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Morphological assessment and susceptibility of bamboo to bio-degrading agents in Ghana

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Abstract: The search for suitable substitute for dwindling timber resources has led to the study of silvicultural and technological properties of different bamboo species. *Bambusa vulgaris* is the most dominant bamboo species found in Ghana and its utilization is limited to the basic and temporary products. The susceptibility to biodegradation as well as variation in morphological characteristics between the two varieties of the species found in Ghana was studied. Internodal length ranged from 26.9 to 34.0 cm for *B. vulgaris* and 24.4 to 32.6 cm for *B. vulgaris* var. *vittata*. Internodal length increased from the bottom to the middle and decreased towards the top portion for both varieties. The culm wall thickness ranged from 7.2 to 15.8 mm for *B. vulgaris* and 8.4 to 15.6 mm for *B. vulgaris* var. *vittata*. It decreased from the bottom to the top portion for both varieties. *B. vulgaris* var. *vittata* was rated more susceptible to deterioration by fungi and termites than *B. vulgaris*. The middle and top portions of both varieties were more susceptible to fungi and termites than the bottom portion. *B. vulgaris* was rated more susceptible to borer infestation than *B. vulgaris* var. *vittata* and the middle portion of both varieties was very susceptible, followed by the top and then the bottom portion.

Keywords: Morphological characteristics, susceptibility, biodegradation, visual rating

INTRODUCTION

Bamboo is one of the oldest and most versatile building materials with many applications in the field of construction. The diminishing wood resource and the restrictions imposed on felling in natural forests in the tropics have necessitated the identification of substitute material which is environmentally friendly, widely available and adaptable to varying climatic and edaphic conditions with properties superior to most juvenile fast growing woods. Bamboo emerged as the most suitable alternative (Jayanetti *et al.*, 1998). Chemically, bamboo consist of 40-50% cellulose, 20-30% pentosans and 20-30% lignin (Nakahara, 1995), and its anatomical constituents are: 50% parenchyma cells, 40% fibers and 10% conducting cells with vessels and sieve tubes (Liese, 2005).

According to Sharma (1980), there are about 75 genera and 1250 species worldwide

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and mostly confined to South- East Asia. Fifteen genera and 43 species of bamboo are native to Africa (Kigomo, 1997). *B. vulgaris* is one of the important sympodial bamboos widely distributed in Southwest China and elsewhere in the tropics (INBAR, 2006). *B. vulgaris* is the common native bamboo species in Ghana occurring in the reserves, community lands and farmlands in the forest zones of the country and accounted for about 95% of Ghana's bamboo resources (Oteng-Amoako *et al.*, 2005). About 70% of the local communities in Ghana use bamboo in one form or the other and majority of them are annual users of bamboo products (Tekpetey *et al.*, 2008). The potentials of bamboo are not adequately utilized in Ghana considering their uses elsewhere in Asia.

B. vulgaris the most abundant and widely distributed bamboo species found in Ghana, has two varieties namely the *B. vulgaris* (green coloured) and the *B. vulgaris* var *vittata* (yellow with green strips). There is limited scientific information on the susceptibility of this valuable species to biodeteriorators found in Ghana. Susceptibility of bamboo culms to biological degradation has been a major setback for bamboo utilization and susceptibility differs between species and also between different parts of the culms. The outer part of culms is less susceptible to biodeterioration than the inner part so also the bottom portion is less susceptible than the middle or top portion (Liese, 1980). Liese (1980) found *Dendrocalamus longispathus* to be less susceptible to termite damage than *D. strictus* (According to Banik (1997) and Liese (1998), these variations could be attributed to the species, genotypic constitution and the provenances and have implications on the properties and potential utilization of bamboo.

The previous work on bamboo susceptibility focused on preserving the culms against biodeterioration (Antwi-Boasiako and Abukari, 2008) without assessing the natural capability of the culm to withstand these biodegrading agents. Therefore, there is the need to provide accurate basic knowledge on the relative susceptibility of these bamboo species to borers, termites and fungi which will assist in the selection of effective protective measures to help enhance the sustainable utilization and acceptance of bamboo as alternative to wood in Ghana. The objective of this study is to determine the morphological properties and the level of susceptibility of *B. vulgaris* var. *vittata* (yellow) and *B. vulgaris* (green) to borers, termites and fungi deterioration.

