

# Regeneration study of lowland bamboo (*Oxytenanthera abyssinica* A. R. Munro) in mandura district, Northwest Ethiopia

## Abstract

The present study is about germination and regeneration issues of the multipurpose lowland bamboo in Mandura Woreda. The Woreda has patchily distributed vegetation features characterized by *Combrutum molle* and *Entada abyssinica* growing in association with *Oxytenanthera abyssinica*, commonly known as lowland bamboo. The lowland bamboo forest in the Woreda was flowered in 1998 E.C. Lowland bamboo vegetation is threatened by cutting, decay of new shoots, mass flowering, agricultural expansion, over grazing, fire and cutting style of which fire is the most leading threat reported. Seed germination of the species was found to take on average three to four times faster in Petri-dish than in soils. Two years stored seeds showed less viability, about 65% and 2 days slower rates of germination. Mixed soils found to increase seed viability from 37.5% to 68.78%. Number of culms per clump is highest in protected forests and least in wild forests. The percentage natural expansion (reproduction) was highest in cultivated and wild forest habitats. The ability of clumps to produce new offshoots is directly proportional with the clump circumference.

**Keywords:** clump, culms, germination, *oxytenanthera abyssinica*, regeneration threatened

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**Abbreviations:** ANOVA, analysis of variance; BGRS, benishangul gumuz regional state; CSA, central statistical agency; DA, development agents; DFO, district forest officer; EFAP, Ethiopian forestry action program; EPA, environmental protection authority; FTC, farmers training centres; GTZ, German technical cooperation; IAP, index of species association based on presence; INBAR, international network for bamboo and rattan; LU/LC, land use/land cover; MASL, meters above sea level; NGO's, non-governmental organizations; NTFPs, non timber forest products; US, United States; UV, ultra violet; ZFCO, zonal forest catchment office; ZWEO, zonal and woreda environmental officer

## Introduction

### Background of the study

The pure natural bamboo forest in Ethiopia is the largest in Africa, over about 1 million hectare, and 85% of this area is covered by lowland bamboo (*Oxytenanthera abyssinica*).<sup>1</sup> *O. abyssinica* is an indigenous bamboo to Ethiopia and endemic to tropical Africa. It belongs to the family Poaceae and subfamily Bambusoideae.<sup>2</sup>

Bamboo naturally propagates both sexually from seeds and asexually by rhizomes. Artificial propagation by vegetative methods includes planting of off-sets, culm cuttings, layering, and grafting of rhizome.<sup>3</sup> Off-sets are relatively better with clump forming species, but they require painstaking work for digging the rhizome out, which entails considerable risk of damage to the roots and buds of the offset and mother plant. Some bamboo species are successfully regenerated using culm cuttings.<sup>4</sup> On the other hand, although the gregarious flowering cycle of the species is about 20 years.<sup>5</sup> It also produces seeds from sporadic out-of-phase flowering in the intervening period.<sup>6</sup> This is not the case with most bamboo species, they flower only once in their life time gregariously and die. New bamboo growth may then emerge again on the site from germinating seeds if the land is left undisturbed and seed predation is not detrimental. For these reasons *O. abyssinica* is being established now, and will probably also in the

future depend on seed rather than vegetative propagules. Knowledge of factors that influence seedling emergence, survival and growth is thus vital for successful establishment and expansion of the species.<sup>7</sup>

