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Fungal diversity on fallen leaves of *Ficus* in northern Thailand*

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Abstract: Fallen leaves of *Ficus altissima*, *F. virens*, *F. benjamina*, *F. fistulosa* and *F. semicordata*, were collected in Chiang Mai Province in northern Thailand and examined for fungi. Eighty taxa were identified, comprising 56 anamorphic taxa, 23 ascomycetes and 1 basidiomycete. Common fungal species occurring on five host species with high frequency of occurrence were *Beltraniella nilgirica*, *Lasiodiplodia theobromae*, *Ophioceras leptosporum*, *Periconia byssoides* and *Septonema harknessi*. *Colletotrichum* and *Stachybotrys* were also common genera. The leaves of different *Ficus* species supported diverse fungal taxa, and the fungal assemblages on the different hosts showed varying overlap. The fungal diversity of saprobes at the host species level is discussed.

Key words: Ficus, Fallen leaves, Saprobes, Fungal diversity
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INTRODUCTION

Fungi are chemoheterotrophic organisms that play an important role as decomposers in natural ecosystems (Duarte *et al*., 2006; Gadd, 2007). Fungi have additional economic importance as biocontrol agents, chemical producers of bioactive compounds used in the pharmaceutical and many other industries (Yuen *et al*., 1999; Bucher *et al*., 2004; Duarte *et al*., 2006). The economic impact of fungi in the environment is likely related to the total fungal species pool (Hyde, 2001; Piepenbring, 2007). Research on fungal diversity therefore provides a basis for estimating the functional role of fungi in ecosystems, exploiting these economic fungi and estimating the total fungal species richness in a region or globally (Arnold *et al*., 2001; Mueller and Schmit, 2007).

Although the 1.5 million species estimated by Hawksworth (2001) are commonly accepted (Hyde, 2001; Hyde *et al*., 2007), the actual quantity of fungal species is unclear (Arnold *et al*., 2001; Hyde, 2001; Hyde *et al*., 2007; Schmit and Mueller, 2007). Schmit and Mueller (2007) estimated that there is a minimum of 712 000 fungal species worldwide. This estimate was primarily based on the observed ratio between vascular plant species diversity and fungal diversity in a certain area. Meta-analysis of fungal diversity in small plots (Schmit *et al*., 2005) demonstrated that the numbers of tree species and macrofungal species diversities are correlated (Mueller *et al*., 2007). The actual number of fungi is still unknown; however, only 5%~13% of the total estimated global fungal species have been described. The undescribed fungi may occur in poorly studied countries, hosts, habitats, niches, or tissues, and are mostly microfungi (Hyde, 2001; Schmit and Mueller, 2007). To determine the accuracy of fungal estimates, more information is needed concerning species diversity in poorly studied areas and hosts, especially in poorly studied areas

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(Dulymamode *et al*., 2001; Hyde, 2001).

There have been several studies on fungi in poorly studied habitats in Thailand (Jones and Hyde, 2004). This has included studies on larger fungi in the forests of northern Thailand (Le *et al*., 2007a; 2007b), fungi on peat swamp palms (Pinnoi *et al*., 2006; Pinruan *et al*., 2007), fungi on other monocotyledons (Photita *et al*., 2001; Thongkantha *et al*., 2008), fungi on leaf litter of angiosperms (Promputtha *et al*., 2004; 2005; Duong *et al*., 2006; 2008), and fungi on decaying wood (Kodsueb *et al*., 2008a; 2008b). There has been, however, no study on the litter of *Ficus* species.

Whether fungi are host-specific or generalists are significant in estimating species numbers (Zhou and Hyde, 2001; Hyde *et al*., 2007), is particularly important in studying leaf litter. In tropical forests, plant litter comprises a mixture of diverse host leaves, unlike that in many temperate forests where stands contain low tree diversity. Several studies on the saprobic microfungal diversity associated with plants have been carried out (Hyde *et al*., 2001; Yanna *et al*., 2001; Dulymamode *et al*., 2001; Paulus *et al*., 2006a; 2006b), and to a large extent, fungi tend to be host-specific at the host genus level (Taylor *et al*., 2001). Paulus *et al*.(2006a; 2006b) studied 6 tree hosts from 4 families and found very little overlap. The low overlap may be because the hosts studied were from different families. The next question to ask is whether litter of different species of the same host genus has host-specific fungi or generalists? We, therefore, chose to study the saprobes on 5 species of *Ficus* to establish data on the fungal communities involved in the decay of litter from different species of the same host genus.

