PROTECTION OF BAMBOO AGAINST MOULD USING ENVIRONMENT-FRIENDLY CHEMICALS

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TANG TKH, SCHMIDT O & LIESE W. 2012. Protection of bamboo against mould using environment-friendly chemicals. The protection of the bamboo species *Bambusa stenostachya, Bambusa procera, Dendrocalamus asper* and *Thyrostachys siamensis* against moulds was tested with environment-friendly chemicals under practical conditions. Bamboo samples were treated with several organic acids. Mould growth on the specimens was evaluated 1, 2, 4 and 8 weeks after exposure at the storage site of the Bamboo Nature Company, Binh Duong province, South Vietnam. Treatments with 10% acetic acid and 7% propionic acid completely inhibited mould growth on *B. stenostachya* and *T. siamensis*. For full protection of *B. procera* and *D. asper*, 10% propionic acid was needed.

Keywords: Field test, antimould treatment, organic acids

TANG TKH, SCHMIDT O & LIESE W. 2012. Perlindungan buluh terhadap kulapuk menggunakan bahan kimia mesra alam. Perlindungan buluh *Bambusa stenostachya, Bambusa procera, Dendrocalamus asper* dan *Thyrostachys siamensis* terhadap kulapuk diuji di lapangan menggunakan bahan kimia mesra alam. Sampel buluh dirawat dengan beberapa asid organik. Pertumbuhan kulapuk dinilai pada minggu pertama, kedua, keempat dan kelapan selepas pendedahan di tapak simpanan Syarikat Bamboo Nature, daerah Binh Duong, Selatan Vietnam. Rawatan dengan 10% asid asetik dan 7% asid propionik menghalang sepenuhnya pertumbuhan kulapuk pada *B. stenostachya* dan *T. siamensis*. Perlindungan penuh bagi *B. procera* dan *D. asper* dicapai apabila 10% asid propionik digunakan.

INTRODUCTION

In many tropical countries, bamboo is one of the important vegetative resources after plantation wood and is a major raw material for the forest product industry. In recent years, bamboo has become the main material for industrial manufacturing of round and laminated bamboo furniture and parquet. It is also widely exported as bamboo culms.

Bamboo has low natural durability against fungi and insects compared with wood (Liese 1998). In general, several fungi from the groups of deuteromycetes (moulds), ascomycetes and basidiomycetes colonise the culms of bamboos (Mohanan 1997). Tropical climate with high temperatures and relative humidity above 70% facilitate mould growth. Exposed bamboo is especially affected by moulds during storage, processing, transport in containers and its final use (Liese & Kumar 2003). Moulds grow on the surface and at the cross-ends of culms.

Pentachlorophenol had been widely used for protection of bamboo against moulds and other fungi. However, the chemical is banned in many parts of the world due to its high toxicity (Tang 2009). Thus, bamboo manufacturers have extreme problems in protecting bamboo for local use and export. Since bamboo countries export large quantities of bamboo culms and utilities in containers, the damage due to mould growth at port arrival has become quite serious. Manufacturers need cost-effective and also environment-friendly treatment methods for moist bamboo during its susceptible phase.

Hydrocloric acid has been shown to provide good protection for bamboo compared with sodium hydroxide (Sun et al. 2011). The effectiveness of the acid led us to investigate various organic acids, namely, acetic, boric, citric, formic, propionic and sorbic acids against moulds of bamboo. These acids have

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long been used for food protection and as antiseptics. Suitable concentrations for food are 0.03 to 4% (Wallhäußer & Schmidt 1967). Previous laboratory experiments have shown that moulding of bamboo can be prevented by simple treatment with the above environment-friendly acids in concentrations from 7 to 10% (Tang et al. 2009).

To test the functionality of the acids, field tests under practical conditions were carried out at the Bamboo Nature Company, Binh Duong province of South Vietnam. We investigated the mould susceptibility of four bamboo species—*Bambusa stenostachya*, *Bambusa procera*, *Dendrocalamus asper* and *Thyrostachys siamensis*—which are important in South Vietnam and widely used for production of structures, furniture and export (Phan 2004).

MATERIALS AND METHODS

Mature 3-year-old bamboo culms from *B. stenostachya*, *B. procera*, *D. asper* and *T. siamensis* were collected from a bamboo plantation at the Bamboo Nature Company. They were harvested in June, July and September 2009. Samples were prepared from the fresh culms either as culm parts or splits of 120 and 80 cm in length respectively. In both cases, the epidermis was removed by sanding. These forms of samples were the most common for production of furniture in Vietnam. The moisture content was 100 to 120%. Samples were prepared in seven replicates for each treatment.

