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Vegetative propagation of *Bambusa Vulgaris Var Vittata* by horizontal and slanting methods

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Abstract
Global interests have risen in recent years with the need to cultivate bamboo to supplement the natural bamboo stands and reduce the dependence on the already depleted timber resources. In Ghana, the adoption of the cultivation and use of bamboo to supplement wood supplies from the natural forests has been documented as a viable venture. However, the productivity and success of different propagation methods, such as planting methods via vegetative propagation, are yet to be studied. This study was carried out to determine the culm survival and mortality rates, diameter growth rates of shoots, and the better propagation method of vegetative propagation of *Bambusa vulgaris var vittata* using the horizontal (180^o) and slanting (60^o) methods. Cuttings of two-year-old culms of species were placed in two sunken beds (1x10m), each with 20 sub-plots. A T-Test was used to analyze the results. At (0.05) significant level, the treatment was planted slantly (T^1) and horizontally (T^2) and did not differ significantly in their effects on the response variables. There were no deaths recorded for culms planted slantly. However, one out of the 20 culms planted horizontally died in the 7th week after planting. The volume of culms planted horizontally (180^o) ranged from $7.22\text{x}10^{-6}$ m^3 to $3.64\text{x}10^{-5}$ m^3. The highest volume increment occurred on the 12th week of growth, while the lowest growth in volume occurred on the 5th week. With regards to the culms planted slantly, the highest growth in volume, $1.23\text{x}10^{-5}$ m^3 was recorded in the 10th week while the lowest, $1.18\text{x}10^{-6}$ m^3 was recorded in the 9th week. The diameter growth rates of the shoots planted slantly and those planted horizontally were 0.5025cm/week and 0.4505cm/week, respectively. The horizontal culm planting method is, therefore, a better planting method. However, in terms of nursery maintenance practices such as preparation of cuttings, weeding, watering etc., it is more laborious working with culms planted at 180^o than those planted at 60^o.

Keywords
Vegetative propagation; Bambusa vulgaris var vittata; Horizontal; Slanting; Bamboo

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Contents

1. Introduction

1.1 Background

Bamboo is a non-timber evergreen plant that grows fast. It belongs to the wide grass family of Gramineae (Poaceae) (Akoto et al., 2020; Partey et al., 2017; Nath et al., 2009). This family is made up of seven members because of its flowering characteristics. However, bamboo differs from the other family members because of its woody stem, as they are herbaceous (Nath et al., 2011). Bamboos have long been used for house construction, furniture, handicraft articles, pulp and paper because of their excellent mechanical properties, superior strength, rigidity and fast-growing capacity (Oteng-Amoako et al., 2005). According to International Timber Organization's report, the Bamboo-Timber utilization ratio until 1977 had been low, around 30% and so attention was drawn to the development of composite materials, for example, bamboo and wood composites (Oteng-Amoako et al., 2005). This has greatly influenced the recognition and expansion of the bamboo trade and industry (Obiri et al., 2009). There is, therefore, the need to encourage the cultivation of bamboo (Ray and Ali, 2017; Akoto et al., 2020; Obiri et al., 2020).

During the past decade, significant achievements have been made in China in the processing, utilization and research into bamboo usage such that the processing industry has developed from the simple use of raw culms to the comprehensive use of the resource for making ply bamboos, edible canned shoots and other food products like bamboo crisps or chips, drinks, medicines, handicrafts, dresses and even plaited shoes to mention but a few (Saad et al., 2016; Ray and Ali, 2017). It is envisaged that, with the current trend towards increasing utilization of this Non-Timber Forest Produce (NTFP), the dependence on the already depleted timber resources will be significantly reduced, hence the need to cultivate bamboo to a large extent (Akoto et al., 2020; Partey et al., 2017; Nath et al., 2009; Oteng-Amoako et al., 2005). The potential of bamboo and bamboo products have attracted considerable international and national interest in recent years due to an ever-increasing recognition of its multi-purpose uses for both industrial and socio-economic well-being of predominantly rural populations of developing countries and the potential of these resources for conserving Tropical forests by offering alternative solutions to wood-based products and ecological rehabilitation (Obiri et al, 2020).

