



Culm Characteristics of Yellow Bamboo (*Bambusa vulgaris* var. *striata*) from Private Forest in Sleman Regency, Yogyakarta

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Abstract. Sleman Regency has determined bamboo as a superior non-timber forest product. Yellow bamboo (*Bambusa vulgaris* var. *striata*) is usually used for construction and craft materials. Hence, it is necessary to understand the characteristics of the culm. The study aimed to determine the predictor variables for the total internodes, and the distribution pattern of the length and bamboo wall thickness of the internodes on the yellow bamboo culms. The method used in this research was the method of destructive sampling for 30 bamboo culm samples. The samples were measured using a caliper for diameter at breast height and wall thickness, and measurement tape for the total length of the bamboo culm. For detail measurement, each sample was cut for each internode to be measured the length, diameter, and wall thickness of the internodes. The results showed that the predictor of diameter at breast height (dbh) is a predictor in estimating the total number of internodes on the culm resulting in an R^2 of 0.631. While the total culm height as a predictor was able to explain the total number of internodes with an R^2 value of 0.692. The length of the internodes pattern on the yellow bamboo culm from the bottom to the top side formed a bell curve. In the middle area of the culm, the length of the internode increased, but then it shrank back to the top side. The diameter and wall thickness patterns of the internode were non-linear. In addition, the predictors of diameter at breast height and total height are less accurate to explain the total number of internodes in yellow bamboo culms.

Keyword: Bamboo Clump, Bamboo Internode, Modelling, Non-timber Forest Product, Regression

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1 Introduction

Indonesia has a large potential for non-timber forest products (NTFPs). According to the Regulation of the Minister of Forestry Number: P.35/Menhut-II/2007 concerning Non-Timber Forest Products, the potential for NTFPs from plant species reaches 494 species, and another 63

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species come from animals [1]. Nowadays, the common NTFPs that have been utilized by plant species are cajuput leaves [2]-[5], latex [6], rattan, gum [7], and bamboo [8]-[10].

Sleman Regency is one of the regencies in Indonesia that has determined bamboo as a regional superior non-timber forest product through the Sleman Regent's Decree No. 306/Kep.KDH/A/2013 [11]. Furthermore, the Sleman Regency Government has conducted an inventory of the bamboo potential in the Sleman Regency. As a result, the potential of bamboo in Sleman Regency reaches 12.6 million bamboo culms from 10 species of bamboo, and nearly 5.5 million culms of which are in Kapanewon Pakem [12].

The population of ampel bamboo (green and yellow) in Kapanewon Pakem, Sleman Regency was relatively small compared to other bamboo species. Based on data from Forestry and Plantation Sector Agriculture, Fisheries and Forestry Office of Sleman Regency [12], the total population of ampel bamboo in 2014 at Kapanewon Pakem was 10,012 culms. The results of the inventory of potential yellow bamboo by Machfyroh [13] in 2021 at Kapanewon Pakem showed a result of 1,812 culms. The community has been utilizing the yellow bamboo for construction, aesthetics, herbal medicine, and religion [14]-[15].

As the utilization of yellow bamboo for construction and craft activities, it is necessary to understand the characteristics of the bamboo culm. Understanding the characteristics of bamboo culm, especially the length of the internodes and wall thickness of bamboo, is very important to facilitate the planning of processing bamboo raw materials into processed products [16]. For instance, understanding very well the diameter, length, and wall thickness of the internodes along the bamboo culm can be useful for the user to estimate the need for bamboo raw materials. The objective of this study was to investigate the predictor variables for the total number of internodes on each bamboo culm. It is also to determine the distribution pattern of the length of the internodes and the wall thickness of the culms of yellow bamboo.

2 Research Method

The research was conducted in the private forest areas of Kapanewon Pakem, Sleman Regency, Special Region of Yogyakarta, from March – April 2021. The research materials were 30 mature yellow bamboo culms (*Bambusa vulgaris* var. *striata*) collected from 5 villages in Kapanewon Pakem, Sleman Regency (Figure 1). The sample selection was based on the criteria as follows; a) the bamboo culms were mature (without shields), and b) the willingness of the bamboo owner to harvest their bamboo's culms. The tools used in the data collection were hand saws, machetes, calipers, measuring tape, and stationery. The coordinates of the sampling location were measured using GPS.

