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Lengthwise durability against termites and fungi of *Bambusa bamboos* (L.) Voss and *Dendrocalamus strictus* (Roxb). Nees grown in wet and dry zones of Karnataka, India

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ABSTRACT: The durability of bamboo depends on many factors like the species, edaphic conditions of its growth and also the position of the culm. *Bambusa bamboos* and *Dendrocalamus strictus* are the most commonly grown important commercial bamboo of South India. Experiments were conducted to investigate the durability of *B. bamboos* and *D. strictus* of these 2 species collected from the dry and wet zones in Karnataka. Durability against termites was tested as per IS: 4833-1968 at the termite test yard at Nallal test yard and observations were taken for a period of 36 months. The 36 month observation indicates that *B. bamboos* and *D. strictus* collected from the dry zone were more resistant to termites. The durability test against fungi was conducted as per standard under laboratory conditions by using the white rot and brown rot fungus. The results revealed that in *D. strictus*, culms of wet zone are more durable when compared to culms of dry zone, and in case of *B. bamboos*, dry zone culms are more durable than those of the wet zone. However, the length wise durability of selected bamboos against termites and fungi followed a fixed pattern where the bottom portion of culm showing more durable followed by the middle and the top portion.

Keywords: Bamboo, Dry and wet zone, Durability, Fungi, Termites

INTRODUCTION

Bamboo shows less natural durability compared to wood, due to the shortage of certain chemicals which are present in most woods, but are absent in bamboo. Natural durability is dependent on species, climatic conditions and types of use. Since bamboo lacks heartwood, they lack natural resistance to the insects and fungal decay. Consequently, their use is restricted to low cost housing in rural and tribal areas. The fast growing rate and short maturity period has made bamboo an excellent alternate structural material. Following the fast depleting supplies of wood, engineers around the world are putting great efforts to substitute wood and even steel, with bamboo (Kumar *et al*.,1998).

The natural durability of bamboo varies from species to species and location of use. Presently, no authentic data is available on the natural durability of commercial bamboo like *Bambusa bamboos* and *Dendrocalamus strictus* growing in wet zone and dry zone of Karnataka. In wet locations, fungal attack is predominant and may destroy bamboo within a few years depending on local conditions (Liese, 1959). Information on the natural durability of different bamboo species would enable one to select the bamboo species with better natural durability. Whether this bamboo would fulfil the desired service life requirement for a particular product would still remain a question. The lack of natural durability in bamboo is further compounded with the hollowness of the bamboo culms compared to the end to end massive cross-section of wood. The hollowness provides a safe refuge both to the insects and fungi. Systematic data on the natural durability when there is ground contact and exposed conditions are very

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limited. The present paper relates to the lengthwise natural durability and performance of bamboos grown in dry and wet zones, under graveyard tests against termites in the field and against fungi under laboratory conditions.

MATERIALS AND METHODS

Five full length culms of *B. bamboos* and *D. strictus* free from borer and fungal attacks were brought to the laboratory. One set was procured from the wet zone (Madikere) and the other from the dry zone (Bangalore). The culms were air dried and marked from top to bottom into 30 cms lengths having a node as per standard (IS: 4833-1968).

Field evaluation of the two air dried bamboo species *B. bamboos* and *D. strictus* procured from the wet zone and dry zone, were done at the termite test yard of the Institute at Nallal Research Field Station. Full culm of each species was taken and samples of 30 cms with a node were cut and numbered, from top to bottom. All the samples were mixed and half buried in the soil at the termite test yard following a completely randomized block design. The surrounding soil was firmly pressed around the stakes to ensure good contact with the soil. Observations of the stock were made at intervals of 6 months. During each observation, all the specimens were pulled out of the soil and evaluated for the extent of damage which was made according to the visual assessment and the specimens were re-implanted for further observations. Based on the visual observations on the levels of damage, the durability was assessed.

