

Adaptation and Growth Performance of Lowland Bamboo Species at Fedis District East Hararghe Zone, Oromia, Ethiopia

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Abstract: A study was conducted to evaluate adaptation and growth performance of four lowland bamboo species at Fedis district, East Hararghe Zone, oromia, Ethiopia for four years (June 2019 - June 2022). Four lowland bamboo species were tested in randomized complete block design with three replications. Data on growth parameters: survival rate, new emerging shoot, internodes length, number of nodes, culm height, culm diameter and its root culm diameter were measured and recorded at interval of three months during data collected. Results revealed that there were highly significant ($p < 0.05$) variations among lowland bamboo species at the study area. Among the species tasted, *Dendrocalamus hamiltonii* and *Dendrocalamus membranaceus*, were showed the highest performance and have better survival percentage than *Oxythenantera abyssinica*. *Dendrocalamus hamiltonii*, and *Dendrocalamus membranaceus* are the fastest growing species of bamboo and have better survival percentage. However, *Oxythenantera abyssinica* have medium survival percentage than *Dendrocalamus asper* which have lower survival. Generally, among the species tested *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* showed faster growth performance and *Oxythenantera abyssinica* was showed better performance at Fedis condition, but *Dendrocalamus asper* showed lower performance. With respect to new emerging shoot, internodes length, number of nodes, culm height, and culm diameter at breast height and its root culm diameter, *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* were significantly higher than *Denderocalamus asper*. Based on this, three bamboo species *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* are best performed introduced bamboo species for promotion in the study area. Therefore, the best performed species should be demonstrated and popularized around Fedis and in areas that have similar soil and climatic conditions. So, based on these results we recommended *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* for different production and constriction since they have a good quality of internodes length, ability to emerge new shoots, culm height and diameter. It is better to use for soil and water conservation purpose on degraded area rehabilitation. Since bamboo gives seed once in 40 years which is a big challenge in expansion of the resource, he need further study on bamboo propagation method. These species could be promote for various end uses like human food (*D. hamiltonii* edible shoot) and animals feed, for industrial purposes, and for carbon sequestration (because of their high biomass).

Keywords: Bamboo, Exotic, Indigenous, Lowland, Plantation, Growth Potential, Carbon Sequestration

1. Introduction

Bamboo is a perennial plant belonging to the Poaceae (sometimes called Gramineae) family [8] In terms of taxonomy, it is considered as a giant grass. Ecologically,

bamboo plants have tree-like functions [3]. Ethiopia is one of the most endowed countries in area coverage of natural bamboo forest of the country that estimated to have about 1 million ha, which is about 7% of the world total and 67% of the African bamboo forest areas [1]. Even though Ethiopia is one of the most endowed countries in having huge coverage

of bamboo resource in Africa, the country has narrow genetic diversity only has two species. Ethiopia possesses two very important indigenous bamboo species (African alpine bamboo or *Yushania alpina* and lowland bamboo or *Oxytenanthera abyssinica*) that have numerous traditional and industrial applications. Area coverage of bamboo forest comprised by the two species is estimated at 1.47 million ha very recently [12]. With these two species, it is very difficult to secure constant supply of bamboo raw material for bamboo industries and local handicrafts.

Currently, there is indiscriminate forest loose and depletion hence the unique bamboo resource will be appearing before its economic and environmental advantage is appreciated, unless important reversing mechanisms could not take place [9]. The current economic policy of the nation strongly urges development practitioners to contribute to the economic development of the country. By the year 2020, Ethiopia is envisioning to reach middle income group countries of the world. In this regard bamboo can contribute more in generating income since it can be processed in to products for domestic use and export market. It can also create employment opportunity to a considerable portion of the society and harness environmental degradation problems.

