities in different seasons

The results for the fungal taxa found in Nakhon Si Thammarat Province were that 268 taxa were recorded during the dry season, 253, 240 and 190 taxa during the late rainy season, early rainy season, and rainy season, respectively (Table 5.6). 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 eighty-eight fungal taxa were recorded in the dry season, 280, 250 and 199 taxa were recorded during the late rainy season, early rainy season and rainy season, respectively (Table 5.6).

The similarity of fungi associated with rubber logs during the different seasons was investigated. The most similar fungi were found during the early rainy season and during the dry season (50.98% in Nakhon Si Thammarat Province, 45.61% in Songkhla Province) and during the late rainy season and during the rainy season were the least similar fungi (35.75% in Nakhon Si Thammarat Province, 38.66% in Songkhla Province) (Table 5.7).

Table 5.1 Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages 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
Chaetomium sp.			2.08			
Claussenomyces atrovirens	16.67				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
Glomerella cingulata		4.17			2.08	
Hyphodiscosia sp.		6.25				
Hypocrea rufa					6.25	
Hypoderma sp.		2.08				
Hypomyces sp.						2.08
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				
H. 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

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Leptosphaeria blumeri			4.17			
L. 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				
L. 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					
X. arbuscula		8.33				
Mitosporic fungi						
Acarocybe formosa				35.42	14.58	6.25
A. hansfordii				18.75	8.33	8.33
Acarocybella jasminicola				8.33		
Acladium curtisii	4.17					
Acremoniula sp.				2.08		
A. fagi	4.17	2.08				

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Acremonium sp.1	8.33		2.08			
Acremonium sp.2	2.08					
Acremonium sp.3				6.25	20.83	6.25
A. alternatum					6.25	
A. butyri		12.50		16.67	8.33	4.17
A. cerealis	8.33	12.50				
A. fusidioides	2.08	16.67	10.42	10.42	16.67	
A. kiliense	8.33	6.25		16.67	6.25	12.50
A. murorum					8.33	
A. rutilum	14.58		4.17			
A. strictum		6.25	12.50		12.50	
Actinocladium rhodosporum	4.17	10.42	14.58		14.58	8.33
Alternaria dennisii		2.08				
A. tenuissimum		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
A. muelleri	2.08				2.08	
A. paeospermum			2.08			
Articulospora tetracladia	8.33		2.08			
Aspergillus sp.1[1/]	4.17	4.17	4.17	18.75	12.50	8.33

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Aspergillus sp.2	4.17	4.17	4.17	10.42	6.25	16.67
Aspergillus sp.3[1/]	4.17	4.17	4.17	8.33	4.17	
Aspergillus sp.4[1/]	2.08	2.08	2.08	4.17	12.50	
Aspergillus sp.5	2.08		2.08			
Aspergillus sp.6	2.08		2.08			
A. japonigum				14.58		
A. niger				8.33		
Bachysporium masonii		18.75				
Bactrodesmiella masonii		2.08		6.25	4.17	
Bactrodesmium betulicola				50.00		12.50
B. longisporum		6.25				
B. masonii						14.58
B. pallidum		25.00		4.17	4.17	18.75
B. rahmii	87.50	77.08	41.67	45.83	58.33	41.67
B. spilomeum		31.25	20.83	50.00	45.83	16.67
B. traversianum	25.00	10.42				
Bahusakala cookei						12.50
Beltraniella fertilis					4.17	8.33
B. odinae						2.08
Berkleasmium cf. *minutissimum*					6.25	14.58
B. concinnum					8.33	8.33
B. grandisporus					6.25	
B. leonense					2.08	

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Bidenticula cannae		6.25		4.17	2.08	
Bipolaris sp.1		6.25	10.42	8.33		4.17
Bipolaris sp.2				6.25		
B. australiensis		10.42				
B. biseptata					6.25	
B. cactivora				8.33		6.25
B. frumentacei		6.25				
B. indica					4.17	
B. japonica					2.08	
B. miyakei				4.17		
B. ravenelii	8.33					8.33
B. rostrata	4.17					
B. sacchari				4.17		
Bispora antennata	6.25			4.17		
B. catenula				2.08		
Botryodiplodia sp.	39.58	47.92	14.58	56.25	35.42	25.00
B. 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	
B. laxa						2.08
B. turbinata	2.08					6.25
Brachysporium bloxami					4.17	

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
B. nigrum				4.17		
Calospora patanoides		4.17	8.33		4.17	
Camarosporium rosea						12.50
Camposporium antennatum			2.08	6.25		
C. 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			
C. novae-zalandiae	4.17					
Cercospora sp.	8.33			4.17	4.17	
C. elaeidis		4.17	10.42	14.58		
C. justiciicola		8.33				
C. malayensis	2.08					
Chaetochalara bulbosa					2.08	
Chalara sp.	4.17				6.25	
C. elegans		4.17				
Chalaropsis sp.					2.08	
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	

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Cladosporium sp.2		12.50			12.50	
Cladosporium sp.3		6.25				
Cladosporium sp.4		6.25				
C. acaciicola				8.33		
C. balladynae			2.08			
C. britannicum		2.08				
C. diaphanum				2.08		
C. elatum[1/]		6.25		10.42	12.50	
C. fulvum	6.25					
C. gynoxidicola	8.33					
C. orchidis	6.25		2.08			
C. psoraleae[1/]					2.08	
C. taurophorum			2.08			
C. tenuissimum	4.17	16.67	4.17	18.75	10.42	25.00
Clasterosporium cocoicola		16.67				
C. pistaciae						10.42
Colletotrichum sp.[1/]				4.17		
C. gloeosporioides		2.08				
Codinaea sp.1	6.25					6.25
C. hughesii	4.17					
Cordana pauciseptata						4.17
Coronospora dendrocalami						4.17

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Corynespora sp.		4.17				
C. combreti		8.33				
C. foveolata	4.17	25.00				
C. kamatii			18.75			
C. trichiliae			6.25			
Corynesporopsis quereicola	8.33					
Curvularia sp.				6.25		2.08
C. affinis					4.17	
C. eragrostidis					4.17	
C. geniculata	2.08			2.08		
C. inaequalis			14.58			
C. lunata[1/]	12.50	6.25	2.08	8.33		14.58
C. pallescens			4.17	4.17	10.42	
C. trifolii						2.08
Cylindrocladium sp.					4.17	
C. 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
D. hyalina	14.58	2.08	4.17	8.33	4.17	6.25
D. junci	6.25			4.17	4.17	8.33
Dactylella sp.						6.25
D. aquatica		4.17	4.17			8.33
D. ellipsospora	4.17	2.08	2.08			4.17

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Dendryphiopsis arbuscula			25.00			
Dictyosporium sp.				2.08		6.25
D. elegans						6.25
D. giganticum				2.08		
D. manglieliae	12.50			10.42	8.33	12.50
Diplococcium sp.1	12.50					
D. clarkii					16.67	
D. 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
E. vaginata	4.17			10.42	6.25	8.33
Ellisiopsis gallesiae					2.08	2.08
Endophragmia bisbyi				8.33		
E. boewei					6.25	
E. brevis	20.83					
E. cesatii					6.25	
E. elliptica				2.08		
E. hyalosperma			4.17			
Endophragmiella sp.						8.33
E. cambrensis				4.17		

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Entomosporium sp.		2.08				
Excipularia narsapurensis			18.75			
Exosporiella fungorum					2.08	
Exosporium sp.						4.17
E. ramosum		6.25				20.83
Fulvia berkheyae				2.08	4.17	4.17
Fusariella sp.		6.25	10.42			
F. concinna				8.33		
F. 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
F. chlamydosporum				8.33		
F. moniliforme				4.17	2.08	6.25
F. oxysporum[1/]		8.32		12.50		
F. semitectum			2.08		6.25	
Gliomastix murorum			2.08			
G. vegetum					6.25	
Gonatophragmium mangiferae				2.08		
Graphium calicioides	8.33					
Hansfordia biophila					2.08	4.17
H. nebularis			12.50			
H. ovalispora					6.25	4.17

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Helicoma dennisii						2.08
H. mulleri		2.08				
Helicomyces roseum		2.08		8.33	6.25	
H. scandens	4.17					
Helicoon auratum			2.08			
Helicosporium sp.	2.08					
H. aureum		2.08	6.25	2.08		
H. elatum			2.08			
H. vegetum					10.42	4.17
Helicostylum piriforme		2.08				
Helminthosporium acaciae		8.33				
H. velutinum		6.25				
Hemibeltrania cinnamomi					4.17	
Hemicorynespora deightonii			2.08			
H. 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				

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
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		
M. manitobaensis	2.08	10.42	2.08			
Molowia basicola						2.08
Monacrosporium sp.			4.17			
M. 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.[1/]	8.33			6.25	8.34	4.17
P. 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

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Penicillium sp.1[1/]	6.25	8.33		27.08	25.00	10.42
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[1/]	8.33	6.25	10.42	6.25	4.17	4.17
Pestalotiopsis sp.2[1/]	8.33		4.17			6.24
P. disseminata[1/]	6.25				4.17	
P. sydowiana			4.17			
Phaeoisaria sparsa		2.08				2.08
Phaeoisariopsis cercosporioides				8.33	16.67	6.25
Phaeoramularia leeae						20.83
P. 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			
P. simplex				8.33		
P. tritici			2.08			

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Pleurotheciopsis pusilla				6.25		
Polyscytalina grisea					8.33	
Pseudobeltrania cedrelae	4.17				4.17	
P. macrospora	8.33					
Pseudobotrytis terrestris	8.33					6.25
Pseudocercospora terminaliae	2.08					
P. helleri	2.08					
Pseudospiropes sp.					4.17	
P. hughesii		2.08		12.50	18.75	14.58
P. 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				
S. arenarium	12.50					
S. compactum	8.33					20.83
S. salinum				18.75		2.08
Scutellinia scutellata	4.17					
Septonema fasciculare	4.17	6.25	14.58		18.75	12.50
S. secedens				12.50		

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Sirosporium antenniforme				4.17		
S. carissae					4.17	
S. mori						6.25
Spadicoides afzeliae					27.08	
Spegazzinia lobulata						18.75
S. sundara			2.08			
Spiropes sp.						8.33
S. capensis		4.17				
Speiropsis hyalospora	4.17				6.25	2.08
S. pecatospora	29.17					
Spondylocladiella botrytioides	14.58			10.42		8.33
Sporidesmium sp.1	4.17	16.67				
Sporidesmium sp.2					6.25	
S. australiense	6.25	6.25				
S. bambusicola	2.08					
S. bonarii		25.00				
S. cladii	12.50					
S. dioscoreae				25.00		
S. ehrenbergii				14.58	12.50	
S. flagellatum	66.67	27.08	66.67	6.25	16.67	25.00
S. folliculatum		6.25				
S. fusiforme	8.33					
S. ghanaense				8.33		

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. harknesii	39.58	22.92	33.33			
S. hormiscioides	10.42					
S. jaipurensis			6.25			
S. jasminicola		14.58		10.42	18.75	12.50
S. larvatum		22.92	16.67			
S. leptosporum			14.58			20.83
S. longirostratum	35.42			8.33		6.25
S. obclavatum		14.58				
S. paludosum		2.08				
S. penzigii	20.83	14.58				8.33
S. raphiae						6.25
S. rubi		10.42			8.33	
S. 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		
S. coccosporum			10.42		4.17	
Stemphyliomma valparadisiacum		4.17				
Stenella pithecellobii			6.25	2.08	8.33	
Stigmina celata					4.17	2.08
S. crotonicola		6.25				
S. fici	6.25					

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
S. hartigiana		6.25	8.33			
S. kranzii	8.33					
S. murrayae		6.25				
S. rauvolfiae	6.25					
S. sapii					4.17	
S. thermopsidis		8.33				
S. triumfettae	8.33					
Subulispora sp.					6.25	
S. procurvuta	8.33					4.17
Sympodiella acicola		6.25				
Taeniolella sp.	10.42					
T. alta				4.17		
T. breviuscula		25.00		6.25		
T. exilis				8.33		
T. 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 sp.	4.17	4.17	2.08		6.25	12.50
T. asterinearum		4.17	4.17			2.08
Tomenticola trematis						14.58
Torula sp.	6.25			6.25	10.42	
T. ellisii					6.25	4.17

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
T. herbarum	12.50	4.17	39.58	25.00	20.83	16.67
Triadelphia heterospora		4.17				6.25
T. inquinans					2.08	
Trichoderma sp.1[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	
T. atroviride[1/]	14.58	12.50	14.58	4.17	8.33	14.58
T. aureoviride[1/]	16.67	8.33	14.58	4.17	2.08	
T. hamatum[1/]				4.17	12.50	
T. harzianum[1/]	10.42	27.08	8.33	8.33	2.08	14.58
T. virens[1/]	8.33			4.17	8.33	
T. viride[1/]		8.33	2.08		2.08	8.33
Trichothecium sp.		10.42				
Tricladium sp.				2.08	8.33	
T. fuscum	4.17		2.08		2.08	
Tridentaria implicans		2.08				
Trimmatostroma betulinum			6.25	2.08		
T. 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	

Table 5.1 (Continued) Occurrence (%) of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of composition collected from Nakhon Si Thammarat and Songkhla Provinces

Taxa	Location					
	Nakhon Si Thammarat			Songkhla		
	New*	Middle*	Old*	New*	Middle*	Old*
Veronaea apiculata			4.17			
V. carlinae	14.58	8.33	16.67	4.17	16.67	18.75
V. coprophila	22.92	12.50	14.58	10.42	14.58	12.50
V. musae			12.50	2.08		2.08
V. 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
X. 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	**133**	**157**	**128**	**142**	**163**	**140**

Note: [1/]Isolated from dilution plates

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

Table 5.2 Dominant fungi (over 10% occurrence) on rubber logs (*Hevea brasiliensis*) at each stage of decomposition and each season in Nakhon Si Thammarat Province

Season	Decomposition stage		
	New*	Middle*	Old*
Late rainy season	*Bactrodesmium rahmii* (25.00)	*Annellophora solani* (10.42)	*Aplosporella* sp. (12.50)
(January)	*Botryodiplodia* sp. (12.50)	*Bactrodesmium rahmii* (20.83)	*Hypoxylon* sp.1 (12.50)
	Hypoxylon sp.1 (16.67)	*Botryodiplodia* sp. (16.67)	*Lasiodiplodia* cf. *theobromae* (12.50)
	Sporidesmium flagellatum (10.42)	*Cladosporium tenuissimum* (10.42)	*Paratomenticola lanceolatus* (12.50)
	S. longirostratum (10.42)	*Clasterosporium cocoicola* (10.42)	*Pleuophragmium acutum* (10.42)
	Veronaea coprophila (14.58)	*Corynespora foveolata* (12.50)	*Scolecobasidiella avellanea* (10.42)
		Hypoxylon sp.1 (12.50)	*Sporidesmium flagellatum* (14.58)
		Lasiodiplodia cf. *theobromae* (18.75)	*Torula herbarum* (14.58)
Dry season	*Bactrodesmium rahmii* (18.75)	*Annellophorella ziziphi* (10.42)	*Kirschsteiniothelia* sp. (14.58)
(April)	*Botryodiplodia* sp. (12.50)	*Bactrodesmium rahmii* (18.75)	*Paratrichoconis chinensis* (12.50)
	Curvularia lunata (10.42)	*B. spilomeum* (12.50)	*Sporidesmium flagellatum* (12.50)
	Diploccocium spicatum (10.42)	*Botryodiplodia* sp. (12.50)	*Torula herbarum* (14.58)

Table 5.2 (Continued) Dominant fungi (over 10% occurrence) on rubber logs (*Hevea brasiliensis*) at each stage of decomposition and each season in Nakhon Si Thammarat Province

Season	Decomposition stage		
	New*	Middle*	Old*
	Hypoxylon sp.1 (12.50)	*Hypoxylon* sp.1 (10.42)	
	Kirschsteiniothelia sp. (22.92)	*Hypoxylon* sp.3 (10.42)	
	Lasiodiplodia cf. *theobromae* (12.50)	*Lasiodiplodia* cf. *theobromae* (16.67)	
	Sporidesmium flagellatum (14.58)	*Pestalosphaeria hansenii* (10.42)	
	S. harknesii (12.50)	*Paratomenticola lanceolatus* (10.42)	
Early rainy season	*Bactrodesmium rahmii* (22.92)	*Acremonium fusidioides* (12.50)	*Bactrodesmium rahmii* (14.58)
(July)	*Lasiodiplodia* cf. *theobromae* (10.42)	*Bactrodesmium rahmii* (20.83)	*Nigrospora sphaerica* (14.58)
	Nigrospora sphaerica (10.42)	*B. spilomeum* (10.42)	*Paratomenticola lanceolatus* (16.67)
	Sporidesmium harknesii (10.42)	*Botryodiplodia* sp. (12.50)	*Scolecobasidiella avellanea* (12.50)
	S. longirostratum (10.42)	*Lasiodiplodia* cf. *theobromae* (18.75)	*Sporidesmium harknesii* (12.50)
	S. flagellatum (22.92)	*Paratomenticola lanceolatus* (10.42)	*S. leptosporum* (12.50)
		Scolecobasidium acanthacearum (10.42)	*S. flagellatum* (18.75)
		Sporidesmium larvatum (10.42)	

Table 5.2 (Continued) Dominant fungi (over 10% occurrence) on rubber logs (*Hevea brasiliensis*) at each stage of decomposition and each season in Nakhon Si Thammarat Province

Season	Decomposition stage		
	New*	Middle*	Old*
Rainy season	*Bactrodesmium rahmii* (20.83)	*Bactrodesmium rahmii* (16.67)	*Bactrodesmium rahmii* (14.58)
(October)	*Kirschsteiniothelia* sp. (10.42)	*Sporidesmium flagellatum* (16.67)	*Hypoxylon* sp.1 (10.42)
	Sporidesmium flagellatum (18.75)		*Kirschsteiniothelia* sp. (14.58)
	S. harknesii (10.42)		*Paratomenticola lanceolatus* (12.50)
			Sporidesmium flagellatum (20.83)
			Thyridaria sambucina (10.42)

Note: * Newly fallen logs, middle stage decaying logs, old decaying fallen logs

Table 5.3 Dominant fungi (over 10% occurrence) on rubber logs (*Hevea brasiliensis*) at each stage of decomposition and each season in Songkhla Province

Season	Decomposition stage		
	New*	Middle*	Old*
Late rainy season	*Acarocybe Formosa* (16.67)	*Bactrodesmium rahmii* (16.67)	*Bactrodesmium rahmii* (10.42)
(January)	*A. hansfordii* (12.50)	*B. spilomeum* (14.58)	
	Bactrodesmium betulicola (14.58)	*Diploccocium clarkia* (10.42)	
	B. rahmii (10.42)	*Hypoxylon cohaerens* (10.42)	
	B. spilomeum (18.75)	*Kirschsteiniothelia* sp. (14.58)	
	Botryodiplodia sp. (18.75)	*Lasiodiplodia* cf. *theobromae* (20.83)	
	Kirschsteiniothelia sp. (10.42)	*Phaeoramularia marmorata* (18.75)	
	Lasiodiplodia cf. *theobromae* (18.75)	*Phaeoisariopsis cercosporioides* (10.42)	
	Pestalosphaeria hansenii (10.42)	*Pseudospiropes hughesii* (12.50)	
	Phaeoramularia marmorata (12.50)	*Sclecobasidiella avellanea* (10.42)	
	Staphylotrichum sp. (10.42)	*Spadicoides afzeliae* (14.58)	
		Torula herbarum (10.42)	

Table 5.3 (Continued) Dominant fungi (over 10% occurrence) on rubber logs (*Hevea brasiliensis*) at each stage of decomposition and each season in Songkhla Province

Season	Decomposition stage		
	New*	Middle*	Old*
Dry season	*Aspergillus* sp.1 (10.42)	*Bactrodesmium rahmii* (12.50)	*Bactrodesmium rahmii* (10.42)
(April)	*Bactrodesmium rahmii* (10.42)	*Bactrodesmium spilomeum* (12.50)	
	Cladosporium tenuissimum (14.58)	*Hypoxylon cohaerens* (12.50)	
	Nigrospora sphaerica (12.50)	*Kirschsteiniothelia* sp. (18.75)	
	Penicillium sp.1 (16.67)	*Lasiodiplodia* cf. *theobromae* (18.75)	
	Sporoschismopsis sp.2 (10.42)	*Nigrospora sphaerica* (12.50)	
		Penicillium sp.1 (12.50)	
		Phaeoramularia marmorata (16.67)	
		Spadicoides afzeliae (10.42)	
Early rainy season	*Acremonium butyric* (10.42)	*Bactrodesmium rahmii* (16.67)	*Bactrodesmium rahmii* (12.50)
(July)	*Bactrodesmium betulicola* (16.67)	*B. spilomeum* (10.42)	
	B. rahmii (20.83)		
	B. spilomeum (14.58)		
	Botryodiplodia sp. (14.58)		

Table 5.3 (Continued) Dominant fungi (over 10% occurrence) on rubber logs (*Hevea brasiliensis*) at each stage of decomposition and each season in Songkhla Province

Season	Decomposition stage		
	New*	Middle*	Old*
	Pyriculariopsis parasitica (10.42)		
	Sporoschismopsis sp.2 (27.08)		
	Torula herbarum (10.42)		
Rainy season	*Bactrodesmium betulicola* (12.50)	*Bactrodesmium rahmii* (14.58)	*Bactrodesmium rahmii* (10.42)
(October)	*Botryodiplodia* sp. (14.56)	*Botryodiplodia* sp. (12.50)	
	Kirschsteiniothelia sp. (14.58)	*Phaeroramularia marmorata* (14.58)	
		Sporoschismopsis sp.2 (10.42)	

Note: * Newly fallen logs, middle stage decaying logs, old decaying fallen logs

Table 5.4 Diversity indices of saprobic fungi on wood logs 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*	133	0.9840	4.6498	142	0.9872	4.6185
Middle*	157	0.9880	4.6516	163	0.9901	4.6768
Old*	128	0.9839	4.3949	140	0.9870	4.5685

Note: * Newly fallen logs, middle stage decaying logs, old decaying fallen logs

Table 5.5 Sorensen's similarity indices of fungi on wood logs of rubber (*Hevea brasiliensis*) at different stages of decomposition

Decomposition stage	Location					
	Nakhon Si Thammarat			Songkhla		
	New	Middle	Old	New	Middle	Old
New*		0.4055	0.3969		0.4967	0.4452
Middle*			0.4421			0.5017
Old*						

Note: * Newly fallen logs, middle stage decaying logs, old decaying fallen logs

Table 5.6 Diversity indices of saprobic fungi on wood logs of rubber (*Hevea brasiliensis*) 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	83	100	70	253	0.9954	5.3106
Dry season	87	104	77	268	0.9958	5.3580
Early rainy season	74	94	72	240	0.9950	5.2333
Rainy season	59	74	57	190	0.9934	4.9711
Songkhla						
Late rainy season	93	95	92	280	0.9960	5.3951
Dry season	96	100	92	288	0.9963	5.4216
Early rainy season	84	87	79	250	0.9952	5.2292
Rainy season	70	73	56	199	0.9949	5.0328

Note: * Newly fallen logs, middle stage decaying logs, old decaying fallen logs

Table 5.7 Sorensen's similarity indices of fungi associated with wood logs of rubber (*Hevea brasiliensis*) versus seasons : 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		0.5087	0.4073	0.3575		0.4405	0.4221	0.3866
Dry season			0.5098	0.4158			0.4561	0.4412
Early rainy season				0.4149				0.4286
Rainy season								

5.4 Discussion

5.4.1 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*. (2004a) and Kodsueb (2007). However, information of terrestrial lignicolous fungi is still poorly understood and need further study. Most studies of 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 422 species. The present study demonstrated a rich fungal diversity compared to that previously reported fungi on decaying terrestrial wood logs. For instance, Huhndorf and Lodge (1997) found 157 taxa; Crites and Dale (1998): 19 taxa; Nordén and Paltto (2001): 140 taxa; Schmit (2005): 207 taxa; Küffer *et al*. (2008): 59 taxa; Ódor *et al*. (2006): 161 taxa and Iršénaité and Kutorga (2006): 203 taxa. In addition, when compared to the fungi on submerged wood; Tan *et al.* (1989) found 20 taxa; Ho (1998): 222 taxa; Tsui (1999): 300 taxa; Sivichai *et al.* (2002): 58 taxa; Ho *et al.* (2002): 155 taxa; Maria and Shidhar (2004): 37 taxa and Van Ryckegem and 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. Thirty-eight ascomycetes were recorded including, 20 taxa found on newly fallen logs, 23 taxa found in middle stage decaying logs and 20 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 (Seephueak *et al*., 2010) and branch litter 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 and Shearer, 1988; Abdullah and 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 and Hyde, 2001).

This is similar to the succession studies on rubber wood logs as according to Küffer *et al.* (2008), Schmit (2005), Heilmann-Clausen and Christensen (2003). The studies of fungal succession on wood logs showed 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 or the impoverished community, when the diversity and number of taxa decrease. Heilmann-Clausen and Christensen (2003) explained that, logs in intermediate stage 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.

In this study, two methodologies were used to study fungal diversity on fallen rubber logs; a moist chamber technique and a dilution pour-plate technique. Four hundred and three fungal taxa were recorded from the moist chamber technique and 19 taxa recorded from dilution pour-plate. For the sporocarp survey, the results (48 taxa) are shown in Chapter 6. In this study, the moist chamber is one of the best techniques for revealing fungi on fallen logs according to previous studies (Huhndorf and Lodge, 1997; Crites and Dale, 1998; Kodsueb, 2007).

5.4.2 Wood log size and decomposition stage

Previous studies defined three woody debris categories: coarse woody debris, CWD ($\geq$ 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 ($\geq$ 10 cm diameter). The assumption is the large woody debris and small woody debris support different fungal communities. In this study, five hundred and twenty fungal taxa (450 microfungi and 70 macrofungi) were recorded on branch litter, while 470 fungal taxa (422 microfungi and 48 macrofungi) 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 and 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 and 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 and Christensen, 2003). However, the importance of large logs for maintenance of a defined set of specialised species is largely recognized (Heilmann-Clausen and Christensen, 2004).

5.4.3 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 considerable 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 elegans* 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 and 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 and 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 (Kennedy *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 and Todd (1979), Kodsueb *et al.* (2007) and Seephueak *et al.* (2010; 2011) reported that there was a greater variety and number of fungi during the dry season. Nikolcheva and 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 used 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 422 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 *et al*., 2010) to estimate species numbers.

CHAPTER 6

DIVERSITY OF MACROFUNGI ON SOIL AND LITTER IN RUBBER PLANTATION HABITAT

6.1 Introduction

Saprobic fungi are an essential group of organisms in rubber plantation ecosystems as they are the main decomposers of litter and wood. They are responsible for a large part of the heterotrophic respiration in plantation ecosystem. Wood degrading fungi have a range of catabolic enzymes that enable them to utilize wood as an energy and nutrient source (Rayner and Boddy, 1988). Leaf litter, branch litter and wood logs of rubber tree (*H. brasiliensis*) are significant process of nutrient cycling in rubber plantation, playing a major role in the transfer of energy and nutrient. It is now well established that the decomposition of plantation litter on the soil surface is brought about by variety of microorganisms including insects, bacteria and fungi. Among the microbes, fungi are regarded as efficient decomposers of organic matter, especially plant litter (Shanthi and Vittal, 2010a). Saprobic litter fungi contribute substantially to these processes because fine litter production represents the bulk of the input of biomass to the decomposition system in tropical region. Resource distribution in time and space strongly influence the activity of litter fungi, as different species have different degrees of resource selectivity, either taxon-selectivity or component-selectivity (Rayner *et al*., 1985). The resource represents both the substratum and the source of organic nutrients for these fungi, and its durability affect directly mycelia longevity. The fast rate of decomposition of fine litter on the ground in tropical region necessitates rapid colonization of newer resources (Hedger, 1985).

There are three basic types of wood decay; white rot, brown rot and soft rot (Cooke and Rayner, 1984) by having both lignolytic and cellulolytic enzymes. White rot fungi are capable of degrading lignin, cellulose and hemicellulose. Fungi responsible for this type of decay are mainly basidiomycetes, but some xylariaceous ascomycetes species also have this capability. Brown rot fungi, which appear to be exclusively basidiomycetes, degrade cellulose and hemicelluloses, leaving the lignin only slightly modified. Soft rot is caused by a wide range of ascomycetes and, as with brown rot, it is only the cellulose and hemicelluloses that are utilized. Soft-rot differs from brown rot mainly in that the decay process is much slower (Cooke and Rayner, 1984). Among the most important organism groups, wood-inhabition fungi play an important role in the rubber plantation ecosystems. Either they decompose dead wood, i.e. the polypores or they may live as parasites on living organic material, such as leaves (Küffer *et al*., 2004).

Although the occurrence of fruiting bodies does not necessarily reflect the activity and distribution of mycelia, the observation and collection of fruiting bodies have been used to determine macrofungal species occurrence in space and time. However, temporal variation in the detectability of litter fungi sporocarps confuses the perception of spatial variation in the occurrence of species. One of the impediments to landscape studies of fungi is the difficulty of identifying species in the field, even when fruiting bodies are present. Microscopic examination is necessary to separate many species (Braga-Neto *et al*., 2008).

This study focused on mainly mushroom fruiting body growing on soil, leaf, branch litter, and wood logs of rubber tree. Rubber plantation management and fragmentation have a negative impact on the biodiversity of organism of plantation. Studies on species richness and composition of various organism groups in rubber tree are therefore of great interesting. No research studied about macrofungi in rubber plantation.

6.2 Materials and Methods

6.2.1 Fruiting bodies sample

The macrofungal samples were collected at six periods in 2010: January, March, May, July, September and November. The sporocarp survey, the fruiting bodies visible at the surface of leaf litter, branch litter, wood logs and soil were examined. Branch litter and wood logs belonging to the following three groups were used for fruiting body collection: newly fallen branches/logs, i.e. wood hard and bark present, middle stage decaying branches/logs, i.e. bark absent and the wood softening but still maintaining its structural integrity, and old decaying fallen branches/logs, i.e. wood soft and losing its integrity (Schmit, 2005).

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 morphological study involving examination under stereo and compound microscopes using relevant texts and references (Smith, 1975; Nian, 1998; Ruksawong and Flegel, 2001; Desjardin *et al*., 2004; Chandrasrikul *et al*., 2008).

6.2.2 Sampling design

Sporocarps of macrofungi were collected at two sites in a 25 year-old rubber plantation in Nakhon Si Thammarat and Songkhla Provinces. Three plots were distributed on a grid system of 200 x 200 m and the site study was conducted at 3 subplots of 50 x 50 m. In the study, material was collected at six periods in 2010: January, March, May, July, September and November. The first collection was made in January which was late in the rainy season, and the temperature was between 26.6 and 27.6^{o}C. Rainfall was recorded at between 68.3 and 175.4 mm. The second collection occurred during March in the dry season which the temperature ranged form 27.9-28.9^{o}C and rainfall was recorded 22.5-79.4. The third collection was in May which is in the end of dry season (but early rainy season in Nakhon Si Thammarat Province) and had the temperature range 29.7-30.1^{o}C and the rainfall was recorded as being between 18.1-123.2 mm. The fourth collection was in July which is in the early rainy season (in Songkhla Province) which the temperature range was 27.9-28.2^{o}C. The rainfall was recorded as between 115.5-132.0 mm. The fifth collection was in September, the rainfall was recorded as being between 109.2-307.6 mm. and had the temperature range 27.5-27.8^{o}C. The final collection was made in November which was in the middle rainy season when the temperature ranged form 25.7-26.6 ^{o}C and the rainfall was recorded as 825.3-1043.3 mm.

6.2.3 Definition and statistical analyses

Branch and wood log macrofungal species were recorded as either present or absent from each season and each stage of decomposition. Macrofungi on leaf litter and soil were recorded in each period only. The number of sample on which a fungal species was found was designated as the occurrence of a fungus and was used to calculate the percentage occurrence of a species on litter using the following formula. % occurrence of taxon A = (number of samples on which each fungus was detected/ total number of samples examined) x 100%. Macrofungi species diversity at each stage of woody litter degradation and each peroid was calculated using Shannon-Wiener index (H) and Simpson's index (D) (Shannon and Weaver, 1949).

The Shannon-Wiener index H = $-\Sigma PilnPi$, where Pi is the frequency of fungal species i occurring at a specific stage or season. Values of H for real communities are often 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 i and N = total number of species in the community. Values of D range between 0 and 1.

Sorensen's similarity index (S) was applied to compare the similarity of species on the different stages and different seasons (branch litter and wood logs): S = 2c/(a+b), Where a is the number of species in stage or season A and b is the number of species at stage or season B and c is the number of species in both stages or seasons. Similarity is expressed with values between 0 (no similarity) and 1 (absolute similarity) (Wang *et al*., 2008).

