DECAY RESISTANCE OF FIVE INDONESIAN BAMBOO SPECIES AGAINST FUNGI

S Suprapti

Forest Products Research and Development Center, Jalan Gunung Batu 5, Bogor 16610, Indonesia. E-mail: sihatisuprapti@yahoo.com

Received June 2009

SUPRAPTI S. 2010. Decay resistance of five Indonesian bamboo species against fungi. The decay resistance of five bamboo species, i.e. ampel bamboo (*Bambusa vulgaris*), betung bamboo (*Dendrocalamus asper*), andong bamboo (*Gigantochloa pseudoarundinacea*), tali bamboo (*G. apus*) and wulung bamboo (*G. atroviolacea*), collected from Bogor and Yogyakarta, was evaluated using the Kolle flask method (dried blocks on malt agar in flasks). The bamboo samples were divided longitudinally into three parts, namely, bottom, middle and top portions. *Bambusa vulgaris, G. apus* and *G. atroviolacea* were found to be moderately resistant to attack by 15 fungi, whereas *G. pseudoarundinacea* and *D. asper* were not resistant. Weight losses between bottom, middle and top portions of bamboo were not significantly different. However, the highest weight loss was encountered on the middle portion of *G. pseudoarundinacea* exposed to *Pycnoporus sanguineus* HHBI-324 (38.3%), while the lowest was found on the bottom portion of *B. vulgaris* exposed to *Lentinus lepideus* (2.3%). The most severe decay was caused by *P. sanguineus* HHBI-324, *Tyromyces palustris* and *Polyporus* sp.

Keywords: *Bambusa vulgaris, Dendrocalamus asper, Gigantochloa* spp., durability, brown rot, soft rot, white rot

SUPRAPTI S. 2010. Kerintangan pereputan lima spesies buluh di Indonesia kepada kulat. Kerintangan pereputan lima spesies buluh dari Bogor dan Yogyakarta iaitu *Bambusa vulgaris, Dendrocalamus asper, Gigantochloa pseudoarundinacea, Gigantochloa apus* dan *Gigantochloa atroviolacea* dinilai menggunakan kaedah balang Kolle (blok buluh kering diletak di atas agar malt di dalam balang). Sampel buluh dipotong secara memanjang kepada tiga bahagian iaitu bawah, tengah dan atas. *Bambusa vulgaris, G. apus* dan *G. atroviolacea* menunjukkan kerintangan sederhana kepada 15 kulat manakala *G. pseudoarundinacea* dan *D. asper* tidak tahan. Kehilangan berat di bahagian bawah, tengah dan atas tidak berbeza dengan signifikan. Namun, kehilangan berat paling tinggi pada bahagian tengah *G. pseudoarundinacea* yang didedah kepada *Pycnoporus sanguineus* HHBI-324 (38.3%) manakala kehilangan berat yang paling sedikit dicerap pada bahagian bawah *B. vulgaris* yang didedah kepada *Lentinus lepideus* (2.3%). Pereputan paling teruk diakibatkan oleh *P. sanguineus* HHBI-324, *Tyromyces palustris* dan *Polyporus* sp.

INTRODUCTION

In Indonesia, bamboo is recognised as one of the non-wood forest products. According to Widjaja (2001), there are about 143 species of bamboo and it is estimated that 60 species grow in Java. Bamboos are perennial woody grasses belonging to the Gramineae family. Bamboo is used extensively for building or house construction, light bridge, scaffolding, ladder, wall, roof framing, mat, basket, fencing, container, tool handle, pipe, tobacco drying shed, bird cage, toy, musical instrument, cooking pot, furniture, handicraft, interior decoration, raw material for pulp and paper, chopstick, toothpick, skewer for barbecueing meat, bamboo-based panel, textile, boat frame, hunting and fishing tools, and bamboo shoot as vegetable (Heyne 1987, Yudodibroto 1987, Subiyanto *et al.* 1995, Misdarti 2006, Krisdianto 2008, Sulastiningsih 2008).