The genus *Ficus* (Moraceae) includes some 750 species of woody plants occurring in most tropical and subtropical forests throughout the world (Weiblen, 2000). *Ficus* is an evergreen or deciduous tree, frequently growing on other trees (strangling) with smooth pale gray bark and abundant white latex (Gardner *et al*., 2000). There is little known concerning the fungal diversity on this host genus (Suryanarayanan and Vijaykrishna, 2001; Paulus *et al*., 2006a). Paulus *et al*.(2006a; 2006b) reported on the fungal diversity in leaf litter of 2 species of *Ficus* in Australia, while Suryanarayanan and Vijaykrishna (2001) isolated 28 endophyte fungi from *Ficus benghalensis*. *Ficus* is the second largest tree genus in northern Thailand after *Syzygium* with 30 species of *Ficus* growing in the region (Gardner *et al*., 2000).

The purpose of the present study is to assess the diversity of saprobic fungi on 5 species of *Ficus* in northern Thailand in order to (1) investigate fungal distribution on saprobic fallen leaves of *Ficus* species; and (2) evaluate the different fungal communities involved in the decay of litter from different species of the same host genus.

MATERIALS AND METHODS

Survey design

To examine the effect of host species on microfungal assemblages, 5 species of *Ficus* were chosen for the study. Individual trees of each species were located at each of the sites selected for sampling (Table 1). Thirty fallen leaves at various stages of decay were haphazardly collected from each *Ficus* species from each site within 2 d. All samples were placed in Ziplock plastic bags containing tissue paper moistened with sterile distilled water and sealed and incubated at room temperature. Material was examined in the laboratory on Days 5, 15 and 25 after sampling.

Assessment of microfungal diversity

For the assessment of fungal presence, all leaves were cut into 5 cm×5 cm quadrates for observation.

Table 1 Location of *Ficus* species surveyed in Chiang Mai Province in northern Thailand

Plant sepcies	Location
Ficus altissima	MRC, T. Pa Pae, A. Mae Taeng, Chiang Mai Province, Thailand, 19°07′12″ N, 98°44′2.64″ E.
F. virens	Out door of MRC, T. Pa Pae, A. Mae Taeng, Chiang Mai Province, Thailand, 19°07′12″ N, 98°44′2.64″ E.
F. benjamina	About 5 km east of MRC, M. Mae Taeng, Chiang Mai Province, Thailand, 19°05′12″ N, 98°44′2.64″ E.
F. fistulosa	Near Mae Malai, M. Mae Taeng, Chiang Mai Province, Thailand, 19°05′0″ N, 98°5′42″ E.
F. semicordata	Tung Cho National Park, forest trail, Tung Joaw Village, Mae Teng Dist., Chiang Mai Province, Thailand, 19°08′4.2″ N, 98°38′ 54″ E.

Fruiting bodies of microfungi were observed under a stereoscope. A slide was then prepared for one representative fruiting structure of each taxon and placed in water and observed under a compound microscope. Micrographs were taken and stains were added as appropriate. Slides were made semipermanent by the addition of 90% (v/v) lactic acid. Species identifications were made using morphological characters. Herbarium specimens and slides of all taxa are maintained at the Mushroom Research Foundation Herbarium with some duplicates in Zhejiang University Herbarium.

Definitions and statistical analyses

Taxa were recorded as either present or absent from each leaf. The number of leaves, on which a particular fungal species was observed, designated the 'occurrence of a fungus' and was used to calculate the 'percentage occurrence' of a taxon on leaves of one tree species using the following formula (Tsui *et al*., 2001; Yanna *et al*., 2002):

Percent occurrence of taxon A (%)=occurrence of taxon A/occurrence of all taxa in one tree species×100.

Fungal species diversity on each *Ficus* species was calculated using Shannon-Wiener's index *H*:

$$H=-\sum P_i \ln P_i,$$

where P_i is the frequency of fungal species *i* occurring on specific host leaves (Begon *et al*., 1993; Wong and Hyde, 2001).