Despite these facts; research and development activities on bamboo resource of the country is scanty. Bamboo is not included in tree planting programs in which millions of tree seedlings have been established every year. Up to now only a very limited research works have been undertaken: vegetative propagation of highland bamboo [7], propagation of lowland bamboo by seed [4], utilization-suitability of *Yushania alpina* for oriented particle board [6], the use of lowland bamboo as re-enforcement in construction [11] and Adaptation and Growth performance of Different lowland bamboo Species [13]. A bamboo protects steep slopes, soils and water ways, prevents soil erosion, provides carbon sequestration and brings many other ecosystem benefits. Its extensive root network may help to prevent erosion. Bamboo in the future may be able to increase the bio-capacity by simultaneously increasing the area of fertile global hectares. It has immense potential in reducing CO₂ that is blamed for environmental pollution and the most valuable species for environmental protection. And also bamboo is a fast growing and high yielding perennial plant with a considerable potential to the socioeconomic development and environmental protection [2]. Among the various measures that should be taken in averting these problems, widening the genetic base of the resource is indispensable. These will require introduction and evaluation of potential species from different parts of the world to establish bamboo plantations in areas where indigenous species could not grow. So that the overall aim of this study is to evaluate adaptability and growth performance of different introduced bamboo species in different agro ecologies of the country.

Therefore, it is important to introduce and adapt high economic value of exotic bamboos species to improve the income of small farm holder, to divers the genetic resources of bamboos species and for environmental protection in

Ethiopia. Bamboo is versatile with a very short growth cycle. Bamboo is a high yield renewable natural resource for agro-forestry and engineering based products [5]. Based on this all indispensable values of the species, the study of bamboo adaptation was started at Fedis district East Hararghe condition since 2018 with the objectives of to evaluate the adaptability potential of different provenance of lowland bamboo species around the study area and to provide the best performing of lowland bamboo species. Therefore, it is important to introduce and adapt high economic value of exotic bamboos species in the study area, with the objectives of: to evaluate the adaptability potential of different lowland bamboo species around the study area and to provide the best performing of lowland bamboo species.

2. Materials & Methods

2.1. Description of the Study Area

The study will conducted in Fedis district of the East Hararghe Zone of Oromia Regional State. Fedis district is one of the twenty districts in East Hararghe zone, which is located at 550 km east of Addis Ababa and about 24 km from Harar town in the southern direction. The district comprises 19 peasant associations (PAs), which are associated with two different agro-ecological zones. The geographical location of the district is 8° 22' 0" and 9° 14' 0" N and 42° 62' 0" and 42° 19' 0" E. The altitude of the area ranges between 850 to 2118 m.a.s.l. Topographic features of the study area is 70% plain area, 28% plateau and 2% mountain or hill. Cultivable land/cropland (21.02%), pasture (2.80%), forest (11.2%), grass land (38.01%), communal land (10.5%) and remaining (14.04%) is considered as mountainous, valley and otherwise unusable [14]. According to [11]. report, the district has two basic agro-climatic conditions, namely midland (39%), and lowland (61%).

The district experience mean annual rainfall of 650 to 850mm and the average temperature is 25 °C to 30 °C. The district has a bimodal rainfall distribution pattern with heavy rains from April to June and long and erratic rains from August to October. The soil of the study area is dominantly red brown clay soils. The vegetation type of the district is characterized by forest, bushes and shrubs. The area of the district covered by forest, bushes and shrubs is 42954ha [14]. The district consists of 19 rural PAs and two rural towns and has total human population is 149,664 of which 76,182 (50.9%) are males and 73, 482 (49.09%) are females [15]. The average family size is estimated to be 6 and 4 per household in rural and urban areas respectively. The average landholding per farm family is 0.73 hectare and has a total area of 110502 hectare [14]. Agriculture in the district is characterized by small-scale subsistence mixed farming-system with livestock production as an integral part.

2.2. Treatments and Experimental Design

The experiment were laid out in a RCBD with three replications. The block were folded to accommodate the four treatments within fairly uniform soil condition. The distance

between blocks and plots were 3m and 3m, respectively. And also the space between each plant was 3m. As a treatment four lowland bamboo species were used: *Dendrocalamus hamiltonii*, *Dendrocalamus membranceous*, *Oxythenanthera abyssinica* and *Dendrocalamus asper*. Among those mentioned species *Oxytenanthera abyssinica* is the

indigenous bamboo species. The cuttings were collected from Mechara Agricultural Research Center. The exotics bamboo species were originally comes from China in warm temperate subzone to tropical zone bamboo are growing wildly. Then, cuttings/seedlings were out planted at filed planting sites to evaluate their adaptability and performance of the species.

