Vertical distribution of saprobic fungi on bamboo culms

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The fungi on decaying culms of bamboo were investigated along a vertical gradient at sites in Hong Kong and the Philippines. Saprobic fungi on standing culms of *Bambusa* spp. and *Dendrocalamus* spp. were vertically stratified in both countries, with a higher biodiversity towards the bases of the culms.

Key words: bambusicolous fungi, fungal distribution, microfungi, tropical fungi.

Introduction

Bambusicolous fungi have been poorly documented with most studies of a taxonomic nature (Rehm, 1913, 1914; Sydow and Sydow, 1913, 1914; Eriksson and Yue, 1998; Zhou and Hyde, 2001). There have been few studies on the distribution of fungi on bamboo (e.g. Hino, 1961; Petrini *et al.*, 1989; Hyde *et al.*, 2001, 2002; Zhou and Hyde, 2002).

Previously studies on the distribution of fungi on standing hosts have shown that the saprobes are distributed along a vertical gradient. This is true of fungi in the intertidal region on grasses (Poon and Hyde, 1998) and mangroves (Hyde, 1988, 1989, 1990; Sadaba *et al.*, 1995) and on fungi on grasses in terrestrial regions (Dix and Webster, 1995). We were interested in establishing if similar vertical patterns are present on standing culms of bamboo in the tropics. We therefore initiated a study to investigate the fungi of standing culms of *Bambusa* spp. and *Dendrocalamus* spp. in forests in Hong Kong and the Philippines.

Materials and methods

Collections were carried out at Mt. Makiling, College, Laguna, Luzon, the Philippines, in June 1995 and 1996 and at Tai Po Kau Forestry Reserve, Tai

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Po Kau, New Territories, Hong Kong in September 1995 and 1996. Samples from *Bambusa* and *Dendrocalamus* spp. were studied in both countries. Details of sites are described by Hyde *et al.* (2001).

Sampling procedures

Three clumps of bamboo were chosen randomly in an area of forest at each site and 2 standing dead culms were randomly selected from each clump and cut down. Each culm was equally divided into three levels; basal, middle and apical. Twenty samples (20-22 × 2.5-3 cm) were randomly cut from each level of each culm (3 clumps × 2 dead culms × 20 samples = 120 samples for each level). Samples were processed immediately upon return to the laboratory. Culms were placed in individual 'snap lock' plastic bags with moist paper tissue, and incubated for 1-2 weeks. Samples were then examined under a dissecting microscope for the presence of fungi which were identified. Voucher slides and material are deposited in the Hong Kong University Mycological Herbarium [HKU(M)].

Calculations and analyses

$$\text{Frequency of occurrence (\%)} = \frac{\text{Number of collections of an individual fungus on samples examined}}{\text{Total number of samples examined}} \times 100$$

$$\text{Similarity (\%)} = \frac{\text{Number species common to both levels}}{\text{Total number of species in the two levels}} \times 100$$

Multivariate analysis (Kenkel and Booth, 1992) was performed to summarise and reveal underlying trends of fungal community structure to the collection site, host and the vertical portion of host. To perform ordination of variables simultaneously, correspondence analysis was performed (Kenkel and Booth, 1992). A data matrix consisting of the numbers of colonised samples from each sample units (i.e. apical, middle or basal portions of either hosts from either sites) and the number of fungi recorded was subjected to correspondence analysis (Anon, 1995).

Results

The frequency of occurrence, distribution and percentage similarity of fungi occurring on the basal, middle and apical culm levels of *Bambusa* and *Dendrocalumus* spp. in Hong Kong and the Philippines are presented in Tables 1-5.

Table 1. Frequency of occurrence of fungi at different levels of decaying culms of *Bambusa* sp. collected in the Philippines (organised in order of overall occurrence).