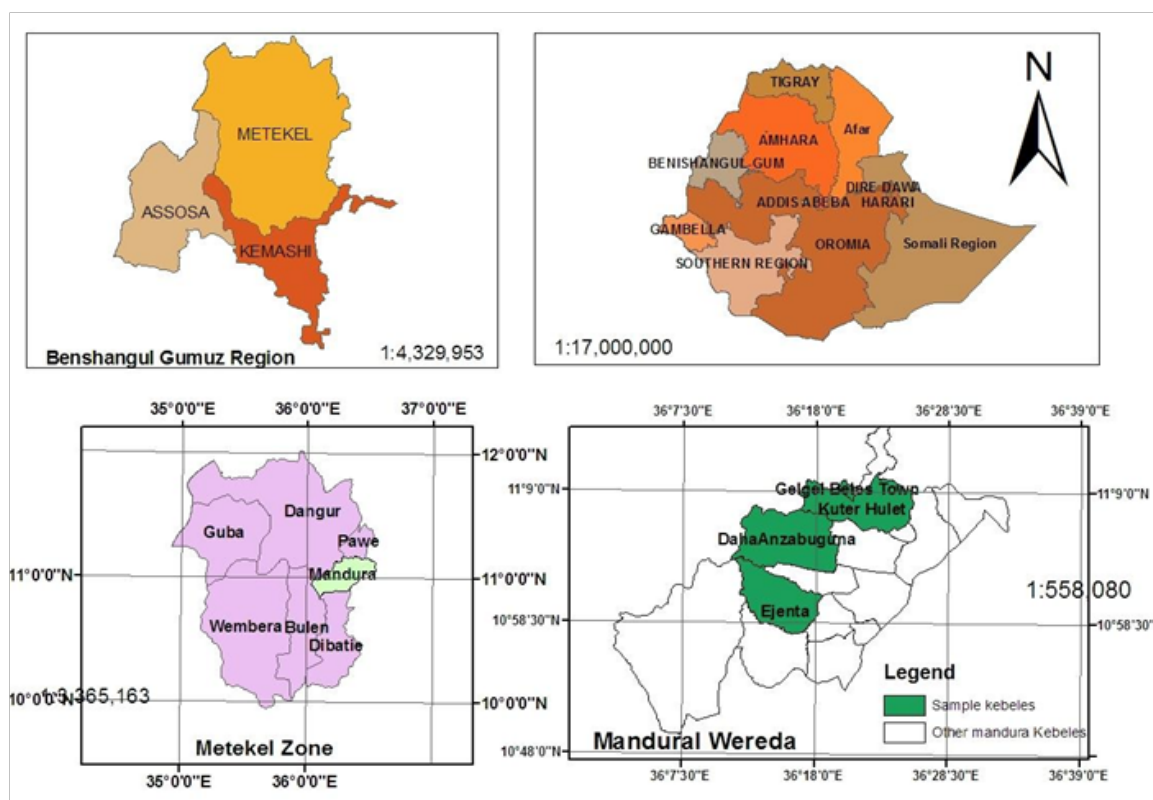
Bamboo forest is a material source for furniture, building, pulp, particleboard, bio-energy, food, forage and medicine. It plays a vital role in environmental amelioration, bio-diversity preservation soil and water conservation and has waste purification potential.<sup>8,9</sup> Given its fast growth, high soil conservation potential, multiple use and adaptability to low quality sites, bamboo has the capacity to redress most of the deforestation-related problems.

In the past, bamboo forests were located in the more inaccessible areas, which protected them from destruction. The highland bamboo forest at Masha, south-western Ethiopia, and the lowland bamboo forests at Assosa, Metekel, and Mandura, in western Ethiopia are examples. These forests are now decreasing rapidly as result of demand for construction and new roads that are being constructed (personal observation). The rate of clearance is accelerating as more forests are cleared due to agricultural expansion or burning to increase grazing land and due to natural mass flowering of the plant.<sup>8</sup>

## Materials and methods

### Description of the study area

**Location:** The Benishangul Gumuz Regional State (BGRS) was established in 1994 as one of the nine regional states of Ethiopia. The BGRS borders the Republic of Sudan in the west, Amhara region in the North, Oromiya in the South east and Gambella region in the South. Administratively, it is divided in to 3 zones (Metekela, Assosa, and Kemashi) that are divided in to 19 Woredas, and one special Woreda. Metekela zone is divided into 7 Woredas out of which Mandura Woreda, the study area is located North 10° 55' - 11° 00' latitude North and 30° 12' - 30° 36' longitude east (Figure 1), comprising 17 rural Kebeles and 3 town Kebeles. Gilgel Belesse is the center of Mandura Woreda and also the Zonal town. The Woreda has large topographic drops from east to west.



**Figure 1** The location of study Kebeles in Mandura Woreda Metekel Zone, Ethiopia.

## Sampling methods

**Site selection:** Five Kebeles (villages) were selected based on (1) availability of bamboo resources, (2) utilization potentials and significance to the surrounding community, (3) convenience to capturing as much socio-economic information as possible, and (4) the manufacturing and consumption of bamboo products.

**Vegetation data:** To describe the vegetation the stratified sampling method were used and vegetation data were collected from 10×10m quadrats lied in homogeneous vegetation units. A total of 8 quadrats were considered. Two quadrates (6 and 7) were from cultivated bamboo forest, other two quadrats (5 and 8) were in protected bamboo forest, and the rest four quadrats (1-4) were laid in wild forest of bamboo (2 from Duanzbaguna and 2 from Ajenta Villages). Community similarity among quadrats was quantified using Sorensen similarity coefficient. This coefficient of similarity ( $S_s$ ) was defined using the formula:

$$S_s = 2a / (2a + b + c)$$

Where  $S_s$  = Sorensen similarity coefficient

$a$  = number of species common to both quadrat

$b$  = number of species in quadrat 1

$c$  = number of species in quadrat 2<sup>10</sup>

Association among *O. abyssinica* and other woody trees was calculated using Jaccard's index. The Jaccard index of species association ( $I_A$ ) is based on species presence ( $p$ ):

$$IAP = [a / (a + b + c)] \times 100.$$

Where  $IAP$  = Jaccard index

$a$  = number of quadrat in which the two species under comparison occur together

$b$  = number of quadrat in which one of the two species occur alone

$c$  = the number of quadrat in which the other species is found alone<sup>11</sup>

## Seed viability test

Seed viability of *O. abyssinica* was evaluated by germinating seed under predetermined conditions. Sixty seeds from each sample were divided in to 3 replicates of 20 seeds each. Seeds collected in 2002 and 2004 E.C. were germinated on Petri-dishes with filter paper in the laboratory. The substrate used for germination test was free of moulds or other micro-organisms and provided with adequate aeration and moisture.<sup>12</sup> Seed viability and length of time was compared between seeds collected in 2002 and 2004 E.C. by using student's t-test to check how time length of seed storage affects effectiveness and duration of germination.

