Original Research Article
Adaptation and Growth Performance of Different Introduced Bamboo Species in Central Tigray, Northern Ethiopia

ABSTRACT

Bamboo is a giant bushy grass and typically a faster growing perennial than any other tree species and it starts to give utility within three or four years of planting time, except bearing seeds. The study was conducted on four bamboo species (Bambussabambos, Phyllostachusedulis,Yushaniaalpina, and Bambussa vulgaris) to evaluate their adaptability potential and growth performance at LaelayMaichew district, central zone of Tigray, Ethiopia. The design of the experiment was carried out using a randomized complete block design (RCBD) with three replications. The distance between the experimental plots and blocks was 2 m and 3 m, respectively, and the spacing between bamboo seedlings in the plot was 2 m x 2 m, with 4 bamboo seedlings per plot. A total of 48 bamboo seedlings were planted in the experimental site. The growth parameters; including survival rate, new emerging shoot, internode length, number of nodes, culm height, culm diameter, and root culm diameter were measured and recorded. The collected data were statistically analyzed using one-way analysis of variance (ANOVA) between treatments following the post hock test of Tukey at P<0.05 using SPSS for Windows version 20. The results revealed that Bambussabambos has a better survival percentage (100%), followed by Bambussa vulgaris (58.3%), Yushaniaalpina (41.67%), and Phyllostachusedulis (0 %). The growth parameters: new emerging shoot (culm), collar diameter,diameter at stump height, and diameter at breast height of Bambussabambos were significantly higher than those of Yushaniaalpina and Bambussa vulgaris (P=.001). However, for similar parameters, Yushaniaalpina showed non-significant variation with Bambussa vulgaris (at P>0.05). The mean heights between treatments (Bambussabambos (5.1 m), Yushania alpine (4.5 m), and Bambussa vulgaris (4.2 m)) were observed statistically non-significantly different (at P=.26).The other growth parameters were: the mean value of total internode length(TIL) and middle internode length (MIL) of Bambussabambos was significantly higher than that of Bambussa vulgaris (at P<0.05). The study revealed that, among the four bamboo species, Bambussabambos showed higher growth performance and adaptability potential, followed by Yushaniaalpina and Bambussa vulgaris. As a result, the best-performing introduced bamboo species (Bambussabambos) could be promoted to end users in related agro-ecological areas for various benefits. Further studies should be recommended on the adaptability of theintroduced bamboo species in other agro-ecologies.

***Key words**: Bamboo species, Adaptation, Growth performance,Introduced*

1. INTRODUCTION

Bamboo is an exceptionalgroup of giant bushy grasses in tropical and subtropical ecology in whichthe woody culms arise from underground rhizomes [1].Bamboo is a woody-stemmed perennial grass that typically grows in hollow, semi-solid to solid culms with distinct internodes, nodes, rhizomes, and branches.Theyare shrubs, which have a tree like habit, their culms are erect and sometimesclimbing.They are part of the grass subfamilycalled Bambusoidae, which is in the Gramneaefamily [2].

Bamboo is one of the fastest-growing plants in the world with rapid regeneration potential, which offers significant advantages over the other plant species [3]. Environmentally, bamboo plants have tree-like functions[4], and it is a multi-purpose plant [5],which can provide an opportunity for watershed development and the restoration of degraded areas through mitigation of soil erosion [3]. There are almost over 10,000 verified bamboo uses and products [6].These include timber products, cloth, plastic mixes, food,energy, health, and cosmetics. It has also a proven eventualityin the restorationof degraded lands, watershed protection, and climate change mitigation and adaption strategy[7].

Over 1,500 different bamboo species found throughout the world, and they cover more than 14 million hectares of land in the tropical, subtropical, and temperate environments on every continent except in Antarctica and Europe[8, 9]. With respect to the entire bamboo community, China is the first country having the highest diversity of bamboo species (800 bamboo species) and followed by India with 160species)[10]. Africa has more than 43 bamboo species occurring naturally or introduced [11]. The two bamboo species are indigenous to Ethiopia: *Oxytenantheraabyssinica*(A. Richard) (lowland bamboo) and *Oldeaniaalpina*(K. Schum.) (highland bamboo). The pure natural bamboo forest in Ethiopia is the largest in Africa, having area coverage of over 1 million ha [12], which is about 7% of the world total and 67% of the African bamboo forest area [13].The preservation of bamboo's genetic diversity and resources is vital for the wellbeing of people on a national and regional scale [12].

