Fungal succession on bamboo in Hong Kong

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Zhou, D.Q. and Hyde, K.D. (2002). Fungal succession on bamboo in Hong Kong. In: *Fungal Succession* (eds. K.D. Hyde and E.B.G. Jones). Fungal Diversity 10: 213-227.

Fungal succession on *Bambusa tuldoides* has been studied in Hong Kong. Fungal communities changed over time during the decay process. Based on sporulation of fungi, the fungal communities on bamboo baits can be categorized into early colonisers, middle-stage colonisers, later colonisers, regular inhabitants and sporadic inhabitants. Fungal communities on naturally dead bamboo and baits comprised rare species and mainly middle-stage colonisers. Seasonality had an effect, as more fungi were present during the wet season. Rainfall positively impacted on fungal occurrence, but temperature and relative humidity appeared to have little influence. *Anthostomella* species are regular inhabitants of bamboo, being dominant throughout the observation period and probably play a dominant role in its decomposition.

Key words: bamboo baits, colonisers, fungal community, seasonality.

Introduction

Studies of fungal succession on plant substrates are well documented (Wildman and Parkinson, 1979; Kuter, 1986; Frankland, 1992, 1998; Tokumasu *et al.*, 1994), but fungal succession on bamboo is poorly documented. Leung (1998) placed several bamboo baits in terrestrial habitats in Hong Kong and observed a succession of fungi occurring on these baits. Sixty fungal taxa (including 33 unidentified fungi), comprising 16 ascomycetes and 44 anamorphic fungi were identified during a one year exposure period. The observation time, however, was relatively short and fungal succession was probably still at an initial stage after one year. In temperate regions fungal succession on bracken litter would probably not cease until after 5-6 years, when bacteria are dominant and 95% dry mass reduction is estimated to take 11-23 years (Frankland, 1976, 1998). In tropical regions, the time for complete decay of a plant may be relatively shorter than in temperate regions, as there is a greater fungal diversity and these fungi have more intensive activity (Stevens,

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1989). The size of bamboo baits in Leung (1998), were also small (10 × 2 cm), so that the majority of fungi in the succession process may not have been sampled. A survey over a longer period using larger bamboo baits is therefore desirable.

In this paper, succession and diversity of fungi on naturally dead bamboo samples and baits of *Bambusa tuldoides* at Tai Po Kau Nature Reserve, Hong Kong was investigated. It is understood that succession as observed here, is the sequential sporulation of fungi on a subsrate. The relationships between fungal succession and climatic factors were also analyzed.

Materials and methods

The study site covering about 0.3 hectares was selected in a bamboo forest at Tai Po Kau Nature Reserve, New Territories, Hong Kong, which comprised two bamboo species, i.e., *Bambusa tuldoides* and *B. shiuyingiana*. The bamboo forest lies on the bank of Tai Po Kau forest stream near the lookout post, at the field office of Tai Po Kau Nature Reserve, Department of Agriculture and Fishery, Hong Kong SAR. *Bambusa tuldoides* was selected for the fungal succession study, because this species occupies a major proportion of the forest, about 70% of the total coverage. On 23 August 1998, 114 healthy bamboo culms were randomly cut, labeled and left to rot naturally on the forest floor to be exposed as baits for fungal succession. Every two months, four whole bamboo culms were randomly retrieved and cut into samples *ca.* 25 cm long. Fifty of these samples were randomly selected for study at each period. At the same time, one standing healthy bamboo culm in the site was also collected as a control. This was also cut into samples 25 cm long and 10 samples were randomly selected. Fifty naturally dead bamboo culm samples (*ca.* 25 cm long) were also arbitrarily collected from the same site at the same time, in order to compare the fungal diversity with that of the succession samples. A total of 1320 naturally dead bamboo, healthy bamboo samples and bamboo baits were collected during the two-year observation period. The samples were returned to the laboratory, where they were incubated in zip-lock polythene bags lined with moistened tissue. The samples were checked after three days, one week, one month and two months for fungal fruiting bodies. Squash mounts and sections of fungal fruiting bodies were mounted in water for observation and measurement.

All bamboo samples were collected based on random sampling techniques using a random table.

Data analysis, i.e., diversity index (Shannon-Wiener index) (Shannon and Weaver, 1949), evenness index (Ludwig and Reynolds, 1988), species-area

curves, species richness and similarity indices (Bray-Curtis coefficient and Sørensen's index) (Bray and Curtis, 1957) were calculated using the equations.