## Impact of sowing depth and soil type on germination

Seeds for sowing depth test and soil type were collected from an extensively flowered and heavily seeded lowland bamboo forest in Assossa Zone, Southwest Ethiopia (11°14' N and 36°16' E) by Pawie Agricultural Research Centre (PARC). The experiment on sowing depth was conducted using plastic polyethene 0.5 l volume, 16 plastic polyethene bags were filled with a mixture of sand and peat soil (ratio 1 sand: 1 peat) and 16 plastic polyethene bags were filled with pure natural peat soil (unmixed) of the area. A randomised

complete block design was used in the experiment. In the experiment, each block consisted of 4 polyethene bags. Four seeds were sown at random and in embryo end up orientation in each of the various depth categories. The depths were: 0mm (surface), 5mm, 10mm and 15mm and replicated four times, *i.e.*, 4 seeds  $\times$  4 treatments  $\times$  2 blocks (*i.e.*, a total of 32 sample units). During the experiment, seedling emergence was recorded on a daily basis for four consecutive weeks starting from the first germination. Data was analysed by using SPSS statistical software. Block means of the different treatments were applied for one-way ANOVA calculations to investigate the impact of sowing depth and soil type on germination.

### Vegetative expansion potential

To study reproductive potential and population of lowland bamboo, ten bamboo clumps were taken from quadrants of the 3 habitat categories: Category P (protected habitat), Category C (cultivated habitat) and Category W (wild habitat). Population size was counted based on number of culms in all of the clump observation, whereas reproductive ability of *O. abyssinica* was examined by counting number of newly developing culms in three different categories of habitats (P, C and W) and circumference classes. This was done by taking ten clumps of *O. abyssinica* from quadrants of the three habitats (protected, cultivated and wild habitat) randomly and the total number of newly emerged culms in the study year, number of cut culms, and number of decayed suckers was counted from each clumps. Then the total newly emerging culms were compared using ANOVA and the relationship between circumference and newly emerging culms was made using Pearson's correlation. For this part, data collection was carried out in September, when the young culms developed from bud (youngest rhizomes); they were distinguishable from those sprouting out of mature culms. Thus, it helped to compare vegetative reproduction potential of *O. abyssinica* in different habitats and different clump sizes.

## Results

### Analysis of vegetation feature

Vegetation feature of Mandura Woreda is made up of different patchy distribution of forests that contain plants like *Combrutum molle*, *Entada abyssinica*, *Lonchocarpus laxiflorus* and clumps of *O. abyssinica* associated among themselves. Based on the Sorensen

coefficient, highest similarity of forest vegetation was found between quadrats 6 and 7 that were taken from cultivated forest. In these quadrants only *O. abyssinica* was seen. The second highest similarity of forest vegetation was found between quadrats 4 and 8. Some valuable vegetation such as *Combrutum molle*, *Entada abyssinica* and *Lonchocarpus laxiflorus* were found.

The lowest similarity of vegetation between quadrats was found among quadrats 3 and 6, and quadrats 3 and 7. Although both of the quadrats were classified as lowland bamboo forest, however vegetation in quadrat 6 and 7 was influenced by cultivation activity of humans and the other plants are removed as wild. In Mandura Woreda, *O. abyssinica* grows mixed with several trees species. In the surveyed quadrats, it was clear that *Combrutum molle* and *Entada abyssinica* have high association with *O. abyssinica* (IAP=62.5 %). Both of the plant species were found growing together with *O. abyssinica* in all of the quadrats except quadrants 6 and 7. Some species such as *Trilepisium madagascariense*, and *Lonchocarpus laxiflorus* have less association with *O. abyssinica* (IAP=12.5 %) see (Figure 2).

### Seed viability test

The seedling emergence speed of lowland bamboo seeds were generally fast, less than 5 days on Petri dish but 9-12 days in soil. The percentage of viability is more (98%) on Petri dish and less (65.8%) in soil. The viability and speed of germination of seeds of *O. abyssinica* decreases as time of seed storage goes. From viability test seeds collected in 2004 E.C were 98.3% and all seeds germinated in 2 days. But seeds collected in 2002 E.C, only 33.3% was germinated and 4 days were taken up to the last germination (Figure 3).

### Seed germination

Percentage of seedling emergence varied with the type of soil condition and sowing depth. Students t-test (at sig=0.05) showed that seedling emergence was significantly different (higher in mixed soil than the unmixed soil). Time taken for seedling emergence was not significantly different in the two soil condition. More than half of seeds in mixed soil emerged as seedling within 12 days. Regarding sowing depth, cumulative emergence (percentage) was highest in 10mm depth (100%) and lowest at surface (0mm) and 15mm. In unmixed (pure peat) soil less than half of seeds emerged as seedling. In unmixed soil the cumulative emergence percentage was equal in the four depths (Table 1).

