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Amelioration of durability of bamboo through copper-chrome-boron by different treatment processes

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Abstract: *Bambusa balcooa*, *B. bambos B. nutans*, *Dendrocalamus giganteus* and *D. strictus* were evaluated for natural durability through grave yard test and revealed that none of the species is durable in ground contact. Treatment with copper-chrome-boron (CCB) at 4 per cent concentration and four methods of treatment *i.e.*, Boucherie, VAC-FRI, Wick, and Diffusion were selected for the study. CCB treated *D. giganteus* exhibited only 34.83 per cent destruction of samples, while 66 per cent of *B. balcooa* samples were destroyed in grave yard test. Among the bamboo species tested, *B. balcooa* with very good culm thickness performed worst and *D. giganteus* best in the field. Wick process imparted considerable protection to *D. giganteus*, *D. strictus* and *B. nutans*. Wick process performed best among the treatment methods applied and on the basis of field performance of bamboo, the methods are graded as Wick process >Diffusion >Boucherie >VAC-FRI >Control. Moisture content, treatment time and retention of preservative influenced performance of treated bamboo in the field.

Key words: Bamboo, copper-chrome-boron, deterioration, preservation.

INTRODUCTION

Bamboo is the most versatile forest produce and its potential can be harnessed in the service of the humble and great. It is a woody grass belonging to the subfamily *Bambusoideae* of the family *Poaceae*. World wide there are more than 1,250 species of bamboo, which are unevenly distributed in various parts of the humid tropical, subtropical and temperate regions of the earth. This natural resource plays an important role in the livelihood of rural people and in the cottage industry. Bamboo, an excellent alternate structural material has many advantages over wood, like fast growth rate and short maturity period. The only disadvantage is lack of natural resistance to decay and insects. Its use has therefore, been limited to low cost houses in rural and tribal areas. Bamboo consists of 50-70 per cent holo-cellulose, 30 per cent pentosans and 20-25 per cent lignin (Chen *et al.*, 1985). However, none of these has enough toxicity to impart natural durability; presence of large amount of starch makes it highly

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susceptible to attack by staining fungi and powder post beetles. Very little authentic data are available on the natural durability of different bamboo species under different climatic conditions. A wide range of protective procedures, including chemical preservation methods are known, similar to those for timber under tropical conditions (Willeitner and Liese, 1992). But they are seldom applied due to lack of awareness and knowledge of bamboo protection methods and preservatives.

Several studies have been conducted on the treatability of bamboos and their performance in structures. Recent studies on treatability have indicated that bamboos are easily treatable but early failures were attributed to the lack of improper distribution of preservative chemicals (Kumar *et al.*, 1998). There are a number of preservatives and methods adopted to treat bamboo. Traditional methods increase the resistance of bamboos to borer attack but are ineffective against termites and fungi. Moreover, such methods are best suited to a small-scale user. Since bamboos have a large variety of uses and are required throughout the year, traditional methods have limited value. On commercial-scale, bamboo needs chemical treatment for long service life. A study on the field performance of different bamboo species, with and without preservative treatment, in relation with moisture content, retention levels of preservative and treatment methods is reported here.

METHODOLOGY

Bamboo species and treatment methods

Five commercially important bamboo species, *Bambusa balcooa* Roxb., *B. bambos* (L.) Voss, *B. nutans* G.C. Wall. ex Munro, *Dendrocalamus giganteus* Wallich ex Munro and *D. strictus* (Roxb.) Nees, were selected for the study. Copper-chrome-boron (CCB) at 4 per cent concentration and four methods of treatment, *viz.*, Boucherie (B), VAC-FRI (V-F), Wick (W) and Diffusion (D) were used. Mature green culms of bamboos of 3- to 5-years of age were collected from New Forest, Forest Research Institute, Dehra Dun in different months.

Moisture content determination

A specimen of 5 cm thickness in round form from each bamboo culm was taken. Samples were placed in oven of Narang make at 103 ± 2°C for 24 h for measurement of moisture content as per standard method (IS: 401).

Chemical analysis

Sections of 5 cm thick were cut at mid length of the treated culm. After drying, disc was powdered and suitable aliquots were subjected to chemical analysis as per standard procedure (IS: 2753).

