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Staining effects on moisture resistance and gloss of lacquer coated bamboo surfaces

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Abstract: An experiment was conducted to study the effect of staining on moisture resistance and gloss of lacquer coated bamboo surfaces. Strips of *Bambusa nutans, B. polymorpha* and *Dendrocalamus giganteus* were stained with commercial teak, rosewood and walnut stains. These strips were then given two coats of lacquer. For comparative analysis, one set of unstained lacquer coated samples of the three species were also prepared. Moisture resistance properties were studied in a humidity and temperature controlled chamber. In general, gloss of the surfaces got enhanced by staining the strips. All the three stains were found to be able to give attractive colours and enhance the lustre of the surfaces of *B. nutans*. *D. giganteus* exhibited more gloss in addition to having a new colour when coated with lacquer after staining, only with rosewood stain. Overall, the best stain in enhancing gloss of all three species was found to be the rosewood stain. Only *B. polymorpha,* which has relatively large lumens exhibited increases in moisture intake after staining.

Key words: Bamboo, gloss, lacquer, moisture resistance, staining

INTRODUCTION

Bamboo has a very long history and this nature's most valuable gift for rural India, belongs to the family *Poaceae*. It represents one of the greatest alternative sources of lignocellulosic material found mostly in tropical and subtropical zones of the world (Papadopoulos *et al*., 2004; Pannipa *et al*., 2011). It is one of the most important minor forest products which provides subsistence income to tribal communities (Sundriyal *et al*., 2002). According to Suri and Chauhan (1984) India is the home of 136 indigenous species and 11 exotic species of bamboos belonging to 30 genera. Among these, *Bambusa* and *Dendrocalamus* are most widely distributed. India is the second richest country after China in terms of bamboo genetic resources with 9.57 million hectares of forest area under bamboo cover which constitutes about 12.8% of the total area under forests (Bahadur and Jain, 1981; Tewari, 1992). Its versatile uses include building and structural applications like bridges.

Bamboo is a lignocellulosic material whose dimensional stability is dependent on its hygroscopicity and the prevalent surrounding environmental conditions. Extreme variations in these surrounding conditions e.g. temperature, relative humidity (RH), moisture, will almost always affect unprotected/untreated bamboo material in service,

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particularly where these variations are detrimental to certain applications (Erakhrumen and Ogunsanwo, 2009). As a lignocellulosic material, it is expected that bamboo will absorb and/or release moisture to the surrounding environment at the required temperature and RH, as also influenced by the species' equilibrium moisture content (EMC) and/or fibre saturation point (FSP).

Though bamboo has been in use for centuries, investigations on its finishing properties are rather scarce. *Dendrocalamus giganteus,* which can grow up to 30 m in height and 20-25 cm in diameter, is the biggest of the Indian bamboos. The sections cut from the culms are reported to be useful as water buckets and boxes (Suri and Chauhan, 1984). The mechanical properties of this species have been studied and were compared with other structural bamboos (Sattar *et al*., 1994). The usefulness of this bamboo species in making composite laminated beams and as columns after filling with concrete were also reported (Lima Junior and Dias, 2001; Lima Junior *et al*., 2010). Treatment by urea has been reported to be useful in controlling seasoning defects in this bamboo (Upreti *et al.,* 2005). Though no work on finishing in *D. giganteus* is reported, it was found that varnish performed better than linseed oil finish or French polish in controlling water uptake into strips of *D. strictus* (Kishan Kumar *et al*., 2008).

Finishing of bamboo surface is done to maintain the dimensional stability and to enhance its aesthetic value. Coatings give glossy appearance to the surfaces and make them look attractive. They also act as a barrier for moisture exchange between the surface and surroundings. Stain is composed of the same three primary ingredients as finishes (pigment, solvent, and binder) but is predominantly pigment (or dye) and solvent with little binder. Stain is designed to add colour to the substrate. Unlike finishes, stains do not provide a surface coating or film. The binder from a stain resides mainly below the surface while the pigment remains near the top or at the surface. Stains can provide colour stability even against UV (Goktas *et al*., 2008).