MATERIALS AND METHODS

Ten (10) mature culms each of *B. vulgaris* var. *vittata* (yellow) and *B. vulgaris* var. *vulgaris* (green) were harvested in the month of April from the naturally grown stands at Mesewam near Kumasi in the Moist semi- deciduous forest. Bamboo clumps with visible signs of pest and disease attack as well as those gutted by fire were excluded from sampling. The culms were then cross cut into three equal parts based upon the total length of the culm namely the top, middle and the bottom. The samples were transported into the processing workshop at the Forestry Research Institute of Ghana (FORIG) to be processed into experimental specimens.

Morphological properties

The culms were cross cut at the internode and the internode lengths were determined using a measuring tape. The culm wall thickness was determined using sensitive digital calipers by measuring the wall thickness at four different points as stated by (ISO/FDIS 22157-1:2004(E)).

Termite and fungi susceptibility study using graveyard and visual rating methods

Samples dimension of 3.0 cm (width) x 25 cm (length) x culm wall thickness were prepared and well coded with permanent makers for easy identification and assessment. A total of 45 samples each for the *B. vulgaris* var. *vittata* (yellow) and *B. vulgaris* (green) comprising 15 each of the top, middle and bottom portions for each variety were used for this study. All the test samples were sterilized at 100°C for 12 h in an electric oven. The samples were then randomly installed in soil at 40 cm within row and 40 cm between at the FORIG compound for termite and fungi assessment using the visual rating system, ASTM D1758-06 (2008). The samples were inspected monthly and the termite and fungi activity on the bamboo stakes were assessed for a period of 12 months according to ASTM D 1758-06, fungi and termite rating system are presented on Tables 1 and 2 respectively;

Table 1. ASTM D 1758-06, Fungi rating system

Rate	Description
10	No decay, trace attack permitted
9	Trace attack to 3% of cross section
8	Decay 3 to 10% of cross section
7	Decay 10 to 30% of cross section
6	Decay 30 to 50% of cross section
4	Decay 50 to 75% of cross section
0	Failure

Table 2. ASTM D 1758-06, termite rating system

Rate	Description
10	No attack, 1 to 2 small nibbles permitted
9	Nibbles to 3% of cross section
8	Penetration 3 to 10% of cross section
7	Penetration 10 to 30% of cross section
6	Penetration 30 to 50% of cross section
4	Penetration 50 to 75% of cross section
0	Failure

The susceptibility of each variety and the various positions along the culm was assessed based upon the rating the stakes attain within the months exposure period.

Borer susceptibility

The samples preparation is the same as used for fungi and termites studies shown above. A total of 144 samples each for the *B. vulgaris* var. *vittata* (yellow) and *B. vulgaris* (green) comprising 48 each of the top, middle and bottom portions for each variety were used. The test samples were arranged on a raised platform out of ground contact and under shed conditions (to protect the test samples from direct weather condition) for borer attack. The borer susceptibility of the test samples was assessed monthly based upon the number of borer- holes created on the test samples. The number on borer-holes was counted at each inspection and was used as a susceptibility indicator.

RESULTS AND DISCUSSIONS

Morphological properties

From Table 3, the mean internodal length and culm wall thickness of both varieties varied significantly from bottom to the top portion of the culm. The internode length increased from the bottom portion to the middle and decreased towards the top whilst the culm wall thickness decreased from the bottom to the top portion in both varieties. The internode length at the middle portion was 20% and the top portion was 19.5% longer than that of the bottom portion for the *B. vulgaris*. In the *B. vulgaris* var. *vittata* however, internode length at the middle portion was 25% and the top portion was 23% longer than that of the bottom portion. These results confirmed the observation made by Wahab *et al.* (2009) when they studied the physical characteristics of cultivated *B. vulgaris* culm. The culm wall thickness decreased by 34.8% from bottom to the middle and 32% from the middle to the top portion in *B. vulgaris*. In the *B. vulgaris* var. *vittata*, culm wall thickness was decreased by 32.7% from bottom to middle and 20% from the middle to the top portion. Similar observation was made by Wahab *et al.* (2009) for the cultivated *B. vulgaris* culm. The relative longer internode length of both varieties makes them ideal bamboo species for the production of handicraft products.

Termite and fungi susceptibility

The rate of deterioration by both termite and fungi increases with increasing exposure period for both varieties studied as shown in Figs. 1 and 2. Again, the rate of biodeterioration varied from the bottom to the top. Deterioration rating by both termite and fungi was lower in the middle and top potions than in the bottom portion for both varieties (Figs. 1 and 2). Since these organisms attack bamboo for food, this trend implies that there may be more starch in the middle and top portion than at the bottom portion. Etoh (1996) observed this trend and explained that the starch is stocked in the upper portions of the culm compared with the bottom. Again, the bottom portion being relatively resistant to fungi and termite deterioration may due to its thicker walls.

