Rhizome Propagation Methods of Lowland bamboo (*Oxytenanthera abyssinica)*incentral Tigray, Northern Ethiopia

Abstract

Bamboo is a plant species that has a range of economic, environmental, and sociocultural importance. Bamboo can be propagated through sexual and asexual propagation methods. Both methods have their own advantages and disadvantages. The study aims to evaluate different rhizome cutting materials that are relatively suitable for large-scale plantations. The materials for propagating bamboo by vegetative means are whole or portions of the rhizomes, each with a single culm having two to six basal nodes, preferably 1- to 2-year-old culms from the peripheral portion of the clump having 2, 4, 6 basal nodes and 1.5-2 cm, 2-4 cm, and 4-6 cm in diameter. The design of the experiment is a split plot design with three replications and nine plots. This experiment is laid in 1029 m^2 (21 m x 49 m). The size of each plot is 45 m^2 (15 m by 5 m), and the distance between plots and plants in plots is 2 m. The number of nodes is assigned in the main plot, and the diameter of the planting material is assigned in the subplot. There are a total of 9 treatment combinations and a total of 108 planting materials. Significantly higher (P = 0.01) mean survival rate (59%) was observed in the planting material with two basal nodes and 2-4 cm diameter and the planting material with six nodes and 2-4 cm diameter. Further research is crucial to devise effective vegetative propagation methods for large scale plantations without compromising the survival capability of the planting materials.

Key words: Propagation methods, bamboo, offset

Introduction

Bamboo is a plant species classified under the subfamily Bambusoideae of the family Poaceae(Soreng *et al.*, 2015).Bamboo is among the fast growing plants that are grown on the planet Earth. Bamboo plant is known to have various environmental, economic, social, and cultural benefits(Abebe *et al.*, 2021; Guadie *et al.*, 2019; Nwaihu *et al.*, 2015; Ogunjinmi *et al.*, 2009; Osei *et al.*, 2019; Rahim andIdrus, 2019).

Bamboo is an excellent soil and water conservation material because of its peculiar dense clump formation and extensive interlocking fibrous root system(A. Singh *et al.*, 2014).Bamboo can be used as a soil and water bioengineering materials and is a cost-effective material for erosion control and slope stabilization works(Tardio *et al.*, 2018).

The mechanical strength of bamboo makes it as good alternative for various construction materials like wood and steel (Janssen, 1981). Bamboo plants can be used for various housing purposes such as roofing and flooring. Bamboo culms are not only used directly without any alteration as structural members such as beams and columns; it can also be used as reinforcement in concrete as a replacement to steel (Fahim *et al.*, 2022).

Despite the fact that bamboo stands are not considered as forests in a future regime of reducing emissions from deforestation in developing countries (REDD) (Lobovikov *et al.*, 2007), bamboo stands exhibit a high rate of annual growth, which can serve as high carbon sequestration and storage potential (Song *et al.*, 2011).

The global coverage of bamboo forest resources is estimated to be 35,040,000 hectares of land, and this value is equivalent to 0.86% of the total global forest resources (FAO, 2020). Another study by (Du *et al.*, 2018) indicated that the total bamboo stock of the globe is approximately 30,538,350 hectares of land. Even though the global bamboo resource is increasing over 1990-2020, it is because of only two potential bamboo producing countries, namely India and China (FAO, 2020). In 2018, a group of researchers estimated that the total coverage of bamboo forest in the African continent is 3,404,310 hectares(Du et al., 2018).Later on, FAO estimated 4,648,000 hectares (13% of the global bamboo) of land covered with bamboo, and 85.7% of this is available in eastern and southern Africa (FAO, 2020). Different studies indicate that the total bamboo stock of Ethiopia is approximately 1 million hectares of land (Du et al., 2018; Zhao *et al.*, 2018). This stock is disproportionately distributed across all regions in the country.Of which 425000ha are in Tigray and some parts of Amhara regions(Dessalegn Yalew *et al.*, 2022).