Even though Ethiopia is one of the most endowed country having huge coverage of bamboo resource in Africa, but the country has limited genetic diversity, with only two bamboo species, *O.alpina(highland bamboo)* and *O. abyssinica(lowland bamboo)*, which are confined to specific agro ecological areas [14]. With the two bamboo species it has a significant challenge to secure a constant supply of bamboo raw material forindustries, enterprises and regional and/or national handicrafts.Even though, bamboo species play a crucial role in addressing climate change mitigation, reduce land degradation and creating economic opportunitiesfor a substantial segment of the population, it is deteriorating in an alarming rate due to overexploitation, shifting cultivation and extensive forest fire. This all problems with bamboo species in Ethiopia and similarly in Tigrayis due to the low diversity and availability of bamboo species/ bamboo resource.

Therefore,this study was designed to introduce and evaluate the adaptability potential and growth performance of introduced bamboo species in Tigray. This will increase the genetic diversity of bamboo species, create income diversify and promote sustainable land management practices. The objective of this study wasto introduce and evaluate the adaptability and growthperformance ofthe new introduced exotic bamboo species in central zone of Tigray.

2. MATERIALS & METHODS

2.1. Description of the study area

The experiment was carried out in LaelayMaichewdistrict (figure 1).The district is geographically located between 13º 36''North latitude and 39º 36'' East longitude. LaelayMaichew district islocated about 245 km North West of Mekelle city, the regional capital of Tigray. The district has an altitude whichranges from 2050 to 2200 m a.s.l.with two agro-ecological zones, namely,lowlandand mid-highland.The mean annual temperature of the district ranges from12^{o}c to 28^{o}c and the annual rainfall varies between 500-900mm[15].

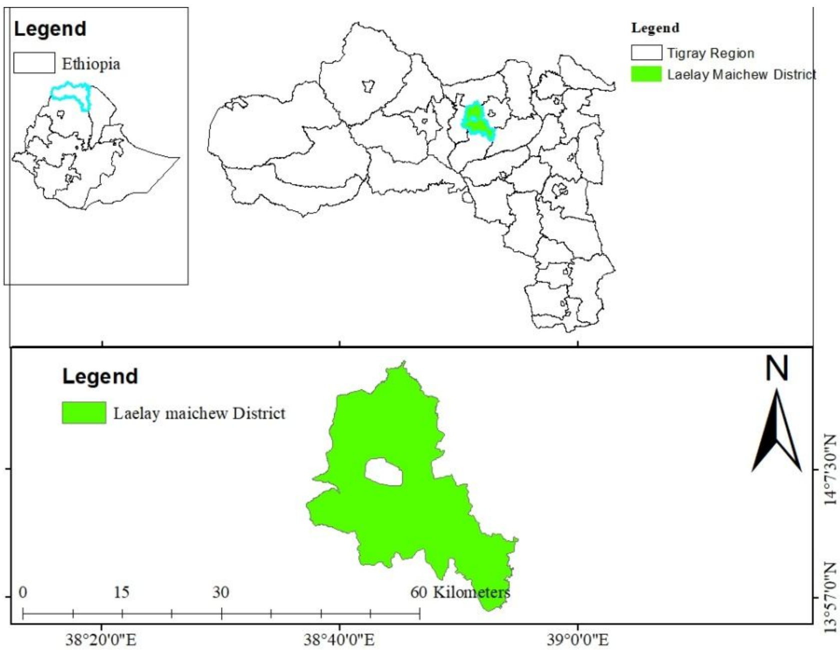

Figure 1: Map of the study area

2.2. Treatments and Experimental Design

In this study, thedesign of the experiment is carried out using randomized complete block design (RCBD) with three replications. The experiment contains 12 experimental units: four treatments (*Bambussabambos, Phyllostachusedulis,Yushaniaalpina*and*Bambussa vulgaris*), replicated three times.The distance between the experimental plots and blocks were 2 m and 3 m, respectively.The spacing between the bamboo seedlings within the plotswas2 m X 2 m.The total number of bamboo seedlings in the experiment is 48 seedlings (4 seedlings per plot ×3 replications× 4 species). All the bamboo species were obtained from forestry research center of Addis Ababa,and planted inJuly, 2020.The exotics bamboo species were originally comes from China and planted at field to evaluate their adaptability and growth performance of the species.