Effective chemicals (namely, citric, formic and sorbic acids) from previous laboratory experiments (Tang et al. 2009), acetic, boric and propionic acids, and the concentrations used are shown in Table 1. In the previous experiment, sample size was smaller compared with the current experiment. Therefore, instead of 3 min used previously, bamboo specimens in this experiment were dipped for 10 min in the treatment solution. In both cases, only the outer layers of the samples became impregnated. Samples were then bundled and placed on supports over wet soil ground (Figure 1). After 1 day of exposure to natural infection, samples were covered with plastic sheet to avoid sunlight and drying (Figure 1). The test was carried out in a roof-covered raw material storage area in the factory of the Bamboo Nature Company. It was known that the storage space suffered from severe mould contamination from an area underneath the ground floor which experienced high humidity produced by water evaporation from uncovered ground soil.

The tests were carried out in three periods, each of 8 weeks during the rainy season in 2009 (June–August, July– September and September–November). The temperature during exposure was about 28 °C and the relative humidity, between 80 and 90%.

The development of mould growth on the surface of the specimens was assessed according to the rating scheme given in Table 2 (British Standard Institution 2005). The visual evaluation of damage was rated after 1, 2, 4 and 8 weeks.

RESULTS AND DISCUSSION

Results of the experiments for the four study bamboo species are summarised in Tables 3 to 6. Differences occurred in moulding between exposure periods. In most treatments, specimens from the second period were more quickly overgrown by moulds due to the high relative humidity of about 90%.

There were significant differences in efficacy of antimould treatments for the bamboo species. Treatment with 10% propionic acid prevented mould growth on all four bamboo species during the whole exposure period of eight weeks. Ten

Table 1 Organic acids used in the investigation

Chemical	pH
10% acetic acid	2.8
7% propionic acid	2.9
10% propionic acid	2.8
3% boric acid + 7% acetic acid	3.0
3% boric acid + 7% propionic acid	3.0
Water (control)	Not determined

Figure 1 Bundled specimens on supports over wet soil ground and covered for infection

Table 2 Rating scheme for determining mould growth on bamboo specimens

Rating	Description	Definition
0	No coverage	No growth
1	1–10% coverage	Slightly overgrown
2	11–25% coverage	Moderately overgrown
3	26–50% coverage	Severely overgrown
4	> 50% coverage	Very severely overgrown

Table 3 Efficacy of antimould treatments for *Bambusa stenostachya*

Organic acid	Period*	Exposure time							
		1 week		2 weeks		4 weeks		8 weeks	
		C	S	C	S	C	S	C	S
Acetic acid 10%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Propionic acid 10%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Propionic acid 7%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Boric acid 3% + acetic acid 7%	I	0	0	0	0	0	0	0	0
	II	1	1	1	1	2	2	1	2
	III	0	2	2	2	2	2	2	2
Boric acid 3% + propionic acid 7%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Control	I	1	2	2	3	2	3	2	3
	II	2	3	3	4	3	4	3	4
	III	1	3	3	3	3	3	4	4

*Test period in 2009, each lasting eight weeks: I = June–August, II = July–September, III September–November; C = culm parts, S = split parts

Table 4 Efficacy of antimould treatments for *Bambusa procera*

Organic acid	Period*	Exposure time							
		1 week		2 weeks		4 weeks		8 weeks	
		C	S	C	S	C	S	C	S
Acetic acid 10%	I	1	2	1	2	2	2	2	2
	II	2	3	3	4	3	4	3	4
	III	1	2	2	2	2	3	2	3
Propionic acid 10%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Propionic acid 7%	I	1	1	1	2	1	2	2	2
	II	1	2	2	3	3	3	3	3
	III	1	2	1	2	1	2	2	2
Boric acid 3% + acetic acid 7%	I	2	3	4	4	4	4	4	4
	II	3	4	4	4	4	4	4	4
	III	1	3	3	3	3	3	3	3
Boric acid (3%) + propionic asid 7%	I	0	0	1	1	1	1	1	1
	II	1	1	2	2	2	2	2	2
	III	1	1	1	1	1	1	1	1
Control	I	2	3	3	3	3	3	3	3
	II	4	4	4	4	4	4	4	4
	III	3	4	3	4	3	4	3	4