Replicates and size of samples

Samples of 30 cm length with one node in the middle were prepared from the treated culms. Twelve replicates of each species for each treatment, *i.e.*, total 48 samples were taken and labeled properly and kept for installation in test yard. Twelve replicates of untreated samples of each species were installed along with treated specimens. Two types of control *i.e.*, 1) bamboo in round form (R) and 2) bamboo in split form (S)- 12 samples of each, were taken for the study.

Treatment of green bamboo

Boucherie process

Three culms each of green bamboos *viz.*, *B. balcooa*, *B. bambos*, *B. nutans*, *D. giganteus* and *D. strictus*, and of 6.2 m (20 feet) length were taken and attached to the Boucherie unit with branches and leaves intact. The CCB (4%) was pumped from a container by a pressure pump via a rubber sleeve into the culm base (IS: 1902). The time taken for the treatment of different bamboo species was recorded. Treated culms were detached from the unit and kept for 15 days to allow fixation of the preservative. Chemical analysis was performed as per standard procedure (IS: 2753).

Wick process

In sap displacement treatment, green culms of 1.86 m (6 feet) length of above mentioned species, along with branches and leaves were immersed vertically up to 25 cm, in CCB (4%) aqueous solution in plastic container. The preservative solution rises by wick action (Singh and Tewari, 1980). These bamboo culms were kept standing vertically for 7 days and after that the same culms were inverted and kept for the same period in the same solution. After 14 days of treatment, culms were left at room temperature to allow diffusion and fixation of preservative. Chemical analysis was performed and replicates for field test were prepared as described above.

VAC-FRI process

Bamboo culms (3-4 years aged) of the above mentioned species were felled and divided into 1.86-2.48 m (6-8 feet) length; outer and inner diameters were measured and one end was dipped in CCB(4%) solution and other end was connected with the unit VAC-FRI developed at FRI (Tripathi and Dev, 2003). Four culms of each bamboo species were treated at a time for 3 or 6 h, after that the treatment unit was stopped and bamboos were left as such for one hour. The treated culms were separated and left for 7 days for diffusion and fixation of preservative. Chemical analysis was performed and specimens/replicates were made as described for grave yard test.

Dip diffusion process

Mature green culms of 3-4 years of age of each bamboo species were collected and splitted into 1/8th split form of 1.86-2.48 m (6-8 feet) long strips and immersed in 25-30 liters of CCB(4%) solution in a tank for 7 days. Strips were taken out, dried for 15 days and specimen discs were taken off to quantify the preservative. Samples of 0.31 m (1 foot) length were prepared for grave yard test. Twelve replicates of each species along with same numbers of controls were taken for the grave yard test.

Installation of bamboo samples in grave yard

The treated and untreated samples of different bamboo species, after fixation of preservatives, were installed (half buried in ground) in the test yard at Dehra Dun. These samples were periodically observed up to 24 months for fungal/termite attack and data were recorded as per procedures laid down for wood in Indian Standard (IS:4833). To establish the treatment difference, the mean values of different parameters were subjected to analysis of variance (ANOVA) SPSS at 5 per cent significance level. Suitable data transformation was done wherever necessary, simple correlation (r) among different parameters was also determined.

RESULTS AND DISCUSSION

Durability of untreated and preservative treated bamboo

Bambusa nutans

B. nutans culms or in split form treated at moisture content 37-40 per cent by various methods took 4 h to get retention level 11.7 kg/m^3 by Boucherie process (B), while by VAC-FRI process (V-F), it took 4 h to get retention of 9.5 kg/m^3,whereas, 12.1 kg/m^3 retention was achieved by Wick process (W) when culms were treated for 14 days. Maximum retention *i.e.*,12.4 kg/m^3 could be achieved in split *B. nutans* by Dip diffusion (D) process which took 7 days. Control samples both in round and split forms destroyed within 3 months of installation, whereas, samples treated with V-F process were completely decayed within 15 months of installation. Very mild termite (Vsw) and very mild termite and fungal attack could be observed in bamboo treated with D and B processes after 18 months of installation whereas, no termite and fungal attack was observed on the bamboo treated with Wick process even after 24 months of installation (Table 1).