Equitability: it is most commonly expressed as Pielou's evenness index (J') (Ludwig and Reynolds, 1988):

$$J' = H/H_{max}$$

Where H = Shannon-Wiener Index;

$H_{max} = Log_2 S'$

J' = 1 when the community structure is perfectly even (i.e. all taxa are found in an equal number of samples) and J' = 0 (or close to 0) when the community structure is at the extreme of uneven (i.e. only one taxon presents).

S' = species richness

Percentage frequency of occurrence

$$= \frac{\text{Number of samples on which a given taxon occurred}}{\text{number of samples examined}} \times 100\%$$

Shannon-Wiener index (diversity index): This index was used to calculate diversity (Shannon and Weaver, 1949):

$$H = - \sum P_i \log P_i$$

Where H = the probability of finding each taxon in a collection, and P_i = the number of individuals in *i*th species. This index can also be calculated with the program developed with *W.Q. Wang*.

Species similarity matrix: a matching triangular array of similarities between every pair of species, in terms of patterns of occurrence across the samples. The two most useful in ecology is Bray-Curtis coefficient (Bray and Curtis, 1957) and Sørensen's index.

Bray-Curtis coefficient: the similarity between *j*th and *k*th samples was calculated as follows:

$$S_{jk} = 100\left(1 - \frac{\sum_{i=1}^{P} \left| y_{ij} - y_{ik} \right|}{\sum_{i=1}^{P} \left(y_{ij} + y_{ik} \right)}\right) \qquad = 100 \bullet \frac{\sum_{i=1}^{P} 2\min\left(y_{ij}, y_{ik} \right)}{\sum_{i=1}^{P} \left(y_{ij} + y_{ik} \right)}$$

Where y_{ij} = score (count or biomass) for *i*th species in *j*th samples (i = 1,2,..,p; j = 1,2,3, n).

Species-area curve: This was also plotted to estimate the minimum number of bamboos that it was necessary to establish the community in any habitat.

Species richness (S'): the number of species present in any given area.

Results and discussion

Fungal diversity

Fifty-seven fungal taxa were found on the bamboo baits and this was higher than that on naturally dead bamboo samples (38 species). The average number of fungi occurring on each bamboo bait was 2.1, but on each naturally dead bamboo sample it was 0.8 (Table 3). The diversity index (Shannon-Wiener index) for fungal communities on bamboo baits was 2.4, while for naturally dead bamboo this was 2. The similarity indices between the fungal communities occurring on naturally dead bamboo samples or bamboo baits during different periods were generally low (Tables 5, 6). Possible reasons for the lower numbers of fungi on naturally collected bamboo samples are discussed later. In general, the fungal diversity on bamboo appears to be lower than that on the other woody substrata in terrestrial or aquatic conditions (Gamundi *et al.*, 1987; Aoki *et al.*, 1990; Leung, 1998; Ho *et al.*, 2002). The reasons for this are unclear.

Anamorphic fungi (34 spp.) were the dominant group of fungi on the bamboo baits during the observation period, followed by ascomycetes (22 spp.) and 1 basidiomycete (Tables 2, 3). The fungal communities on naturally dead bamboo samples were almost equally composed of ascomycetes (20 spp.) and anamorphic fungi (18 spp.) (Tables 1, 3). *Marasmius rotula* (basidiomycete) appeared on the bamboo baits (as a sporadic inhabitant) after 18 months.

Previous authors have also reported that anamorphic fungi were dominant during succession studies. Leung (1998) found that anamorphic fungi (44 spp.) were dominant over ascomycetes (16 spp.) on the baits of *Bambusa* sp. in Hong Kong and he also identified an unidentified basidiomycete occurring on the bamboo baits during the later stage of the succession. Tsuneda (1983) suggested that the reason why basidiomycetes occurred late in fungal succession was because of their relatively low saprobic competitive abilities for the water- or solvent-soluble constituents of plant materials. Several authors have also reported that anamorphic fungi were dominant over other taxonomic groups in the succession process of other substrates. Tokumasu *et al.* (1994)

Table 1. Frequency of occurrence of fungi on naturally dead bamboo.