Bioassay of different Bamboo species against wood decay fungi

B. bamboos and *D. strictus* culms were received from both wet and dry zones. Three culms of *B. bamboos* and *D. strictus* collected from the commercial timbers for testing natural durability against the fungus test. Each culm from both types of samples were divided into three portions viz. top, middle and bottom. Test specimens were prepared from all the portions of the culm by splitting culm to the size of 1.9 x 1.9 mm. Test blocks were conditioned in incubator at 70% relative humidity and 24^{0} C to attain constant weight (W1) and then these blocks were subjected to accelerated laboratory test (IS: 4873-1968) employing agar block method in culture bottles. The test fungi viz. *Trametes versicolor & Trametes hirsuta* (white rot fungus) *and Polyporus meliae & Tryromyces palustris* (Brown rot fungus) were used the test was done in six replicates for each selected fungus.

RESULTS AND DISCUSSION

Natural durability of Bamboo against termites procured from Wet and Dry Zone

The durability of bamboo depends mainly on the climatic conditions and the physical environment. Experiments to investigate the influence of climatic conditions and physical environment on bamboo were carried out. The two bamboo species *B. bamboos* and *D. strictus* collected from wet zone and dry zone were subjected to graveyard tests, to study their durability against termites. The results of the 36 months observation are given in (Table 1 & 2). This study indicates that *B. Bamboos* and *D. strictus* collected from the dry zone were more resistant to termites compared to *B. bamboos* and *D. strictus* collected from the wet zone.

Table 1: Percentage of destruction by termites on *B. bamboos* (Wet Zone & Dry Zone) over a period of 36 months

Zone	Culm Position	Months after implantation (MAI)					
		6M	12M	18M	24M	30M	36M
Wet	Top	34.2	67.6	97.4	100.0	100.0	100.0
	Middle	38.4	69.7	96.2	100.0	100.0	100.0
	Bottom	33.3	73.1	93.2	97.4	98.0	99.0
Dry	Top	19.4	38.4	63.0	81.9	85.0	90.4
	Middle	23.2	54.1	75	97.4	100.0	100.0
	Bottom	17.2	36.4	55.6	82	85.0	90.0

Table 2: Percentage of destruction by termites on *D. strictus* over a period of 36 months

Zone	Culm Position	Months after implantation (MAI)					
		6M	12M	18M	24M	30M	36M
Wet	Top	34.2	67.6	97.4	100.0	100.0	100.0
	Middle	38.4	69.7	96.2	100.0	100.0	100.0
	Bottom	33.3	73.1	93.2	97.4	98.0	99.0
Dry	Top	19.4	38.4	63.0	81.9	85.0	90.4
	Middle	23.2	54.1	75.0	97.4	100.0	100.0
	Bottom	17.2	36.4	55.6	82.0	85.0	90.0

From the results, it was firstly observed after 6 months, that some of the bamboo stakes (dry and wet zone) of *B. bamboos* and *D. strictus* showed the onset of termite damage. Total damage on some of stakes of *B. bamboos* (wet zone) initiated after a period of 18 months of exposure to termites. With respect to the lengthwise durability of the culm, the bottom portion followed by the top and middle portion of the culm of *B. bamboos* (wet zone) was durable against termites. The same was in the case with *B. bamboos* (dry zone) i.e. the bottom portion of the culm was found more durable followed by the top and middle portion of the culm. Total damage of all the stakes of *B. bamboos* of the wet zone was observed after 36 months (Fig. 1).

Total damage on some of the stakes of *D. Strictus* (wet zone) was observed after a period of 12 months. The bottom portion followed by the top and middle portion of the culm of *D. strictus* (wet zone) was durable against termites. Total damage was not observed in stakes of *D. strictus* (dry zone) after the test period of 36 months. With respect to the lengthwise durability of this culm, the durability of the top portion was found more durable followed by the middle and bottom portion (Fig. 2).

Most properties of bamboo depend upon the species and climatic conditions under which they grow (Sekhar and Gulati, 1973). *B. bamboos* and *D. strictus* grown in the wet zone showed less durability against termites probably due to fast growth rate of bamboos, low maturity and its chemical composition was found more favourable to termite attack. It is also expressed that the chemical composition of bamboo influences the consumption and assimilation of food of termites (Mishra, 1979). It is therefore expected that with an increase in the growth rate of bamboo in the wet zone, an increase in the carbohydrate contents (free sugars and starch) is anticipated. The hemi-cellulose and cellulose groups constitute the major portion of carbohydrates in bamboo. Since, termites are considered xylophagous in habit and their food is considered to comprise of carbohydrates, cellulose and hemicellulose group as well as lignin which constitute the major parts of bamboo. Termites find it difficult to digest these components. However, termites are able to digest these components with the help of symbiotic association of micro-organisms and also partially by the action enzymes present in the termites (Mishra, 1980; Mishra and Sen Sarma, 1985 a, b). It was observed that the top, middle and bottom portion of the culm procured from the wet zone was more or less identical in their susceptibility to termites i.e. from the top to bottom portion of the culm (Fig. 1).

