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Effect of Age and Height on Some Selected Physical Properties of Ethiopian Highland Bamboo (*Yushania Alpina*)

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Abstract

Ethiopian highland bamboo is a multipurpose and a fast growing plant that supports local livelihoods in many ways. It is a source of food, fodder, furniture, textile raw material, building material, industrial inputs, fuel and other purposes in Ethiopia. Physical properties are considered to be important factors in determining the suitability of bamboo for various applications. A sufficient knowledge of the physical properties of bamboo ensures safe design for materials used in service. In this study, Effects of age and height on the basic density, moisture content, wall thickness and culm diameter of Ethiopian highland bamboo (Yushinia alpina) were studied on 2, 3 and 4 years-old bamboo. The result of the study show that four years old bamboo had the highest moisture content and wall thickness and the lowest density and culm diameter. Density and culm diameter did not show significant difference between 2, 3, and 4 years of old bamboo. However, variation in moisture content and wall thickness were observed between the three age groups. Density had greatest in bottom and lowest, in the top. There is no variation of moisture content, wall thickness and culm diameter at different height positions (Bottom, Middle and Top).

Keywords: Density, Moisture content, Shrinkage, Well thickness, Culm diameter,

Introduction

Bamboo is the strongest and fastest growing perennial grass species that belongs taxonomically to the subfamily of *Bambusoideae* under the family of *Gramineae* (Nath et al. 2009). More than 1,500 species and 90 genera of bamboo are found in the world (Zhou et al. 2005). About 43 species and 11 genera bamboo are found in Africa. 67% of African bamboo resources and more than 7% of the world total area covered by bamboo are found in Ethiopia (LUSO Consult, 1997).

Ethiopia has two bamboo species namely, Ethiopian highland bamboo (*Yushania alpina*) and Ethiopian lowland bamboo (*Oxytenanthera abyssinica*). It covers one million hectares of Ethiopian highland bamboo and Ethiopian lowland bamboo resources, which accounts for about 15% and 85 % respectively (Ensermu et al. 2000). Bamboo provides a wide range of goods and services, which can outdo any other plant species. It is a source of food, fodder, furniture, textile raw material, building material, industrial inputs, medicine and fuel (Kassahun 2003).

Ethiopian highland bamboo (*Yushania alpina*) has become the most important non-wood material for the wood-based industry in Ethiopia; basic physical properties must be studied. This information is very important to assess its suitability for various end products and usage (Sattar et al. 1990). The physical characteristics and properties such as the culms height, number of internodes per culms, internode length, internode diameter, culm wall thickness, moisture content and basic density are considered to be important factors in determining the suitability of bamboo for various application and chemical

treatment. Besides that, the study on the anatomical and physical properties is also important for the selection of suitable bamboo for industrial use, construction and housing (Abd Latif et al. 1990).

Bamboo physical properties were also reported to be affected by age and culm height (Kamruzzaman et al. 2008, Azmy et al. 2011). Therefore, information on physical properties of bamboo at different ages and height level is required for appropriate end-use. Some selected physical properties of Ethiopian highland bamboo (*Yushania alpina*) species has not been studied in Ethiopia and there is the lack of information on its basic selected physical properties that may have implications on its industrial uses. In this study, the effect of age and culms height on the basic density, moisture content and shrinkage were investigated, to determine of the suitability of this bamboo for industrial applications.

Materials and Methods

Field sampling

Bamboo culms for this study were collected in November, 2015 from Injibara, North Western Ethiopia. Twelve representative highland bamboos (*Yushania alpina*) for two, three and four years old were randomly harvested. The age of culms was estimated based on visual inspection (i.e. colour, present or absence of sheaths in culms and surface lichen growth) by experienced field personnel. The bamboo culms were cut 30 cm above the ground. Each culm was cut to a merchantable height. These culms were later subdivided into three equal lengths of bottom, middle and top portions of 4 m each.