In recent decades, bamboo has attracted more attention as an alternative to timber due to its ease of cultivation. It can grow almost anywhere, in various seasons and has short rotation, i.e. three to five years (Misdarti 2006, Li *et al.* 2007). A total of 80% of bamboo usage in Indonesia was for construction material including housing, 10% for wrapping material, 5% for fencing and rural uses, and 5% for small-scale industry (Martawijaya 1964). In Indonesia, 10 species of bamboo are being utilised in the building industry (Widjaja & Risyad 1987). Several bamboo species which

have been used for housing construction are ampel bamboo (*Bambusa vulgaris*), betung bamboo (*Dendrocalamus asper*), andong bamboo (*Gigantochloa pseudoarundinacea*), apus or tali bamboo (*G. apus*) and wulung or hitam bamboo (*G. atroviolacea*). In spite of its many excellent properties, bamboo is susceptible to attack by insect (powder-post beetles and termites) and decay fungi such as sap-staining fungi and fungi causing brown rot, white rot and soft rot (Liese 1980, Li 2004, Krisdianto 2008). Bamboos, like other lignocellulose materials, are subject to biodegradation by fungi under particular condition and this may affect their quality (Hamid *et al.* 2003). Bamboo is attacked by brown rot, white rot and soft rot fungi, above its fibre saturation point. Like the decay resistance in wood, the natural durability of bamboo is related to the endurance of a bamboo species to attack of destructive organisms such as termites, powder-post beetles, marine borers and decay fungi. Bamboo resistance indicates the durability of a bamboo species against destroying organism. The resistance of bamboo against decay fungi serves as an important parameter in bamboo establishment. Some factors influencing bamboo resistance, for example site, growth rate, age, portion of bamboo, extractives content and the microenvironment are being considered.

Previous researches on bamboo resistance against fungi included graveyard (buried block) tests of *G. apus* and durability of *G. apus* against *Schizophyllum commune* (Martawijaya 1964), durability of two bamboos against fungi (Suhirman & Khusniati 1987), graveyard test of seven bamboo species (Kumar *et al.* 1994) and decay resistance of bamboo (*Gigantochloa scortechinii*) against two fungi (Hamid *et al.* 2003).

The objectives of this research were to determine the resistance of bamboo to 15 selected fungi and the effects of bamboo portions, namely, bottom, middle and top, with regard to resistance to these decaying fungi.

MATERIALS AND METHODS

Samples were prepared by cutting the bottom, middle and top portions into dimensions of 5 (length) × 2.5 (width) × 0.5–3.5 cm (thickness). The length of samples was in the longitudinal direction. Each bamboo species was represented by one bamboo stem. Samples for the test were taken continuously from the lowest internode of bamboo up to the end or the top portion. All samples, free of node, were split 2.5 cm in width and 5.0 cm in length. The thickness of samples depends on the wall thickness of bamboo species. Samples were oven dried at 105 °C for 24 hours or until they had achieved constant weight before being subjected to fungi. The species of bamboo tested are presented in Table 1. There were five bamboo species containing 15 bamboo portions (bottom, middle and top). A total of 900 bamboo blocks were subjected to 15 fungal strains, giving rise to 60 blocks assigned to each fungi strain.

The fungi used were *Chaetomium globossum* FRI Japan-5-1, *Coriolus versicolor* FRI Japan-1030, *Dacryopinax spathularia* HHBI-145, *D. spathularia* HHBI-223, *Lentinus lepideus* Mad.-534, *Phlebia brevispora* Mad., *Pycnoporus sanguineus* HHBI-324, *P. sanguineus* HHBI-8149, *Polyporus* sp. HHBI-209, *Postia placenta* Mad-696, *Phanerochaete chrysosporium* HHBI-320, *P. sordida* HHBI-321, *Schizophyllum commune* HHBI-204, *S. commune* HHBI-222 and *Tyromyces palustris* FRI Japan-507. The culture medium was made from 3% malt extract and 2% agar in distilled water, except for *C. globosum* which used potato dextrose agar 39 g.

The decay test was conducted according to Kolle-flask method by DIN 52176 standard, modified by Martawijaya (1975), and Djarwanto and Suprapti (2004). The medium components were mixed thoroughly, put into Kolle-flask as much as 80 ml per flask, plugged with cotton, then sterilised in an autoclave at 121 °C, with