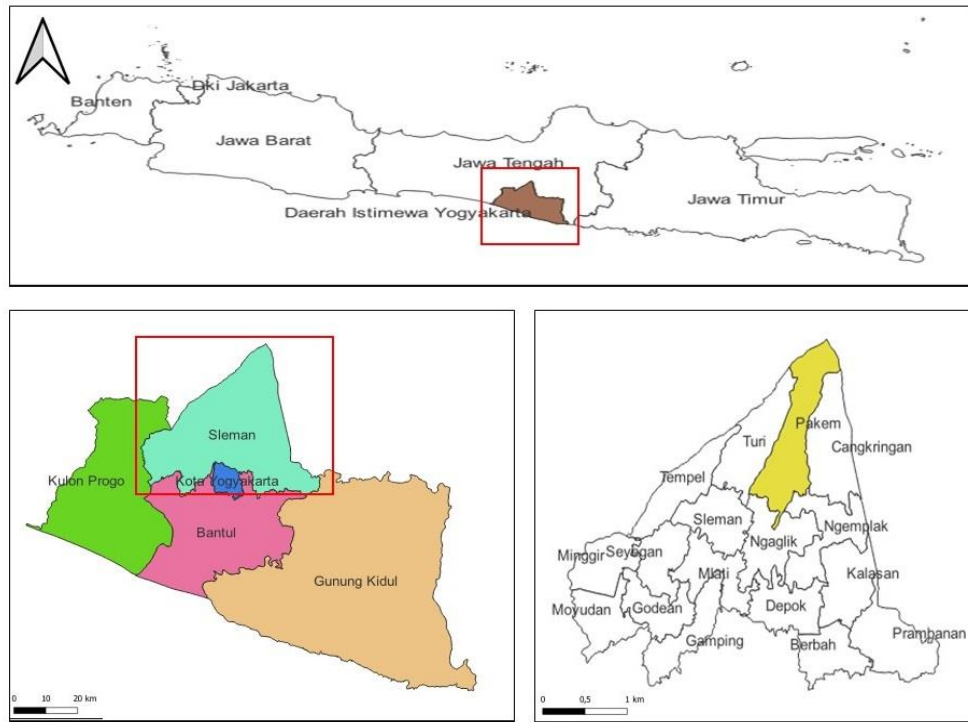


Figure 1 Research location

Data collection was carried out using the survey method. In the initial stage, the research team identified locations of the clumps of yellow bamboo distribution in Kapanewon Pakem, identifying the key informants such as Kapanewon officials, Padukuhan officials, and community leaders to get data on the yellow bamboo's owner. Based on the data of bamboo inventory in Kapanewon Pakem on the potential of yellow bamboo by Machfyroh [13] 54 people planted yellow bamboo. The total yellow bamboo was 100 clumps and 1,812 culms.

Parameter measurement of yellow bamboo culm had carried out using the destructive sampling method. The yellow bamboo culm has been cut down were then measured in diameter at breast height (dbh) and total height. Then, the bamboo samples were cutten into pieces according to the length of each bamboo internode. Each bamboo internode had measured for wall thickness and length. It is started from the first internode at the bottom to the last internode at the top of the bamboo culm (Figure 2).