Table 3. Mean internode length (cm) and culm wall thickness of the top, middle and bottom portions of *B. vulgaris* and *B. vulgaris* var. *vittata*

		B. vulgaris		*B. vulgaris* var. *vittata*	
	Sections	Mean ± std	Range	Mean ± std	Range
Internode length (cm)	Top	33.4 ±3.2	24.8 -39.0	31.6 ±2.8	27.2 - 36.5
	Middle	34.0 ±2.5	28.0 -37.8	32.6 ±2.2	29.2 - 35.1
	Bottom	26.9 ±2.5	21.7 -30.6	24.4 ±4.1	14.5 - 30.0
	Whole culm	31.2 ±5.0	21.7 -39.0	29.3 ±4.9	14.5 - 36.5
Culm wall thickness (mm)	Top	7.2 ±1.1	5.8 - 9.6	8.4 ±2.0	5.7 - 11.4
	Middle	10.3 ±1.9	6.9 -13.8	10.5 ±1.7	8.0 - 13.5
	Bottom	15.8 ±2.2	11.7 -21.4	15.6 ±2.4	9.4 - 20.1
	Whole culm	11.5 ±4.1	5.8 -21.4	11.6 ±3.7	5.7 - 20.1

It was observed that, the deterioration caused by the fungi was higher than that caused by termites (Figs. 1 and 2). Okahisa (2007) reported that while deterioration caused by fungi was positively influenced by sugar content in the bamboo, there is no correlation between the sugar content and consumption rate (deterioration rate) of termite. Tekpetey *et al*. (2008) and Okahisa (2007) reported that alkaloids which are important decay resistant phytochemicals are absent in *B. vulgaris* but they indicated the presence of anthraquinone an important antimicrobial compound in it. This anthraquinone may affect the feeding activity of termites by upsetting the microbial community in termite's gut as reported by Okahisa (2007). This may be the reason for termites causing less damage to both varieties studied. Fungi on the other hand thrive more on bamboo due to its higher sugar content and lack of alkaloids hence making bamboo more susceptible to fungi deterioration than termites. Fig. 3 showed that *B. vulgaris* var. *vittata* was more susceptible to attack by both termite and fungi than *B. vulgaris*, even though the rate of fungi colonization was high in *B. vulgaris* in the intital stage than in *B. vulgaris* var. *vittata*.

It was observed that the deterioration was confined to the inner part of the culm wall in both varieties. Etoh (1996) and Okahisa (2007) also made the observation and

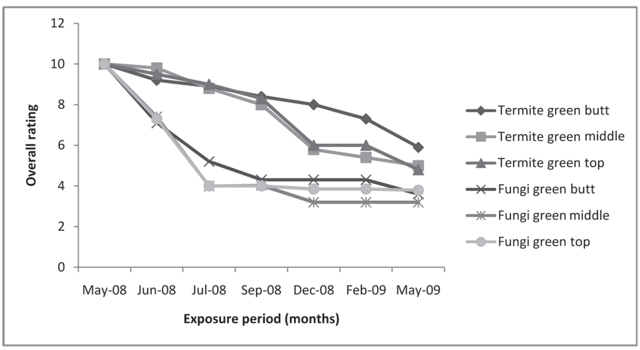

Figure 1. Overall rating of deterioration caused by fungi and termites within the exposure period for *B. vulgaris*

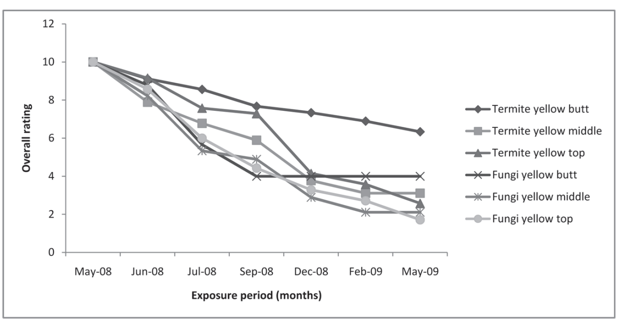

Figure 2. Overall rating of deterioration caused by fungi and termites within the exposure period for *B. vulgaris* var. *vittata*

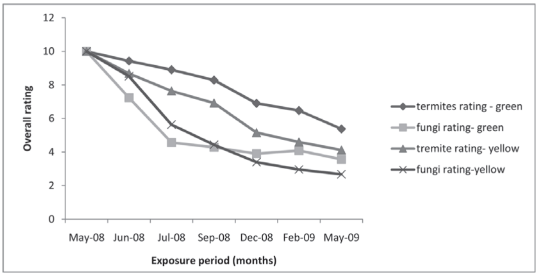

Figure 3. Overall rating of deterioration caused by fungi and termites within the exposure period for *B. vulgaris* var. *vitata* and *B. vulgaris*

reported that the starch content in bamboo is higher towards the inner side of the culm, hence this trend of deterioration.