The primary function of applying a finish (paint, varnish etc.) on to the surface of a wood or bamboo product is to protect the surface, help maintain an attractive appearance, provide a cleanable surface and above all to retard moisture exchange between the product and the surrounding atmosphere. Gloss of a surface coating is one aspect which augments the aesthetics of a wood or bamboo product. The ability of a coated surface to reflect light decides this property (Zivkovic, 2004). This property often finds importance in quality evaluation of a product, especially where the aesthetic appearance of the product is of importance. Although bamboo can be used both outdoors and indoors without finishing, unfinished surfaces exposed to the weather change colour and are roughened by photo-degradation mainly due to degradation in lignin polymer in the cell wall. As the lignin is degraded, water leaches out degradation products and washes away loosened surface cellulose fibers, causing a rough surface (Feist *et al*., 1991). The more important aspect of dimensional stability depends on the exchange of moisture the product undergoes with the atmosphere. Schniewind and Arganbright (1984) suggest that coatings can be effective in achieving a measure of dimensional stability for wooden objects through checking moisture exchange.

Lignocellulosic materials undergo rapid surface degradation upon exposure to light and water (Evans *et al*., 1992). For value added products, providing a suitable colour to the bamboo plays an important role. It is against this background that a study was initiated into the surface gloss and moisture uptake of three lacquer coated and stained bamboo species.

MATERIALS AND METHODS

The study aimed at investigating the effects of three different commercial stains (Teak, Walnut and Rosewood) that can affect the gloss and moisture properties of lacquer coated bamboo strips of three different species: *Bambusa nutans, B. polymorpha* and *Dendrocalamus giganteus.*

Twenty strips of approximate length 16.5 cm and width 2-3 cm were prepared for the three species used in the study according to material availability. These strips were sanded to smooth surfaces using 60, 80 and 120 grit sized sand papers progressively.

The 20 strips in each bamboo were subdivided into four sets consisting of 5 samples each. One set was given two coats of lacquer and was used as the control set (C). The samples in the second set were stained with walnut stain by applying the stain with a cloth on to the sanded surface. After the stain dried fully, these samples were coated with two coats of lacquer and this set was designated as the walnut-stained set (W). In a similar fashion, two more sets using teak wood stain (T) and rosewood (R) stains were prepared. Thus there were 5 unstained samples and 15 stained samples in one bamboo. Four sets of similar samples were prepared for the other two bamboos also. Thus, in total there were 60 samples in the study.

Gloss measurements

A Tri-Micro Gloss meter was used to measure the gloss of the coated bamboo strips in the study. Fifteen random gloss measurements were taken on the surfaces of samples in each set. For a single species there were 60 gloss readings measured. The measurements were taken at 60^{o} (Sen, 2000). This was used to analyze the change in glossiness due to various stains.

Moisture uptake measurements

After the gloss measurements were completed, the sixty strips were kept in a humidity and temperature controlled chamber. The technique of moisture uptake studies conducted by Forest Products Laboratory, Madison was followed in this experiment (Feist *et al*., 1985). The samples were conditioned at 35C and 30% RH. The weight of each strips were monitored until the strips attained constant weight (conditioned weights). Thereafter, the RH inside the chamber was raised to 90%. The weight of the strips were monitored periodically until it became constant.

Evaluation

The change in gloss due to staining was calculated as

$$\text{Gloss change \%} = \frac{(\text{Gloss of stained sample - Gloss of unstained sample})*100}{\text{Gloss of unstained sample}}$$

The moisture uptake was calculated as:

$$\text{PWG} = \frac{(\text{Final weight - Conditioned weight})*100}{\text{Conditioned weight}}$$

where, PWG is the percent weight gain.

Statistical analysis of data was performed using SPSS package.

RESULTS AND DISCUSSION

There are reports published to improve the gloss of lacquer by addition of inorganic pigments (Kohler *et al*., 1982). Against this background, analysis was done to observe the effect of stains on the gloss of lacquer coating used. All the stains used brought attractive colours on the strips. The teak stained samples attained a golden tinge. The walnut stained samples in general had a golden-blackish look. The rosewood stained samples were the darkest with a hue of reddish-black. The results obtained on the gloss and moisture uptake studies are presented below.

Gloss studies

The mean gloss values were measured on the coated samples. These ranged between 13.3 to 42.6 GU. To understand the difference in the gloss values, individual values were analysed using ANOVA (at 95% confidence interval) and the results are given in Table 1.