6.3 Results

6.3.1 Macrofungal taxonomic composition

Sporocarp surveys on soil and litter in rubber plantation habitat yielded 131 macrofungal taxa, comprising 42 families and 66 genera were identified (Table 6.1). Among them, 113 taxa (86.26%) belong to basidiomycetes and 18 taxa (13.74%) to ascomycetes. Forty-four species were found on soil, 15 species found on leaf litter, 70 species found on branch litter and 48 species found on wood logs. The total macrofungi found in each substrate are shown in Table 6.1.

6.3.2 Macrofungi on soil

A total of 44 species were found on soil in rubber plantation including, 31 species found in Nakhon Si Thammarat Province and 20 species found in Songkhla Province (Table 6.2). One species was in ascomycetes and 43 species found in basidiomycetes. Seven species, *Agaricus* sp.1, *Agaricus* sp.2, *Calvatia excipulifomis*, *Coprinus disseminata*, *Leucocoprinus birnbaumii*, *Pluteus cinereo-fuscus*, *Podoscypha nitudula* were found in both areas.

6.3.3 Macrofungi on rubber leaf litter

Only 15 species of fruiting bodies were found on leaf litter comprising, seven species found in Nakhon Si Thammarat Province and nine species found in Songkhla Province (Table 6.2). Two species, were ascomycetes (*Xylariaceae*) and 13 species were basidiomycetes; ten species in *Marasmiaceae* the others are *Mycenaceae*, *Psathyrellaceae* and *Entolomataceae*. *Marasmius alborescens* and *M. siccus* were dominat species (over 10% occurrence).

Table 6.1 Macrofungi collected from soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Taxa	Family	Substrate			
		Soil	Leaf litter	Branch litter	Wood logs
Ascomycota					
Aleuria aurantia	*Pyronematacae*	✓			
Bertia moriformis	*Bertiaceae*				✓
Bulgaria javanicum	*Bulgariaceae*			✓	
B. maxicana	*Bulgariaceae*			✓	✓
Cookeina sulcipes	*Sarcoscyphaeae*			✓	
C. tricholoma	*Sarcoscyphaeae*			✓	✓
Daldinia concentrica	*Xylariaceae*			✓	✓
D. escholizii	*Xylariaceae*			✓	✓
Hypocrea pezizoidea	*Hypocreaceae*			✓	✓
H. splendens	*Hypocreaceae*			✓	✓
Nectria pseudotrichia	*Hypocreaceae*			✓	
Xylaria sp.1	*Xylariaceae*			✓	
X. arbuscula	*Xylariaceae*			✓	✓
X. aristata	*Xylariaceae*		✓	✓	✓
X. caespitulosa	*Xylariaceae*			✓	
X. cubensis	*Xylariaceae*			✓	✓
X. hypoxylon	*Xylariaceae*		✓	✓	✓
X. multiplex	*Xylariaceae*			✓	✓
Basidiomycota					
Agaricus sp.1	*Agaricaceae*	✓			
Agaricus sp.2	*Agaricaceae*	✓			
Agaricus sp.3	*Agaricaceae*	✓			
A. trisulphuratus	*Agaricaceae*	✓			

Table 6.1 (Continued) Macrofungi collected from soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Taxa	Family	Substrate			
		Soil	Leaf litter	Branch litter	Wood logs
Aleurodiscus mirabilis	*Alurrodiscaceae*			✓	
A. oakesii	*Alurrodiscaceae*			✓	
Amanita sp.	*Amanitaceae*	✓			
Auricularia sp.1	*Auriculariaceae*			✓	
A. auricula	*Auriculariaceae*			✓	✓
A. fuscosuccinia	*Auriculariaceae*			✓	
A. polytricha	*Auriculariaceae*			✓	✓
Aurificaria euphobiae	*Hymenochaetaceae*			✓	
Bolbitius candolleana	*Bolbitiaceae*	✓			
Calvatia excipulifomis	*Agaricaceae*	✓			
Campanella junghuhnii	*Marasmiaceae*			✓	
Claudopus repens	*Entolomataceae*		✓	✓	
Clavaria vermicularis	*Clavariaceae*	✓			
Collybia nepheloides	*Tricholomataceae*	✓			
C. peronata	*Tricholomataceae*	✓			✓
Coprinus disseminata	*Agaricaceae*	✓			
Coriolopsis polyzona	*Polyporaceae*				✓
Coriolus hirsutus	*Polyporaceae*			✓	✓
Cortinarius sp.	*Cortinariaceae*	✓			
Craterellus aureus	*Cantharellaceae*	✓			
Cyathus striatus	*Agaricaceae*				✓
Dacryopinax spathularia	*Dacrymycetaceae*			✓	
Dictyophora indusiata	*Phallaceae*	✓			
Entoloma sp.1	*Entolomataceae*			✓	

Table 6.1 (Conitued) Macrofungi collected from soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Taxa	Family	Substrate			
		Soil	Leaf litter	Branch litter	Wood logs
Entoloma sp.2	*Entolomataceae*	✓			
Entoloma sp.3	*Entolomataceae*	✓			
Entoloma sp.4	*Entolomataceae*	✓			
Entoloma sp.5	*Entolomataceae*	✓			
E. incanum	*Entolomataceae*	✓			
Fomitopsis feei	*Fomitopsidaceae*				✓
Ganoderma sp.	*Ganodermataceae*				✓
Geastrum mirabile	*Geastraceae*				✓
Gloiocephala epiphylla	*Physalacriaceae*				✓
Heinemannomyces sp.	*Mycenaceae*		✓		
Hemimycena delicatella	*Mycenaceae*				✓
Heterobasidion annosum	*Bondarzewiaceae*			✓	✓
Hexagonia tenuis	*Polyporaceae*			✓	✓
Hygrocybe cantharellus	*Hygrophoraceae*	✓			
H. coccinae	*Hygrophoraceae*	✓			
H. coccineocrenata	*Hygrophoraceae*	✓			
Irpex flavus	*Meruliaceae*			✓	
Junghuhnia nitida	*Meruliaceae*			✓	
Laccaria laccata	*Laccariaceae*	✓			
Lactarius hygophoroides	*Russulaceae*			✓	✓
Lentinus sp.	*Polyporaceae*			✓	
L. citiatus	*Polyporaceae*			✓	
L. connatus	*Polyporaceae*			✓	
L. giganteus	*Polyporaceae*			✓	

Table 6.1 (Conitued) Macrofungi collected from soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Taxa	Family	Substrate			
		Soil	Leaf litter	Branch litter	Wood logs
L. polychrous	*Polyporaceae*			✓	
L. similis	*Polyporaceae*			✓	
L. squarrosulus	*Polyporaceae*			✓	✓
Lenzites elegans	*Polyporaceae*			✓	✓
Lepiota sp.1	*Agaricaceae*	✓			
Lepiota sp.2	*Agaricaceae*	✓			
L. cortinarius	*Agaricaceae*	✓			
L. echinacea	*Agaricaceae*	✓			
Leucocoprinus birnbaumii	*Agaricaceae*	✓			
L. fragilissimus	*Agaricaceae*	✓			
L. zeylanicus	*Agaricaceae*	✓			
Lycoperdon perlatum	*Agaricaceae*	✓			
Marasmiellus candidus	*Marasmiaceae*			✓	
Marasmius sp.1	*Marasmiaceae*			✓	✓
M. alborescens	*Marasmiaceae*		✓	✓	
M. androsaceus	*Marasmiaceae*		✓		
M. berteroi	*Marasmiaceae*		✓		
M. cohaerens	*Marasmiaceae*		✓	✓	
M. conicopapilatus	*Marasmiaceae*			✓	✓
M. florideus	*Marasmiaceae*			✓	
M. micraster	*Marasmiaceae*		✓	✓	
M. pellucidus	*Marasmiaceae*		✓		✓
M. pulcherripes	*Marasmiaceae*		✓	✓	✓
M. siccus	*Marasmiaceae*		✓	✓	✓

Table 6.1 (Conitued) Macrofungi collected from soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Taxa	Family	Substrate			
		Soil	Leaf litter	Branch litter	Wood logs
M. aurantioferrugineus	*Marasmiaceae*		✓	✓	✓
Meruliopsis corium	*Phanerochaetaceae*			✓	✓
Microphale brassicolens	*Marasmiaceae*		✓		
M. perforns	*Marasmiaceae*			✓	
Microporus affinis	*Polyporaceae*				✓
M. xanthopus	*Polyporaceae*			✓	
Mycena osmundicola	*Mycenaceae*			✓	
M. stylobates	*Mycenaceae*			✓	
Pluteus sp.	*Pluteaceae*				✓
P. aglaeotheles	*Pluteaceae*	✓			
P. cinereo-fuscus	*Pluteaceae*	✓			
Podoscypha nitidula	*Podoschypheae*	✓		✓	
Polyporus sp.1	*Polyporaceae*			✓	✓
Polyporus sp.2	*Polyporaceae*				✓
P. elegans	*Polyporaceae*			✓	✓
P. retirugis	*Polyporaceae*			✓	
Psathyrella sp.	*Psathyrellaceae*			✓	
P. candolleana	*Psathyrellaceae*		✓		
Pycnoporus cinnabarinus	*Polyporaceae*			✓	
P. sanguineus	*Polyporaceae*			✓	✓
Ramaria cyanocephala	*Gomphaceae*	✓			
R. fragilima	*Gomphaceae*	✓			
R. grandis	*Gomphaceae*	✓			
Rhodophyllus sp.	*Entolomataceae*	✓			

Table 6.1 (Conitued) Macrofungi collected from soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Taxa	Family	Substrate			
		Soil	Leaf litter	Branch litter	Wood logs
R. cyanoniger	*Entolomataceae*	✓			
Rigidoporus microporus	*Meripilaceae*				✓
Schizophyllum commune	*Schizophyllaceae*			✓	✓
Strobilomyces velutipes	*Boletaceae*	✓			
Termitomyces globulus	*Lyophyllaceae*	✓			
Thelephora vialis	*Thelephoraceae*	✓			
Trametes flavida	*Polyporaceae*			✓	✓
T. hirsuta	*Polyporaceae*			✓	
T. modesta	*Polyporaceae*			✓	✓
T. scabosa	*Polyporaceae*			✓	✓
Tremella fuciformis	*Tremellaceae*			✓	✓
Volvariella volvacea	*Pluteaceae*	✓			
Xeromphalina campanella	*Mycenaceae*			✓	✓
Total number of macrofungi recorded on soil and litter		44	15	70	48

6.3.4 Macrofungi on branch litter

The 70 species were found on branch litter comprising, 46 taxa in Nakhon Si Thammarat Province and 48 taxa in Songkhla Province (Table 6.2). Sixteen species were found in ascomycetes and 54 species were found in basidiomycetes. The fungal taxa at different stages of branch decay were distinct. The number of taxa in middle stage decaying and old decaying fallen branches tended to be higher than on newly fallen branches. In both areas, four species were found in newly fallen branches, 52 species were found in middle stage decaying branches and 41 species were found in old decaying fallen branches. The number of taxa found on middle stage decaying branches and old decaying fallen branches in Nakhon Si Thamarat Province were 35 and 23 taxa respectively, whereas the number of taxa found on newly fallen branches was three. The result obtained in Songkhla Province corresponded to the results from Nakhon Si Thammarat Province. In Songkhla Province, 35 and 24 taxa were found on middle stage decaying and old decaying fallen branches, respectively, whereas four taxa were found on newly fallen branches. In both areas, it was found that three species (85.71%) were overlapping in newly fallen branches, 18 species (51.43%) were overlapping in middle stage decaying branches and 6 species (25.53%) were overlapping in old decaying fallen branches.

The similarity in macrofungal communities associated with rubber branch litter at each stage of decomposition was closest in middle stage decaying and old decaying fallen branches (51.16%). Newly fallen and old decaying fallen branches showed slightly (12.24%) less similarity than newly fallen versus middle stage decaying branches (13.33%).

6.3.5 Macrofungi on wood logs

A total of forty-eight macrofungi were found on wood logs comprising, 26 taxa in Nakhon Si Thammarat Province and 41 taxa in Songkhla Province (Table 6.2). Twelve species were found in ascomycetes and 36 species were found in basidiomycetes. The fungal taxa at different stages of log decay were distinct. The number of taxa in middle stage decaying and old decaying fallen logs tended to be higher than on newly fallen logs, like on branch litter. In both areas, six species were found in newly fallen logs, 35 species were found in middle stage decaying logs and 33 species were found in old decaying fallen logs. The number of taxa found on middle stage decaying logs and old decaying fallen logs in Nakhon Si Thamarat Province were 19 and 16 taxa respectively, whereas the number of taxa found on newly fallen logs was four. The result obtained in Songkhla Province corresponded to the results from Nakhon

Si Thammarat Province. In Songkhla Province, 29 and 25 taxa were found on middle stage decaying logs and old decaying fallen logs, respectively, whereas four taxa were found on newly fallen logs.

In both areas, it was found that two species (50.00%) were overlapping in newly fallen logs, 13 species (54.17%) were overlapping in middle stage decaying branches and 8 species (39.02%) were overlapping in old decaying fallen logs. The similarity in macrofungi communities associated with rubber wood logs at each stage of decomposition according to on branch litter, the closest in middle stage decaying and old decaying fallen logs (26.47%). Newly fallen logs and old decaying fallen logs showed slightly (11.11%) less similarity than newly fallen versus middle stage decaying logs (24.39%).

Table 6.2 Diversity indices of macrofungi on soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*)

Substrate	Total (N)	Location					
		Nakhon Si Thammarat			Songkhla		
		No. of species	Index D	Index H	No. of species	Index D	Index H
Soil	44	31	0.9909	3.5295	20	0.9784	3.5966
Leaf litter	15	7	0.7789	1.6087	9	0.8345	2.1859
Branch litter	70	46	0.9787	3.7597	48	0.9806	3.8295
Wood logs	48	26	0.9647	3.3584	41	0.9783	3.7552

6.3.6 Seasonal effect on the macrofungal community

The macrofungi at different seasons were distinct. In Nakhon Si-Thammarat Province, the fruiting bodies were found in the early rainy season (May) tended to be higher than other seasons at all substrates. Seventy-one taxa found in May, 44 taxa in September, 38 taxa in July, 29 taxa in January, 17 taxa in November and nine taxa in March. In addition, the result obtained in Songkhla Province, the fruiting bodies were found in the early rainy season (July) tended to be higher than other seasons at all subtrates. Eighty-four taxa found in July, 64 taxa in November, 50 taxa in May, 43 taxa in September, 22 taxa in January and 13 taxa in March (Table 6.3).

Table 6.3 Diversity indices of macrofungi on soil, leaf litter, branch litter and wood logs (*Hevea brasiliensis*) at each season

Location/	Season						Index	Index
substrate	Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]	D	H
Nakhon Si Thammarat								
Soil	1	0	20	10	7	1	0.9998	3.6109
Leaf litter	1	1	5	4	4	3	0.9688	2.7301
Branch litter	17	4	21	11	18	9	0.9905	4.1538
Wood logs	10	4	25	13	15	4	0.9962	4.2121
Total	**29**	**9**	**71**	**38**	**44**	**17**		
Songkhla								
Soil	1	1	7	10	2	3	0.9784	3.5966
Leaf litter	1	0	1	8	5	5	0.9678	2.8693
Branch litter	10	6	28	32	20	27	0.9987	4.7437
Wood logs	10	6	14	34	16	29	0.9986	4.6169
Total	**22**	**13**	**50**	**84**	**43**	**64**		

Note: [1]January, late rainy season, [2] March, dry season, [3] May, early rainy season (in Nakhon Si Thammarat Province), [4]July, early rainy season (in Songkhla Province), [5]September and November, middle rainy season

6.3.7 The dominant macrofungi and colonization

The common macrofungi found on soil, leaf litter, branch litter and wood logs were shown in Table 6.4. Two species, *Marasmius alborescens* and *M. siccus* were dominant species (over 10% occurrence) found on leaf litter. Two species, *Hexagonia tenuis* and *Schizophyllum commune* were occurring dominant species on branch litter. Three species, *Hexagonia tenuis*, *Schizophyllum commune* and *Meruliopsis corium* were dominant species found on wood logs.

Five species of macrofungi were found on all types of litter comprising *Xylaria aristata*, *X. hypoxylon*, *Marasmius aurantioferrugineus*, *M. pulcherripes* and *M. siccus* (Table 6.4).

Thirty-four species, *Auricularia auricula*, *A. polytricha*, *Bulgaria maxicana*, *Cookeina tircholoma, Coriolus hirsutus, Daldinia concentrica*, *D. escholizi*, *Heterobasidion annosum, Hexagonia tenuis*, *Hypocrea pezizoidea*, *H. splendens*, *Lactarius hygophoroides*, *Lenzites elegans, Lentinus squarrosulus*, *Marasmius* sp.1, *Marasmius aurantioferrugineus*, *M. conicopapilatus*, *M. pulcherripes*, *M. siccus*, *Meruliopsis corium*, *Polyporus* sp.1, *P. elegans, Pycnoporus sanguineus*, *Schizophyllum commune, Trametes flavida, T. modesta*, *T. scabosa*, *Tremella fuciformis*, *Xeromphalina companella, Xylaria arbuscula*, *X. aristata*, *X. cubensis*, *X. hypoxylon* and *X. multiplex* were found on branch litter and wood logs (Table 6.4).

Four species, *Cladopus repens*, *Marasmius alborescens*, *M. cohaerens* and *M. micraster* were found on both leaf litter and branch litter. In addition, one species, *M. pulcherripes* was found on both leaf and wood logs (Table 6.4).

Table 6.4 Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota																
Bertiaceae																
Bertia moriformis															1.39	2.78
Bulgariaceae																
Bulgaria javanicum						1.39	1.39		1.39							
B. maxicana									1.39	1.39		1.39	1.39		1.39	6.94
Hypocreaceae																
Hypocrea pezizoidea						5.56	4.17					4.17	2.78			
H. splendens					4.17			4.17			2.78	1.39			1.39	
Nectria pseudotrichia									1.39							
Pyronematacae																
Aleuria aurantia	1.39															

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Sarcoscyphaeae																
Cookeina tricholoma							2.78					2.78	2.78			
C. sulcipes						2.78										
Xylariaceae																
Daldinia concentrica						1.39	1.39						1.39		1.39	
D. escholizii						1.39							1.39			
Xylaria sp.1						1.39										
X. arbuscula						1.39			1,39							2.13
X. aristata			4.17						1.39						1.39	
X. caespitulosa							1.39									
X. cubensis						1.39			1.39							2.78
X. hypoxylon			6.94			2.78	1.39								1.39	
X. multiplex						2.78	2.78		2.78				1.39		1.39	

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Basidiomycota																
Agaricaceae																
Agaricus sp.1	2.78	1.39														
Agaricus sp.2	1.39	1.39														
Agaricus sp.3	1.39															
A. trisulphuratus		2.78														
Calvatia excipulifomis	1.39	1.39														
Coprinus disseminata	1.39	1.39														
Cyathus striatus															1.39	6.94
Lepiota sp.1	1.39															
Lepiota sp.2	1.39															
L. cortinarius	1.39															

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
L. echinacea	1.39															
Leucocoprinus birnbaumii	1.39	1.39														
L. fragilissimus		1.39														
L. zeylanicus	1.39															
Lycoperdon perlatum		2.78														
Alurrodiscaceae																
Aleurodiscus mirabilis						4.17										
A. oakesii									1.39							
Amanitaceae																
Amanita sp.	2.78															
Auriculariaceae																
Auricularia sp.1									2.78							

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
A. auricula						1.39	1.39		2.78			1.39			2.78	4.17
A. fuscosuccinia										4.17						
A. polytricha							1.39		2.78	5.56					5.63	6.94
Bolbitiaceae																
Bolbitius candolleana		1.39														
Boletaceae																
Strobilomyces velutipes	1.39															
Bondarzewiaceae																
Heterobasidion annosum										2.78						4.17
Cantharellaceae																
Craterellus aureus	1.39															
Clavariaceae																

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Clavaria vermicularis	1.39															
Cortinariaceae																
Cortinarius sp.	1.39															
Dacrymycetaceae																
Dacryopinax spathularia						1.39										
Entolomataceae																
Claudopus repens			1.39						4.17							
Entoloma sp.1						1.39	1.39		1.39							
Entoloma sp.2	1.39															
Entoloma sp.3	2.78															
Entoloma sp.4	1.39															
Entoloma sp.5	1.39															

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
E. incanum	1.39															
Rhodophyllus sp.		1.39														
R. cyanoniger	1.39															
Fomitopsidaceae																
Fomitopsis feei												1.39	1.39		1.39	
Ganodermataceae																
Ganoderma sp.												1.39			1.39	
Geastraceae																
Geastrum mirabile															1.39	2.78
Gomphaceae																
Ramaria cyanocephala		1.39														
R. fragilima	1.39															

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
R. grandis	1.39															
Hygrophoraceae																
Hygrocybe cantharellus		2.78														
H. coccinea		1.39														
H. coccineocrenata	2.78															
Hymenochaetaceae																
Aurificaria euphobiae									1.39							
Laccariaceae																
Laccaria laccata		1.39														
Lyophyllaceae																
Termitomyces globulus	1.39															

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Marasmiaceae																
Campanella junghuhnii						1.39			1.39	1.39						
Marasmiellus candidus							1.39			1.39						
Marasmius sp.1						1.39			1.39							6.94
M. alborescens			13.89						2.78	4.17						
M. androsaceus				1.39												
M. berteroi				2.78												
M. cohaerens			1.39			2.78										
M. conicopapilatus										1.39			4.17			4.17
M. floridеus						1.39			1.39	1.39						
M. micraster				9.72						1.39						

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
M. pellucidus				2.78								2.78			2.78	
M. pulcherripes				2.78					4.17	2.78		1.39	4.78		1.39	4.17
M. siccus			1.39	12.50		1.39				4.17		1.39			1.39	
M. aurantioferrugineus			1.39						1.39						1.39	2.78
Microphale brassicolens				2.78												
M. perforns							1.39									
Meripilaceae																
Rigidoporus microporus												1.39	1.39			
Meruliaceae																
Irpex flavus							2.78									
Junghuhnia nitida									1.39							
Mycenaceae																
Heinemannomyces sp.				2.78												

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Hemimycena delicatella																2.78
Mycena osmundicola						1.39										
M. stylobates							1.39									
Xeromphalina campanella										2.78					2.78	4.17
Phallaceae																
Dictyophora indusiata		1.39														
Phanerochaetaceae																
Meruliopsis corium						2.78			8.33	2.78			4.17		2.78	11.11
Physalacriaceae																
Gloiocephala epiphylla																2.78
Pluteaceae																
Pluteus sp.																2.78

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
P. cinereo-fuscus	1.39	1.39														
P. aglaeotheles	1.39															
Volvariella volvacea		1.39														
Podoschypheae																
Podoscypha nitidula	2.78	1.39					1.39									
Polyporaceae																
Coriolopsis polyzona												2.78				
Coriolus hirsutus						4.17			1.39						1.39	2.78
Hexagonia tenuis					1.39	4.17	8.33	4.17	8.33	11.11	2.78	4.17	12.50		9.86	19.44
Lentinus sp.										1.39						
L. citiatus							1.39									
L. connatus									1.39							

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
L. giganteus									2.78							
L. polychrous						2.78										
L. similis										1.39						
L. squarrosulus										1.39						4.17
Lenzites elegans						1.39	1.39			5.56			2.78		2.78	2.78
Microporus affinis																4.17
M. xanthopus									1.39							
Polyporus sp.1						1.39			1.39			1.39		1.39		
Polyporus sp.2												1.39	1.39		1.39	
P. elegans						1.39						2.78				
P. retirugis						1.39	1.39									
P. cinnabarinus						4.17	2.78		1.39							

Table 6.4 (Continued) Occurrence (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
P. sanguineus						1.39			1.39	2.78			2.78			
Trametes flavida						1.39			1.39							6.94
T. hirsuta						2.78										
T. modesta						1.39						1.39		1.39	1.39	
T. scabosa						2.78	4.17	1.39	2.78	2.78	1.39	2.78		1.39	4.17	
Psathyrellaceae																
Psathyrella sp.										1.39						
P. candolleana				1.39												
Russulaceae																
Lactarius hygophoroides							1.39		2.78						1.39	
Schizophyllaceae																
Schizophyllum commune					8.33	11.11	11.11	8.33	8.33	8.33	6.94	12.50	8.33	1.39	5.56	12.50

Table 6.4 (Continued) Occurrences (%) of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation (*Hevea brasiliensis*) in Nakhon Si Thammarat and Songkhla Provinces

Taxa	Substrate															
	Soil		Leaf litter		Branch litter						Wood Logs					
	Nakhon Si-Thammarat	Songkhla	Nakhon Si-Thammarat	Songkhla	Nakhon Si Thammarat			Songkhla			Nakhon Si Thammarat			Songkhla		
					New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Thelephoraceae																
Thelephora vialis	1.39															
Tremellaceae																
Tremella fuciformis									5.56	1.39					2.78	
Tricholomataceae																
Collybia nepheloides		2.78														
C. peronata		1.39													1.41	
Total number of macrofungi recorded from soil and litter	31	20	7	9	3	35	23	4	35	24	4	19	16	4	29	25

Note: * Newly fallen branches/logs, middle stage decaying branches/logs, old decaying fallen branches/logs

6.4 Discussion

6.4.1 Macrofungal diversity and colonization

The community of macrofungi on soil, leaf litter, branch litter and wood logs in rubber plantation seemed to be specially structured in 200 x 200 m along rainfall and edaphic gradients. Our result indicated that the macrofungal production in a rubber plantation variedly predicts in space and time, suggesting that litter macrofungal species are not randomly distributed at mesoscales. Braga-Neto *et al*. (2008) reported that rainfall and clay content in soil predict morphospecies richness and composition, but responses of the number of morphospecies to edaphic factors depended on rainfall.

In this study, the number of macrofungi was high in the early rainy season. On soil, 23 species (52.27%) were found in early rainy season, whereas only one species found in the dry season. On leaf litter, 12 species (80.00%) were found in the early rainy season, and one species found in the dry season. On branch litter, 33 speceis (47.14%) found in early rainy season and nine species found in the dry season. In addition, 29 species (60.42%) found on wood logs in early rainy season and five species found in the dry season. The investigation was similar to the report by Singer and Arujo (1979) and Braga-Neto *et al*. (2008) studied and expected positive relation between morphospecies richness in early rainfall. Braga-Neto *et al*. (2008) explained that rainfall is a primary determinant of the availability of water in forest ecosystems.

Braga-Neto *et al*. (2008) reported that the absence of a significant correlation between the number of morphospecies and clay content for the high-rainfall periods may be related to a decrease in topographic influence over the moisture gradient, presumably caused by less limiting moisture conditions driven by higher rainfall. On the other hand, rainfall influences on morphospecies richness were consistent among rainfall groups. We found an expected positive relation between morphospecies richness and early rainy season cumulative, since litter fungal fruit body production depends on short-term rainfall (Singer and Araujo, 1979).

Although slightly differences in abundance or morphospecies richness between early rainy season, rainy season and late rainy season were found, the low proportion of shared morphospecies suggests that an increase in rainfall in the early rainy season of fruiting body production of different species, an indication of differential responses to seasonal/moisture regimes. However, most morphospecies were infrequent or rare, and the detectability of most litter fungal species seems to be low. Repeated surveys of the same plots will be needed to detect most species.

6.4.2 Wood decaying fungi

The majority of wood-decay fungi studied have been concerned with basidiomycetes from early stage of decomposition, and with ascomycetes particularly from intermediate decomposition stage (Rayner and Boddy, 1988). Host-wood species, physic-chemical properties, and microclimate govern the basic fungal community dynamics, as does the prior history of the substratum (Chapela *et al*., 1988). The decay process often commences in the standing tree, in attached lower or stressed branches (Rayner and Boddy, 1988). Fungi may gain access either through wounds, tissues following microbial or stress damage or via lenticels or leaf scars.

In this study, macrofungi decaying on newly fallen wood comprising *Hexagonia tenuis*, *Hypocrea splendens*, *Trametes scabosa* and *Schizophyllum commune*. Then, in the middle decaying stage, the secondary invaders such as *Xylaria hypoxylon*, *X. multiplex*, *Auricularia auricula*, *A. polytricha*, *Meruliopsis corium* and *Coriolus hirsutus* could invade and replace pioneers in decaying wood. Rayner and Boddy (1988) studied fruiting bodies on oak and ash reported that pioneer species such as *Stereum guaspartum*, *Phlebia rufa*, *Phellinus ferreus*, *Exidia glandulosa* and *Vuilleminia comedens* in oak or *Daldinia concentric*a, *Hypoxylon rubiginosum* and *Peniophora limitata* in ash, can colonize living or recently dead wood. After that, *Coriolus versicolor*, *Phlebia radiate*, *Sterium hirsutum* and *Peniophora lycii* in oak and *Radulomyces confluens* in ash, could invade and replace pioneers in already dead wood. The finally, macrofungi were found on branch and wood log in the late decaying stages such as, *Mycena* sp., *Marasmius* sp. and *Pluteus* sp.

Decomposing dead wood gradually releases sources of nutrient (Harmon *et al*., 1994). Exposed stumps of felled trees, fallen branches, twigs or timbers may become rapidly colonized by large numbers of individuals of fairly nonselective saprotrophs, thereby forming numerous smaller decay columns. Community structure and development is affected by the degree of exposure, contact with the ground of with other wood, and is influenced by microenvironmental conditions and the arrival mode of individuals. Exposed surfaces may be colonized by established air-borne spores of *Coriolus versicolor*, *Bjerkander adusta*, *Stereum hirsutum*, *Chondrostereum purpureum* basidimycetes or ascomycetes in the genus *Hypoxylon* or *Xylaria* commonly found on hardwoods.

Such a mode of establishment often produces slower expansion of decay columns compared to that from ground contact, presumably due to more stressful drying regimes. Buried or ground contact wood may be colonized by soil derived spores and mycelia (Worrall *et al*., 1997). That different individual produces different types and rate of decay is now evident (Worrall *et al*., 1997). Moreover, the spatio -temporal combination of extracellular enzymes secreted by a fungus is dependent not only on its evolutionary heritage, but also on the local environmental and biotic condition (Griffin, 1994).

6.4.3 The macrofungal community

Direct examination of leaf litter, branch litter, wood logs and on soil for fruiting structures is a traditional method of surveying for basidiomycetes and ascomycetes activity. But the flora detected using this approach is often very different to that isolated by plating wood portions from interior wood regions.

Inferences regarding community dynamics if based on sporophore surveys should be made with extreme caution as their appearance may bear little relationship to the arrival, activity or decline of the supporting mycelia and the relationship will vary for different individuals. Thus, the time taken for the mycelium to derive sufficient resource to devote to sporophores production may be one or more seasons but may be evident only temporarily and the active mycelium of some fungi may not produce sporophores until their final stage of colonization. Some, such as *Ganoderma* and *Fomes* produce perennial fruit bodies (Straatsma *et al*., 2001) which may survive for several years, whereas others may produce seasonal and or ephemeral fruit bodies. Fruiting may also be influenced by environmental factors such as temperature and precipitation, natural and artificial amendments to soil and by local or nonlocal ecological disturbance (Straatsma *et al*., 2001).

Fungal habitat may be lost, with implicit reduction of fungal species diversity, either by deforestation, or because of commercial forestry management practices, such as the conversion to less-mixed or monoculture plantation (rubber plantation), stand felling of particular age, and the removal of coarse woody debris (Norden and Paltto, 2001) red-list (endangered, vulnerable, or rear) species may be particularly sensitive, often showing a preference for large diameter logs in late decay stage, of which manage forests are largely deficient (Kruys *et al*., 1999).

Pesticides such as herbicides and fungicides are known to affect biodiversity in rubber plantation. The resulting impact on community interactions may have implications in the dynamic between pathogens and saproptophs and the consequent natural limitation of plant diseases, and even on the subsequent decay rates of litter and hence nutrient cycling (Newsham *et al*., 1992; Zhdanova *et al*., 1994).

CHAPTER 7

DETERMINATION OF CELLULOSE AND XYLAN DEGRADING ABILITY OF SOME ISOLATED FUNGI

7.1 Introduction

Decomposition processes are mediated by microorganisms that are extremely important for environmental maintenance because of their fundamental role in cycling nutrients and organic matter, changing organic matter into inorganic matter and providing nutrients, which preserves the energetic balance in ecosystems (Nunes *et al*., 2011). Many studies have been carried out on litter decomposition and the dynamics of nutrient release to analyze the effect of climate and litter quality (Seneviratne, 2000; Sariyildiz and Anderson, 2003; Saparrat *et al*., 2008). In recent years, attention has turned to the degrading capacity of microorganisms by evaluating their enzyme activities (Hammel, 1997; Carreiro *et al*., 2000; Fioretto *et al*., 2000; Hao *et al*., 2006).

Enzymes involved in the degradation of the main litter components, such as cellulose, hemicellulose and lignin, and those involved in the cycling of nitrogen, phosphorus and sulphur, are of primary interest in understanding the factors controlling plant litter decomposition (Tanaka, 1993; Fioretto *et al*., 2001). Cellulose, hemicellulose and lignin are the major components of forest litter, comprising 50-80% of the dry mass. Cellulose and hemicellulose are recalcitrant products added to soil through plant remains and must be transformed into soluble substances prior to microbial assimilation through extracellular enzymes. The microbial degradation of cellulose, hemicellulose and other oligosaccharides may be brought about by those enzymes directly involved in initial chemical breakdown (Swift, 1979; Burns, 1982).