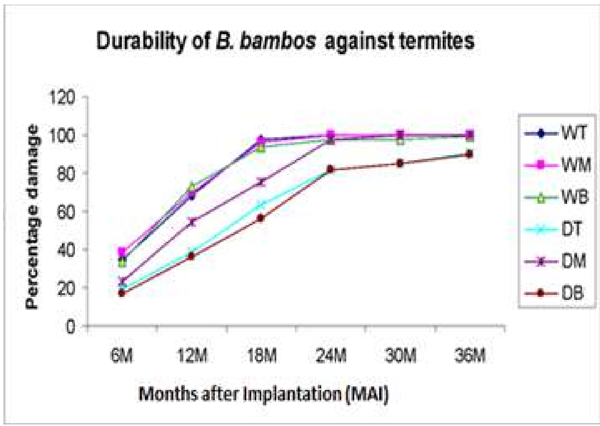

Figure 1: Durability of *B. bamboos* (wet zone and dry zone) against termites

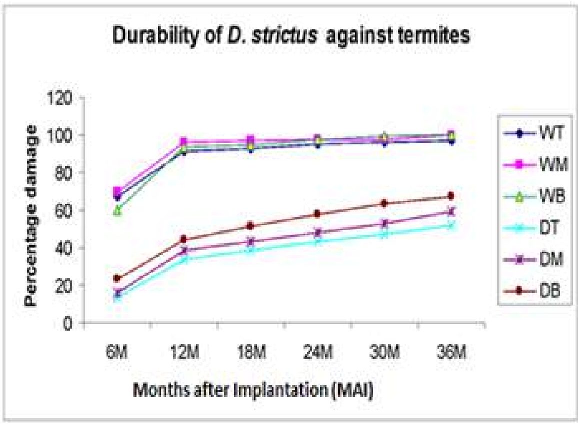

Figure 2: Durability of *D. strictus* (wet zone and dry zone) against termites

Bamboos grown in dry zones showed slow growth and its chemical composition was found less favourable to termite attack. Bamboos that grow in poor dry soils are usually more solid than those grown in rich soils. *D. strictus* growing in drier part of western India, generally, has solid culms (Kadambi, 1949). The same results were observed with *D. strictus* of dry zone i.e. only 60 % damage was found in *D. strictus* stakes tested for a period of 36 months. The middle portion followed by the top portion was more durable than the bottom portion of the *D. strictus* culm of the dry zone (Fig. 1). *B. bamboos* of the dry zone showed 80 % damage during the same test period. The top and bottom part of the culm was more durable than the middle portion in *B. bamboos* of dry zone (Fig. 2).

The other factors which contribute to the durability of bamboo are maturity. *D. strictus* showed an increase in strength values between 2.5 to 4 years. Thereafter, the strength starts falling (Sekhar *et al.,* 1991). To possess an optimal strength, the bamboo is required to reach a 'maturity age'. Consequently, it is not known whether these bamboo samples tested had reached this maturity age. The outer rind in both the wet zone and dry zone bamboos was found to be immune to attack by termites because of the presence of hemi-cellulose groups. This hemi-cellulose and cellulose was bound by lignin, providing stiffness and toughness to the plant tissues. This lignin was found to interfere with the digestion in termites by binding to the digestive enzymes and the carbohydrate substrate in the termites gut and considered indigestible (Howe and Westley, 1988). Bamboo grown on slopes is stronger than bamboo grown in valleys, and that bamboo that grows in poor dry soils are usually more solid than those grown in rich soils.

