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Adaptability and Growth Performance of Introduced Bamboo Species in North East Ethiopia

Gezahagn Getachew*, Derbie Wudu, Gebeyehu Alamire, Hodaddis Kasahun, Andualem Ayalew, Tigabu Redae, and Muluken Wudu

Sirinka Agricultural Research Center (SARC), P.O.Box 74, Woldia, Ethiopia

ABSTRACT

The common bamboo species in Ethiopia are *Arundinaria alpina* and *Oxytenanthera abyssinica*. *Arundinaria alpina* is a highland bamboo species growing in altitudes from 2400 – 3500 and *Oxytenanthera abyssinica* is a lowland bamboo growing within the altitudes from 500 - 1800 meter above sea level. But those two bamboo species grow scarcely in the study area. Keeping the importance of increasing diversity, generation of high economic earnings would possible through introducing available bamboo species for different agroecology. From this perspective, it is imperative to identify the best adaptable exotic bamboo species in the north eastern part of Amhara region. The experiment was conducted in Kobo research site of Amhara regional state, Ethiopia. Randomized complete block design with three replications was used to conduct the experiment. Bamboo seedlings were obtained from international network for bamboo and rattan (INBAR-Ethiopia) and planted on July 22/ 2013. An observation on the survival of the propagated material, diameter, height and number of newly emerged shoots were recorded every three months with follow up on every month. The species were *Denderocalamus brandisii, Bambusa tulda, Bambusa balcooa* and *Denderocalamus asper*. The results showed that, *Bambusa balcooa* and *Bambusa tulda* has better survival percentage than *Denderocalamus brandisii* and *Denderocalamus asper*. Additionally, *Bambusa balcooa* and *Bambusa tulda* had significantly higher height and Diameter at Breast Height than *Denderocalamus asper*. Therefore, both *Bambusa balcooa* and *Bambusa tulda* should be demonstrated and popularized around kobo and other areas that have similar soil and climatic conditions.

Keywords: Diameter at Breast Height, *Denrocalamus, Bambusa,* Exotic bamboo, Height, Northeast Ethiopia,

INTRODUCTION

Bamboo species are perennial giant herbaceous and woody grass, belongs to the subfamily Poaceae or Graminaceae (Liese & Köhl, 2015). It has about 90 genera with more than 1500 species that are native and widely distributed in the tropical, subtropical and temperate regions of all continents except Antarctica and Europe (Kaminski et al., 2016; Yigardu et al., 2016). They have a latitudinal distribution from 47°S to 50° 30'N and an altitudinal distribution from sea level to 4,300 m. The growth vigor of bamboos is unmatched by any other plant in nature; some species reach 40 meters in height and only in a few months' time. Other species can grow faster than 1 meter per day. Bamboo is also a very hardy plant and easily propagated (Ronald, 2005). Bamboo plants grow from seeds or rhizomes. The rhizome system is very important to bamboo. As bamboo does not have a central trunk as in trees, the rhizomes provide the foundation.

Basically, there are two types of rhizomes viz., sympodial (pachymorph) and monopodial (leptomorph), depending on whether it is a clumping or running bamboo. Monopodial: A monopodial form of bamboo can also be called non-clump forming or running bamboo; this growth is usually found in cooler climates and grows "as single, free standing culms. Sympodial: These are typically clump forming bamboos. In these bamboos new culms emerge close to each other because of small rhizome necks thereby forming tight clumps. Most of the tropical and subtropical bamboos belong to this group. E.g. *Bambusa, Dendrocalamus, Thyrsostachys, Gigantochloa* (Janssen, 2000; Kigomo, 2007; Lobovikov et al., 2007a; Lobovikov et al., 2007b). Bamboos have been described as various names such as "poor man's timber", "Green Gold", "Cradle to Coffin" because of its wide range of

*Corresponding author: ggezahagn@gmail.com

uses. Bamboo is widely recognized as highly renewable, fast growing, economic raw material. Products from bamboo are grouped into industrial use, food products, construction and structural application, wood substitutes and composites, and cottage and handicraft industry. Moreover, bamboo has the capability of mitigating climate change as it restores degraded land, act as carbon sequesters and protects from soil erosion (Kelbessa et al., 2000; Njuguna & Kigomo, 2008). In Africa, indigenous bamboo grows mainly in the highlands and medium altitudes of eastern and central Africa. In nature, bamboo grows as pure stands or is mixed with other trees.