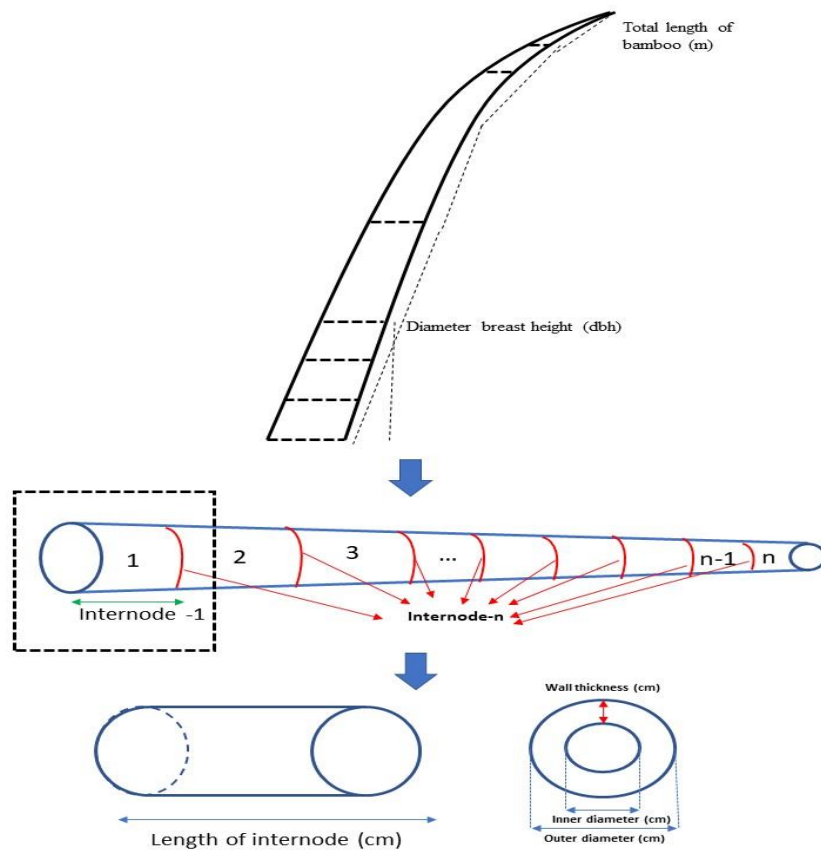


Figure 2 Measurement of yellow bamboo culm

The measured data were diameter at breast height (dbh), total bamboo height, bamboo wall thickness, length of each bamboo internode, and the total number of internodes per bamboo culm. Linear and non-linear regression analyses were performed using a Microsoft Excel 365 program. The analyses were used to see the distribution pattern, the relationship between diameter at breast height, the number of internodes per culm, the relationship between total height, and the number of internodes per culm. The descriptive analysis had also carried out to see the pattern of internode length and wall thickness of bamboo along the culm from the bottom to the top side.

3 Results and Discussion

3.1 Characteristics of Yellow Bamboo Sample

Data on diameter at breast height, the total height of the culm, the number of internodes per culm, and the length of each internode were follow the normal distribution. The culm samples of yellow bamboo (*Bambusa vulgaris* var. *striata*) spread from small diameter culm to large diameter culm (Table 1.). Yellow bamboo culms have an average diameter at a breast height of 5.27 cm and a total height of 7.40 m.

The yellow bamboo samples used in this study were able to represent the distribution of small to large diameters, as well as the total height from low to high. Thus, the results of this study can represent the population of yellow bamboo originating from private forests in Kapanewon Pakem, Sleman Regency, Special Region of Yogyakarta.

Table 1 Internode Characteristics of Yellow Bamboo (*Bambusa vulgaris* var. *striata*)

	Minimum	Maximum	Mean	Standard of deviation
Number of internodes	14.00	49.00	30.97	9.44
Diameter breast height (cm)	2.74	8.15	5.27	1.54
Total length (m)	3.10	11.90	7.40	2.59

The characteristics of the bamboo culm, especially the number of internodes on the culm, will differ between types of bamboo. For instance, giant bamboo in Indonesia, Sembilang bamboo (*Dendrocalamus giganteus* Wallich ex Munro) has 54 – 68 internodes in each culm [17], and Tali bamboo (*Gigantochloa apus*) culm in Purwokerto has culm length around 34.2 -44 cm and wall thickness 1.5 – 2.4 cm [18]. The bamboo *Melocanna baccifera* in India also showed a variance in total culm height (3.2-15.3 m), the number of internodes/culm (14-49), and length of internode (3.9-54.2 cm) [19]. According to Atlas Bambu Indonesia 1 [20], the summary of culm characteristics of Indonesia's bamboo are as follows:

Table 2 Culm characteristics some Indonesia's bamboo

Species	Diameter (cm)	Length of internode (cm)	Wall thickness (mm)
<i>Bambusa vulgaris</i>	5-10	20-45	7-15
<i>Bambusa maculata</i>	7-8	30-50	10
<i>Bambusa blumeana</i>	Up to 15	25-45	30
<i>Gigantochloa apus</i>	7-15	20-60	15
<i>Gigantochloa atroviolaceae</i>	8-9	40-50	6-8
<i>Gigantochloa pseudoarudinaceae</i>	5-13	40-45	20
<i>Gigantochloa robusta</i>	7-9	Up to 40	18
<i>Gigantochloa atter</i>	5-10	27-51	8-10
<i>Gigantochloa manggong</i>	7.5-10	8-53	8.6-19.4
<i>Dendrocalamus asper</i>	12-18	40-50	30

Source: [20]

3.2 The relationship among diameter at breast height (dbh), total length, and number of internodes

The total number of internodes on each bamboo culm (Y) estimated with the predictor diameter at breast height (dbh) with a non-linear regression model in the form of Power resulted in a coefficient of determination (R²) of 0.631 (Figure 3). The value of the coefficient of determination in other forms (linear, polynomial, and logarithmic) produces a value below 0.631. The number of internodes in each bamboo culms could only be explained by 63.1% by

the predictor of diameter at breast height. There are still other factors of 36.9% that are not included as predictors in this study that affect the estimation of the number of internodes in yellow bamboo culms.

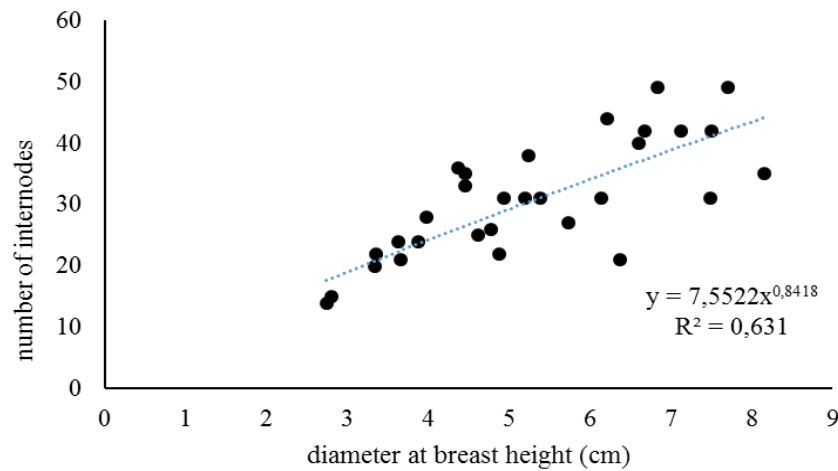


Figure 3 Relationship between diameter at breast height and number of internodes in yellow bamboo

Similar results also occur in the predictor (X) using the total height of bamboo. The predictor of total bamboo height was only able to estimate the number of internodes in yellow bamboo culm at 69.17% (Figure 4). The rest (30.83%) was affected by other factors. They were not included in this study. Factors other than the diameter at breast height and the total height of the bamboo, need to be investigated further so that the number of internodes on each bamboo culms can be estimated more accurately. The potential predictors to estimate culm characteristics were volume and weight [19], and culm density [21].

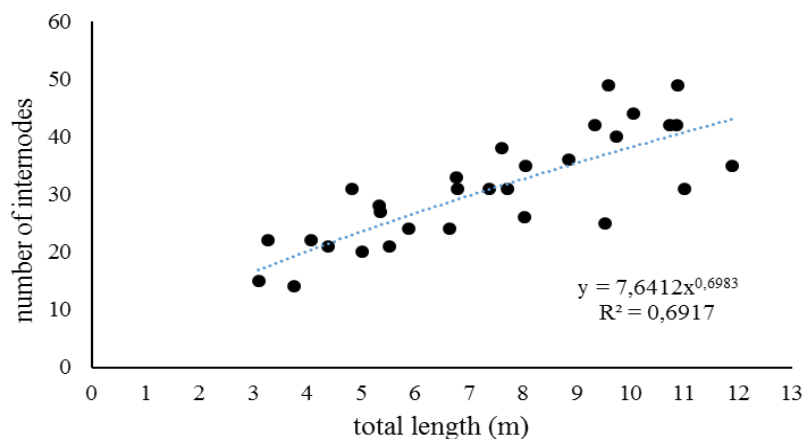


Figure 4 Relationship between total height and number of internodes in yellow bamboo

The relationship between diameter at breast height and total height is in the form of a non-linear logarithmic regression equation ($R^2 = 0.5308$) (Figure 5). Research from Inoue [22]–[27] on the

relationships between diameter breast height and the total height of several species of bamboo in Japan and Brazil also shows that the larger the diameter would be followed by the higher the total height of the bamboo. Furthermore, Inoue's research [27] also states that the relationship between diameter and the total bamboo height produces a coefficient of determination of 0.629.