Table 1 The bamboo species tested against decaying fungi

Bamboo species	Local name	Origin
Bambusa vulgaris	Bambu ampel	Yogyakarta
Dendrocalamus asper	Bambu betung	Bogor
Gigantochloa apus	Bambu tali or bambu apus	Bogor
Gigantochloa atroviolacea	Bambu wulung or bambu hitam	Yogyakarta
Gigantochloa pseudoarundinacea	Bambu andong or bambu gombong	Yogyakarta

a pressure of 1.5 atmospheres for 30 min and allowed to cool. After cooling, the medium in each flask was inoculated with pure culture of the test fungi. They were then incubated until the mycelium growth on the surface of the medium spread evenly. Before being used, all blocks were numbered, oven dried at 105 °C for 24 hours, and then weighed repeatedly until they achieved a constant weight. Tests blocks were put in triplicates (representing bottom, middle and top portions of bamboo) on the culture aseptically. Four flasks each contained a triplicate of samples with one fungus strain. Therefore, each flask was regarded as replication. The flasks were incubated for 12 weeks and the test blocks were cleaned, weighed and oven dried. The percentage of weight loss of bamboo sample for decay determination was calculated under oven-dry weight condition before and after incubation (Martawijaya 1975, Suhirman & Khusniati 1987, Djarwanto & Suprapti 2004, Zhang *et al.* 2007). The percentage of weight loss was analysed using factorial design with factorial pattern of 5 × 3 × 15 (bamboo species × portion of bamboo × fungus), with four replications. Statistical differences between treatments were analysed using Tukey's test.

Based on the average weight loss of samples by fungal attack, the decay resistance of bamboo was determined based on class (Martawijaya 1975, Djarwanto & Suprapti 2004) and expectancy of service life (Seng 1990) (Table 2).

RESULTS AND DISCUSSION

Decay of bamboo, like decay of wood, could be detected by weight loss. Wood decayed by either brown rot, white rot or soft rot fungi is characterised by loss in weight and strength (Takahashi & Nishimoto 1967, Greaves 1979, Coggins 1980). Strength loss of southern pine (*Pinus* spp.) caused by white-rot fungus (*C. versicolor)* was considerably lower (30–40%) than that caused by the brown-rot fungi (*P. placenta*), i.e. 80–100% (Curling *et al.* 2002). Brown-rot fungi primarily utilise the cellulose and hemicellulose components of wood (Rayner & Boddy 1988, Highley & Illman 1991, Hakala 2007). Brown-rot fungi degrade components of wood and other lignocellulosic materials using cellulase enzyme, and only modify lignin during the attack (Rowell 1996). The mechanism of brown-rot fungi attack on lignocelluloses is an enzymatic reaction that breaks down the large polymers into smaller pieces which results in an early and rapid strength loss as the cellulose molecule is reduced. During this reaction phase, a second enzymatic system takes place in which carbohydrates and lignin are broken down, thereby causing weight loss (Rowell 1996). Meanwhile, white-rot fungi primarily utilise the cellulose, hemicellulose and lignin components of wood (Coggins 1980, Rayner & Boddy 1988, Hakala 2007). Highley and Illman (1990) stated that the ability of white rot to degrade lignocellulose was dependent upon the production of several extra-cellular enzymes (ligninase, cellulase and hemicellulase complexes). Soft-rot fungi degrade components of wood and other lignocellulosic materials by cellulolytic enzyme (Greaves 1979). Takahashi and Nishimoto (1967) stated that soft-rot fungi could not metabolise lignin but could only modify it.

The means for weight loss of bamboo at the bottom, middle and top portions are presented in Tables 3, 4 and 5. The weight loss of each bamboo portion caused by fungus seemed to vary. The weight loss of moso bamboo (*P. pubescens*) caused by 34 white rot fungi showed variation (Zhang *et al.* 2007). The weight loss of *G. apus* exposed to *S. commune* was 15% (Martawijaya 1964). Meanwhile, weight loss of

Table 2 Classification of bamboo resistance based on the weight loss by fungal attack

Average weight loss (%)	Decay resistance	Resistance class	The expectancy of service life (years)*
None or negligible	Very resistant	I	≥ 8
Less than 5	Resistant	II	6–7
5 to 10	Moderately resistant	III	4–5
10 to 30	Non-resistant	IV	2–3
More than 30	Perishable	V	< 2

Sources: Martawijaya (1975) and * = Seng (1990)

D. asper by *P. sanguineus* was 18.32% (Suhirman & Khusniati 1987). The weight loss of *G. scortechinii* exposed to brown rot (*Coniophora puteana*) varied from 5.3 to 9.9% and that caused by white rot (*C. versicolor*), from 8.90 to 9.95% (Hamid *et al.* 2003).

