**Adaptation and Growth Performance of Different Bamboo Species in Highland Area of Bale, Oromia Region, Southeast Ethiopia**

**Abstract**

This study was conducted aimed to introduce different exotic bamboo species to Bale via evaluating their adaptability and growth performance under the field condition of Bale highland area, Ethiopia. For hundreds of years, Ethiopia was limited to two native bamboo species. The introduction of foreign species to the nation began in 2007 with the goal of diversifying the genetic base of the resource. Since then, studies on the species' adaptability have been carried out over the nation in an effort to comprehend their potential eco-zone, albeit no prior attempts have been done in the Bale zone, the current study region. Thus, ten bamboo species were introduced and evaluated for their adaptability at Sinana Agricultural research center in highland area of Bale, Ethiopia. The mean value of survival rate was recorded within a range of 22.22% in *Y. alpina* to 96.30% *D. dienbienensis* among the studied species. Culm height ranged 18.30 in *Y. alpina* to 371.70 cm in *D. dienbienensis* while Culm diameter was within range of 1.12 B*. lapidea* to 2.93 cm in *D. dienbienensis*. Furthermore, maximum number of culms was recoreded in *D. dienbienensis* followed by *D. “sp.”*, *D. asper*, *B. longinternode* and *D. membranaceus*, respectively. On other hand, *B. longinternode* had the highest number of nodes (14.33) whereas the dominant internode length (30.53 cm) recorded in *D. membranaceus*. *D. dienbienensis, D. membranaceus, D. asper, B. polymorpha, B. longinternode, and D. barbatus* showed greater potential for adaptability than the others, according to the data. Because of their many advanstages in the research region, they might be marketed to users as an alternative bamboo species resource. However, because bamboo species require a long time to set seed, research into their identification and vegetative propagation strategy development is advised.

**Keywords**; Culm, Exotic, Internode, Survival rate

**1. INTRODUCTION**

Bamboo species are perennial giant herbaceous and woody grass belongs to the subfamily *Poaceae* or *Graminaceae*(Tansae and Yulong, 2021; Hassan et al., 2022). Globally, it has 1718 species with 232 found beyond their native ecosystem(Canavan et al.,2017). A total of 115 bamboo species are reported in Africa (Tinsae & Yulong, 2021). Of these only two species named by *Oxytenanthera abyssinica* (lowland Bamboo) and *Yushinia alpina* (highland Bamboo) are indigenous to Ethiopia (Yigardu et al., 2016; Asabeneh et al., 2015). Additionally, as their name implied the two species are restricted in limited agro ecological regions, i.e. in highland (2400 - 3500 m a.s.l) and lowland (500-1800 m a.s.l.) areas.

The introduction of exotic bamboo species to Ethiopia was began in 2007 aimed to diversify the genetic base of the resource in different agro-ecology parts of the country (Yigardu et al., *2016;* Gezahegn et al.,2021). The introduction was undertaken by Ministry of Agriculture and Rural Development of Ethiopia in collaboration with a project called “East African Bamboo Project (Yigardu and Mengistie, 2010). Since then, 23 different Bamboo species under seven genera were introduced and some of them have been tested under field conditions for their adaptability in different parts of the country. The species could be used in woodworking and furniture industries substituting wood, for pulp and paper production and for construction purposes. Moreover, bamboo has the capability of mitigating climate change as it restores degraded land, act as carbon sequesters and protects soil from erosion (Kelbessa et al., 2000; Azene et al., 2007; Hassan et al., 2022).

For the species that are not tested in many locations, further evaluation of the species for their adaptability and growth performance should be undertaken. Before this study’s initiation Bale was restricted with a single species namely *A. alpina*. This has necessitated intervention measure to be taken for the introduction and adaptability study of new Bamboo species in the area. Hence, this study was conducted aimed to introduce different exotic bamboo species to Bale via evaluating their adaptability and growth performance under the field condition of Bale highland area, Ethiopia.

**2. MATERIALS AND METHODS**

**2.1. Description of the Study area**

The experiment was conducted on station at Sinana Agricultural Research Center located in Bale zone Oromia region, southeast Ethiopia (Fig. 1). The research center is located at 463 km away from Addis Ababa, 33 km and 50 km from the nearby towns Robe and Goba, respectively. Its geographical extent ranges from 07º 06'12'' to 07º 07'29'' northern latitude and from 40º 12'40'' to 40º 13'52'' eastern longitude. The elevation of the center is found within a range of 2400 to 2464 m above sea level with topography of gentle slope to plain, which has beautiful scene for vision.