According to Addo-Danso et al. (2019), bamboo is a good substitute timber in Ghana. It could be relied upon for wood needs as Ghana's forests continue to dwindle at an alarming rate due to the combined effect of deforestation, forest fragmentation and degradation. However, the flowering mechanisms of bamboo are still not fully understood. It is observed that most bamboos seldom flower; even if they do, most seeds are not fully developed, and only a few bear fertile seeds (Nath et al., 2009). Those fertile ones also have weak viability. Bambusa vulgaris, for example, which is the most abundant in Ghana (Obiri et al., 2020), has not been given the needed research attention regarding flower gregariousness since it was described in 1810 (IDRC and IUFRO, 1980). Again, several studies in Ghana on bamboo (Akoto et al., 2020 and 2018; Obiri et al., Partey et al., 2017, Peprah et al., 2014) have proven the successful vegetative propagation of bamboo in Ghana. However, the best vegetative planting method and its subsequent early growth performance of bamboo in Ghana are yet to be explored. Such studies are necessary to improve knowledge and understanding of bamboo vegetative propagation, all in an attempt to increase its production through cultivation in Ghana. The objectives of this study were to determine the culm survival and mortality rates, the growth rate (diameter and height) of shoots, and a better propagation method.

2. Materials and Method

2.1 Study Setting

A plot of dimension 4x40 m was cleared at the University of Energy and Natural Resources permanent nursery. The site is located under a light to moderate canopy of deciduous trees, as this favours bamboo growth (IDRC and IUFRO, 1980). It is a flat ground, sandy loam and well-drained soil. Two sunken beds were constructed by first digging to about twenty centimeters deep and refilling with topsoil from the nursery site. Some poultry droppings were added as manure. Each bed was measured 1 x 10 m. Each bed was then divided into 20 equal subplots. Drains or shallow tunnels were constructed along the walkways of the bed to allow water to flow through them to moisten the beds. The site was well prepared ahead of time in order not to cause undue delay in the planting of propagules after collection and cutting.

Two-year-old culms of Bambusa vulgaris var vittata were carefully selected from Sunyani Parks and Gardens as stock plants at six o'clock in the morning (when the sun was still not out). Culms selected were vigorous, healthy and straight, with average diameters of 5 cm at breast height. With a sharp cutlass, the selected bamboo culms were cut down without the stump, and the immature top portions and branches were cut off. With a sharp bow saw, two culm cuttings were made. Each cutting had two nodes. Lengths were not equal because of the irregular internodes, but at least 10 cm of culm was left at the end of each node. One of the cuttings was labeled Treatment One (T^1). The other was treated differently by cutting two saw-sections in the internode to about half the diameter of the culm size and denoted Treatment Two (T^2). This was done just to make it possible for it to be filled with water.

Treatment One (T^1) was planted slantly, and Treatment Two (T^2) was done horizontally. The selection of the treatments (planting method) was based on the common practice of propagating bamboo through stem cuttings (Njuguna and Kigomo, 2008; Nduwamungu, 2018). To determine the variations, the treatments were replicated. In this regard, T^1 and T^2 were each given 20 replicates to make up 40 planting materials. Cuttings were first segregated into three classes, thus, the base (7 cuttings), mid (7 cuttings) and top portions (6 cuttings) to ensure approximately equal representation of treatment in each class (Coe – ICRAF, 2002). Randomization was used to avoid bias, which could result from differences in soil fertility, wind or pest exposure or any other sources of error in the allocation of treatment (Chapman and Hall, 1983; Spiegel, 1988).

2.2 Experimental precautions

The following precautions were taken;

1. Planting was done randomly as soon as cuttings were collected to avoid desiccation of culm cuttings.
2. Cuttings were covered with damp sacks and transported in the boot of a car to prevent desiccation by the wind.
3. Cuttings were carefully placed to prevent nodes from rubbing against each other since the buds were delicate.
4. Shading was provided immediately after planting.
5. Watering was done, and all culm cavities were filled to the brim with water.
6. Neither synthetic plant hormones nor fungicides were applied.

2.3 Data collection

Data was collected weekly for 10 weeks. The following are specifics of the data collection.

1. Point of diameter measurements was marked with indelible ink at eight (8) centimeters from the ground.
2. A black light band was tied to each of the selected shoots measured for continuity of measurements.
3. Diameter and height measurements were taken weekly using a pair of calipers and measuring tape, respectively.
4. By viewing the shoot as a cone (Figure 1), the following formula was used in calculating the volume (m3) of each shoot.

$$v = \frac{1}{3}\pi\frac{d^2}{4}h \quad (1)$$

Where l = slant height (m) measured on the field. h= actual height (m), derived using Pythagoras' theorem d= diameter (cm), measured on the field

Data was input into excel; it was used for onward manipulation and retrieval of results on volumes, diameter growth rates of shoots, culm survival and mortality rates.

