Fungal saprobes and pathogens occurring on tissues of *Dracaena lourieri* and *Pandanus* spp. in Thailand

Thongkantha, S.[1], Lumyong, S.[2], McKenzie, E.H.C.[3] and Hyde, K.D.[4,5*]

[1]Mushroom Research Foundation, 128 Moo 3, Ban Phadeng, Maetang, Chiang Mai, Thailand 50150
[2]Department of Microbiology, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand 50200
[3]Landcare Research, Private Bag 92170, Auckland, New Zealand
[4]School of Science, Mae Fah Luang University, Tasud, Chiang Rai 57100, Thailand
[5]International Fungal Research & Development Centre, The Research Institute of Resource Insects, Chinese Academy of Forestry, Beilongsi, Kunming, Yunnan 650224, PR China

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Studies of fungi on *Dracaena* and *Pandanus* were initiated in Thailand in order to investigate the biodiversity of fungi from wild and cultivated *Dracaena lourieri*, *Pandanus amaryllifolius P. penetrans* and *P. odoratissimus*. One-hundred and twenty-seven saprobes were found on decaying tissues, particularly on leaves, and comprised 40 ascomycetes, 1 basidiomycete and 86 anamorphic taxa. Eight ascomycetes and 3 anamorphic taxa were new to science. Distinct fungal communities were found on samples of *Dracaena* and *Pandanus* species. In terms of the numbers of taxa recovered, fungi were more diverse on wild species than on the cultivated species. Fifty-five fungal taxa were identified from leaf baits of *Pandanus penetrans* hung on host plants in Doi Suthep Pui National Park during the decomposition process. Distinct fungal communities were observed in sequence on the leaf baits, with different species being dominant at each succession stage. The highest fungal diversity occurred between months 7 and 12 (mature stage). At month 18, the leaf baits were found to be skeletonised, so the fungal communities had decreased in number. Only half of the taxa identified from *P. penetrans* occurred on both baits and natural leaves. Twenty-three fungi were identified from samples showing symptoms of anthracnose on leaves, leaf blast or leaf spots. Factors affecting the colonization of fungi on *Draceana* and *Pandanus* are discussed.

Key words: biodiversity, fungi, succession

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*Corresponding author: Kevin D. Hyde; e-mail: kdhyde@hkucc.hku.hk

Introduction

Studies of fungal diversity, and discoveries of new fungal species are published on a regular basis (Lu and Hyde, 2000; McKenzie *et al*., 2002; Pinruan *et al*., 2002, 2004a,b,c; Bussaban *et al*., 2003; Pinnoi *et al.*, 2003a,b, 2004; Hidayat *et al*., 2006; Liu *et al*., 2008; Cai *et al*., 2008; Rodas *et al*., 2008). Most new species described from Thailand between 1902-2004 were listed by Jones and Hyde (2004), while a preliminary checklist of fungi recorded from this tropical country was updated by Hywel-Jones and Boonpratuang (2001). This information helps us to estimate global fungal numbers, provide estimates to establish whether the current level of biodiversity is being maintained, and furthermore, mankind can make use of natural products and novel compounds produced by fungi (Pointing and Hyde, 2001). This may be especially true for undiscovered species that may produce novel compounds (Zhang *et al*., 1998; Boonphong *et al*., 2001; Seephonkai *et al*., 2001; Hawksworth, 2002; Collemare *et al*., 2008; Huang *et al*., 2008). There have been several estimates of worldwide fungal numbers, but all are based on data from temperate regions (e.g. 1.5 million, Hawksworth, 1991; 9.9 million, Cannon, 1997). It is hard to determine which estimate is the most realistic, especially if the estimations are based on

incomplete data. The lack of information from the tropics, where fungi may be far more diverse than in temperate regions, is an important gap in our knowledge (Hyde, 2001; Hyde *et al*., 2007).

Pandanus species (*Pandanaceae*) and *Dracaena lourieri* (*Dracaenaceae*) are mono-cotyledonous plants with morphologically similar leaves. In Thailand, there are several distinct species of *Pandanus* throughout the country (Gardner *et al*., 2000). Members of both genera are often used as herbs and as medicines (Ichikawa *et al*., 1977; Pongbunrod, 1979; Meksuriyen and Cordell, 1988; Sirisaard and Tantipathananandh, 2005), while several species are cultivated as ornamentals. The green leaf fibre of *Pandanus* is sometimes used for weaving into mats and baskets, as well as for house thatch.

There have been several taxonomic studies of monocotyledon-inhabiting fungi in the tropics including those on bamboo (Hyde *et al*., 2002a,b; Zhou and Hyde, 2002), banana (Photita *et al*., 2001, 2003), grasses (Wong and Hyde 2001), ginger (Bussaban *et al.* 2001a,b) and palms (Techa, 2001; Yanna *et al*., 2001a,b; Hidayat *et al*., 2006; Pinnoi *et al*., 2006; Pinruan *et al*., 2007). Several new species of fungi were found on *Pandanaceae*, collected from eleven tropical countries (Whitton, 1999; Whitton *et al*., 1999a,b, 2000a,b) and Mauritius (Dulymamode *et al*., 1998a,b,c,d,e, 1999, 2001a,b). However, fungi on this host family have not been investigated ecologically. An investigation of the fungi occurring on different *Pandanus* species at the one sampling site, on the same species over different seasons, or different sites is important in terms of providing answers to questions on the diversity of fungi in the tropics and establishing whether the fungi on *Pandanus* spp. are unique or the same as on other monocotyledonous plants.

Materials and methods

Diversity and ecology of saprobic fungi on Dracaena and Pandanus

Ten dead plant tissues were randomly collected from 10 plants of each host at different sites during 3 seasons: cool dry (November-January), hot dry (March-May) and hot wet (July-September). *Dracaena lourieri* (Figs 1-2) was collected from Chiang Dao National Park, Chiang Mai (ca. 400 m altitude), *Pandanus amaryllifolius* (Fig. 3) from one site at Medicinal Plant Garden in Doi Suthep Pui National Park, Chiang Mai (950 m altitude) and one site in Rayong Province, *P. odoratissimus* (Fig. 5) from the coast in Rayong (108 m altitude) and, *P. penetrans* (Fig. 4) from one site in Doi Suthep Pui National Park (950 m altitude) and one site at the foothills of Kardthee Village in Phayao Province (300 m altitude).

All samples (ca 30 cm long) were placed in separate plastic bags with tissue paper, sprayed with sterile water to create humid conditions and incubated at room temperature. The fungi present on the samples were examined and recorded within 1-4 weeks of incubation. Each fungus was identified according to taxonomic keys, and a species list with frequency of occurrence is presented for each host. Saprobic fungi were isolated by single spore methods (Choi *et al.,* 1999), and grown on ½ strength PDA. Small sections of the samples containing the fungi were cut out, dried, and prepared as herbarium specimens. Correspondence analyses were performed to test whether the species composition of the trials were statistically different.

Fungal succession on Pandanus penetrans leaves

Mature leaves of *Pandanus penetrans* were cut from plants in Doi Suthep Pui National Park from the same site as that listed above. Twelve mature green leaves were cut from each of eleven randomly selected *Pandanus* plants. Ten of these leaves were randomly selected as a day 0 sample. The other leaves were tied with nylon string to the host plants to prevent the leaves being carried away by rain or wind. At each sampling time ten decaying bait leaves were randomly collected from the eleven trees. It was planned to collect the bait leaves at week 1, and months 1, 2, 4, 6, 12, 18 and 24. However, sampling was stopped when the leaves had completely decayed at 18 months. Samples were placed in separate plastic bags in the forest and taken back to the laboratory. They were incubated individually in the plastic bags, with an addition of tissue paper moistened with sterilized water. All

Figs 1-5. Plants selected for the present study. **1-2**. *Dracaena lourieri*. **3.** *Pandanus amaryllifolius*. **4.** *P. penetrans*. **5.** *P. odoratissimus*.

leaves were examined under a microscope for the presence of fungi after one day of incubation and then periodically for up to 2 weeks. Squash mounts of sporulating fungi were made in water and/or other suitable mountains for examination with differential interference contrast microscopy. Fungi were isolated by single spore isolation, and herbarium specimens prepared. The percentage occurrence and a correspondence analysis were performed to examine the difference in fungal communities at different times of decay. The percentage occurrence was calculated. A 2- or 3-dimensional correspond ence analysis was performed to examine the difference in fungal communities on different collections.