Table 3: Percentage of destruction by termites on commercial bamboo *B. bamboos* and *D. strictus* over a period of 36 months

Zone	Culm Position	Months after impregnation					
		6M	12M	18M	24M	30M	36M
Wet	Top	30.0	55.7	61.7	65.0	71.7	80.0
	Middle	40.0	62.3	68.3	73.3	80.0	90.0
	Bottom	35.0	59.0	66.7	75.0	80.0	83.3
Dry	Top	31.7	59.7	65.0	71.7	75.0	80.0
	Middle	15.0	44.0	48.3	51.7	55.0	63.3
	Bottom	6.7	19.3	26.7	30.0	35.0	40.0

In commercially available bamboos viz. *B. bamboos* and *D. strictus*, it was first observed that after 6 months some of the bamboo stakes showed the onset of termite damage. The top, middle and bottom part of the culm of *B. bamboos* showed more or less the same durability against termites. All the stakes of *B. bamboos* did not show 100% damage during the entire test period of 36 months (Table 3).

Commercial bamboo, *D. strictuss* takes showed better durability compared to *B. bamboos*. The bottom portion of the culm was found more durable against termites followed by the middle and top portion of the culm. All the stakes of *D. strictus* did not show 100% damage during the entire test period of 36 months (Fig. 3).

Nitrogen requirement is considered high among termites, for their growth and development and its reduction or low content could lead to stress (Mishra and Sen Sarma, 1985b). Consequently, Nitrogen content in bamboo is directly related to termite damage i.e. higher nitrogen content leads to greater damage and vise versa. *B. bamboos* with 0.35 % Nitrogen is considered more susceptible to termite damage compared to *D. strictus* with 0.26 % nitrogen.

Ash or mineral content constitute a minor portion of bamboo. Its value is highest in outer skin ranging from 4.25% to 5.25%, maximum being in *D. strictus* and minimum being in *B. bamboos*. Higher quantities of ash and mineral content is not preferred by the termites and is not absorbed by their body and are thrown out in the faeces. Moreover, termites avoid food rich in ash beyond a particular level. Hence, it was observed that a maximum weight loss percentage was observed in *B. bamboos* compared to *D. strictus* (Seema *et al.*, 2007).

The presence of crystal form of silica in Bamboos (Chauhan and Rao, 1992) generally inhibits digestion and is called digestibility reducers. (Howe and Westley, 1988). Silica content was observed to be maximum in *D. strictus* (1.75%) and minimum in *B. bamboos* (1.25%). Irrespective of species a minimum of (0.79%) was found in the middle layer and maximum of (2.33%) was found in the outer layer followed by the inner layer (1.75%). It was observed that the outer skin was highly resistant to termites and these termites preferred to gain entry into the bamboo culm from the cut end. Consequently it was concluded that the silica content in bamboo was inversely related to bamboo attack and its presence played a prominent role in inducing resistance to termite damage on bamboo (Seema *et al.*, 2007) .