The major soil type in the center is Cambisols with minor occurrence of Vertisols. The soils are deep fine textured and have slightly acidic to strongly acidic reaction (Abayineh and Ashenafi, 2006). The precipitation of the center ranged from 823 to 1566 mm with an annual average of 1174 mm. The area has bimodal rainfall pattern with distinct peaks in April and September. The seasonal rainfall varies from 346 to 861 mm during the first rainy season (March to July) and 353 to 894 mm during the main season (August to December).



Figure1. Location of the study area

The mean annual maximum and minimum temperatures are 21 and 9.5°C, respectively (Olkeba et al., 2012). Crop production in the study area is characterized by cereal dominated cropping system. Wheat is extensively grown followed by barley. Some highland pulses such as field pea, faba bean, and oil crops like mustard and linseed are also grown.

**2.2. Treatments and Experimental procedures**

 In the study about 10 (ten) Bamboo species seedlings were obtained from Arbagona nursery site located in Sidama zone, southern Ethiopia. The species were *Yushinia alpina* K. Schum, *Bambusa lapidea* McClure*, Dendrocalamus liboensis* Hsueh & D.Z.Li*, Dendrocalamus* *“sp.”, Dendrocalamus barbatus* Hsueh & D.Z.Li, *Bambusa longinternode* Roxb, *Bambusa polymorpha* Munro, *Dendrocalamus asper* (Schult) Backer, *Dendrocalamus membranaceus* Munro and *Dendrocalamus dienbienensis* H.N.Nguyen & V.T.Nguyen. Randomized complete block design with three replications was used to conduct the experiment in the field. The spacing between plants was 3 m x 3 m consisting of nine plants within a plot size of 9 m x 9 m for each species.

**2.3. Data Collection and Analysis**

Survival rate, number of culm, number of node, culm height, culm diameter and internode length data parameters were collected during the study period. Survival count was made for the whole Bamboo plants found within a plot whereas for the other biological parameters five plants were considered obtaining randomly from the sampled plots. In the study, culm diameter was measured using digital caliper whereas culm height was measured by using graduated stick pole. To this end, the collected data was analyzed with the help of *R x64 4.1.0* computerized software program.

**3. RESULTS AND DISCUSSION**

**3.1. Survival rate**

The mean values of survival rate for the studied species was summarized and presented below (Table 1). The values were recorded within a range of 22.22 for *Y. alpina* to 96.30% for *D. dienbienensis* species. The values were found within a range of survival rate reported by Gezahegn et al., *(*2021) in Kobo district Northern Ethiopia.

Table1. Mean values of survival rate as influenced by different Bamboo species

|  |  |
| --- | --- |
| Treatments (species type) | Values recorded (%) |
| *Dendrocalamus* *dienbienensis* | 96.30 a |
| *Dendrocalamus membranaceus* | 88.89 ab |
| *Dendrocalamus asper* | 88.89 ab |
| *Bambusa polymorpha* | 74.07 abc |
| *Bambusa longinternode* | 66.67 abc |
| *Dendrocalamus barbatus* | 66.67 abc |
| *Dendrocalamus “sp.”* | 66.67 abc |
| *Dendrocalamus* *liboensis* | 62.96 bc |
| *Bambusa lapidea* | 48.15 cd |
| *Yushinia alpina* | 22.22 d |
| *CV (%)* | 26.000 |
| *LSD(p<0.05)* | 30.40 |
| *Level of significance* | 0.003 |

\*N/B: Mean values in the column with the same letters are not statistically different

As to Gebrekidan et al., (2020) species attaining > 50% survival rate would be considered for plantation. Thus, since 80% of the current studied Bamboo species had showed > 50% survival rate they would be similarly suggested for plantation purpose in the area. The lack of stastical differences in survival rates among some species may have suggested that, their level of adaptation in the area is more or less the same.

**3.2. Number of culm**

The mean value of number of culm for the studied species has shown below (Table2). The highest number of culm was reported for *D. dienbienensis* species closely followed by *D. “sp.”*, *D. asper*, *B. longinternode* and *D. membranaceus* with more than nine culms. For species *D. liboensis*, *B. lapidea*, *B. polymorpha* and *Y. alpina* the value was less than five in each. Among the species, the least number of culm was reported in *Y. alpina* species with a mean value of 2.33.

The values showed, the species reported with more than nine numbers of culms/clump are more likely preferable for soil and water conservation activities than the remaining’s. This is because Bamboo species characterized by more number of culms are capable of controlling soil erosion by reducing the speed of runoff and buffering erodible soil particles with the help of their abundant stem and root structures.