Sørensen's index of similarity (*S*) was applied (Magurran, 1988; Tsui *et al*., 2001) to compare the similarity of the species on leaves of different *Ficus* spp.: $S=2c/(a+b)$, where *a* is the total number of species on host A leaves, *b* is the total number of species on host B leaves, and *c* is the number of species on both host leaves. Similarity is expressed with values between 0 (no similarity) and 1 (absolute similarity).

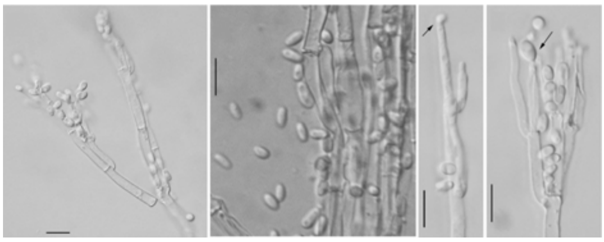
RESULTS

Species richness and dominant fungi on *Ficus* spp.

Examination of decaying leaves of 5 species of *Ficus* from northern Thailand yielded 80 fungal taxa, comprising 56 anamorphic taxa, 23 ascomycetes and 1 basidiomycete. We have identified many taxa to species level, although in several cases the morphology of the taxa in our study was not identified to species (unidentified species, Table 2). Five species, *Beltraniella nilgirica*, *Lasiodiplodia theobromae*, *Ophioceras leptosporum*, *Periconia byssoides* and *Septonema harknessi* were common species occurring on all five host species (>3% occurrence, Table 2). In addition, *Colletotrichum* and *Stachybotrys* were common genera, with several species occurring on the *Ficus* leaves (Table 2). Figs.1~5 also show some rare fungal taxa on the different host species.

(a) (b) (c)

Fig.1 ***Ellisiopsis gallesiae*** **on fallen leaves of** ***Ficus altissima.*** **(a) Morphology of conidia; (b) and (c) Morphology of conidiophores. Bar=10 μm**



(a) (b) (c) (d)

Fig.2 Morphology of ***Sagenomella striatispora*** **on fallen leaves of** ***Ficus fistulosa*****. (a) Characters of conidiophore; (b) Characters of conidia and conidiophore; (c) and (d) developing conidia from conidiophores. Arrow indicates the young conidium. Bar=10 μm**

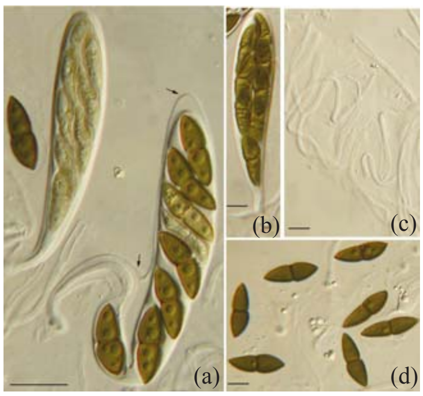


Fig.3 Morphology of ***Kirschsteiniothelia*** **spp. on fallen leaves of** ***Ficus semicordata*****. (a) Characters of asci. Arrows indicate the outer layer of the ascus wall; (b) Characters of ascus; (c) Characters of pseudoparaphyses; (d) Characters of ascospores. (a) Bar=20 μm; (b)~(d) Bar=10 μm**

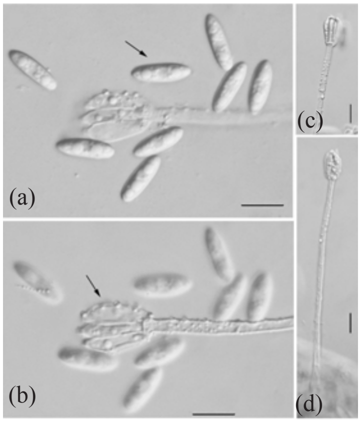


Fig.4 Morphology of *Stachybotrys bisbyi* on fallen leaves of *Ficus benjamina*. (a) Characters conidia. Arrow indicates the smooth wall of the conidium; (b) Characters of conidiophore. Arrow indicates the rough wall of conidiophore cell; (c) and (d) Characters of conidiophores. Bar=10 μm