Control samples of *B. nutans* were severely damaged by termites and fungi both exhibiting a score of 5.0 (Bwf, Dwf). Samples treated by V-F process started decaying after 15 months of installation and only fungal infestation was observed. Contrary to this only very mild termite attack on 10 per cent of samples treated by D process was

Table 1. Dry salt retention (kg/m³) in treated bamboo species with CCB (4%), applying different treatment processes and level of deterioration

Species	Methods of treatment	Moisture content (%)	Treatment time (h/days)	Average retention kg/m³	Level of deterioration* (after 24 months)	Service life till all samples were sound (months)	Samples (%) running in field
B. nutans	B	37.2	4h	11.7	Vswf-0.75	18	85
	W	37.2	14d	12.1	N	24	100
	V-F	40.8	4h	9.5	Df-5.0	15	0
	D	37.2	7d	12.4	Vsw-0.5	18	90
	C (R)	40.8	-	-	Bwf5.0	3	0
	C (S)	37.2	-	-	Dwf 5.0	3	0
B. balcooa	B	48.5	4h	6.8	Bwf-4.5	21	10
	W	48.5	14d	5.6	Sw-1.0	21	80
	V-F	43.0	5h	5.6	Df-5.0	15	0
	D	48.5	7d	6.7	Sw-1.0	15	80
	C (R)	48.5	-	-	Dwf 5.0	15	0
	C (S)	48.5	-	-	Dwf 5.0	21	0
B. bambos	B	79.6	5h	13.5	Mwf-2.5	18	50
	W	79.6	14d	11.8	N	24	100
	V-F	88.2	8h	11.3	swf-1.5	21	50
	D	79.6	7d	19.7	Df-5.0	18	0
	C (R)	79.6	-	-	Bwf 5.0	18	0
	C (S)	79.0	-	-	Bwf 5.0	21	0
D. giganteus	B	50.0	4h	11.6	Swf- 1.5	18	70
	W	77.0	14d	8.8	Vswf- 0.75	18	85
	V-F	43.0	5h	7.1	Swf- 1.5	18	70
	D	55.0	7d	11.0	N	21	100
	C (R)	55.5	-	-	Dwf-5.0	18	0
	C (S)	52.3	-	-	Dwf-5.0	21	0
D. strictus	B	39.5	4h	5.0	Swf- 1.5	18	70
	W	50.3	14d	5.7	Vsf- 0.5	18	90
	V-F	86.5	6h	4.5	Mwf -2.5	21	50
	D	65.5	7d	13.6	N	24	100
	C (R)	65.5	-	-	Dw- 5.0	15	0
	C (S)	65.0	-	-	Dw- 5.0	15	0

B: Boucherie; W: Wick process; V-F: VAC-FRI; D: Diffusion; C (R): Control (Round); C(S): Control (Split)

***Level of deterioration**

N	0	No attack (Normal)
Vsw	0.50	Very mild termite attack
Vswf	0.75	Very mild termite and fungal attack
Swf	1.50	Mild termite and fungal attack
Mw	2.00	Moderate termite attack
Mw+Vsf	2.25	Moderate termite and very slight fungal attack
Mf+Sw	2.50	Moderate fungal and slight termite attack
Mwf	3.00	Moderate termite and fungal attack
Bf+Sw	3.50	Severe fungal and slight termite attack
Bw+Sf	3.50	Severe termite and slight fungal attack
Bf+Mw	4.00	Severe fungal and moderate termite attack
Bw+Mf	4.00	Severe termite and moderate fungal attack
Bwf	4.50	Severe termite and fungal attack
Dw	5.00	Destroyed by termite attack
Df	5.00	Destroyed by fungal attack
Dwf	5.00	Destroyed by termite and fungal attack

observed after 18 months of installation, thus all the treatments exhibited potential protection against fungal decay. D, B, and W processes imparted substantial protection even after 24 months of installation. CCB treatment had protected *B. nutans* efficiently as compared to CCA (Tripathi and Nautiyal, 2008). Early decay of untreated bamboo shows its non-durable nature.