Moisture content (MC)

Sample blocks representing the 3 age-group (2, 3 and 4 years), 3 height portions (bottom, middle and top) and four replicates, consisting of thirty-six bamboo samples were used. All sample blocks were cut from fresh culms were 3cm × 3cm × culms wall thickness. They were weighed and dried in an oven at 103±2°C for 48 h until a constant weight was attained. The sample blocks were then placed 30 min. in a desiccators, the moisture content of the sample was calculated as follows:

$$Moisture\ content = \frac{Green\ weight - Oven\ dry\ weight}{Oven\ dry\ weight}\ X\ 100\ \%$$

Basic density

Sample for basic density studies were obtained from the middle portion of each internode at the bottom, middle and top culms portions. Each sample blocks were cut to the size of 30cm × 30cm × culms wall thickness. Density was determined on the basis of oven-dry weight and green volume. The sample blocks were oven dried for 48 h at 103±2°C until a constant weight were attained. The sample blocks were then weighed to give the oven dried weight. The green volume of the samples was obtained using the water displacement methods. Basic density was calculated using the following formula:

$$Basic\ density\ = \frac{Ovendry\ weight\ (kg)}{Green\ volume\ (m^3)}$$

Determination of Shrinkage

For this study, 3cm X 3cm X actual thickness samples were cut for each of the height positions and age. The shrinkage in wall thickness and culm diameter were determined from green to oven-dry condition. The wall thickness was determined at four perpendicular positions to each other while the diameter shrinkage was measured along two diameters perpendicular to each other. Wall thickness and diameter measurements were made with a digital caliper. Shrinkage was measured by the following formula.

$$Shrinkage\ persentage = \frac{Green\ dimantion - Overdry\ weight}{Green\ dimantion}\ X\ 100$$

Statistical analysis

Statistical analysis was carried out using SAS version 9.1.2. Analysis of variance (ANOVA) was used to determine whether or not the differences in means were significant. If the differences were significant, least significant difference (LSD) test was used to determine which of the means were significantly different.

Results and Discussion

Effects of age and height on moisture content

The effects of ages and culm height on the moisture content bamboo species are illustrated in Figure 1. The results showed that moisture content value ranged from 94.3 to 152.7%, 72.2 to 136.7% and 65.9 to 115.1% for two, three and four years old bamboo respectively. There was significance difference between age two to three and four year while values were no significance difference observed between three and four years (Table 2.). The four years old culms had lower moisture contents than the two and three old bamboo culms. Younger culms showed higher percentage of moisture content. The moisture content decreased as the stand age increased. This is supported by (Falayi & Soyoye 2014) who reported that the moisture content reduces with maturity of bamboo.

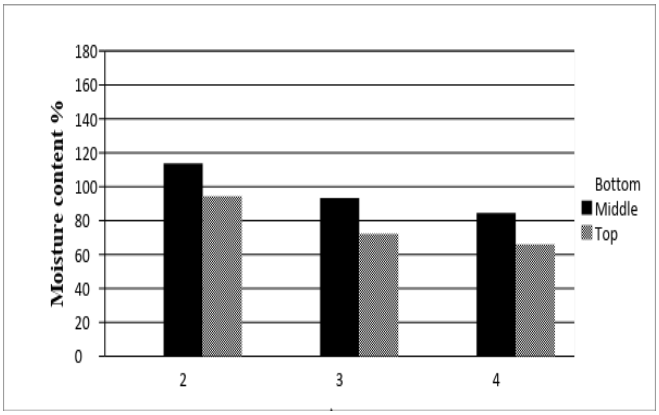

Figure 1: Mean moisture content of bamboo culm at different stand age and culm height.

In each age group, the bottom portion contained the highest proportion of moisture content while the lowest, the top height positions (Figure 1). Moisture content decreased as the height of culm increased for Ethiopian highland bamboo (*Yushania alpina*) species. This finding is similar to other bamboo species reported by earlier researchers (Wahab et al. 2009, Kamruzzaman et al. 2008 & Anwar et al. 2005). .