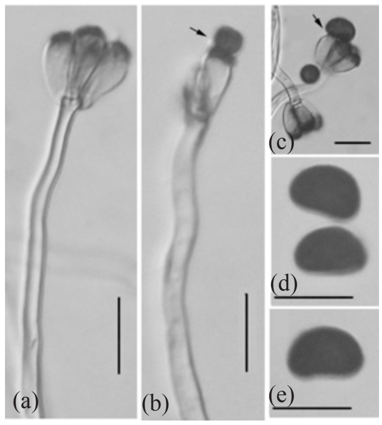


Fig.5 Morphology of *Stachybotrys renispora* on fallen leaves of *Ficus virens.* (a) Characters of conidiophore; (b) and (c) Characters of conidia and conidiophores. Arrow indicates the succession of conidium; (d) and (e) Characters of conidia. Bar=10 μm

Table 2 Percent occurrence (%) of fungal taxa on leaves of 5 species of *Ficus* in northern Thailand

Fungus name	FV	FF	FA	FS	FB
Ascomycetes					
Amphisphaeria fallax			2.3		
Anthostomella limitata	2.2	2.4			
Anthostomelle nannorrhopis			2.3	3.4	5.8
Chaetomium sulphureum			4.7		
Diaporthe adunca			4.7		
Diaporthe perjuncta		2.4		3.4	
Eutypella scoparia		2.4		3.4	
Glomerella acutata					
Glomerella cingulata	1.1		1.2		
Guignardia spp.	1.1	2.4	1.2		2.9
Hyponectria populi				3.4	
Kirschsteiniothelia spp.				1.7	
Lasiosphaeria breviseta	4.4				
Lophiostoma minosporum				6.8	
Massarina hepaticarum			4.7		
Melanospora brevirostris				3.4	
Munkovalsaria appendenta	1.1			1.7	1.4
Mycoenterolobium platysporium	2.2		2.3		
Mycosphaerella dianthi		4.8			2.9
Mycosphaerella freycineitae	4.4			3.4	
Nectria sinopica			1.2		
Ophioceras leptosporum	4.4	4.8	4.7	6.8	5.8
Rhytisma acerinum				3.4	
Mitosporic fungi					
Acremonium charticola			2.3		
Ajrekarella polychaetriae	2.2				
Alternaria alternata		4.8			4.3
Beltraina querna			1.2		
Beltraniella nilgirica	4.4	4.8	3.6	6.8	5.8
Cercospora apii	2.2				2.9
Chaetospermum artocarpi		4.8			
Chaetospermum chaetosporum					5.8
Cladosporium cladosporioides	3.3	3.6		6.8	
Colletotrichum dematium	2.2	4.8	3.6		2.9
Colletotrichum gloeosporioides			3.6		
Colletotrichum graminicola			4.7		
Cylindrocolla urticae					5.8
Dicyma state of *Ascotricha chartarum*	2.2		2.3		
Dinemasporium strigosum	2.2	4.8			2.9
Discosia artocreas		2.4			
Discosia brasiliensis					1.4
Mitosporic fungi					
Ellisiopsis gallesiae			2.3		
Fusariella hughesii	4.4		4.7		
Fusariella obstipa			2.3		
Fusarium chlamydosporum		4.8			
Fusarium oxysporum	5.5				
Fusarium solani	4.4				
Giulia tenuis				1.7	
Kellermania yuccifolia		2.4			
Kontospora halophila				1.7	
Koorchaloma jamaicensis		2.4			
Lasiodiplodia theobromae	3.3	4.8	3.6	6.8	5.8
Menispora ciliata				3.4	
Menispora glauca				3.4	
Microdochium phragmitis		4.8	4.7		
Mycoenterolobium platysporum	2.2		2.3		
Periconia byssoides	4.4	4.8	4.7	6.8	4.3
Pestalotiopsis gigas	2.2				2.9
Pestalotiopsis owenii	4.4				2.9
Phaeoisaria clematidis			2.3		
Phoma eupyrena					5.8
Phoma valerianae	2.2	2.4			
Phomopsis asparagi	2.2		1.2		1.4
Plectophomella nypae	2.2				
Sagenomella striatispora		2.4			
Schwarzmannia goebeliae	1.1				
Septonema harknessi	4.4	4.8	4.7	5.1	5.8
Sphaeridium candidum		2.4			2.9
Stachybotrys bisbyi					2.9
Stachybotrys nephrospora					2.9
Stachybotrys oenanthes	4.4		2.3		2.9
Stachybotrys renispora	3.3				
Stachybotrys sansevieriae			2.3	3.4	
Torula graminis					5.8
Torula herbarum	4.4				
Trichothecium roseum		2.4	3.6	3.4	
Volutella ciliata	4.4		3.6	6.8	
Wiesneriomyces javanicus	2.2	4.8		3.4	
Xylohypha nigrescens			4.7		
Zygosporium chartarum					2.9
Basidiomycete					
Halocyphina spp.			1.2		