Bambusa balcooa

Bamboo culms were treated at 43-48.5 per cent moisture content and a lower retention of preservative *i.e.*, 5.6 to 6.8 kg/m^3 was achieved by different processes. W and V-F processes exhibited 5.6 kg/m^3 retention, while slightly higher *i.e.*, 6.7 to 6.8 kg/m^3 retention was achieved by D and B processes (Table 1). Untreated *B. balcooa* specimens exhibited more natural durability, *i.e.*, 15 months as compared to *B. nutans*. *B. balcooa* treated with CCB by Boucherie was severely affected by fungi and termite exhibiting 4.5 score level; it is contrary to the results of *B. balcooa* treated with CCA by B process which performed best exhibiting 100 per cent of the samples running in field after 24 months of installation (Tripathi and Nautiyal, 2008). Whereas, 80 per cent of specimens treated by W and D processes were affected by mild termite attack *i.e.*, level of deterioration was 1.0. *B. balcooa* could not be protected substantially after treatment with B and V-F processes. Control samples were attacked by termites and fungi and exhibited higher natural durability *i.e.*, 15 to 21 months as compared to *B. nutans* and other species.

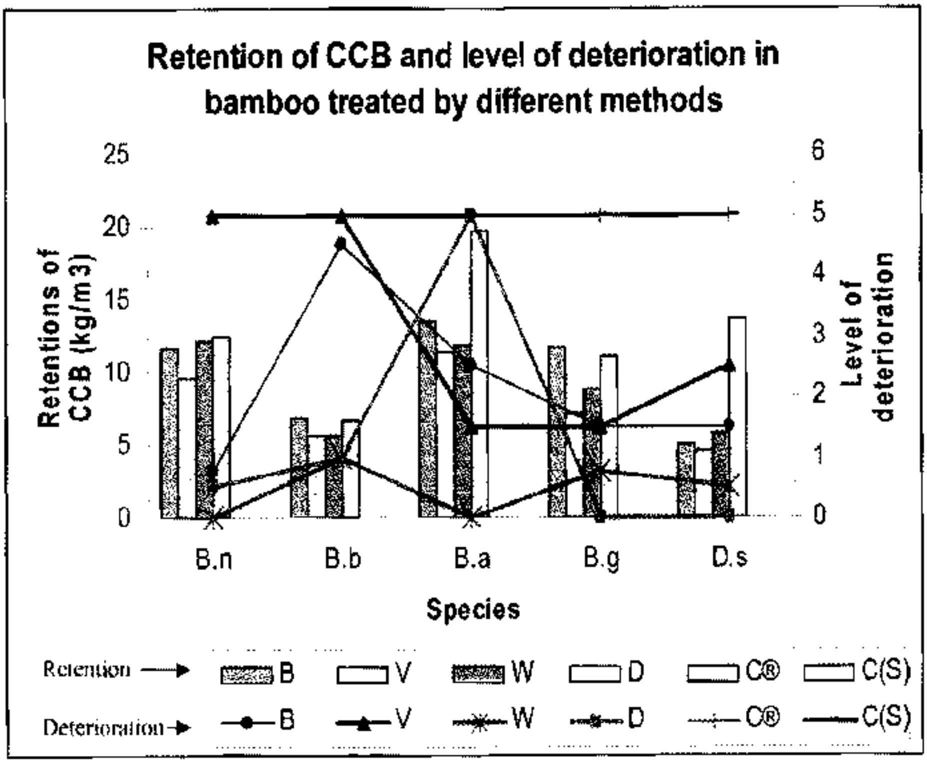
Bambusa bambos

The treatment was done at moisture content 79 to 88.2 per cent. The species exhibited 18 to 21 months of natural durability. Although all processes exhibited comparatively high retentions *i.e.*, 11.3 to 19.7 kg/m^3 of CCB, but only W and V-F processes provided remarkable protection to the samples. Cent per cent samples treated with W process were normal in the field even after 24 months of installation. Control samples of this species deteriorated between 18 to 21 months, whereas, treatment with W process has completely protected the samples after treatment. Study shows that treatment by B process was completed in 5 h and it yielded 13.5 kg/m^3 retention but only 50 per cent samples were normal after 18 months and 50 per cent of samples were affected moderately by termite exhibiting score of 2.5. Wick process yielded only 11.8 kg/m^3 of retention but it had exhibited better performance of samples in the field as compared to B treatment. It is interesting to note that higher retention of (13.5 kg/m^3) of preservative in bamboo by B process performed less satisfactorily as compared to the bamboo with lower retention (11.8 kg/m^3) by W process. The possible reason may be that the slow process of treatment might have helped in better distribution of preservative. V-F process took 8 h to treat bamboo and it yielded 11.3 kg/m^3 of retention exhibiting only mild termite attack (1.5 score) on 50 per cent of samples after 21 months. Treatment by diffusion process took 7 days and yielded higher retention (19.7 kg/m^3) but contrary to the above results all the samples were completely destroyed by fungi after 18 months. Study reveals that it is not only the retention of the preservative but other factors which are responsible for its performance in the field.