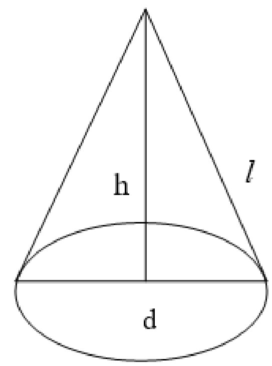

Figure 1. Cone representing a shoot

3. Results

3.1 Culm survival rates

Table 1 shows the survival of culms planted for 13 Weeks. Only one culm planted horizontally died within the period, indicating a high survival rate of plantings for both methods.

Table 1. Culm survival rates

Mode of Planting	Number of culms planted	Number sprouted	Number survived	Survival (%)
Slantly (T^2)	20	20	20	100%
Horizontal (T^2)	20	20	19	95%

3.2 Growth Rate of Shoots

The volume of culms planted horizontally, 180^o (Figure 3), ranged from 7.22×10^{-6} m^3 to 3.64×10^{-5} m^3. The highest volume increment occurred in the 12th week of growth, while the lowest growth in volume occurred in the 5th week. Concerning the culms planted slantly, 60^o (Figure 2), the highest growth in volumes (1.23×10^{-5} m^3) was recorded in the 10th week while the lowest (1.18×10^{-6} m^3) was recorded in the 9th week (Figure 5).

Figure 2. Images of Culm Shoots planted slantly (60^o)

Figure 3. Images of Culm Shoots Planted Horizontally (180^o)

Figure 4. Images of Culm Shoots Planted Horizontally (180^o)Bamboo Nursery representing both culm shoots planted horizontally and Slantly

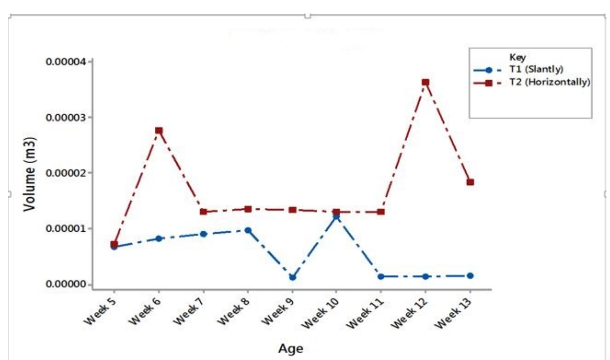

Figure 5. Images of Culm Shoots Planted Horizontally (180^o)The growth curves of the Slanting and the Horizontal Planting methods of *Bambusa vulgaris var vittata*

3.3 Identification of a Better Planting Method

From figure 6, the mean diameter growth of bamboo culms planted slantly (T^1) was 0.5025cm/week and that planted horizontally was 0.4505cm/week. There was no significant difference between the treatments when tested at 0.05 significant level. However, there was a significant difference (Figure 7) between the mean height growth for the slantly (T^1) and horizontally (T^2) treatments at a 0.05 significant level.

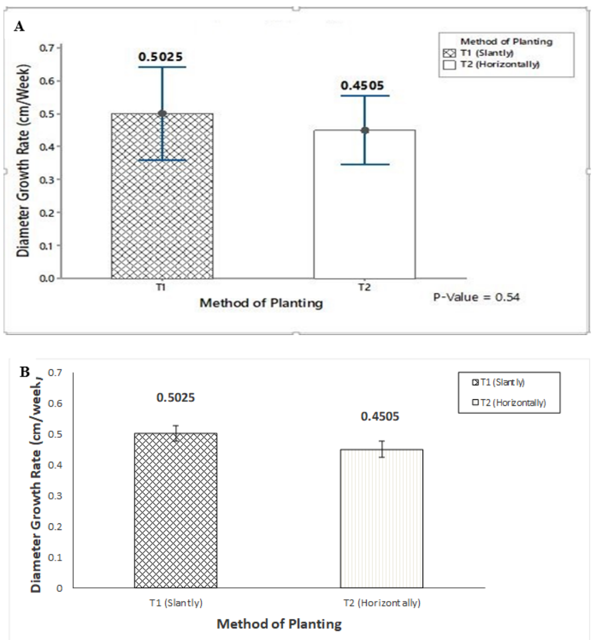

Figure 6. Diameter growth rates of Bambusa vulgaris var vittata planted slantly and Horizontally at a 95% confidence interval

Results on the diameter growth patterns between the 5th and 13th weeks were constantly higher for T^1 (slanted) compared to T^2 (horizontal), as indicated in Table 2.