The common bamboo species in Ethiopia are *Arundinaria alpina* and *Oxytenanthera abyssinica*. *Arundinaria alpina* is a highland bamboo species growing in altitudes from 2400 - 3500 meter above sea level. It is a sympodial, medium sized bamboo with a stout rhizome (Alemayehu et al., 2015; Yigardu & Masresha, 2011). It is mainly found in pure stands as patches on the fertile sites of the highlands. The total area of *Arundinaria alpina* is estimated to be about 120,000 - 130,000 ha (Kigomo, 2007). *O. abyssinica*, on the other hand, is a lowland bamboo growing within the altitudes from 500 - 1800 meter above sea level (Alemayehu et al., 2015). It is a sympodial, small sized bamboo that grows on poor soils and low precipitation. *O. abyssinica* has estimated to cover from 750,000 to 900,000 ha in Ethiopia (Biras & Hunde, 2009). But those only two species accounts negligible with respect to a wide growing area and spectrum of the region; and the prospected product to meet the increasing demand. Ethiopia plans to reach the middle-income countries of the world. In this regard, bamboo can contribute more to income generation, since it can be processed in domestic and export market products. It can also create employment opportunities for a considerable part of society and address environmental degradation problems. Despite these facts; the country's bamboo resource research and development activities are scarce. Bamboo is not included in tree planting programs in which millions of tree seedlings have been planted every year. From this perspective, it is imperative to identify the best adaptable exotic bamboo species in north eastern Amhara region.

MATERIALS AND METHODS

Study area:

The experiment was conducted in Kobo research site of Sirinka Agricultural Research Center, Ethiopia (Fig. 1). Kobo is located at 575 km north of Addis Ababa, and its latitude has 12° 9' 19.44" N and 39° 38' 48.12" E. Altitude of bamboo plantation site has around 1482 meter above sea level.

The mean minimum and maximum temperature and annual rainfall of the plantation site during the

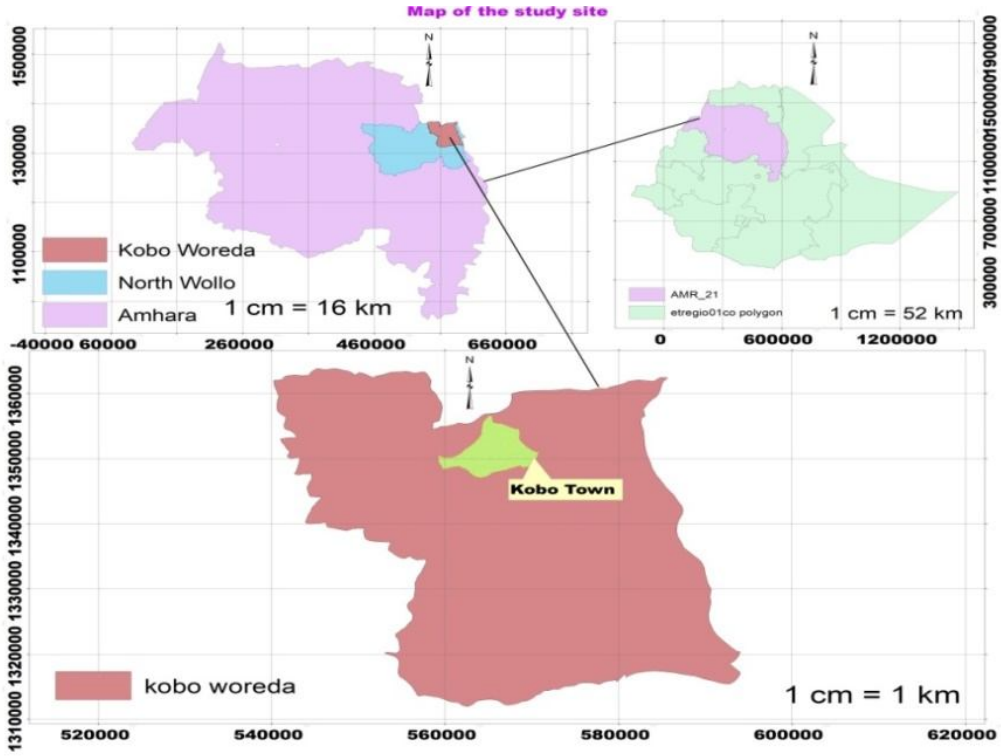

Fig.1: Map of the study area

experimental period was illustrated in Fig. 2 and 3.

Additionally, the major soil type of the area has silty clay loam. Its daily average reference evapotranspiration rate is about 5.94 mm. The average infiltration rate of the soil is 8 mm/hour and its pH is 7.8. The average field capacity and permanent wilting point of the site is 11.5% and 3.2%, respectively on volume basis (Solomon et al., 2013).