Dendrocalamus giganteus

The performance of this species was improved after treatment with CCB. It took only 4 and 5 h to treat bamboo by B and V-F processes respectively, while W and D processes took 14 and 7 days respectively. Considerable retention of preservative *i.e.*, 11.6 and 11.0 kg/m^3 could be achieved by B and D processes whereas, lower retention (7.1 kg/m^3) was achieved by V-F. W process could impart better retention (8.8 kg/m^3) as compared to V-F process.

Control samples were severely attacked by termites and fungi; control samples in split form exhibited life of 21months, while in round form it exhibited natural durability of 18 months. It was observed that bamboo samples were severely attacked by fungi from the cut ends which was buried in ground; only siliceous epidermal layer was left as such and inner part of the wall was completely deteriorated. Very mild termite and



B: Boucherie; W: Wick process; V-F: VAC-FRI; D: Diffusion; C(R): Control (Round); C(S): Control (Split)

Figure 1. Retention of preservative (CCB) in different species of bamboo and level of deterioration (Scale) in graveyard test

fungal attack (Vswf 0.75) was observed on 15 per cent of the samples treated by W process and after 18 months of installation 85 per cent of the samples are still in sound condition. No deterioration could be seen on any samples treated by D process. Mild termite and fungal attack (1.5 score) was found only on 30 per cent of the samples treated by V-F after 18 months of installation, and 70 per cent of the samples are in good condition. Thus, *D. giganteus* performed best among all other species tested in the field (Table 1, Fig. 1).

Dendrocalamus strictus

This species performed excellently after treatment with CCB by W and D processes. It took 4 h to treat bamboo by B, 6 h by V-F, 7 days by D and 14 days by W processes and maximum retention (13.6 kg/m^3) was achieved by D process. Whereas, retention of preservative by other processes ranged between 4 to 5.7 kg/m^3. Although retention levels were much lower in bamboo treated by B, W, and V-F processes, but the performance of samples was excellent in the field. Samples treated by B process exhibited only mild termite and fungal attack (Swf score 1.5) on 30 per cent of samples after 18 months of installation. Whereas, samples treated by W process exhibited only very mild fungal attack (Vsf score 0.5) on 10 per cent of samples after 18 months of installation and 90 per cent of samples are in good condition in the field. Bamboo treated by V-F process exhibited moderate termite and fungal attack on 50 per cent of samples after 21 months of installation. *D. strictus* treated by D process imparted 13.6 kg/m^3 CCB retention and 100 per cent of samples were normal even after 24 months of installation. Therefore, encouraging results were obtained after treatment by D process.