FV: *Ficus virens*; FF: *F. fistulosa*; FA: *F. altissima*; FS: *F. semicordata*; FB: *F. benjamina*

Fungal diversity

Communities of fungal taxa on different *Ficus* species leaf litter were relatively distinct. The number of taxa varied from 24 (*F. semicordata*) to 33 (*F. virens* and *F. altissima*) (Table 3). The fungal communities on *F. virens* and *F. altissima* were the most similar but were different from those on *F. semicordata* (Table 4). The percentages of ascomycetes on *F. virens* and *F. altissima* were similar (24% and 30%, respectively). *F. semicordata* had the highest percentage of ascomycetes (46%) among the host species. The percentages of anamorphic taxa on *F. virens* and *F. altissima* were also similar.

Table 3 Diversity of fungi on different *Ficus* species

Ficus species	Number of species			Total	Index *H*
	Ascomycetes	Mitosporic fungi	Basidomycetes		
Ficus virens	8	25		33	3.3525
F. fistulosa	6	19		25	3.0887
F. altissima	10	22	1	33	3.3196
F. semicordata	11	13		24	3.0881
F. benjamina	5	21		26	3.1496

Table 4 Index of similarity among different *Ficus* species

	Ficus virens	*F. fistulosa*	*F. altissima*	*F. semicordata*	*F. benjamina*
Ficus virens		0.41	0.45	0.35	0.44
F. fistulosa			0.31	0.41	0.43
F. altissima				0.35	0.31
F. semicordata					0.28
F. benjamina					

DISCUSSION

Studies of fungal diversity on *Ficus* have not been carried out until recently, although this genus is very common in forests throughout the world (Weiblen, 2000; Paulus *et al*., 2006a; 2006b). Suryanarayanan and Vijaykrishna (2001) studied fungal endophyte diversity on different host tissues of *F. benghalensis* in India. They found little overlap between fungal endophyte composition on the leaves and aerial roots. Paulus *et al*.(2006a; 2006b) studied saprobic microfungi in leaf litter of Australia tropical rainforests, including two *Ficus* species. They found that fungal assemblages of *F. destruens* and *F. pleurocarpa* grouped closely together. The overlapping species were *Beltraniella portoricensis*, *Beltrania* cf. *concurvispora*, *Cylindrocladium coulhounii*, *Dictypchaeta* cf. *novae-guineensis*, *Cylindrosympodium cryptocaryae*, *Idriella acerosa*, *Idriella lunata*, *Menisporopsis theobromae*, *Ophiognomonia elasticae*, *Parasypodiella elongate* and *Trichoderma viride*. In the present study, we investigated fungal diversity on leaves of five *Ficus* species. Our results show that the overlap of fungal species was much higher than that in previous studies on fallen leaves from different hosts in different families. Similarity ranged from 28% to 45%. Some species, such as *Ophioceras leptosporum*, *Beltraniella nilgirica*, *Lasiodiplodia theobromae*, *Periconia byssoides* and *Septonema harknessi*, were shared by all hosts with high occurrence, indicating that a ‘core fungal group’ might be responsible for the decay of *Ficus* leaves (Wong and Hyde, 2001). In this study some fungi are new records on *Ficus*. Among these, many species are widespread, such as *Diaporthe adunca*, *Lasiosphaeria breviseta*, *Colletotrichum gloeosporioides* and *Torula herbarum*. At least one species, *Munkovalsaria appendenta*, is a new record for Thailand. Further studies are needed to find more fungi on the leaves of *Ficus*, for our investigation was limited, with one tree of each host being sampled once.