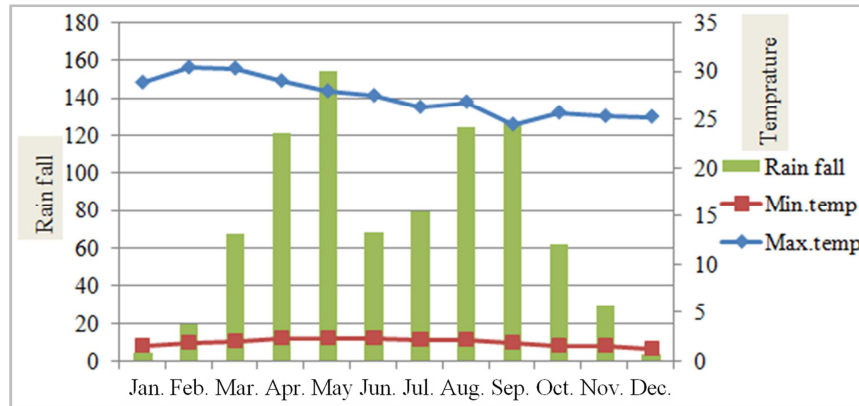


Figure 1. Rain fall and temperature data of fedis district, 2020GC.

2.3. Data Collection

The parameters measured were number of culm, culm height, diameter at breast height (DBH), number of shoot sprouts per clump, shoot sprouts height, root collar diameter, biomass and adaptability of species. Concerning about growth performance of the lowland bamboo species, data like; Culm height, Culm diameter, internodes length, number of nodes, new shoot emerging, survival rate, and other growth parameters were considered during data collection. The data were collected every two month interval to observe the changes among the species.

2.4. Data Analysis

The collected raw data were analyzed with analysis of variance (ANOVA) following the General Linear Model

(GLM) procedure using SAS statistical software version 9.4. For significant differences, mean separation using LSD was conducted at 5 % level of significance. Therefore, for these analyses the following parameters were considered and measured; Number of new emerging shoots, Survival rate in %, root collar diameter, internodes length, number of nodes, culm height and diameter data were collected.

3. Result and Discussion

The four years of lowland bamboo adaptation trial at Fedis district showed statistically different ($p < 0.05$) in survival percentage, new emerging shoot, internodes length, number of nodes, culm height, culm diameter and its root culm diameter among treatments (Tables 1 and 2).

Table 1. Average means Comparisons between treatments at 0.05 significant levels (Mean).

Treatments	Year 1	Year 2	Year 3	Year 4	Average mean
<i>Dendrocalamus hamaltoni</i>	94.4 ^a	94.4 ^a	94.4 ^a	94.4 ^a	94.4 ^a
<i>Dendrocalamus membracius</i>	90.67 ^a	90.67 ^a	90.67 ^a	90.67 ^a	90.67 ^a
<i>Oxythenanthera abyssinica</i>	68.33 ^b	68.33 ^b	65.00 ^b	60.03 ^b	65.42 ^b
<i>Dendrocalamus asper</i>	40.67 ^c	40.67 ^c	37.67 ^c	35.33 ^c	38.58 ^c
CV (%)	19.49	22.7	25.58	28.15	22.74
LSD (0.05)	3.59	4.05	4.10	4.22	6.73

Table 2. Average means Comparisons between treatments at 0.05 significant levels (Mean).

Treatment	Av. NES	Av.IL (cm)	NON (no.)	Av.CH (m)	Av.CD (cm)	Av. RCD (cm)
<i>D. hamiltonii</i>	5.33 ^a	20.37 ^a	25.33 ^a	6.34 ^a	3.44 ^a	3.51 ^a
<i>D. membranceous</i>	3.39 ^b	18.07 ^a	23.39 ^a	5.95 ^b	2.93 ^b	3.18 ^a
<i>O. abyssinica</i>	3.67 ^b	11.84 ^b	16.33 ^b	4.84 ^c	2.71 ^b	2.89 ^b
<i>D. asper</i>	2.75 ^c	10.07 ^b	15.83 ^b	4.81 ^c	2.71 ^b	2.89 ^b
CV (%)	22.26	24.8	28.71	25.5	21.13	9.4
LSD (0.05)	6.91	6.08	6.92	1.35	1.09	0.55

*Means with the same letter are not significantly different. Av. NES – Average of New Emerging Shoots, Av. IL (cm) – Average of Internodes Length, Av. NON– Average of Number of node, Av. CH (m) – Average of Culm height, Av. CD (cm) – Average of Culm Diameter