Control samples were completely damaged by termites within 15 months. Thus, natural

Table 2. Mean deterioration (%) observed in different species of bamboo treated with CCB by different methods

Treatments	Bamboo species					Mean*
	B. n	*B. b*	*B. a*	*D. g*	*D. s*	
B	15.50	91.33	49.50	28.00	30.00	42.86
	(23.16)	(72.88)	(44.69)	(31.92)	(33.19)	(41.17)
W	1.00	20.83	2.83	14.50	9.33	9.70
	(3.97)	(27.14)	(8.70)	(22.36)	(17.77)	(15.99)
V-F	97.83	99.50	50.00	30.50	49.33	65.43
	(83.27)	(87.65)	(44.98)	(33.50)	(44.60)	(58.80)
D	10.50	19.83	98.50	2.16	2.66	26.73
	(18.87)	(26.41)	(84.37)	(5.96)	(8.44)	(28.81)
Control	99.33	99.00	99.00	99.00	98.50	98.96
	(86.69)	(85.99)	(85.34)	(86.12)	(85.10)	(85.85)
Mean	44.83	66.10	59.96	34.83	37.96	
	(43.19)	(60.01)	(53.62)	(35.97)	(37.82)	

*Values in parenthesis are arcsin values

$CD_{(0.05)}$ = Species = 0.74; Treatments = 0.74; Species X Treatments = 1.64; B: Boucherie;W: Wick process; V-F: VAC-FRI; D: Diffusion; C(R): Control (Round); C(S): Control (Split)

Table 3. Simple Correlations 'r' between moisture content, treatment time, preservative level and level of deterioration

	Moisture	Time	Retention	Deterioration
Moisture	1.000	.162	.164	.083
Time	.162	1.000	.744**	-.716**
Retention	.164	.744**	1.000	-.478*
Deterioration	.083	-.716**	-.478*	1.000

** Correlation is significant at 0.01 level (2-tailed):* Correlation is significant at 0.05 level (2-tailed)

durability of *D. strictus* is better than that of *B. nutans* and at par with *B. balcooa,* whereas *B. bambos* and *D. giganteus* exhibited better natural durability as compared to *D. strictus*. This confirmed the earlier observations on natural durability of bamboos reported by Purushotham *et al.* (1954). According to durability classification (IS:401), bamboos thus fall in Class-III (non-durable category) with little variation in natural durability among different species (Table 1). The level of deterioration caused by termite and fungi in different bamboo species treated by various methods was subjected to ANOVA at a significance level 0.05 for performance of species with and without treatment (Table 2). It can be concluded that bamboo treated with CCB by W process exhibited minimum decay (9.70%) followed by D (26.73%), B (42.86%), and V-F processes (65.43%). W process performed best followed by D and B processes, V-F process was found least effective. The performance of species is in the order of *D. giganteus* > *D. strictus* > *B. nutans* > *B. bambos* > *B. balcooa.* However, earlier studies conducted by the same methods on the same species with CCA preservative exhibited the performance of the species in the order *D. strictus* > *D. giganteus* > *B. balcooa* > *B. bambos* > *B. nutans*. (Tripathi and Nautiyal, 2008). Similarly, treatment methods in the present study were also compared and these were in the order Wick>Diffusion> Boucherie>VAC-FRI>Control (Table 2). Therefore, it can be stated that the field performance of bamboos is preservative and treatment specific.

It is well known that moisture content greatly influences treatment of bamboo especially in the green condition, where the movement of preservative occurs via diffusion of sap (Kumar *et al.*, 1994). Besides this, treatability of bamboo also plays an important role to set adequate loading of preservative. Earlier studies on treatability of bamboo (Kumar and Dobriyal, 1992) suggest that anatomical structure and moisture content both greatly influence the treatment of bamboo. Moisture content which plays an important role in sap displacement processes of bamboo treatment was correlated (r) with treatment time, retention and level of deterioration in different bamboo species.

Correlation (r) among all the parameters is shown in Table 3. A significant positive correlation (r = + 0.74; P< 0.01) could be observed between treatment time and retention of preservative. Negative and significant correlation (r = - 0.48; P< 0.05) was found between retention and deterioration of bamboo. Negative and significant correlation (r = - 0.72 P< 0.01) was found between treatment time and level of deterioration. Therefore, it can be concluded that more the treatment time, more will be the retention levels of preservative. However, no significant correlation between moisture content and deterioration level was found in the study, contrary to the earlier reports (Kumar *et al.*, 1994). Therefore, early deterioration at low levels of preservatives can be easily explained by negative and significant correlation between retention and deterioration. The present study suggests that there is a need to see the cumulative effects of factors responsible for deterioration of samples.

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