*Test period in 2009, each lasting eight weeks: I = June–August, II = July–September, III September–November; C = culm parts, S = split parts

Table 5 Efficacy of antimould treatments for *Dendrocalamus asper*

Organic acid	Period*	Exposure time							
		1 week		2 weeks		4 weeks		8 weeks	
		C	S	C	S	C	S	C	S
Acetic acid 10%	I	1	2	1	2	2	2	2	2
	II	2	3	3	4	3	4	3	4
	III	1	2	2	2	2	3	2	3
Propionic acid 10%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Propionic acid 7%	I	1	1	1	2	1	2	2	2
	II	1	2	2	3	3	3	3	3
	III	1	2	1	2	1	2	2	2
Boric acid 3% + acetic acid 7%	I	2	3	4	4	4	4	4	4
	II	3	4	4	4	4	4	4	4
	III	1	3	3	3	3	3	3	3
Boric acid (3%) + propionic acid 7%	I	0	0	1	1	1	1	1	1
	II	1	1	2	2	2	2	2	2
	III	1	1	1	1	1	1	1	1
Control	I	2	3	3	3	3	3	3	3
	II	4	4	4	4	4	4	4	4
	III	3	4	3	4	3	4	3	4

*Test period in 2009, each lasting eight weeks: I = June–August, II = July–September, III September–November; C = culm parts, S = split parts

Table 6 Efficacy of antimould treatments for *Thyrostachys siamensis*

Organic acid	Period*	Exposure time							
		1 week		2 weeks		4 weeks		8 weeks	
		C	S	C	S	C	S	C	S
Acetic acid 10%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Propionic acid 10%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Propionic acid 7%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Boric acid 3% + acetic acid 7%	I	0	1	1	2	1	2	1	2
	II	1	1	2	3	2	3	3	3
	III	0	2	2	2	2	3	3	3
Boric acid 3% + propionic acid 7%	I	0	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0	0
Control	I	1	2	2	3	2	3	2	3
	II	2	3	3	4	3	4	3	4
	III	1	3	3	3	3	3	4	4

*Test period in 2009, each lasting eight weeks: I = June–August, II = July–September, III September–November; C = culm parts, S = split parts

per cent acetic acid, 7% propionic acid and the boric/propionic acid mixture prevented complete mould growth during all exposure periods in *B. stenostachya* and *T. siamensis*, but not in *B. procera* and *D. asper*. Generally, results of this field test are similar to our previous laboratory experiments with smaller samples (Tang et al. 2009). There were also differences among bamboo species with regard to the degradation by rot fungi (Schmidt et al. 2011). Further experiments regarding mould susceptibility of different bamboo species may be of interest.

The effective acid solutions had acidic pH values between 2.8 and 3.0. Our previous laboratory tests proved that only solutions with acidic pH were effective, namely, the free acids (Tang et al. 2009). Their salts with alkaline pH values were less or not effective. For example, acetic acid inhibited moulds but sodium acetate did not. This meant that the preserving function of a solution was mainly due to its acidity. Propionic acid had also protected sugar cane bagasse from moulding (Liese & Walter 1978) and prevented ilomba wood from bacterial staining (Schmidt 2006).

A possible disadvantage of the dipping procedure with organic acids may be that the acid solutions are not durable. In view of repeated use of the dipping solution, propionic acid, for example, was oxidised to acetic acid, carbon dioxide and water. Thus, fresh acid solutions should be used always. Corrosion of the dipping containers must also be considered, if made from iron. More importantly, the acids do not fix to the bamboo tissue and are washed out by rain. The bamboos are only protected during the short storage period. It is also important to ensure that the susceptible phase of bamboo drying after dipping is performed in a roof-covered area.

This investigation has shown that bamboos can be protected from moulding at least during the critical period after harvest. The non-poisonous and environmental-friendly organic acids used in this study, especially 10% propionic acid, were effective in inhibiting mould growth. Their effectiveness was mainly due to their acidity. The

proposed method is economical because the costs of the acids are acceptable, i.e. Europe: €80/t and NAFTA, Asia: USD130/t according to BASF Chemical Company.

Further investigations should deal with the possible consequences of the treatment for subsequent bamboo use in long-term service, including influence on colour, smell and gluing ability of parquets.

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