3.1. Survival Rate

During the four year trail years the selected lowland bamboo species was adapted and well performed at Fedis area. The results showed that *Dendrocalamus hamiltonii* (94.4%) has the highest survival rate followed by *Dendrocalamus membracius* (90.67%) and *Oxythenantera abyssinica* (65.42%) as illustrated in Table 1. But, *Denderocalamus asper* was lower adaptable and showed the least survival rate (38.58%). These indicate that as the agro ecology of Fedis is suit to the three species throughout the trail years. *Dendrocalamus hamiltonii* and *Dendrocalamus membracius* selected lowland bamboo species was not attacked by pests and diseases. But some growth and morphological variation were observed among the species this is due to the growth and adaptability characteristics of the species. As indicated in Table 1 the least adapted was *Dendrocalamus asper* (38%). This selected lowland bamboo species was attacked by pests and diseases. These also another indicator as the species are not well performed under Fedis area. The result is similar with the report from bako [13].

3.2. New Emerging Shoot

The capacity of lateral buds forming new rhizome and shoots is closely related to rhizome age, vigor, and nutrient storage. Based on the analysis results of the four year data *Dendrocalamus hamiltonii* bamboo species (5.33) were revealed a significant difference in number of new emerging shoots throughout the trail years. Next to this *Dendrocalamus membranceous* (3.39) and *Oxythenantera abyssinica* (3.67) the species which shows a good performance in emerging new shoots. This is due to the well performance, adaptability and producing new emerging shoots ability of the specie when compare to the other lowland bamboo species which selected for this experiment at Fedis condition.

The result is similar with the report from [10]. (unpublished) which shows higher shoot emerging for *Dendrocalamus hamiltonii*. Whereas, *Dendrocalamus asper* (2.75) specie were revealed a low performance in emerging new shoots number during the trail periods. According to the comparison made among the treatments *Dendrocalamus asper* were significantly different in new emerging shoots when compare with others but the rest two species is not significantly different. The findings similar with the report [13]. This indicted that the lower shoot emerging ability might be due the low growth performance of the specie.

3.3. Internodes Length

Direct or indirectly bamboo internodes length can indicate the quality of bamboo product which used for different purpose. Bamboo culms structure is cylindrical and is divided into sections by diaphragms or nodes. The section between two nodes is internodes. Internodes are hollow in most bamboos, but solid in some species. As the present study revealed that the results of internodes length among the selected species were significantly different. So, as indicated

in Table 2 *Dendrocalamus hamiltonii* and *Dendrocalamus membranceous* showed higher internodes length as compare to others which is similar with the report of [10] (unpublished) which show higher internodes length for *Dendrocalamus hamiltonii*. Whereas, *Oxythenantera abyssinica* and *Dendrocalamus asper* was showed lower internodes length.

Dendrocalamus hamiltonii and *Dendrocalamus membranceous* had significantly higher in culm internode length (20.37cm) and (18.07cm) respectively than *Oxythenantera abyssinica* (11.84cm) and *Denderocalamus asper* (10.07 cm). These values are similar with others [5]. Other studies said, *Dendrocalamus hamiltonii* has a range of 41.95-56.1 centimeter of culm internode length in different district [16] and 30-60 centimeter culm internode length in India [5].

3.4. Number of Nodes

As the present study revealed that the results of number of nodes among the selected species were significantly different. *Dendrocalamus hamiltonii* (25.33) and *Dendrocalamus membranceous* (23.39) has significantly higher number of nodes than *Oxythenantera abyssinica* (16.33) and *Denderocalamus asper* (16.83). *Dendrocalamus hamiltonii* and *Dendrocalamus membranceous* showed higher number of nodes as compare to others which is similar with the report of [10] (unpublished). Whereas, *Oxythenantera abyssinica* and *Dendrocalamus asper* was showed lower number of nodes. Similar study states that the highest mean number of nodes was reported to be 19.44 [17].