Cellulose and xylan, which are typical structural components in the litter as well as lignin, are hydrolyzed by microbially derived extracellular enzymes: cellulases and xylanases. The microorganisms secreting these enzymes therefore play an important role in the decomposition process of the plant litter (Tanaka, 1993). In order to establish the functional role of saprophytes it would be useful to establish their pattern of substrate utilization and which enzymes they produce (Carroll and Petrni, 1983). If they are weak parasites or latent pathogens they may produce proteinase and pectinase (Brett, 1990; Reddy and Basappa, 1997), while if they are mutualistic saprobes they are likely to produce cellulases, mannanase and xylanases (Pointing, 1999). In this study, we tested the ability of saprobic fungi isolated from leaf litter to produce cellulase and xylanases in order to study decomposition of rubber leaves.

The cellulolytic and xylanolytic enzymes were in a relationship between their change and the dynamics of the decomposer microorganisms (Tanaka, 1993). There have been only a few studies which were concerned with the characteristics of cellulolytic and xylanolytic enzymes associated with leaf decomposition. The enzyme tests may help us to understand the functional roles of fungi and the decomposition of leaf litter. The objective of this study was to determine the ability of some fungi associated with rubber leaf litter to degrade cellulose and xylan.

7.2 Materials and Methods

7.2.1 Fungal strains

Fifty-eight dominant isolates of rubber leaf litter fungi (Table 7.1) were selected to determine the ability to produce cellulolytic and xylanolytic enzymes. All of these fungi have been reported as having higher decomposition ability of cellulolytic materials (Song *et al*., 2005; Hao, 2006; Gautam *et al*., 2011; Agriculture and Consumer Protection, 2011). The fungi were maintained on potato dextrose agar (PDA) and were transferred to malt extract agar (MEA) for 7 days before use as inoculums.

7.2.2 Screening for cellulase enzyme

Fungi were tested for their ability to produce the hydrolytic enzyme cellulase in a plate assay method using 1% carboxymethyl cellulose (CMC) in a basal salt medium (cellulolysis basal medium; CBM) (Gautam *et al*., 2011). A 5 mm diameter mycelial plug on MEA was put onto the CMC agar, thereafter incubated at 28-32^{o}C in darkness. When the colony diameter was approximately 30 mm, the plates were flooded with 0.1% w/v aqueous congo red and left for 15 minutes, poured off the staining material and washed the agar surface with distilled water. Then, the plates were flooded with 1M NaCI to destain for 15-20 minutes and then the destain was poured off. The zone of cellulose hydrolysis appeared as a clear zone around the colony (Maria *et al*., 2005; Gautam *et al*., 2011).

Extracellular cellulolytic activity was measured by the method described by Choi *et al.* (2005); enzymatic reaction ratio = the ratio of clear zone diameter to that of colony diameter. The test results were classified into 4 categories as follows (Choi *et al*., 2005).

Strong reaction (+++): the extracellular enzyme ratio was higher than or equal to 2. Medium reaction (++): the extracellular enzyme ratio was less than 2 but more than 1. Weak reaction (+): the extracellular enzyme ratio was equal to or less than 1 but more than zero. No reaction (-): there is no reaction at all.

7.2.3 Screening for xylanase enzyme

Xylanase enzyme was tested by preparing the xylanolysis basal medium (XBM), incorporating 4% w/v birchwood xylan and 1.6% w/v agar and autoclaved, aseptically transferred to Petri dishes (it was necessary to cool the agar until viscous and gently mix before pouring to ensure uniform distribution of xylan in the agar medium).

A 5 mm diameter mycelial plug on MEA was put onto the medium and incubated at 28-32°C in darkness. When colony diameter was approximately 30 mm, the agar plates were stained as follows: it was necessary to flood plates with iodine stain (0.25% w/v aqueous I_2 and KI) and leave for 5 minutes. Thereafter, we poured off the staining agent and washed the agar surfaces with distilled water. Xylan degradation around the colonies appeared as a yellow opaque area against a blue/ reddish purple colour for undegraded xylan (Pointing, 1999).

7.3 Results

7.3.1 Cellulolytic fungi

Thirty-nine fungal species (65.52%) showed some degree of clearance of the cellulose-containing medium. None of fungal species showed strong cellulolytic activity (+++) on agar plates. Nevertheless, 15 species (38.46%) belonging to *Aspergillus japonicus* var. *aculeatus*, *A. kanagawaensis*, *A. parasiticus*, *A. tamarii*, *Beltrania* sp., *Beltraniella pirozynskii*, *Botryodiplodia* sp., *Cylindrocarpon* sp., *Helicostylum piriforme*, *Penicillium canescens*, *P. citrinum*, *Trichoderma atroviride*, *T. inhamatum*, *T. reesei* and *T. virens* showed medium cellulolytic activity (++) on agar plates.

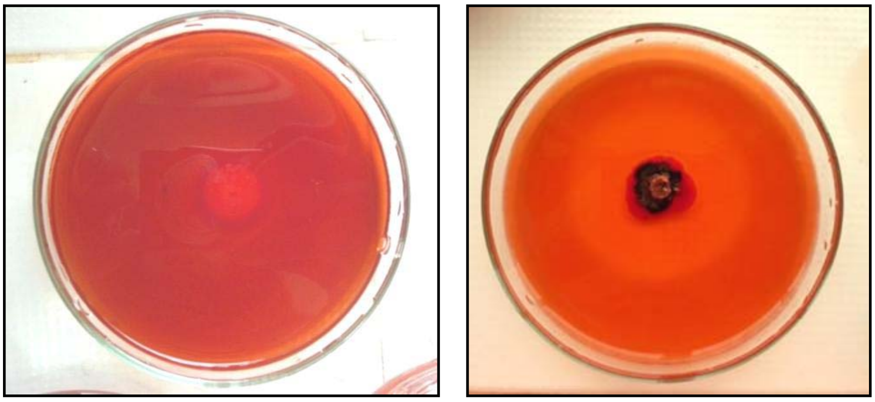
Twenty-four fungal species (61.54%) showed weak reaction (+) on agar plates and the rest of the species did not show any clearance of the cellulose (-) containing medium (Table 7.1 and Figure 7.1).

7.3.2 Xylanolytic fungi

Thirty-five fungal species (60.34%) produced extracellular xylanase on XBM, including *Acremonium cerealis*, *Aspergillus carbonarius, A. niger*, *A. parasiticus*, *A. pulverulentus*, *A. japonicus* var. *aculeatus*, *A. tamarii*, *A. japonicus* var. *japonicus*, *A. kanagawaensis*, *A. sclerotiorum*, *A. sydowii*, *Beltrania* sp., *Botryodiplodia* sp., *Cylindrocarpon* sp., *Cylindrocladium parvum*, *Fusarium redolens*, *H. piriforme*, *Kirschsteiniothelia* sp., *Rhizopus* sp., *Paecilomyces varioti*, *Pestalotiopsis disseminata*, *Phomopsis* sp., *Phyllosticta* sp., *Syncephalastrum recemosum, T. atroviride*, *T. aureoviride*, *T. koningii*, *T. hamatum*, *T. harzianum*, *T. longibrachiatum*, *T. inhamatum*, *T. pseudokoningii*, *T. reesei, T. virens* and *T. viride*. The rest of the species (23 species) did not show xylan degradation activity. The detection results of xylan degradation activity on xylan agar are shown in Table 7.1 and Figure 7.2.

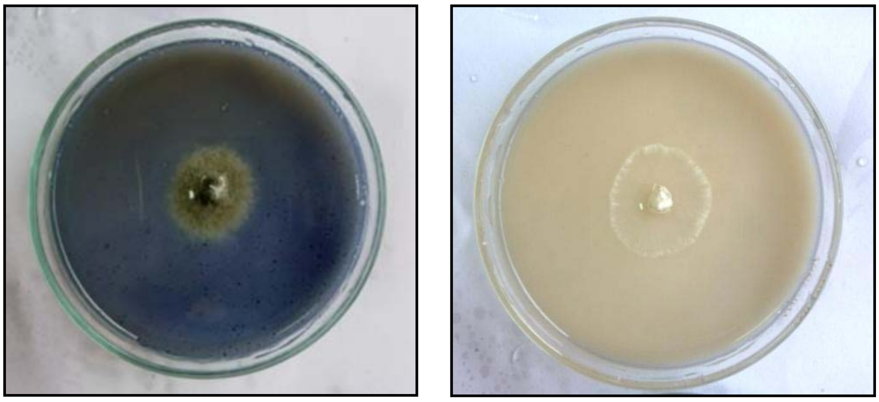
7.3.3 Cellulolytic and xylanolytic fungi

Fifty-eight isolate had their ability to produce cellulolytic and xylanolytic enzymes on agar plates determined. Among them, 26 species produced both cellulase and xylanase enzymes belonging to *Aspergillus carbonarius*, *A. japonicus* var. *aculeatus*, *A. japonicus* var. *japonicus*, *A. kanagawaensis, A. niger, A. parasiticus, A. sclerotiorum*, *A. tamarii*, *Beltrania* sp., *Botryodiplodia* sp., *Cylindrocarpon* sp., *Fusarium redolens*, *Helicostylum piriforme*, *Phyllosticta* sp., *Rhizopus* sp., *Syncephalastrum recemosum*, *T. atroviride*, *T. aureoviride, T. harzianum, T. inhamatum, T. koningii, T. longibrachiatum, T. pseudokoningii*, *T. reesei, T. virens* and *T. viride*. Ten fungi taxa did not produce both cellulolytic and xylanolytic enzymes. These belonged to *Cladosporium tenuissimum*, *Aspergillus sojae*, *Penicillium janthinellum*, *P. minicluteum*, *P. simplicissium*, *P. rubrum*, *Pestalotiopsis guepini*, *Scolecobasidiella avellanea, Trichoderma parceramosum* and *Veronaea carlinae*.



No reaction　　　　　　　　Clear zone

Figure 7.1 Change reactions of cellulolytic fungi on 1% CMC agar by congo red dye staining



No xylan degradation　　　　　　　　Xylan degradation

Figure 7.2 Change reactions of xylanolytic fungi on xylan agar after flooding with iodine stain

Table 7.1 Summary of cellulolytic and xylanolytic activity tests

Fungal taxa	Enzyme activity	
	Cellulase*	Xylanase**
Acremonium cerealis	- (20)	D (3)
A. kiliense	+ (12)	U (3)
Aspergillus carbonarius	+ (19)	D (3)
A. japonicus	+ (15)	U (3)
A. japonicus var. *aculeatus*	++ (8)	D (3)
A. japonicus var. *japonicus*	+ (16)	D (3)
A. kanagawaensis	++ (6)	D (3)
A. niger	+ (19)	D (3)
A. parasiticus	++ (6)	D (3)
A. pulverulentus	- (6)	D (3)
A. sclerotiorum	+ (4)	D (3)
A. sojae	- (5)	U (3)
A. sydowii	- (6)	D (3)
A. tamarii	++ (8)	D (3)
A. terreus	+ (11)	U (4)
Beltrania sp.	++ (4)	D (4)
Beltraniella sp.	+ (6)	U (3)
B. pirozynskii	++ (13)	U (3)
Botryodiplodia sp.	++ (15)	D (2)
Botryotrichum puliferum	+ (15)	U (5)
Cladosporium tenuissimum	- (20)	U (5)
Colletotrichum sp.1	+ (10)	U (3)
Cylindrocarpon sp.	++ (4)	D (3)
Cylindrocladium parvum	- (8)	D (3)

Table 7.1 (Continued) Summary of cellulolytic and xylanolytic activity tests

Fungal taxa	Enzyme activity	
	Cellulase*	Xylanase**
Fusarium oxysporum	+ (7)	U (3)
F. redolens	+ (6)	D (3)
F. semitectum	+ (10)	U (3)
Helicostylum piriforme	++ (3)	D (3)
Kirschsteiniothelia sp.	- (16)	D (4)
Penicillium canescens	++ (16)	U (4)
P. chrysogenum	+ (11)	U (3)
P. citrinum	++ (14)	U (4)
P. griseofulvum	+ (15)	U (3)
P. janthinellum	- (10)	U (5)
P. minioluteum	- (10)	U (5)
P. rubrum	- (20)	U (5)
P. simplicissium	- (15)	U (3)
Paecilomyces varioti	- (20)	D (3)
Pestalotiopsis guepini	- (8)	U (3)
P. disseminata	- (10)	D (3)
Phomopsis sp.	- (10)	D (3)
Phyllosticta sp.	+ (6)	D (4)
Rhizopus sp.	+ (6)	D (2)
Scolecobasidiella avellanea	- (20)	U (3)
Syncephalastrum recemosum	+ (3)	D (2)
Trichoderma atroviride	++ (3)	D (2)
T. aureoviride	+ (3)	D (2)
T. hamatum	- (6)	D (2)

Table 7.1 (Continued) Summary of cellulolytic and xylanolytic activity tests

Fungal taxa	Enzyme activity	
	Cellulase*	Xylanase**
T. harzianum	+ (7)	D (2)
T. inhamatum	++ (3)	D (2)
T. koningii	+ (5)	D (2)
T. longibrachiatum	+ (4)	D (2)
T. parceramosum	- (3)	U (4)
T. pseudokoningii	+ (3)	D (2)
T. reesei	++ (3)	D (2)
T. virens	++ (3)	D (2)
T. viride	+ (3)	D (2)
Veronaea carlinae	- (20)	U (3)

Note: * Strength reaction of cellulase: ++ = medium; + = weak; - no reaction in (x) culture age (days)

** Reaction of xylanase: D = degradation; U = undegradation in (x) culture age (days)

7.4 Discussion

7.4.1 Enzyme production

Fungal enzymes are gaining importance in agriculture, industry and human health, as they are often more stable (at high temperature and extreme pH) than the enzymes derived from plants and animals (Maria *et al*., 2005; Tang *et al*., 2008). Kumaresan and Suryanarayanan (2002) studied the extracellular enzyme production by the foliar endophytic fungi of *Rhizophora apiculata* and demonstrated their involvement in litter degradation after senescence. In addition, Gessner (1980) studied degradative enzyme production by salt-marsh fungi and the results showed 20 fungi to be capable of degrading cellulose, cellobiose, lipids, pectin, starch, tannic acid and xylan.

In this study, 58 culturable fungi isolated from rubber leaf litter were tested for their ability to produce cellulase and xylanase enzymes. Twenty-six fungi produced both cellulase and xylanase enzymes during incubation periods of 2-19 days. Five fungal species showed the highest production of cellulase and xylanase namely *A. parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *Helicostylum piriforme* and *T. virens*. They were used to study their ability to assist in the degradation of rubber leaf litter.

Choi *et al.* (2005) explained that saprophytes that degraded xylan (hemicellulose) are also likely to have the ability to degrade cellulose. Xylan and cellulose occupy 25 to 40% and 40 to 50% of the wood mass. After all simple food sources, such as glucose and starch, are used up. Plant litter degrading fungi will start to degrade the cell wall components. As a result, saprophytes that produce both cellulases and hemicellulases, such as xylanases should have the ability to complete with other types of fungi surviving on dead wood and leaves (Carrol and Petrini, 1983).

7.4.2 Cellulolytic fungal activity

A cellulolytic enzyme system consists of three major components: endo-ß-glucanase, exo- ß -glucanase and ß -glucosidase (Agriculture and Consumer

Protection, 2011). Cellulolytic organisms can convert cellulose into various economically important products such as monomeric sugars, single cell, protein, antibiotics, and compost of everyday use for man (Gautam *et al*., 2011). Utilization of cellulosic material has been thought in recent years to contribute to the production of food and energy. There are some reports concerning the biomass of bacteria or fungi and the activity of cellulolytic enzymes on decomposition of leaf litter (Newell and Hicks, 1982; Fioretto *et al*., 2001; Gautam *et al*., 2011). Especially, fungi are very good at producing diverse enzymes that can degrade natural polymeric compounds such as cellulose, pectin and starch.

In this study, *Aspergillus* (4 species), *Beltrania* sp., *Beltraniella pirozynkii*, *Botryodiplodia* sp., *Cylindrocarpon* sp., *Helicostylum piriforme*, *Penicillium* (2 species) and *Trichoderma* (4 species) were shown to have a medium cellulytic activity (++). Among these, 5 top species: *A. parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *H. piriforme* and *T. virens* were selected for further study. Hao *et al.* (2006) studied the decomposition of *Q. variabilis* leaf litter in subtropical forest and the results showed that *Alternaria* sp., *Penicillum* sp., *Acremonium* sp. and *Trichoderma* sp. showed high cellulolytic activity. In addition, Agriculture and Consumer Protection (2011) and Gautam *et al.* (2011) report that fungi of the genera *Trichoderma* and *Aspergillus* are thought to be cellulase producers, and crude enzymes produced by these fungi are commercially available for agricultural use.

Hao *et al.* (2006) explained that during the initial decomposition of *Q. variabilis* leaf litter, fungi primarily consumed the available organic compounds, such as soluble carbohydrates and non-lignified holocellulose, which already existed in the leaf litter (Kirk, 1983), so the decomposition rate may depend primarily on the cellulase levels. Jahangeer *et al*. (2005) screened the cellulolytic ability of fungi from native environments and the results showed that 67.83% of fungi produced cellulolytic enzymes such as *Aspergillus* sp., *Trichoderma* sp., *Fusarium* sp., *Alternaria* sp., *Penicillium* sp. and *Rhizopus* sp.

7.4.3 Xylanolytic fungal activity

Many microorganisms are known to produce different types of xylanases; the nature of these enzymes varies between different organisms (Kulkarni *et al*., 1999; Haltrich *et al*., 1996). The xylanolytic enzymes include endo- ß -1,4-xylanase (1,4- ß -D-xylan xylanohydrolase, ß -D-xylosidase (1,4-ß-xylan xylanohydrolase), and debranching enzymes (esterases) (Chen *et al.,* 1997). Many bacterial and fungal species produce the full complement of enzymes necessary to enable them to utilize xylan as a carbon source (Haltrich *et al*., 1996; Hann and Van Zyl, 2003). However, filamentous fungi are particularly interesting producers of xylanases. Xylanase levels from fungal cultures are typically much higher than those from yeast or bacteria. Moreover, in addition to xylanases, fungi produce several auxiliary enzymes required for the degradation of the substituted xylan. A majority of both fungi that produce xylanase and fungi that produce ß -D-xylosidase enzymes belong to the genus *Aspergillus*, many of which have been well characterized (Enkerli *et al*., 1999; Medeiros *et al*., 2003; Pang and Ibrahim, 2005; Polizeli *et al*., 2005; Rengasayee *et al*., 2005; Palaniswamy *et al*., 2008).

The attention on the applications of xylan degrading enzymes has led to the discovery of many new enzymes with previously unknown characteristics, from various microorganisms (Haltrich *et al*., 1996). Xylanases show great potential for industrial applications mainly for the bioconversion of lignocelluloses to sugar, ethanol, and other useful substances, clarification of juices and wines, improving the nutritional quality of silage and green feed and the de-inking processes of waste papers (Viikari *et al*., 2001; Pang and Ibrahim, 2005; Mishra and Dadhich, 2010).

In this study, 35 fungal taxa of various genera: *Acremonium, Aspergillus* (10 species), *Beltrania*, *Botryodiplodia*, *Cylindrocarpon*, *Cylindrocladium*, *Fusarium*, *Helicostylum*, *Kirschteiniothelia*, *Rhizopus*, *Paecilomyces*, *Pestalotiopsis*, *Phomopsis*, *Phyllostica*, *Syncephalastrum* and *Trichoderma* (11 species) were shown to have ability to produce xylanases using brichwood xylan as a carbon source. The results are in accordance with those of Palaniswamy *et al.* (2008) who reported that *Acremonium*, *Aspergillus*, Basidiomycetes, *Fusarium*, *Humicola*, *Mucor*, *Penicillium*, *Rhizopus* and

Trichoderma were potential fungal sources of xylanases. In addition, Mishra and Dadhich (2010) reported that *Trichoderma* sp. RJ2, *Aspergillus niger* RJ2, *Fusarium* spp. RJ1 and *Penicillium* sp. RJ6 produced the highest levels of extracellular xylanases.

Medeiros *et al*. (2003) studied the fungi isolated from decomposing litter in the Amazon forest and the results showed that *Penicillium coryophilum*, *Aspergillus niger* and *Trichoderma longibrachiatum* produced xylan-degrading enzymes when cultivated in liquid media containing oat spelt xylans. Moreover, Haltrich *et al*. (1996) gave an overview of fungal xylanases and showed that the enzymes could be produced by filamentous fungi such as *Trichoderma, Aspergillus, Penicillium, Aureobasidium, Fusarium, Chaetomium, Phanerochaete, Rhizomucor, Humicola* and *Talaromyces.*

CHAPTER 8

DECOMPOSITION OF RUBBER LEAF LITTER BY SOME CELLULOLYTIC AND XYLANOLYTIC FUNGI

8.1 Introduction

Litter production and nutrient return in natural forests as well as in plantations are very important aspects of nutrient cycling. Since a considerable amount of nutrients are returned through litter fall in the form of leaves, twigs, barks, branches and flowers, they are available for re-absorption. The sequential process of litter fall, its decomposition and subsequent mineralization are essential in sustaining a dynamic ecosystem. The decomposition of leaf litter is an important process in the ecosystem, as it allows the nutrient and carbon cycle to be closed (Lavella *et al*., 1993; Suberkropp and Gulis, 2003; Walpola *et al*., 2011). As decomposition and soil organic matter formation are main useful behaviors of soil organisms, these ultimately have a crucial role in maintaining soil fertility and plant growth.

Rubber leaf litter is an important energy source for food webs in rubber plantations. They are the major source of soil organic matter in rubber plantation ecosystems. Quantity and quality of organic matter in soil ecosystem is of utmost importance in regulating the soil health. Subsequently rubber leaf litter itself becomes the principal organic matter source in rubber plantations and its turnover is estimated to be about 6 tonnes/ha/year (Krishnakumar and Potty, 1992).

Although an increasing amount of study on litter decomposition and nutrient cycling in tropical rain forest has been made available during the past few years (Gong and Ong, 1983) studies on leaf decomposition in plantations such as rubber plantations are relatively few. In rubber plantations it is difficult to manage the plantations so that they produce a litter mass with a fine layer that has leaves with a high nutrient content (Silva *et al*., 1998). The initial carbon to nitrogen ratio (C/N ratio) of rubber leaf litter is 23, and can be considered low (Höfer *et al*., 2000; Walpola *et al*., 2011). Organic carbon (C) and nitrogen (N) are important nutrients in organic materials and one of the indicators used for the food quality of plant litter is the ratio of carbon to nitrogen. Relatively lower nitrogen concentrations cause higher C : N ratio, which is considered to be low food quality, compared to higher nitrogen concentration, which has a lower C : N ratio and suggests high food quality (Leichtfried, 1995).

The rate of leaf litter decomposition varies widely. Many factors affect the rate of leaf litter decomposition and these factors interact with each other, such as physical factors, for example temperature, rainfall (Irons *et al*., 1994), mechanical abrasion, water chemistry, pH of the soil (Mulholland *et al.,* 1987; Griffith and Perry, 1994), as well as microbial activities, biofilm activities and altitude. Interactions among these factors affect the decomposition rate, and the diverse chemical composition of different types of leaf litter plays a crucial role in determining the rate of decomposition and nutrient cycling (Suberkropp *et al*., 1975; Burton *et al*., 1985; Dutta *et al*., 2001).

Microorganisms such as single-celled fungi and bacteria play a very important role in improving the structure, organic matter content and distribution of nutrient elements in the soil. They are crucial for the mineralization of leaf litter and also render it more palatable for leaf shredding invertebrates (Suberkropp, 1992). Consequently, along with driving decomposition processes fungi are important intermediaries in the energy flow through ecosystem.

In this chapter we have described the results of an experiment in which determined the mass loss, nutrients changes and concentration of during the decomposition of rubber leaf litter by some cellulolytic and xylanolytic fungi isolated from rubber leaf litter.

8.2 Materials and Methods

8.2.1 Leaf samples

Newly fallen leaves of rubber trees were gathered from rubber plantations in Naknon Si Thammarat Province. They were placed in plastic bags. The samples were returned to the Department of Pest Management Laboratory for processing within 2 days.

8.2.2 Fungi

Five species of fungi, *Aspergillus parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *Helicostylum piriforme* and *Trichoderma virens* were used in this study. It has been proved that they produced high cellulolytic and xylanolytic activity in agar plate tests. Each fungus was kept on PDA slant at 10^{o}C. The inoculum was prepared by culturing the fungus on PDA for 5 days. Then, 5 mm diameter mycelial plugs were cut from the edge of colony and used as inoculum.

8.2.3 Decomposting ability of each fungus

The experiment was performed based on the methods described by Fell and Master (1980); Chale (1993) and Sappa-aramdecha (2002) with some modifications. 184 g of leaves sample (100 g dry weight) were cut into 1 x 4 cm of rectangle, then soaked in 5% clorox for 10 min and washed 2 times with distilled water, placed into 7 x 15 cm plastic boxes with contained 30 ml of distilled water. Twenty pieces of 5-mm-diameter mycelial plugs on PDA were put into the plastic boxes (in control treatment, no fungus), thereafter incubated at the room temperature (28-32^{o}C) for 0-90 days.

Each treatment was replicated 4 times. The leaf samples were taken every 15 days to determine dry mass of the remaining leaves and nutrient concentration.

Leaf materials were removed from plastic boxes, and rinsed with distilled water. Samples were dried at $60^{o}C$ for 72 hours and weighed to obtain dry mass values (DM). The total of nutrient was analyzed at Central Lab, Faculty of Natural Resources, Prince of Songkla University. Nitrogen was determined by the Micro-Kjeldahal method, phosphorus using a spectrophotometer, potassium determined by flame photometry, calcium and magnesium by atomic absorption spectrophotometry (AOAC, 1997).

8.2.4 Statistical analysis

Data were subjected to analysis of variance procedures for a completely randomized design using the Statistical Analysis System (SAS) computer software package. The one-way analysis of variance was also done on the percentage of leaf litter that remained each time after partial decomposition. Data was compared with Duncan's Multiple Range Test (DMRT) at $P<0.01$. The leaf decomposition constant (k) was calculated by fitting the amount of dry mass (DM) of leaf litter to the exponential model. $Y_t/Y_0 = e^{-kt}$ or $k = -[\ln(Y_t/ Y_0)]/t$, where Y_t is the DM remaining after the time (t) in days and Y_0 is the DM at the beginning of the experiment (Petersen and Cummins, 1974; Kurzatkowski *et al.*, 2004; Walpola *et al.*, 2011).

8.3 Results

8.3.1 Mass loss and decomposition rate

The pattern of dry mass loss of rubber leaf litter in laboratory conditions after decomposition by the tested fungi are shown in Table 8.1. Weight loss from the rubber leaf litter was statistically significantly different ($p<0.01$) between fungal treatment and control treatment (no fungus). The percentage of leaf litter that remained at the end of the experiment was 51.89 - 54.89% of the initial mass, whereas in the control the leaf litter remained 60.22%. In other words, between 48.11-45.11% of the initial mass of the litter was lost by the tested fungi after 90 days of decomposition, while 39.78% were lost in the control.

A high value of decomposition rate (k) indicated a high rate of leaf litter weight loss. If the value of k was higher, the litter was decomposed faster (Devi and Yadava, 2007). In this study, *T. virens* treatment showed a high value of k value ($k=0.0292\ d^{-1}$) which was higher than with the other fungi, indicating that *T. virens* decomposed the rubber leaves faster than the other fungi, followed by *Cylindrocarpon* sp. ($k=0.0289\ d^{-1}$), *H. piriforme* ($k=0.0279\ d^{-1}$), *A. parasiticus* ($k=0.0272\ d^{-1}$) and *Beltrania* sp. ($k=0.0267\ d^{-1}$) (Table 8.1).

Table 8.1 The remaining dry mass (%) of rubber leaf litter after decomposing by *A. parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *H. piriforme* and *T. virens* for 15-90 days

Treatment	Time of decomposition (days)						k*
	15	30	45	60	75	90	
A. parasiticus	72.71∂0.01d	67.06∂ 0.67bc	63.72∂0.66c	61.39∂0.54d	58.22∂1.58b	54.22∂1.14bc	0.0272
Beltrania sp.	74.07∂0.02c	67.72∂0.66b	66.07∂0.03b	58.89∂0.64e	57.06∂1.68bc	54.89∂1.00b	0.0267
Cylindrocarpon sp.	72.71∂0.01d	66.07∂0.02d	65.72∂0.38b	61.55∂0.33d	55.05∂2.28c	52.22∂0.64d	0.0289
H. piriforme	72.71∂0.01d	66.55∂0.64cd	66.07∂0.02b	62.89∂0.64c	58.89∂1.48b	53.39∂0.54c	0.0279
T. virens	75.39∂0.54b	66.89∂0.64bc	65.89∂0.33b	64.39∂0.39b	57.89∂0.84b	51.89∂0.33d	0.0292
Control (no fungus)	76.22∂0.34a	69.40∂0.01a	68.74∂0.02a	67.40∂0.01a	62.55∂0.64a	60.22∂0.64a	0.0225
F-test	**	**	**	**	**	**	
C.V.(%)	0.35	0.79	0.52	0.76	2.60	1.41	

Note: k* = Decomposition rate /day^{-1}

** Mean followed by the same letter in are not significantly different by Duncan's Multiple Range Test at p<0.01

8.3.2 Nutrient content and the release of nutrient

The initial total nutrient contents in the newly fallen leaves of rubber trees are 2.26 g nitrogen, 0.15 g phosphorus, 0.56 g potassium, 1.45 g calcium and 0.33 g magnesium. After 90 days of decomposition, the nutrient content in the rubber leaf litter tend to be decreased in all treatments. The nutrient content of rubber leaf litter that remained the end of the experiment was 1.46-1.80 g nitrogen, 0.10-0.12 g phosphorus, 0.22-0.30 g potassium, 1.06-1.32 g calcium and 0.25-0.28 g magnesium. A high value of decomposition rate (k) indicated a high rate of nutrient release. After 90 days of decomposition, the k value in all treatments showed similar. Potassium showed a high value of k value (0.0230-0.0396 d^{-1}), followed by phosphorus (0.0117-0.0223 d^{-1}), nitrogen (0.0101-0.0195 d^{-1}), magnesium (0.0078-0.0132 d^{-1}) and calcium (0.0042-0.0140 d^{-1}) (Figure 8.1-8.6).