Weight loss is possibly affected by the amounts of chemical components in bamboo species. Li (2004) stated that the durability of bamboo against fungal attack was strongly associated with chemical composition, among others cellulose, lignin and pentosan. Cellulose, lignin

Table 3 The mean weight loss of the bottom portion of bamboo and its resistance class

Fungus	Weight loss percentage and resistance class of bamboo species				
	B. vulgaris	*D. asper*	*G. apus*	*G. atroviolacea*	*G. pseudoarundinacea*
C. versicolor	6.7 (III)	24.2 (IV)	6.1 (III)	10.6 (IV)	31.7 (V)
P. chrysosporium	5.4 (III)	14.7 (IV)	6.5 (III)	7.8 (III)	24.2 (IV)
P. sordida	3.7 (II)	6.4 (III)	6.4 (III)	7.1 (III)	5.6 (III)
P. brevispora	4.2 (II)	9.5 (III)	6.2 (III)	7.6 (III)	23.9 (IV)
P. placenta	2.4 (II)	6.1 (III)	8.7 (III)	6.2 (III)	8.2 (III)
P. sanguineus HHBI-324	7.4 (III)	34.4 (V)	22.0 (IV)	11.9 (IV)	33.5 (V)
P. sanguineus HHBI-8149	3.8 (II)	12.8 (IV)	5.3 (III)	6.4 (III)	15.3 (IV)
S. commune HHBI-204	3.4 (II)	10.8 (IV)	6.0 (III)	7.4 (III)	18.6 (IV)
S. commune HHBI-222	3.9 (II)	4.5 (II)	3.7 (II)	3.5 (II)	3.2 (II)
D. spathularia HHBI-145	4.4 (II)	7.8 (III)	6.3 (III)	4.8 (II)	2.9 (II)
D. spathularia HHBI-223	5.0 (III)	8.6 (III)	4.9 (II)	5.3 (III)	7.2 (III)
L. lepideus	2.3 (II)	5.1 (III)	4.6 (II)	6.4 (III)	10.0 (IV)
Polyporus sp.	8.5 (III)	33.6 (V)	10.0 (IV)	9.5 (III)	20.4 (IV)
T. palustris	6.6 (III)	35.7 (V)	19.1 (IV)	19.3 (IV)	8.4 (III)
C. globosum	8.2 (III)	13.7 IV)	7.0 (III)	6.0 (III)	8.7 (III)

Data (%) represent means of four replications. Letters in parentheses refer to the resistance class of bamboo.

Table 4 The mean weight loss of the middle portion of bamboo and its resistance class

Fungus	Weight loss percentage and resistance class of bamboo species				
	B. vulgaris	*D. asper*	*G. apus*	*G. atroviolacea*	*G. pseudoarundinacea*
C. versicolor	4.0 (II)	13.5 (IV)	6.9 (III)	10.3 (IV)	27.9 (IV)
P. chrysosporium	7.5 (III)	9.0 (III)	6.4 (III)	7.2 (III)	15.2 (IV)
P. sordida	5.4 (III)	6.3 (III)	6.0 (III)	7.4 (III)	4.8 (II)
P. brevispora	6.9 (III)	14.9 (IV)	5.3 (III)	3.6 (II)	9.9 (III)
P. placenta	4.4 (II)	5.8 (III)	7.4 (III)	4.1 (II)	5.7 (III)
P. sanguineus HHBI-324	13.2 (IV)	21.1 (IV)	10.9 (IV)	12.0 (IV)	38.3 (V)
P. sanguineus HHBI-8149	4.7 (II)	19.2 (IV)	5.4 (III)	3.7 (II)	18.5 (IV)
S. commune HHBI-204	7.6 (III)	6.9 (III)	6.2 (III)	4.8 (II)	31.7 (V)
S. commune HHBI-222	5.3 (III)	3.8 (II)	5.0 (III)	2.7 (II)	3.7 (II)
D. spathularia HHBI-145	5.1 (III)	5.4 (III)	6.2 (III)	4.2 (II)	4.9 (II)
D. spathularia HHBI-223	5.0 (III)	6.8 (III)	5.7 (III)	3.9 (II)	8.8 (III)
L. lepideus	3.8 (II)	7.7 (III)	5.8 (III)	3.3 (II)	8.4 (III)
Polyporus sp.	24.1 (IV)	11.6 (V)	11.4 (IV)	22.8 (IV)	21.5 (IV)
T. palustris	32.5 (V)	15.6 (IV)	10.4 (IV)	9.2 (III)	22.8 (IV)
C. globosum	8.0 (III)	9.4 (III)	10.9 (IV)	4.0 (II)	8.4 (III)

Data (%) represent means of four replications. Letters in parentheses refer to the resistance class of bamboo.