Species	Seasons and collection dates										
	Dry			Wet			Dry			Wet	
	10/98	12/98	03/99	05/99	07/99	09/99	11/99	02/00	04/00	06/00	09/00
Acrodictys bambusicola	4	2	2	8	26	0	0	2	0	2	4
A. erecta	0	0	0	14	10	0	2	0	0	0	4
Anthostomella bruneiensis	0	0	0	0	3.3	0	0	0	0	0	0
A. contaminans	0	0	2	6	6	21	26	0	8	14	8
A. flagellariae	2	0	0	2	14	0	0	10	4	6	4
A. irregularispora	0	0	0	0	0	4	4	0	0	0	2
Apiospora montagnei	0	0	0	6	0	0	2	0	0	0	0
A. sinensis	2	0	0	12	4	6	0	2	0	8	14
Arecophila bambusae	0	0	0	0	2	0	0	0	0	2	0
Arthrinium phaeospermum	0	0	4	28	0	8	2	0	0	14	8
Arthrinium sp.	0	0	0	0	0	0	4	0	0	0	6
Astrocystis cocoës	0	0	0	0	0	2	2	0	0	4	0
Astrosphaeriella bakeriana	0	0	0	0	4	0	0	0	0	0	4
A. fissuristoma	0	0	0	0	12	0	0	2	8	10	4
A. stellata	0	0	2	0	0	0	6	0	14	22	8
A. uberina	0	0	0	0	0	3.3	0	0	0	0	0
Coelomycetes sp.	0	0	0	10	0	0	0	0	0	0	0
Cordella johnstonii	2	0	0	2	0	0	0	0	0	0	0
Didymosphaeria futilis	0	0	0	0	0	0	2	0	0	0	0
Ellisembia bambusae	0	0	0	0	2	0	0	0	0	4	0
E. bambusicola	0	0	0	4	0	2	2	0	0	0	0
E. coronatum	0	0	0	0	0	0	0	2	0	0	0
Endophragmiella oblonga	0	0	0	0	0	0	2	0	0	0	0
Eutypella gliricidiae	0	0	0	0	2	0	0	0	0	0	0
Fusarium sp.	0	0	0	4	0	0	0	0	0	0	0
Gilmaniella bambusae	0	0	6	22	0	26	0	2	0	12	4
Hypoxylon karii	0	0	0	0	2	0	0	0	0	0	0
Massarina sp.	0	0	0	0	0	0	0	0	2	0	2
Oxydothis oraniopsis	0	0	0	4	0	0	0	0	0	0	0
Phaeoisaria clematidis	2	0	0	24	0	10	0	0	0	12	2
Pleurophragmium simplex	0	0	4	0	0	0	0	4	0	6	0
Podosporium elongatum	0	0	0	26	0	16	0	0	0	16	10
P. nilgirense	4	8	0	6	0	20	18	6	6	20	18
Ramichloridium musae	0	0	0	0	14	0	0	0	0	4	6
Roussoëlla hysterioides	0	0	0	0	6	0	2	0	0	0	0
R. pustulans	0	0	0	0	0	4	0	2	0	0	0
Spadicoides bambusicola	0	0	0	0	0	2	0	0	0	0	0
Veronaea indica	0	0	0	0	10	0	2	2	0	2	0
Total frequency of occurrence	16	10	20	178	117	124	76	34	42	158	56
Evenness	0.7	0.5	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.8	0.6
Shannon-Wiener index	1.7	0.5	1.7	2.4	2.4	2.2	2.1	2.1	1.6	2.6	2.5

Table 2. Frequency of occurrence fungi on bamboo baits.