Table2. Mean values of culm number as influenced by different Bamboo species

|  |  |
| --- | --- |
| Treatments(species type) | Values recorded |
| *Dendrocalamus dienbienensis* | 14.00 a |
| *Dendrocalamus “sp.”* | 10.67 ab |
| *Dendrocalamus asper*  | 10.33 ab |
| *Bambusa longinternode* | 9.67 ab |
| *Dendrocalamus membranaceus* | 9.33 ab |
| *Dendrocalamus barbatus*  | 6.00 bc |
| *Bambusa polymorpha*  | 4.33 c |
| *Bambusa lapidea* | 3.67 c |
| *Dendrocalamus* *liboensis* | 3.33 c |
| *Yushinia alpina* | 2.33 c |
| CV (%) | 27.70 |
| LSD(<0.05) | 4.76 |
| Sign.level | < 0.001 |

\*N/B: Mean values in the column with the same letters are not statistically different

**3.3. Culm Height**

The recorded value of culm height (cm) for the studied species was analyzed and presented below (Table3). Accordingly, the maximum culm height growth was recorded in *D. dienbienensis,B. longinternode, D. membranaceus, D. “sp.”* and *D. asper* with non-significant variation among themselves. The mean value recorded for these five species was more than 400 cm whereas the others were below 250 cm. The values are relatively lower compared to others finding conducted very recently in Ethiopia (Gezahegn et al., 2021; Musa and Birra, 2023). The variability might be linked to the type of species, agro-ecology, climate and soil conditions.

Notwithstanding culm diameter, culm height is very crucial in terms of bamboo yield. Generally, the higher the height of the culm, will contribute to the higher yield of bamboo during the harvest. Thus, as to this finding species named by D. dienbienensis B. longinternode, D. membranaceus, D. “sp.” and D. asper would be more preferable for the higher Bamboo yield production compared to others.

Table3. Mean values culm height as influenced by different Bamboo species

|  |  |
| --- | --- |
| Treatments(species type) | Values recorded(cm) |
| *Dendrocalamus dienbienensis* | 471.70 a |
| *Bambusa longinternode* | 423.80 a |
| *Dendrocalamus membranaceus* | 419.30 a |
| *Dendrocalamus “sp.”* | 408.70 a |
| *Dendrocalamus asper*  | 401.30 a |
| *Bambusa polymorpha*  | 220.00 b |
| *Dendrocalamus barbatus*  | 217.30 bc |
| *Bambusa lapidea* | 196.30 bc |
| *Dendrocalamus liboensis* | 153.70 bc |
| *Yushinia alpina* | 118.30 c |
| CV (%) | 29.30 |
| LSD(<0.05) | 101.100 |
| Sign.level | < 0.001 |

\*N/B: Mean values in the column with the same letters are not statistically different

**3.4. Number of Nodes**

Results analyzed for the effect of Bamboo species on number of node was presented (Table 4). The result reveals the value of number of node found to be statistically variable (p < 0.001). In this respect, *B. longinternode,D. dienbienensis, D. “sp.”, D. asper and D. membranaceus* possessed a mean value > 12 nodes per culm height. However, species *Y. alpina, D. liboensis, B. lapidea, D. barbatus* and *B. polymorpha* had < 8 nodes.

Table4. Mean values of number of nodes as influenced by different Bamboo species

|  |  |
| --- | --- |
| Treatments(species type) | Values recorded |
| *Bambusa longinternode* | 14.33 a |
| *Dendrocalamus dienbienensis* | 13.60 a |
| *Dendrocalamus “sp.”* | 13.13 a |
| *Dendrocalamus asper*  | 12.93 a |
| *Dendrocalamus membranaceus* | 12.47 ab |
| *Bambusa polymorpha*  | 7.27 bc |
| *Dendrocalamus barbatus*  | 6.53 c |
| *Bambusa lapidea* | 5.47 c |
| *Dendrocalamus liboensis* | 3.33 c |
| *Yushinia alpina* | 2.33 c |
| CV | 34.60 |
| LSD(<0.05) | 5.43 |
| Sign.level | < 0.001 |

\*N/B: Mean values in the column with the same letters are not statistically different

**3.5. Internode Length**

The result revealed the mean value of internode length among the species found to be statistically (p < 0.004) variable. The recorded values were found within a range of 14.40 to 30.53 cm (Table 5). Among the species, D. membranaceus had the highest internode length followed by D. dienbienensis, D. asper, B. longinternode and D. “sp.”, respectively.