Sorenson index was used to measure similarity between species diversity on different hosts. Species area curves were used to determine the adequacy of the sampling size. Shannon index (H') was used to express species diversity of a community (Shannon and Weaver, 1949).

Pathogenic fungi on Dracaena and Pandanus leaves

Dracaena lourieri and *Pandanus* spp. plants with leaf spots or other disease symptoms were collected in the same sites as

those in the saprobe study and returned to the laboratory. Fungi on the diseased tissue were isolated and identified. Some were tested for their pathogenicity according to Koch's postulates.

Isolates of parasitic and saprobic fungi which have been previously reported as plant pathogens, and a few endophytic isolates of *Xylaria* were tested for their pathogenicity to *Dracaena lourieri*, *Pandanus amaryllifolius* and *P. penetrans* leaves. The selected fungal isolates (*Acremonium*, *Cladosporium, Colletotrichum*, *Curvularia*, *Fusarium*, *Guignardia*, *Oxydothis*, *Phomopsis* and *Xylaria*) were grown on ½ strength PDA for 1-4 weeks depending on their growth rate. Pathogenicity testing was determined by inoculating healthy leaves in a plastic bag with the mycelium of the pathogen. Some leaves were wounded with a sterile needle, while other leaves were unwounded. For controls, the same procedure was followed, using disks of sterile ½ strength PDA. Any lesions on the leaves were determined after 10-15 days of incubation. Necrotic lesions were removed and plated onto ½ strength PDA for recovery of the pathogenic strains.

Results

Diversity and ecology of saprobes

Determination of sample size

The species area curve for most samples of saprobes on *Dracaena lourieri* and *Pandanus* spp. reached asymptote (Fig. 6). Therefore, the number of samples (10 leaves from 10 plants) was large enough to obtain a highly representative result. The species area curve for *D. lourieri* leaves during the cool dry season (D2) almost reached asymptote.

Fungal taxonomic composition

The fungi occurring on *Dracaena lourieri* and *Pandanus* spp. are listed in Tables 1-4. One-hundred and twenty-seven taxa were recorded, comprising 40 ascomycetes, 1 basidiomycete and 86 anamorphic fungi. The most common taxa occurring on dead leaves of *Dracaena lourieri* were *Stachybotrys chartarum* (on 75% of leaves), *Botryodiplodia theobromae* (65%) and *Zygosporium bioblizi* (a new species) (65%). *Aspergillus parasiticus*, *Colletotrichum gloeosporioides*, *Microthyrium* sp. 1, *Phomopsis archeri* and *Trichothecium roseum* were found on 50-55% of samples. *Cladosporium cucumerinum*, *Cryptophiale*-like, *Fusarium oxysporum*, Hyphomycete 5, *Monodictys* sp. 2, *Nectria*-like 2 and *Stachybotrys theobromae* usually occurred on 40-45% of samples (Table 1).

Fungal taxa found on decaying leaves of *Pandanus amaryllifolius* with high overall percenttage occurrences were *Acremonium* sp. 6 (on 100% of leaves), *Nectria*-like 3 (75%), *Phoma* sp. (70%), *Botryodiplodia theobromae* (65%), *Zygosporium oscheoides* (55%) and *Nigrospora oryzae* (35%) (Table 2).

Dead tissues of *Pandanus odoratissimus* were frequently colonized by *Acremonium* sp. 3 (50%), *Aspergillus parasiticus* (67.5%), *Botryodiplodia theobromae* (40%), *Monodictys* sp. 1 (52.5%), *Phomopsis* sp. 1 (35%), *Cladosporium cucumerinum* (30%), *Linocarpon lammiae* (27.5%) and *Ophiostoma* sp. (25%) (Table 3).

The taxa occurring on *Pandanus penetrans* leaves with at least 20% of samples both from natural samples and baits are compared in Table 4. *Myrothecium pandanicola* (a new species), *Nectria*-like 1, *Oxydothis linospadicis*, *Phaeosphaeria*-like, *Sporidesmium ghanaense* and *Trichoderma* sp. were frequently found on both types/kinds of samples (20-63.3% frequency of occurrence).

Effect of hosts and their habitats on fungal communities

Fungal community composition was influenced by the host plant. Figure 7 shows distinct fungal community occurrence on *Dracaena lourieri* (2 collections)*, Pandanus amaryllifolius* (2)*, P. odoratissimus* (4) and *P. penetrans* (8). A percentage of total variance explained by the model of three dimensional corresponding analyses is 37.94%.

In comparison to samples from different habitats, fungal communities on *P. odoratissimus* from the beach in Rayong Province were distinct and were dissimilar to those of *D. lourieri* and *P. penetrans* from rainforests in Chiang Mai. The highest number of fungal taxa occurred on collections of *D. lourieri* (Table 1-4). *Acremonium*, *Aspergillus*, *Botryodiplodia*, *Cladosporium*, *Memnoniella*, *Nigrospora*,

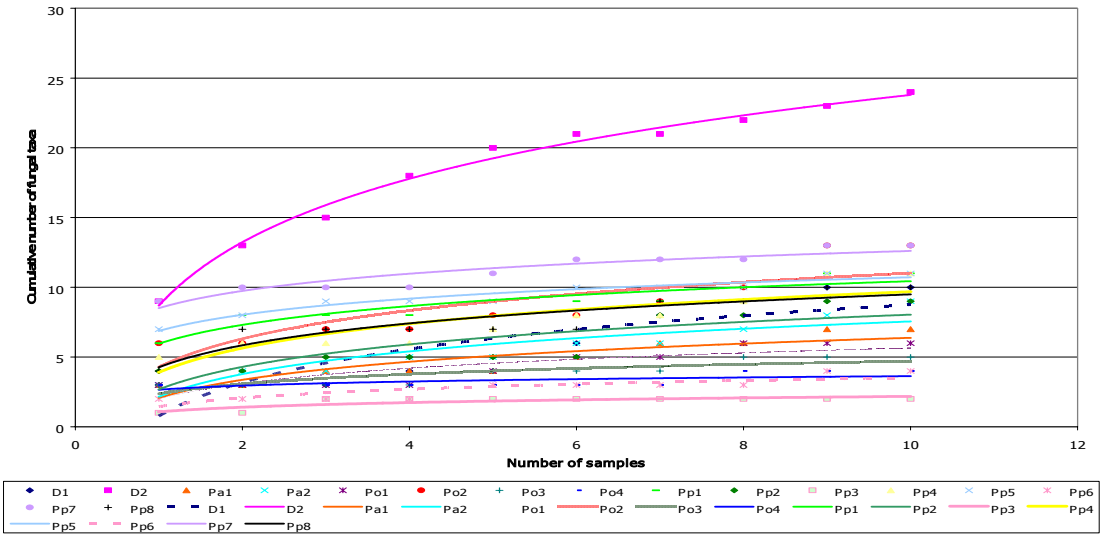


Fig. 6. Species area curve for fungi collected on *Dracaena lourieri* and *Pandanus* spp. at each sampling time.

Table 1. Frequency and overall percentage occurrence of fungal taxa on decaying leaves of *Dracaena lourieri* collected from Chiangdao National Park in Chiang Mai during hot wet season (D1) and cool dry season (D2).