The height growth assessment after the 5th week of the Bambusa vulgaris cuttings evolved and was statistically significant between the two treatments (T^1 and T^2). Across the 91 days, the T^1 (slanted) showed steadily higher height growth compared to the T^2 (horizontal) propagation (Table 3).

Table 2. Relative mean diameter of *Bambusa vulgaris var vittata* planted slantly (T^1) and horizontally (T^2) after 13 weeks.

Treatments Mean (cm)	Time (Weeks) 5	6	7	8	9	10	11	12	13	
T1	0.2284	0.2451	0.3532	0.387	0.4835	0.5801	0.6174	0.805	0.8229	0.5025
T2	0.2079	0.227	0.2651	0.3348	0.4268	0.498	0.5918	0.7211	0.782	0.4505
P-Value										0.54

Significance level p = 0.05

Table 3. Relative mean height of *Bambusa vulgaris var vittata* planted slantly (T^1) and horizontally (T^2) after 13 weeks.

	Time (Weeks)									
Treatments Mean (cm)	5	6	7	8	9	10	11	12	13	
T1	0.0501	0.0610	0.0703	0.0721	0.0759	0.1202	0.1703	0.2201	0.2500	0.1211
T2	0.0201	0.0311	0.0408	0.0418	0.0493	0.0603	0.0810	0.1114	0.1202	0.0618
P-Value										0.01

Significance level p = 0.05

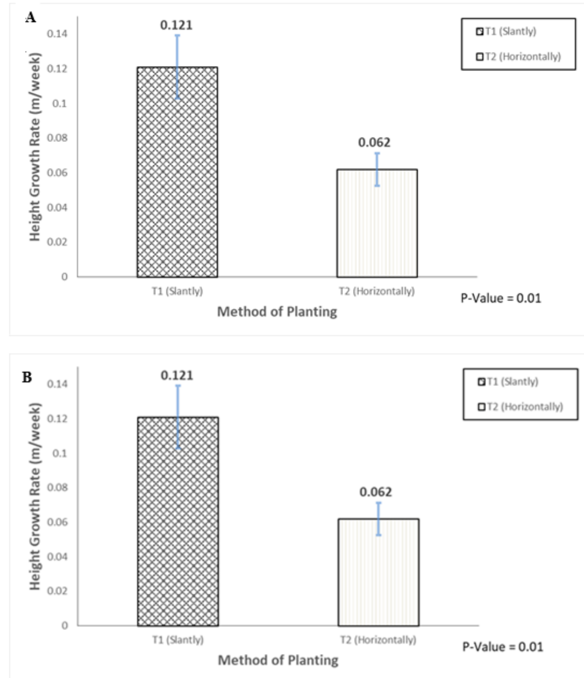

Figure 7. Height growth rates of Bambusa vulgaris var vittata planted slantly and Horizontally at a 95% confidence interval

4. Discussion

4.1 Culm Survival and Mortality Rates

The survival rates of culms planted Slantly (60^o) and horizontally (180o) were very high. The culms were selected from two-year-old mother culms and, therefore, could have vigorous buds. This was also realized by IDRC and IUFRO (1980), who observed that the best planting materials could be obtained from bamboo between one and three years. The required growth factors, including moist, deep, and well-drained sandy loamy soil, coupled with the exposed photosynthetic surfaces of the planted culms, resulted in the high survival rates of the shoots. Zhou et al (2005) and Garima et al (2021) emphasized the need for good soils, which is essential for the growth and development of bamboo, whilst Nduwamungu (2018) also observed that water requirements of cuttings were high and so watering must be done regularly. Much emphasis was placed on plant hygiene during this project to ensure that the health status of the stock plant and cuttings were very good. This was maintained through nursery sanitation like weeding, avoiding over-watering and less handling of cuttings and preventing insect invasion by always filling culms to the brim. This agrees with the observation by Nduwamungu and Musengimana (2015), who reported that seedlings at nurseries with poor sanitation and more handling were more susceptible to diseases and injury than those in hygienic nurseries. Ntirugulirwa et al. (2012) also reported that there should be a need to fill culms to prevent desiccation. It has been observed in this research that the supply of water to fill the culms does not only prevent desiccation but also drives away termites and ants without the use of insecticides. This was also evident in the study.