2.3. Data collection

The experimental trial was conducted from 2020 to 2024 at LaelayMaichew district to evaluate their adaptability potential and growth performance of bamboo species to select the best performed bamboo species. The collected data were: survival rate, number of culm(emerging shoots), culm height, root collar diameter, diameter at stump height(DSH), diameter at breast height (DBH), internodes length, number of nodes, lower internodes length, middle internodes length and upper internodes length.

2.4. Data Analysis

Prior to the analysis of the treatments effects, assumptions of normality data on the adaptability and growth Parameters of the introduced bamboo species were checked using the Shapiro – Wilk test. The collected data were statically analyzed using one - way analysis of variance (ANOVA) between treatments following the post hock test of Tukey at P<0.05 using SPSS for windows version 20.

3. RESULTS AND DISCUTIONS

3.1. Survival rate (%)

The survival rate (%) of the introduced bamboo species in the experimental trial showed that *Bambussabambos*has the highest survival rate (100%)followed by *Bambussa vulgaris* (58.3%), *Yushaniaalpina (41.67%)*as illustrated in Figure 2.However, *Phyllostachusedulis* was not adaptable, which showed the least survival rate with(0 %). The result of this study indicated that,the agro ecology of LaelayMaichew district is suitable to*Bambussabambos*,*Bambussa vulgaris* and *Yushaniaalpina*. Similar result was reported for*Bambusabambos* by[16], which have survived 100%, [17] account for 94% and [18] *B. bambos* survived(91.67%) in south eastern zone of Tigray. The best survivingintroduced bamboo species in this study was not attacked by pests and diseases. However, *Phyllostachusedulis, exhibited* 0% survival rate was highly attacked by pests and disease.Pests and diseases might be other factors for the low survival rate of bamboo species in LaelayMaichew. According to its nature *Phyllostachusedulis*is well adapted in humid tropics and temperate zone with enough water availability and more humidityzone[19, 20].This might be one factor for the least adapted bamboo species in the experimental trial in semi-arid zone.This result agrees with [18]that *Phyllostachusedulis* survived (16.6%) which was the least survived in south eastern zone of Tigray.