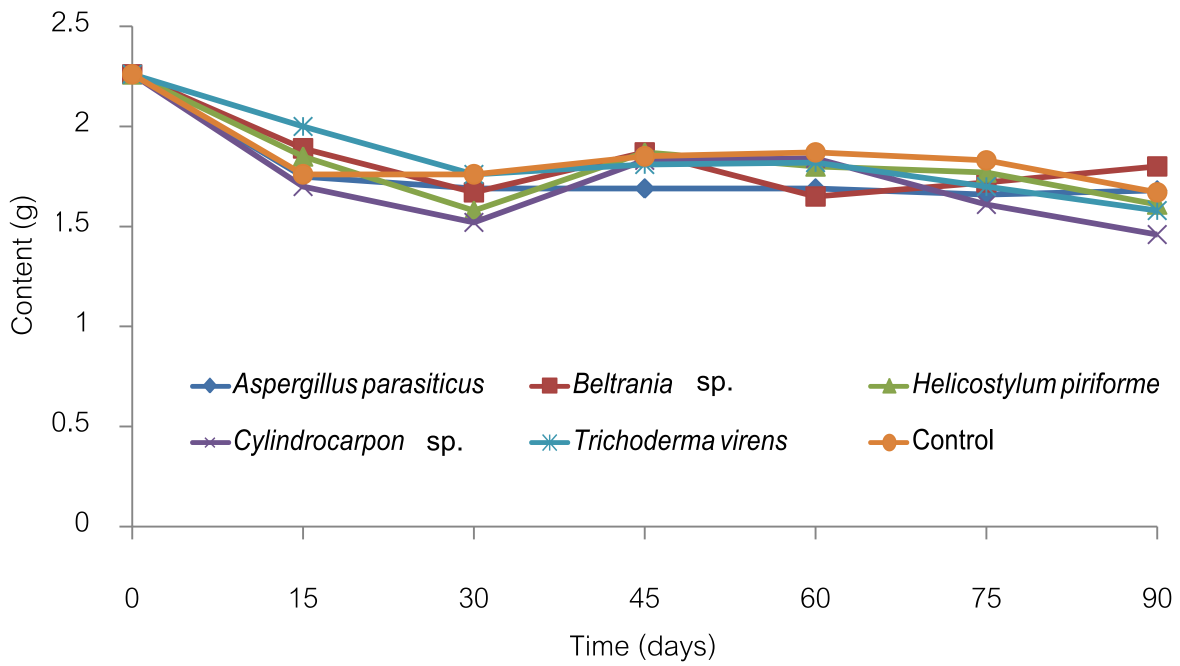


Figure 8.1 Remaining of nitrogen content in rubber leaf litter decomposition period (90 days)

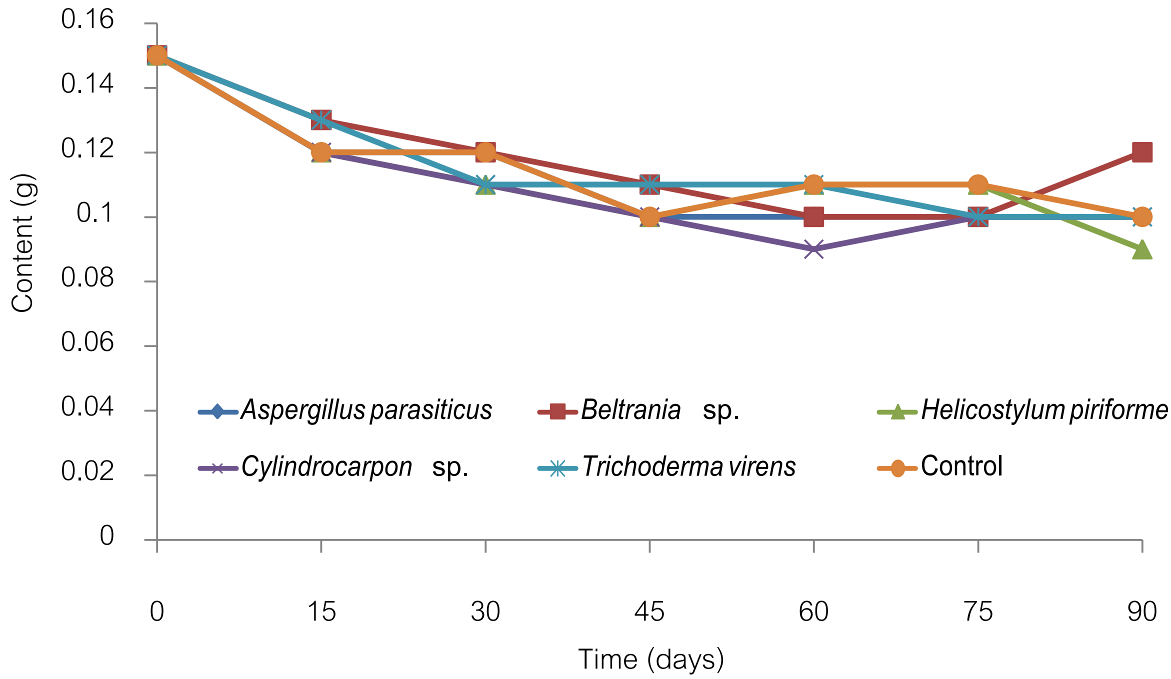


Figure 8.2 Remaining of phosphorus content in rubber leaf litter decomposition period (90 days)

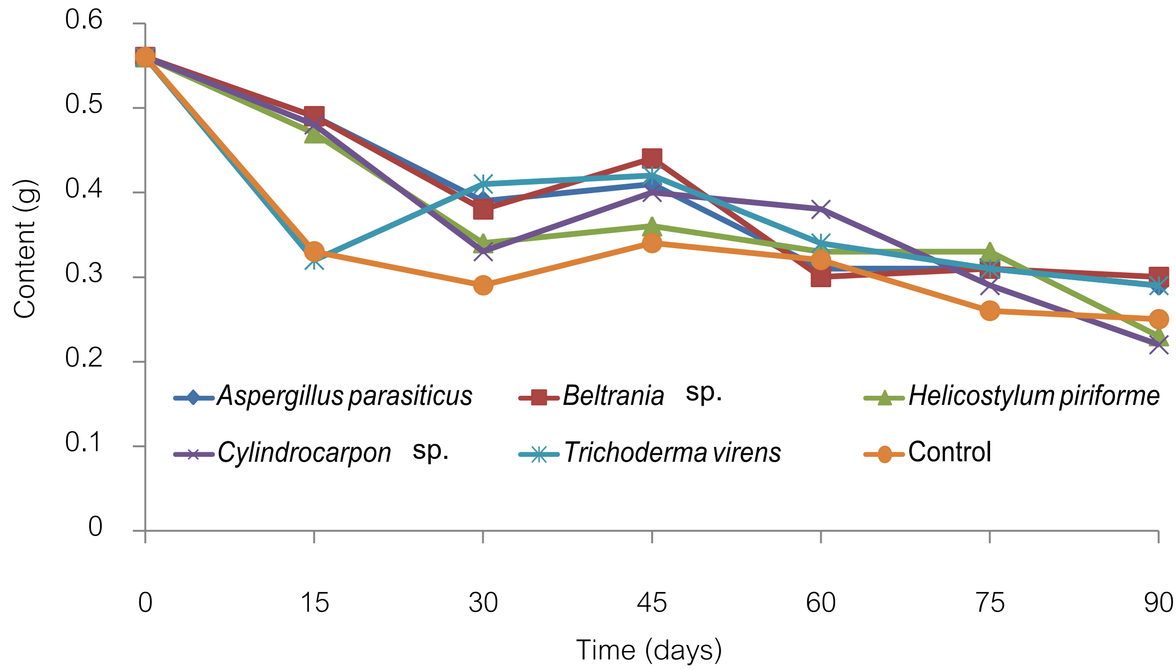


Figure 8.3 Remaining of potassium content in rubber leaf litter decomposition period (90 days)

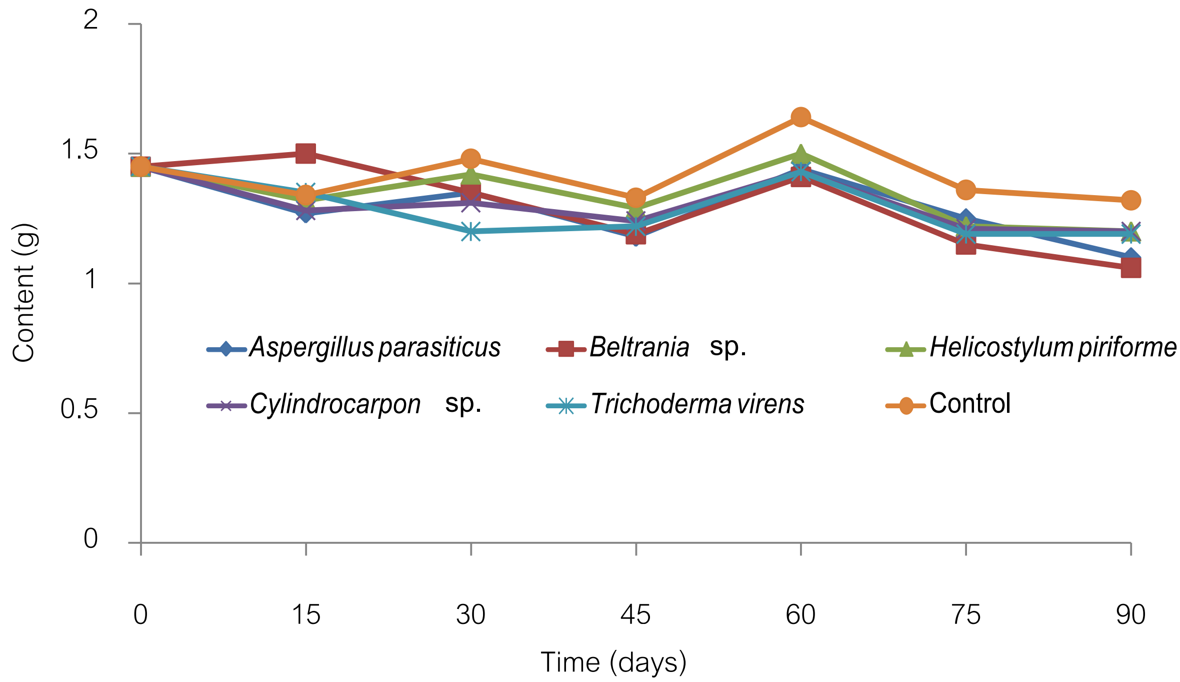


Figure 8.4 Remaining of calcium content in rubber leaf litter decomposition period (90 days)

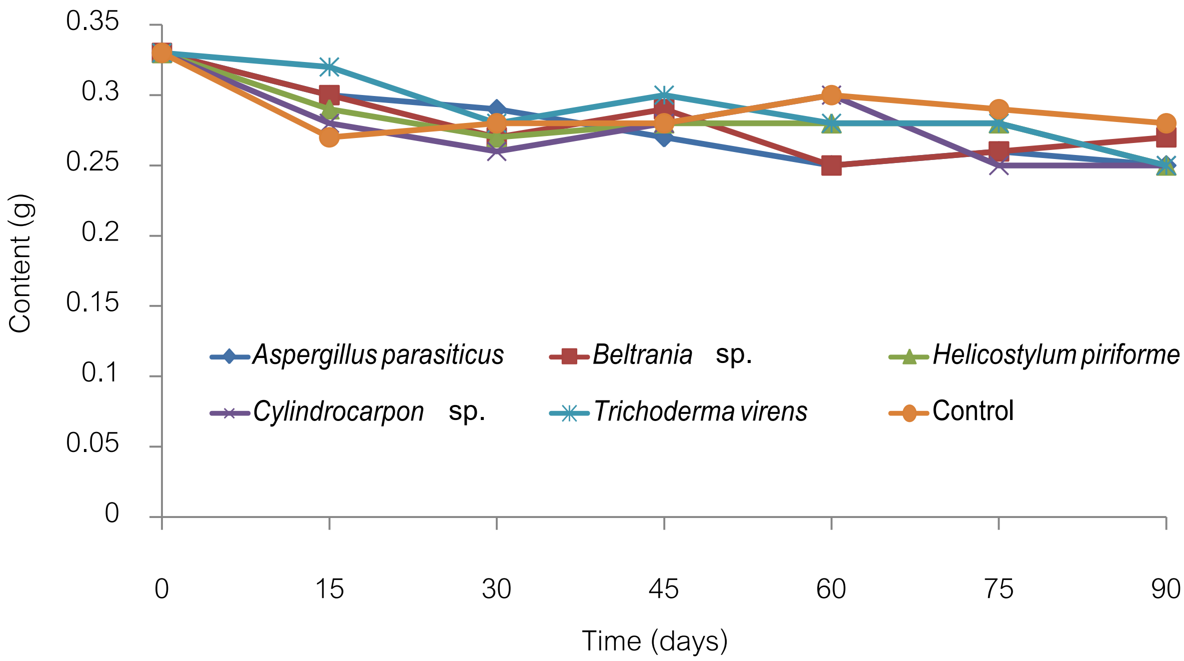


Figure 8.5 Remaining of magnesium content in rubber leaf litter decomposition period (90 days)

8.4 Discussion

8.4.1 Mass loss and rate of decomposition

This is the first study of rubber leaf decomposition in Thailand. The duration of the decomposition process in this study was 90 days in our laboratory. The decomposition of rubber leaf litter was significantly faster in fungi treated sample than in the control leaves (no fungus). The high value of k indicated that the rate of weight loss of leaf litter was high (Devi and Yadava, 2007). In this study the k value was between 0.0225-0.0292 d^{-1}, which is close to the range of that found in a tropical forest according to a previous study by Steinke and Ward (1987) which reported on the decomposition rate of *Bruguiera gymnorrhiza* during summer in South Africa with k value of 0.0123 d^{-1}. In addition, Mfilinge *et al.* (2002) found that the decomposition rate of *K. candelia* in subtropical forest was 0.0203 d^{-1}.

In this study, all treatments are classified as rapid decomposition rate types. According to Petersen and Cummins (1974) and Walpola *et al.* (2011), breakdown rates can be classified as rapid ($k>0.01$ d^{-1}), intermediate (0.01 $d^{-1} > k > 0.005$ d^{-1}) and slow ($k<0.005$ d^{-1}). The results were shown to be the same as Walpola *et al.* (2011) who studied leaf litter decomposition in *Ochlandra stridula*, *Alstonia macrophylla, H. brasilensis* and mixed leaves in coarse litterbags, and reported that the rapid breakdown rate occurred in *Alstonia macrophylla* (k=0.0550 d^{-1}), *H. brasiliensis* (k=0.0253 d^{-1}) and in mixed leaves litter (k=0.0155 d^{-1}) whereas in *Ochlandra stridula* there was shown an intermediate rate (k=0.0090 d^{-1}). In addition, Kurzatkowski *et al.* (2004) studied the decomposition of *Hevae*, *Bactris* and *Polyculture* leaf litter in the central Amazon area and found that the k value of each leaf litter contained in coarse litterbags was 0.009, 0.009 and 0.006 d^{-1}, respectively.

Akanil and Middleton (1997) reported leaf litter decomposition of *Salix alba, Populus alba, Typha latifolia, Phragmites australis* and *Acacia longifolia* using the fibers of glass technique and reported that after 180 days, soft leaved species such as

Acacia longifolia decomposed more quickly (0.52% loss day^{-1}) than the longer leaved species such as *Typha latifolia* and *Phragmites australis* (0.31 and 0.3% loss day^{-1}).

The higher weight loss in leaf litter in the initial stages and a gradual decrease at the last phase of decomposition as observed in the present study may be due to high initial content of water-soluble materials and simple substrate that is easily broken down by decomposers, especially by microorganisms and by removal of leaf litter particles by water (Bahuguna *et al*., 1990; Bargali *et al*., 1993; Devi and Yadava, 2007). Aziz (2007) studied microorganisms decomposition on *Salix alba* and *Salix fragilss* leaf litter found that using mixed inoculation (*Pseudomonas fluorescens* and *Azotobacter choroococum*) was the best for decomposition and nutrient release. Greater weight loss during the rainy season may be due to a high percentage of soil moisture and a high soil temperature, and also due to leaching of water-soluble substances from the litter mass. Smaller weight loss during winter may be due to cool and dry conditions. This is obvious from the positive correlation between the rate of weight loss with soil moisture and rainfall (Austin and Vitousek, 1991; Dasselar and Latinga, 2000).

8.4.2 Change of Nutrient content in leaf litter

During decomposition, nutrients from leaf litter are released by either leaching or microbial breakdown of structural components. In the latter process, elements limiting microbial growth are expected to be retained or accumulated to a minimum concentration and thereafter released at the same rate as organic matter weight loss, whereas nonlimiting elements would be released throughout the decomposition (Berg and Staaf, 1980). Lousier and Parkinson (1978); MacLean and Wein (1978) and Jordan *et al*. (1982) suggested that the process of microbial breakdown is quantitatively more important, and that element release rates assume different patterns over time in different environments.

A high value of decomposition rate (k) indicated a high rate of nutrient release. In this study, potassium showed a high value of k value (k=0.0326 d^{-1}), followed by phosphorus ($k=0.0173\ d^{-1}$), nitrogen ($k=0.0146\ d^{-1}$), magnesium ($k=0.0108\ d^{-1}$) and calcium ($k=0.0094\ d^{-1}$), respectively which according to previous studied. Singh (1980) reported that potassium, phosphorus and nitrogen are higher rate of release. Similar trend has been observed by Agejuyigbe (2000); Oladoye *et al*. (2007) in the humid tropical forest. This rapid release could be attributed to the rapid loss of water soluble compounds. Potassium and phosphorus are usually constituents of metabolites enzyme system of the plant sap. Calcium and magnesium are constituents of the structural make-up, such as the cell wall (Oladoye *et al*., 2007).

The rate at which nutrients are release depends on several factors including the composition of the litter, the structural nature of the nutrient in the litter matrix, microbial demand for the nutrient and the availability of exogenous sources of the nutrient (Swift *et al*., 1979; Scastedt, 1984). Climatic variable such as temperature and moisture have a great impact on the decomposition processes and nutrient release in leaf litter under natural conditions (Swift *et al*., 1979; Aziz, 2007). However, in this study, the nutrient concentrations trend to be increased may be due to the weight loss of leaf litter and component in substrate was decreased, thus the nutrient concentration of decomposed rubber leaf litter is high.

CHAPTER 9

CONCLUSIONS

The purpose of this study was to investigate the fungal diversity and fungal communities on leaf litter, branch litter, wood logs and soil in rubber plantation. Moreover, cellulolytic and xylanolytic enzyme activity and their ability to degrade rubber leaf litter were examined. The microfungi on leaf litter, branch litter and wood logs classified as newly fallen leaves/branches/logs, middle stage decaying leaves/branches/logs and old decaying fallen leaves/branches/logs, and at different seasons were studied. The microfungal communities on leaf litter, branch litter and wood logs were shown in Chapters 3, 4 and 5, respectively. The macrofungi (fruiting bodies) were observed on soil, leaf litter, branch litter and wood logs were shown in Chapter 6. The determination of cellulase and xylanase degrading ability of the isolated fungi were shown in Chapter 7. Finally, decomposition of rubber leaf litter by some cellulolytic and xylanolytic fungi were shown in Chapter 8.

9.1 Saprobic fungi from leaf liter

This is the first study of fungal communities on rubber leaf litter in Thailand. Results obtained showed that different stages of decomposition supported different assemblages and numbers of fungal taxa. A total of 503 fungal taxa were found on leaf litter. In the middle stage of decaying fallen leaves had the greatest diversity of leaf litter fungi, followed by newly fallen leaves and old decaying fallen leaves. Thirty fungal taxa were dominant species (over 10% occurrence) found at all stages of decomposition comprising, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Cladosporium tenuissimum*, *Hypoxylon* sp.1, *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Pestalosphaeria hansenii*, *Pestalotiopsis* sp.1, *Subulispora procurvata*, *Veronaea carlinae*, *V. coprophila* and *Wiesneriomyces javanicus*. In this study, samples collected in the dry season (April) were higher microfungal diversity than other seasons. *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Subulispora procurvata* and *Veronaea coprophila* were dominant species found at all seasons.

9.2 Saprobic microfungi from branch litter

The microfungal communities on branch litter (1-5 cm diameter) were investigated and described as shown in Chapter 4. A total of 450 fungal taxa were found on branch litter. In the middle stag decaying branches had the greatest diversity, followed by newly fallen branches and old decaying fallen branches. Ten dominant fungal taxa were found in all stages of decomposition comprising *Hypoxylon* sp.2, *Kirschsteiniothelia* sp., *Pestalosphaeria hansenii*, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Lasiodiplodia* cf. *theobromae*, *Nigrospora sphaerica*, *Paratomenticola lanceolatus*, *Torula herbarum* and *Veronaea carlinae*. In the dry season, the microfungal communities on branch litter were the greatest. Three taxa of microfungal were dominant species found during all seasons comprising *Bactrodesmium rahmii, Kirschsteiniothelia* sp. and *Lasiodiplodia* cf. *theobromae*.

9.3 Saprobic microfungi from rubber wood logs

The microfungal communities on wood logs ($\geq$ 10 cm diameter) of *H. brasiliensis* were investigated and described in Chapter 5. A total of 422 fungal taxa were found on wood logs. Fungal communities that were found on both wood logs and branch litter of rubber tree are more similar, except the fungal diversity of wood logs is slightly less than on the branch litter. In the middle stage decaying logs had the greatest diversity, followed by newly fallen logs and old decaying fallen logs. Six species, *Bactrodesmium rahmii*, *Botryodiplodia* sp., *Kirschsteiniothelia* sp., *Lasiodiplodia* cf. *theobromae*, *Paratomenticola lanceolatus* and *Veronaea coprophila* were dominant fungi found at all decomposition stages. In addition, the diversity of microfungi on wood logs was the highest in dry season. One species, *Bactrodesmium rahmii* was the dominant species found at all seasons.

A total of 927 fungal taxa were found on rubber plant litter, 503 species from the decaying leaves, 450 species from the decaying branches and 422 species from decaying wood logs. The overlapping of microfungal communities associated with rubber plant litter was found 194 species (40.71%) on leaf litter and branch litter, 175 species (38.83%) on leaf litter and wood logs, 205 species (47.02%) on branch litter and wood logs. Finally, 139 species (20.22%) found overlap at all plant litters.

9.4 Macrofungi on soil and rubber litter

Sporocarp surveys on soil, leaf litter, branch litter (1-5 cm diameter) and wood logs ($\geq$ 10 cm diameter) in rubber plantation habitat yielded 131 macrofungal taxa, comprising 42 families 66 genera were identified. Among them, 113 taxa (86.26%) belong to basidiomycetes and 18 taxa (13.74%) to ascomycetes. Forty-four species were found on soil, 15 species found on leaf litter, 70 species found on branch litter and 48 species found on wood logs. The macrofungi at different seasons were distinct. The number of fruiting bodies in the early rainy season was higher than in other seasons. The result obtained on soil, leaf litter, branch litter and wood logs are similar. Two species, *Marasmius alborescens* and *M. siccus* were dominat species (over 10% occurrence) found on leaf litter. *Hexagonia tenuis* and *Schizophyllum commune* were occurring dominant species on branch litter. *Hexagonia tenuis*, *Schizophyllum commune* and *Meruliopsis corium* were dominant species found on wood logs. Five species of macrofungi were found at all types of litter comprising *Xylaria aristata*, *X. hypoxylon*, *Marasmius aurantioferrugineus*, *M. pulcherripes* and *M. siccus*

9.5 Cellulolytic and xylanolytic enzymes

In this investigation, 39 fungal species out of 58 species (65.52%) showed clearance of the cellulose containing medium. For xylanolytic fungi, 35 fungal species (61.54%) produced extracellular xylanase on XBM. Twenty-six species produced both cellulase and xylanase enzymes belonging to *Aspergillus carbonarius*, *A. japonicus* var. *aculeatus*, *A. japonicus* var. *japonicus*, *A. kanagawaensis, A. niger, A. parasiticus, A. sclerotiorum*, *A. tamarii*, *Beltrania* sp., *Botryodiplodia* sp., *Cylindrocarpon* sp., *Fusarium redolens*, *Helicostylum piriforme*, *Phyllosticta* sp., *Rhizopus* sp., *Syncephalastrum recemosum*, *T. atroviride*, *T. aureoviride, T. harzianum, T. inhamatum, T. koningii, T. longibrachiatum, T. pseudokoningii*, *T. reesei, T. virens* and *T. viride*. Among these, five species exhibited the highest production of cellulase and xylanase including *A. parasiticus*, *Beltrania* sp., *Cylindrocarpon* sp., *H. piriforme* and *T. virens*.

9.6 Rate of decomposition

The weight loss from the rubber leaf litter was significant different between fungal treatment and control treatment. The percent of leaf litter remained at the end of experiment was 51.89-54.89%, whereas in control the leaf litter remained was 60.22%. Weight loss in cellulotytic and xylanolytic fungal treatments were rapidly decreased, 23.78% loss of dry weight within 15 days, thereafter they continued decreasing until end of the experiment. The highest decomposition constant (k) was obtained in *T. virens* treatment (k=0.0292 d^{-1}), followed by *Cylindrocarpon* sp. (k=0.0289 d^{-1}), *H. piriforme* (k=0.0279 d^{-1}), *A. parasiticus* (k=0.0272 d^{-1}) and *Beltrania* sp. (0.0267 d^{-1}).

9.7 Suggestions and comments

After several years of study on fungal diversity of rubber tree (*H. brasiliensis*), I realize that some data in the experiments are not completed. The changes of moisture, temperature and chemical component in rubber plant litter at each stage of decomposition and each season have not been investigated. They are important in terms of drawing conclusions from the study. More details on these data will improve our confidence to conclude which factors really influence fungal diversity during the decomposition of rubber plant litter.

In this study, I acknowledge that several of the species are name complexes e.g. *Colletotrichum gloeosporioides* (Hyde *et al*., 2009; Phoulivong *et al*., 2010), however the account reveals the present 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 microfungi on rubber plant litter and the fruiting bodies. 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.

9.8 Future study

To obtain further knowledge supporting biodiversity of saprobic fungi on *H. brasiliensis*, further study should be carried out such as:

1. The endophytic fungi on *H. brasiliensis* are unknown. Further experiments are needed to examine biodiversity and life strategies of endophytic, pathogenic and saprobic fungi which are related during decomposition stage especially in newly fallen plant litter.

2. Studies of enzymes from microfungi on rubber leaf litter confirmed that some cellulolytic and xylanolytic fungi are effective in increasing the rate of decomposition and nutrient available. Further study should concentrate on the production of valuable compounds, which can be applied for agricultural and biotechnological uses.

3. Studies of community dynamics if based on sporophore surveys should be made with extreme caution as their appearance may bear little relationship to the arrival, activity or decline of the supporting mycelia and the relationship will vary for different individuals. Thus, the time taken for the mycelium to derive sufficient resource to devote to sporophores production may be one or more seasons but may be evident only temporarily and the active mycelium of some fungi may not produce sporophores

until their final stage of colonization. Thus, repeated surveys of the same plots will be needed to detect most species.

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Appendix A

Table 3.1 Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota												
Amerosporium sp.		2.08										
Aquaticheirospora lignicola								2.08				
Astrosphaeriella sp.	6.25			2.08			4.17					
Broomella acuta							2.08			2.08		
Ceratocystis ulmi		2.08			2.08							
Ceratohorum uncinatum		4.17										
Ceratosporella deviata											2.08	
Chaetomium sp.									2.08			
Dothidotthia sp.2	2.08			4.17						2.08		
Eupenicillium sp. [1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Glomerella cingulata		6.25						14.58	8.33	2.08	10.42	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Gnomonia amoena	2.08											
G. fragariae			8.33			4.17						
Hypoxylon sp.1	2.08	8.33	4.17	2.08	10.42	2.08	6.25	8.33	6.25	8.33	4.17	12.50
Hypoxylon sp.2	2.08	2.08	2.08	2.08		2.08	2.08			6.25	8.33	4.17
H. cohaerens	2.08	6.25			6.25		2.08			4.17	4.17	
Leptosphaeria darkeri		2.08								2.08	4.17	
Linocarpon sp.			4.17					2.08	8.33			
Linospora sp.	2.08	14.58	2.08	4.17	6.25	2.08	2.08	6.25			8.33	4.17
Nectria ventricosa		2.08			4.17			4.17				
Kirschsteiniothelia sp.	4.17		2.08	12.50	16.67	8.33	14.58	18.75	18.75	8.33	22.92	14.58
Pestalosphaeria hansenii	2.08	2.08	4.17	2.08	10.42	12.50	8.33	12.50	2.08	14.58	18.75	8.33
Talaromyces flavus[1/]	2.08			2.08			2.08			2.08		
Thyridaria sambucina		2.08	4.17		4.17	4.17		4.17	4.17		4.17	6.25

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Xylaria sp.					2.08			2.08			2.08	
X. hypoxylon								10.42				
Basidiomycota												
Marasmius sp.			6.25			6.25			4.17			
Mitosporic fungi												
Acarocybe deightonii	2.08			6.25								
A. hansfordii		2.08			2.08							
Acremonium sp.					2.08							
A. butyri	2.08		2.08	2.08		4.17		2.08	2.08	2.08		
A. cerealis[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. fusidioides		2.08	2.08			2.08			2.08			
A. kiliense[1/]					2.08							
A. murorum		2.08			2.08							
A. strictum		2.08										

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Actinocladium rhodosporum									2.08			
Alternaria sp.[1/]				2.08							2.08	
A. pluriseptata						2.08			2.08			
A. radicina			6.25			2.08						
Anguillospora sp.										2.08		
Annellophroagmia sp.			2.08			4.17						6.25
Aposphaeria peizizoides	20.83	10.42		10.42	2.08		2.08			2.08		
Articulospora tetracladia	6.25		2.08				4.17	12.50	6.25		8.33	14.58
Aspergillus sp.1	2.08	2.08	4.17	4.17	6.25			2.08		2.08		
Aspergillus sp.2	2.08	2.08	2.08	4.17	4.17	4.17		2.08	2.08	2.08		2.08
Aspergillus sp.3						2.08						2.08
A. aculeatus[1/]						2.08				2.08		
A. carbonarius[1/]										2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
A. caespitosus[1/]		2.08										
A. japonicus[1/]					2.08							
A. var. *aculeatus*[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. var. *japonicus*[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. kanagawaensis[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. niger[1/]											2.08	
A. puniceus[1/]										2.08		
A. pulverulentus[1/]											2.08	
A. parasiticus[1/]										2.08		
A. restrictus[1/]			2.08			2.08			2.08	2.08		2.08
A. sclerotiorum[1/]			2.08			2.08					2.08	2.08
A. sojae[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. sydowii[1/]											2.08	2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
A. tamarii[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Bactrodesmium betulicola							2.08					
B. longisporum							2.08					
B. pallidum						2.08						2.08
B. rahmii	2.08	2.08	6.25		6.25	6.25	6.25	25.00	25.00	2.08	4.17	4.17
B. spilomeum				4.17	2.08		6.25				2.08	
Balladynopsis vanderystii	4.17			2.08								
Beltrania sp.[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Beltrania santapaui			2.08			2.08			2.08			
Berkleasmium cf. *minutissimum*					2.08							
B. macropus	6.25											
Bipolaris sp.1	8.33			4.17	4.17			2.08				

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Bipolaris sp.2	2.08			2.08			2.08	2.08		2.08		
Bipolaris sp.3	2.08						4.17					
B. heveae							2.08			2.08		
Bisporostilbella sp.											4.17	
Botryodiplodia sp. [1/]	25.00	4.17	6.25	14.58	6.25	8.33	10.42	6.25		4.17	8.33	2.08
Brachydesmiella biseptata			2.08			2.08					2.08	6.25
Calospora platanoides					4.17			6.25			4.17	
Camarosporium rosae				6.25								
C. salicinum									2.08			
Camposporium sp.								2.08				
C. antennatum	2.08						2.08	2.08				
C. cambrense	2.08			2.08	2.08		8.33				2.08	
Canalispora pallidum				2.08						2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Canalisporium caribense			2.08			2.08						2.08
C. pallidum												2.08
Cercospora sp.1	2.08	2.08		4.17						2.08		
Cercospora sp.2		4.17			2.08						2.08	
Cercospora sp.3	4.17						2.08					
Cercospora sp.4	4.17						2.08					
Cercospora sp.5								2.08			2.08	
C. apii		2.08			6.25							
C. chevalieri												4.17
C. fusimaculans		2.08			8.33							
C. opuli				2.08								
C. vaginae				2.08								
Ceriospora polygonacearum										2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Chaetochalara sp.	4.17			2.08			6.25					
Chaetopsina fulva		8.33			8.33			4.17				
Chalara sp.	2.08						2.08				2.08	6.25
Chalariopsis sp.		4.17										
Chrysosporium pannorum		2.08			2.08							
Chuppia sarcinifera					2.08							
Circinotrichum fertile		2.08					4.17	2.08				
C. maculiforme	4.17		2.08	2.08								
C. poonense		2.08						2.08				
Cladosporium sp.1[1/]				2.08								
Cladosporium sp.2			6.25			2.08						
C. balladyner						2.08						
C. britannicum		4.17		2.08					4.17			

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. flavum	4.17	14.58		16.67	29.17	20.83						
C. gallicola							6.25		4.17			
C. orchidis	2.08	4.17		22.92	18.75	2.08		2.08			2.08	2.08
C. psoraleae[1/]									2.08			
C. tenuissimum[1/]	6.25		4.17	8.33	2.08	4.17	18.75	10.42	8.33			
C. uredinicola					2.08							
Clavariopsis aquatica	2.08			2.08								
Codinaea sp.1		2.08		2.08	2.08		4.17	4.17	4.17		4.17	
Codinaea sp.2								6.25			2.08	
Codinaea sp.3	2.08			4.17		2.08		2.08				
C. assamica	8.33			2.08			2.08	2.08		2.08		
C. britannica								4.17				
C. fertilis	2.08		2.08	2.08		4.17	6.25	2.08			2.08	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. hughesii											2.08	
Colletotrichum sp.1[1/]		6.25			2.08						2.08	
Colletotrichum sp.2	4.17	2.08		2.08	2.08		12.50	2.08		2.08		
Colletotrichum sp.3	2.08			2.08			2.08			2.08		
C. dematum	2.08			2.08								
C. gloeosporioides[1/]	6.25			8.33			2.08	2.08		6.25	8.33	
Corynespora sp.1								4.17				
C. cassiicola		6.25	4.17		2.08	2.08					2.08	
C. novae-zelandiae			2.08			2.08						
Corynesporopsis quereicola			4.17			10.42			2.08			4.17
Coryneum sp.	4.17			2.08								
C. elevatum						2.08						
Curvularia geniculata						2.08						

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. lunata	2.08	4.17	2.08	4.17	20.83	4.17		12.50	4.17		2.08	2.08
C. pallescens			2.08			2.08	6.25	2.08	4.17			
C. senegalensis					2.08							
Cylindrocarpon sp. [1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Cylindrocladium sp.1						4.17						2.08
Cylindrocladium sp.2	2.08						4.17	2.08				
C. parvum[1/]		4.17	2.08			6.25		2.08	6.25		4.17	8.33
C. scoparium	6.25	6.25		4.17			8.33				4.17	
Cytosporina sp.		2.08										
Dactylaria sp.1		4.17	2.08	6.25		2.08	2.08	6.25		10.42	6.25	4.17
Dactylaria sp.2	2.08	2.08	4.17		2.08	10.42	6.25			8.33	4.17	2.08
Dactylaria sp.3			2.08								6.25	2.08
D. hyalina	2.08	4.17	6.25		2.08	2.08		8.33	6.25		2.08	10.42