Table 5 The mean weight loss of the top portion of bamboo and its resistance class

Fungus	Weight loss percentage and resistance class of bamboo species				
	B. vulgaris	*D. asper*	*G. apus*	*G. atroviolacea*	*G. pseudoarundinacea*
C. versicolor	7.2 (III)	15.2 (IV)	4.8 (II)	7.7 (III)	20.7 (IV)
P. chrysosporium	8.7 (III)	7.2 (III)	6.5 (III)	7.6 (III)	16.6 (IV)
P. sordida	5.4 (III)	7.5 (III)	5.4 (III)	5.4 (III)	5.3 (III)
P. brevispora	4.8 (II)	11.1 (IV)	3.8 (II)	4.1 (II)	10.3 (IV)
P. placenta	4.5 (II)	3.7 (II)	4.8 (II)	5.1 (III)	13.0 (IV)
P. sanguineus HHBI-324	22.5 (IV)	19.0 (IV)	9.0 (III)	14.4 (IV)	32.6 (V)
P. sanguineus HHBI-8149	5.0 (III)	8.9 (III)	4.0 (II)	3.8 (II)	8.7 (III)
S. commune HHBI-204	8.8 (III)	15.0 (IV)	4.5 (II)	5.8 (III)	26.6 (IV)
S. commune HHBI-222	4.6 (II)	4.6 (II)	3.2 (II)	2.8 (II)	4.0 (II)
D. spathularia HHBI-145	5.2 (III)	6.7 (III)	5.0 (III)	3.4 (II)	4.1 (II)
D. spathularia HHBI-223	4.7 (II)	8.8 (III)	5.9 (III)	7.7 (III)	3.3 (II)
L. lepideus	4.1 (II)	5.8 (III)	4.3 (II)	3.9 (II)	11.0 (IV)
Polyporus sp.	36.2 (V)	21.0 (IV)	21.7 (IV)	20.9 (IV)	27.4 (IV)
T. palustris	37.4 (V)	16.5 (IV)	23.8 (IV)	21.0 (IV)	26.9 (IV)
C. globosum	7.0 (III)	8.0 (III)	7.5 (III)	4.6 (II)	9.3 (III)

Data (%) represent means of four replications. Letters in parentheses refer to the resistance class of bamboo.

and pentosan contents in *Phyllostachys heterocycla* and *P. nigra* were 49.1, 42.3; 26.1, 23.8 and 27.2, 24.1% respectively. Holocellulose contents in the bottom portion of bamboo stem was the lowest, followed by the middle and top portions (Tables 3–5). Lignin contents in the bottom, middle and top portions were unique.

Statistical analysis (Table 6) revealed that bamboo species, location on bamboo stem and fungal species significantly affected weight loss ($p \leq 0.05$). Tukey's test ($p \leq 0.05$) revealed that the lowest weight losses occurred on *B. vulgaris*, *G. apus* and *G. atroviolacea*. The highest weight loss was shown by *G. pseudoarundinacea*. Statistical analysis showed that weight losses between bamboo at the bottom, middle and top portions were not significantly different ($p \leq 0.05$): 10.4, 9.9 and 10.4% respectively. Based on statistical analysis, the greatest weight loss of bamboo occurred at the middle portion of *G. pseudoarundinacea* which was exposed to *P. sanguineus* HHBI-324, i.e. 38.3% (Table 4). The lowest weight loss was at the bottom portion of *B. vulgaris* decayed by *L. lepideus,* i.e. 2.3% (Table 3).

Based on resistance class or durability of bamboo against fungi in the laboratory (Table 6), *B. vulgaris*, *G. apus* and *G. atroviolacea* were considered moderately resistant (class III). However, *G. pseudoarundinacea* and *D. asper* fell into non-resistant class (class IV). According to Seng (1990), wood in class III is expected to have a service life of three years, while that of class IV is very short. In this study, resistance of bamboo to destroying organism varied depending on bamboo species, the location where the bamboo was installed or placed, felling/cutting time and bamboo origin. In fact, service life of bamboo can range from three years to decades. According to Liese (1980), bamboo resistance or its service life is usually shorter than that of wood, from one to three years. Table 6 shows that decay by *D. asper* belongs to class IV and, therefore, its service life is very short. A study conducted in Yogyakarta and Central Java regions indicated that service life of solid *D. asper* (in original shape) could be more than 15 years. Service life of split *D. asper* used to support roof tiles was eight years. This shows that the place where the bamboo was harvested can affect its durability. *Dendrocalamus asper,* originated from West Java, showed lower durability than that from Java and Sulawesi (Heyne 1987). Therefore, *D. asper* from West Java is only used for scaffolding as supporting frames when erecting high building or installing temporary construction base, while that from Java and Sulawesi is very strong and resistant,