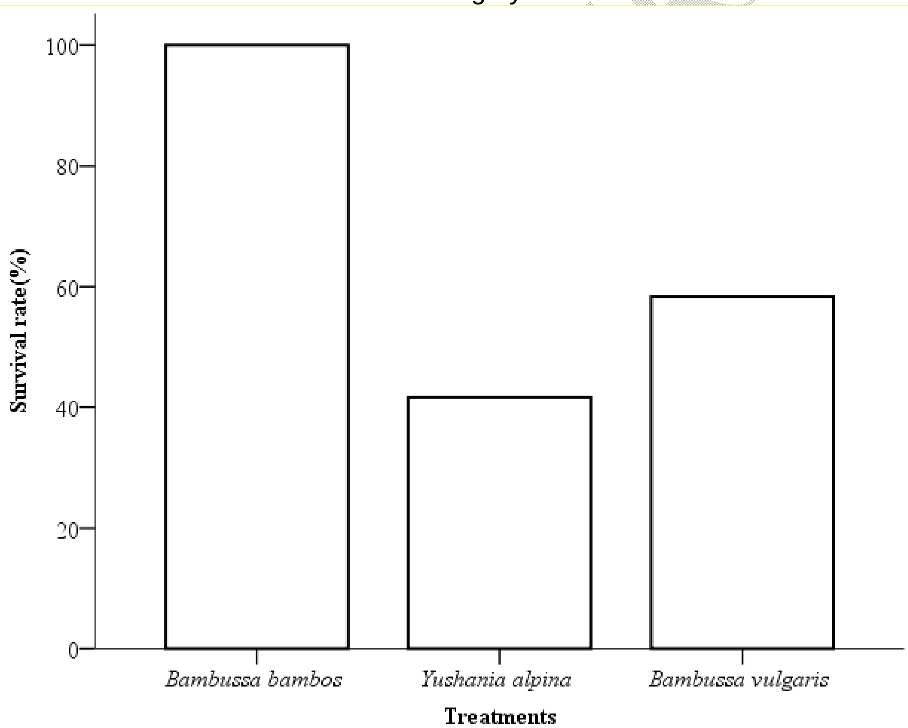

Figure 2: The survival rate (%) ofintroduced bamboo species

3.2. Growth performance of the different bamboo species

3.2.1. Number of new emerging shoots (culm)

The production of new culms per clump of bamboo species depends mostly on the clump age, nutrient storage and the rainfall availability [21, 22]. In this study, there was a significant variation of culm number betweenthe treatments (*Bambussabambos,Yushaniaalpina*and*Bambussa vulgaris*).The number of culms for *Bambussabambos*was significantly higher than *Yushaniaalpina*and*Bambussa vulgaris* (at *P*=0.001).However, the number of culms between *Yushaniaalpina*and*Bambussa vulgaris*were observed non-significant variation at P>0.05(Table 1). Similar result was reported that the highest meannumber of culms per clump of *Bambusabalcooa*was 19.44[23, 9]. However, this result is in the contrary to [18] which indicates, the number of culm per clump of *Bambussabambos*is lower as compared to*O. abyssinica.*Even though the number new shoots of *Bambussabambos*(109)exhibited superiority over *Bambusa vulgaris*(75)byproducing maximum number of culms in the trial ,very close number of culms per clump (66) of *Bambusa vulgaris* was reportedin south-western Ethiopia[24]. The variation of new emerging shoot could be due to the variation of agro ecological zones and the species characteristics.

3.2.2. Culm Diameter (CD, DSH and DBH)

The culm diameter of bamboo species varies depending on the type of species, age and environmental condition [25]. For most bamboo species, their culms can reach maximum diameters at around two to three years of age [25].In this study the mean value of the parameters (CD,DSH and DBH) were observed highly significant different at *P*=0.001(Table 1). The mean collar diameter, diameter at stump height and diameter at breast height of *Bambussabambos* was significantly higher than *Yushaniaalpina*and*Bambussa vulgaris*(at P=0.001).However, fora similar parameters:*Yushaniaalpina*was shown non-significant variation with *Bambussa vulgaris*(at *P*>0.05).The variation of diameter size between the bamboo speices might be due to the growth characteristics of the different bamboo species and environmental factor (low rainfall availability). This result is in lines with [25, 26], soilquality,water availability and climate are the factors which influence the culm diameter of bamboo species; in which these factors make a variation even with in the same species in different location.Other findings similar to this study were reported by [27, 28],a significant variation of the culm diameter between the difference bamboo speciesmight be due to the growth performanceand adaptability potential of the species.

3.2.3.Culm Height (m)

The mean height between treatments (*Bambussabambos*(5.1m),*Yushaniaalpina*(4.5 m)and*Bambussa vulgaris*(4.2m)) were observed statisticallynon-significant different at P=0.262(Table 1). The result agreed with[29], which shows that, the Culm height for *Dendrocalamushamlitonii*(5.34m), *Dendrocalamusmemebranceous*(4.95 m) *Oxythenanteraabyssinica*(3.84m) and *Dendrocalamusasper*(3.81 m) showed statistically non-significant difference in height at the age of four years of establishment. The culm height of *BambussabambosandBambussa vulgaris* aligns with previous research conducted in south eastern Tigray, in which*Bambussabambos*(2.26m) and*Bambussa vulgaris* (2.35 m) shows non- significant height variation [18]. Other similar results were reported by [30], the culm height of matured *Dendrocalamushamlitonii*has 20 meter and *Dendrocalamusasper*has 20-30 meter which is almost similar among the species. This could be due the similar growth characteristics of the species for a certain age. However, the full length of emerging shoot is varied among the species;this might be due to the species adaptability and performance conditions variation [27]. Since culms are a valuable agricultural product, the primary goal of selection is to improve biomass production.