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
D. junci				4.17			2.08	6.25			2.08	
D. obtriangularia			4.17			2.08						2.08
Dactylella ellipsospora			4.17									
D. obtriongularia			2.08									
Dendrospora erecta		4.17									2.08	
Dendryphiopsis atra	4.17			2.08								
Dichomera prunicola		2.08			4.17							
Dictyosporium sp.					2.08							
D. elegans										4.17		
D. manglietiae				2.08			2.08		2.08	2.08		4.17
Diplococcium sp.				6.25			6.25			2.08		
Diplodia sp.		6.25		8.33	8.33							
D. zeae			10.42			10.42			10.42			4.17

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Diplodina sp.		8.33			4.17							
Diplorhinotrichum candidulum										2.08		
Discosia maculicila	2.08			2.08								
Elletevera parasitica		4.17			6.25							
Ellisembia paravaginata				4.17			2.08			2.08		
E. vaginata	2.08	4.17		2.08	10.42			6.25		2.08	4.17	
Ellisiopsis sp.						2.08						
Endophragmia bisbyi	4.17			2.08			2.08					
E. hyalosperma											2.08	
E. parva											8.33	
Endophragmiella theobromae											2.08	
Ephelis borealis			2.08			4.17			2.08			2.08
Exosporium phyllantheum		8.33			2.08			2.08			6.25	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Fibulocoela sp.	4.17			6.25								
Faseriella sp.			2.08			2.08			4.17			2.08
Fulvia sp.		2.08			4.17							
Fusarium sp.1			2.08			4.17			2.08			2.08
Fusarium sp.2						6.25						
Fusarium sp.3	14.58			10.42	6.25		8.33					
Fusarium sp.4	4.17	2.08			8.33		6.25				2.08	
Fusarium sp.5	8.33	8.33		2.08	6.25		2.08					
Fusarium sp.6	2.08	8.33		2.08	2.08		2.08					
Fusarium sp.7	2.08			2.08	4.17		2.08					
Fusarium sp.8		4.17			8.33			10.42			6.25	
F. moniliforme[1/]				2.08						2.08		
F. oxysporum[1/]	2.08	2.08					2.08			2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
F. redolens[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	
F. semitectum[1/]	2.08			4.17			12.50			2.08		
Fusoma rubricosa		2.08			4.17			4.17				
Genicularia cystospora	2.08			4.17			4.17					
Griphoshaeria corticola									2.08			
Gyrothrix podosperma		2.08			2.08			2.08	4.17	2.08		
G. circinata		2.08						2.08				
Hansfordia pulvinata	4.17	6.25		10.42	12.50	2.08				2.08		
Haplographium mangiferae		4.17			4.17		2.08					
Harknessia sp.	2.08											
Harpographium sp.	2.08	2.08		2.08			4.17					
Harposporium sp.					2.08						2.08	
Helicosporium aureum								2.08				2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Helicostylum piriforme[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Helminthosporium sp.				4.17	2.08		2.08		2.08			
H. heveae	2.08	2.08		2.08	2.08		2.08	2.08		2.08	2.08	
Hendersonia sp.		6.25			6.25			4.17			6.25	
H. celtifolia			4.17			6.25			2.08			
Hendersonula sp.		8.33			10.42			2.08			2.08	
Henicospora coronata		6.25	8.33		2.08	6.25		4.17	14.58		2.08	2.08
Heteroconium sp.									2.08			
Heteropatella alpina	2.08			4.17								
Hobsonia mirabilis			2.08									
Hormiactis candida		2.08					2.08		6.25			
Hyphodiscosia jaipurensis									6.25			
Idriella sp.1			6.25			10.42						2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Idriella sp.2		4.17						2.08			2.08	
I. fertile			2.08		2.08	2.08					2.08	2.08
I. lunata		12.50	2.08	12.50	8.33	6.25	12.50	6.25				2.08
Kellermannia yaccaegena	2.08			6.25								
Kramasamuha sp.	2.08		2.08									
Lasiodiplodia cf. *theobromae*[1/]	2.08	4.17	2.08	6.25	8.33	8.33	10.42	14.58	20.83	10.42	12.50	2.08
Lateriramulosa uni-inflata	2.08			4.17								
Leptodiscella africana	4.17	4.17			8.33	6.25	2.08	6.25	2.08		2.08	8.33
Menispora sp.	2.08						2.08	2.08		2.08	8.33	
Menisporopsis profusa	2.08	2.08										
M. theobromae	10.42	4.17		2.08	6.25						2.08	
Microsporium sp.		2.08			4.17							
Monacrosporium sp.1	2.08											

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Monacrosporium sp.2			2.08						2.08			
Monacrosporium sp.3		2.08			2.08						2.08	
Monochaetia sp.	16.67	6.25		4.17	2.08		2.08			2.08		
Monodictys glauca		4.17			6.25							
Murogenella terricola			2.08			2.08						2.08
Mycovellosiella solani-torvi											2.08	
Nigrospora sphaerica	4.17	2.08	4.17	12.50	20.83	4.17	8.33	10.42	16.67	20.83	14.58	8.33
Paecilomyces sp.[1/]	2.08		4.17	4.17			2.08	2.08				
P. varioti[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Panchanania jaipurensis		6.25	6.25			2.08		12.50	18.75		2.08	8.33
Paranospora novae-zelandiae			4.17			2.08			6.25			
Parasympodiella podocarpi	4.17											
Penicillium sp.1	4.17	2.08	2.08	14.58	14.58	6.25	2.08	4.17		2.08		2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Penicillium sp.2	2.08		2.08	2.08	10.42	4.17		2.08		2.08		
Penicillium sp.3	2.08		2.08			4.17				2.08		
Penicillium sp.4[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Penicillium sp.5[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Penicillium sp.6[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. canescens[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. citrinum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. janthinellum[1/]		2.08			2.08			2.08				
P. griseofulvum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. minioluteum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. rubrum[1/]	2.08		2.08	2.08		2.08	2.08			2.08		
P. simplicissium[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Pestalotia sp.		4.17			4.17	4.17						

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Pestalotiopsis sp.1	2.08	2.08	2.08	4.17	8.33	2.08	6.25		2.08	8.33	8.33	4.17
Pestalotiopsis sp.2	2.08			2.08	2.08	8.33	8.33	2.08				
Pestalotiopsis sp.3				6.25	2.08			2.08		4.17		
Pestalotiopsis sp.4	2.08											
P. disseminata	2.08		2.08		8.33	10.42	8.33			2.08	8.33	10.42
P. guepini[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. sydowia			2.08			2.08					2.08	6.25
Peyronellaea sp.	2.08											
Phaeoisaria sparsa				6.25			2.08			2.08	2.08	
Phaeoisariopsis sp.		2.08			4.17							
Phaeoramularia oldenlandiae												2.08
Phoma sp.	2.08						2.08					
Phomopsis sp.	6.25	4.17		2.08	2.08						2.08	

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Phyllosticta sp.					8.33						2.08	
Pilulina nigrospora												2.08
Pithomyces graminicola				2.08								
Pleurophragmium acutum	2.08			8.33			4.17					
Polyschema sp.		2.08			6.25							
Pseudogliomastix sp.			4.17			6.25						
Pseudospiropes hughesii		6.25			4.17							
Pteroconium intermedium				2.08			2.08					
Pucciniopsis sp.		8.33			4.17			2.08				
Pyriculariopsis parasitica								2.08				
Ramularia tulasnea	8.33			2.08								
Rhexoampullifer sp.				2.08								
Rhinocladiella sp.					2.08							

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Rhombostilbella rosae			2.08									
Sarcopodium tortuosum		6.25										
Scolecobasidiella avellanea							6.25			10.42	2.08	
Scolecobasidium compactum			4.17			6.25		10.42	6.25		6.25	2.08
S. dendroides					2.08				4.17			
S. salinum									4.17			
Selenosporella sp.						2.08	2.08		2.08			
Septocylindrium aromaticum			6.25			6.25						2.08
Seynesiella sp.1				6.25								
Sirosporium antenniforme	2.08			4.17			4.17			2.08		
Spegazzinia deightonii				2.08					2.08	2.08		
S. loboluta										2.08		

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Speiropsis hyalospora		12.50			4.17	4.17	4.17	10.42	2.08		2.08	
S. pedatospora						2.08			4.17			
Spermospora avenae	2.08			2.08								
S. subulata					4.17							
Spiropes capensis		2.08	6.25		8.33						4.17	
S. effusus		4.17			2.08							
S. fumosus			2.08			4.17						
S. japonicus		2.08			2.08			2.08				
S. penicillium		2.08			2.08			2.08			4.17	
Spondylocladiella botrytioides	2.08		2.08	4.17		2.08	4.17	4.17	2.08	4.17		
Sporidesmium sp.1		6.25			2.08						2.08	
Sporidesmium sp.2					2.08			2.08				
Sporidesmium sp.3					2.08			2.08				

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Sporidesmium sp.4					2.08			2.08				
Sporidesmium sp.5	4.17			4.17								
S. aburiense								2.08				
S. baccharidis			8.33	2.08		4.17			2.08			2.08
S. bambusae	4.17						4.17			2.08		
S. bambusicola									6.25			
S. dioscoeae					2.08			2.08	4.17			
S. flagellatum			2.08			2.08						4.17
S. japonicus			6.25			4.17						
S. jasminicola							2.08	4.17	4.17			
S. leptosporum		2.08			2.08	2.08		2.08	4.17	4.17		
S. longirostratum		6.25			2.08							

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. nodipes			2.08			2.08						
S. rubi	2.08		2.08		2.08		2.08	2.08	4.17	2.08		
S. uvariicola												2.08
Sporoschismopsis sp.	2.08			2.08								
Stachybotrys sp.		4.17			2.08		2.08					
S. sansevieriae		2.08			2.08						2.08	
Stenella liabicola											8.33	
S. pithecellobii	4.17	4.17		6.25	2.08		4.17		2.08	12.50	8.33	4.17
Stigmina sp.											2.08	
S. combreticola	4.17			4.17		2.08			2.08			2.08
S. kranzii								2.08				
S. murrayae												2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. obtecta									2.08		2.08	
Stilbospora sp.				2.08								
Stilbum sp. [1/]	2.08			2.08								
Strumella coryneoidea			4.17			2.08						
Subulispora sp.	8.33			6.25					2.08	2.08		
S. procurvata		4.17	2.08		4.17	14.58	8.33	20.83	18.75	2.08	12.50	10.42
Syncephalastrum recemosum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Taeniolella scripta					6.25						2.08	
Taeniolina centaurii								2.08				
Tetraploa aristata	4.17	4.17	2.08	10.42	16.67	2.08	2.08	18.75	10.42	6.25	10.42	
Tetraposporium sp.								2.08				
Torula sp.			2.08	6.25		4.17	16.67		6.25	6.25		
T. herbarum			2.08		14.58	2.08	10.42	16.67	10.42	14.58	12.50	4.17

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Toxosporiums sp.		2.08			2.08						4.17	
Tretospora sp.	8.33			2.08								
Triadelphia heterospora		4.17		4.17								
Trichoderma sp.1		2.08			2.08			2.08				
T. atroviride[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. aureoviride[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. harmatum[1/]			2.08			2.08						2.08
T. harzianum[1/]	2.08	2.08	6.25	2.08	2.08	6.25	2.08	2.08	2.08	2.08	2.08	2.08
T. inhamatum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. koningii[1/]	2.08			2.08						2.08		
T. longibrachiatum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. parceramosum[1/]		2.08						2.08				
T. pseudokoningii[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. reesei[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. virens[1/]		2.08			2.08			2.08				
Trichodochium disseminatum	2.08			2.08	8.33			2.08		2.08		
Tricladium castaneicola	2.08			2.08	2.08		4.17	2.08				
T. fuscum	2.08									2.08		
Triscelophorus acerinum	2.08			2.08								
T. acuminatus		2.08	2.08		2.08					2.08	4.17	22.92
T. monoporus					2.08			2.08	4.17			4.17
T. panapensis	2.08	4.17	2.08	4.17		2.08	6.25	16.67	25.00		8.33	4.17
Truncatella sp.							2.08					
Tubercularia vulgaris		2.08										
Varicosporium eladeae							4.17					
Veronaea sp.		2.08			2.08							

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
V. botryosa							2.08					
V. carlinae		2.08	6.25	10.42	4.17	6.25	8.33	10.42	10.42	2.08	8.33	
V. coprophila	4.17	18.75	12.50	12.50	20.83	20.83	10.42	20.83	12.50	6.25	12.50	8.33
Verticillium sp.	2.08	2.08		2.08								
Vulutella fructi	4.17											
Wiesneriomyces javanicus	6.25	10.42	4.17	4.17	4.17	4.17	2.08	12.50	6.25		4.17	4.17
Zanclospora sp.		2.08			2.08			2.08			2.08	
Zygosporium echinosporum	2.08			6.25	2.08	2.08						
Z. gibbum				12.50	2.08	6.25					4.17	
Z. masonii		6.25		12.50	8.33	4.17	2.08					
Z. oscheoides							2.08					
Zygomycota												
Rhizopus sp.[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08

Table 3.1 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Total number of species	123	126	96	125	136	106	104	107	83	84	102	76
recorded at each season		345			367			294			262	

Note: 1/ Isolate from dilution plates

* Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

Table 3.2 Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota												
Claussenomyces prasinulus		2.08										
Cucurbitaria elongata	4.17								6.25	6.25		
Dothidotthia sp.1	2.08				4.17		2.08	2.08		4.17		
Dothidotthia sp.2								2.08				
Dothiorella sp.		2.08										
Eupenicillium sp. [1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Gaeumannomyces graminis	4.17											
Glomerella cingulata											2.08	
Hypoxylon sp.1	10.42	6.25	6.25	6.25	6.25	2.08	6.25			14.58	4.17	6.25
Hypoxylon sp.2	4.17	2.08		4.17	4.17	6.25	2.08		2.08	4.17		
Hypoxylon sp.3		2.08			4.17	4.17				6.25	4.17	
Hypoxylon sp.4					2.08						2.08	

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
H. cohaerens											4.17	
Kirschsteiniothelia sp. [1/]	8.33	10.42	18.75	10.42	16.67	8.33	16.67	12.50	16.67	16.67	20.83	18.75
Leptosphaeria blumeri								2.08				
L. darkeri								2.08			2.08	6.25
Linocarpon sp.		2.08			2.08						2.08	
Linospora sp.		8.33			2.08			4.17			2.08	
Lophiostoma semiliberum			2.08									
L. viridarium	2.08											
Oedothea vismiae	4.17			10.42								
Pestalosphaeria hansenii		12.50	6.25	4.17	10.42	4.17	2.08	8.33	4.17	4.17	4.17	
Thyridaria sambucina			10.42	2.08	2.08	6.25	2.08	12.50	12.50		14.58	12.50
Basidiomycota												
Marasmius sp.			2.08			2.08						4.17
Oomycota												

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Phytophthora sp.	4.17											
Mitosporic fungi												
Acarocybe formosa				2.08								
Acremonium alternatum	2.08											
A. cerealis[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. fusidioides	2.08				4.17							
A. kiliense[1/]	2.08			6.25	2.08		2.08				2.08	
A. strictum										2.08		
Acrodictys sacchari		4.17										
Acrostaurus turneri									2.08			4.17
Acticulospora tetracladia			14.58		2.08	2.08		4.17	4.17			4.17
Alternaria pluriseptata			2.08									2.08
Annellophora solani		6.25									4.17	

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Arnoldiomyces sp.		6.25										
Arthrinium meulleri	6.25			2.08								
Arthrobotryum atrocephalum	2.08	10.42			2.08			4.17				
Aspergillus sp.1	8.33	4.17	2.08	2.08	4.17	4.17				2.08	4.17	2.08
Aspergillus sp.2		2.08	2.08	2.08	2.08	2.08	2.08					
Aspergillus sp.3				4.17		4.17						
A. cabonarium[1/]											2.08	2.08
A. caespitosus										2.08		
A. flavus				2.08							2.08	
A. japonicus[1/]	2.08			2.08			2.08			4.17		
A. var. *aculeatus*[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. var. *japonicus*[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. kanagawaensis[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
A. niger[1/]	2.08			2.08					2.08			
A. parasiticus[1/]					2.08							
A. pulverulentus[1/]				4.17								
A. puniceus[1/]									2.08		2.08	
A. restrictus[1/]											2.08	
A. sclerotiorum[1/]										2.08		
A. sojae[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. sydowii[1/]		2.08			2.08					2.08		
A. tamarii[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
A. terreus[1/]	2.08									2.08	2.08	
Bacillispora aquatica			2.08						2.08			2.08
Bactrodesmium sp.								2.08				
B. betulicola							2.08					

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
B. myrtii				2.08						2.08		
B. pallidum					2.08			2.08				
B. rahmii	2.08	8.33		6.25	4.17	4.17		20.83	10.42	10.42	4.17	2.08
B. spilomeum	2.08		6.25			4.17	14.58		6.25	2.08		
Beltrania sp. [1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
B. rhombica			2.08									
Beltraniella fertilis			2.08			2.08			6.25		4.17	
B. humicola											4.17	
B. odinae						2.08						
B. pini						2.08						
B. pizozynskii	2.08			2.08		2.08						208
Berkleasmium cf. *minutissimum*		2.08		2.08	2.08							
Bidenticula cannae							2.08					

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Bipolaris sp.					2.08			2.08				
B. ellisii[1/]		2.08										
B. haveae	2.08			4.17			2.08	2.08		2.08		
Bispora antennata									2.08			
Botryodiplodia sp.		8.33		2.08	4.17	2.08	4.17	20.83	12.50	6.25	4.17	20.83
Botryotrichum sp.	2.08											
B. piluliferum			2.08									
Brachydesmiella biseptata		4.17			2.08					2.08	6.25	6.25
Cacumisporium sp.	6.25			6.25								
Camposporium sp.									8.33			
C. antennatum			4.17			2.08			10.42			
C. cambrense				2.08	2.08		4.17	8.33	4.17		2.08	
C. laundonii			2.08									

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Canalisporium exiguum		2.08										
C. pallidum				2.08	4.17			4.17				
Cercospora sp.	8.33			4.17	2.08							
Chaetopsina fulva		8.33			2.08			6.25				
Chalara cylindrosperma				2.08								
C. elegans		4.17									2.08	
Chryseidea sp.						4.17						
Circinotrichum maculiforme		2.08				2.08					4.17	
C. poonense	4.17					8.33	2.08			2.08		
Cladosporium sp.1[1/]	2.08			4.17	4.17	6.25		2.08				
Cladosporium sp.2	4.17	2.08			8.33			2.08				
Cladosporium sp.3		4.17										
C. acaciicola				8.33								

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. britanicum[1/]				2.08			2.08					
C. cladosporioides					2.08						6.25	
C. elatum	6.25			4.17			6.25			4.17		
C. gallicola								2.08				
C. nigrelum				2.08								
C. orchidearum		4.17			8.33						2.08	
C. oxysporum		4.17		4.17	8.33		12.50	6.25	2.08			
C. staurophorum						2.08						
C. tenuissimum	8.33	2.08		16.67	8.33	10.42	4.17	2.08		2.08		
C. uredinicola									4.17			
Codinaea sp.1		4.17			2.08			8.33				
Codinaea sp.2								2.08				
C. assamica						2.08						

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. britannica		4.17			4.17			4.17				
C. fertilis			10.42		4.17	2.08						4.17
C. hughesii					2.08			2.08	4.17			
Colletotrichum sp.					4.17			2.08				
C. dematum	6.25									2.08		
C. gloeosporioides	10.42	10.42	2.08	8.33	4.17	4.17	18.75	6.25		18.75	8.33	2.08
Conioscypha sp.	2.08											
Corynespora cassiicola					2.08							
C. trichiliae	2.08											
Curvularia sp.	2.08	4.17		4.17			2.08					
C. affinis				2.08								
C. deightonii						2.08						2.08
C. geniculata	4.17			4.17		2.08						

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. lunata	2.08	4.17		2.08	6.25	8.33		2.08			2.08	2.08
C. pallescens	8.33	2.08		2.08	6.25	4.17		4.17	4.17	2.08		
C. peniseti								2.08				
C. uncinata				2.08	2.08							
Cylindrocarpon sp. [1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
C. didymum							6.25					
Cylindrocladium parvum	2.08	4.17		2.08			4.17					
C. scoparium		2.08	12.50		4.17	4.17		2.08	4.17	4.17	4.17	
Cylindrotrichum oligospermum		4.17						4.17				
Dactylaria sp.1	12.50	4.17	4.17	8.33	4.17	4.17	6.25	4.17	2.08	8.33	4.17	
Dactylaria sp.2		2.08	4.17	2.08	4.17	8.33	8.33	2.08		2.08	2.08	
Dactylaria sp.3					2.08						4.17	
D. hyalina		4.17	4.17		2.08	2.08	6.25	4.17	4.17		2.08	2.08

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
D. junci	10.42	2.08	8.33	6.25	2.08	2.08	4.17		16.67	4.17	4.17	14.58
Dactylella ellipsospora			2.08									
Dictyosporium sp.								2.08				
D. elegans	2.08			2.08			2.08			2.08		
D. heptasporum								2.08				
D. manglietiae												2.08
Diplococcium asperum		6.25						2.08			2.08	
D. pallidum					4.17			2.08				
D. spicatum		2.08		4.17	20.83		2.08	8.33			4.17	
Diplocladiella scalarioides	2.08											
Diplodia sp.				6.25								
D. melaena				6.25		2.08				2.08		
Discosia artocreas			6.25									

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ellisembia vaginata	2.08											8.33
Ellisiopsis sp.			4.17		2.08	8.33		2.08	10.42			
E. gallessiae	12.50	10.42		2.08			2.08	2.08			2.08	
Endophragmia sp.1					2.08			2.08				
Endophragmia sp.2					2.08			2.08				
E. bisbyi					2.08			2.08			2.08	
E. elliptica			2.08									
E. parva			6.25			4.17			4.17			2.08
Endophragmiella theobromae				4.17			2.08					
Faseriella sp.	2.08	2.08		6.25	2.08		4.17	2.08			4.17	
Fulvia berkheyae	2.08	4.17			2.08		8.33			6.25	2.08	
Fusarium sp.1	20.83	8.33		10.42	4.17	2.08	2.08		2.08	4.17		
Fusarium sp.2	8.33	6.25		2.08	4.17	4.17		2.08		2.08		

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Fusarium sp.3	6.25	4.17			8.33		2.08	2.08				
Fusarium sp.4	2.08			2.08			2.08					
F. redolens[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
F. semitectum							2.08					
Fusicladium sp.	2.08											
Grophium putredinis						2.08						
Gyrothrix circinata	2.08	2.08	4.17		2.08	6.25	2.08	4.17	2.08			
G. podosperma		4.17				2.08		8.33				
Hansfordia pulvinata	8.33	8.33		4.17	18.75	4.17	2.08					
H. ovalispora						2.08						
Haplariopsis fagicola				2.08								
Haplographium mangiferae					2.08							
Helicorhoidion botryoideum	4.17						6.25					

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Helicosporium aureum	2.08											6.25
Helicostylum piriforme[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Helminthosporium sp.		4.17									4.17	
H. heveae	2.08	2.08		2.08	2.08		2.08	2.08		2.08	2.08	
Henicospora coronata		2.08	12.50		4.17	2.08	4.17	10.42	8.33		4.17	14.58
Heteroconium chaetospira		2.08										
Hormiactis alba	4.17		2.08									
Humicola grisea		2.08										
Hyalotiella sp.						2.08						
Idriella sp.	2.08					4.17						
I. fertile		4.17			4.17			2.08			2.08	2.08
I. lunata	2.08	6.25		6.25	4.17			4.17		2.08	4.17	
Kramasamuha sp.			4.17						2.08			2.08

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Lasiodiplodia cf. *theobromae*	4.17	16.67	4.17	10.42	14.58	16.67	8.33	20.83	8.33	6.25	8.33	
Leptodiscella sp.			2.08						2.08			2.08
L. africana			4.17			4.17			4.17		4.17	2.08
Massariothea sp.			4.17									
Menispora sp.									2.08		4.17	
Mitteriela ziziphina				2.08								
Monacrosporium sp.1			6.25									
Monacrosporium sp.2			2.08									
Moorella speciosa												2.08
Mycoleptodiscus indicus			2.08									
Mycovellosiella solani-torvi				4.17			4.17				2.08	
Myrothecium roridum	2.08											
Mystrosporiella litseae			4.17					2.08				

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Neottiosporella sp.			6.25			4.17						
Nigrospora sphaerica	4.17	4.17		8.33	16.67	8.33	12.50	16.67	12.50	10.42	6.25	2.08
Paecilomyces sp.	2.08	6.25		2.08	4.17	4.17	6.25			2.08	2.08	
P. varioti[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. lanceolatus				4.17					2.08			
Panchanania jaipurensis		4.17	18.75		2.08	6.25		6.25	10.42			10.42
Parasympodiella sp.						2.08						
Paratomenticola lanceolatus			2.08									2.08
Penicillifer pulcher	2.08											
Penicillium sp.1	6.25	2.08		4.17	2.08		2.08		2.08	2.08	2.08	
Penicillium sp.2		2.08		4.17	2.08	4.17	2.08	2.08				
Penicillium sp.3	4.17	2.08	2.08	2.08	2.08	4.17	2.08	2.08	2.08	2.08		
Penicillium sp.4[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Penicillium sp.5[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Penicillium sp.6[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. canescens[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. chrysogenum[1/]				2.08		4.17						
P. citrinum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. griseofulvum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. miczynskii[1/]							4.17					
P. miniloluteum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
P. rolfsii				4.17		4.17						
P. simplicissium[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Pestalotia sp.						2.08						
Pestalotiopsis sp.1	8.33	2.08		2.08	2.08	8.33	6.25	2.08	6.25		6.25	2.08
Pestalotiopsis sp.2	4.17				6.25	6.25		4.17				

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Pestalotiopsis sp.3				2.08			4.17			6.25		
P. disseminata				4.17	4.17			6.25		6.25	2.08	
P. guepini[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	
Phaeoisariopsis cercosporioides		2.08				2.08		2.08			2.08	
Phaeoramularia sp.						4.17						
P. capsicicola							2.08					
Phaeosphaeria sp.						4.17			2.08			
Phoma sp.	6.25									2.08		
Phomopsis sp.					2.08							
Phyllosticta sp.									2.08			
Pleurophragmium acutum	2.08	2.08		6.25	4.17			2.08			6.25	
P. simplex		4.17										
Pleurotheciopsis pusilla		2.08	4.17				2.08		2.08			

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Pseudobeltrania penzigii		2.08										
Pseudorobillarda sp.					2.08							
Pseudospiropes hughesii		4.17			4.17							
P. obclavatus		2.08			2.08							
P. parasitica		4.17			2.08							
Raffaelea sp.		4.17										
Rhinocladiella sp.	2.08	2.08	8.33	2.08	4.17	4.17						
Robillarda phragmitis		2.08			2.08		2.08				2.08	
Scolecobasidium canthacearum				2.08		4.17				2.08		
S. dendroides								2.08			2.08	
S. compactum				2.08							4.17	
S. salinum							4.17	4.17				
Scolecobasidiella avellanea	6.25		14.58	6.25		18.75	4.17		4.17	4.17	4.17	10.42

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Setocyta ruborum	4.17			4.17								
Spegazzinia deightonii				2.08								
S. lobulata				4.17								
S. sundara				2.08								
Speiropsis hyalospora	4.17	8.33	8.33	6.25	8.33	6.25		6.25	2.08		8.33	6.25
S. pedatospora						8.33			4.17			4.17
Spiropes sp.							2.08					
Spondylocladiella botrytioides		2.08			2.08							
Sporidesmium sp.					4.17							
S. flagellatum										2.08		2.08
S. harknesii	4.17	2.08	2.08	2.08	2.08							
S. nodipes	2.08	2.08		2.08								
S. pallidum					2.08			2.08				

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. rubi	6.25	2.08					6.25				2.08	
S. socium					4.17							
Sporoschisma uniseptatum		6.25			2.08						2.08	
Sporoschismopsis sp.		2.08	2.08		2.08					4.17	2.08	
Sporothrix schenckii	8.33											
Stachybotrys sp.		2.08										
Stenella liabicola		2.08			2.08						2.08	
S. pithecellobii					2.08					2.08	6.25	
Stigmina hartigiana		2.08			2.08							2.08
Subulispora britannica								2.08			2.08	
S. procurvata	12.50	8.33	10.42	8.33	6.25	16.67	4.17	18.75	16.67		12.50	18.75
Syncephalastrum recemosum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Taeniolella scripta		2.08									2.08	

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Talaromyces flavus[1/]	4.17			4.17								
Tetospora sp.					2.08							
Tetraploa aristata		2.08			2.08	2.08			4.17			2.08
Tetraposporium sp.										2.08		
Tiarosporella sp.	2.08											
Torula sp.		4.17										
T. herbarum		6.25		4.17	4.17		16.67	2.08		12.50	6.25	2.08
Trematosphaeria pertusa		2.08								4.17	2.08	
Trichoderma sp.1		2.08		2.08	6.25	2.08	2.08	2.08	2.08	2.08	2.08	
Trichoderma sp.2		2.08			4.17		4.17					
T. atroviride		2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. aureoviride[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. harmatum[1/]	2.08				2.08							

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. harzianum	2.08	2.08	4.17	4.17			2.08	2.08		4.17		
T. inhamatum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. longibrachiatum[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. parceramosum[1/]				4.17	2.08							
T. pseudokoningii[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. reesei[1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. virens[1/]							4.17				2.08	
T. viride[1/]					2.08		4.17					
Trichothecium roseum	4.17			2.08			2.08					
Tricladium angulatum			2.08									
T. castaneicola			12.50		8.33			2.08	6.25			
T. fuscum			2.08		2.08							
Trimmatostrona betulinum		2.08										

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Triscelophorus acuminatus			20.83		2.08	4.17			10.42		2.08	12.50
T. monosporus			2.08									
T. panapensis		2.08						8.33			2.08	
Trisulcosporium acerinum				6.25								
Veronaea carlinae	18.75	6.25	25.00	14.58	14.58	10.42	12.50	12.50	4.17	2.08	4.17	2.08
V. coprophila	8.33	14.58	14.58	4.17	18.75	10.42	4.17	12.50	4.17	2.08	6.25	10.42
V. musae	6.25			4.17								
Verticillium dahliae	4.17											
Wiesneriomyces javanicus	6.25	6.25	10.42	4.17	2.08		2.08				8.33	6.25
Zanclospora brevispora				2.08								
Zygosporium deightonii						2.08		4.17				
Z. echinosporum	2.08				6.25	2.08						
Z. gibbum	10.42	2.08	2.08	2.08	14.58			2.08				

Table 3.2 (Continued) Occurrence (%) of fungi on leaf litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Z. majus					4.17	4.17						
Z. masonii	6.25	2.08		6.25				2.08				
Zygomycota												
Mortierella polycephala		2.08										
Rhizopus sp. [1/]	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Total number of species	100	113	69	107	122	88	77	90	62	63	88	53
recorded at each season		282			317			229			204	

Note: [1/] Isolated from dilution plates

[*] Newly fallen leaves, middle stage decaying leaves, old decaying fallen leaves

Appendix B

Table 4.1 Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota												
Acrophialophora fusispora		2.08										
Astrosphaeriella sp.					6.25							
Boerlagiomyces grandisporus		4.17			2.08							
Botryosphearia sp.		4.17			2.08			2.08			6.25	
Ceratocystis ulmi			2.08									
Chaetomium sp.1	2.08											
Chaetomium sp.2						4.17						
Claussenomyces atrovirens		2.08			2.08							
Dothidotthia sp.1				6.25							2.08	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Dothidotthia sp.2				2.08						4.17		
Dothiorella sp.			2.08	2.08								
Eupenicillium sp.					2.08							
E. brefeldianum						2.08			4.17			
E. javanicum				2.08								
Gaeumannomyces graminis						4.17						
Glomerella cingulata	2.08						4.17					
Gnomonia creastris	2.08											
Hypoxylon sp.1	2.08	2.08	6.25	4.17	2.08		6.25	6.25		6.25	8.33	8.33
Hypoxylon sp.2	6.25	6.25	16.67	2.08	6.25	2.08	6.25	8.33		4.17	6.25	6.25
Hypoxylon sp.3	6.25	4.17	4.17	4.17			6.25		6.25	6.25	6.25	8.33
Hypoxylon sp.4	2.08	6.25	2.08	6.25	2.08		4.17	4.17	8.33	4.17	6.25	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Hypoxylon sp.5	4.17	4.17								2.08		
Hypocrea rufa	2.08		4.17						4.17			2.08
Kirschsteiniothelia sp.[1/]	14.58	12.50	12.50	20.83	18.75	10.42	25.00	18.75	6.25	20.83	18.75	16.67
Leptosphaeria blumeri								4.17				
L. cercocarpi		4.17			4.17			4.17			4.17	
L. conoidea							6.25					
L. millefolii		2.08			2.08			2.08			2.08	
L. russellii			4.17						8.33			
Linocarpon sp.1											4.17	
Linodochium hyalinum			2.08									2.08
Linospora sp.			4.17									
Lophiostoma fuckelii						2.08			2.08			2.08