Bamboo is among the species in the world with high species diversity. There are over 90 genera of bamboo globally with over 1200 species (Bystriakova *et al.*, 2003; Lobovikov et al., 2007; Soderstrom andEllis, 1988). Of the 1200 species globally,43 species are found in Africa. Of which, only two species of bamboo (*Yushania alpina* and *Oxytenanthera abyssinica*) are native to Ethiopia (Bekele *et al.* (1993). But now a day, there are different attempts to increase the diversity of bamboo species in Ethiopia. As a result, 25 species of bamboo have been introduced to Ethiopia in the last few decades(Mulatu Yigardu *et al.*, 2016).

Bamboo plants can be propagated through sexual(from seed) and asexual (from vegetative part)propagation methods. The success rate of the sexual propagation method is much higher than the asexual propagation method. But the availability of bamboo seeds is affected by many factors. Of which, bamboo plants have irregular flowering patterns; some did not produce seeds at all (e.g., Bambusa vulgaris) (Banik, 1995), and most gregarious flowering bamboos die after seed set(Guerreiro andVega, 2021)and lastly bamboo seeds exhibit short storage time after collection(Ayana *et al.*, 2012; Lakshmi *et al.*, 2018; G. Singh andRicha, 2016; Thapliyal *et al.*, 1991). Therefore, it is important to use the vegetative propagation methods in the absence of seed availability. The most widely used vegetative propagation methods for bamboo are rhizome or offset cuttings, layering and culm cuttings (Gaur, 1985). Three of the vegetative propagation methods have their own advantages and disadvantages. The main advantage of culm cutting and branch cutting is the availability of planting material (Razvi *et al.*, 2011) while the main disadvantage is the low survival rate of the planted materials(Mulatu Yigardu andMasresha, 2014).The rhizome cutting propagation method is more successful than the other two vegetative propagation methods but has limited applicability for large scale plantation as it uses a large bulk of soil with at least three or for culms(Hamalton *et al.*, 2022). Therefore, this study is designed to evaluate the effect of culm diameter and node numbers of the planting material on the survival rate and growth parameters of lowland bamboo (*Oxytenantheraabyssinica*).

2. Materials and Methods

2.1. Description of the study site

This study is conducted in Northern Ethiopia, Tigray Regional State, Central Zone, MerebLekeDistrict. MerebLeke is a District bordered on the south by Laelaymaichew, on the southwest by Tahtay maychew, on the west by the North Western Zone, on the north by the Mereb River (which separates it from Eritrea), on the east by Ahferom district, and on the southeast by Adwa(Figure 1).