Taxa	Frequency of occurrence (%)			
	Apical	Middle	Basal	Overall
Ellisembia vaginata	8.3	25.8	34.2	22.8
Acremonium kiliense	7.5	18.3	32.5	19.5
Curvularia lunata	7.5	15.8	19.2	18.6
Phaeoisaria sp.	8.3	20	26.7	18.33
Corynespora foveolata	8.3	24.2	18.3	17.1
Acrodictys bambusicola	10	20	18.3	16.2
Cladosporium cladosporioides	24.2	22.5	2.5	15.8
Chaetomium globosum		4.2	29.2	11.7
Mucor sp.	-	8.3	26.7	11.7
Guignardia manokwaria	-	3.3	7.5	10.83
Corynespora cassiicola	13.3	11.7	5	10
Dactylaria triseptata	-	14.2	15.8	10
Papulaspora sp.	-	-	29.2	9.7
Endothia singularis	7.5	10	10.8	9.45
Acrodictys erecta		3.3	20.8	8.1
Gliomastix fusigera	4.2	8.3	7.5	6.7
Arecophila philippinensis	6.7	5.8	6.7	6.4
Anthostomella longipileata	-	4.2	10.8	5
Acrodictys globulosa	-	5	9.2	4.7
Stagnospora carcinella	-	1.7	12.5	4.7
Septoria sp.	-	5.8	7.5	4.5
Ellisembia paravaginata	3.3	5	4.2	4.2
Rhizosphaera pini	1.7	5	5.8	4.2
Brachysporiella gayana	-	1.7	10	3.9
Stachybotrys chartarum	-	-	10.8	3.6
Acrodictys fimicola	-	-	9.2	3.1
Anthostomella philippinensis	-	4.2	5	3.1
Annulatascus sp.	2.5	5.8	-	2.8
Massarina desmonci	-	1.7	6.7	2.8
Libertella heveae	0.83	2.5	4.2	2.5
Monodictys levis	-	-	7.5	2.5
Trichocladium asperum	3.3	0.83	3.3	2.5
Arecophila bambusae	-	0.83	5.8	2.2
Massarina arundinariae	-	4.2	5	2.2
Stilbella bambusae	-	5	1.7	2.2
Curvularia pallescens	0.83	0.83	4.2	1.95
Pleurophramium bitunicatum	-	-	5	1.7
Rhizosphaera kalkoffii	-	1.7	2.5	1.4

Table 1. (continued).

Taxa	Frequency of occurrence (%)			
	Apical	Middle	Basal	Overall
Sporidesmium bambusicola	-	4.2	-	1.4
Pithomyces maydicus	0.83	1.7	-	1.25
Exserticlava triseptata	2.5	0.83	-	1.1
Guignardia philippinense	-	-	3.3	1.1
Dictyosporium elegans	-	-	2.5	0.83
Guignardia sp.	-	-	2.5	0.83
Epithyrium resinae	-	-	1.7	0.55
Helicosporium panacheum	-	-	1.7	0.55
Cercosporidium guanicense	-	-	0.83	0.28
Diploccocium dendrocalami	-	-	0.83	0.28
Microthyrium sp.	-	-	0.83	0.28
Piricaudiopsis appendiculata	-	0.83	-	0.28

Table 2. Frequency of occurrence of fungi on the different levels of senescent culms of *Dendrocalamus* sp. collected in Philippines (organised in order of overall occurrence).