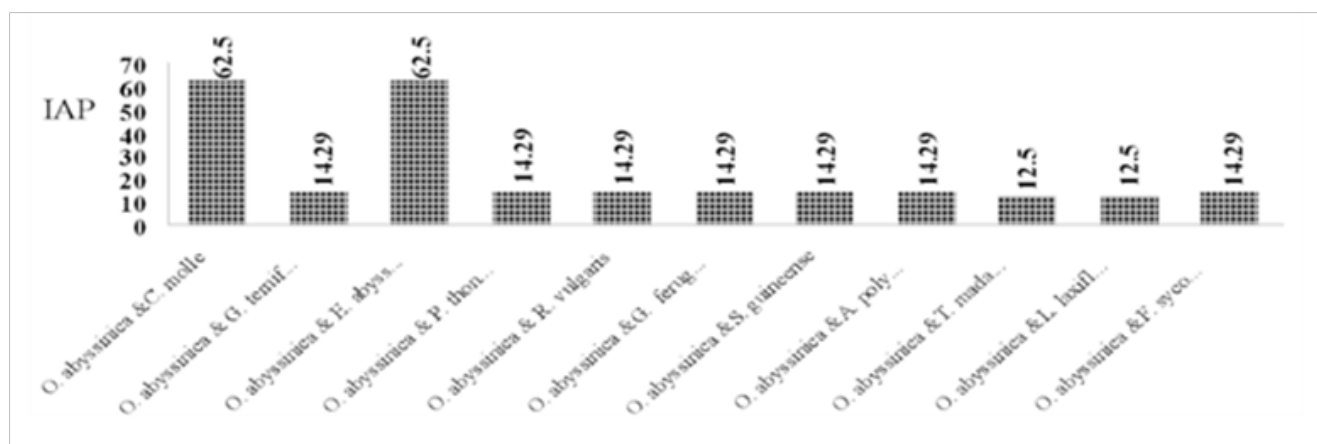
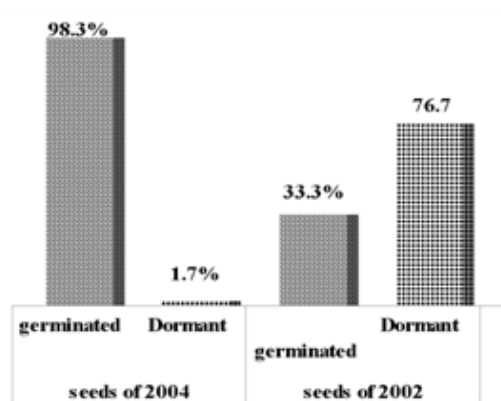


Figure 2 Graph showing IAP value of different plants associated with *O. abyssinica*.

**Table 1** Time length and Percentage of seed germination of *O. abyssinica*

Depth	Mixed soil		Unmixed soil	
	% of seed germination	X days for germination	% of seed germination	X of days for germination
0 mm	50	10.5	0	-
5 mm	75	10	50	10.5
10 mm	100	9.5	50	9.5
15 mm	50	11	50	10.5
Total average	275	11	150	10.5
	68.75	10.25	37.5	10.17



**Figure 3** Comparisons of seed viability between seeds collected in 2004 and 2002 E.C.

ANOVA test (95% degree of freedom) show there is no difference observed in speed of emergence of seedling in all sowing depths in both soil types (Table 2).

**Table 2** ANOVA of difference in seedling immergence in different sowing depth

	df	Mean square	F	Sig.
Between Groups	3	1.338	0.922	0.478
Within Groups	7	1.452		
Total	10			

## Population and expansion ability

### Population size

The smallest average number of culms per clump was observed in group W (wild forest) that is 47. The number of culms in group C (cultivated forest) is 85 and in P (protected forest) 86 culms per clump. The significance test by one-way ANOVA is presented in (Table 3). The mean value of group W was significantly different from others (group P and C) at the 0.05 significance level.

**Table 3** Summary table for ANOVA to determine the significant difference of number of culms in the three types of habitats of lowland bamboo

Source of variation	(SS)	(df)	Mean square (MS)	F	Sig.
Between Groups	12118.72	2	6059.361	4.664	0.016
Within Groups	42874.92	33	1299.24		
Total	54993.64	35			

\*Significance level at  $P < 0.05$ .

### Vegetative expansion ability

Vegetative reproduction is by producing new culms from rhizomes. The percentage of new culm productions are given in Table 4. As it can be observed in the table percentage of production of new culms is highest in cultivated forest, 38.77% (group C) and lowest in protected forest, 20.73% (group P) of lowland bamboo (Table 4).