Some previous research results showed that the hosts or tissues are important factors that influence the fungal communities (Ho *et al*., 2001; Paulus *et al*., 2003; Rambelli *et al*., 2004) and that some saprobes might be host-specific (Hyde *et al*., 1997). Wong and

Hyde (2001) investigated fungal diversity on *Gramineae*, and their results showed that fungal composition on host species level varied. Studies on microfungi of tree leaves in tropical regions suggested that the fungal assemblages on different host species were variable, and some other terms, such as 'host exclusivity', 'host fidelity', 'host affinity', 'host affinity', 'host preference' and 'host recurrence', were used to describe plant-fungal associations with definitive host (Zhou and Hyde, 2001). Taylor *et al.*(2001) noted that saprobic fungi were specific at a host genus level. In the present study, our results indicated that saprobic fungal diversity was high at the host species level, with some rare fungal taxa occurring on each of the different host species.

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References

Arnold, A.E., Zuleyka, M.Z., Gilbert, G.S., 2001. Fungal endophytes in dicotyledonous neotropical trees: patterns of abundance and diversity. *Mycol. Res.*, **105**(12): 1502-1507. [doi:10.1017/S0953756201004956]

Begon, M., Harper, J.L., Townsend, C.R., 1993. Ecology: Individuals, Population and Communities, 3rd Ed. Blackwell Science, Boston.

Bucher, V.V.C., Pointing, S.B., Hyde, K.D., Reddy, C.A., 2004. Production of wood decay enzymes, loss of mass, and lignin solubilization in wood by diverse tropical freshwater fungi. *Microbial Ecology*, **48**(3):331-337. [doi:10.1007/s00248-003-0132-x]

Duarte, S., Pascoal, C., Cássio, F., Bärlocher, F., 2006. Aquatic hyphomycete diversity and identity affect leaf litter decomposition in microcosms. *Oecologia*, **147**(4):658-666. [doi:10.1007/s00442-005-0300-4]

Dulymamode, R., Cannon, P.F., Peerally, A., 2001. Fungi on endemic plants of Mauritius. *Mycol. Res.*, **105**(12): 1472-1479. [doi:10.1017/S0953756201004701]

Duong, L.M., Jeewon, R., Lumyong, S., Hyde, K.D., 2006. DGGE coupled with ribosomal DNA gene phylogenies reveal uncharacterized fungal phylotypes. *Fungal Diversity*, **23**(1):121-138.

Duong, L.M., McKenzie, E.H.C., Lumyong, S., Hyde, K.D., 2008. Fungal succession on senescent leaves of *Castanopsis diversifolia* in Doi Suthep-Pui National Park, Thailand. *Fungal Diversity*, **30**(1):23-36.

Gadd, G.M., 2007. Geomycology: biogeochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. *Mycol. Res.*, **111**(1):3-49. [doi:10.1016/j.mycres.2006.12.001]

Gardner, S., Sidisunthorn, P., Anusarnsunthorn., V., 2000. A Field Guied to Forest Trees of Northern Thailand. Kobfai Publishing Project, Bangkok.

Hawksworth, D.L., 2001. The magnitude of fungal diversity: the 1.5 million species estimate revisited. *Mycol. Res.*, **105**(12):1422-1432. [doi:10.1017/S0953756201004725]

Ho, W.H., Hyde, K.D., Hodgkiss, I.J., Yanna, 2001. Fungal communities on submerged wood from streams in Brunei, Hong Kong, and Malaysia. *Mycol. Res.*, **105**(12): 1492-1501. [doi:10.1017/S095375620100507X]

Hyde, K.D., 2001. Where are the missing fungi? Does Hong Kong have any answers? *Mycol. Res.*, **105**(12): 1514-1518. [doi:10.1017/S0953756201004889]

Hyde, K.D., Fröhlich, J., Taylor, J.E., 1997. Diversity of Ascomycetes on Palms in the Tropics. *In*: Hyde, K.D. (Ed.), Biodiversity of Tropical Microfungi. The Hong Kong University Press, Hong Kong, p.141-156.