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Orbilia sp.								2.08				
Oxydothis sp.		2.08				2.08			2.08			
Pestalosphaeria hansenii				4.17	4.17	6.25	8.33	4.17	10.42	6.25	8.33	6.25
Phaeosphaeria sp.					4.17			2.08				
Pleospora sp.		2.08										
Stegopeziza dumeti							2.08					
Thyridaria sambucina				2.08	2.08	4.17	4.17	4.17			8.33	
Trematosphaeria pertusa		2.08			4.17	4.17		6.25	4.17			
Typhula ishikariensis							2.08					
Mitosporic fungi												
Acarocybe formosa				2.08	2.08							

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
A. hansfordii	6.25	2.08										
Acarocybella jasminicola		2.08	6.25			6.25			2.08			6.25
Acladium conspersum			4.17									
Acremonium sp.1	4.17		4.17									
A. butyri[1/]						2.08		2.08				8.33
A. fusidioides						6.25						
A. strictum				2.08	2.08	2.08	6.25					
Acrodictys sp.					2.08						2.08	
Actinocladium rhodosporum						14.58	6.25	10.42	18.75	2.08		
Actinospora megalospora	2.08											
Annellophora dendrographii				4.17								

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Anthina sp.	6.25											
Arthobotryum atrocephalum			10.42						2.08			8.33
Arthrocladium caudatum					2.08						4.17	
Articulospora tetracladia		2.08	6.25			2.08			2.08			
Aspergillus sp.1[1/]				2.08	4.17		2.08	4.17				
Aspergillus sp.2[1/]												2.08
Aspergillus sp.5[1/]		4.17	2.08			2.08		2.08	2.08		2.08	2.08
A. moringae[1/]								4.17				
Asteroma coryli											6.25	
Bactrodesmium pallidum								8.33				
B. rahmii	2.08	10.42	22.92	12.50	12.50	25.00	8.33	12.5	8.33	6.25	12.50	22.92

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
B. spilomeum				2.08				2.08	2.08	6.25		
Berkleasmium cf. *minutissimum*		2.08								2.08		
B. concinnum				6.25			2.08	2.08			2.08	
Bidenticula cannae									6.25			
Bipolaris sp.			4.17			2.08	2.08					4.17
B. australiensis							4.17			4.17		
B. biseptata				2.08			2.08			4.17		
B. cactivora			6.25									8.33
B. dematioidea	2.08											
B. heveae							2.08			6.25		
B. phlei				2.08								

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
B. ravenelii							2.08			2.08		
Botrydiplodia sp.	4.17	4.17	4.17			8.33	14.58	6.25	2.08			6.25
Botryotrichum sp.			2.08									
Brachiosphaera tropicalis							2.08					
Brachydesmiella biseptata								2.08				
Brachysporiella gayana	6.25	4.17		4.17	6.25		6.25	2.08	2.08	8.33	4.17	
B. laxa			4.17									4.17
Brachysporium sp.	4.17			2.08			2.08			2.08		
B. dingleyae	2.08	4.17					4.17	2.08		4.17		6.25
Camposporium sp.			2.08						4.17			2.08
C. antennatum									4.17			

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. cambrense							2.08	2.08	2.08			
Canalisporium caribense								2.08				
Ceratosporella deviata						2.08			2.08			
C. novae-zelandiae						2.08			2.08			
Ceratosporium fuscescens			4.17			6.25						2.08
Cercospora sp.1				6.25	2.08	6.25	2.08	2.08			2.08	
Cercospora sp.2		2.08			2.08			2.08				
Cercospora sp.3					6.25							
C. achyranthina					2.08							
C. apii	4.17		2.08									
C. canescens					12.50							

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ceriospora polygonacearum		4.17										
Chaetoconidium arachnoideum	2.08											
Chalara sp.						4.17	2.08					
C. urceolata						2.08						
Chrysosporium condensatum				2.08								
Circinotrichum fertile		2.08										
C. poonense	2.08	2.08										
Cladosporium sp.1	4.17			4.17						4.17		
C. britannicum				4.17	2.08							
C. elatum	2.08		6.25	6.25			2.08					4.17
C. gallicola						6.25						

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. tenuissimum				2.08	4.17	4.17					6.25	
Clasterosporium cocoicola	2.08						4.17			6.25		
C. flagellatum			2.08									2.08
Clavariopsis aquatica				2.08								
C. brachycladia				2.08								
Colletotrichum gloeosporioides[1/]	2.08		4.17						2.08			
Cordana pauciseptata			2.08						2.08			
Cordella clarkii										4.17	2.08	
Corynespora sp.1			2.08									
C. cassiicola			6.25								6.25	4.17
C. proliferata						4.17						

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. trichiliae						6.25						
Corynesporopsis quereicola			2.08			4.17			4.17			2.08
Cruvularia affinis			2.08						2.08			
C. deightonii										6.25		
C. lunata[1/]	4.17		6.25	2.08						10.42	4.17	14.58
C. pallescens						2.08						
Cylindrocladium sp.1					2.08							
C. parvum[1/]					2.08			2.08				
C. scoparium		4.16	4.17		2.08						2.08	
Cylindrocolla urticae									2.08			
Cylindrotrichum sp.1					2.08			2.08				

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. oligospermum		4.16			2.08			2.08				
Dactylaria sp.1				8.33	4.17	4.17	2.08			4.17		
Dactylaria sp.2					2.08	2.08				2.08		
Dactylaria sp.3				4.17		6.25	4.17	2.08				
D. hyalina		4.16	6.25	4.17		6.25		2.08			4.17	
D. junci	4.17						2.08					
Dactylella sp.		6.25			2.08						4.17	
D. ellipsospora	4.17	4.17	10.42	4.17		4.17		2.08		2.08		
Dendeyphion comosum							6.25					
Dictyosporium sp.1				2.08						2.08		
D. manglietiae						6.25		2.08				

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Diplococcium sp.1	4.17		8.33	2.08	2.08	8.33		2.08		2.08		8.33
Diplococcium sp.2				10.42	18.75							
D. asperum	2.08			2.08						4.17		
D. clarkii		2.08										
D. lawrencei								2.08				
D. spicatum		4.17		4.17	4.17			4.17		2.08	6.25	
Diplocladiella scalaroides		2.08			2.08			2.08				
Ellisembia paravaginata		4.17			8.33						8.33	
E. vaginata						4.17						
Endophragmia sp.									2.08			
E. bisbyi						4.17						

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
E. hyalosperma	8.33			6.25			10.42			6.25		
E. pinicola	2.08						2.08			2.08		
Endophragmiella sp.								2.08				
E. boewei										2.08		
E. lignicola	2.08											
Excipularia narsapurensis										4.17		
Exosporium phyllantheum	8.33			4.17			6.25			6.25		
Fasariella sp.					2.08							
F. kansensis		6.25	8.33			2.08			6.25			4.17
Fusarium sp.1		6.25			4.17	10.42		2.08	4.17	2.08	8.33	
Fusarium sp.2	4.17	4.17			2.08	2.08				4.17	2.08	2.08

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Fusarium sp.3	2.08		6.25	2.08				4.17			2.08	2.08
Fusarium sp.4				4.17	2.08			2.08			4.17	
Fusarium sp.5	2.08	6.25		2.08			2.08					
Fusarium sp.6				2.08								
F. oxysporum[1/]							2.08					
F. semitectum[1/]					2.08	2.08						
Fusicladium sp.		2.08										
Gliomastix musicola										4.17		
Goidanichiella sp.						2.08						
Gyrothrix circinata								2.08				
G. podosperma			4.17									

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Hansfordia biophila	2.08			2.08			2.08	4.17				
H. nebularis							2.08					
H. ovalispora		4.17	6.25		8.33	4.17			2.08			2.08
Haplographium mangiferae								2.08				
Helicomyces sp.					2.08							
H. roseus						2.08						
Helicosporium vegetum			2.08									
Helminthosporium velutinum			4.17	2.08		4.17		8.33	2.08			
Henicospora coronata					2.08			2.08				
Hirudinaria macrospora		2.08	2.08									
Hormiactis sp.1								2.08				

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
H. candida					2.08			2.08				
Idriella fertile								6.25				
I. lunata	2.08							2.08			2.08	
Janetia faureae		4.17			2.08			4.17				
Lasidiodiplodia cf. *theobromae*	10.42	4.17	16.67	20.83	14.58	22.92	12.50	14.58	14.58	20.83	18.75	25.00
Lateriramulosa uni-inflata		2.08	2.08									
Lemonniera brachycladia				6.25								
Leptodiscella africana	4.17	2.08	2.08	4.17	2.08	2.08	2.08	4.17		4.17		
Mariannaea elegans									4.17			
Monacrosporium sp.1		6.25	6.25	6.25								
Monacrosporium sp.2		2.08										

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Mycoleptodiscus indicus			2.08						4.17			
Mycovellosiella solani-torvi												2.08
Myrothecium roridum			4.17			2.08						
Myxocyclus sp.			2.08									
Nawawia filiformis			4.17						2.08			
Nematoctonus sp.			2.08									
Nigrospora sphaerica				10.42	18.75	14.58	12.50	2.08				
Paecilomyces sp.												8.33
P. lilacinus[1/]						8.33	2.08	2.08				
Panchanania jaipurensis						2.08			6.25			
Parapleurotheciopsis sp.	8.33	6.25			4.17		6.25	2.08		4.17	6.25	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Parasympodiella podacarpi				2.08	4.17					4.17	6.25	
Paratomenticola lanceolatus		6.25	2.08	4.17	8.33	14.58	12.50	10.42			6.25	8.33
Paratrichoconis chinensis			2.08			2.08		4.17				2.08
P. polygonecearum					4.17							
Penicillium sp.1[1/]	4.17	2.08	2.08	2.08		4.17			8.33			
Penicillium sp.2[1/]	2.08						2.08				2.08	
Penicillium sp.3[1/]	4.17				2.08							
Penicillum sp.4[1/]					4.17						6.25	
Periconia byssoides				2.08								
P. cambrensis					2.08							
P. jabalpurensis						2.08			2.08			

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
P. lateralis	2.08											
Periconiella cyatheae	2.08									6.25		
Pestalotiopsis sp.1				8.33						6.25	8.33	
Pestalotiopsis sp.2		4.17			4.17			4.17			2.08	
Pestalotiopsis sp.3					2.08							
P. disseminata[1/]							6.25		4.17			6.25
P. hansenii				8.33			2.08					
P. sydowiana[1/]							10.42			4.17		
Phaeodactylium alpiniae		6.25	6.25			6.25						
Phoma sp.[1/]	2.08											
Phomopsis sp.[1/]			4.17						2.08			2.08

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Phyllosticta sp. [1/]									6.25			
Pithomyces graminicola				8.33			2.08			2.08		
Pleurophragmium acutum			4.17			6.25						
Pleurotheciopsis pusilla							4.17					
Polymorphum sp.		2.08										
Pseudobotrytis terrestris		6.25	10.42		4.17	8.33		2.08	2.08		4.17	6.25
Pseudocercospora pterocauli				6.25								
Pseudodiplodia sp.		6.25									4.17	
Pseudospiropes hughesii			2.08		6.25	8.33		2.08			4.17	
P. obclavatus			4.17	6.25	2.08	4.17	2.08		2.08	4.17		
Pyriculariopsis parasitica	4.17			2.08			6.25			6.25		

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Rhinocladiella sp.1		4.17	12.50						6.25		6.25	
Schizotrichum lobeliae				4.17								
Scolecobasidiella sp.					4.17							
S. avellanea					6.25	4.17			2.08			
Scolecobasidium acanthacearum				2.08		4.17	2.08					
S. compactum			4.17		6.25		2.08		2.08			4.17
S. dendroides					2.08							
S. salinum					6.25		2.08			8.33		
Scytalidium lignicola	2.08						2.08					
Septonema fasciculare		2.08			2.08	2.08			8.33		2.08	2.08
Spadicoides obovata	4.17						2.08			4.17		
Spegazzinia deightonii		4.17						4.17				

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. parkeri							2.08					
S. sundara			2.08		2.08							
Speiropsis hyalospora						2.08				2.08	2.08	2.08
Spondlocladiella botrytioides							2.08	2.08				
Sporidesmium sp.1				2.08								
Sporidesmium sp.2		2.08			2.08			2.08				
Sporidesmium sp.3		4.17			4.17			6.17				
S. australiense				2.08		4.17						
S. bambusicola						6.25	2.08					
S. cambrense		6.25									6.25	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. coronatum					2.08						8.33	
S. dioscoreae								6.25				
S. flagellatum				8.33	6.25	6.25	6.25	6.25		6.25	8.33	
S. ghanaense			2.08	6.25			2.08			6.25		6.25
S. harknesii	4.17	2.08		4.17	6.25	4.17		2.08	2.08		6.25	8.33
S. jasminicola				4.17								
S. larvatum		2.08			2.08	2.08			4.17		2.08	
S. leptosporum				6.25	2.08		2.08					
S. longirostratum				6.25	6.25	4.17					4.17	4.17
S. nodipes		6.25	2.08	6.25				4.17		4.17		
S. parvum						2.08						8.33

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. penzigii		14.58	6.25			10.42			2.08			12.50
S. rubi				2.08	12.50	22.92		4.17	2.08		4.17	4.17
S. subulatum		6.25		8.33	2.08			2.08			2.08	
S. tenuisporum				4.17								
S. uvariicola				2.08								
S. zambiense			4.17			12.50			2.08			6.25
Sporoschisma uniseptatum	2.08											
Sporoschismopis sp.1		2.08	2.08		2.08				2.08		8.33	2.08
Stachybotrys oenanthes	2.08						2.08			4.17		
S. sanserieriae	4.17			4.17			2.08			6.25		
Staphylotrichum coccosporum	2.08											

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Stenella pithecellobii				6.25			6.25		8.33			
Stigmina celata				6.25	4.17					6.25		
S. crotonicola				6.25								
S. kranzii				4.17			2.08			2.08		
S. mangiferae						2.08						
S. murrayae					16.67							
S. rauvolfiae				2.08		6.25						
S. sudanensis	8.33			2.08			8.33			6.25		
Subulispora sp.1			2.08						2.08			
S. britannica						4.17			6.25			
S. procurvata		4.17	4.17				2.08		4.17			

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Taeniolella breviuscula		2.08			6.25						6.25	
Tetracrium amphibium				4.17	6.25	6.25					2.08	
Tetraploa aristata		2.08		4.17	12.50	4.17		2.08	4.17		8.33	2.08
T. ellisii	8.33			4.17						4.17		
Tetraposporium asterinearum				4.17	4.17	6.25		4.17	4.17			
Tetratosperma sp.	4.17			4.17								
Thyrsidina sp.	2.08									8.33		
Torula herbarum	16.67	4.17		18.75	8.33	6.25	2.08	2.08		10.42	16.67	8.33
Tretospora sp.1					2.08							
Tretospora sp.2							2.08	6.25	2.08		2.08	
Trichoderma sp.1[1/]	4.17	4.17									4.17	

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Trichoderma sp.2[1/]	4.17	8.33					2.08					
Trichoderma sp.3[1/]	4.17	2.08					2.08					
Trichoderma sp.4[1/]	4.17											
Trichoderma sp.5[1/]	4.17											
Trichoderma sp.6[1/]	4.17											
T. atroviridae[1/]	4.17	4.17	2.08		2.08			4.17	4.17			
T. hamatum[1/]					2.08			2.08	4.17			
T. harzianum[1/]						6.25		10.42				
T. inhamatum		208										
T. virens[1/]					2.08			2.08			2.08	
Trichodochium disseminatum							4.17					
Tricladium sp.	2.08	4.17		2.08	2.08			2.08				4.17

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. fuscum				2.08	10.42							
Tridentaria sp.									4.17			
T. implicans	2.08	4.17	4.17		4.17			4.17			2.08	
Tripospermum myrtii	2.08			2.08			4.17			6.25		
Triscelophorus acuminatus		2.08			2.08		2.08					
T. panapensis		2.08				2.08						
Venturia crataegi	2.08			2.08						2.08		
Veronaea apiculata		4.17			4.17			4.17	4.17		4.17	
V. carlinae	2.08			4.17	14.58	14.58	2.08	2.08	2.08	4.17	8.33	
V. coprophila	6.25	4.17		2.08	10.42		2.08	10.42		8.33	14.58	
V. musae								2.08			2.08	8.33

Table 4.1 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Wiesneriomyces javanicus					2.08			2.08			2.08	
Zygosporium minus										4.17		
Oomycota												
Phytophthora sp.							2.08					
Zygomycota												
Rhizopus sp.	2.08	2.08									2.08	
Total number of species	77	85	76	97	104	88	83	90	69	68	71	54
recorded at each season			238			289			242			193

Note: [1/] Isolated from dilution plates

*Newly fallen branches, middle stage decaying branches, old decaying fallen branches

Table 4.2 Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota												
Anthostomella formosa		2.08			6.25	6.25			2.08			
Astrosphaeriella sp.2	2.08	2.08									4.17	
Chaetomium sp.1						2.08						
Claussenomyces atrovirens		8.33	2.08		8.33	2.08		8.33	6.25	2.08	4.17	
Dothidotthia sp.1				4.17			4.17					
Glomerella cingulata		4.17	2.08		8.33					2.08		
Hypoxylon sp.1	14.58	12.50	2.08	14.58	18.75	6.25	8.33	10.42	12.50	14.58	8.33	12.50
Hypoxylon sp.2	2.08	2.08	4.17	6.25	2.08	10.42	4.17	4.17	8.33	6.25	4.17	2.08
Kirschsteiniothelia sp.	18.75	18.75	10.42	14.58	14.58	14.58	16.67	16.67	12.5	10.42	12.50	12.50
Leptosphaeria darkeri												4.17
Linocarpon sp.1	2.08	4.17	4.17	6.25	6.25	4.17	2.08	2.08	4.17			6.25
Linospora sp.		2.08	6.25		6.25	2.08		4.17	6.25			4.17
Lophodermium sp.					4.17			2.08				

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Oxydothis sp.	2.08	8.33										
Pestalosphaeria hansenii	8.33	12.50	2.08	4.17	14.58	6.25	4.17	16.67	12.50	8.33	14.58	
Plectosphaerella cucumerina					6.25							
Thematosphaeria pertusa	4.17	2.08									8.33	6.25
Thyridaria sambucina	4.17	14.58	8.33						4.17	2.08	4.17	6.25
Xylaria sp.1											6.25	
Mitosporic fungi												
Acarocybe sp.1				4.17			2.08			4.17		
A. deightonii	4.17						4.17					
A. formosa	6.25	10.42		16.67	6.25		8.33	10.42		8.33	6.25	
A. hansfordii	8.33		6.25	4.17		10.42	2.08		6.25	6.25		4.17
Acarocybella jasminicola	6.25	6.25								2.08		
Acremonium sp.1	2.08	8.33		2.08			8.33	2.08			4.17	
Acremonium sp.2				2.08								

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Acremonium sp.3				2.08								
A. kiliense	4.17	8.33						6.25			14.58	4.17
A. murorum									6.25	2.08	2.08	6.25
A. strictum	2.08	2.08	2.08	6.25		10.42	2.08		8.33		2.08	6.25
Acrodicty sp.								6.25				
A. fuliginosa				2.08			6.25			2.08		
Acrostaurus turneri	6.25				2.08							
Actinocladium rhodosporum	4.17	6.25	6.25		2.08	4.17	4.17	4.17	4.17	2.08		
Arthinium muelleri				2.08								
Articulospora tetracladia		2.08	4.17					2.08				
Aspergillus sp.1[1/]	2.08	2.08	4.17		4.17		2.08	2.08	2.08			
Aspergillus sp.2[1/]			2.08			2.08			2.08			
Aspergillus sp.3[1/]	4.17	4.17		4.17	4.17	4.17	4.17	4.17		4.17	4.17	

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Aspergillus sp.4[1/]										4.17		
Aspergillus sp.6[1/]												4.17
Aspergillus niger[1/]	2.08						14.58	8.33				
Aureobasidium sp.						2.08						
Bactrodesmium sp.		6.25			4.17			4.17			6.25	
B. betulicola	12.50	8.33		12.50	4.17	2.08	16.67	6.25		8.33	8.33	
B. pallidum	6.25	2.08		6.25	6.25		6.25	6.25		6.25	2.08	
B. rahmii	12.50	16.67	12.50	12.50	14.58	12.50	16.67	25.00	12.50	8.33	16.67	10.42
B. spilomeum	20.83	16.67	8.33	8.33	6.25	8.33	25.00	10.42	2.08	14.58	10.42	6.25
Beltraniella pirozynkii					2.08	2.08		2.08				
Berkleasmium cf. *minutissimum*					2.08							
B. concinnum					6.25							
Bidenticula cannae			2.08			6.25						

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Bipolaris ellisii		10.42		4.17			8.33	8.33				
B. erythrospila					4.17			2.08				
B. indica	4.17			2.08			2.08			2.08		
B. ravenelii						2.08			2.08			
Bispora antennata						6.25			2.08			
Botryodiplodia sp.	20.83	22.92	4.17	8.33	18.75	6.25	10.42	22.92	8.33	20.83	25.00	16.67
Brachsporium dingleyea				2.08	2.08			4.17				
Brachydesmiella biseptata						6.25			6.25	4.17		
B. musifomis											4.17	
Brachyhelicoon xylogenum					2.08							
Brachysporiella gayana			4.17						2.08		4.17	8.33
Brachysporium sp.		2.08			2.08			2.08				
B. britanicum				4.17			2.08					

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Camposporium cambrense			2.08								2.08	
Canalisporium caribense					10.42			8.33				
Cantelabrella musifomis												2.08
Cephaliophora irregularia				2.08								
Ceratosporella novae-zelandiae				2.08			4.17	4.17	2.08			
Cercospora achyranthina	8.33	6.25		8.33			4.17			8.33	4.17	
C. apii							29.17				6.25	
C. elaedis	2.08		2.08			6.25	2.08		4.17			2.08
Ceriospora polygonacearum		2.08			2.08							
Chaetopsis grisea		4.17										
Chalara sp.					2.08			4.17	2.08			
C. cylindrosperma					2.08							
Chalaropsis sp.							2.08					
Circinotrichum poonense	2.08	2.08		2.08	2.08	2.08	6.25		8.33			

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Cladosporium sp.1					6.25							
Cladosporium sp.2	2.08			4.17			4.17			4.17		
C. elatum	4.17			4.17	4.17		6.25	8.33				
C. gallicola				4.17								
C. orchidis				4.17			6.25			4.17		
C. tenuissimum	2.08	2.08	4.17		2.08	4.17	14.58	16.67	10.42	6.25	2.08	
Codinaea sp.			2.08			4.17						
C. assamica		2.08	2.08		8.33	4.17		4.17	2.08	2.08		
Colletotrichum sp.1[1/]		10.42			4.17	4.17		6.25	2.08		2.08	
C. gloeosporioides[1/]	2.08		2.08		8.33	6.25	4.17	8.33	6.25		2.08	2.08
Corynespora sp.1					2.08							
Corynespora sp.2						4.17			2.08			4.17
Corynespora sp.3		2.08	10.42									
C. cassiicola		2.08			2.08	2.08		2.08				

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. novae-zelandiae									2.08			
C. trichiliae		6.25			2.08							
Corynesporopsis quereicola		2.08									2.08	
Crytocoryneum condensatum				2.08	2.08							
Curvularia sp.								4.17				
C. lunata[1/]	6.25		4.17		2.08	8.33	8.33	16.67	4.17	2.08	4.17	
Cylindrocladium parvum[1/]	4.17			10.42			8.33			2.08		
C. scoparium					2.08							
Cylindrotrichum oligospermum		8.33			10.42			12.50				
Dactylaria sp.1	2.08	2.08					4.17	4.17	4.17			
Dactylaria sp.2			8.33									6.25
Dactylaria sp.3			4.17						2.08			4.17
D. hyalina	2.08	4.17		2.08		2.08	2.08	2.08		2.08	2.08	
D. purpurella				6.25						2.08		

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Dactylella ellipspspora						2.08						
Dendryphion comosum					4.17			2.08			4.17	
Dictyoarthrinium sp.						2.08						
Dictyosporium sp.			4.17			2.08			2.08			
D. giganticum				2.08	4.17					4.17	2.08	
D. heptasporum		6.25										
D. manglietiae			2.08			4.17			2.08			4.17
Diploccocium sp.2	2.08			6.25			2.08					
D. asperum			4.17						2.08			
D. spicatum		8.33	4.17	6.25	8.33	6.25	2.08	4.17	6.25	2.08	4.17	
Diplocladiella scalaroides				2.08		4.17	6.25		4.17			
Diplodia sp.[1/]	6.25	2.08					2.08	4.17		2.08		
Discosia artocreas		2.08			2.08							
Ellisembia sp.			4.17						6.25			

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
E. paravaginata		2.08	2.08		6.25			8.33			2.08	
E. repentioriunda			6.25									4.17
E. vaginata	8.33	2.08					2.08	6.25		4.17	4.17	
Ellisiopsis gallesiae					2.08							
Endophragmia boewei		2.08	2.08				2.08			4.17	6.25	8.33
E. brevis										4.17		
E. cesatii				6.25			4.17			2.08		
E. elliptica	6.25		2.08	4.17		10.42	8.33		2.08			
E. hyalosperma	6.25			4.17			4.17					
Endophragmiella baewei		2.08										
Exosporium monanthotaxis		4.17			6.25						4.17	
Fasariella sp.		6.25									2.08	
F. sarniesis		2.08	2.08		6.25			4.17			2.08	2.08
Fulvia berkhaeyae		4.17			2.08	4.17		4.17				

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Fusarium sp.1		6.25	4.17	4.17	8.33	4.17	8.33	4.17				4.17
Fusarium sp.2	6.25	2.08	4.17	8.33	2.08	2.08	14.58	2.08				
Fusarium sp.3	6.25	2.08		8.33	2.08		14.58	6.25				
Fusarium sp.4		4.17						8.33				
F. aquaeductum		2.08										
F. moniliforme	2.08			6.25			6.25					
F. redolens												6.25
F. semitectum							2.08			2.08		
Gliomastix cerealis								4.17				
G. musicola					2.08							
Gyrothrix circinata	2.08			2.08			2.08		4.17			
G. podosperma								4.17				
Hansfordia biophila		14.58						2.08				
H. ovalispora			6.25			8.33			8.33			8.33

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Helicomyces sp.					2.08	4.17						
Helicosporium aureum			2.08		4.17							
H. vegetum					2.08							
Henicospora coronata										4.17		
Hirudinaria macrospora					2.08							
Hormiactic alba	6.25											
H. candida			2.08			6.25			6.25			4.17
Humicola grisea								6.25			2.08	
Hyalodendron sp.	2.08											
Hyphodiscosia jaipurensis	4.17		8.33									
Idriella lunata		6.25	2.08		8.33	4.17		6.25	4.17			2.08
Lasiodiplodia cf. *theobromae*	8.33	12.50	12.50	25.00	10.42	12.50	10.42	16.67	12.50	6.25	6.25	2.08
Lateriramulosa uni-inflata					4.17	2.08						2.08
Lauriomyces sakaeratensis									2.08			

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Leptodiscella africana		6.25	8.33		2.08	6.25			4.17			
Microthyrium fagi	4.17			8.33			4.17			2.08		
Monacrosporium sp.1					2.08							
Mycoleptodiscus indicus	4.17											
Nigrospora sphaerica	10.42	10.42	10.42	2.08		2.08	6.25	6.25	12.50	4.17	10.42	
Paecilomyces sp.					2.08			2.08			8.33	
P. lilacinus	2.08	2.08		2.08	2.08		4.17	4.17			4.17	
Panchanania jaipurensis		2.08	4.17		2.08			2.08			2.08	
Parapleurotheciopsis sp.	8.33											
Parasympodiella podocarpi			16.67		2.08			2.08				4.17
Paratomenticola lanceolatus	18.75	12.50	8.33	4.17	6.25	6.25		8.33	4.17	8.33	8.33	8.33
Paratrichoconis chinensis		8.33			8.33			4.17			6.25	
Penicillium sp.1[1/]	2.08	6.25	2.08	2.08	2.08		20.83	12.50	8.33	6.25	14.58	8.33
Penicillium sp.2[1/]		4.17	12.50	2.08	2.08	4.17	2.08	8.33		2.08	10.42	

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Penicillium sp.3[1/]	2.08			2.08			2.08		12.50			
Periconia lateralis			2.08									
P. tirupatiensis		6.25										
Pestalotiopsis sp.1	4.17	6.25	6.25	2.08	4.17		2.08	4.17	4.17			
Pestalotiopsis sp.2		8.33						8.33				
P. disseminata	2.08									2.08		
Phaeoisariopsis cercosporioides	4.17			8.33			8.33			4.17		
Phaeoramularia marmorata	8.33	8.33		8.33	8.33		4.17	6.25		4.17		
P. oldenlandiae				6.25			2.08					
Phialocephala bactrospora		4.17										
Phoma sp.[1/]				2.08	2.08			6.25				
Phomopsis sp.[1/]	6.25			2.08								
Piricauda pseudarthiae		6.25										
Pleurophragmium acutum		6.25	2.08		8.33			4.17	2.08			4.17

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Pseudospiropes hughesii			2.08	6.25		6.25			2.08			
P. obclavatus		14.58	8.33			8.33	2.08		8.33	10.42	4.17	8.33
P. roussetianus			2.08			2.08						
P. subuliferus					6.25			6.25			4.17	
Pyriculariopsis sp.						2.08			4.17			
P. parasitica	14.58	22.92	12.50	8.33	6.25	12.50	8.33	16.67	12.50	6.25	16.67	10.42
Rhinocladiella sp.1			2.08	4.17		6.25			2.08			4.17
Rhinocladiella sp.2		2.08		2.08	2.08			2.08		2.08	2.08	
Rhinocladiella sp.3					2.08			2.08				
Rhinocladiella sp.4		2.08			2.08			2.08				
Saccardaea atra		6.25										
Scolecobasidiella avellanea			4.17			8.33	2.08		12.50	2.08	2.08	4.17
Scolecobasidium acanthacearum				4.17					2.08			
S. anellii				2.08								

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. compactum			6.25						4.17			
S. salinum				2.08			8.33					
Septonema fasciculare	8.33	6.25	4.17		16.67	14.58		8.33	6.25	4.17	8.33	
Sirosporium stylidii				2.08								
Spadicoides bina						4.17			6.25			
Spegazzinia sp.				2.08								
S. parkeri				2.08								
Speiropsis hyalospora		2.08		2.08	4.17	4.17	2.08	12.50	6.25			
Spondylocladiella sp.				2.08			4.17					
S. botrytioides	2.08						8.33		6.25	2.08		4.17
Sporidesmium autraliense						4.17			6.25			2.08
S. bambusicola					8.33			6.25				
S. dioscoreae	4.17			6.25			4.17			6.25		
S. ehrenbergii			6.25			6.25			4.17			8.33

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. ellisii						4.17			4.17			
S. flagellatum	2.08	6.25	4.17		12.50		4.17	16.67	6.25	2.08	18.75	12.50
S. harknesii		4.17	4.17						2.08			4.17
S. hormiscioides	4.17			2.08			6.25					
S. jasminicola	2.08		6.25	2.08		2.08	2.08		4.17	6.25		8.33
S. leptosporum		8.33						8.33			8.33	
S. longirostratum			4.17			2.08			2.08			
S. njalaense								4.17			4.17	
S. nodipes		2.08	4.17		8.33	2.08		6.25	4.17		2.08	6.25
S. rubi	6.25			12.50			2.08					
S. socium	4.17			2.08						4.17		
Sporoschisma uniseptatum				4.17			2.08	6.25		4.17		
Sporoschismopsis sp.1		6.25	6.25	2.08		8.33	10.42	8.33	4.17	4.17	12.50	8.33
Sporoschismopsis sp.2	2.08	2.08		4.17	2.08		4.17	2.08		6.25		

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Stachybotrys parvispora					2.08							
Staphylotrichum sp.						8.33						
S. coccosporum						4.17			4.17			
Stenella pithecellobii		2.08			8.33			8.33		6.25	10.42	4.17
Stigmina sp.1								6.25				
Stigmina sp.2		2.08			2.08			4.17				
S. combreticola			4.17									
S. hartigiana			4.17		2.08	2.08		8.33	4.17			
S. obtecta								6.25				
S. phaeocarpa		4.17										
S. rauvalfiae		4.17	8.33		6.25	2.08		6.25	8.33		4.17	2.08
S. sudanensis											4.17	
Subulispora sp.				2.08								
S. procuvata	8.33		4.17	14.58	10.42	4.17	2.08	4.17	4.17			