Table 1: ANOVA of gloss values measured on the three bamboo surfaces

Source of variation	Df	Mean Square	F	Sig.
Gloss on *B. polymorpha*	3	577.44	19.51	<0.001
Error	56	29.60		
Gloss on *B. nutans*	3	212.09	6.39	0.001
Error	56	33.17		
Gloss on *D. giganteus*	3	520.84	2.87	0.045
Error	56	181.73		

Table 1 indicates that the gloss values are indeed significantly different for the samples of each of the bamboo species studied. To clearly understand their individual behaviour due to staining, Duncan's subsets of the gloss values were formed for each of the three species. The subsets thus obtained are given in Table 2.

Table 2: Duncan subsets for gloss values (GU) measured on the three bamboo surfaces with stains and without stains

Stain used	N	Subsets for BP		Subsets for BN		Subsets for DG	
		1	2	1	2	1	2
Unstained	15	24.8		13.3		29.7	
Teak	15	24.9			18.8	31.3	
Walnut	15	28.8			21.1	31.7	
Rosewood	15		38.0		21.4		42.6
Sig.		0.057	1.000	1.000	0.241	0.703	1.000

BP - *Bambusa polymorpha*
DG - *Dendrocalamus giganteus*
BN - *Bambusa nutans*

In the case of *B. polymorpha* and *D. giganteus* only the rosewood stain has helped in bringing about a significantly higher gloss to the strips. i.e., the rosewood stain brought about a good colour to the strips of both these species but also can cause the product to have more lusture when coated with lacquer after staining. On the other hand, the other two stains have neither increased nor decreased the gloss of the strips of these species. Thus, the teakwood and walnut stains are useful in giving good colours to the products made with these bamboos without compromising on the lusture when coated with lacquer.

B. nutans illustrates an entirely different behaviour as evident from Table 2. All the three stains used are found to be equally effective in enhancing the gloss on lacquer application to the surface. Thus, all the three stains were able to give good colour to the products made out of *B. nutans*, but also enhance the lusture of them. Having looked at the actual gloss values measured, it would be more interesting to have an understanding of the actual gloss enhancement caused by the stains. The gloss enhancement percentages calculated are shown in Fig. 1.

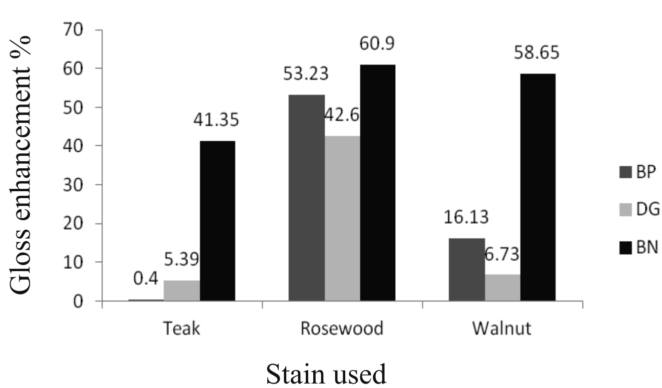

Figure 1: Gloss enhancement percentage due to staining

Fig. 1 is indicative of the fact that the gloss values of *B. nutans* show considerable enhancement (in the range of 41 to 61 %) with the three stains applied. Rosewood stain results in good gloss enhancement (42-61 %) on the surfaces of all the three bamboos. Teak and walnut stains result in comparatively lower enhancements (0.4-16.13 %) on *B. polymorpha* and *D. giganteus* surfaces. It is pertinent to note that an increase of 25% in gloss of varnished poplar wood surfaces has been reported by giving a prior staining through ammonia fumigation before applying the surface coat (Gupta *et al.*, 2007)

Moisture uptake studies

This aspect was studied through the percentage weight gain (PWG) achieved by the samples due to high humidity exposure. The average of percentage weight gains (PWG) shown by the stained and unstained samples of the three bamboos coated with lacquer are shown in Fig 2.