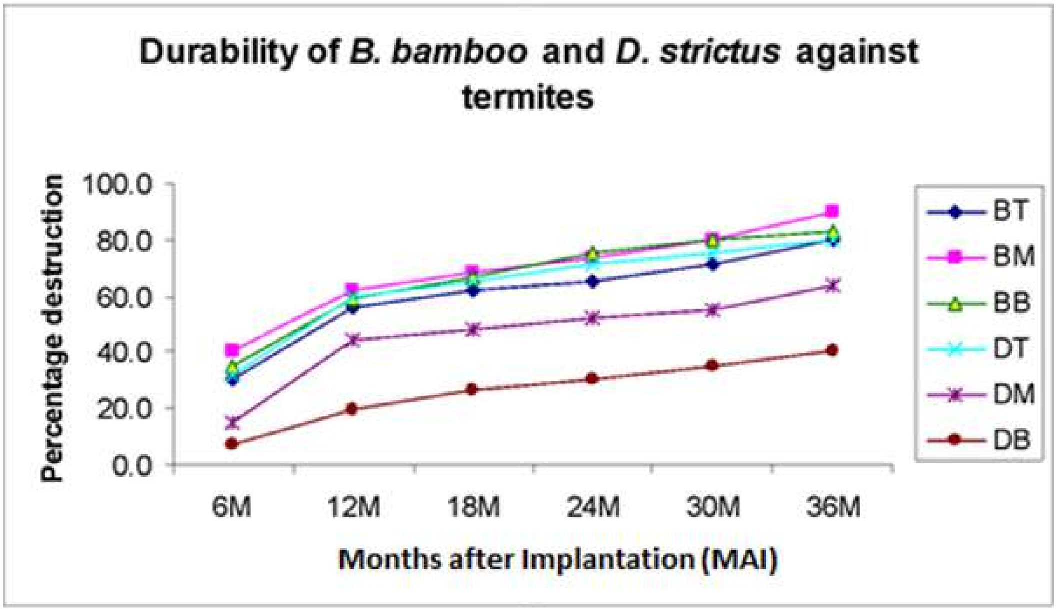

Figure 3: Durability of Commercial bamboo against termites *B. bamboos* and *D. strictus*

Indian species of bamboo was observed to contain higher lignin content with low silica and ash content. (Semana *et al*., 1967). Lignin and phenolic compounds were considered to contribute to some resistance both to termite and fungi (Abushama and Abdel Nur, 1978).

The natural durability of bamboo varies from species to species and location of utilization. Laboratory evaluations of 13 species of bamboo were carried out using a common wood destroying termite, *Microcerotermes beesoni* Synder. The results indicated that among the various species of bamboo tested, maximum damage was observed in *D. hamilitonii* (73.36% wt loss) and minimum was recorded in *B. nutans* (22.12% wt. loss) closely followed by *D. strictus* (25.63%), *B. balcoona* (27.42%) and *D. giganteus* (29.92%). Investigations revealed that a single component, such as starch or water soluble sugars, pentosans, cellulose or lignin do not influence the termite resistance quality of bamboo (Singh *et al.*, 1988).

Table 4: Weight loss bamboo grown in dry and wet zone*

Name of the fungus tested with		**Position of culm**	***D.s* Wet**	***D.s* Dry**	***B.b* Wet**	***B.b* Dry**
White rot	*Trametes hirsuta*	Top	9.31	48.87	17.10	10.48
	T. versicolor	Top	50.51	57.77	34.27	27.03
Brown rot	*Polyporous meliae*	Top	26.67	31.51	23.81	12.0
	Tryromyces palustris	Top	22.93	22.19	13.00	10,91
White rot	*Trametes hirsuta*	Middle	16.17	44.91	23.09	6.44
	T. versicolor	Middle	44.21	55.27	34.69	20.22
Brown rot	*Polyporous meliae*	Middle	18.52	36.81	22.88	10.73
	Tryromyces palustris	Middle	25.63	20.40	18.46	10.26
White rot	*Trametes hirsuta*	Bottom	43.72	56.12	24.72	4.62
	T. versicolor	Bottom	49.06	45.26	32.94	29.10
Brown rot	*Polyporous meliae*	Bottom	24.75	28.28	13.14	13.10
	Tryromyces palustris	Bottom	26.05	22.23	16.75	9.89

*Average of 6 replicates

Laboratory evaluation of Bamboo species for their durability against fungal decay

After 16 weeks, the test blocks were withdrawn from the culture bottles. Carefully brushed off the fungal mats and dried in the oven and again conditioned and weighed to obtain constant weight (W2). The percentage weight loss of each test block was calculated from the initial weight and weight after fungal exposure with the following formula.

$$\text{Weight loss \%} = \frac{W1 - W2}{W1} \times 100$$

Wet and dry zone bamboo

Weight losses against white and brown rot of *D. strictus* and *B. bamboos* with different portions of culms are given in Table 4 and Table 5 shows the average weight loss of white and brown rot with different portions of culms. In *D. strictus*, culms of wet zones are more durable when compared to culms of dry zones. Whereas, in *B. bamboos* the reverse is true; i.e. dry zone culms are more durable than wet zone. There is a definite pattern in durability of bamboo from different portions of the culm. Bottom portion of the culm is more durable and it starts decreasing from the middle and top portion of the culm.

Table 5: Average weight loss in top, middle, and bottom portion of culms of *D. strictus* and *B. bamboos* grown in wet and dry zone*

Culm Position	*D. strictus*		*B. bamboos*	
	Wet zone	Dry zone	Wet zone	Dry zone
Top	27.36	40.9	24.78	15.11
Middle	26.13	39.35	22.05	11.91
Bottom	35.9	37.97	21.88	14.16

*Average of 12 replicates

Commercial available bamboo

Various parameters influenced the natural resistance of bamboo including factors such as age, diameter, climate, environment and height. Untreated bamboo has an average life of less than 1-3 years, exposed to atmosphere and soil. Undercover the average life of these can be expected for more than 4-7 years. Under favourable conditions as rafters or frames average life could exceed 10-15 years (Liese, 1968).