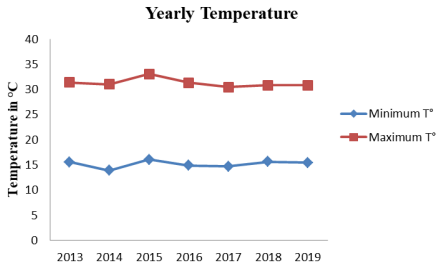

Fig. 2: Mean minimum and maximum temperature of the study site Kobo

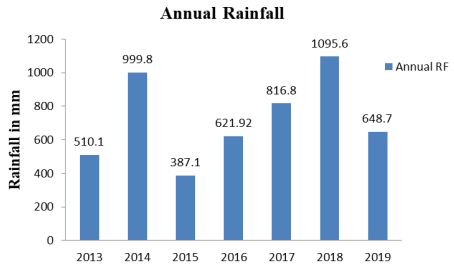

Fig. 3: Mean annual rainfall of the study site Kobo

height were commenced after every three months and follow up was taken every month. The treatments or introduced bamboo species were *Dendrocalamus brandisii*, *Bambusa tulda*, *Bambusa balcooa* and *Dendrocalamus asper*. The collected data was statistically analyzed by using analysis of variance (ANOVA) with R-statistical software, and Sigmaplot was used for simple analysis and graphical presentation.

RESULTS

The six years bamboo adaptation trial at Kobo showed statistically different ($p<0.05$) in culm height, culm diameter at breast height, number of newly emerged culms, number of nodes, internode length and its survival percentage among treatments (Table 1 and Fig. 4).

Additional results showed that *Bambusa balcooa* (100 %) has the highest survival rate followed by *Bambusa tulda* (94.4%) and *Denderocalamus asper* (83.3%) as illustrated in Fig. 4. But, *Dendrocalamus brandisii* was not adaptable and showed the least survival rate which was all dead (0 %).

DISCUSSION

At the age of six years after establishment, *Bambusa tulda* (6.31 m), *Bambusa balcooa* (5.62 m) and *Dendrocalamus asper* (4.98 m) showed not statistically significant results in height (Table 1). In line with this study, culm height of matured *Bambusa tulda* has 20 meter, *Bambusa balcooa* 20 meter and *Dendrocalamus asper* has 20-30 meter which is almost similar among species (Salam and

Table 1: Growth performance of different exotic bamboo species at Kobo

Bamboo Species	Height (m)	DBH (cm)	Internode length (cm)	No. of culm	No. of nodes
Bambusa balcooa	5.62±1.3	2.57±0.63^{b}	37.44±3.75^{a}	25.17±11.37^{a}	20.17±4.55^{ab}
Bambusa tulda	6.31±3.19	3.67±2.06^{a}	25.28±8.73^{b}	10.11±6.32^{b}	22.89±7.62^{b}
Dendrocalamus asper	4.98±2.62	2.27±1.24^{b}	29.50±14.35^{b}	15.39±9.73^{b}	16.83±8.29^{a}

a and b indicate significantly different means between treatments (Tukey HSD, $p < 0.05$; mean ± SE). DBH: Diameter at Breast Height

Experimental Design and Statistical Analysis:

The experiment was laid using randomized complete block design (RCBD) with three replications. The collected bamboo seedlings were planted at 2 m X 2 m spacing and there were 6 bamboo seedlings per plot. Distance between plots and blocks were 2 m and 3 m, respectively. For each treatment 18 seedlings were planted. Bamboo seedlings were obtained from international network for bamboo and rattan (INBAR-Ethiopia) and planted on July 22/ 2013. Data collection on survival of the seedling, number of newly emerged culms, diameter and height of the culm, internode length, culm wall thickness, clump size and clump

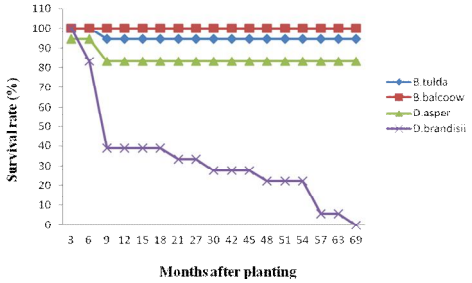

Fig. 4: Survival percentage of different bamboo species at six years after establishment at Kobo, northeast Ethiopia

Pongen, 2008; Yigardu et al., 2016). Krishnakumar reported that the highest mean height of *Bambusa balcooa* over five years was about 7.39 meter (Krishnakumar et al., 2017). Other studies said, *Bambusa tulda* has a range of 15.95-18.65 meter height in different district (Nirala et al., 2016), 17.7-21.3 meter of culm height in India (Bhattacharya et al., 2006) and 8-20 meter culm height in India (SINGH et al., 2010). Additionally, after two years of plantation in bambusetum of Balipara Tract and Frontier Foundation, India, has recorded a culm height of *Bambusa tulda* 4.5 meter and *Bambusa balcooa* 6 meter (Dutta and Baruah, 2016).