Species	Seasons and collection dates										
	Dry		Wet				Dry			Wet	
	10/98	12/98	03/99	05/99	07/99	09/99	11/99	02/00	04/00	06/00	09/00
Acrodictys bambusicola	0	0	8	68	76	4	0	2	0	0	0
A. erecta	0	0	2	16	38	4	0	0	0	0	0
Anthostomella contaminans	0	0	0	2	20	40	46	20	32	36	27
A. flagellariae	0	0	0	4	12	24	44	8	20	27	12
A. sulcigena	0	0	0	2	8	10	2	0	0	0	0
Apiospora montagnei	0	0	0	2	10	4	0	0	0	7	0
A. sinensis	0	1	2	13	8	0	0	0	0	5	3
Arecophila bambusae	0	0	0	0	0	2	0	0	0	0	1
Arthrinium luzulae	0	0	2	13	20	6	0	0	0	0	0
A. phaeospermum	0	0	4	20	14	4	0	0	0	2	1
Arthrinium sp.	0	0	0	0	0	8	8	0	0	0	0
Astrosphaeriella australiensis	0	0	0	6	16	10	0	0	0	0	0
A. fissuristoma	0	0	0	6	20	34	6	6	0	5	6
A. minima	0	0	0	0	0	16	0	0	0	0	0
A. stellata	0	0	0	0	0	8	32	6	28	39	23
Coelomycetes sp.	0	2	0	12	2	0	0	0	0	0	0
Cordella johnstonii	0	0	4	8	20	4	4	0	0	0	0
Dictyosporium zeylanicum	0	0	0	0	0	0	0	0	2	0	0
Didymosphaeria futilis	0	0	0	0	0	0	8	0	0	14	11
Discomycetes sp.	0	0	0	0	2	0	0	0	0	0	0
Doratomyces purpureofuscus	0	0	0	2	0	0	0	0	0	0	0
Ellisembia bambusae	0	0	4	0	0	0	8	0	2	2	1
E. bambusicola	0	0	2	0	0	0	2	2	10	0	1
E. coronatum	0	0	0	0	0	0	0	10	0	0	0
E. macrotrichum	0	0	0	0	0	4	0	2	0	0	0
E. pseudoseptata	0	0	0	0	0	0	0	0	4	0	0
Eutypella gliricidiae	0	0	0	0	4	2	0	2	0	0	0
Fusarium sp.	0	0	2	20	4	8	0	0	0	0	0
Gilmaniella bambusae	0	0	0	54	64	16	4	0	0	1	2
Gliocladium sp.	0	0	4	0	0	0	0	0	0	0	0
Graphium putredinis	0	0	0	2	0	0	0	0	0	0	0
Hyphomycetes sp.	0	0	8	0	0	0	0	0	0	1	0
Marasmius rotula	0	0	0	0	0	0	0	0	0	2	0
Massarina eburnea	0	0	0	0	2	0	0	0	0	0	0
M. immersa	0	0	0	0	6	0	0	0	0	0	0
Monochaetia karstenii	0	0	0	6	6	4	0	0	0	0	0
Niesslia sp.	0	0	0	0	2	0	0	0	0	0	0
Oxydothis grisea	0	0	0	0	8	0	0	0	0	0	0
O. oraniopsis	0	0	0	8	6	6	0	0	0	0	0
Petroconium sp.	0	0	2	10	6	4	0	0	0	0	0
Phaeoisaria clematidis	0	0	4	24	16	10	0	0	18	2	0
Phomopsis sp.	0	0	0	0	0	16	0	0	0	0	0
Pleurophragmium simplex	0	0	0	0	16	0	0	16	4	0	0

Table 2 continued.

Species	Seasons and collection dates										
	Dry			Wet			Dry			Wet	
	10/98	12/98	03/99	05/99	07/99	09/99	11/99	02/00	04/00	06/00	09/00
Podosporium elongatum	0	2	8	50	36	16	26	16	18	0	0
P. nilgirense	0	4	0	24	32	20	50	28	18	2	1
Ramichloridium musae	0	0	14	24	32	10	6	0	0	0	1
Roussoëlla hysterioides	0	0	0	10	36	14	4	6	0	0	2
R. pustulans	0	0	6	4	4	2	0	0	0	0	0
Spirodecospora bambusicola	0	0	0	4	8	4	0	0	0	0	0
Sporidesmium eupatoriicola	0	0	2	0	0	0	0	0	0	0	0
S. flagellatum	0	0	0	0	0	0	0	0	4	0	0
S. macrotrichum	0	0	0	0	6	0	0	0	0	0	0
S. rubi	0	0	0	0	0	0	0	2	14	0	0
S. uapacae	0	0	0	0	0	0	0	0	8	0	0
Thyridium chrysomallum	0	0	0	0	0	4	2	0	2	0	0
Veronaea botryosa	0	0	0	0	0	0	0	4	0	0	0
V. indica	0	0	4	32	24	8	0	2	0	0	1
Total frequency of occurrence	0	10	82	444	584	326	252	132	184	145	93
Evenness	0	0.64	0.66	0.57	0.59	0.62	0.56	0.65	0.61	0.48	0.52
Shannon-Wiener index	/	1.27	2.62	2.71	2.98	3.06	2.27	2.52	2.37	1.93	1.98

Table 3. Fungal species diversity on naturally dead bamboo and bamboo baits.

	Naturally dead bamboo samples	Bamboo baits
Ascomycetes	20	21
Basidiomycetes	0	1
Anamorphic fungi	18	35
Species richness	38	57
Species per sample	0.75	2.1
Shannon index	2.0	2.4
Sørensen's index	0.8 *	

*: This figure shows similarity between fungal communities on dead bamboo samples and bamboo baits.

Table 4. Ecological classification of fungi on bamboo baits.