Bamboo culms have different characteristics from woody tree culms. In several measurements of bamboo samples in this study, big-diameter bamboo rods have a short height while small-diameter bamboo culms can have a tall height. This phenomenon still cannot be explained by studies on the characteristics of existing bamboo culms [16], [19], [27].

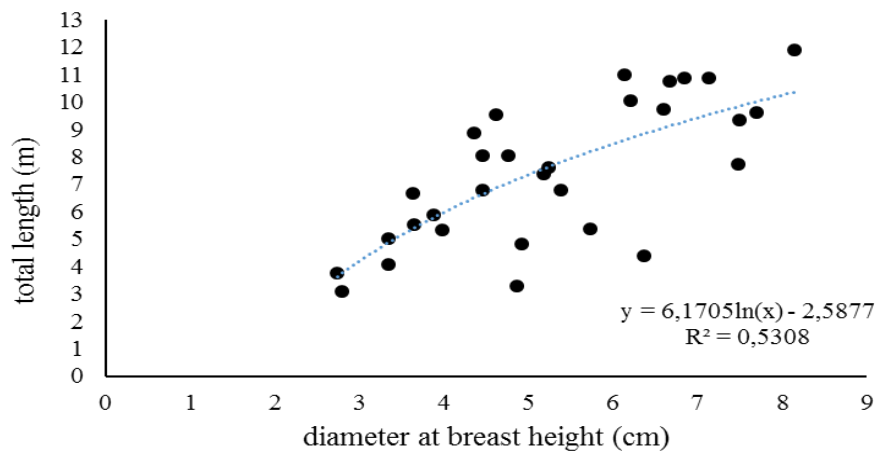


Figure 5 Relationship between diameter at breast height and total length

3.3 Internode Pattern of Yellow Bamboo

The length of the bamboo internodes from the bottom will increase until the middle of culm. Then the length will decrease (Figure 6). The pattern of bamboo culms that enlarge in the middle and then shrink back to the top also occurs in betung bamboo (*Dendrocalamus asper*) from Bandung, West Java [28].

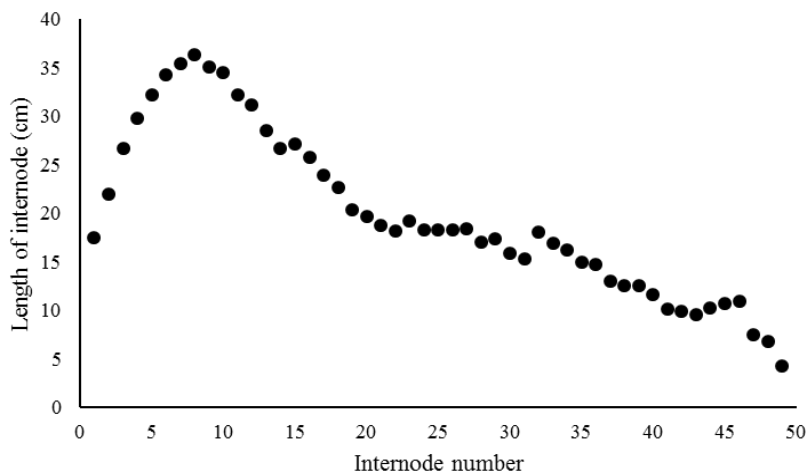


Figure 6 Pattern of internode length from bottom to the top side

The internode length increased until internode number 8 and then decreased gradually until the end of it. The longest internode at number 8 was 36.32 ± 5.04 cm. This pattern is also found in the Tonkin Cane (*Pseudosasa amabilis*) bamboo in China which the longest internode was in the number 9 (27.52 ± 3.25 cm) and then decreased gradually [29].