Effects of age and height on basic density

Table 1 shows that, the basic density of Ethiopian highland bamboo (*Yushania alpina)* were found to vary from 485.5 to 689.77 kg/m3 for the two years-old bamboo culms, 563.06 to 704.03 kg/m3 for the three years-old bamboo culms and 588.13 to 719.92 kg/m3 for the four years-old culms. The four-years-old culms had higher density than the two and three years-old culms. However, the LCD test showed that density was not significantly different ($P < 0.05$) between 2, 3 and 4 year-old Ethiopian highland bamboo *(Yushania alpina).* The result was similar with that of Kamruzzaman et al. (2008) who reported that the density was not significantly different between 2, 3 and 4 year of *Bambusa balcooa and Melocanna baccifera.*

Table 1: Mean density of bamboo culm at different stand ages and culm height

Age Group	Height Position	Density kg/m^3
Two	Bottom	689.77
	Middle	485.50
	Top	624.27
Three	Bottom	563.066
	Middle	691.566
	Top	704.033
Four	Bottom	588.13
	Middle	692.48
	Top	719.92

In relation to height positions, the highest basic density (682.75 kg/m^3) was observed in top bamboo culms while the lowest basic density (613.75 kg/m^3), in bottom bamboo culms (Table 1). The same trend of result was obtained by Falayi & Soyoye 2014. There was no significant ($P<0.05$) difference between bottom, middle and top height positions. However, the basic density of the culm increased with increasing height levels of the culms. Our results was similar with other investigators also noted the increase in density with increasing height levels of the bamboo culm (Santhoshkumar & Bhat 2014).

Effects of age and height on shrinkage in wall thickness

The proportion of shrinkage in wall thickness was highest in two age bamboo culm while lowest in three and four age bamboo culms (Table 2). Shrinkage in wall thickness was significant difference ($P < 0.05$) between the two to three and four years old while values were no significance difference observed between three and four years

old culm. The rate of shrinkage in wall thickness was decreasing from bottom to top (Table 3). This result was similar to other investigators Maya et al. 2013 who reported that, the culms taper from the bottom portion towards the tip with a decrease in culms wall thickness. The variations between all the three height portions were not significant difference for Ethiopian highland bamboo (*Yushania alpina).*

Effects of age and height on shrinkage in culm diameter

The proportion of shrinkage in culm diameter was highest in two age bamboo culm and lowest in three and four age bamboo culm (Table 2). The variations in values were insignificant for all age groups. Bottom portion showed maximum proportion of shrinkage in culm diameter whiles the top portion, lowest (Table 3.). There was significant ($P<0.05$) difference between bottom to middle and top height positions. Sattar *et al.* (1994) reported that shrinkage in culm diameter significantly along the culm height for bamboo culms.

Table 2: Mean density, moisture content, wall thickness and culm diameter of bamboo culms at different age.

Age Groups	Shrinkage in Wall thickness %	Shrinkage in Culm Diameter %	Density Kg/m3	Moisture Content %
Two	17.2[a]	8.85[a]	599.85 [a]	120.3[a]
Three	11.3[b]	5.79[a]	652.89 [a]	100.7[b]
Four	10.4[b]	5.21[a]	666.85 [a]	88.5[b]

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$

Table 3: Mean density, moisture content, wall thickness and culm diameter of bamboo culms at different culm height positions.

Height Portion	Shrinkage in Wall thickness %	Shrinkage in Culm diameter %	Density Kg/m3	Moisture Content %
Bottom	15.96[a]	10.82[a]	613.75 a	134.84[a]
Middle	11.74[a]	4.73[b]	623.19a	97.19[b]
Top	11.20[a]	4.28[b]	682.75[a]	77.52[c]

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$

Conclusions

Physical properties such as basic density, moisture content, well thickness and culm diameter are important properties that determine the utilization of bamboo in construction and for structural purposes. These physical properties were studied. The study revealed that the four year old culms had lower moisture contents than the two and three old bamboo culms. Moisture content and shrinkage in wall thickness at different age groups were significantly different for Ethiopian highland bamboo (*Yushania alpina*). The highest moisture content, well thickness, culm diameter were observed in bottom bamboo culms while the lowest basic density in bottom bamboo culms. The four-year-old culms had higher density than that of other age group but lower shrinkage in culm wall thickness. Two and three years old culms with a low basic density can be more easily split and bend. They are preferred for handcraft work and furniture making. In the other hand, four years old culms with high density could be suitable for paper manufacture, bamboo based panel boards and structural applications.

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