Taxa	Frequency of occurrence (%)			
	Apical	Middle	Basal	Overall
Sporidesmium baccharidis	4.2	15	15.8	11.67
Acrodictys bambusicola	8.3	10	15.8	11.4
Corynespora foveolata	10.8	15	8.3	11.4
Curvularia lunata	2.5	13.3	9.2	8.3
Gliomastix fusigera	-	5.8	13.3	6.4
Acremonium kiliense	-	1.7	13.3	5
Chlamydomyces palmarum	5	-	-	3.3
Cladosporium cladosporioides	5.8	1.7	-	2.5
Sporidesmium bambusicola	1.7	2.5	3.3	2.5
Stilbella bambusae	2.5	-	4.2	2.2
Brachysporiella gayana	-	-	5.8	1.95
Ellisembia vaginata	-	-	5	1.7
Rhizosphaera kalkoffii	1.7	2.5	-	1.4
Rhizosphaera pini	0.83	3.3	-	1.4
Endophragmiella oblonga	-	-	3.3	1.1
Gliomastix murorum	0.83	-	2.5	1.1
Monodictys putredinis	-	-	2.5	0.83
Diploccocium dendrocalami	-	-	1.7	0.55
Sporothrix sp.	-	-	1.7	0.55
Dictyosporium elegans	-	0.83	-	0.28

Table 3. Frequency of occurrence of fungi on the different levels of senescent culms of *Bambusa* sp. collected in Hong Kong (organised in order of overall occurrence).

Taxa	Frequency of occurrence (%)			
	Apical	Middle	Basal	Overall
Cladosporium cladosporioides	34.2	14.2	0.83	48.7
Acrodictys bambusicola	36.7	15	5	18.9
Phaeoisaria sp.	-	13.3	34.2	15.8
Podosporium elongatum	5	15.8	14.2	11.7
Acrodictys globulosa	7.5	12.5	12.5	10.8
Curvularia lunata	7.5	9.2	13.3	10
Podosporium nilgerense	-	15	13.3	9.4
Gliomastix fusigera	4.2	11.7	8.3	8.1
Endothia singularis	1.7	6.7	7.5	5.3
Trichocladium asperum	-	5.8	6.7	4.2
Acrodictys fimicola	-	3.3	8.3	3.9
Corynespora cassiicola	0.83	1.7	9.2	3.9
Anthostomella brevifissura	-	4.2	6.7	3.6
Ellisembia vaginata	-	5	5	3.3
Mucor sp.	-	-	9.2	3.1
Anthostomella philippinensis	-	-	4.2	2.8
Hypoxylon fuscopurpureum	-	1.7	6.7	2.8
Annulatascus hongkongensis	-	3.3	5	2.7
Pseudothyrium sp.	-	7.5	-	2.5
Sporidesmium baccharidis	-	-	7.5	2.5
Astrosphaeriella stellata	-	4.2	2.5	2.2
Brachysporiella gayana	-	1.7	4.2	2.0
Roussoella minutella	1.7	2.5	1.7	2
Diplozythiella bambusina	-	2.5	3.3	1.9
Monodictys levis	-	2.5	3.3	1.9
Anthostomella contaminans	-	-	5	1.7
Exserticlava basiformis	-	-	2.5	1.7
Massarina desmonci	-	3.3	1.7	1.7
Berkleasmium concinnum	-	2.5	1.7	1.4
Endophragmiella oblonga	-	0.83	3.3	1.4
Monodictys putredinis	-	-	3.3	1.1
Pleurophramium bitunicatum	-	-	3.3	1.1
Sporoschisma mirabile	-	2.5	0.83	1.1
Rosellinia chusqueae	-	1.7	0.83	0.84
Lasmenia balansae	-	2.5	-	0.83
Alveophoma caballeroi	-	-	1.7	0.6
Dictyosporium elegans	-	-	1.7	0.6
Apiospora sp.	-	-	0.83	0.28
Bactrodesmium spilomeum	-	-	0.83	0.28
Canalisporium caribense	-	-	0.83	0.28
Gilmaniella bambusae	-	-	0.83	0.28
Tetraploa javanica	-	-	0.83	0.28