Furthermore, the pattern of bamboo internodes that form a bell pattern was also reported by Singnar et al. [19] on *Melocanna baccifer* (Roxb.) Kurz bamboo in India and Chaowana et al. [16] on 5 bamboo species (*Dendrocalamus asper*, *Dendrocalamus sericeus*, *Dendrocalamus membranaceus*, *Thyrosostachys oliveri*, and *Phyllostachys Makinoi*) from Thailand. Thus, the characteristics of bamboo culms have shown a similar pattern in the form of a curve with a bell shape. However, other research on other types of bamboo still needs to be done to further strengthen that the pattern of bamboo culm internode is generally a curve with a bell shape.

The diameter pattern of the internode and bamboo wall thickness were different from the pattern of the length of the segments along the bamboo culm. The thick pattern of the bamboo walls at the bottom is thicker than the bamboo walls at the top (Figure 7). The pattern formed is linear. In some internodes before the top side, the thickness of the bamboo culm wall is 0 or there are no more cavities in the internode. The diameter and wall thickness pattern along the internode number are also found in Tonkin Cane (*Pseudosasa amabilis*) in China [29].

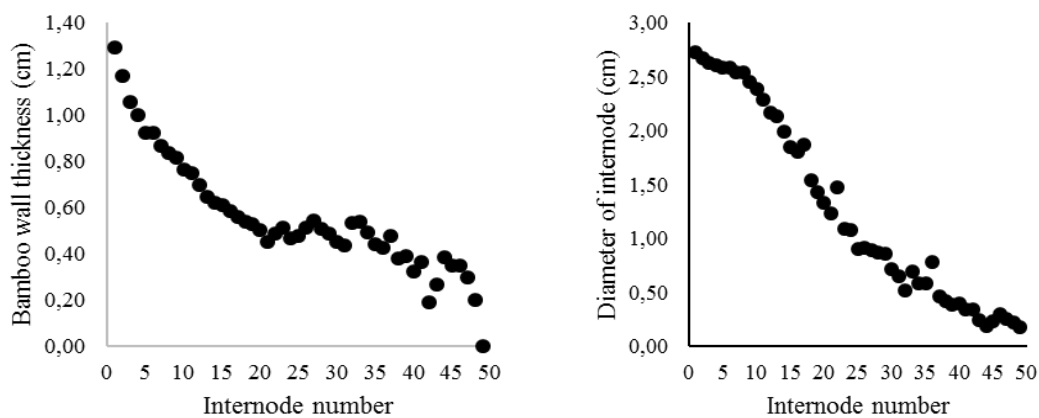


Figure 7 Pattern of diameter and wall thickness from the bottom to the top side

The phenomenon of the bamboo wall getting a thickness pattern at the bottom and then thinning in the middle and top side also occurred in 5 types of bamboo in Thailand [16]. Another study in India by [19] explained that the diameter of the bamboo at the bottom would be larger than in the middle and top side, and it was followed by a thick bamboo wall thickness at the bottom and then thinning towards the middle and top side.

Internode characteristics of Yellow ampel (*Bambusa vulgaris* var. *Striata*) have a similar pattern with Tonkin Cane (*Pseudosasa amabilis*) bamboo for one dimensional culm morphometric [29]. According to [29], one dimensional culm morphometric (diameter of internode, length of

internode, and wall thickness of internode) was a basic unit to understand the internode characteristics of the bamboo culm. Further examination can be conducted to elaborate on the hollow area and total cylinder volume of the bamboo culm.

4 Conclusion

The results showed that the length of the internode of yellow bamboo (*Bambusa vulgaris* var. *striata*) from the bottom to the top formed a bell pattern. The length of the internodes will increase until the middle of the bamboo culm, then shrink back to the top side bamboo internodes. However, the wall thickness of the internode and diameter of the internodes have formed a non-linear pattern. The wall thickness and diameter of the internode decrease gradually from the bottom to the top of the bamboo culm. In addition, the predictors of diameter at breast height and the total height of bamboo, have not been able to predict the number of internodes in bamboo culms. Further research can be conducted on other types of bamboo as well as at various locations where bamboo was discovered. Thus, comprehensive information on the characteristics of bamboo internodes can help in the process of further utilization of bamboo trunks.

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