Table 6 The mean weight loss and resistance class of five bamboo species

Bamboo	Weight loss on part of bamboo (%)				Class
	Bottom portion	Middle portion	Top portion	Average	
Bambusa vulgaris	5.1	9.2	11.1	8.4 c	III (II–V)
Dendrocalamus asper	15.2	10.5	10.6	12.1 b	IV (II–V)
Gigantochloa apus	8.2	7.3	7.6	7.7 c	III (II–IV)
Gigantochloa atroviolacea	8.0	6.9	7.9	7.6 c	III (II–IV)
Gigantochloa pseudoarundinacea	15.3	15.4	14.7	15.1 a	IV (III–V)

Values within a column followed by the same letter are not significantly different, Tukey's test ($p \leq 0.05$).

and therefore, can be used as house poles, suspended bridge and boat frames. According to the result of graveyard test by Martawijaya (1964), the service life of *G. apus* was 18 months (split bamboo) and 21 months (round bamboo). Kumar *et al.* (1994) stated that the service life of seven Indian bamboo species was less than two years. Hamid *et al.* (2003) reported that the service life of bamboo was estimated to last from only six months to three years only when in soil contact.

The bottom and top portions were non-resistant (class IV), while the middle portion was moderately resistant (class III), which was still close to class IV. This happens possibly due to the age of felling whereby the bamboo is still not mature yet. Therefore, its bottom portion is more susceptible to fungi attack compared with the middle part. Liese (1980) stated that the bottom portion of bamboo had on average higher resistance than the middle or top portion. According to durability classification by Kumar *et al.* (1994), bamboo belongs to class III (not durable) with little variation in durability between different species.

Bamboo resistance against fungi is possibly affected by their extractives content. Higher benzene–ethanol extractives in bamboo could be advantageous for decay resistance (Li 2004). The extractives contents in *P. heterocycla* and *P. nigra* were 4.6 and 3.4% respectively. Extractives contents in the bottom, middle and top portions were 6.6, 6.8 and 7.3 respectively (Li *et al.* 2007).

Fungi capabilities to decay bamboo varied in accordance with bamboo species as shown by the variety of their weight losses (Table 7). The capability of *D. spathularia* HHBI-223 to decay bamboo was greater than that of *D. spathularia* HHBI-145; however the differences were not too significant. Suprapti and Djarwanto (2001) reported that the capability of *D. spathularia* HHBI-223 to decay wood was almost similar to that of *D. spathularia* HHBI-145. The capability of *P. sanguineus* HHBI-324 to decay bamboo was greater than that of *P. sanguineus* HHBI-8149. This could be due to different strains of fungi, as shown by the colour of fungi mycelium which was consistently different after the thickening of mycelium. Suprapti and Djarwanto (2001) stated that the mycelium growth of *P. sanguineus* HHBI-8149 on the surface of agar media and of wood block occurred more slowly compared with the growth of *P. sanguineus* HHBI-324 (isolated from East Kalimantan). The capability of *S. commune* HHBI-204 to decay bamboo was greater than that of *S. commune* HHBI-222. The fungi species that afforded greatest capability to decay wood was *S. commune* HHBI-204, followed by *S. commune* HHBI-222 (Suprapti & Djarwanto 2001). Pildain *et al.* (2005) stated that even the same fungus but of different strains could possibly bring about significant differences in weight loss. Tali bamboos piled up in open places and exposed to rain were conducive to growth of *S. commune* and *D. spathularia* after two to three months and three to six months of exposure respectively, when used as fence or sign post (personal observation).