Successional group	Taxonomic group			Total
	Ascomycetes	Basidiomycetes	Anamorphic fungi	
Early colonisers	2	0	6	8
Middle-stage colonisers	8	0	6	14
Late colonisers	1	0	2	3
Regular inhabitants	3	0	3	6
Sporadic inhabitants	7	1	18	26
Total	21	1	35	57

observed fungal succession on pine needles in Germany and identified 1 ascomycete, 1 basidiomycete, 62 anamorphic fungi and 9 zygomycetes. Similar results have also been reported on *Nothofagus dombeyi* leaf litter (Gamundi *et al.*, 1987), on momi fir needles (Aoki *et al.*, 1990) and submerged wood (Ho *et al.*, 2002).

Successional replacement

Fungi replace one another at different stages of succession and this has been observed by several authors (Frankland, 1976, 1998; Leong *et al.*, 1991; Leung, 1998; Tokumasu, 1998; Ho *et al.*, 2002). Frankland (1976) found that weak parasites first dominated dead bracken, followed by primary saprobes, then secondary saprobes and finally common soil fungi. Ho *et al.* (2002) categorized the fungi that occurred on submerged wood baits into 3 groups, i.e., pioneer, early and later successional groups. Leung (1998) divided fungi identified on bamboo baits into two groups, i.e., early colonisers and regular inhabitants. The temporal replacement of fungi in the present study can be categorized into (1) early colonisers, i.e., those fungi occurring during the first 4 months and disappearing thereafter; (2) middle-stage colonisers, i.e., those dominant during 6-10 months and disappearing thereafter; (3) later colonisers, which became dominant after 10 months and persisted until the end of the experiment; (4) regular inhabitants, which occurred throughout or mostly throughout the experimental period, and (5) sporadic inhabitants, which occurred on bamboo baits sporadically (Table 4). In all of these studies, succession has been correlated with identification of sporulating fungi and this may not reflect what takes place within the bamboo. It would be extremely difficult, however, to prove that succession is taking place rather than observation of a sequential appearance of fruiting bodies. One procedure would be to cut up the bamboo samples, surface sterilize them, place them on agar and isolate fungi growing from the samples. Such a method however, would have many problems, as the samples would need to be cut into very small units and most of the isolates would probably be sterile mycelia.

In general, most fungi on bamboo baits were rare species, which were encountered once or twice. The dominant species mostly occurred on bamboo baits from *ca.* 6 months onwards, while quite a few species were present throughout the observation period (Table 2). The dominant early colonisers were *Apiospora sinensis*, *Arthrinium luzulae*, *A. phaeospermum*, coelomycete sp., *Fusarium* sp., *Petroconium* sp., *Roussoëlla pustulans* and *Veronaea indica*; while *Acrodictys bambusicola*, *A. erecta*, *Anthostomella sulcigena*, *Apiospora montagnei*, *Astrosphaeriella australiensis*, *Cordella johnstonii*, *Eutypella gliricidiae*, *Gilmaniella bambusae*, *Monochaetia karstenii*, *Oxydothis*

Table 5. Similarity analysis (Bray-Curtis coefficient) of fungal communities on naturally dead bamboo samples.

Date	10/98	12/98	03/99	05/99	07/99	09/99	11/99	02/00	04/00	06/00	09/00
10/98	100	46	11	16	16	12	10	40	17	14	20
12/98		100	13	9	14	12	16	36	24	12	15
03/99			100	14	5	17	14	30	11	23	19
05/99				100	23	51	17	13	12	47	38
07/99					100	22	18	28	39	38	43
09/99						100	40	15	29	62	47
11/99							100	16	33	29	32
02/00								100	27	27	23
04/00									100	49	51
06/00										100	57
09/00											100

Table 6. Similarity analysis (Bray-Curtis coefficient) of fungal communities on bamboo baits.

Date	10/98*	12/98	03/99	05/99	07/99	09/99	11/99	02/00	04/00	06/00	09/00
10/98	0	0	0	0	0	0	0	0	0	0	0
12/98		100	7	4	3	4	5	9	6	4	4
03/99			100	23	18	24	14	13	12	8	8
05/99				100	72	42	23	21	19	8	9
07/99					100	47	28	30	23	15	14
09/99						100	50	39	42	36	30
11/99							100	47	56	57	49
02/00								100	48	30	40
04/00									100	52	47
06/00										100	71
09/00											100

* 10/98's value is zero (no fungi occurred when the healthy sampling bamboos were newly cut).

oraniopsis, Ramichloridium musae, Roussoëlla hysterioides, Spirodecospora bambusicola and *Thyridium chrysomallum* were middle-stage colonisers. Later colonisers were *Astrosphaeriella stellata, Ellisembia bambusae* and *E. bambusicola*; while *Anthostomella contaminans, A. flagellariae, Podosporium elongatum, Astrosphaeriella fissuristoma, Phaeoisaria clematidis* and *Podosporium nilgirense* were regular inhabitants (Table 2). There were 26 sporadic inhabitants, which occurred on bamboo baits (Tables 1, 2). These groups of fungi occurring during different periods are summarized in Table 4. *Marasmius rotula* (a basidiomycete) was identified during the later stages of succession (Tables 2, 4).