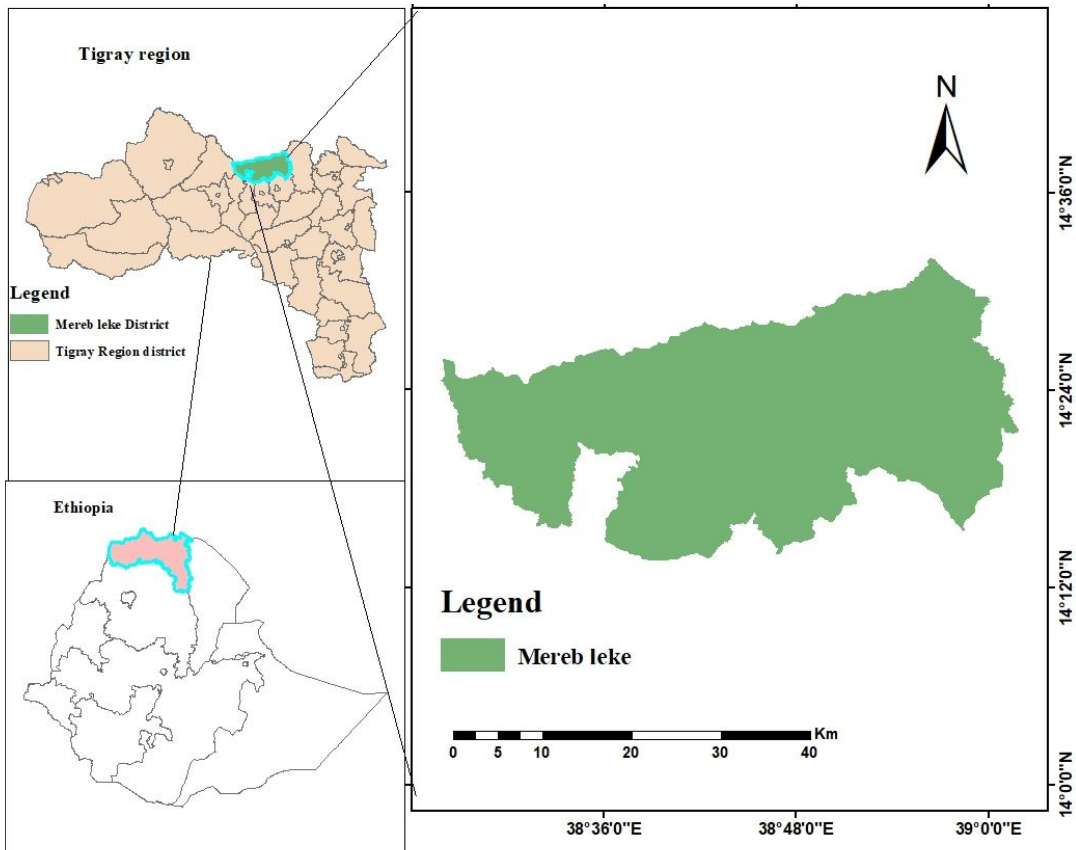


Figure 1: Map of the study area

Climate

The climatic condition of Mereb-leke district is represented by the nearby station of Adwa district meteorological station. The temperature and rainfall of the area over the years 2006-2016 are displayed below (Figure 2).

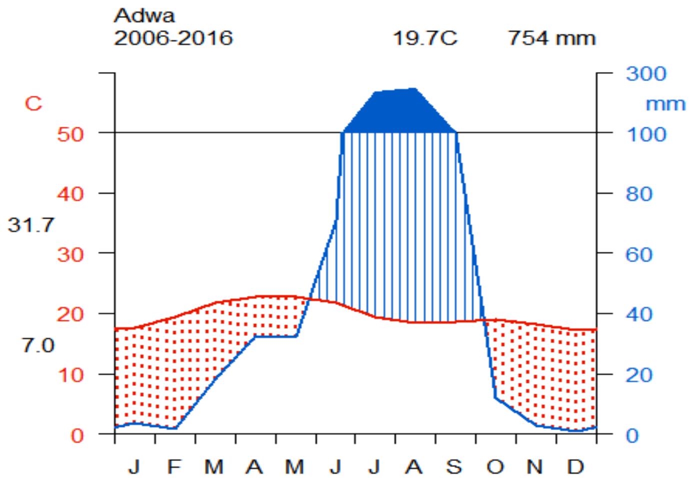


Figure 2: climatic diagram of the study area from 2006-2016 (Source: Tigray Region Meteorological office)

Materials

The materials for propagating bamboo by vegetative meansare whole or portions of the rhizomes, each with a single culm having two to six basal nodes (called offsets). Preferably 1- to 2-years old culms from the peripheral portion of a clump are selected for offset planting, and cut at 2,4,6 basal nodes having 1.5-2 cm,2-4 cm,4-6 cm in diameter. The culms are cut in a slanting manner right above the node without damaging the basal portion of the branches. The rhizome attaching the culm is dug and cut 30 to 45 cm from the ground. The rhizome and roots attached must not be damaged when collecting the offsets.

Experimental design

The design of this experiment is a split-plot design with three replications and nine plots. This experiment is laid in 1029 m^2 (21 m×49m). The size of each plot is 45 m^2 (15 m×5m). The distance between plots and plants in the plots is 2 m.The number of nodes is assigned in the main plot, and the diameter of the planting material is assigned in the subplot. The distance between blocks is 2m and the distance between plots is 1.5m.This experiment contains three replications and three plots with each replication. Each node number (main plot) is assigned to each plot and in each plot, all the three diameter classes (sub plot)are represented four times (12 planting material per plot) with 2m plant spacing. In this experiment, there are a total of 9 treatment combinations and a total of 108 planting materials.Therefore, the treatment combinations are listed as follows:

Treatment 1 is two basal nodes with 1.5-2cm diameter of planting material

Treatment 2 istwo basal nodes with 2-4cm diameter of planting material

Treatment 3 istwo basal nodes with 4-6 cm diameter of planting material

Treatment 4 isfour basal nodes with 1.5-2cm diameter of planting material

Treatment 5 is four basal nodes with 2-4cm diameter of planting material

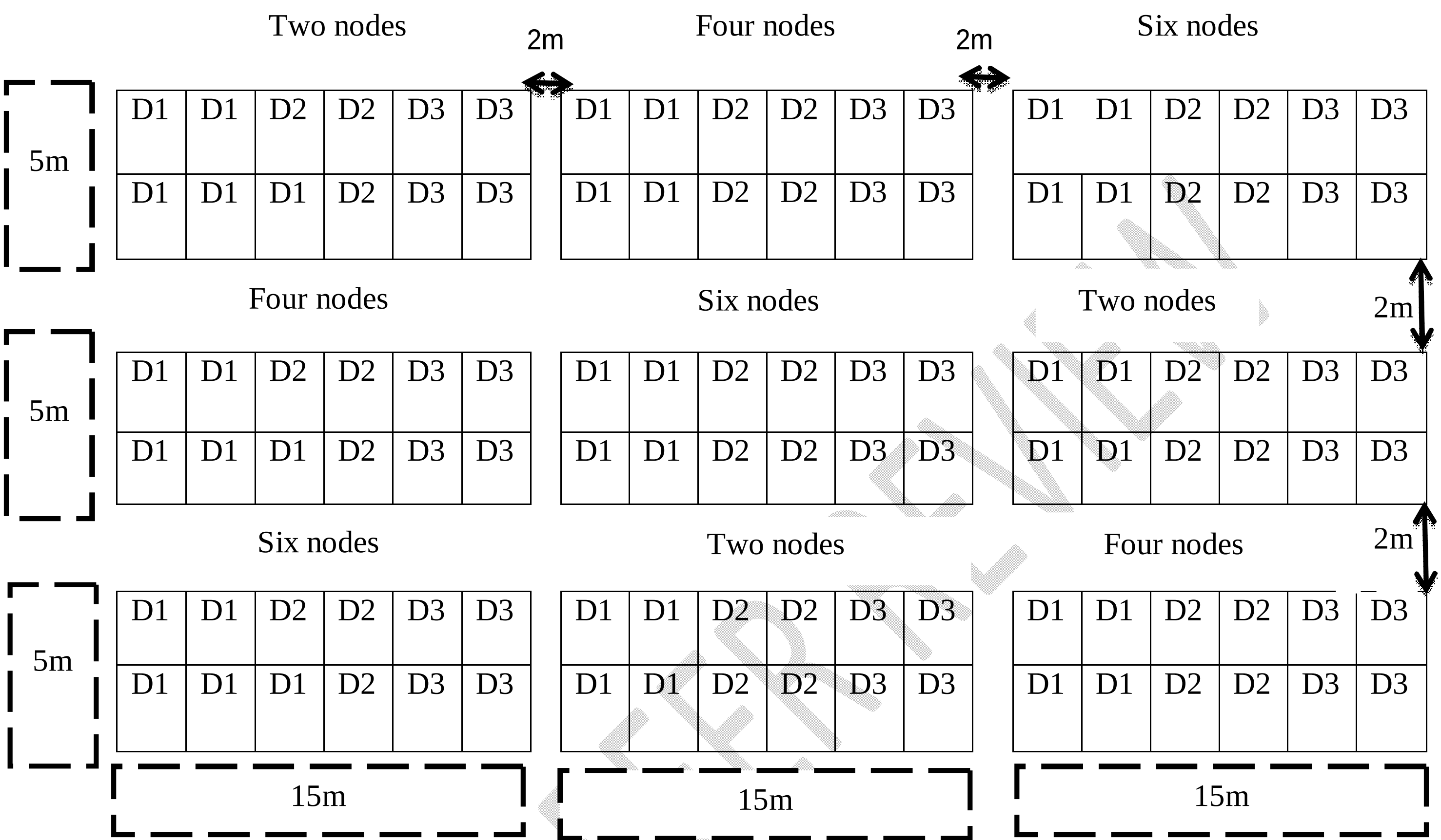
Treatment 6 isfour basal nodes with 4-6cm diameter of planting material

Treatment 7 is six basal nodes with 1.5-2cm diameter of planting material

Treatment 8 is six basal nodes with 2-4cm diameter of planting material

Treatment 9 is six basal nodes with 4-6 cm diameter of planting material

Experimental layout and treatment arrangements



Where, D1 is diameter 1.5-2cm,D2 is diameter 2-4cm, and D3 is diameter 4-6cm

Pit size is 0.5 m×0.5 m, edge distance is 1 m, plot area is 45m^2

Data collection

First round Data collection was conductedin September 2018 (4 months after plantation), and second round data was collected in 2023 so as to see the performance of the planting materials. The number of new shoots was counted. Collar diameter and culm diameter were measured using a digital caliper. Height was measured using a graduated pole. The survival count was made on the final date of data collection.