Furthermore the new culm production difference in the three habitats was tested by Tukys' honesty test ( $p < 0.05$ ). The new culms production was significantly different among the protected and cultivated (group P and group C) and among cultivated and wild forest of lowland bamboo (group C and group W). But the potential of production of new culms of lowland bamboo is not significantly different between protected and wild forest (group P and group W) (Table 5).

**Table 4** Percentage of new culms production in the three habitats of lowland bamboo

Group	Average of total culm	Average of new culm	%of new culm
P	86	17.83	20.73
C	85.33	33.08	38.77
W	46.75	16.83	36

**Table 5** Turkey HSD test to determine the significant difference of number of new culms in the three types of habitats of lowland bamboo

Group(I)	Group(J)	Mean difference (I-J)	Std. error	Sig.
P	C	-15.25000*	3.40992	0
C	W	16.25000*	3.40992	0

\*The mean difference is significant at the 0.05 level.

### Disturbance to lowland bamboo population

Human disturbance by cutting in the three habitats, (protected forest, cultivated forest, and wild forest) was shown in Figure 4. Culms were highly cut (harvested) in cultivated forest (group C) and wild forest per clump (group W) and least number of culms cut (harvested) in protected bamboo forest per clump (group P). During the survey in all the three habitats there was no new shoots cut observed except rare damage of new shoots by animals and decay.

The establishment of newly emerging shoots was affected by crowdedness (shade) and litter mass. The number of new shoots decayed observed during the survey were shown in Figure 5. High number of shoots was decayed in protected forest and least number of bamboo shoot decayed in wild forest.

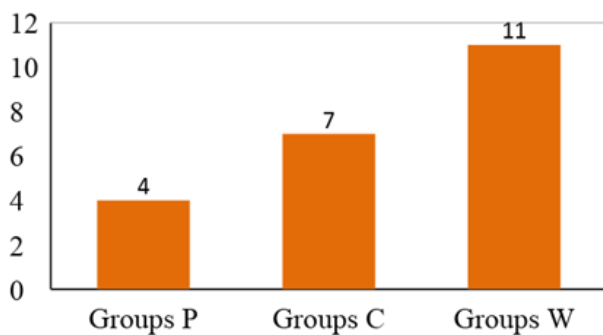


Figure 4 Number of culms cut (harvested) in the three habitats.

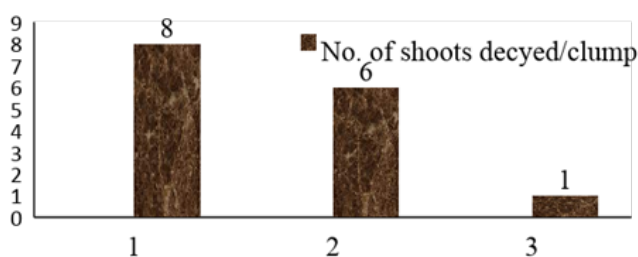


Figure 5 Number of new shoots decayed in the three habitats.

## Discussion

### Vegetation features

Vegetation feature of Mandura Woreda is made up of different patchy distribution of forests that contain plants like *Combrutum molle*, *Entada abyssinica*, *Lonchocarpus laxiflorus* and clumps of *O. abyssinica* associated among themselves. According to the Sorensen coefficient, highest similarity of forest vegetation was found between quadrats 6 and 7 that were taken from cultivated forest. And the lowest similarity of vegetation was between quadrats 3 and 6, and quadrats 3 and 7. Although both of the quadrats were classified as low land bamboo forest, however vegetation in quadrat 6 and 7 was influenced by cultivation activity of humans and the other plants except *O. abyssinica* are removed as wild. The second highest similarity of forest vegetation was found between quadrats 4 and 8. Some valuable vegetation such as *Combrutum molle*, *Entada abyssinica* and *Lonchocarpus laxiflorus* were found in common. In Mandura Woreda, *O. abyssinica* grows mixed with different trees species. In the quadrats surveyed, it was clear that *Combrutum molle* and *Entada abyssinica* have high association with *O. abyssinica* ( $Iap=62.5\%$ ). These plants range from shrub to small trees in their habit, so that their existences do not affect *O. abyssinica* forming canopy shad. Some species such as *Trilepisium madagascariense*, and *Lonchocarpus laxiflorus* have less association with *O. abyssinica* ( $Iap=12.5\%$ ). These plants are tall trees that can form canopy so that *O. abyssinica* is less associated with these species.

### Seed viability test

Lowland bamboo seeds are found most successful and practical propagation materials. Viability of seed on Petri dish was fast which took less than 5 days for emergence of plumule. The duration of seed storage causes variation on efficiency and speed of viability, in this

experiment two years difference in storage duration decreases seed viability by 65%. Viability of seeds collected in 2004 E.C. is 98.3% and germinate in 2 days, but viability is 33.3% and germinates in 4 days for seeds collected in 2002 E.C. This lies in agreement with<sup>13</sup> that reported loses of bamboo seed viability about 2–3 months after harvest. The fast and high seedling emergence percent of *O. abyssinica* agree with the result reported by<sup>14</sup> for *Bauhinia retusa*.