Frankland (1998) has reviewed previous studies and explained the possible mechanisms for the successional of fungi on substrata. She thought there were several possible causes: availability of space and species of

differential performance; processes and phenomena conditioning, the first e.g. dispersal, competition between species and animal grazing involving whole communities: inherent characters that defined the outcome of the latter and operated between populations and individual mycelia, e.g. differential rates of growth and nutrient uptake. These explanations may partially account for successional occurrence of fungi. The most compelling activities during fungal succession may be with inherent characters operating between populations and mycelia among different fungal species through differential rates of growth and nutrient uptake. Unfortunately this is impossible to observe *in situ*.

Where do the early colonisers come from?

The issue of where the early colonisers on various substrata come from has yet to be clearly established (Frankland, 1992, 1998, Leung, 1998; Norden *et al.*, 1999). The early colonisers may be endophytes, as endophytes exist asymptomatically in all tissues of living plants (Bacon and White, 2000). Umali *et al.* (1999) studied endophytes in *Bambusa tuldoides* at Tai Po Kau, Hong Kong. They identified 23 species and 14 "morphospecies" of mycelia sterilia. Of the eight early colonisers found on bamboo baits in this study (Table 2), *Arthrinium phaeospermum, Fusarium* sp. *Phomopsis* sp. and *Podosporium elongatum* were also found as endophytes (Umali *et al.*, 1999). *Apiospora sinensis*, *Arthrinium phaeospermum,* coelomycete sp., *Fusarium* sp., *Roussoëlla pustulans* and *Veronaea indica*, found on the bamboo baits, were also found on naturally dead bamboo samples. *Fusarium* spp. and *Mucor* spp. were also found on baits in this study, after they were incubated in zip-lock polythene bags. They are also possibly endophytes.

The similarity indices (Sørensen's index) between fungal communities on bamboo baits and naturally dead bamboo samples were high (0.84) (Table 3). The two fungal communities were very similar, with many fungal species common to both substrates (Tables 1, 2). Thus the early colonisers may therefore arrive from other nearby substrata, such as naturally decaying bamboos. Endophytes, however, can not be excluded, as four species identified by Umali *et al.* (1999) were also found as early colonisers on bamboo baits and many of the endophytes isolated in traditional studies cannot be identified and remain as mycelia sterilia (Umali *et al.*, 1999).

Comparison of fungal diversity on bamboo baits and naturally dead bamboo

Species richness and frequency of occurrence of fungi on naturally dead bamboo samples were lower than that on bamboo baits (Tables 1-3). It is likely that the bamboo sampled in this study died several years ago. According to the field workers at Tai Po Kau Nature Reserve, many bamboo plants were blown over in 1996 by a typhoon. Thus the bamboo plants at the site may have been

dead for about four years. The fungi on the bamboo may be at later stages of succession, when fungal species and total numbers begin to decline (Dix and Webster, 1995). The naturally dead bamboo plants *in situ* looked much more decayed and easier to break than the bamboo baits.

Fungal succession on various baits are well documented (Willoughby and Archer, 1973; Sanders and Anderson, 1979; Shaerer and von Bodman, 1983; Shearer and Webster, 1991; Gönczöl and Révay, 1993; Ghawana *et al.* 1997; Leung, 1998; Ho *et al.*, 2002). Shearer and Crane (1986) recorded 134 fungi on submerged, decayed plant substrata and balsa wood baits from two cypress-tupelo swamps and a hardwood swamp and its adjoining lake in southern Illinois, USA. Ho *et al.* (2002) identified 157 taxa from 350 naturally occurring submerged wood samples. At the same time, they identified 59 fungi from 140 *Machilus velutina* baits, and 60 fungi from 140 *Pinus massoniana* baits in a freshwater stream at Tai Po Kau, Hong Kong. The average number of fungi on naturally occurring wood, and baits of *M. velutina* and *P. massoniana* were 3.1, 4.3 and 3.8. The results showed that the average number of fungi on baits were higher than that on naturally occurring wood.