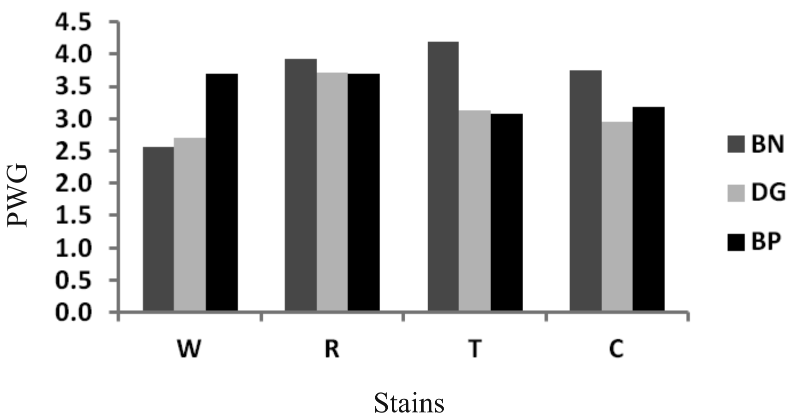

Figure 2: Percent weight gains exhibited by stained and unstained bamboo strips

Fig. 2 is indicative of the fact that the moisture uptake of *B. nutans* show highest PWG without any stains applied. This is in spite of the fact that freshly felled *B. nutans* are reported to have less moisture in their columns compared to *D. giganteus* and *B. polymorpha* (Rehman and Ishaq, 1947). Jain and Pandey (1992) have reported the moisture content of *D. giganteus* to be 97.3% at the bottom gradually falling to 56.7% at a height of about 22 m. This trend is true with teak stained samples as well. Since the results do not show any clear pattern, the observations on PWG were analysed species-wise using one-way ANOVA. As the percentage weight gains were of low values (generally <5 %) these were first square root transformed before running the ANOVA (Ahrens *et al.*, 1990).

PWG response of each bamboo to different stains

Table 3 gives the ANOVA results of the PWG of stained and unstained samples of the three bamboos studied.

Table 3: One-way ANOVA of the PWG of the stained and unstained bamboos

Species	Df	Mean Square	F	Sig.
BP	3	0.040	20.0	<0.001
Error	16	0.002		
BN	3	0.203	6.54	0.004
Error	16	0.031		
DG	3	0.081	0.59	0.633
Error	16	0.138		

Table 3 reveals that except for *D. giganteus*, the other two bamboos exhibit different moisture uptake properties among themselves. Duncan's subsets were formed with transformed PWG values of these two bamboos to understand this behaviour which are illustrated in Tables 4 and 5.

Table 4: Duncan's subsets transformed values of PWGs of *B. polymorpha*

Stain used	N	Subset	
		1	2
T	5	1.76	
C	5	1.78	
W	5		1.92
R	5		1.92
Sig.		0.358	0.947

Table 5: Duncan's subsets transformed values of PWGs of *B. nutans*

Stain used	N	Subset	
		1	2
W	5	1.59	
C	5		1.93
R	5		1.98
T	5		2.04
Sig.		1.000	0.378

Tables 4 and 5 give interesting results as far as the role of stain in moisture uptake is concerned. In *B. polymorpha* (Table 4) teak stain is able to give colour to the bamboo without affecting the moisture blocking capacity of the lacquer coated bamboo. The other two stains adversely affect the moisture blocking property of this coated bamboo. On the other hand, in the case of *B. nutans* (Table 5) the walnut stain helps in reducing PWG along with giving colour. However, the other two stains give colour without affecting the PWG. As seen from Table 3, in the case of *D. giganteus*, none of the stains used affect the PWG.

It is inferred that all these three stains can be safely used on *B. nutans* and *D. giganteus* without compromising the moisture blocking capacity of lacquer coating. The anatomical differences between the three bamboos seem to be contributing to the differences found in the moisture intakes. For instance, *B. nutans* with a smaller lumen size of 2.77 µm (Hurter and Eng, 2002; Clayton *et al*., 2006) resulted in lower moisture intake at least with one stain (Table 5). *D. giganteus* with a medium lumen size of 5.66 µm (Hurter and Eng, 2002) remained unaffected by staining as far as moisture intake is concerned. On the other hand, *B. polymorpha,* which has large lumen sizes up to 13 µm (http://uses.plantnet-project.org/en/Bambusa_polymorpha) exhibited more moisture intake with two stains (Table 4).

CONCLUSIONS

From the study, it can be concluded that the hygroscopicity of lacquer coated *B. nutans* and *D. giganteus* do not get adversely affected by staining which augments their glosses in addition to providing new shades which would be very helpful for the bamboo handicrafts sector. *B. polymorpha*, which has relatively larger lumens showed a small increase from 3.5% to 3.7% in moisture uptake but the gloss augmentation and colouration are found in this species also.

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