Taxa	D1	D2	%	Taxa	D1	D2	%
Acremonium sp. 1	1	6	**35**	*Guignardia* sp.	3		**15**
Acremonium sp. 6		7	**35**	Hyphomycete 5		3	**15**
Acremonium sp. 7		3	**15**	*Memnoniella echinata*	3		**15**
Anthostomella tomicoides	1		**5**	*Microthyrium* sp. 1	1	10	**55**
Ascomycete 1[#]	1		**5**	*Monodictys* sp. 2		8	**40**
Aspergillus niger		6	**30**	*Nectria*-like 1	3		**15**
Aspergillus parasiticus		10	**50**	*Nectria*-like 2	3	5	**40**
Botryodiplodia theobromae	3	10	**65**	*Nigrospora oryzae*	3		**15**
Canalisporium variabile		5	**25**	*Oidiodendron griseum*		5	**25**
Chloridium virescens		3	**15**	*Ophioceras chiangdaoensis* [#]	3	3	**30**
Cladosporium cucumerinum		8	**40**	*Paraphaeosphaeria obtusispora*	1		**5**
Coelomycete 1		4	**20**	*Periconia cookei*	3		**15**
Colletotrichum gloeosporioides	3	8	**55**	*Pestalotiopsis guepinii*	3	2	**25**
Colletotrichum sp.		2	**10**	*Phomopsis archeri*	3	8	**55**
Cryptophiale-like		9	**45**	*Phomopsis* sp. 1	4		**20**
Cylindrocarpon sp.		4	**20**	*Pseudohalonectria suthepensis*		1	**5**
Cylindrocladium sp. 2		2	**10**	*Ramichloridium subulatum*		8	**40**
Dictyosporium heptasporum		1	**5**	*Stachybotrys chartarum*	5	10	**75**
Fusarium oxysporum	4	5	**45**	*Stachybotrys theobromae*		8	**40**
Fusicladium sp.	4		**20**	*Trichothecium roseum*		10	**50**
Glomerella cingulata	2	2	**20**	*Zygosporium blioblitzi* [#]	3	10	**65**

	D1	D2	Total
Total number of fungal records	60	186	**246**
Number of anamorphic fungi	13	27	**32**
Number of ascomycetes	9	5	**10**
Number of basidiomycetes	0	0	**0**
Total taxa	22	32	**42**

#New species known only from *D. lourieri* with the description in Thongkantha, 2006 or McKenzie *et al*., 2007.

Table 2. Frequency and overall percentage occurrence of principal fungal taxa on *Pandanus amaryllifolius* leaves collected from Medicinal Plant Garden in Chiang Mai (Pa1) and a garden in Rayong (Pa2) during hot wet season.

Taxa	Pa1	Pa2	%	Taxa	Pa1	Pa2	%
Acremonium sp. 6	10	10	**100**	*Nectria*-like 3	8	7	**75**
Botryodiplodia theobromae	6	7	**65**	*Nigrospora oryzae*	4	3	**35**
Dactylaria purpurella		4	**20**	*Phoma* sp.	4	10	**70**
Hyphomycete 6		6	**30**	*Phomopsis* sp. 1	3		**15**
Memnoniella echinata	4	1	**25**	*Verticillium* sp.	4		**20**
Microthyrium sp. 2		4	**20**	*Zygosporium oscheoides*	6	5	**55**

	Pa1	Pa2	Total
Total number of fungal records	49	57	**106**
Number of anamorphic fungi	8	8	**10**
Number of ascomycetes	1	2	**2**
Number of basidiomycetes	0	0	**0**
Total taxa	9	10	**12**

Table 3. Frequency and overall percentage occurrence of fungal taxa on decaying tissues of *Pandanus odoratissimus* collected from Nang Rum Beach in Rayong during hot dry season (Po1-leaves) and cool dry season (Po2-leaves, Po3-prop roots and Po4-seeds).

Taxa	Code	Po1	Po2	Po3	Po4	%
Acremonium sp. 3	S104h	**9**	**3**	**8**		**50**
Acremonium sp. 5	S106h	1	2			7.5
Ascomycete 3	S105a	1	4			13
Ascomycete 4	S178a		5			13
Aspergillus parasiticus	S102h	**5**	**4**	**10**	**8**	**68**
Aspergillus sp. 1	S107h	1	5			15
Botryodiplodia theobromae	S082c		**3**	**6**	**7**	**40**
Byssosphaeria-like	S108a	2	2			10
Chaetomium globosum	S119a		6			15
Cladosporium cucumerinum	S103h	7	5			30
Curvularia eragrostidis	S169h		3			7.5
Emericella nidulans	S172a		1			2.5
Emericella sp.	S180a		2			5
Exserohilum sp.[#]	S174h		2			5
Hyphomycete 1	S117h	1				2.5
Hyphomycete 4	S171h		3			7.5
Leptosphaeria-like	S112a	1				2.5
Linocarpon lammiae	S101a	4	7			28
Memnoniella echinata	S110h	3	1			10
Memnoniella sp.	S183h		2	4		15
Monodictys sp. 1	S109h	**5**	**8**		**8**	**53**
Nigrospora oryzae	S134h		6			15
Ophiostoma sp.	S204a				10	25
Penicillium sp. 2	S176h		2			5
Periconia sp.[#]	S179h		2			5
Phoma destructiva	S182c		2			5
Phomopsis sp. 3	S111h	**3**	**3**	**8**		**35**
Veronaea botryosa	S115h	1				2.5
Verticillium sp.	S173h		4			10

	Po1	Po2	Po3	Po4	Total
Total number of fungal records	44	87	36	33	200
Number of anamorphic fungi	10	18	5	3	20
Number of ascomycetes	4	7	0	1	9
Total taxa	14	25	5	4	29

#New species awaiting description, known only from *P. odoratissimus*, with a description in Thongkantha, 2006.
Bold indicates percentage occurrence of more than 35%.

Table 4. Frequency and overall percentage occurrence of fungal taxa occurring on samples in nature and baits of *Pandanus penetrans* leaves.

Taxa	Pp1	Pp2	Pp3	Pp4	Pp5	%	Pp6	Pp7	Pp8	%
Acremonium sp. 2	4			1		**10**		1		**3.3**
Acremonium sp. 4	1	1		1	1	**8**				
Alternaria alternata	1					**2**				
Ascomycete 2				1		**2**				
Aspergillus sp. 2		1			1	**4**		1		**3.3**
Aspergillus sp. 3	8					**16**				
Astrosphaeriella tornata		3	10		3	**32**		3		**10**
Basidiomycete		1				**2**				
Berkleasmium sp.							2			**6.7**
Canalisporium exiguum	2	1		2	2	**14**		3	9	**40**
Chaetomium globosum		3			1	**8**		1		**3.3**
Cladosporium cucumerinum	2					**4**				
Colletotrichum gloeosporioides	1					**2**				
Curvularia lunata	7					**14**				
Cylindrocladium sp. 1		1		2	1	**8**		1		**3.3**
Dictyochaeta fertilis							1			**3.3**
Dictyosporium heptasporum		1		1		**4**				
Ellisembia adscendens		1			3	**8**	3	3	7	**43.3**
Fusarium oxysporum	5					**10**				
Fusicladium sp.							1			**3.3**
Glomerella cingulata	5					**10**				
Glomerella sp. 1	5					**10**				
Glomerella sp. 2				4		**8**			3	**10**
Helicosporium sp.								1	1	**6.7**
Hyphomycete 2	3					**6**				
Hyphomycete 3									1	**3.3**
Hyphomycete (synnematous) 1				2		**4**				
Hyphomycete (synnematous) 2		1				**2**				
Hyphomycete (synnematous) 3									8	**26.7**
Hyponectria sp.				3		**6**				
Linocarpon lammiae									1	**3.3**
Linocarpon livistonae		1		2		**6**				
Linocarpon siamensis *				4	2	**12**		2	1	**10**
Linocarpon suthepensis *				2		**4**				
Melanochaeta hemipsila			8	4		**24**		5	5	**33.3**
Memnoniella echinata		2			3	**10**		2		**6.7**
Microthyrium sp. 2							3			**10**
Myrothecium pandanicola #		9		4	5	**36**	2	5		**23.3**
Nectria-like 1		1		6	5	**24**		6		**20**
Nigrospora oryzae	8				1	**18**		1	1	**6.7**
Ophioceras leptosporum		1		1		**4**				
Ornatispora sp.#					2	**4**		4	1	**16.7**
Oxydothis linospadicis	1	10		9	10	**60**		10	4	**46.7**
Oxydothis siamensis #	4					**8**				
Paecilomyces variotii	4					**8**				
Penicillium chrysogenum	10	3			10	**46**				
Penicillium sp. 1							2	10		**40**

*New species known only from *P. penetrans* with descriptions in Thongkantha *et al*., 2003 and Thongkantha 2006.

#New species awaiting description, known only from *P. penetrans*, with a description in Thongkantha, 2006.

Pp1 = 10 leaves of *P. penetrans* collected from the foothills of Kardthee Village in Phayao during hot dry season; **Pp2** = 10 leaves of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during hot dry season; **Pp3** = 10 leaf sheaths of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during hot dry season; **Pp4** = 10 leaves of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during hot wet season; **Pp5** = 10 leaves of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during cool dry season; **Pp6** = 10 leaf baits of *P. penetrans* collected at day 0; **Pp7** = 10 leaf baits of *P. penetrans* collected at month 12; **Pp8** = 10 leaf baits of *P. penetrans* collected at month 18.