Data analysis

Data of collar diameter, culm diameter, culm height, and number of culmswere subjected to a test of normality (Shapiro Wilk test of normality).The data distribution in number of culms was subjected to log transformation, and the means were back transformed for better understandability to readers. All nine treatment combinations were analyzed using one way ANOVA.The survival rate of the planting materials was analyzed using percentage.To perform those analyses, SPSS v23 was employed.

Result and discussion

Survival rate (%)

A significant statistical difference (P = 0.01) in mean survival rate (59%) was observed in the planting material with two basal nodes and 2-4 cm diameter and in the planting material with six basal nodes and 2-4 cm diameter than the rest of the other treatment combinations. The lower survival rate (16%) was observed in the planting material with six basal nodes and 1.5-2 cm diameter, followed by the treatment, two basal nodes and 1.5-2 cm diameter of planting material (25%) indicating smaller diameter of cutting materials may have smaller food reserve until they are capable of establishing the root system and this is in line with (Mulatu Yigardu and Masresha, 2014)**.** But there is no overall statistical significance (P = 0.53) between all the treatments in the survival capability of the planting materials except the planting material with two basal nodes and 2-4 cm diameter and in the planting material with six nodes and 2-4 cm diameter.

Collar diameter, culm diameter, and culm height

The overall statistical significance (P = 0.001) in the mean collar diameter of the planting materials was observed between the treatments. The highest mean collar diameter (5.13 ±0.1 cm) was observed in the treatment, six basal nodes with 4-6 cm diameter of planting material followed, by the treatment, four basal nodes with 4-6 cm diameter of planting material(4.961 ± 0.1 cm) and this result is in agreement with (Kebede *et al.*, 2017) whereas, the lowest mean collar diameter (4.5 cm) was observed in the treatment, Six nodes with 1.5-2 cm diameter of planting material,and the treatment, two basal nodes with 2-4 cm diameter of planting material.

Table 1: Mean ±SE of collar diameter, culm diameter and culm height

Treatments	n	Means ±SE		
		Collar diameter	Culm Diameter	Culm height(m)
1	121	4.56±0.06^{bc}	3.701±0.05^{b}	5.8±0.3^{bc}
2	81	4.515±0.05^{c}	3.612±0.04^{b}	6.2±0.14^{abc}
3	38	4.67±0.16b^{c}	3.863±0.2^{ab}	6.68±0.4^{a}
4	72	4.476±0.064^{c}	3.54 ±0.06^{b}	5.91±0.1^{bc}
5	165	4.615±0.05^{bc}	3.78 ±0.06^{ab}	5.78±0.1^{c}
6	83	4.961±0.1^{ab}	4.088 ±0.07^{a}	6.65±0.2^{ab}
7	27	4.475±0.06^{c}	3.71±0.06 ^{b}	6.1±0.16^{abc}
8	89	4.637±0.05^{bc}	3.861±0.05^{ab}	6.16±0.16^{abc}
9	93	5.13 ±0.1^{a}	4.068±0.05^{a}	5.93±0.13^{bc}
P-Value		0.001	0.001	0.002

Where: 1 is two node with 1.5-2cm diameter, 2 is two node with 2-4cm diameter, 3 is two nodes with 4-6 cm diameter, 4 isfour nodes with 1.5-2cm diameter, 5 isfour nodes with 2-4cm diameter,6 isfour nodes with 4-6cm diameter, 7 issix nodes with 1.5-2cm diameter, 8 issix node with 2-4cm diameter, and 9 issix node with 4-6 diameter, n is the number of observations.