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Sympodiella sp.					4.17							
Taeniolella breviuscula		6.25			4.17			6.25			4.17	
Tetraploa aristata	2.08		4.17		4.17			8.33	4.17	2.08		
Tetraposporium sp.												4.17
T. asterinearum						2.08						
Torula sp.1	6.25			2.08			4.17			2.08		
T. herbarum	16.67	14.58	12.50	8.33		6.25	6.25	16.67	10.42	6.25		
Trichoderma sp.1[1/]	2.08			4.17			4.17		6.25			12.50
Trichoderma sp.2[1/]	2.08			4.17						4.17		
Trichoderma sp. 3[1/]		4.17		2.08	4.17		6.25			2.08	4.17	
Trichoderma sp.4[1/]	4.17			6.25		16.67						
Trichoderma sp.5[1/]								6.25		12.50	6.25	
Trichoderma sp.6[1/]	2.08			4.17			2.08			4.17		
T. atroviride[1/]	2.08		4.17	4.17		4.17	2.08		4.17	2.08		6.25

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. citrinoviride[1/]							2.08					
T. harzianum[1/]	2.08	2.08	4.17	2.08		6.25	2.08	6.25	4.17			6.25
T. viride[1/]	2.08	4.17		2.08	2.08		2.08	2.08		2.08	2.08	
Tricladium sp.				2.08								
Tripospermum myrti		2.08									6.25	
Triscelophorus acuminatus				2.08		2.08						
T. monosporum	4.17	6.25										
T. panapensis		2.08	4.17		10.42			2.08	4.17			
Uniseta sp.				4.17								
Veronaea sp.					2.08			4.17			4.17	
V. botryosa	2.08		6.25	2.08		6.25			2.08			6.25
V. carlinae	4.17				6.25		20.83	8.33	14.58		4.17	10.42
V. coprophila	10.42	14.58	8.33	6.25	14.58	2.08	4.17	16.67	6.25		8.33	8.33
V. musae		2.08	4.17		6.25	2.08		4.17		2.08	2.08	

Table 4.2 (Continued) Occurrence (%) of fungi on branch litter of rubber (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Wiesneriomyces javanicus		12.50	8.33						4.17			
Zygosporium gibbum		4.17										
Oomycota												
Phytophthora sp.	4.17			4.17								
Total number of species recorded	91	109	88	101	110	88	94	108	92	74	75	62
at each season		288			299			294			211	

Note: [1/] Isolated from dilution plates

[*] Newly fallen branches, middle stage decaying branches, old decaying fallen branches

Appendix C

Table 5.1 Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota												
Anthostomella formosa	2.08		2.08			2.08						
Chaetomium sp.									2.08			
Claussenomyces atrovirens	6.25			6.25						4.17		
Gaeumannomyces graminis			2.08									
Glomerella cingulata								4.17				
Hyphodiscosia sp.		4.17						2.08				
Hypoderma sp.								2.08				
Hypoxylon sp.1	16.67	12.50	12.50	12.50	10.42	6.25	6.25	4.17	2.08	8.33	2.08	10.42
Hypoxylon sp.2	6.25	8.33	4.17	6.25	6.25	2.08	2.08	6.25	2.08	6.25	4.17	
Hypoxylon sp.3	8.33	8.33	2.08	4.17	10.42	2.08	2.08	4.17	2.08	2.08	8.33	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Hypoxylon sp.4	2.08	6.25	2.08	2.08	4.17	2.08	2.08	2.08	2.08	2.08	2.08	4.17
Hypoxylon sp.5		4.17			4.17			4.17		2.08	2.08	
Hypoxylon sp.6		4.17			2.08						2.08	
H. cohaerens	8.33	6.25		6.25	4.17		4.17	2.08		4.17		
Hysterium pulcare		4.17										
Kirschsteiniothelia sp.	8.33	6.25	8.33	22.92	8.33	14.58	6.25	2.08	6.25	10.42	6.25	14.58
Leptosphaeria blumeri									2.08			2.08
L. darkeri											2.08	
Linocarpon sp.	4.17			2.08		2.08	2.08					
Linodochium hyalinum			2.08									
Linospora sp.		2.08			2.08							2.08
Lophiostoma fuckelii		2.08			4.17			6.25			2.08	
L. viridarium					2.08							

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Nectria ventricosa												2.08
Pestalosphaeria hansenii					10.42	4.17		2.08			2.08	
Thyridaria sambucina			2.08	2.08		2.08	8.33		6.25	8.33		10.42
Trematosphaeria pertusa								2.08				
Xylaria sp.1	6.25			2.08			2.08			2.08		
X. arbuscula		2.08			4.17			2.08				
Mitosporic fungi												
Acladium curtisii							4.17					
Acremonium sp.1	6.25		2.08	2.08								
Acremonium sp.2							2.08					
A. butyri					2.08			6.25			4.17	
A. cerealis	4.17	6.25		4.17	4.17						2.08	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
A. fusidioides		2.08			2.08	2.08	2.08	12.50	8.33			
A. kiliense				2.08	2.08		4.17	2.08		2.08	2.08	
A. rutilum	6.25						6.25		4.17	2.08		
A. strictum			6.25		2.08	2.08		2.08	2.08		2.08	2.08
Acremoniula fagi		2.08					4.17					
Actinocladium rhodosporum			2.08		4.17	6.25	4.17	4.17	2.08		2.08	4.17
Alternaria dennisii								2.08				
A. tenuissimum					4.17							
Annellophora solani	2.08	10.42		8.33	10.42		6.25	8.33		2.08	8.33	
Annellophorella ziziphi									2.08			
Aplosporella sp.			12.50			4.17						
Arthrinium muelleri	2.08											

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Arthrinum paeospermum			2.08									
Articulospora tetracladia	8.33								2.08			
Aspergillus sp.1[1/]	2.08	2.08	2.08	2.08	2.08	2.08						
Aspergillus sp.2[1/]							4.17	4.17	4.17			
Aspergillus sp.3[1/]	2.08	2.08	2.08							2.08	2.08	2.08
Aspergillus sp.4[1/]				2.08	2.08	2.08						
Aspergillus sp.5							2.08		2.08			
Aspergillus sp.6										2.08		2.08
Bachysporium masonii		6.25			4.17			4.17			4.17	
Bactrodesmiella masonii											2.08	
Bactrodesmium longisporum		8.33			8.33			8.33				
B. pallidum					2.08						4.17	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
B. rahmii	25.00	20.83	6.25	18.75	18.75	6.25	22.92	20.83	14.58	20.83	16.67	14.58
B. spilomeum		4.17	4.17		12.50	8.33		10.42	6.25		4.17	2.08
B. traversianum	8.33	4.17		8.33	2.08		6.25	2.08		2.08	2.08	
Bidenticula cannae					2.08						4.17	
Bipolaris sp.		2.08	6.25		4.17	2.08						2.08
B. australiensis		4.17			4.17						2.08	
B. frumentacei		4.17			2.08							
B. ravenelii	4.17			4.17								
B. rostrata				4.17								
Bispora antennata	2.08			4.17								
Botryodiplodia sp.	12.50	16.67	6.25	12.50	12.50	2.08	6.25	12.50	6.25	8.33	6.25	
B. bisbyi[1/]			2.08			4.17			4.17			

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Brachydesmiella biseptata			4.17			2.08			2.08			
Brachyhelicoon xylogenum		2.08										
Brachysporiella gayana						2.08					2.08	2.08
B. turbinata				2.08								
Calospora patanoides		4.17	2.08									6.25
Camposporium antennatum												2.08
C. cambrense		6.25			4.17			2.08	2.08	2.08	2.08	4.17
Capnobotrys neesii			4.17			2.08			2.08			
Ceratosporella deviata	2.08			2.08					2.08	4.17		
C. novae-zalandiae	4.17											
Cercospora sp.				2.08			6.25					
C. elaeidis		2.08			2.08				8.33			2.08

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. justiciicola								6.25			2.08	
C. malayensis										2.08		
Chalara sp.				4.17								
C. elegans								4.17				
Chloridiella sp.	4.17	4.17		2.08								
Cladosporium sp.1			6.25			8.33						
Cladosporium sp.2		4.17			8.33							
Cladosporium sp.3								6.25				
Cladosporium sp.4											6.25	
C. balladynae			2.08									
C. britannicum								2.08				
C. elatum[1/]		6.25										

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. flavum				6.25								
C. gynoxidicola				8.33								
C. orchidis				4.17						2.08		2.08
C. taurophorum												2.08
C. tenuissimum		10.42		2.08	4.17	2.08	2.08	2.08	2.08			
Clasterosporium cocoicola		10.42			4.17						2.08	
Codinaea sp.1				2.08			2.08			2.08		
C. hughesii	2.08			2.08								
Colletotrichum gloeosporioides					2.08							
Corynespora sp.					2.08			2.08				
C. combreti		4.17			2.08			2.08				
C. foveolata	4.17	12.50			8.33			4.17				

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. kamatii			6.25			6.25			6.25			
C. trichiliae						2.08			4.17			
Corynesporopsis quereicola	4.17			4.17								
Curvularia geniculata							2.08					
C. inaequalis			4.17			4.17			2.08			4.17
C. lunata[1/]				10.42	4.17	2.08	2.08	2.08				
C. pallescens			2.08			2.08						
Cylindrotrichum oligospermum									4.17			
Dactylaria sp.1		2.08			2.08			4.17			4.17	6.25
Dactylaria sp.2					2.08	2.08		6.25	4.17		4.17	
D. hyalina	6.25	2.08	2.08	4.17		2.08	4.17					
D. junci	2.08			2.08			2.08					

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Dactylella aquatica		4.17							4.17			
D. ellipsospora	2.08			2.08					2.08		2.08	
Dendryphiopsis arbuscula			8.33			8.33			6.25			2.08
Dictyosporium manglietiae				2.08			2.08			8.33		
Diplococcium sp.1	8.33			4.17								
D. spicatum		2.08		10.42	6.25	6.25	2.08		4.17	2.08	2.08	
Diplodia sp.		8.33			2.08			2.08				
Diplodina macrospora		2.08			2.08							
Domingoella leonensis		6.25			2.08	4.17						
Duosporium cyperi		6.25										
Ellisembia paravaginata	4.17											
E. vaginata				2.08						2.08		

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Endophragmia brevis	8.33			8.33			4.17					
E. hyalosperma									4.17			
Entomosporium sp.											2.08	
Excipularia narsapurensis			6.25			4.17			6.25			2.08
Exosporium ramosum								6.25				
Fasariella sp.		2.08	4.17		2.08	2.08		2.08				4.17
Fusariella sarniesis		4.17			2.08						6.25	
Fusarium sp.1		2.08	2.08	2.08	4.17	2.08	4.17	2.08	2.08			
Fusarium sp.2		2.08	2.08		2.08	2.08		2.08	6.25		2.08	
Fusarium sp.3			4.17			6.25						
F. semitectum						2.08						
F. oxysporum[1/]		2.08			2.08			2.08			2.08	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Gliomastix murorum			2.08									
Graphium calicioides	4.17									4.17		
Hansfordia nebularis						4.17			8.33			
Helicoma mulleri		2.08										
Helicomyces roseus		2.08										
H. scandens	4.17											
Helicoon auratum			2.08									
Helicosporium sp.										2.08		
H. aureum		2.08							4.17			2.08
H. elatum									2.08			
Helicostylum piriforme											2.08	
Helminthosporium acaciae					2.08			2.08			4.17	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
H. velutinum		2.08						4.17				
Hemicola grisea										2.08		
Hemicorynespora deightonii			2.08									
Henicospora coronata		4.17			2.08							
Humicola grisea									4.17			
Hyphodiscosia jaipurensis									6.25			2.08
Idriella lunata		6.25			4.17			8.33				
Janetia eupharbiae											2.08	
Lasiodiplodia cf. *theobromae*	6.25	18.75	12.50	12.50	16.67	4.17	10.42	18.75	4.17	8.33	6.25	2.08
Macrodiplodiopsis sp.			4.17			8.33			2.08			
Megalodochium elaedis		2.08			6.25							
Menispora sp.						2.08						

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
M. manitobaensis		6.25	2.08		4.17		2.08					
Monacrosporium sp.			2.08			2.08						
M. psychrophilum			8.33									
Monilia sp.			2.08									
Nawawia filiformis			4.17									
Nigrospora sphaerica				6.25	2.08	6.25	10.42	2.08	14.58	2.08	2.08	4.17
Paecilomyces sp.[1/]	2.08			2.08			2.08			2.08		
P. lilancinus												2.08
Parapleurotheciopsis sp.			2.08									
Parapyricularia musea			6.25		4.17				4.17			
Parasympodiella podocarpi	4.17											
Paratomenticola lanceolatus	6.25	2.08	14.58	2.08	10.42	6.25	8.33	10.42	16.67	2.08		12.50

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Paratrichoconis chinensis	4.17	4.17		2.08	4.17	12.50					8.33	2.08
Penicillium sp.1[1/]	2.08	4.17		2.08	2.08		2.08	2.08				
Penicillium sp.2										2.08	2.08	
Penicillium sp.3	2.08	2.08		2.08	2.08		2.08	2.08		2.08	2.08	
Penicillium sp.4		2.08			2.08							
Penicillium sp.5							2.08	2.08		2.08	4.17	
Periconia sp.	4.17											
Pestalotiopsis sp.1[1/]	2.08	2.08		4.17	2.08	4.17	2.08		4.17		2.08	2.08
Pestalotiopsis sp.2[1/]				6.25			2.08		2.08			2.08
*P. disseminata**				2.08			2.08			2.08		
P. sydowiana						2.08						2.08
Phaeoramularia marmorata			2.08			8.33						

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Phoma sp.					2.08			2.08				
Phomopsis sp.									4.17			
Pithomyces graminicola	2.08			4.17								
Pleurophragmium acutum	4.17	2.08	10.42		4.17	6.25				8.33	2.08	2.08
P. tritici												2.08
Pseudobeltrania crdrelae	4.17											
P. macrospora	8.33											
Pseudobotrytis terrestris				4.17			4.17					
Pseudocercospora helleri							2.08					
P. terminaliae							2.08					
Pseudospiropes hughesii											2.08	
P. obclavatus		8.33			4.17			4.17				

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Rhinocladiella sp.		2.08			2.08			2.08				
Scolecobasidiella avellanea	6.25		10.42	6.25	4.17	4.17		2.08	12.50		4.17	8.33
Scolecobasidium acanthacearum								10.42			2.08	
S. arenarium	6.25			2.08			4.17					
S. compactum	4.17			2.08			2.08					
Scutellinia scutellata	4.17											
Septonema fasciculare			6.25			4.17	4.17	6.25	2.08			2.08
Spegazzinia sundara									2.08			
Speiropsis hyalospora				4.17								
S. pecatospora	25.00									4.17		
Spiropes capensis								4.17				
Spondylocladiella botrytioides	8.33			6.25								

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Sporidesmium sp.1		8.33			6.25			2.08		4.17		
S. australiense		2.08		2.08	4.17		2.08			2.08		
S. bambusicola							2.08					
S. bonarii		8.33			6.25			8.33			2.08	
S. cladii	2.08			4.17			6.25					
S. flagellatum	10.42	2.08	14.58	14.58	2.08	12.50	22.92	6.25	18.75	18.75	16.67	20.83
S. folliculatum		2.08			2.08						2.08	
S. fusiforme	4.17			2.08						2.08		
S. harknesii	6.25	2.08	6.25	12.50	6.25	8.33	10.42	6.25	12.50	10.42	8.33	6.25
S. hormiscioides	6.25			2.08			2.08					
S. jaipurensis						2.08			2.08			2.08
S. jasminicola		6.25			2.08			6.25				

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. larvatum		4.17	2.08		2.08	4.17		10.42	6.25		6.25	4.17
S. leptosporum						2.08			12.50			
S. longirostratum	10.42			8.33			10.42			6.25		
S. obovatum					4.17			6.25			4.17	
S. paludosum								2.08				
S. penzigii	2.08	6.25		6.25	6.25		8.33	2.08		4.17		
S. rahmii	8.33			2.08			2.08					
S. rubi					2.08			6.25			2.08	
Sporoschisma uniseptatum	6.25			4.17				2.08				
Sporoschismopsis sp.					2.08			6.25				
Staphylotrichum coccosporum			8.33			2.08						
Stemphyliomma valparadisiacum								4.17				

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Stenella pithecellobii						2.08						4.17
Stigmina crotonicola								4.17			2.08	
S. fici	2.08			4.17								
S. hartigiana		4.17	2.08		2.08	2.08			2.08			2.08
S. kranzii	4.17			4.17								
S. murrayae								6.25				
S. rauvolfiae	6.25											
S. thermopsidis		2.08			2.08			4.17				
S. triumfelli	4.17			2.08			2.08					
Subulispora procurvuta	2.08			2.08			2.08			2.08		
Sympodiella acicola		4.17						2.08				
Taeniolella breviuscula		10.42			8.33			4.17			2.08	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. scripta	6.25			4.17								
T. stricta		4.17	6.25		8.33	6.25		4.17	8.33		2.08	
Tetracrium amphibium						2.08		2.08	4.17			2.08
Tetraploa aristata	2.08	2.08	2.08	2.08	2.08	2.08	2.08	4.17		2.08		2.08
Tetraposporium sp.							4.17				4.17	2.08
T. asterinearum		2.08				2.08		2.08				2.08
Torula sp.				2.08			2.08			2.08		
T. herbarum	2.08	2.08	14.58	4.17	2.08	14.58	4.17		8.33	2.08		2.08
Triadelphia heterospora		4.17										
Trichoderma sp.1[1/]		2.08	6.25		2.08	2.08	2.08	2.08	2.08	2.08	8.33	6.25
Trichoderma sp.2		2.08			2.08			2.08			2.08	
Trichoderma sp.3		4.17			2.08			2.08			2.08	

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. atroviride[1/]	8.33	6.25	8.33	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
T. aurioviride[1/]	4.17	2.08	8.33	4.17	2.08	4.17	4.17	2.08	2.08	4.17	2.08	
T. harzianum[1/]	2.08	6.25	2.08	2.08	6.25	2.08	4.17	6.25	2.08	2.08	8.33	2.08
T. virens[1/]	2.08			2.08			2.08			2.08		
T. viride[1/]		2.08			2.08	2.08		2.08			2.08	
Trichothecium sp.		4.17			4.17			2.08				
Tricladium fuscum									2.08	4.17		
Tridentaria implicans		2.08										
Trimmatostroma betulinum			2.08			4.17						
Tripospermum myrti												8.33
Trochophora simplex							4.17					
Tubercularia vulgaris	4.17			4.17								

Table 5.1 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Nakhon Si Thammarat Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Veronaea apiculata												4.17
V. carlinae	4.17	4.17	2.08	4.17	2.08	4.17	2.08	2.08	6.25	4.17		4.17
V. coprophila	14.58	6.25	4.17	6.25	4.17	4.17	2.08		6.25		2.08	
V. musae			2.08			2.08			8.33			
V. parvispora					2.08			2.08		4.17	2.08	
Wiesneriomyces javanicus	6.25	2.08	6.25									
Xenosporium indicum											4.17	
X. larvale	4.17											
Zygosporium gibbum	2.08			2.08	2.08		2.08			2.08		
Total number of species	83	100	70	87	104	77	74	94	72	59	74	57
recorded at each season		253			268			240			190	

Note: [1/]Isolated from dilution plates

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

Table 5.2 Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Ascomycota												
Astrosphaeriella sp.			2.08			4.17						
Claussenomyces atrovirens		2.08										
Dothidotthia sp.1	4.17	2.08	4.17		4.17	4.17	2.08		2.08	4.17		
Dothidotthia sp.2	8.33											
Eupenicillium sp.								2.08				
Gaeumannomyces graminis						2.08						
Glomerella cingulata								2.08				
Hypocrea rufa		2.08			4.17							
Hypomyces sp.			2.08									
Hypoxylon sp.1	2.08		8.33	2.08	2.08	8.33	2.08	2.08	4.17		4.17	4.17
Hypoxylon sp.2	4.17			2.08	2.08	2.08	2.08	2.08		2.08	4.17	2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Hypoxylon sp.3	2.08			2.08	2.08							
Hypoxylon sp.4	2.08			2.08	2.08		2.08	2.08		2.08	4.17	
H. cohaerens		10.42	4.17		12.50	8.33		2.08	8.33		6.25	6.25
Kirschsteiniothelia sp.	10.42	14.58	6.25	6.25	18.75	6.25	4.17	6.25	6.25	14.58	8.33	6.25
Linospora sp.	2.08	4.17	4.17	2.08	2.08	2.08						2.08
Lophostoma viridarium											2.08	
Oedothea vismiae	4.17			2.08			2.08			4.17		
Oxydothis sp.							2.08					
Pestalosphaeria hansenii	10.42		6.25	2.08		6.25	4.17		6.25	4.17	4.17	
Phaeosphaeria sp.	2.08						4.17			2.08		
Thyridaria sambucina				8.33		4.17	8.33		4.17	6.25		
Trematosphaeria pertusa	2.08		4.17								6.25	

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Mitosporic fungi												
Acarocybe formosa	16.67	6.25	4.17	8.33	6.25	2.08	6.25	2.08		4.17		
A. hansfordii	12.50	4.17	4.17	4.17	2.08		2.08	2.08	4.17			
Acarocybella jasminicola	4.17			4.17								
Acremoniula sp.				2.08								
Acremomium sp.		6.25		4.17	6.25	2.08		4.17		2.08	4.17	4.17
A. alternatum					4.17						2.08	
A. butyri	2.08			2.08		2.08	10.42	2.08	2.08	2.08	6.25	
A. fusidioides		4.17		2.08	2.08		4.17	6.25		4.17	4.17	
A. kiliense	2.08			2.08	2.08	4.17	6.25		4.17	6.25	4.17	4.17
A. murorum								8.33				
A. strictum					2.08			8.33			2.08	

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Actinocladium rhodosporum		6.25			4.17	4.17		4.17				4.17
Arthobotrys oligospora									4.17			
Arthrinium sp.					8.33	2.08						4.17
A. muelleri								2.08				
Aspergillus sp.1[1/]	2.08			10.42	8.33	4.17	2.08	2.08	2.08	4.17	2.08	2.08
Aspergillus sp.2[1/]	2.08			4.17	2.08	8.33		2.08	4.17	4.17	2.08	4.17
Aspergillus sp.3[1/]	2.08			4.17	2.08					2.08	2.08	
Aspergillus sp.4[1/]		2.08		2.08	4.17			2.08		2.08	4.17	
A. japonigum	2.08			8.33			2.08			2.08		
A. niger				6.25						2.08		
Bactrodesmiella masonii				2.08			4.17	4.17				
Bactrodesmium betulicola	14.58		2.08	6.25		4.17	16.67		4.17	12.50		2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
B. masonii			4.17			6.25			4.17			
B. pallidum	2.08		6.25	2.08		8.33		4.17	4.17			
B. rahmii	10.42	16.67	10.42	10.42	10.42	10.42	20.83	16.67	12.50	4.17	14.58	8.33
B. spilomeum	18.75	14.58	4.17	8.33	12.50	4.17	14.58	10.42	4.17	8.33	8.33	4.17
Bahusakala cookei			6.25			4.17			2.08			
Beltraniella fertilis		4.17	2.08			2.08			4.17			
B. odinae			2.08									
Berkleasmium cf. *minutissimum*		4.17	6.25		2.08	4.17			4.17			
B. concinnum			4.17		8.33				4.17			
B. grandisporus					2.08			4.17				
B. leonense		2.08										
Bidenticula cannae							2.08	2.08		2.08		

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Bipolaris sp.1	6.25			2.08		2.08						2.08
Bipolaris sp.2	2.08			4.17								
B. biseptata		4.17			2.08							
B. cactivora	6.25		2.08			2.08			2.08	2.08		
B. indica		4.17										
B. japonica								2.08				
B. miyakei	4.17											
B. ravenelii			4.17						4.17			
B. sacchari	2.08			2.08								
Bispora antennata	2.08						2.08					
B. catenula										2.08		
Botryodiplodia sp.[1/]	18.75	6.25	6.25	8.33	8.33	6.25	14.58	8.33	6.25	14.58	12.50	6.25

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Brachydesmiella biseptata		2.08	6.25		2.08	6.25	2.08			2.08		4.17
Brachysporiella gayana				2.08			2.08			6.25	4.17	
B. laxa			2.08									
B. turbinata			4.17									2.08
Brachysporium bloxami								4.17				
B. nigrum				4.17								
Calospora platanoides		2.08						2.08				
Camposporium antennatum				2.08			4.17					
C. cambrense						2.08						
C. rosea						6.25			4.17			2.08
Canalisporium caribense		4.17			2.08				4.17			
Cantelabrella musifomis												2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Cercospora sp.				2.08	2.08		2.08	2.08				
C. elaedis	4.17			4.17			2.08			4.17		
Chaetochalara bulbosa								2.08				
Chalara sp.					4.17						2.08	
Chalaropsis sp.								2.08				
Chuppia sarcinidera			2.08						4.17			
Circinotrichum maculiforme	6.25											
Cirrenalia pseudomacrocephala			4.17									
Cladosporium sp.1	6.25	4.17		2.08	2.08							
Cladosporium sp.2		6.25			4.17						2.08	
C. acaciicola							8.33					
C. diaphanum							2.08					

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. elatum[1/]		6.25		8.33	6.25		2.08					
C. psoraleae[1/]					2.08							
C. tenuissimum			8.33	14.58	2.08	6.25	4.17	6.25	6.25		2.08	4.17
Clasterosporium pistaciae			6.25			4.17						
Codinae sp.			2.08			2.08						2.08
Colletotrichum sp.[1/]	2.08			2.08								
Cordana pauciseptata			4.17									
Coronospora dendrocalami			2.08			2.08						
Curvularia sp.	4.17			2.08		2.08						
C. affinis					4.17							
C. eragrostidis		4.17										
C. geniculatum				2.08								
C. lunata[1/]			2.08	4.17		4.17	2.08		6.25	2.08		2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
C. pallescense	2.08	6.25			4.17					2.08		
C. trifolii			2.08									
Cylindrocladium sp.		2.08						2.08				
Cylindrotrichum oligospermum					2.08							
Dactylaria sp.1	2.08	6.25	4.17	2.08	2.08	6.25		2.08	8.33	2.08	2.08	2.08
Dactylaria sp.2	8.33			2.08		2.08				2.08	2.08	
D. hyalina	4.17	2.08		2.08		2.08		2.08	2.08	2.08		2.08
D. junci	2.08			2.08		2.08		2.08	4.17		2.08	2.08
Dactylella sp.						2.08			2.08			2.08
D. aquatica						6.25			2.08			
D. ellipsospora						2.08						2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Dictyosporium sp.			6.25				2.08					
D. elegans			4.17			2.08						
D. giganticum	2.08											
D. manglieliae		4.17	4.17	2.08	4.17	4.17	4.17		4.17	4.17		
Diploccocium clarkii		10.42			2.08			2.08			2.08	
D. spicatum	2.08		2.08									
Domingoella leonensis	8.33	4.17	6.25	2.08			2.08					
Ellisembia paravaginata			4.17									2.08
E. vaginata							4.17		8.33	6.25	6.25	
Ellisiopsis galesiae		2.08	2.08									
Endophragmia bisbyi	4.17			2.08						2.08		
E. boewei		4.17									2.08	

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
E. cesatii		6.25										
E. elliptica	2.08											
Endophragmiella sp.									8.33			
E. boewei				2.08						2.08		
Exosporiella fungorum					2.08							
Exosporium sp.			4.17									
E. ramosum			6.25			6.25			4.17			4.17
Fulvia berkheyae	2.08	2.08	4.17					2.08				
Fusariella concinna	2.08						2.08			4.17		
Fusarium sp.1		2.08			2.08	6.25	4.17	4.17	2.08	2.08	2.08	
Fusarium sp.2					2.08	4.17		4.17	2.08		2.08	
Fusarium sp.3			6.25			8.33			6.25		2.08	2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
F. chlamydosporum				2.08			6.25					
F. moniliforme	2.08	2.08				2.08			4.17	2.08		
F. oxysporum[1/]	2.08			4.17			2.08			4.17		
F. semitectum					4.17						2.08	
Gliomastix vegetum		6.25										
Gonatophragmium mangiferae							2.08					
Hansfordia biophila						2.08		2.08	2.08			
H. ovalispora		4.17	2.08		2.08							2.08
Helicoma dennisii									2.08			
Helicomyces roseum	2.08	6.25		2.08			2.08			2.08		
Helicosporium aureum	2.08											
H. vegetum		6.25	4.17		2.08			2.08				

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Hemibeltrania cinnamomi		4.17										
Hemicorynespora mitrata			4.17									
Henicospora coronata		8.33	2.08			2.08						
Heteroconium solaninum		6.25			2.08			4.17			8.33	
Hirudinaria macrospora		2.08										
Hormiactis candida	2.08		8.33	4.17			2.08					
Humicola grisea											2.08	
Hyphodiscosia jaipurensis			6.25									
Idriella lunata						4.17						
Lasiodiplodia cf. *theobromae*	18.75	20.83	8.33	8.33	18.75	8.33	8.33	6.25	8.33		4.17	8.33
Leptodiscella africana	2.08	4.17	2.08		2.08	2.08			2.08			
Menispora sp.	2.08											

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Molowia basicola									2.08			
Monilia sp.				2.08								
Moorella speciosa									4.17			
Mycoleptodiscus indicus	2.08						2.08			2.08		
Myrothecium roridum					2.08			2.08				
Nigrospora sphaerica	8.33	6.25		12.50	12.50	8.33	4.17	6.25	6.25		4.17	4.17
Paecilomyces sp.[1/]				2.08	4.17	2.08	2.08	4.17		2.08		2.08
Panchanania jaipurensis		2.08			2.08						2.08	
Parasympodiella podocarpi			2.08			2.08		2.08	2.08			
Paratomenticola lancelolatus	8.33	4.17		4.17	2.08	4.17	4.17	2.08	4.17	2.08	6.25	6.25
Paratrichoconis chinensis			4.17						2.08			2.08
Penicillium sp.1[1/]	2.08	6.25	2.08	16.67	12.50	4.17	6.25	2.08	2.08	2.08	4.17	2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Penicillium sp.2	2.08	6.25		2.08	8.33	6.25	2.08	2.08	2.08		4.17	4.17
Penicillium sp.3	4.17	6.25		6.25	4.17		2.08	2.08		4.17	4.17	
Penicillium sp.4	2.08	6.25		2.08	2.08			2.08		2.08	4.17	
Penicillium sp.5				8.33	2.08		2.08	2.08			2.08	
Penicillium sp.6					4.17			2.08			4.17	
Periconia sp.	6.25	6.25					4.17					
Pestalotiopsis sp.1[1/]	2.08			2.08	2.08	2.08	2.08	2.08	2.08			
Pestalotiopsis sp.2[1/]			2.08			2.08			2.08			
*P. disseminata**		2.08			2.08							
Phaeoisariopsis cercosporioides		10.42	2.08		2.08	2.08		2.08	2.08	8.33	2.08	
Phaeoramularia leeae			8.33			4.17			4.17			4.17
P. marmorata	12.50	18.75	8.33	8.33	16.67		8.33	8.33		8.33	14.58	

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Phialophora bubakii		4.17										
Pleurophragmium simplex	8.33											
Pleurotheiopsis pusilla	6.25											
Polyscytalina grisea					6.25			2.08				
Pseudobeltrania cedrelae		4.17										
Pseudobotrytis terrestris			2.08						2.08			2.08
Pseudospiropes sp.		2.08			2.08							
P. hughesii	6.25	12.50	8.33	4.17	4.17	6.25		2.08		2.08		
Pseudospiropsis aboularvatus							2.08			2.08		
Pyriculariopsis parasitica	8.33	8.33		4.17	8.33		10.42	8.33		4.17	2.08	
Rhinocladiella sp.		2.08	2.08		4.17	2.08						
Saccardaea atra		6.25										

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Schizotrichum lobeliae							2.08					
Scolecobasidiella avellanea	2.08	10.42	2.08	2.08	4.17		2.08	2.08		4.17	2.08	2.08
Scolecobasidium compactum						6.25			8.33			6.25
S. salinum	10.42			4.17		2.08	4.17					
Septonema fasciculare					8.33	4.17		8.33	4.17		2.08	4.17
S. secedens	6.25			4.17			2.08					
Sirosporium antenniforme	2.08									2.08		
S. mori					4.17							
S. carissae			4.17						2.08			
Spadicoides afzeliae		14.58			10.42						2.08	
Spegazzinia lobulata			8.33			6.25			4.17			
Speiropsis hyalospora		6.25	2.08									

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Spiropes sp.			4.17			2.08			2.08			
Spondylocladiella botrytioides	4.17		2.08	4.17		4.17			2.08	2.08		
Sporidesmium dioscoreae	8.33			4.17			4.17			8.33		
S. ehrenbergii	6.25	6.25		2.08	4.17		2.08			4.17	2.08	
S. flagellatum		4.17	6.25	2.08	2.08	4.17	2.08	2.08	6.25	2.08	8.33	8.33
S. ghanaense	4.17			2.08			2.08					
S. jasminicola	6.25	6.25	4.17	2.08	2.08	4.17	2.08	2.08			8.33	4.17
S. harknesii					4.17			2.08				
S. leptosporum			6.25			4.17			4.17			6.25
S. longirostratum	2.08		6.25	2.08			2.08			2.08		
S. penzigii						2.08			6.25			
S. raphiae			4.17									2.08