### Seed germination test

Seed germination of any plant is affected by different factors like temperature, moisture, soil type and sometimes light. In this experiment seed germination of *O. abyssinica* is mainly affected by soil type and moisture. Seeds in Petri dish germinated in less than 5 days where as seeds sown in soil took 9–12 days for germination, this is a fast seedling emergence speed. This in lines with the result in which seeds of *O. abyssinica* germinate in two weeks' time after sowing. Seedlings that are germinated in the Petri dish survive effectively when transplanted to soil. Seedling emergence (viability) is 98% in Petri dish and 65.8% in soil. This is a very high value in the germination efficiency with respect to short viability and low germination rate of bamboo seeds reported by other researchers.<sup>4,15</sup> The variation in speed of germination and percentage of viability could be due to the difference in moisture in the two conditions. In Petri dish, seeds get sufficient moisture and the loss of moisture by evaporation is controlled by laboratory condition. Whereas, in the soil the moisture is lost due to evaporation, down ward percolation of water and fixation of water molecules between soil particles, so that moisture is inadequate for seed germination. Soil type is another factor for seed germination; seeds sown in unmixed soil (pure forest soil) have less percentage of seed viability (37.5%) than mixed soil (68.78%). Student's t-test show significant difference in seed viability between two types of soils ( $\text{sig}=0.05$ ). But difference in duration of germination is insignificant in the two types of soil and sowing depth. In contrast to the<sup>16,17</sup> better seedling emergence speed and cumulative seedling emergence at and near the surface is in conformity with the general trend of increasing seedling emergence with decreasing sowing depth.

The variation in viability percentage in the two types of soil condition could be due to that there is good porosity, drainage and aeration in mixed soil, so that moisture and air circulates sufficiently to seeds to germinate, but in the unmixed soil these conditions are low, so that the viability of seeds decreases. Another factor that affected seed germination in *O. abyssinica* is sowing depth. Seedling emergence is highest in 10mm depth (100%) and lowest at surface (0mm) in mixed soil. In unmixed soil half of seeds germinated at sowing depth of 5mm, 10mm and 15mm but no any seedling germination is observed on the surface.

### Population and expansion ability of *O. abyssinica*

**Culms population:** The number of culms of *O. abyssinica* varied in different habitats. The mean number of culms per clump varied significantly ( $P=0.016$ ) between protected forest, wild forest and cultivated forest. The number of culms is smallest in the wild forest (47 per clump) and highest in the protected forest (86 per clump). But according to the<sup>18</sup> the average number of culms per clump is 72.3. According to<sup>19</sup> most of the non timber forest products (NTFPs) are harvested from common property resources in situations where access appears to be neither restricted nor regulated so that resources are depleted. In cultivated lowland bamboo forest, the number of

culms per clump was high (85). This agrees with the finding of<sup>20</sup> in which, privatization or transfer of control of vegetation forests to a few individuals can lead to a situation where a use of forests is denied access to informal users of forest products, so that the forests can be well managed.

The reason for less number of culms per clumps in the wild forest could be due to uncontrolled harvesting by the community, animal disturbance and fire. In the wild forest in addition to uncontrolled harvesting of bamboo culms, the way of cutting was not properly. During the field observation the researcher observed that culms were cut near the earth's surface. On the other side, the elders in the community claimed that when culms of lowland bamboo are cut near the earth's surface, the ability of clump to produce new shoot decreases. So uncontrolled and unwise harvesting of lowland bamboo culms in the wild forest contributed to the decrease in number of culms per clumps.

On the other side, cultivated and protected forests of *O. abyssinica* in Mandura Woreda, has high number of culms per clump. The reason for large number of culms could be due to controlled system of harvesting culms, proper management and wise way of cutting and being protected from over disturbance by domestic animals (Figure 6).



**Figure 6** Number of culms in clump of protected forest.

### Vegetative expansion ability

Forest regeneration requires the establishment of seedlings and saplings within the same environment where the parent trees grow. The finding of<sup>21-23</sup> also reported that species regenerate mainly from seeds and there is no evidence of vegetative spread. However (Kassahun Embaye<sup>6</sup>) reported that, new bamboo shoots are produced every rainy season from rhizome buds that attain full height and diameter in about 3 months in mature rhizome-root system, which occurs in 3 to 7 years after germination of seeds. During this study the vegetative reproduction of *O. abyssinica* is observed with a production of new shoot. The percentage of expansion ability of new culms varied in different habitats (protected, cultivated and wild forests habitats). Tukys' honesty test ( $P < 0.05$ ) showed significant difference in percentage of new shoot production in each habitats.

Human impact on certain habitat such as tropical forest is responsible for the spread of bamboo that is able to thrive under disturbed conditions.<sup>24,25</sup> The percentage reproductive ability is high in cultivated (33.08 average new shoots per clump) and wild forests (16.83 average new shoot per clump) of lowland bamboo (38.77% and 36% respectively) and lowest in protected forests. Similar survey

in Bambassi Woreda of Benishangul Gumuz Regional State<sup>26</sup> showed the average number of new shoots per clump per year to be 22.