In this study, *Anthostomella* species were regular inhabitants on naturally dead bamboo samples and bamboo baits throughout most of the observation period (Tables 1, 2). Lu and Hyde (2000) considered that *Anthostomella* species were common on bamboo. This genus may play a dominant role in bamboo decomposition.

Dynamics of fungal communities on bamboo baits

A quantitative similarity index (Bray-Curtis coefficient) was used to assess the simultaneous fungal communities on samples and baits at different times during the succession period (Tables 5, 6). As most of similarity values between the fungal communities were very low, this indicates that the fungal communities changed over time following death. There were only a few species in common between different communities at different stages of succession. These findings indicate that fungi replace one another during the succession process (Frankland, 1998). The similarity indices (Shannon-Wiener index) among most fungal communities recovered on the baits during observation periods were low, ranging from 3 to 49. Fungal communities recovered on baits in May and July 1999 and June and September 2000 had higher similarity values ranging from 71 to 72 (Table 6). This indicates that the fungal communities during these latter periods were relatively similar, probably because the fungi were regular inhabitants or middle-stage colonisers, and occurred more frequently during these periods.

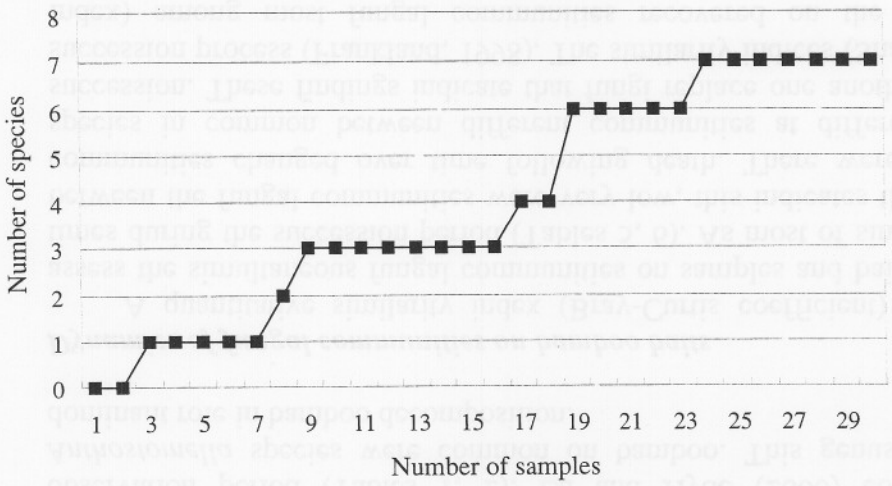

Fig. 1. Species-area curve of the fungi identified on naturally dead bamboo samples in December 1998.

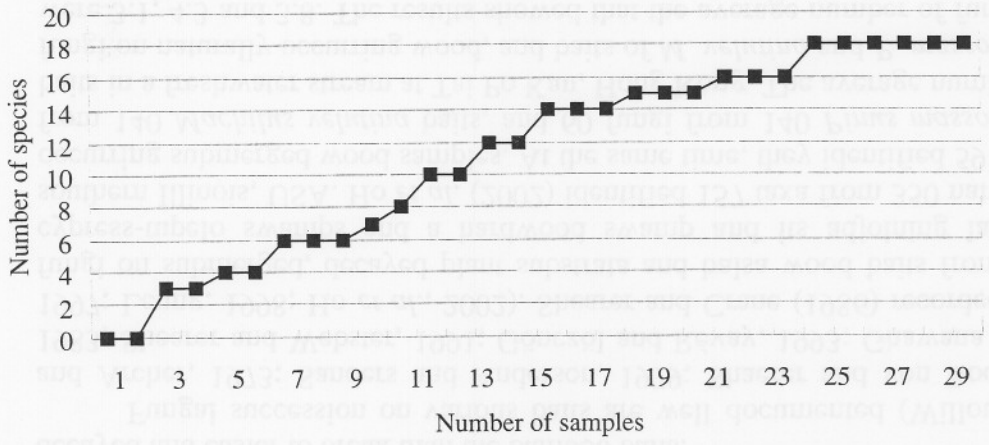

Fig. 2. Species-area curve of the fungi identified on naturally dead bamboo samples in June 2000.