Table5. Mean values of internode length as influenced by different Bamboo species

|  |  |
| --- | --- |
| Treatments(species) | Values recorded(cm) |
| *Dendrocalamus membranaceus* | 30.53 a |
| *Dendrocalamus dienbienensis* | 29.23 ab |
| *Dendrocalamus asper*  | 26.2 abc |
| *Bambusalonginternode* | 24.53 abcd |
| *Dendrocalamus “sp.”* | 24.23 abcd |
| *Dendrocalamus barbatus*  | 22.27 bcd |
| *Bambusa polymorpha*  | 19.13 cde |
| *Bambusa lapidea* | 19.13 cde |
| *Dendrocalamus liboensis* | 17.87 de |
| *Yushinia alpina* | 14.4 e |
| CV (%) | 18.80 |
| LSD(p<0.05) | 7.336 |
| Sign.level | 0.004 |

\*N/B: Mean values in the column with the same letters are not statistically different

Consistent to the observation made on survival rate, culm height, number of node and number of culm the lowest internode length was reported for Y*. alpina* with a mean value 14.40 cm length.

**3.6. Culm Diameter**

Mean value of culm diameter growth for the studied species was analyzed and presented (Table6). There were significant (P<0.05) differences in culm diameter among the planted species. As to result, *D. dienbienensis, B. longinternode, D. “sp.”, D. membranaceus, D. asper* and *D. barbatus* showed the better culm diameter development with > 3.00 cm size each. However, *B. lapidea* had the lowest culm diameter closely followed by *B. polymorpha,* *Y. alpina* and *D. liboensis,* respectively.

Table6. Mean values of culm diameter as influenced by different Bamboo species

|  |  |
| --- | --- |
| Treatments(species) | Values recorded(cm) |
| *Dendrocalamus dienbienensis* | 3.93 a |
| *Bambusalonginternode* | 3.81 a |
| *Dendrocalamus “sp.”* | 3.76 a |
| *Dendrocalamus membranaceus* | 3.76 a |
| *Dendrocalamus asper*  | 3.42 ab |
| *Dendrocalamus barbatus*  | 3.01 abc |
| *Dendrocalamus liboensis* | 2.95 abc |
| *Yushinia alpina* | 2.57 bc |
| *Bambusa polymorpha*  | 2.28 c |
| *Bambusa lapidea* | 2.12 c |
| CV (%) | 26.50 |
| LSD (p<0.05) | 0.984 |
| Sign.level | 0.005 |

\*N/B: Mean values in the column with the same letters are not statistically different

The bamboo diameter could contribute to the higher strength of bamboo species suitable for structural applications such as housings, bridges, flooring, and even furniture. Hence, species that have showed > 3 cm culm diameter development in the current study would be more advantageous for such purpose against to the others.

**4. CONCLUSION AND RECOMMENDATION**

In Ethiopia, exotic Bamboo species introduction was started in 2007 aiming to diversify the genetic base of the resource in the country. Since then, various species were introduced and their adaptability study was conducted in different parts of the country aimed to understand their potential eco-zone despite no efforts was made in Bale, southeast Ethiopia. Thus, study was designed to introduce different exotic bamboo species to Bale highland area by evaluating their adaptability potential. Accordingly, nine exotic species were introduced and evaluated with Y. alpina for their adaptability at Sinana agricultural research center of Bale highland , Oromia region. The mean value of survival rate among the species recorded within a range of 22.22% in *Y. alpina* to 96.30% in *D. dienbienensis*. Culm height ranged 118.30 in *Y. alpina to* 471.70 cm in *D. dienbienensis* while Culm diameter reported within a range of 2.12 B. *lapidea* to 3.93 cm in *D. dienbienensis* species. Further, the maximum number of culm was reported for *D. dienbienensis* closely followed by *D. “sp.”, D. asper, B. longinternode* and *D. membranaceus*, respectively. On other hand, *B. longinternode* had the highest number of nodes (14.333) per culm height while the dominant internode length (30.53 cm) reported for *D. membranaceus* against to the other’s. The observed difference for the survivorship and growth performance traits attributed to the effects of species, climatic and edaphic factors. The result showed that, *D. dienbienensis had* superior performance followed by *D. membranaceus*, *D. asper, B. polymorpha, B. longinternode and D. barbatus, respectively*.Therefore, these six species would be considered as potential resources in the study area and should be demonstrated, promoted and scaled-up to end users for their social, economic and environmental benefits. However, since bamboo species take long time to set seed this is the bottleneck problem in order to multiply and avail their planting materials (seedlings) for end users. Therefore, further study is recommended for the identification and development of their effective vegetative propagation techniques. Additionally, the feed value of the species would remain the focus of future research area as well.

**5. CONFLICT OF INTERESTS**

The authors have not declared any conflict of interests.

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