Average percentage of weight loss of six replicates of individual fungus was shown in the table 6 & 7 which shows that both the species are durable; *D. strictus* is more durable compared to *B. bamboos*. The decay resistance increases from bottom to top portion of the culm in both the species. Generally, it is observed that white rots are more virulent in all bamboo species than brown rot. However, according to durability classification bamboo falls in class III (non- durable category) with little variation in durability among different species. Decay takes place in bamboo because of the high lignin and cellulose content.

Lack of toxic constituents and ready food source for organisms may be the reason for the non- durable category. The lignin present in bamboo is unique and undergoes changes during the elongation of the culm (Satish Kumar *et al.*,1994) which may be the reason for protection against brown rot. This confirms with the work of Liese, 1959; where he indicated that Bamboo is more prone to both soft and white rot attack than brown rot. Decay of culms is caused mainly by fungi, and these include; soft rot, white rot and brown rot. Bacteria also deteriorate culms under storage, with one or more of these organisms attacking the culms in succession. Colonization by the microorganisms and the severity of attack depend on the moisture content and nutrient status (starch content) in the culm, ambient temperature, humidity, etc. The culms of commercially available bamboo were too dry to absorb the required moisture for virulence of fungus. This may be the reason to get decay resistance and resistance class comes in this experiment is under class II (Bakshi, 1967). However, more work has to be carried out to see the moisture absorption capacity and ageing of the bamboo culms.

Table 6: Weight loss of in top, middle, and bottom portion of culms of commercially available *B. bamboos* and *D. strictus*

Bamboo species	Top		Middle		Bottom	
	White rot	**Brown rot**	**White rot**	**Brown rot**	**White rot**	**Brown rot**
B. bamboos	8.33	16.92	9.89	15.03	7.12	10.95
D. strictus	6.49	15.34	5.49	10.8	4.14	7.62

Table 7: Average weight loss of in top, middle, and bottom portion of culms of commercially available *B. bamboos* and *D. strictus*

Bamboo species	Top	Middle	Bottom
B.bamboos	12.63	12.46	9.04
D. strictus	10.92	7.79	5.88

Bamboo consists of 50-70% hemicellulose, 30% pentosans and 20-25% lignin (Tamlang *et al.*, 1980, Chen *et al*., 1985). Ninety percent of the hemicellulose is xylan, with a structure intermediate between hardwood and softwood xylans. Bamboo is known to be rich in silica (0.5-4%), but the entire silica is located in the epidermal layers, with hardly any silica in the rest of the cell wall. Although bamboo also has minor amounts of resins, waxes and tannins, none of these have enough toxicity to impart natural durability. Furthermore, the large amount of starch makes bamboo highly susceptible to attack by staining and decay fungi. The sclerenchyma fibers which are responsible for the strength of bamboo are attacked by fungi and its strength is reduced considerably.

Bamboo is susceptible to a large number of diseases causing fungi (e.g. decay fungi, soft rot, brown rot, etc.) in nature (Liese, 1970; Shukla *et al.,* 1988). The fungus infected wood is attractive to termites. It indicated that fungus was the primary invader in bamboo followed by termites in nature. Fungi can attack bamboo culms with sufficient moisture content, generally above 20%. Air dry bamboo is protected against fungi. Laboratory experiments have shown that bamboo is more rapidly deteriorated by white rot and particularly by soft rot fungi than by brown rotter's.

CONCLUSION

From the above results it could be concluded that the natural durability of *B. bamboos* and *D. strictus* of the dry zone showed better durability against termites compared to the bamboos of the wet zone. The durability of the commercially available bamboos of the above two species was also similar to the durability of the bamboos of the dry zone.

The durability results against fungi revealed that *D. strictus*, culms of wet zone are more durable when compared to culms of dry zone and in case of *B. bamboos*, dry zone culms are more durable than those of the wet zone

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