The highest fungal decay (Table 7) of bamboo was observed with *T. palustris* (brown rot), *P. sanguineus* HHBI-324 (white rot) and *Polyporus* sp. (brown rot) while the lowest was found with *S. commune* HHBI-222 (white rot). The highest capability of fungi to decay wood occurred in *C. versicolor*, followed by *P. sanguineus* HHBI-324, *T. palustris* and *Polyporus* sp. (Suprapti *et al.* 2004). The decaying ability of *C. versicolor* was generally

Table 7 The decaying ability of fungi on bamboo

Fungus	Group of fungus	Weight loss (%)
Coriolus versicolor FRI Japan-1030	White rot	13.2 b
Phanerochaete chrysosporium HHBI-320	White rot	10.0 cd
P. sordida HHBI-321	White rot	5.9 fg
Phlebia brevispora Mad.	White rot	8.4 d
Postia placenta Mad-696	White rot	6.0 f
Pycnoporus sanguineus HHBI-324	White rot	20.2 a
P. sanguineus HHBI-8149	White rot	8.4 d
Schizophyllum commune HHBI-204	White rot	10.9 c
S. commune HHBI-222	White rot	3.9 g
Dacryopinax spathularia HHBI-145	Brown rot	5.1 fg
D. spathularia HHBI-223	Brown rot	6.1 ef
Lentinus lepideus Mad-534	Brown rot	5.8 fg
Polyporus sp. HHBI-209	Brown rot	20.0 a
Tyromyces palustris FRI Japan-507	Brown rot	20.9 a
Chaetomium globosum FRI Japan 5–1	Soft rot	8.0 de

Values within a column followed by the same letter are not significantly different, Tukey's test ($p \leq 0.05$).

higher than that of *C. globosum* (Takahashi & Kishima 1973). The lowest decaying ability of fungi on wood was *C. globosum* while the highest was *T. palustris* and the ability of *P. sanguineus* was between the values of both fungi (Wong 1988). Samples of southern pine (*Pinus* spp.) under exposure to *C. versicolor* resulted in much lower weight loss (< 15%) than samples exposed to the brown-rot fungi (*P. placenta*), i.e. 25–40% (Curling *et al.* 2002).

ACKNOWLEDGEMENT

The author thank H Roliadi for reviewing the manuscript.

REFERENCES

Coggins CR. 1980. *Decay of Timber in Buildings: Dry Rot, Wet Rot and Other Fungi.* Rentokil Limited Felcourt, East Grinstead.

Curling SF, Clausen CA & Winandy JE. 2002. Experimental method to quantify progressive stages of decay of wood by basidiomycete fungi. *International Biodeterioratian and Biodegradation* 49: 13–19.

Djarwanto & Suprapti S. 2004. Laboratory testing on the resistance of wood against fungi. Pp. 15–22 in Herjanto E *et al.* (Eds.) *Prosiding Pertemuan dan Presentasi Ilmiah Standardisasi.* 11–12 Oktober 2004, Jakarta.

Greaves H. 1979. The natural durability of various Australian wood pole species to soft-rotting microfungi. *International Journal of Wood Preservation* 1: 15–20.

Hakala TK. 2007. Characterization of the lignin-modifying enzymes of the selective white-rot fungus *Physisporinus rivulosus*. PhD thesis, University of Helsinki, Helsinki.

Hamid NH, Abd Latif M & Sulaiman O. 2003. Decay resistance of bamboo (*Gigantochloa scortechinii*) compared to 24 Malaysian hardwood. http://www.fao.org/docrep/article/wfc/xii/0039-b4.htm.

Heyne K. 1987. *De Nuttige Planten van Indonesie.* Volume I. Badan Penelitian dan Pengembangan Kehutanan, Jakarta.

Highley TL & Illman BL. 1990. Changes in cell wall components of white pine and maple by white-rot fungi. Pp. 349–360 in Llewellyn *et al.* (Eds.) *Biodeterioration Research 3. Proceedings of the Third Meeting of the Pan American Biodeterioration Society.* 3–6 August 1989, New York.

Highley TL & Illman BL. 1991. Progress in understanding how brown-rot fungi degrade cellulose. *Biodeterioration Abstracts 1991* Vol. 5: 231–244.

Krisdianto. 2008. The effect of microwave heating on permeability of bamboo. *Journal of Tropical Wood Science and Technology* 6: 37–42.

Kumar S, Shuka KS, Dev I & Dobriyal PB. 1994. *Bamboo Preservation Techniques: A Review.* International Development Research Center of Canada and Indian Council of Forestry Research and Education, Dehra Dun.

Li XB. 2004. Physical, chemical, and mechanical properties of bamboo and its utilization potential for fiberboard manufacturing. MSc thesis, Louisiana State University, Baton Rouge.