4.2 Growth Rates of Shoots

The growth of shoots was generally slow in the first two weeks of sprouting but rapid in the third and fourth weeks. In comparison, our results agree with Gebrehiwot et al. (2016), who reported that bamboo has an averagely moderate growth rate in the early stages of development. Measurement began in the fifth week after planting at the point of measurement (POM) of 0.08 m above ground level. There was no significant difference in the diameter growth rates of the shoots. Considering the results by Nduwamumgu (2018), there was a significant difference in mean diameter, higher for the horizontal method of planting (6.39 mm) compared to 4.87 mm for verting planting after 105 days. The increase in elongation was more pronounced in culms planted horizontally (T2) at weeks 6 and 12. This could be attributed to the orientation aiding the chlorophyll in the culm cuttings to function better than those planted slantly. This confirms the observations reported by IDRC and IUFRO (1980). According to the report, all grasses, including bamboo, have intercalary growth. Thus, elongation of the internodes brings about growth in height with an increase in diameter around the nodes at the base. Even though those planted slantly were not increasing in height as much as those planted horizontally, they were steadier until the 8th week (Figure 2).

When the death of the terminal buds occurs, that portion breaks off – reducing the height of the culm. The node immediately below the terminal portion develops new shoots in the form of a cone, with the terminal portion appearing from the centre. As the lengths of the new individual shoots increased with the elongation of the internodes, there was a subsequent increase in the basal portion of the node from which the shoots emerged. According to He et al. (2013) and Gamuyao et al. (2017), shoot emergence results from cell formation and DNA synthesis. Between the 7th and 11th weeks, this phenomenon occurred in the shoots of the culms planted horizontally, resulting in almost no increment to allow new shoots to come out from the broken portions (Figure 2). The continuous "break and grow" of these shoots might have triggered the growth of roots later and, therefore, could not develop into exploitable culms but rather enhanced rooting. However, with time, beyond thirteen weeks, new rhizomes could soon develop into exploitable culms; hence the initial ones could be pruned to give way to the new culms to develop.

4.3 A Better Method of Propagation

Even though culms planted slantly (60^o) had a diameter growth rate of 0.5025cm/week and those planted horizontally (180^o) had a diameter growth rate of 0.4505cm/week, there was no significant difference in the treatments contrary to the findings reported by Nduwamungu (2018). Similarly, Nduwamungu and Musengimana (2015) reported a significant difference between vertical and horizontal treatment diameter responds. The difference in the findings may be attributed to edaphic and environmental factors prevailing in the experimental areas as Ananfack et al. (2022) reported, humus and optimal moisture-containing soil influence the early growth parameters of bamboo. Matching our results to other studies, ICFRE (2003) reported that when one to two nodes of one to three-year-old culms were planted Slantly and horizontally, the horizontal ones gave a better result with a significant difference in the treatment at 0.05 level. In this regard, responds from treatments of diameter growth rates could not be used to determine a better planting method. In terms of volume, culms planted at 180^o (7.22×10^{-6} m^3 -3.64×10^{-5} m3.) is a better propagation method than those planted at 60^o (1.18×10^{-6} m^3 -1.23×10^{-5} m^3). It was, however, easier and faster to dig a slant hole to plant culms slantly than burying the culm horizontally. There was also a significant difference in the two methods regarding the nurturing and maintenance of culms. During watering and filling of planted culms, the water running off or splashing carried debris and soil particles into the culms, thereby closing the cavity and preventing the entry of water, which may lead to desiccation. Hence, more time was required to remove this debris periodically. The same problem was faced during weeding, where the loose particles around the beds were carried into the culm cavities when it rained or during watering. This agrees with the findings in ICFRE (2003), which reported that when one to two nodes of one to three-year-old culms were planted slantly and horizontally, the horizontal ones gave a better result.

5. Conclusion

It has been successfully demonstrated that vegetative propagation of Bambusa vulgaris var vittata could be adopted to enhance plantation development using Bamboo in Ghana. The survival rates of culms planted Slantly (60^o) and horizontally (180^o) were very high, constituting 100% and 95%, respectively. The growth of shoots was generally slow in the first two weeks of sprouting but rapid in the third and fourth weeks. The diameter growth rate of bamboo culms planted slantly was 0.5025cm/week, and that planted horizontally was 0.4505cm/week. Though there is no significant difference in terms of growth and survival rates in culms planted at 60^o and those planted at 180^o, however, in terms of volume, the horizontal planting is a better method than the slanting planting method though it is easier and faster to dig a slant hole for planting culms than burying the culms horizontally. Nurturing and maintenance of culms planted slantly are also easier. During watering and filling of planted culms, the water running off or splashing could carry debris and soil particles into the horizontal culms, thereby closing the cavity and preventing the entry of water, which may lead to desiccation. Hence, more time is required to remove the debris periodically. Consequently, to enhance Bamboo plantation development in Ghana, farmers should adopt Culms planted slantly.

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