Seasonality

Many authors have reported that seasonality affects fungal succession. Tokumasu (1998) observed that the temperature at the surface of decaying needle litter of *Pinus densiflora* was a major factor contributing to seasonal changes in interior fungal communities. Pandey and Dwivedi (1984) also observed that *Colletotrichum gloeosporioides* and *Fusarium oxysporum* f. *psidii* on the leaves of *Psidium guajava* were recorded more frequently in the rainy season. Aleem (1980) suggested that mangrove fungi display a seasonal

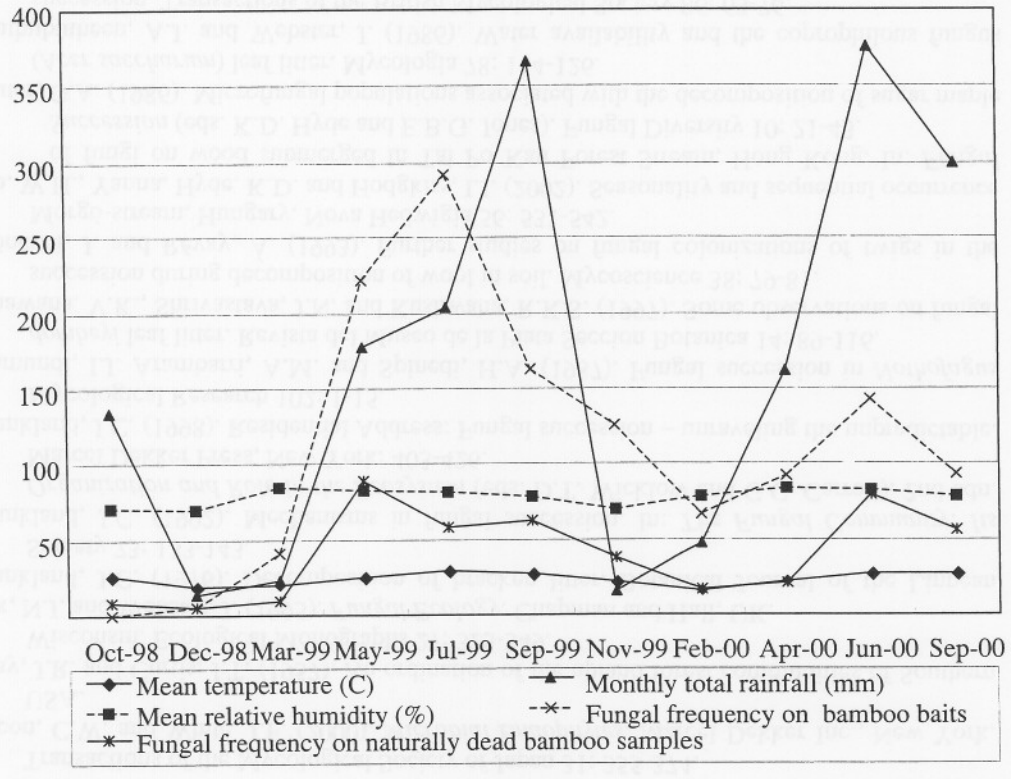

Fig. 3. Climatic factors and frequency of occurrence of fungi on bamboo baits and naturally dead bamboo samples.

periodicity with greater fungal numbers and growth intensity in the wet season. Lamore and Goos (1978) also noted that fungal species richness on naturally occurring wood samples submerged in a temperate stream was highest following a period of heavy rainfall. Kuthubutheen and Webster (1986) pointed out that fruiting bodies of coprophilous fungi were abundant in wet season due to water availability. Leung (1998) also suggested that seasonal factors, especially air temperature and rainfall affected the development of the fungal communities on bamboo baits. A similar phenomenon was also observed in this study. The occurrence of fungi on naturally dead bamboo in the cool dry (December 1998) and hot wet season (June 2000) were quite different. The diversity was much higher in the hot wet season (Figs. 1, 2). The frequency of occurrence of fungi on both naturally dead bamboo samples and bamboo baits peaked in the hot wet seasons, i.e., July 1999 and June 2000 (Fig. 3). Rainfall is therefore, an important factor that has the effect of increasing fungal diversity on bamboo.

Acknowledgements

D. Zhou would like to thank The University of Hong Kong for the award of a Postgraduate Studentship. L.L.P. Vrijmoed is thanked for help with designing the fungal succession experiment and useful discussion. E.B.G. Jones is appreciated for his comments. We are grateful to Helen Leung for technical assistance. The Bray-Curtis Coefficient was calculated using a computer program developed with W.Q. Wang.

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(Received 10 November 2001, accepted 23 May 2002)