Li XB, Shupe TF, Peter GF, Hse CY & Eberhardt TL. 2007. Chemical changes with maturation of the bamboo species *Phyllostachys pubescens*. *Journal of Tropical Forest Science* 19: 6–12.

Liese W. 1980. Preservation of bamboos. Pp. 165–172 in Lessard G & Chouinard A (Eds.) *Bamboo Research in Asia*. Proceedings of a workshop held in Singapore. 28–30 May 1980.

Martawijaya A. 1964. Bamboo preservation in Indonesia. *Rimba Indonesia* IX: 66–76.

Martawijaya A. 1975. *Laboratory Testing on the Resistance of Wood Against Fungi*. Ministry of Agriculture, Jakarta.

Misdarti. 2006. Qualities of laminated bamboo of Toraja Regency, South Sulawesi. *Journal of Forest Products Research* 24: 183–189.

Pildain, Novas BMV & Carmarán CC. 2005. Evaluation of anamorphic state, wood decay and production of lignin-modifying enzymes for diatrypaceous fungi from Argentina. *Journal of Agricultural Technology* 1: 81–96.

Rayner ADM & Boddy L. 1988. *Fungal Decomposition of Wood: its Biology and Ecology*. John Wiley & Sons Ltd., Chichester.

Rowell RM. 1996. Chemical modification of lignocellulosics. In Gatenholm P (Ed.) *Proceedings of the International Workshop Frontiers in Surface Modifications and Characterization of Lignocellulosic Fibers with an Emphasis on Non-paper Making Applications*. 30–31 May 1996, Gullmarsstrand Fiskebäkskil, Sweden.

Seng OD. 1990. *Specific Gravity of Indonesian Woods and its Significance for Practical Use*. Communication No. 13. Forest Products Research and Development Centre, Bogor.

Subiyanto B, Subiyakto & Prasetyo B. 1995. Perkembangan teknologi pemanfaatan bambu untuk industri dan prospeknya di Indonesia. Pp. 1031–1049 in Soegiharto A *et al.* (Eds.) *Prosiding Kongres Ilmu Pengetahuan Nasional VI*. 11–15 September 1995, Jakarta.

Suhirman & Khusniati T. 1987. Laboratory study on the effect of mud-submersion treatment on the durability of two bamboos and one wood species. *Material und Organismen* 22: 289–296.

Sulastiningsih IM. 2008. Some properties of laminated bamboo board made from three bamboo species. *Journal of Forest Products Research* 26: 277–287.

Suprapti S & Djarwanto. 2001. Capability of ten fungus isolates on wood decay (*Kemampuan sepuluh isolat jamur dalam melapukkan kayu*). Pp. 190–170 in *Proceedings of the Third Seminar of Indonesian Wood Research Society*. 22–23 August 2000, Winayamukti University, Bandung.

Suprapti S, Djarwanto & Hudiansyah. 2004. The resistance of five wood species against several wood destroying fungi. *Journal of Forest Products Research* 22: 239–246.

Takahashi M & Nishimoto K. 1967. Studies on the mechanism of wood decay in infrared spectra of EDNA and SDGI wood as decay proceeds. *Wood Research* 42: 1–12.

Takahashi M & Kishima T. 1973. Decay resistance of sixty-five Southeast Asian timber specimens in accelerated laboratory tests. *Tonan Ajia Kenkyu* 10: 525–541.

Widjaja EA. 2001. *Identikit Jenis-jenis Bambu di Jawa. Seri Panduan Lapangan*. LIPI, Bogor. (in Indonesian)

Widjaja EA & Risyad Z. 1987. Anatomical properties of some bamboo utilized in Indonesia. *Recent Research on Bamboos. Proceedings of the International Bamboo Workshop*. 6–14 October 1985, Hangzhou.

Wong AHH. 1988. Natural decay resistance of kempas (*Koompassia malaccensis*) with included phloem against rot fungi: a laboratory evaluation. *Journal of Tropical Forest Science* 1: 162–169.

Yudodibroto H. 1987. Bamboo research in Indonesia. *Proceedings of the International Bamboo Workshop*. 6–14 October 1985, Hangzhou.

Zhang X, Yu H, Huang H & Liu Y. 2007. Evaluation of biological pretreatment with white rot fungi for the enzymatic hydrolysis of bamboo culms. *International Biodeterioration and Biodegradation* 60: 159–164.