Table 4 (continued). Frequency and overall percentage occurrence of fungal taxa occurring on samples in nature and baits of *Pandanus penetrans* leaves.

Taxa	Pp1	Pp2	Pp3	Pp4	Pp5	%	Pp6	Pp7	Pp8	%
Periconia cookei		1			7	**16**	1	8		**30**
Periconia minutissima							1			**3.3**
Pestalotiopsis guepinii							2			**6.7**
Phaeonectriella pandani[#]				1		**2**				
Phaeosphaeria-like[#]		3		4	8	**30**		10	9	**63.3**
Phaeostalagmus cyclosporus					4	**8**		5	8	**43.3**
Phialocephala bactrospora				5		**10**				
Phialocephala sp.		5				**10**		2		**6.7**
Phomatospora sp. 1				2	8	**20**		9	2	**36.7**
Phomatospora sp. 2				1		**2**				
Phomopsis sp. 2	1	2		6	1	**20**				
Pyrenochaeta sp.								1	2	**10**
Sordaria fimicola	2					**4**				
Sporidesmium ghanaense	2	3		2	3	**20**	7	2	10	**63.3**
Stachylidium bicolor		1		2	4	**14**		5		**16.7**
Trichoderma sp.	5	4			5	**28**		6		**20**
Trichothecium roseum		1				**2**				
Tubercularia lateritia							1	1		**6.7**
Tubeufia cerea									3	**10**
Verticicladiella sp.				2		**4**				
Verticillium tenerum	3			2		**10**				
Volutella sp.				3		**6**				
Zygosporium oscheoides		1			4	**10**		4	1	**16.7**
	Pp1	**Pp2**	**Pp3**	**Pp4**	**Pp5**	**TT**	**Pp6**	**Pp7**	**Pp8**	**TT**
Total number of fungal records	89	62	18	79	94	**342**	28	112	77	**217**
Number of anamorphic fungi	18	18	0	14	16	**35**	12	19	10	**27**
Number of ascomycetes	5	7	2	14	8	**20**	1	9	9	**12**
Number of basidiomycetes	0	1	0	0	0	**1**	0	0	0	**0**
Total taxa	23	26	2	28	24	**56**	13	28	19	**39**

*New species known only from *P. penetrans* with descriptions in Thongkantha *et al*., 2003 and Thongkantha 2006.
Pp1 = 10 leaves of *P. penetrans* collected from the foothills of Kardthee Village in Phayao during hot dry season; **Pp2** = 10 leaves of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during hot dry season; **Pp3** = 10 leaf sheaths of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during hot dry season; **Pp4** = 10 leaves of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during hot wet season; **Pp5** = 10 leaves of *P. penetrans* collected from Doi Suthep Pui National Park in Chiang Mai during cool dry season; **Pp6** = 10 leaf baits of *P. penetrans* collected at day 0; **Pp7** = 10 leaf baits of *P. penetrans* collected at month 12; **Pp8** = 10 leaf baits of *P. penetrans* collected at month 18.

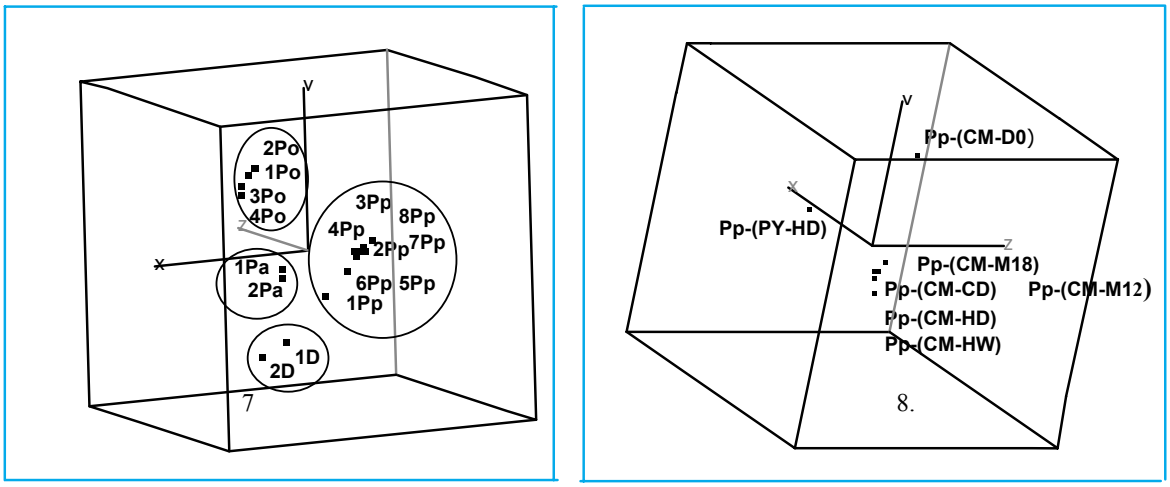
Phomopsis and *Zygosporium* were the overlap genera found on *Dracaena* and *Pandanus*. The Sorensen indices also show that fungal taxa occurring on *D. lourieri* and *P. penetrans* (40-50%) were more similar than those on *P. amaryllifolius*, *P. odoratissimus* and *P. penetrans* (10-20%) (Table 5). The similarities of fungi discovered from naturally occurring samples and baits (day 0 plus month 12 and month 18) of *P. penetrans* was high (50%).

Fungal occurrence on Pandanus penetrans leaves from different sites and effect of stages of decay

Three-dimensional correspondence analysis plots of fungal communities on *Pandanus penetrans* leaves collected from different sites and stages of decay are presented in Fig. 8. The percentage of total

Table 5. Similarity of fungal taxa composition between *Dracaena lourieri* and *Pandanus* species.

Sorenson index (%)	*D. loureiri*	*P. amaryllifolius*	*P. odoratissimus*	*P. penetrans* (Natural samples)
P. amaryllifolius	20			
P. odoratissimus	10	20		
P. penetrans (Natural samples)	40	10	10	
P. penetrans (baits in day 0, month 12 and 18)	10	20	10	50



Figs 7-8. Three-dimensional correspondence analysis of fungal communities. **7.** Recorded from leaves of *Dracaena lourieri* collected during hot wet season **(1D)** and cool dry season **(2D)** in Chiang Mai**;** leaves of *Pandanus amaryllifolius* collected during hot wet season in Chiang Mai **(1Pa)** and Rayong **(2Pa)**; decaying tissues of *P. odoratissimus* collected during hot dry season in Rayong (**1Po**-leaves) and cool dry season (**2Po**-leaves, **3Po**-prop roots and **4Po**-seeds);. natural dried leaves [in Phayao **(1Pp**-hot dry season**)** and Chiang Mai **(2Pp** and **3Pp**-hot dry season**), 4Pp**-hot wet season, **5Pp**-cool dry season] and leaf baits of *P. penetrans* collected at day 0 **(6Pp)**, month 12 **(7Pp)** and month 18 **(8Pp)**. A percentage of total variance explained by the model is 37.94%. **8.** On *Pandanus penetrans* leaves from Chiang Mai (CM) and Phayao (PY) during 3 seasons of cool dry (CD), hot dry (HD) and hot wet (HW) or during succession study at day 0 (D0), month 12 (M12) and month 18 (M18).

variance explained by the model is 72.82%. Distinct fungal communities were found on *Pandanus penetrans* leaves from different sites and at different stages of decay.

Collections of *Pandanus penetrans* from Chiang Mai show that the fungal community at day 0 differed from those at months 12 and 18 (Fig. 8). The number fungal taxa occurring at day 0, month 12 and month 18 were 13, 28 and 19 respectively. Only *Ellisembia adscendens* (43.3% of samples) and *Sporidesmium ghanaense* (63.3%) were found at all stages of decay (Table 4).