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
S. rubi		4.17			2.08			2.08				
S. socium						2.08						
Sporoschisma uniseptatum			2.08									
Sporoschismopsis sp.1		4.17			2.08			2.08			2.08	
Sporoschismopsis sp.2		6.25		10.42			27.08	6.25		4.17	10.42	
Staphylotrichum sp.	10.42											
S. coccosporum		4.17										
Stenella pithecellobii					2.08		2.08				6.25	
Stigmina celata		4.17							2.08			
S. sapii		4.17										
Subulispora sp.					2.08			2.08			2.08	
S. procurvata			2.08			2.08						

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Taeniolella alta				4.17								
T. breviuscula	4.17						2.08					
T. exilis							8.33					
T. scripta		4.17			2.08							
Teratosperma singulare								2.08				
Tetraploa aristata	4.17	6.25			2.08							
Tetraposporium sp.			2.08			4.17		4.17	4.17		2.08	2.08
T. asternearum			2.08									
Tomenticola trematis			4.17			2.08			4.17			4.17
Torula sp.	2.08	2.08		2.08	2.08		2.08	4.17			2.08	
T. ellisii			2.08		2.08	2.08		4.17				
T. herbarum	6.25	10.42	4.17	4.17	4.17	4.17	10.42	2.08	4.17	4.17	4.17	4.17

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Triadelphia heterospora			4.17						2.08			
T. inquinans		2.08										
Trichoderma sp.1				2.08	4.17			4.17		2.08	2.08	
Trichoderma sp.2	2.08	2.08		2.08	4.17		2.08	4.17		2.08	2.08	
Trichoderma sp.3	2.08	2.08		2.08	2.08		2.08	2.08		2.08	2.08	
T. atroviride[1/]		2.08	4.17	2.08	2.08	4.17		2.08	4.17	2.08	2.08	2.08
T. aureoviride[1/]							4.17	2.08				
T. hamatum[1/]				2.08	4.17			2.08		2.08	6.25	
T. harzianum[1/]	2.08			2.08		4.17	2.08	2.08	4.17	2.08		6.25
T. virens[1/]				2.08	2.08					2.08	6.25	
T. viride					2.08	4.17			2.08			2.08
Tricladium sp.		8.33		2.08								

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
T. fuscum											2.08	
Trimmatostroma betulinum	2.08											
T. salicis				2.08								
Tripospermum myrti			6.25		4.17	2.08	2.08	4.17				
Triscelophorus panapensis		4.17	4.17			4.17						
Ulocladium alternariae								2.08			2.08	
Veronaea carlinae		6.25	4.17	2.08	4.17	8.33	2.08	4.17	2.08		2.08	4.17
V. coprophila	2.08	6.25	4.17	2.08	2.08	4.17	6.25	6.25	4.17			
V. musae							2.08		2.08			
Verticillium dahliae		4.17									2.08	
Virgaria nigra			6.25	4.17								6.25
Wiesneriomysis javanicus		4.17										

Table 5.2 (Continued) Occurrence (%) of fungi on rubber logs (*Hevea brasiliensis*) collected from Songkhla Province at different seasons and in each stage of decomposition

Taxa	Late rainy season			Dry season			Early rainy season			Rainy season		
	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*	New*	Middle*	Old*
Xenosporium indicum			4.17									
Ypsilonia sp.	2.08											
Zanclospora novae-zelandiae	2.08	4.17					2.08					
Total number of species	93	95	92	96	100	92	84	87	79	70	73	56
recorded at each season	280			288			250			199		

Note: [1/] Isolated from dilution plates

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

Appendix D

Table 6.1 Occurrence (%) of macrofungi were found on soil at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Ascomycota							
Aleuria aurantia	*Pyronematacae*				1.39		
Basidiomycota							
Agaricus sp.1	*Agariceceae*	1.39		1.39		1.39	
Agaricus sp.2	*Agariceceae*			1.39	1.39		
Agaricus sp.3	*Agariceceae*				1.39		
A. trisulphuratus	*Agariceceae*			2.78			
Amanita sp.	*Amanitaceae*				1.39	1.39	
Bolbitius candolleana	*Bolbitiaceae*				1.39		
Calvatia excipulifomis	*Agariceceae*			2.78	1.39		
Clavaria vermicularis	*Clavariaceae*			1.39			
Collybia nepheloides	*Tricholomataceae*	1.39					1.39
C. peronata	*Tricholomataceae*				1.39		
Coprinus dissiminata	*Agaricaceae*				1.39	1.39	
Cortinarius sp.	*Cortinariaceae*			1.39			
Craterellus aureus	*Cantharellaceae*			1.39			
Dictyophora indusiata	*Phallaceae*				1.39		
Entoloma sp.2	*Entolomataceae*			1.39			
Entoloma sp.3	*Entolomataceae*			1.39			1.39
Entoloma sp.4	*Entolomataceae*					1.39	
Entoloma sp.5	*Entolomataceae*			1.39			
E. incanum	*Entolomataceae*					1.39	
Hygrocybe cantharellus	*Hygrophoraceae*		1.39			1.39	1.39
H. coccinae	*Hygrophoraceae*					1.39	1.39

Table 6.1 (Continued) Occurrence (%) of macrofungi were found on soil at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
H. coccineocrenata	*Hygrophoraceae*			1.39	1.39		
Laccaria laccata	*Laccariaceae*				1.39		
Lepiota sp.1	*Agariceceae*			1.39			
Lepiota sp.2	*Agariceceae*			1.39			
L. cortinarius	*Agariceceae*				1.39		
L. echinacea	*Agariceceae*				1.39		
Leucocoprinus birnbaumii	*Agariceceae*			1.39	1.39		
L. fragilissimus	*Agariceceae*				1.39		
L. zeylanicus	*Agariceceae*			1.39			
Lycoperdon perlatum	*Agaricaceae*				2.78		
Pluteus aglaeotheles	*Pluteaceae*			1.39			
P. cinereo-fuscus	*Pluteaceae*			2.78			
Podoscypha nitidula	*Podoschypheae*			1.39	2.78		
Ramaria cyanocephala	*Gomphaceae*				1.39		
R. fragilima	*Gomphaceae*			1.39			
R. grandis	*Gomphaceae*			1.39			
Rhodophyllus sp.	*Entolomataceae*			1.39			
R. cyanoniger	*Entolomataceae*				1.39		
Strobilomyces velutipes	*Boletaceae*					1.39	
Termitomyces globulus	*Lyophyllaceae*			1.39			
Thelephora palmata	*Thelephoraceae*			1.39			
Volvariella volvacea	*Pluteaceae*				1.39		
Total number of macrofungi recorded on soil		2	1	23	20	8	4

Note: [1]January, late rainy season, [2]March, dry season, [3]May, early rainy season (in Nakhon Si Thammarat Province), [4]July, early rainy season (in Songkhla Province), [5]September and November, middle rainy season.

Table 6.2 Occurrence (%) of macrofungi were found on leaf litter at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Ascomycota							
Xylaria aristata	*Xylariaceae*				1.39	1.39	1.39
X. hypoxylon	*Xylariaceae*			2.78	1.39	1.39	1.39
Basidiomycota							
Claudopus repens	*Entolomataceae*				1.39		
Marasmius alborescens	*Marasmiaceae*				1.39		
M. androsaceus	*Marasmiaceae*			4.17	4.17	2.78	2.78
M. berteroi	*Marasmiaceae*				1.39	1.39	
M. cohaerens	*Marasmiaceae*					1.39	
M. micraster	*Marasmiaceae*				4.17	2.78	2.78
M. pellucidus	*Marasmiaceae*				1.39		1.39
M. pulcherripes	*Marasmiaceae*				1.39		1.39
M. aurantioferrugineus	*Marasmiaceae*			1.39			
M. siccus	*Marasmiaceae*	1.39	1.39	2.78	4.17	4.17	4.17
Microphale brassicolens	*Marasmiaceae*					1.39	1.39
Heinemannomyces sp.	*Mycenaceae*				1.39	1.39	
Psathyrella candolleana	*Psathyrellaceae*				1.39		
Total number of macrofungi recorded on leaf litter		1	1	4	12	9	8

Note: [1]January, late rainy season, [2]March, dry season, [3]May, early rainy season (in Nakhon Si Thammarat Province), [4]July, early rainy season (in Songkhla Province), [5] September and November, middle rainy season

Table 6.3 Occurrence (%) of macrofungi were found on branch litter at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Ascomycota							
Bulgaria javanicum	*Bulgariaceae*		4.17				
B. maxicana	*Bulgariaceae*					1.39	1.39
Cookeina sulcipes	*Sarcoscyphaeae*						2.78
C. tricholoma	*Sarcoscyphaeae*				1.39	1.39	
Daldinia concentrica	*Xylariaceae*			2.78			
D. escholizii	*Xylariaceae*	1.39					
Hypocrea pezizoidea	*Hypocreaceae*	2.78	2.78	2.78		1.39	
H. splendens	*Hypocreaceae*			2.78	1.39	1.39	1.39
Nectria pseudotrichia	*Hypocreaceae*				1.39		
Xylaria sp.1	*Xylariaceae*	1.39					
X. arbuscula	*Xylariaceae*					1.39	
X. aristata	*Xylariaceae*				1.39		
X. caespitulosa	*Xylariaceae*	1.39					
X. cubensis	*Xylariaceae*					1.39	
X. hypoxylon	*Xylariaceae*			2.78	1.39		
X. multiplex	*Xylariaceae*	2.78		2.78	2.78		
Basidiomycota							
Aleurodiscus mirabilis	*Alurodiscaceae*	2.78	1.39	1.39			
A. oakesii	*Alurodiscaceae*	1.39	1.39	1.39			
Auricularia sp.1	*Auriculariaceae*			1.39	1.39		
A. auricula	*Auriculariaceae*	2.78		1.39	1.39		
A. fuscosuccinia	*Auriculariaceae*			2.78	2.78		
A. polytricha	*Auriculariaceae*			4.17	2.78	2.78	
Aurificaria euphorbiae	*Hymenochaetaceae*		1.39				
Campanella junghuhnii	*Marasmiaceae*				1.39		

Table 6.3 (Continued) Occurrence (%) of macrofungi were found on branch litter at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Claudopus repens	*Entolomataceae*			1.39	1.39		
Coriolus hirsutus	*Polyporaceae*	1.39		1.39	1.39	1.39	
Dacryopinax spathularia	*Dacrymycetaceae*					1.39	
Entoloma sp.1	*Entolomataceae*			1.39			
Heterobasidion annosum	*Bondarzewiaceae*				1.39	1.39	
Hexagonia tenuis	*Polyporaceae*	5.56	4.17	8.34	4.17	8.34	5.56
Irpex flavus	*Meruliaceae*	1.39		1.39			
Junghuhnia nitida	*Meruliaceae*	1.39					
Lactarius hygophoroides	*Russulaceae*				1.39	1.39	1.39
Lentinus sp.	*Polyporaceae*			1.39			
L. citiatus	*Polyporaceae*				1.39		
L. connatus	*Polyporaceae*			1.39			
L. giganteus	*Polyporaceae*					1.39	1.39
L. polychrous	*Polyporaceae*			1.39			1.39
L. similis	*Polyporaceae*						1.39
L. squarrosulus	*Polyporaceae*			1.39			
Lenzites elegans	*Polyporaceae*			2.78		2.78	2.78
Marasmiellus candidus	*Marasmiaceae*				1.39	2.78	1.39
Marasmius sp.1	*Marasmiaceae*					1.39	
Marasmius alborescens	*Marasmiaceae*			8.34	5.56	4.17	4.17
M. ntioferrugineus	*Marasmiaceae*			1.39	1.39		
M. cohaerens	*Marasmiaceae*			1.39		1.39	
M. conicopapilatus	*Marasmiaceae*						1.39
M. florideus	*Marasmiaceae*						1.39
M. micraster	*Marasmiaceae*						1.39

Table 6.3 (Continued) Occurrence (%) of macrofungi were found on branch litter at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
M. pulcherripes	*Marasmiaceae*				4.17		2.78
M. siccus	*Marasmiaceae*	1.39	1.39		1.39	1.39	1.39
Meruliopsis corium	*Phanerochaetaceae*	1.39		4.17	2.78	1.39	4.17
Microphale perforns	*Marasmiaceae*				1.39		
Microporus xanthopus	*Polyporaceae*				1.39		
Mycena stylobates	*Mycenaceae*				1.39		
Podoscypha nitidula	*Podoschypheae*		1.39	1.39			
Polyporus sp.1	*Polyporaceae*					1.39	
Polyporus elegans	*Polyporaceae*			1.39			
P. retirugis	*Polyporaceae*					1.39	1.39
Psathyrella sp.	*Psathyrellaceae*				1.39		
Pycnoporus cinnabarinus	*Polyporaceae*	1.39				1.39	1.39
P. sanguineus	*Polyporaceae*	1.39		1.39	1.39		
Schizophyllum commune	*Schizophyllaceae*	6.95	6.95	8.34	8.34	11.12	11.12
Trametes flavida	*Polyporaceae*					1.39	
T. hirsuta	*Polyporaceae*	1.39		1.39			
T. modesta	*Polyporaceae*			1.39			
T. scabosa	*Polyporaceae*	1.39		4.17	4.17		2.78
Tremella fuciformis	*Tremellaceae*			1.39	2.78	1.39	1.39
Xeromphalina campanella	*Mycenaceae*				1.39		
Total number of macrofungi recorded on branch litter		**19**	**9**	**33**	**32**	**21**	**22**

Note: [1]January, late rainy season, [2]March, dry season, [3]May, early rainy season (in Nakhon Si Thammarat Province), [4]July, early rainy season (in Songkhla Province), [5] September and November, middle rainy season

Table 6.4 Occurrence (%) of macrofungi on wood logs at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Ascomycota							
Bertia moriformis	*Bertiaceae*				1.39		1.39
Bulgaria maxicana	*Bulgariaceae*			2.78	1.39	2.78	
Cookeina tricholoma	*Sarcoscyphaeae*			1.39	2.78	1.39	
Daldinia concentrica	*Xylariaceae*			1.39		1.39	
D. escholizii	*Xylariaceae*	1.39					
Hypocrea pezizoidea	*Hypocreaceae*			1.39	2.78	2.78	
H. splendens	*Hypocreaceae*	1.39		2.78	4.17		
Xylaria arbuscula	*Xylariaceae*						1.39
X. aristata	*Xylariaceae*					1.39	
X. cubensis	*Xylariaceae*						1.39
X. hypoxylon	*Xylariaceae*				1.39		
X. multiplex	*Xylariaceae*	1.39					1.39
Basidiomycota							
Auricularia auricula	*Auriculariaceae*			2.78	1.39		
A. polytricha	*Auriculariaceae*			2.78	2.78	1.39	2.78
Collybia peronata	*Tricholomataceae*					1.39	
Coriolopsis polyzona	*Polyporaceae*			1.39		1.39	
Coriolus hirsutus	*Polyporaceae*				4.17		
Cyathus striatus	*Agariceceae*				1.39	1.39	2.78
Fomitopsis feei	*Fomitopsidaceae*			2.78	1.39		
Ganoderma sp.	*Ganodermataceae*					1.39	1.39
Geastrum mirabile	*Geastraceae*					2.78	1.39
Gloiocephala epiphylla	*Physalacriaceae*						2.78
Hemimycena delicatella	*Mycenaceae*						2.78

Table 6.4 (Continued) Occurrence (%) of macrofungi on wood logs at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Heterobasidion annosum	*Bondarzewiaceae*				2.78	2.78	
Hexagonia tenuis	*Polyporaceae*	6.69	5.56	11.11	11.11	8.34	5.56
Lactarius hygophoroides	*Russulaceae*				1.39		
L. squarrosulus	*Polyporaceae*					1.39	1.39
Lenzites elegans	*Polyporaceae*	1.39			1.39	1.39	2.78
Marasmius sp.1	*Marasmiaceae*			2.78		2.78	2.78
M. conicopapilatus	*Marasmiaceae*			2.78	2.78		4.17
M. pellucidus	*Marasmiaceae*			1.39	1.39		2.78
M. pulcherripes	*Marasmiaceae*			4.17	4.17	1.39	1.39
M. siccus	*Marasmiaceae*				2.78		
M. aurantioferrugineus	*Marasmiaceae*				4.17		
Meruliopsis corium	*Phanerochaetaceae*	2.78	2.78	2.78	4.17	4.17	1.39
Microporus affinis	*Polyporaceae*				1.39		1.39
Pluteus sp.	*Pluteaceae*			2.78			
Polyporus sp.1	*Polyporaceae*			1.39	1.39		
Polyporus sp.2	*Polyporaceae*					1.39	
P. elegans	*Polyporaceae*			1.39	1.39		
Pycnoporus sanguineus	*Polyporaceae*			1.39		1.39	
Rigidoporus microporus	*Meripilaceae*					1.39	1.39
Schizophyllum commune	*Schizophyllaceae*	6.95	6.95	8.34	11.12	9.73	12.51
Trametes flavida	*Polyporaceae*	1.39	1.39	1.39			
T. modesta	*Polyporaceae*				1.39	1.39	
T. scabosa	*Polyporaceae*		2.78	1.39	1.39	1.39	
Tremella fuciformis	*Tremellaceae*				1.39	1.39	
Xeromphalina campanella	*Mycenaceae*				4.17		2.78

Table 6.4 (Continued) Occurrence (%) of macrofungi on wood logs at each period

Taxa	Family	Month					
		Jan[1]	Mar[2]	May[3]	July[4]	Sep[5]	Nov[5]
Total number of macrofungi recorded on wood logs		8	5	22	29	23	21

Note: [1]January, late rainy season, [2]March, dry season, [3]May, early rainy season (in Nakhon Si Thammarat Province), [4]July, early rainy season (in Songkhla Province), [5]September and November, middle rainy season

Appendix E

Table 8.1 Dry mass, nutrient content and decomposition rate (k) of nutrient on rubber leaf litter after 90 of decomposition in *A. parasiticus*

Time (days)	Average dry mass of the remaining (g)	Nutrient contents (g)				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0	100.00	2.26	0.15	0.56	1.45	0.33
15	72.71	1.75	0.12	0.49	1.27	0.3
30	67.06	1.69	0.12	0.39	1.35	0.29
45	63.72	1.69	0.10	0.41	1.18	0.27
60	61.39	1.69	0.10	0.31	1.44	0.25
75	58.22	1.66	0.10	0.31	1.25	0.26
90	54.22	1.68	0.10	0.29	1.10	0.25
Total loss	45.78	0.58	0.05	0.27	0.35	0.08
k (per day)	0.0272	0.0132	0.0180	0.0293	0.0123	0.0123

Table 8.2 Dry mass, nutrient content and decomposition rate (k) of nutrient on rubber leaf litter after 90 of decomposition in in *Beltrania* sp.

Time (days)	Average dry weight of the remaining (g)	Nutrient contents (g)				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0	100.00	2.26	0.15	0.56	1.45	0.33
15	74.07	1.89	0.13	0.49	1.50	0.30
30	67.72	1.67	0.12	0.38	1.35	0.27
45	66.07	1.87	0.11	0.44	1.19	0.29
60	58.89	1.65	0.10	0.30	1.41	0.25
75	57.06	1.72	0.10	0.31	1.15	0.26
90	54.89	1.80	0.12	0.30	1.06	0.27
Total loss	45.11	0.46	0.03	0.26	0.39	0.06
k (per day)	0.0267	0.0101	0.0117	0.0275	0.0140	0.0082

Table 8.3 Dry mass, nutrient content and decomposition rate (k) of nutrient on rubber leaf litter after 90 of decomposition in *Cylindrocarpon* sp.

Time (days)	Average dry weight of the remaining (g)	Nutrient contents (g)				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0	100.00	2.26	0.15	0.56	1.45	0.33
15	72.71	1.85	0.12	0.47	1.32	0.29
30	66.55	1.58	0.11	0.34	1.42	0.27
45	66.07	1.87	0.10	0.36	1.29	0.28
60	62.89	1.80	0.11	0.33	1.50	0.28
75	58.89	1.77	0.11	0.33	1.22	0.28
90	53.39	1.61	0.09	0.23	1.20	0.25
Total loss	46.61	0.65	0.06	0.33	0.25	0.08
k (per day)	0.0279	0.0151	0.0223	0.0396	0.0084	0.0122

Table 8.4 Dry mass, nutrient content and decomposition rate (k) of nutrient on rubber leaf litter after 90 of decomposition in *H. piriforme*

Time (days)	Average dry weight of the remaining (g)	Nutrient contents (g)				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0	100.00	2.26	0.15	0.56	1.45	0.33
15	72.71	1.70	0.12	0.48	1.28	0.28
30	66.07	1.52	0.11	0.33	1.31	0.26
45	65.72	1.83	0.10	0.40	1.24	0.28
60	61.55	1.84	0.09	0.38	1.43	0.30
75	55.05	1.61	0.10	0.29	1.21	0.25
90	52.22	1.46	0.10	0.22	1.20	0.25
Total	47.78	0.80	0.05	0.34	0.25	0.08
k (per day)	0.0289	0.0195	0.0184	0.0406	0.0084	0.0132

Table 8.5 Dry mass, nutrient content and decomposition rate (k) of nutrient on rubber leaf litter after 90 of decomposition in *T. virens*

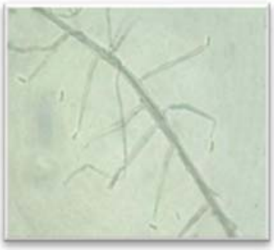
Time (days)	Average dry weight of the remaining (g)	Nutrient contents (g)				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0	100.00	2.26	0.15	0.56	1.45	0.33
15	75.39	2.00	0.13	0.32	1.35	0.32
30	66.89	1.76	0.11	0.41	1.20	0.28
45	65.89	1.81	0.11	0.42	1.22	0.30
60	64.39	1.82	0.11	0.34	1.43	0.28
75	57.89	1.70	0.10	0.31	1.19	0.28
90	51.89	1.58	0.10	0.29	1.19	0.25
Total	48.11	0.68	0.05	0.27	0.26	0.08
k (per day)	0.0292	0.0160	0.0164	0.0230	0.0089	0.0116

Table 8.6 Dry mass, nutrient content and decomposition rate (k) of nutrient on rubber leaf litter after 90 of decomposition in control (no fungus)

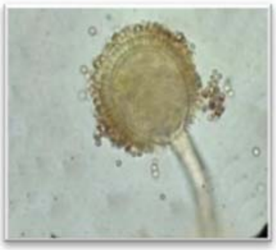
Time (days)	Average dry weight of the remaining (g)	Nutrient contents (g)				
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
0	100.00	2.26	0.15	0.56	1.45	0.33
15	76.22	1.76	0.12	0.33	1.34	0.27
30	69.40	1.76	0.12	0.29	1.48	0.28
45	68.74	1.85	0.10	0.34	1.33	0.28
60	67.40	1.87	0.11	0.32	1.64	0.30
75	62.55	1.83	0.11	0.26	1.36	0.29
90	60.22	1.67	0.10	0.25	1.32	0.28
Total	39.78	0.59	0.05	0.31	0.13	0.05
k (per day)	0.0254	0.0135	0.0170	0.0353	0.0042	0.0078

Appendix F

Microfungi were found on rubber plant litter



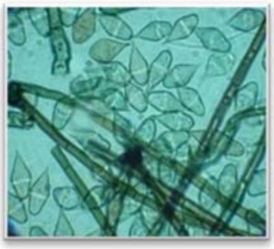
Acremonium sp.



Aspergillus aculatus

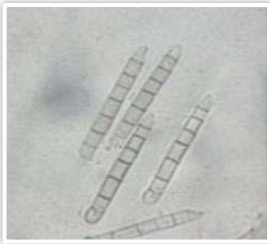
Aspergillus terrues

Bactrodesmius rahmii

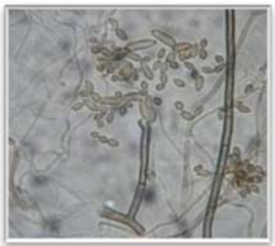


Beltrania mangifera

Beltraniella sp.



Camposporium cambrense

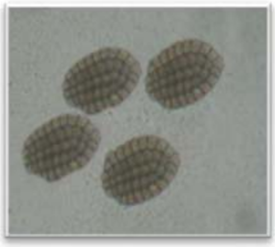


Cladosporium tenuissinum

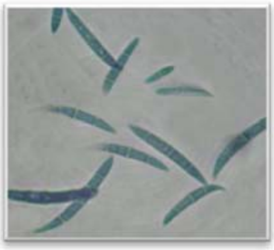
Codinaea fertilis

Curvularia lunata

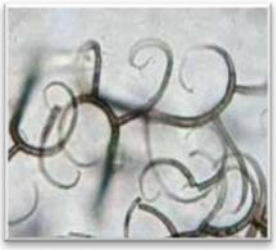
Cylindrocarpon sp.



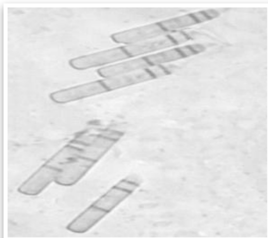
Dictyosporium elegans



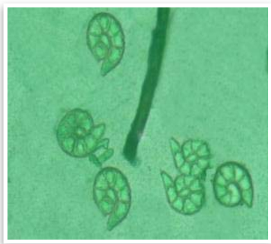
Fusarium semitectum



Gyrothix circinata

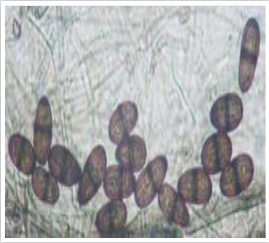


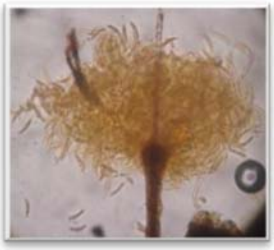
Hanicospora coronata

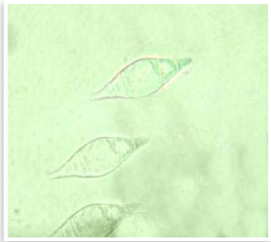


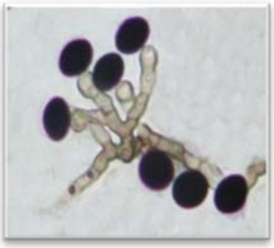
Helicoma sp.


Kirschsteiniothelia sp.

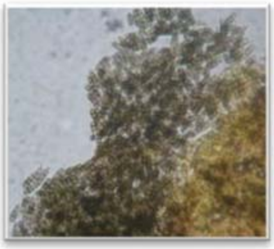

Lasiodiplodia cf. *theobromae*

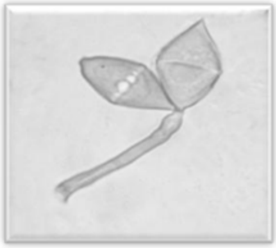

Menisporopsis profusa

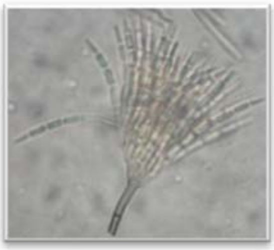

Monacrosporium sp.


Nigrospora sphaerica


Paratrichoconis sp.

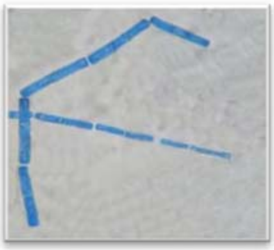

Pestalotiopsis sp.


Pseudobeltrania macrospora


Speiropsis hyalospora

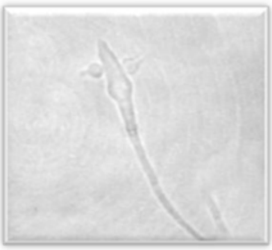

Sporidesmium flagellatum

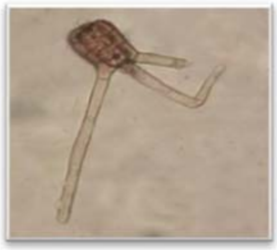

Sporidesmium harknesii

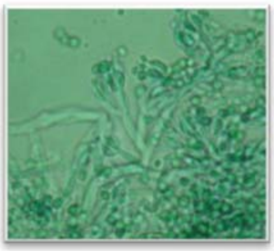

Sporoschismopsis sp.


Stigmina sp.

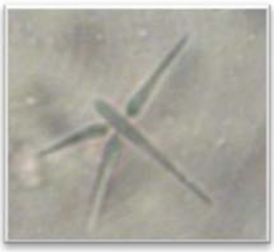

Subulispora procurvata


Teratosperma sp.

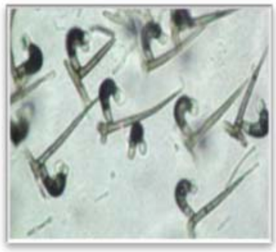

Tetraploa aristata


Trichoderma virens


Tricladium fusscum


Triscelophorus sp.

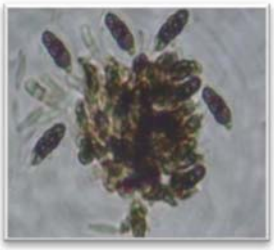

Veronaea carlinae

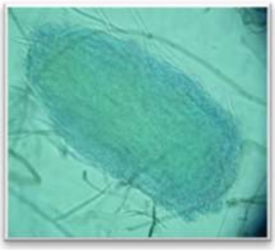
			
Veronaea cophophila	*Wiesneriomyces javanicus*	*Zygosporium masonii*	*Zygosporium oscheoides*

Macrofungi were found on rubber plant litter

			
Auricularia auricula	*Cyathus striatus*	*Cookeina sulcipes*	*Geastrum mirabile*
			
Hexagonia tenuis	*Marasmius pulcherripes*	*Marasmius siccus*	*Podoscypha nitudula*
			
Schizophyllum commune	*Tremella fuciformis*	*Xylaria arbuscula*	*Xylaria cubensis*

Unidentified Microfungal


Unidentified 1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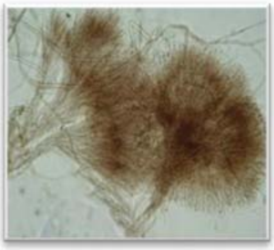
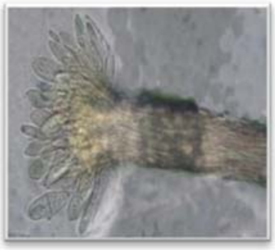
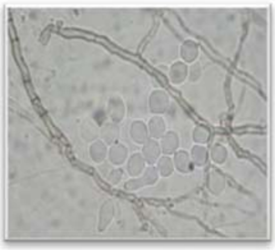
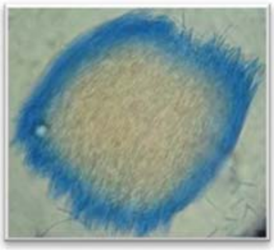

Unidentified 3


Unidentified 4


Unidentified 5


Unidentified 6


Unidentified 7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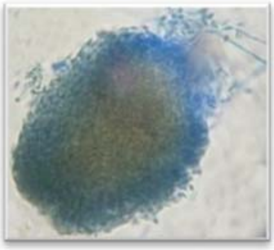
Unidentified 12


Unidentified 13


Unidentified 14


Unidentified 15

VITAE

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Student ID 5210630007

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List of Publication and Proceedings

1. Seephueak, P., Petcharat, V. and Phongpaichit, S. 2010. Fungi associated with degrading leaf litter of para rubber (*Hevea brasiliensis*). Mycology 1 : 213-227.
2. Seephueak, P., Phongpaichit, S., Hyde, K.D. and Petcharat, V. 2011. Diversity of saprobic fungi on decaying branch litter of the rubber tree (*Hevea brasiliensis*). Mycosphere 2 : 307-330.
3. Seephueak, P., Phongpaichit, S., Hyde, K.D. and Petcharat, V. 2011. Diversity of saprobic fungi on decaying rubber logs (*Hevea brasiliensis*). Sydowia 63 : 249- 282.

4. Seephueak, P., Phongpaichit, S. and Petcharat, V. 2011. Diversity of litter decomposing fungi of para rubber tree (*Hevea brasiliensis*). Agriculture Science Journal 43 : 343-346.
5. Seephueak, P., Phongpaichit, S. and Petcharat, V. 2011. Biodiversity of saprobic fungi on the leaf and branch litter of rubber tree (*Hevea brasiliensis*). Proceedings of the 12th the International Marine and Freshwater Mycology Symposia, Asian Mycological Congress, Incheon, Korea, 7-11 August 2011.
6. Seephueak, P., Phongpaichit, S. and Petcharat, V. 2011. Diversity of litter decomposing fungi of para rubber tree (*Hevea brasiliensis*). Proceedings of the 10th Hort for Wealth and Well-Being. National Horticulture Conference, Miracle Grand, Bangkok, Thailand, 18-20 May 2011.