The success in the cultivated and wild forests of low land bamboo accounts for high percentage of new shoot production due to the presence of disturbance in the forests. When there is moderate disturbance in any vegetation, the vegetation expansion and vegetation diversity increases. In the cultivated forests the owners collect mature culms for different uses properly and this moderate disturbance activates the clumps to produce many new shoots. In the same manner, in the wild forest of lowland bamboo there is severe disturbance by human beings, domestic animals, wild animals and fire. Even though this all factors do have their own negative effects on the reproductive ability of the plant, they activate the clump to produce more new shoots.<sup>29-40</sup>

The finding of<sup>15</sup> states that, abundance of culms and culm debris in the centre of culms might inhibit culms growth, but absence of culm debris in the centre of clumps allow the new culm emergence. This is in line with the finding of the present research. On the other hand the protected forest is free of any anthropological, wild animal and fire effect; it is less threatened by the factors that stimulate the plant for vegetative regeneration. Due to this their percentage production of new shoot is least. In this study the productive ability of new shoot in each clump is positively correlated with circumphrance of clumps with correlation value of  $r = 0.66$ . This shows that there is strong correlation between new shoot production and circumference of clumps that is significant at 0.01 confidence level (2- tailed).<sup>40-55</sup>

### Threats to lowland bamboo population

Collection of culms by humans is one of the threats for the population of lowland bamboo culms. This threat was highest in cultivated and wild forests of lowland bamboo forests (7 culms per clump). But least number of culms was collected in the protected forests (3 culms per clumps). This was done only for governmental activities like building fence of the protected forest and FTC (Farmers Training Centres). The other threat of population of culms in each clump is decay of newly emerging shoots due to effect of fungus and shortage of light. The finding of states that, abundance of culms and culm debris in the centre of clump might inhibit new culms growth, but absence of culm debris in the centre of clumps allow the new culm emergence. According to this study, highest numbers of shoots decay is recorded in protected forest. This is due to the presence of large number of mature culms and culm debris that form dense canopy and crowd between culms preventing light reach to ground and favours inhibiting new shoots. The decay of new shoots decreases in cultivated and wild forests of lowland bamboo because in these two habitats the canopy formation is thin and allow penetration of light to reach the new shoots. (Figure 7).<sup>56-59</sup>

During this study, additional threats to cutting culms and decay of new shoots were identified by the community interview and focus group discussion. The threats were mass flowering, agricultural expansion, overgrazing by domestic animals, fire and cutting style. There were ranking during the focus group discussion by using direct matrix ranking (Table 4). Fire was reported the leading threat followed by mass flowering for decline of *O. abyssinica* in Mandura Woreda. The studied lowland bamboo forest in Mandura Woreda is found to be frequently burnt. Repeated intensive burning leads to conversion of both forest and woodland to grassland, in which, combustion of woody vegetation enables increased light levels to reach the ground,

thus allowing the development of dense grass layer, which in turn renders the habitat more susceptible to fire.<sup>28</sup> This phenomenon, pose a serious threat to the perpetuity of *O. abyssinica* in the Woreda.



**Figure 7** Decayed newly emerging *O. abyssinica* shoot due to culm and leave debris.

According to the respondents in the study area, as the age of low land bamboo forest stays for longer time, mass flowering (Gawi) cause the mature culms to produce seeds and then dry. Informants indicated that, this condition can be predicted by looking new features in the bamboo clump. When the time of flowering (Gawi) approaches the clump decreases and finally stops producing new culms and most of mature culms become hollow. Even though these characters predicate the time of flowering of the plant, the community had no indigenous knowledge to protect the species from mass flowering. Even though flowering of the plant may lead to regeneration, it changes the mature culms into smaller and less fire tolerant seedlings. This condition affects the plant to be easily burned by fire and cause unrecoverable drying of the plant and lead to decline and even local extinction of *O. abyssinica*. Human activities are other serious threats for the existence of *O. abyssinica* in the study Woreda. If culms are collected at wrong time and in wrong way the vegetative reproduction ability of the clump decreases. In the study area the community does not care about the proper position of culms to cut and this played great role as a threat of *O. abyssinica*. (Figure 8).<sup>60-63</sup>



**Figure 8** Forest affected by wild fire in study areas during the survey.

## Conclusion

Mandura Woreda has different patchily distributed vegetation features containing plants like *Combrutum molle*, *Entada abyssinica*, *Lonchocarpus laxiflorus* and *O. abyssinica*. In the study Woreda *O. abyssinica* grows mixed with different tree species. *Combrutum molle* and *Entada abyssinica* grows more associated with *O. abyssinica*. Seed germination of *O. abyssinica* is fast which took average 3 days on Petri dish and 9-12 days in soil. Duration of storage of seeds before germination has its own effect on speed and effectiveness of seed germination. So, seeds stored for two years loss their viability by 65% and speed of germination slows by 2 days on Petri dish test. Using mixed soil with sand in the ratio of 1:1 increases seed viability from 37.5% to 68.78%. Although different authors reported the effect of depth of sowing on germination speed and efficiency, in this research the effect of depth is not significant on speed of germination.