Fungal occurrence on different parts of Pandanus odoratissimus and P. penetrans

Plant tissues affected fungal occurrence. Fungal communities on leaves of *Pandanus odoratissimus* were different from those on prop roots and seeds (Fig. 9). This is indicated by the principal-coordinate axes c1 and c2, which separate into distinct clusters of species in two-dimensional correspondence analysis. Axis c1 separate the fungal communities on leaves from those of prop roots and seeds (Fig. 9). Fewer fungi were found on prop roots and seeds than on leaves, *Aspergillus parasiticus* and *Botryodiplodia theobromae* (Table 3) were found on all tissues. In *P. penetrans* from the rainforest at Doi Suthep Pui National Park during hot dry season, more taxa occurred on decaying leaves (26 taxa) than on leaf sheaths (2) (Table 4).

Seasonal pattern of fungal occurrences on Pandanus penetrans leaves

Figure 10 shows three-dimensional correspondence ordinations of fungal communities occurring on *Pandanus penetrans* leaves at Doi Suthep Pui National Park including the natural samples that were collected during 3 seasons (cool dry, hot dry and hot wet), and the succession study samples at 3 stages of decay (day 0, month 12 and month 18). The percentage of total variance explained by the model is 82.14%. There is no seasonal pattern of fungal occurrence on *Pandanus penetrans* leaves both in natural samples and succession study samples (Fig. 10). The number of fungal taxa occurring on leaves collected during the cool dry, hot dry and hot wet seasons were 24, 26 and 27 respectively. *Myrothecium pandanicola* sp. nov., *Nectria*-like 1, *Ornatispora* sp., *Oxydothis linospadicis, Penicillium* sp. 1,

Table 6. Frequency and overall percentage occurrence of fungal taxa on *Pandanus penetrans* leaves during the succession process.

Taxa	Number of leaves (maximum 10) on which fungi detected								Overall percentage occurrence
	19/1/2003 Day 0	26/1/2003 Week 1	19/2/2003 Month 1	19/3/2003 Month 2	19/5/2003 Month 4	20/7/2003 Month 6	19/1/2004 Month 12	19/6/2004 Month 18	
Acremonium sp. 2			1				1		2.5
Acremonium sp. 4		7	2	4	9				27.5
Aspergillus sp. 2							1		1.3
Astrosphaeriella tornata							3		3.8
Berkleasmium sp.	2			1					3.8
Canalisporium exiguum							3	9	15.0
Cepharosporiopsis sp.						2			2.5
Chaetomium globosum		2					1		3.8
Chaetosphaeria sp.						3			3.8
Chloridium virescens				8	9				21.3
Coelomycete 2		1							1.3
Coelomycete 3			1						1.3
Colletotrichum gloeosporioides		1							1.3
Cylindrocladium sp. 1							1		1.3
Dictyochaeta fertilis	1								1.3
Ellisembia adscendens	3		5	7	1		3	7	32.5
Fusicladium sp.	1	2		1					5.0
Glomerella sp.						2		3	6.3
Helicosporium sp.							1	1	2.5
Hyphomycete 3								1	1.3
Hyphomycete 9					2				2.5
Hyphomycete (synnematous) 1					1				1.3
Hyphomycete (synnematous) 3						2		8	12.5
Linocarpon lammiae								1	1.3
Linocarpon siamensis sp. nov.							2	1	3.8
Melanochaeta hemipsila (*Sporochisma saccardoi*)							5	5	12.5
Memnoniella echinata							2		2.5
Microthyrium sp. 2	3	1	4	1					11.3
Myrothecium pandanicola sp. nov.	2	4		1		4	5		20.0
Nectria-like 1						10	6		20.0
Nigrospora oryzae							1	1	2.5

*possibly new taxa

Table 6 (continued). Frequency and overall percentage occurrence of fungal taxa on *Pandanus penetrans* leaves during the succession process.

Taxa	Number of leaves (maximum 10) on which fungi detected								Overall percentage occurrence
	19/1/2003 Day 0	26/1/2003 Week 1	19/2/2003 Month 1	19/3/2003 Month 2	19/5/2003 Month 4	20/7/2003 Month 6	19/1/2004 Month 12	19/6/2004 Month 18	
Ornatispora sp.*							4	1	6.3
Oxydothis linospadicis		5	1	1	4	2	10	4	33.8
Oxydothis oraniopsis						2			2.5
Penicillium sp. 1	2						10		15.0
Periconia cookei	1			2			8		13.8
Periconia minutissima	1								1.3
Periconiella daphniphylli						1			1.3
Pestalotiopsis guepinii	2		1	1					5.0
Phaeosphaeria-like*		5	1	2	10		10	9	46.3
Phaeostalagmus cyclosporus							5	8	16.3
Phialocephala sp.						10	2		15.0
Phomatospora berkeleyi							9	2	13.8
Pyrenochaeta sp.					1		1	2	5.0
Sporidesmium ghanaense	7	6	5	7	1	4	2	10	52.5
Stachylidium bicolor			2		7		5		17.5
Trichoderma sp.							6		7.5
Trichothecium roseum			2	1					3.8
Tubercularia sp.	1		1	1			1		5.0
Tubeufia cerea								3	3.8
Sterile mycelia 1	2	5	4						13.8
Sterile mycelia 2				9					11.3
Verticillium sp. 1		3	1	6	1				13.8
Volutella sp.						5			6.3
Zygosporium oscheoides					1		4	1	7.5
Total number of fungal records (437)	**28**	**42**	**31**	**53**	**47**	**47**	**112**	**77**	
Number of anamorphic fungi (40)	**12**	**8**	**11**	**13**	**10**	**7**	**19**	**10**	
Number of ascomycetes (15)	**1**	**4**	**4**	**3**	**2**	**5**	**10**	**9**	
Total taxa (55)	**13**	**12**	**14**	**16**	**12**	**12**	**28**	**19**	

*possibly new taxa

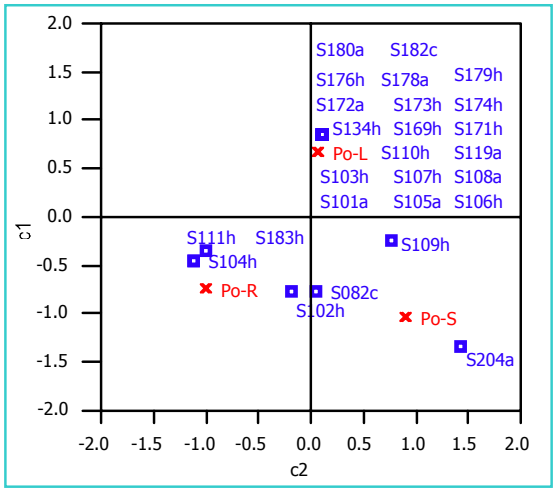


Fig. 9. Two-dimensional correspondence analysis of fungal communities (see fungal name of each code in table 3) on leaves (L), prop roots (P) and seeds (S) of *Pandanus odoratissimus* (Po) in Rayong Province during cool dry season. This plot accounts for 100% of the variance in the data set.

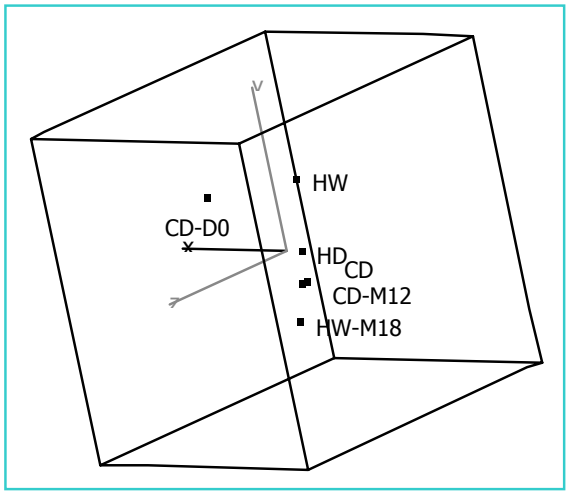


Fig. 10. Three dimensional correspondence ordinations of fungal communities on *Pandanus penetrans* leaves from Doi Suthep Pui National Park collected during cool dry (CD), hot dry (HD) and hot wet (HW) seasons, and samples collected during succession study at day 0 (D0), month 12 (M12) and month 18 (M18).

Periconia cookei, *Phaeosphaeria*-like, *Phaeostalagmus cyclosporus*, *Phomatospora* sp. 1, *Sporidesmium ghanaense*, *Stachylidium bicolor*, *Trichoderma* sp. and *Zygosporium oscheoides* were abundant in both natural leaves and baits (Table 4).