Table 1.ANOVAtable for means±SE comparison between treatments at 0.05 significant levels (Mean±SE).

Treatments	Parameters				
	Culm no.	CD(cm)	DSH(cm)	DBH(cm)	Height(m)
Bambussabambos	109 ±15.7a	3.85 ±0.19a	3.38 ±0.15a	2.97 ±0.19a	5.1 ± 0.4a
Yushaniaalpina	53 ±12.6b	2.13 ±0.15b	1.97 ±0.16b	1.84 ±0.19b	4.5 ±0.2a
Bambussa vulgaris	75 ±31.7b	1.89 ±0.13b	1.55 ±0.09b	1.5 ±0.02b	4.2 ±0.5a
P-value	0.001	0.001	0.001	0.001	0.262

Means of the treatments in a column with similar lowercase letters are not significantly different (P>0.05), while the difference letters in column indicates significant difference (P<0.05) between the ttreatments. Culm no. -culm number, CD-collar diameter (cm), DSH-diameter at stump height (cm), DBH-Diameter at breast height (cm).

3.2.4. Number of Nodes and Internodes Length

The culm structure of all bamboo species is cylindrical and is divided into sections by nodes. Inter nodes are hollow in most bamboos, but solid in some species. The length of bamboo internodes might reveal information about the quality of bamboo products used for various purposes.In this study, the mean value for the parameters (number of nodes, lower internode length(LIL) and Upper internode length(UIL)between treatments were showed statistically non-significant different at P>0.05(Table 2) and this is in the contraryto[5, 26, 28] result which says, the mean value for the number of node was revealed a significant difference between the different bamboo species in different study sites. This could be due the unique characteristics of the bamboo species across different locations. However, the mean value of total internode length (TIL) and middle internode length (MIL)was observed a significant difference between treatments at P<0.05(Table 2). The highest mean was observed from *Bambussabambos* and followed by *Yushaniaalpina,* while the least mean was recorded from *Bambussa vulgaris.*The result disagreed with [18] , the average internode length of *Bambussabambos*was non- significant difference with*Bambussa vulgaris* in south eastern Tigray. The significant variation of internode length between the treatments across different study areas might be due the age of establishment, species type, water availability and site conditions.The growth characteristics, such as culm length, internode length, hollowness or solidity, culm diameter, number of branches per node, and total number of culms/clump, are among the crucial characteristics bamboo quality determination [31].

Table 2.ANOVAtable for means ±SE comparison of Bamboo species at 0.05 significant levels (Mean±SE).

Treatments	Parameters				
	No.Nodes	TIL(cm)	LIL(cm)	MIL(cm)	UIL(cm)
Bambussabambos	28±1.1a	27.07±0.8a	30.9±1.3a	30.8±0.8a	19.5±0.3a
Yushaniaalpina	24±3a	24.26±0.9a	31.6±1.6a	26.7±1.1ab	14.8±1.5a
Bambussa vulgaris	18±2.4a	19.9±1.1b	26.3±3.2a	19.6±2.6b	12.9±2.3a
P-value	0.076	0.002	0.254	0.01	0.063

*Statistically the mean values with the same letter in the column are not significantly different (P>0.05), while the difference letters in column indicates significant difference (p<0.05) between the treatments.No.Nodes-Number of nodes, TIL- Total internode length (cm), LIL- Lower internode length (cm), MIL- Middle internode length (cm), UIL- Upper internode length (cm).

4. CONCLUSSIONSAND RECOMMENDATIONS

This study provides useful evidence on the growth performance and adaptability potential of four exotic bamboo species in central Tigray, Ethiopia. The study revealed that, among the four bamboo species,*Bambussabambos* showed higher growth performance and adaptability potential followed by *Yushaniaalpina*and*Bambussa vulgaris*.
As a result, the best-performing introduced bamboo species is *Bambussabambos*and shouldbe promoted to end users in related agro-ecological areas for various uses.Additionally, it needs training for the local communities, stakeholders and small enterprises on the production and management of the introduced bamboo species. Further studies should be recommended on the adaptability of these species in other agro-ecologies.

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

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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