From the result, *B.tulda* (3.67 cm) has showed significantly higher diameter at breast height than that of *B. balcooa* (2.57 cm) and *D. asper* (2.27 cm) see Table 1. In line with this research, the mean diameter of *Bambusa balcooa* has 5.42 cm in over five years (Krishnakumar et al., 2017). The culm diameter at breast height of matured *Bambusa tulda* has ranged between 8-15 cm, *Bambusa balcooa* 8-15 cm and *Denderocalamus asper* has 20cm (Salam and Pongen, 2008; Yigardu et al., 2016). In contrary, the highest average DBH (4.03 cm) was recorded for *B. balcooa* at the age of two years in India (Dutta & Baruah, 2016). *B. balcooa* showed better growth than that of *B. tulda* in natural condition. But, a long term monitoring suggested to understand the impact of environment (Dutta & Baruah, 2016). Other studies said, *Bambusa tulda* has a range of 4.415-8.373 centimeter culm diameter in different district (Nirala et al., 2016), 5-10 centimeter culm diameter in India (Singh et al., 2010). Additionally, *Bambusa tulda* has a range of 5.0-8.8 centimeter of culm diameter in India (Bhattacharya et al., 2006). Therefore, *Bambusa tulda* has better for construction, flutes, handicrafts, edible shoots, paper/pulp**,** bamboo boards, composites and laminates due to its thicker in culm diameter (Salam & Pongen, 2008).

Bambusa balcooa (25.17) has significantly higher number of culms per clump than *Bambusa tulda* (10.11) and *Denderocalamus asper* (15.39) see Table 1. Similar study states that the highest mean number of culms per clump of *Bambusa balcooa* was reported to be 19.44 (Krishnakumar et al., 2017; Yigardu et al., 2016). *Bambusa balcooa* exhibited its superiority over *Bambusa vulgaris* by producing maximum number of culms in the first year (6.5), second year (13), third year (19.34), fourth year (26.05) and fifth year (32.37) after establishment (Krishnakumar et al., 2017). Other studies said, *Bambusa tulda* has six and *Bambusa balcooa* has four culms per clump in India (Dutta & Baruah, 2016).

Bambusa balcooa had significantly higher in culm internode length (37.44 cm) than *Denderocalamus asper* (29.5 cm) and *Bambusa tulda* (25.28 cm) see Table 1. These values are similar with others, indicated culm internode length of matured *Bambusa tulda* culms to be 20 - 45 cm, *Bambusa balcooa* 20 - 40 cm and *Dendrocalamus asper* 30 cm (BTSG-KFRI, 2015; Salam & Pongen, 2008) . Krishnakumar stated that the highest mean internode length of *Bambusa balcooa* over five years to be 31.13 cm (Krishnakumar et al., 2017). Other studies said, *Bambusa tulda* has a range of 41.95-56.1 centimeter of culm internode length in different district (Nirala et al., 2016) and 30-60 centimeter culm internode length in India (Singh et al., 2010).

Last but not least, *Bambusa balcooa* (100 %) has the highest survival rate followed by Bambusa *tulda* (94.4 %) and *Denderocalamus asper* (83.3 %) see Figure 5. This supported by Krishnakumar study, the performance of *Bambusa balcooa* across the agro climatic regions was consistent and higher than *Bambusa vulgaris* and *Bambusa bambos* (Krishnakumar et al., 2017). Similarly, *Bambusa tulda* has easily grown in the plains of tropical and sub-tropical conditions and with moist alluvial soil to fine textured soils also in well drained sandy and clayey soils (BTSG-KFRI, 2015). But, *Dendrocalamus brandisii* was not adaptable and showed the least survival rate which was all dead (0 %). This might be due to the shortage of water and less humidity according to its nature. Literatures said, *D. brandisii* grows well in plains and in hilly tracts with well drained sandy and clayey soils but prefers a tropical climate and responds well to water availability (BTSG-KFRI, 2015; Zulkarnaen & Andila, 2015). *Dendrocalamus brandisii*, being a fast growing species, has ideally suited for exploitation in farm forestry and agroforestry in humid tropics (Viswanath et al., 2013).

In conclusion, *Bambusa balcooa* and *Bambusa tulda* have better survival percentage than *Denderocalamus brandisii* and *Dendrocalamus asper*. With respect to culm number, height and diameter at breast height, *Bambusa balcooa* and *Bambusa tulda* were significantly higher than *Denderocalamus asper*. Based on this, both *Bambusa balcooa* and *Bambusa tulda* are best performing introduced bamboo species for scaffolding, construction, ladder, paper/pulp, handicrafts and bamboo board material. Additionally, it needs training for the local communities and small enterprises on the production and management of those two bamboo species. Therefore, *Bambusa balcooa* and *Bambusa tulda* should be demonstrated and popularized around kobo and in areas that have similar soil and climatic conditions.

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