Fungal succession on Pandanus penetrans leaves

Determination of sample size

The species area curve for each sampling of *Pandanus penetrans* leaves during the successsion study almost reached asymptote (Fig. 11). Although the curve did not completely level off, the number of samples was large enough to obtain a highly representative result.

Fungal taxonomic composition on Pandanus penetrans leaves and effect of stages of decay

Fifty-five taxa were identified on *Pandanus penetrans* leaves during the succession process (Table 6). The common taxa were *Sporidesmium ghanaense* (on 52.5% of samples), *Phaeosphaeria*-like (46.3%), *Oxydothis linospadicis* (33.75%), *Ellisembia adscendens* (32.5%), *Acremonium* sp. 4 (27.5%), *Chloridium virescens* (21.25%), *Myrothecium pandanicola* sp. nov. (20%), *Nectria*-like (20%), *Stachylidium bicolor* (17.5%), *Phaeostalagmus cyclosporus* (16.25%), *Canalisporium exiguum* (15%), *Penicillium chrysogenum* (15%) and *Phialocephala* sp. (15%) (Table 6).

Three-dimensional correspondence analysis of fungal communities on leaves of *Pandanus penetrans* showed that fungal compositions were distinct at each stage of the succession (Fig. 12). The values of Shannon index varied between 2.1-2.4 during days 0-180, reaching a peak of 3.1 at about 12 months (Fig. 13). The overall numbers of fungi found at each sampling time are shown in Fig. 14. Dominant species at each stage of decay are distinct.

Almost all fungi recorded on green leaves at day 0, such as *Ellisembia adscendens*, *Myrothecium pandanicola* sp. nov. and *Sporidesmium ghanaense* were associated with brown spots. Pioneer (day 0 - month 6), mature (month 7-12) and impoverished communities (month 13-18) were observed. There were 12-16 taxa found in the pioneer community stage, with *S. ghanaense* having the highest frequency. In the mature community, the diversity was high (28 taxa) and had peaked with a number of taxa with low percentage occurrence. *Oxydothis linospadicis*, *Penicillium chrysogenum, Periconia cookie*, *Phaeosphaeria*-like and *Phomatospora* sp. 1 had a high level of occurrence. In the impove-

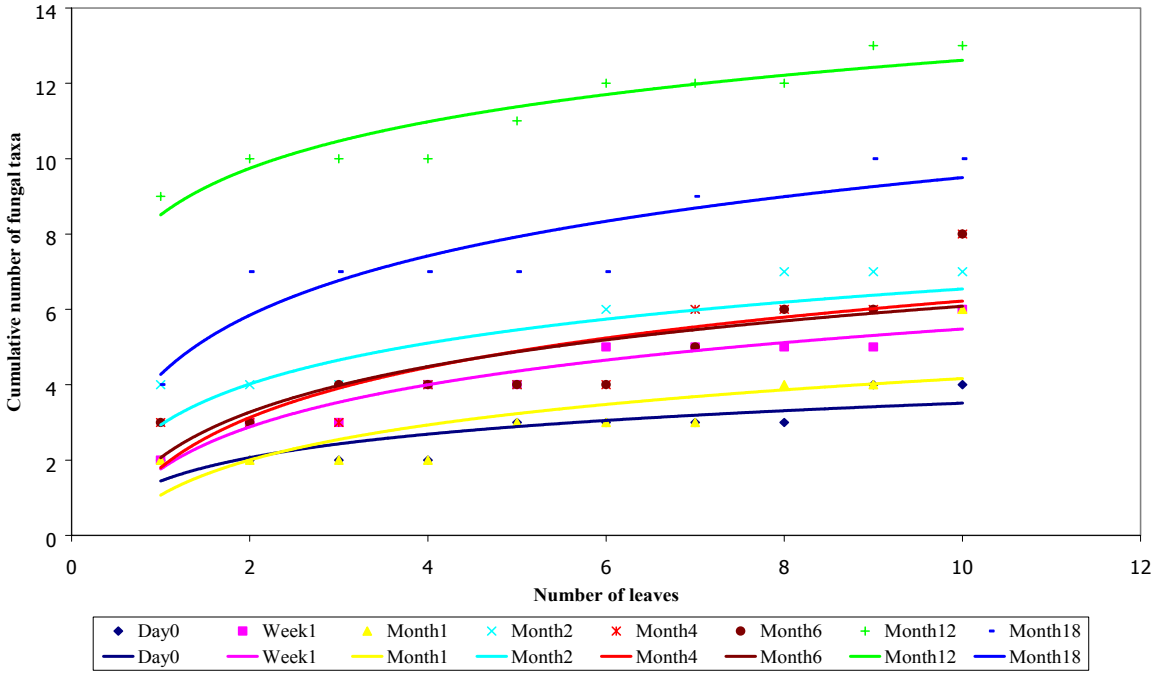


Fig. 11. Species area curve for fungi collected on *Pandanus penetrans* leaves at different stages of succession.

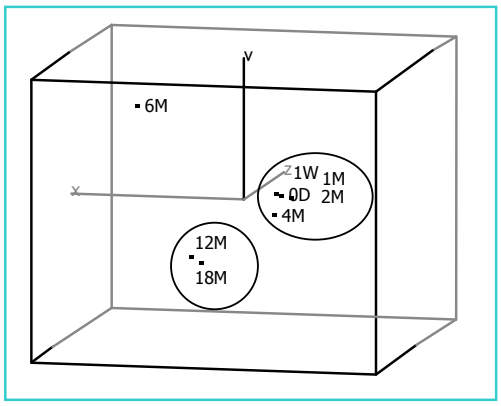


Fig. 12. Three-dimensional correspondence analysis of fungal samples of *Pandanus penetrans* at day 0, week 1 and months 1-18. Percentages of total variance is 64.79%.

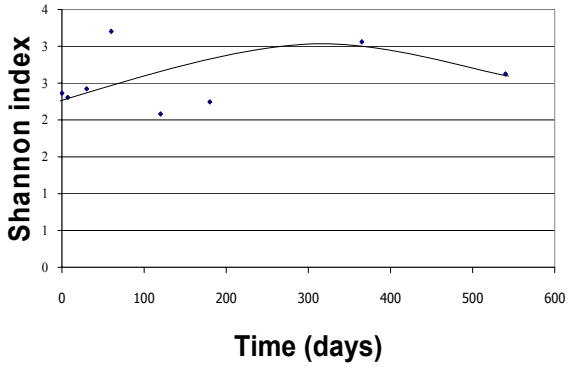


Fig. 13. Shannon indices for *Pandanus penetrans* leaves throughout the experiment.

rished stage, the diversity and number of taxa declined. Dominant taxa were *Canalisporium exiguum Phaeosphaeria*-like and *S. ghanaense*.

Pathogenic fungi on Dracaena and Pandanus leaves

Twenty-three fungi were identified from samples of *Dracaena lourieri* and species of *Pandanus* showing symptoms of anthracnose on leaves, speckle or leaf spot (Table 7), and tested for pathogenicity. Only *Colletotrichum gloeosporioides*, *Curvularia lunata*, *Fusarium oxysporum*, *Guignardia* sp. and *Phomopsis* sp. caused disease lesions on the host leaves and all could be reisolated. The controls produced no disease symptoms.

Discussion

The results from the present study suggest that saprobes and pathogens may be specific to different plant species. The results confirm that the taxa on *Dracaena* and *Pandanus* are diverse, and could be a source for more undescribed fungi (McKenzie and Hyde, 1997; Whitton, 1999; Dulymamode *et al*., 2001a; McKenzie *et al*., 2002; Hyde *et al*., 2007). Eleven new taxa were found in this study. Three of them have been described, *Linocarpon siamensis*, *L. suthepensis* and *Zygosporium blioblizi* (Thongkantha *et al*., 2003; McKenzie *et al*., 2007), while *Myrothecium pandanicola* sp. nov., *Ophioceras chiangdaoensis* sp. nov., *Oxydothis siamensis* sp. nov., and *Phaeonectriella pandani* sp. nov. are described in Thongkantha (2006), but have yet to be validly described. New species of *Exserohilum*, *Ornatispora*, *Periconia* and *Phaeosphaeria* have yet to be informally described

Biodiversity of saprobic fungi on Dracaena lourieri and Pandanus spp.