The overall mean difference in culm diameter of the treatments was statistically significant (P=0.001). Statistically higher mean culm diameter of 4.068±0.05 cm and 4.088 ±0.07 cmwere observed in the treatment, six nodes with 4-6 cm diameter of planting material,and in the treatment, four nodes with 4-6 cm diameter of planting material,respectively and this is in agreement with (Kebede et al., 2017). Whereas the lowest mean culm diameter was observed inthe treatment:two nodes with 1.5-2cm diameter, two nodes with 2-4cm diameter, four nodes with 1.5-2cm diameter, and six nodes with 1.5-2cm diameter (see table 1above).The overall mean difference in culm height was statistically significant (P=0.002). The highest mean of culm height was observed in the treatment, two nodes with 4-6 cm diameter of planting material (6.68±0.4m). Whereas the lower mean of culm height (5.78±0.1 m) was observed in the treatment, four nodes with 2-4 cm diameter of planting material

After three months

After two years

Figure 3: planted propagating materials in the experimental site

Number of culms

The highest number of culms (55) was observed in the treatment with four basal nodes with 1.5-2 cm diameter, followed by the planting material with two nodes and 1.5-2 cm diameter. However, the overall statistical significance in number of culms between the different planting materials is not statistically significant (P = 0.78). As the final data was taken 3 years after plantation, once the planting material established the root system, no significance was observed in every other growth parameters. This could be due to the adaptation of the species to the site.

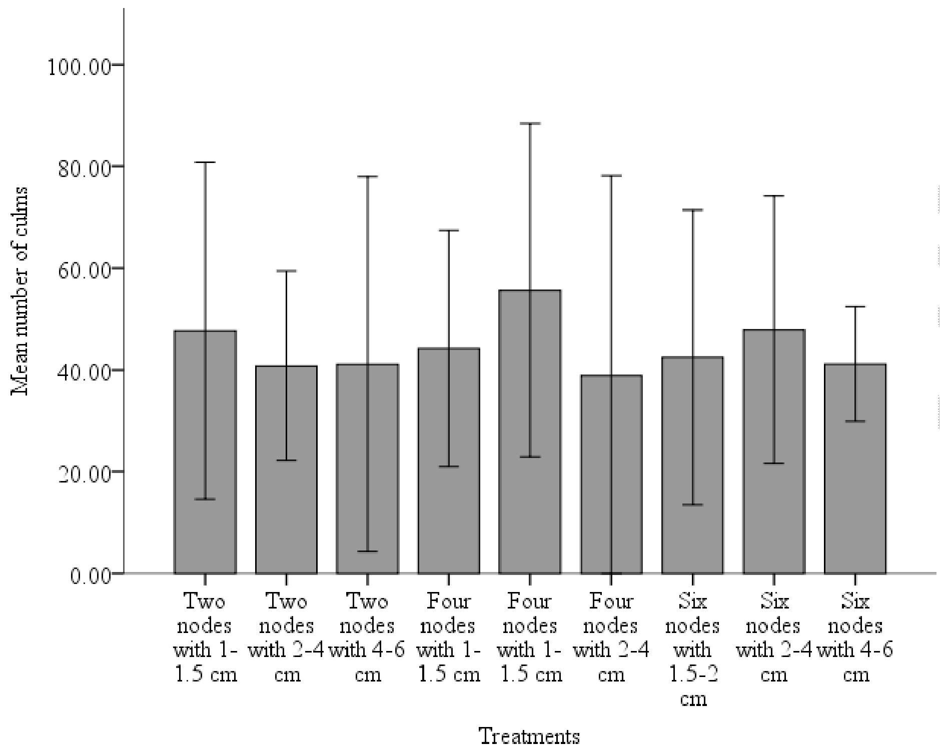


Figure 4: Mean number of culms between the treatments

Conclusion and recommendations

This study revealed that the planting material with two nodes and a 2-4 cm diameter of planting material, and the cutting material with six nodes and a 2-4 cm diameter of planting material exhibited the higher survival capability than all the treatment combinations. The authors recommend further research be done to obtain even more effective vegetative propagation methods that could be applied to a large-scale plantation with better survival capability.

Availability of data and materials:All the data's and materials used in this article are available from the corresponding author.

Disclaimer (Artificial intelligence): No artificial intelligence has been used in this manuscript.

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