Hyde, K.D., Ho, W.H., Mckenzie, E.H.C., Dalisay, T., 2001. Saprobic fungi on bamboo culms. *Fungal Diversity*, **7**(1): 35-48.

Hyde, K.D., Bussaban, B., Paulus, B., Crous, P.W., Lee, S., Mckenzie, E.H.C., Photita, W., Lumyong, S., 2007. Diversity of saprobic microfungi. *Biodivers. Conserv.*, **16**(1): 7-35. [doi:10.1007/s10531-006-9119-5]

Jones, E.B.G., Hyde, K.D., 2004. Introduction to Thai Fungal Diversity. *In*: Jones, E.B.G., Tanticharoen, M., Hyde, K.D. (Eds.), Thai Fungal Diversity. BIOTEC, Thailand.

Kodsueb, R., McKenzie, E.H.C., Lumyong, S., Hyde, K.D., 2008a. Diversity of saprobic fungi on *Magnoliaceae*. *Fungal Diversity*, **30**(1):37-53.

Kodsueb, R., McKenzie, E.H.C., Lumyong, S., Hyde, K.D., 2008b. Fungal succession on woody litter of *Magnolia liliifera* (*Magnoliaceae*). *Fungal Diversity*, **30**(1):55-72.

Le, H.T., Nuytinck, J., Verbeken, A., Lumyong, S., Desjardin, D.E., 2007a. *Lactarius* in Northern Thailand: 1. *Lactarius* subgenus *Piperites*. *Fungal Diversity*, **24**(1):173-224.

Le, H.T., Stubbe, D., Verbeken, A., Nuytinck, J., Lumyong, S., Desjardin, D.E., 2007b. *Lactarius* in Northern Thailand: 2. *Lactarius* subgenus *Plinthogali*. *Fungal Diversity*, **27**(1): 61-94.

Magurran, A.E., 1988. Ecological Diversity and its Measurement. Croom Helm, London.

Mueller, G.M., Schmit, J.P., 2007. Fungal biodiversity: What do we know? What can we predict? *Biodivers. Conserv.*, **16**(1):1-5. [doi:10.1007/s10531-006-9117-7]

Mueller, G.M., Schmit, J.P., Leacock, P.R., Buyck, B., Cifuentes, J., Desjardin, D.E., 2007. Global diversity and distribution of macrofungi. *Biodivers. Conserv.*, **16**(1): 37-48. [doi:10.1007/s10531-006-9108-8]

Paulus, B., Gadek, P., Hyde, K.D., 2003. Estimation of microfungal diversity in tropical rain forest leaf litter using particle filtration: the effects of leaf storage and surface treatment. *Mycol. Res.*, **107**(6):748-756. [doi:10.1017/S0953756203007913]

Paulus, B., Gadek, P., Hyde, K.D., 2006a. Successional patterns of microfungi in fallen leaves of *Ficus pleurocarpa* (Moraceae) in an Australian tropical rainforest. *Biotropica*, **38**(1):42-51.

Paulus, B., Kanowski, J., Gadek, P., Hyde, K.D., 2006b. Diversity and distribution of saprobic microfungi in leaf litter of an Australian tropical rainforest. *Mycol. Res.*, **110**(12):1441-1454. [doi:10.1016/j.mycres.2006.09.002]

Photita, W., Lumyong, S., Lumyong, P., Hyde, K.D., 2001. Endophytic fungi of wild banana (*Musa acuminata*) at Doi Suthep Pui National Park, Thailand. *Mycol. Res.*, **105**(12):1508-1513. [doi:10.1017/S0953756201004968]

Piepenbring, M., 2007. Inventoring the fungi of Panama. *Biodivers. Conserv.*, **16**(1):73-84. [doi:10.1007/s10531-006-9051-8]

Pinnoi, A., Lumyong, S., Hyde, K.D., Jones, E.B.G., 2006. Biodiversity of fungi on the palm *Eleiodoxa conferta* in Sirindhorn peat swamp forest, Narathiwat, Thailand. *Fungal Diversity*, **22**(2):205-218.