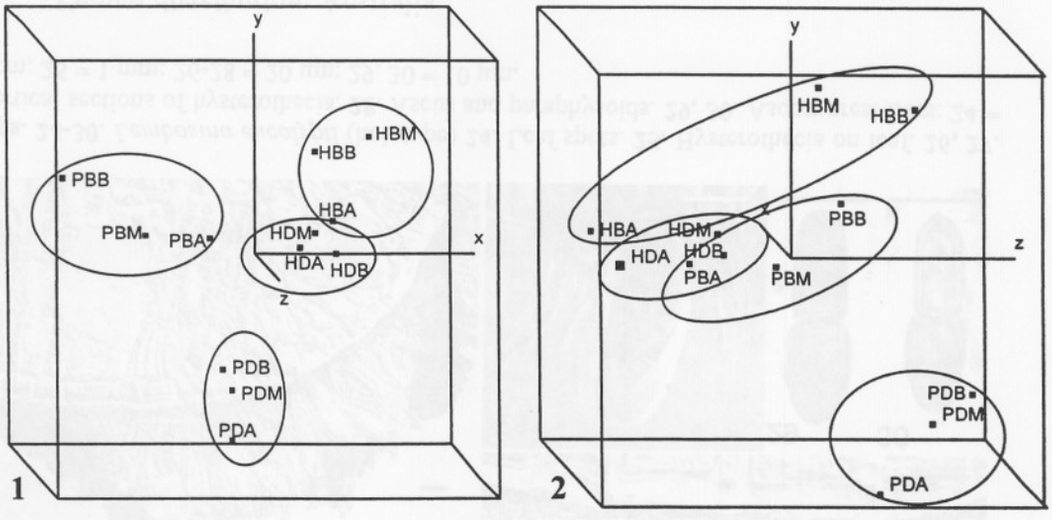
Table 4. Frequency of occurrence of fungi on the different levels of senescent culms of *Dendrocalamus* sp. collected in Hong Kong (organised in order of overall occurrence).

Taxa	Frequency of occurrence (%)			
	Apical	Middle	Basal	Overall
Acrodictys bambusicola	4.2	10.8	14.2	9.7
Cladosporium cladosporioides	15	10.8	3.3	9.7
Curvularia lunata	5	10	4.2	6.4
Podosporium elongatum	1.7	5.8	10.8	6.1
Gliomastix fusigera	4.2	3.3	5	4.2
Corynespora foveolata	-	5	6.7	3.9
Corynespora cassiicola	4.2	2.5	4.2	3.6
Ellisembia vaginata	-	4.2	4.2	2.8
Endothia singularis	1.7	5.8	0.83	2.8
Arthrinium phaeospermum	-	-	7.5	2.5
Astrosphaeriella stellata	-	2.5	4.2	2.2
Bertia sp.	-	6.7	-	2.2
Podosporium nilgerense	-	5.8	-	1.9
Exserticlava vasiformis	-	-	5	1.7
Brachysporiella gayana	-	1.7	2.5	1.4
Berkleasmium concinnum	-	-	2.5	0.74
Dactylaria triseptata	-	-	2.5	0.74
Exserticlava triseptata	-	-	2.5	0.74
Microthyrium sp.	-	1.7	-	0.56

Table 5. Similarity of fungal taxa composition between apical, middle and basal parts of bamboo.

	Sorenson Index (%)		
	Apical-Middle	Middle-Basal	Apical-Basal
Philippines			
Bambusa	34	39	25
Dendrocalamus	36	27	27
Hong Kong			
Bambusa	24	38	18
Dendrocalamus	33	37	30

Three-dimensional correspondence analysis was performed to visualise the effect of collection site, host and vertical portion of host on the colonisation by fungi. The first three principle axes accounted for 56.7% (x-axis: 23.3%, y-axis: 19%, z-axis: 14.4%) of the variability in the data matrix. The analysis shows that four clusters of fungal communities exist (Figs. 1, 2). The fungal communities were mainly influenced by collection site and host. The effect of collection site and host is similar as indicated by the similar distances between the clusters representing *Bambusa* sp. and *Dendrocalamus* sp. from the two



Figs. 1, 2. Three dimensional correspondence ordination of fungal communities recorded on apical, middle and basal portions of *Bambusa* spp. and *Dendrocalamus* spp. in Hong Kong and the Philippines. **1.** Diagram orientated at x- and y-axes. **2.** Diagram orientated at y- and z-axes.

sites. The results indicate that there was a significant vertical distribution of fungi along levels of culms. Fungal communities on the apical portion lie towards the negative values along z-axis, and those on the basal portion lie towards the positive values (Fig. 2).