A high number of fungal taxa were found (126 species were identified from 160 plant samples). Surprisingly, none of the species of fungi reported on *Pandanaceae* by McKenzie and Hyde (1996) and McKenzie *et al*. (2002) were found in the present study. *Linocarpon lamiae*, which was described from *Pandanus tectorius* by Whitton (1999), was the only species described from the *Pandanaceae* that also occurred in this study, on *P. odoratissimus* (Thongkantha *et al*., 2003). The high diversity of saprobes on *D. lourieri, P. odoratissimus* and *P. penetrans* parallels the diversity found in previous studies on five *Pandanus* species from Mauritius (Dulymamode *et al*., 2001a) and some other monocotyledons from tropical rainforests such as bamboo (Hyde *et al*., 2001, 2002a,b), grasses (Wong and Hyde, 2001) and palms (Fröhlich and Hyde, 2000; Yanna *et al*., 2001b, 2002; Hidayat *et al*., 2006). The saprobes recorded in the current study can be compared with those recorded on various hosts from rainforests in Thailand. Somrithipol *et al*. (2002) identified 70 fungi from 130 samples of *Delonix regia* pods in Khao Yai National Park, with an overlap with the present study of 11%. At Suthep Pui National Park, Photita *et al*. (2003) recorded 80 fungi on decaying tissues of *Musa acuminata* from 5 sites, with an overlap with this study of 15%; Bussaban *et al*. (2004) reported 130 fungal taxa from 320 samples of ginger (*Alpinia malaccensis* and *A. siamense*), with an overlap with the present study of 12%; and Promputtha *et al*. (2004) reported 37 taxa from 90 dead leaves of *Magnolia liliifera*, with an overlap of 10% with the present study. The overlap of fungi occurring on *Dracaena* and *Pandanus* species with those recorded on both dicotyledonous and monocotyledonous hosts is thus low. This may be influenced by geographical distribution and host-recurrence (Dulymamode *et al*., 2001a; Yanna *et al*., 2001b; Zhou and Hyde, 2001).

The fungal communities on the leaf bases of *D. lourieri*, *P. odoratissimus* and *P. penetrans* are richer (particularly in ascomycete taxa) than on the leaf apices. The leaf bases may act as sites of storage for nutrient reserves, which overwinter and support early growth in spring (Isaac, 1992). They are also stouter and may decay more slowly. The overall fungal community on *P. tectorius* (88 species) is greater than that on *P. furcatus* (45) with a smaller number of overlapping species, which may be due to *Pandanus furcatus* having a relatively thin cuticle on its leaves, no trunk or branches and is typically found along the edges of streams in areas covered by forests. Conversely, *P. tectorius* has a distinct trunk, many branches, with a thicker cuticle on the leaves and is found along the coastline (Whitton, 1999; McKenzie *et al*., 2002). Low species diversity has been also found on leaves of banana (Photita *et al*., 2003) and *P. amaryllifolius* (in this study). *D. lourieri*, *P. odoratissimus* and *P. penetrans* (in the present study) and palms (Yanna *et al*., 2001a,b) offer more durable, strongly sclerenchymatous substrata that tend to support a higher fungal diversity.

Fungi that are known to occur on several hosts tend to be less fastidious, more ubiquitous species. For example McKenzie *et al*., (2002) found that of 133 species of fungi known from *Freycinetia*, 44 species are known also to inhabit *Pandanus*, giving a species composition overlap of 33%. Of the

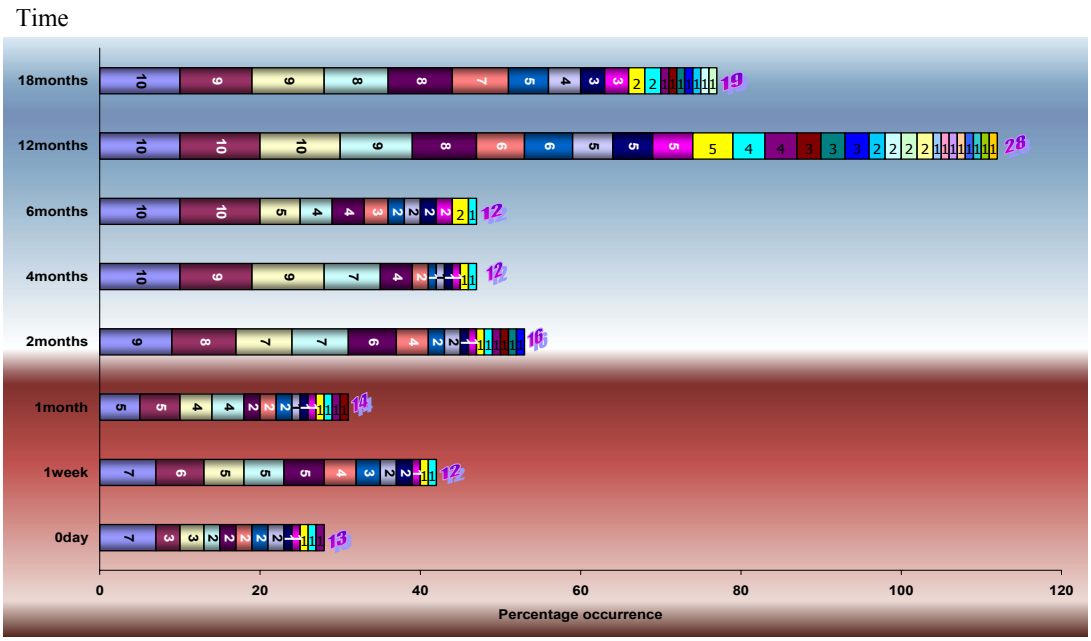


Fig. 14. Number and percentage occurrence of fungal taxa on *Pandanus penetrans* leaves during different stages of decay. Taxa recorded at each sampling time are ordered with the most abundant to the left and the least abundant to the right.

Table 7. A comparison of the potentially pathogenic taxa recovered from *Dracaena lourieri*, *Pandanus amaryllifolius* and *P. penetrans*.

Fungal Name	*D. lourieri*	*P. amaryllifolius*		*P. penetrans*
	Chiang Dao 1/6/05	Phayao 20/2/05	Suthep Pui 12/4/05	Suthep Pui 12/4/05
Acremonium sp.				+
Aspergillus sp.				+
Cercospora sp.			++	
Cladosporium oxysporum	++	++		
Colletotrichum gloeosporioides	++	+		+++
Curvularia lunata				+
Fusarium oxysporum			++	+
Guignardia sp.	++	+		+
Herpomyces sp.				+
Gliocladium roseum				+
Myrothecium pandanicola sp. nov.				+
Nigrospora oryzae	+	+		
Oxydothis sp.				+
Penicillium sp.				+
Phomopsis sp.				+
Ramichloridium sp. 1				+
Ramichloridium sp. 2				+
Sporidesmium ghanaense				+++
Sterile mycelia (grey 1)	+			
Sterile mycelia (grey 2)				++
Sterile mycelia (grey 3)				+
Sterile mycelia (white 1)			+	
Sterile mycelia (white 2)				+
Total taxa	5	3	3	18

\+ = low frequency of occurrence or found on only 1 sample
++ = moderate frequency of occurrence or found on more than 2 samples
+++ = high frequency of occurrence or found on more than 5 samples

overlapping species, 36 are known from other substrata besides the *Pandanaceae*.