Borer susceptibility

The number of borer holes increased with increasing exposure period to the maximum and start to decrease for both species (Figs. 4 and 5). Statistically, there was significant difference between the two varieties of *B. vulgaris* with respect to their susceptibility to borers attack ($\alpha = 95\%$) with the green being very susceptible to borers degradation than the yellow type. Previous reports indicated that the beetle damage has a positive correlations with the starch content of the bamboo (Liese, 1980; Ninomiya *et al.*, 2002), therefore it can be inferred that the *B. vulgaris* has higher starch content that the *B. vulgaris* var. *vittata*.

In both varieties, the borer damage was confined to the inner soft portions of the culms with the outer part being more fibrous and intact and that the inner culm is more susceptible to biodegradation than the outer culm (Shimaji *et al.* (1976)*;* Liese, (1980) and Okahisa, (2007)). According to Shimaji *et al.* (1976) and Liese (1980), this is due the anatomical features of bamboo where the parenchyma cells containing the starch grains are highly dense at the inner portion of culm and the sclerenchymatous bundle sheath are radially elongated towards the outer culm.

The middle portions of both the *B. vulgaris* var. *vittata* and *B. vulgaris* were very susceptible to borers degradation than the bottom and the top portions ($\alpha = 95\%$). This conforms to the observations by Okahisa (2007) on starch distribution in *Phyllostachys pubescens* that the starch content is higher in the middle portion, followed by the top and the bottom ends. Also, it was observed that the mean number of borer - holes reached the maximum point and started to decline in both varieties (Figs. 4 and 5).

CONCLUSION

The internode length of both *B. vulgaris* and *B. vulgaris* var. *vittata* increased from

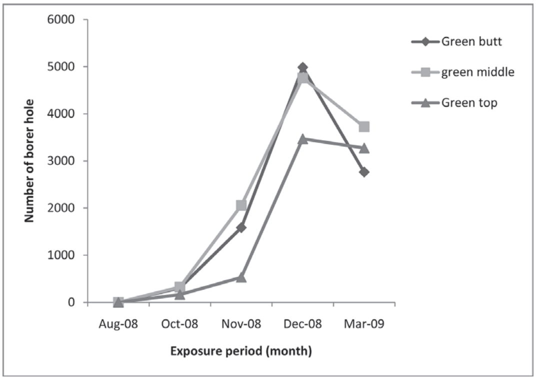

Figure 4. Number of borer holes created in *B. vulgaris* within the exposure period

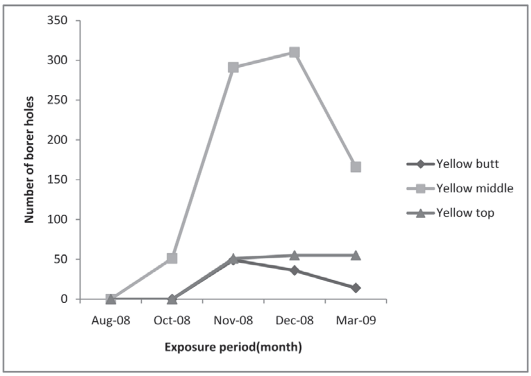

Figure 5. Number of borer holes created in *B. vulgaris* var. *vittata* within the exposure period

bottom to the middle and decreased towards the top. Culm wall thickness of both species decreased from bottom to the top portions. Generally, the internode length and culm wall thickness of *B. vulgaris* was longer and thicker than those of *B. vulgaris* var. *vittata*. Although both species are susceptible to fungi and termite degradation, *B. vulgaris* var. *vittata* was more susceptible to fungi and termites deterioration than *B. vulgaris*. The middle and top portions of both species were more susceptible to fungi and termites than the bottom portion.

B. vulgaris was rated more susceptible to borer infestation than *B. vulgaris* var. *vittata* and the middle portion of both species was very susceptible, followed by the top and bottom portions. The attack of all biodeteriorating agents were confined to the inner side of the culm. Therefore, the inner portion of the culm must be preservative treated l or split off when used as a construction or handicraft material. Both the species were susceptible to biodeterioration and must be treated with appropriate preservatives in order to prolong the service life of any end product made out of it.

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