3.5. Culm Height & Diameter

At the age of four years after establishment, *Dendrocalamus hamiltonii* (5.34 m), *Dendrocalamus membranceous* (4.95 m) *Oxythenantera abyssinica* (3.84m) and *Dendrocalamus asper* (3.81 m) showed not statistically significant results in height (Table 2). In line with this study, culm height of matured *Dendrocalamus hamiltonii* has 20 meter and *Dendrocalamus asper* has 20-30 meter which is almost similar among species [17] Krishnakumar reported that the highest mean height of *Bambusa balcooa* over five years was about 7.39 meter [17]. Other studies said, *Bambusa tulda* has a range of 15.95-18.65 meter height in different district [16], 17.7-21.3 meter of culm height in India (Bhattacharya et al., 2006) and 8-20 meter culm height in India [5].

From the result, *Dendrocalamus hamiltonii* (3.44 cm) has showed significantly higher diameter at breast height than that of *Dendrocalamus membranceous* (2.93 m) *Oxythenantera abyssinica* (2.71m) and *Dendrocalamus asper* (2.71 m). In line with this research, the mean diameter of *Dendrocalamus hamiltonii* has 5.42 cm in over five years [18]. The culm diameter of matured *Dendrocalamus hamiltonii* has ranged between 10-18 cm, *Dendrocalamus membranceous* 6-10 cm and *Denderocalamus asper* has 20cm ([16]. In contrary, the highest average diameter (4.03

cm) was recorded for the similar species result at the age of two years in India [19]. Other studies said, the same species has a range of 4.415-8.373 centimeter culm diameter in different district [16], 5-10 centimeter culm diameter in India [5]. Therefore, *Dendrocalamus hamiltonii* and *Dendrocalamus membranaceus* has better for construction, flutes, handicrafts, edible shoots, paper/pulp, bamboo boards, composites and laminates due to its thicker in culm diameter [5]. The result agreed with the report from [10] (unpublished) which shows higher culm height for *D. hamiltonii*. Though, the culm diameter is indicated by the thickness or size of the culm which is directly or indirectly related with the quality of bamboo production.

According to the current analysis *Dendrocalamus hamiltonii* is statistical significant as displayed in Table 2 while *Denderocalamus asper* shows the least in culm height with compare to the rest. The result agreed with the report from Pawe by Yared keede (unpublished) which shows higher culm height for *Dendrocalamus hamiltonii* and lower culm height recorded for *Denderocalamus asper* [10]. This may depend upon the growth performance and adaptability of the species. Beside this, the culm diameter also analyzed and compared. Though, the culm diameter is indicated by the thickness or size of the culm which is directly or indirectly related with the quality of bamboo production. As the result, the current analysis show slight variation between the species on culm diameter.

So, as presented in Table 1 above *Dendrocalamus hamiltonii* and *Oxythenantera abyssinica* bamboo species were statistical higher than both *Denderocalamus asper* in culm diameter. *Dendrocalamus hamiltonii* measured higher value on average height (6.34m to 8m) as compared to the finding of [10].

3.6. Root Collar Diameter

Significant variation ($p < 0.05$) in root collar diameter growth is also observed among the studied species (table 2). The four years age of *D. hamiltonii* (3.51cm), *D. membranaceus* (3.18cm), *Oxythenantera abyssinica* (2.89cm) and *D. asper* (2.89cm) were showed statistically significant results in root collar diameter. According to the observation made, the maximum root collar diameter was measured for *D. hamiltonii* (3.51cm), followed by *D. membranaceus* (3.18cm) over the entire experimental period.

4. Conclusion and Recommendations

In conclusion, the study and observation made showed clearly that *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* are the fastest growing species of bamboo and have better survival percentage than *Dendrocalamus asper*. Generally, among the species *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* showed faster growth performance at Fedis and *Oxythenantera abyssinica* was showed better performance. *Dendrocalamus asper* showed lower performance. With respect to new emerging shoot, internodes

length, number of nodes, culm height, and culm diameter at breast height and its root culm diameter, *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* were significantly higher than *Denderocalamus asper*. Based on this, three *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* are best performing introduced bamboo species for promotion in the study area. Additionally, it needs training for the local communities and small enterprises on the production and management of those three bamboo species.

Therefore, *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* should be demonstrated and popularized around Fedis and in areas that have similar soil and climatic conditions. So, based on these results we recommend *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus* and *Oxythenantera abyssinica* for different production since they have a good quality of internodes length, ability to emerge new shoots, culm height and diameter. It is better to use for soil and water conservation purpose on degraded area rehabilitation. Since bamboo gives seed once in 40 years which is a big challenge in expansion of the resource, he need further study on bamboo propagation method.

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