Pinruan, U., Hyde, K.D., Lumyong, S., McKenzie, E.H.C., Jones, E.B.G., 2007. Occurrence of fungi on tissues of the peat swamp palm *Licuala longicalycata*. *Fungal Diversity*, **25**(1):157-173.

Promputtha, I., Lumyong, S., Lumyong, P., McKenzie, E.H.C., Hyde, K.D., 2004. Fungal saprobes on dead leaves of *Magnolia lillifera* (Magnoliaceae) in Thailand. *Cryptogamie Mycologie*, **25**(1):43-47.

Promputtha, I., Jeewon, R., Lumyong, S., McKenzie, E.H.C., Hyde, K.D., 2005. Ribosomal DNA fingerprinting in the identification of non sporulating endophytes from *Magnolia liliifera* (Magnoliaceae). *Fungal Diversity*, **20**(1):167-186.

Rambelli, A., Mulas, B., Pasqualetti, M., 2004. Comparative studies on microfungi in tropical ecosystems in Ivory Coast forest litter: behaviour on different substrata. *Mycol. Res.*, **108**(3):325-336. [doi:10.1017/S0953756204009396]

Schmit, J.P., Mueller, G.M., 2007. An estimate of the lower limit of global fungal diversity. *Biodivers. Conserv.*, **16**(1):99-111. [doi:10.1007/s10531-006-9129-3]

Schmit, J.P., Mueller, G.M., Leacock, P.R., Mata, J.L., Wu, Q.X., Huang, Y.Q., 2005. Assessment of tree species richness as a surrogate for macrofungal species richness. *Biol. Conserv.*, **121**(1):99-110. [doi:10.1016/j.biocon.2004.04.013]

Suryanarayanan, T.S., Vijaykrishna, D., 2001. Fungal endophytes of aerial roots of Ficus benghalensis. *Fungal Diversity*, **8**(1):155-161.

Taylor, J.E., Lee, S., Pedro, C.W., 2001. Biodiversity in the Cape Floral Kingdom: fungi occurring on *Proteaceae. Mycol. Res.*, **105**(12):1480-1484. [doi:10.1017/S0953756201004944]

Thongkantha, S., Lumyong, S., McKenzie, E.H.C., Hyde, K.D., 2008. Fungal saprobes and pathogens occurrence on tissues of *Dracaena loureiri* and *Pandanus* spp. *Fungal Diversity*, **30**(1):149-179.

Tsui, C.K.M., Hyde, K.D., Hodgkiss, I.J., 2001. Colonization patterns of wood-inhabiting fungi on baits in Hong Kong rivers, with reference to the effects of organic pollution. *Antonie van Leeuwenhoek*, **79**(1):33-38. [doi:10.1023/A:1010210631215]

Weiblen, G.D., 2000. Phylogenetic relationship of functionally dioecious *Ficus* (Moraceae) based on ribosomal DNA sequences and morphology. *American Journal of Botany*, **87**(9):1342-1357. [doi:10.2307/2656726]

Wong, M.K.M., Hyde, K.D., 2001. Diversity of fungi on six species of *Gramineae* and one species of *Cyperaceae* in Hong Kong. *Mycol. Res.*, **105**(12):1485-1491. [doi:10.1017/S0953756201004695]

Yanna, Ho, W.H., Hyde, K.D., 2001. Fungal communities on decaying palm fronds in Australia, Brunei, and Hong Kong. *Mycol. Res.*, **105**(12):1458-1471. [doi:10.1017/S0953756201005214]

Yanna, Ho, W.H., Hyde, K.D., 2002. Fungal succession on fronds of *Phoenix hanceana* in Hong Kong. *Fungal Diversity*, **10**(1):185-211.

Yuen, T.K., Hyde, K.D., Hodgkiss, I.J., 1999. Interspecific interactions among tropical and subtropical freshwater fungi. *Microbial Ecology*, **37**(4):257-262. [doi:10.1007/s002489900151]

Zhou, D., Hyde, K.D., 2001. Host-specificity, host-exclusivity and host-recurrence in saprobic fungi. *Mycol. Res.*, **105**(12):1449-1457. [doi:10.1017/S0953756201004713]