In the Philippines, the percentage similarity of fungi along *Bambusa* culm levels was relatively low between apical and basal portions (25%), and high between the apical and middle portions (34%) and middle and basal portions (39%) (Tables 1, 5). *Dendrocalamus* had relatively low similarities in fungi occurring on the apical and basal (27%) and middle and basal portions (27%), and high similarities between apical and middle portions (36%) (Tables 2, 5).

In Hong Kong the percentage similarity of fungi along *Bambusa* culm levels was relatively low between the apical and basal portions (18%) and relatively high between the apical and middle (24%), and middle and basal portions (38%) (Tables 3, 5). In the case of *Dendrocalamus* samples, the similarities in fungi between apical and basal portions were relatively low (30%), with higher similarities between the apical and middle portions (33%) and middle and basal portions (37%) (Tables 4, 5).

The Sorensen Indexes show that fungal taxa occurring on the middle and basal portions were most similar, followed by the apical and middle portions, with least similarity between the apical and basal portions. An exception was found on fungal taxa that occurred on *Dendrocalamus* in the Philippines being most similar between apical and middle portions (Table 5). Correspondence

analysis, however, indicates that the fungal communities on the middle and basal portions were the most similar in all host and sites, as expressed by the shortest distances between the points (Figs. 1, 2).

Some taxa were common to all levels of *Bambusa* and *Dendrocalamus*, while other were confined to certain portions. In the Philippines, 16 species were common to all levels of *Bambusa* (Table 1), while 13 taxa were confined to the basal culm portions. Five taxa were observed on all culm levels of *Dendrocalamus*, while six taxa were confined to the basal portions (Table 3). In Hong Kong *Acrodictys globulosa*, *A. bambusicola*, *Cladosporium cladosporioides*, *Curvularia lunata*, *Podosporium elongatum*, *Gliomastix fusigera*, *Endothia singularis*, and *Roussoella minutella* were common to all culm levels of *Bambusa*. Seven taxa were recorded on all culm portions of *Dendrocalamus*. Species that were present at all levels on both hosts and at both sites were *Acrodictys bambusicola* and *Curvularia lunata*.

Discussion

Vertical distribution

The basal portions of the senescent culms of both hosts, at both sites (countries) yielded the highest number of collections. The middle portion yielded the next highest number of collections, followed by the apical portion. The predominant fungi at the basal portion were anamorphic taxa, followed by ascomycetes. Similar patterns were observed in the middle and apical portions. Bamboos are mostly characterized by culms, which are clumped together at the base. This may contribute to presence of humid conditions around the base of the culm for long periods. Fungi, which require damp conditions may therefore, develop readily in this region. Moisture retention and humidity in the substratum will help fungi to grow (Dix and Webster, 1995). High availability of moisture increases diffusion of solutes to the fungi and therefore increases enzyme activities (Carroll and Wicklow, 1992; Dix and Webster, 1995). In the upper region, culms are spread out and are more exposed to wind and solar radiation and, therefore, water retention is likely to be lower.

The fungal communities at the lower and upper internodes of *Dactylis glomerata* differed at different levels (Dix and Webster, 1995). A higher moisture content was recorded at the base of dead stems, which contributed towards the presence of more basal inhabitants. Higher numbers of fungi were also recorded in the basal regions (230), as compared to the apical regions (201) of standing *Acanthus* plants in the intertidal region (Sadaba *et al.*, 1995). Sadaba *et al.* (1995) suggested several factors that could affect the distribution

of fungi along a standing plant in the intertidal region. They were the nature of the substratum, the salinity gradient and the magnitude of tidal inundation.

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