In this study, the similarity of fungi occurring on *D. lourieri* (from rainforest), *P. amaryllifolius* (from gardens) and *P. odoratissimus* (coastline) is low. The similarity of fungi on *D. lourieri* and *P. penetrans* (both natural and baits in the rainforest) are high. Distinct fungal communities were also found on the collection of *P. penetrans* leaves from different sites. The results indicate that the fungal communities may be affected by the host habitats which differ in humidity, rainfall and winds. Fungal diversity may also be related to disturbance. Fungi assemblages on palms in a tropical pristine forest were more diverse than those on agricultural palms or palm in botanical gardens (Taylor *et al*., 1999). Taylor *et al*. (2000) found that the fungal communities in natural stands of *Archontophoenix alexandrae* from rainforests of north Queensland were significantly richer than those of palms grown outside their natural habitat, e.g. naturalized in new habitats in Hong Kong. In the present study, decaying leaves of *D. lourieri* from garden plants supported only a few taxa of *Colletotrichum*, *Fusarium* and *Phomopsis* (Thongkantha, pers. obs.). Saprobic fungi are unlikely to be host-specific (Shivas and Hyde, 1997). Therefore, host-specificity is unlikely to influence saprobic fungal diversity. An important factor that may influence the biodiversity of saprobic fungi on various hosts is therefore host-recurrence. To allow for a better understanding of host-recurrence and specificity, Lodge (1997) suggested that comparisons must be made between samples of the same species located at different sites, or samples from different species located at the same site. The reasons as to why fungi may occur recurrently on certain hosts is not understood, but may be related to the presence of these fungi as endophytes. Unfortunately there has been no study on the endophytic fungi on *Dracaena* and *Pandanus*. In addition, various studies of endophytes on other hosts found a large number of unidentified taxa especially sterile mycelia, coelomycetes and Xylariaceae (Rodrigues and Samuels, 1990; Rodrigues, 1994; Taylor *et al*., 1999; Photita *et al*., 2001; Bussaban *et al*., 2004; Rakotoniriana *et al*., 2008).

Fungal occurrence on different tissues of Pandanus odoratissimus and P. penetrans

Fungal communities found on different dead tissues of *Pandanus odoratissimus* (leaves, prop roots and seeds) and *P. penetrans* (leaves and leaf sheaths) showed low overlap. The recurrence of fungi on certain tissue types has been noted in banana (Photita *et al*., 2003), *Magnolia liliifera* (Promputtha *et al*., 2004) and palms (Yanna *et al*., 2001a, b; Pinnoi *et al*., 2006; Pinruan *et al*., 2007). The structural differences of plant tissues may account for the fungi being confined to specific tissues as some fungi may have enzyme systems that can degrade the sclerenchyma tissues containing lignin, while others only degrade cellulose. Poon and Hyde (1998) found that fungi on *Phragmites australis* were vertically distributed, influenced by moisture as the bases were submerged. Ascomycete taxa were distinct on the lower culm tissues comprising sclerenchyma, while anamorphic taxa were rich on the upper herbaceous tissues. Sadaba *et al*. (1995) found different fungal communities on herbaceous and woody parts of *Acanthus ilicifolius*, more ascomycetes occurring on the lower woody part and more anamorphic taxa on the upper herbaceous parts. The recurrence of certain fungi on different tissue types may be due to differences in nutritional requirements, or the ability of the fungi to utilize different substrates (Adaskaveg *et al*., 1991; Isaac, 1992; Ingold and Hudson, 1993). Alternatively, it may be related to the distribution of endophytes, a theory that requires testing. The enzymatic activities of fungi also warrants further investigation in order to understand whether their abundance on specific tissue types is due to differing enzymatic capabilities (Yanna *et al*., 2001a,b).

Seasonal pattern of fungi on Pandanus penetrans

There is no seasonal pattern of fungal occurrence on *Pandanus penetrans* collected from tropical rainforests of Thailand. This may be due to collection sites in Thailand showing low fluctuation in temperature, humidity and rainfall (Photita *et al*., 2001). No seasonal differences were observed between fungi isolated from palms in the tropics, in both endophytes (Fröhlich *et al*., 2000) and saprobes

(Yanna *et al*., 2001b). The effect of seasonality may be more acute in temperate regions where greater fluctuations in temperature, humidity and rainfall occur.

Fungal succession on Pandanus penetrans leaves

Succession of fungi on leaf litter of monocotyledonous plants (e.g. grass, palms) and pines from temperate and tropical areas have been studied by direct and indirect methods (Kendrick and Burges, 1962; Sandhu and Sidhu, 1980; Hurst *et al*., 1983; Tokumasu *et al*., 1994; Hyde and Alias, 2000; Yanna *et al*., 2001b, 2002; Tokumasu and Aoiki, 2002). There have also been extensive studies of fungal succession on leaf litter of dicotyledonous trees (Saito, 1956; Hering, 1965; Hogg and Hudson, 1966; Pasqualetti *et al*., 1999; Promputtha *et al*., 2002; Duong *et al*., 2008). Fungal communities change over time during the decay process of naturally dead bamboo and bamboo baits in Hong Kong (Zhou and Hyde, 2002). In the present study changes in fungal composition throughout the decay process on *Pandanus penetrans* leaf baits were directly observed after incubation in a moist chamber. Three stages of fungal succession were recognized, including the pioneer stage, mature stage and impoverished or later stage that are similar to those of previous studies (e.g. Dix and Webster, 1985; Promputtha *et al*., 2002; Yanna *et al*., 2002). Early colonizers may be endophytes (Bacon and White, 2000) or latent pathogens (Hudson, 1980). Fungal communities occurring on banana leaves as pioneer colonizers were *Deightoniella torulosa*, *Nigrospora* spp. and *Verticillium theobromae*, and were later replaced by species of *Alternaria*, *Aspergillus*, *Cephalosporium*, *Cladosporium*, *Fusarium*, *Paecilomyces* and *Penicillium* with time (Meredith, 1962). *Asterina clasterosporium*, *Cylindrocladium brasiliense*, *Endomelanconium phoenicicola*, *Pestalotiopsis palmarum* and *Sporidesmium pedunculatum* were common on green leaves of *Phoenix hanceana* palm in first stage of decay (Yanna *et al*., 2002). The mature community at months 2-6 frequently comprised *Codinaea intermedia*, *Diaporthe phoenicis*, *Thozetella effusa* and *Tubakia* sp.

The time taken for decomposition of plant material varies among plant species, the study area, tissues types and the thickness of samples. For instance, pine needles may take ten years to decompose completely in a cool temperate pine forest (Hudson, 1980). Decomposition time of couch grass stems (Hudson and Webster, 1958), sugarcane and pineapple leaves (Hudson, 1962; Tiwari *et al*., 1994) in tropical areas are relatively short (14-24 months). Sugarcane bagasse needed 7 months (Sandhu and Sidhu, 1980), while *Castanopsis diversifolia* and palm (*Phoenix hanceana*) leaves need only 4 months to completely decay (Yanna *et al*., 2002; Lam, 2006). Decomposition of senescent leaves of *Manglietia garrettii* in a rain forest in Thailand was completed within 2 months (Promputtha *et al*., 2002). Mature green leaves of *Pandanus penetrans* in this study were found to be completely decayed after 18 months.

***Pathogenic fungi on leaves of Dracaena lourieri and Pandanus* spp.**

Relatively few fungi have been recorded as pathogens of *Dracaena* and *Pandanus*. For example, *Annellolacinia pandanicola* J. Fröhl, *Diplococcium pandani* B. Huguenin, *Echidnodes pandani* (Rostr.) Han, *Meliola* spp. *Phyllosticta pandanicola* E. Young, and *Volutellaria fuliginea* I. Hino & Katum were reported from species of *Pandanus* (McKenzie and Hyde, 1997). In the present study species of *Acremonium*, *Aspergillus*, *Cercospora, Colletotrichum, Curvularia*, *Fusarium*, *Gliocladium*, *Herpomyces*, *Myrothecium, Oxydothis*, *Penicillium*, *Phomopsis*, *Ramichloridium* and *Sporidesmium* were observed from anthracnose on leaves or leaf spots of *Pandanus penetrans* in rainforests of Thailand. Green and older leaves of *Dracaena lourieri* and *P. amaryllifolius* were frequently covered with anthracnose and leaf spots caused by *Colletotrichum gloeosporioides* and *Guignardia* sp. respectively. *Cladosporium oxysporum* and *Nigrospora oryzae* were found in large necrotic lesions on leaves of *D. lourieri* and *P. amaryllifolius* from garden plants. All these

fungi have been previously reported as plant pathogens in various hosts world wide (Clay, 1988; Smith *et al*., 1989; Farr *et al*., 1989; Jones, 2000; Brooks, 2002) and Thailand (Sontirat *et al*., 1994; Photita *et al*., 2001, 2004). Most of the fungi associated with leaf disease of *D. lourieri* and *Pandanus* spp. in this study were also recovered as saprobes on dead leaves. Taylor (1998) found that dead samples of garden palms contained a few typical palm fungi such as *Lasiodiplodia* and *Pestalotiopsis* which are believed to be plant pathogens. Some saprobes can also be facultative parasites (Photita *et al*., 2004).

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