Number of culms per clump of *O. abyssinica* varied in different habitats (Table 4). The mean number of culms per clump is highest in protected forests and least in wild forests due to uncontrolled harvesting of the community, animal and fire disturbance and wrong cutting style. Vegetative expansion of *O. abyssinica* is means of regeneration in which new shoots emerge from the rhizoid every rainy season. The percentage expansion (reproduction) is different in wild, protected and cultivated habitats. It is highest in cultivated and

wild forest habitats (38.77% and 36%) per year respectively, but least in protected forest (20.73%). The ability of clumps to produce new shoots is directly proportional with the circumference of the clump.

## Recommendations

Since the seeds of *O. abyssinica* require good moisture content to germinate, the seeds should be sown in highly humid environment. The study recommends conservation education to villagers and encouraging villagers to establish privet woodlots to provide lowland bamboo for construction, fence, making beehive and building poles. This will minimize the daily walking routine of villagers into the wild forest and make individuals to cultivate *O. abyssinica* in their wood lots. Deliberate human intervention through further research is needed to restore normal recruitment and regeneration trend of *O. abyssinica* in the Woreda. In partnership with cultivators, the Department of Agriculture/Forestry in the Woreda and NGOs operating at local level extension packages need to be developed and applied to improve cultural practices of lowland bamboo cultivation including timing, methods of harvesting and propagation.

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## Conflicts of interest

The author declares there is no conflicts of interest.

## References

- Kassahun Embaye. The indigenous bamboo forests of Ethiopia: an overview. *Ambio*. 2000;29(8):518–521.
- Ohrnberger D. *The Bamboos of the World*. 1999.
- Uchimura E. *Bamboo cultivation*. In: Lessard G, Chouinard A, editors. 1980.
- Liese W. *Bamboos: Biology, Silvics, Properties and Utilisation*. 1985.
- Fanshawe DB. Bamboo *Oxytenanthera abyssinica*. its ecology, silviculture and utilisation. *Kirkia*. 1972;8(2):157–166.
- Kasahun Embaye. The potential of bamboo as an interceptor and converter of solar energy into essential goods and services: focus on Ethiopia. *Journal of Sustainable Development & World Ecology*. 2009;8(4):346–355.
- Kassahun Embaye. Study on Ecological aspects and resource management of bamboo forests in Ethiopia. *Acta Universitatis Agriculturae Sueciae Silviculturae*. 2003;273:25.
- Kelecha WM. The Bamboo Potential of Ethiopia. *Forestry and Wildlife Conservation and Development Authority*. 1980.
- Embaye K, Christersson L, Ledin S, et al. Bamboo as bioresource in Ethiopia: management strategy to improve seedling performance (*Oxytenanthera abyssinica*). *Bioresour Technol*. 2003;88(1):33–39.
- Kent M. Vegetation Description and Analysis: a Practical Approach. *Environmental Geoscience*. 2011.
- Mueller Dombois D, Ellenberg H. *Aims and Methods of Vegetation Ecology*. 1974.
- Beniwal BS, Dhawan VK, Joshi SR. Standardization of nursery techniques of *Melocanna baccifera* (syn. *M.bambusoides*). *Van Vigyan*. 1996;34(3):81–83.
- Rao IV. Delivery systems for planting materials: requirements and approaches. *Constraints to production of Bamboo and Rattan*. INBAR. 1994.
- Prasad P, Nautiyal AR. Influence of seed orientation on seedling emergence in *Bauhinia retusa* Ham. Ex Roxb. *Seed Sci Technol*. 1996;23:861–864.
- Banik RL. Techniques of bamboo propagation with special reference to pre-rooted and pre-rhizomed branch cuttings and tissue culture. *Theses and Dissertations*. 1985;160–169.
- Iji PA, Tarawali G, Baba M. The influence of stage of development and sowing depth on seed quality and seedling emergence of *Gliricidia sepium*. *Seed Sci Technol*. 1993;2(1):197–202.
- Yorinori NA, Sada SY, Pissai A. The effect of depth of sowing and early ageing of popcorn (*Zea mays*) seed upon the percentage of plant emergence. *Revista do Sector de Ciencia Agrarias*. 1996;15(2):173–178.
- Study on Utilization of Lowland Bamboo in Benishangul Gumuz Region*. INBAR. Ethiopia. 2010.
- Jodha NS. *A Framework for Integrated Mountain Development*. 1990.
- Arnold JEM. *Socio-economic benefits and issues in non-wood forest products use*. Report of the International Expert Consultation on Non-Wood Forest Products. *FAO*. 1995.
- Kigomo BN. Distribution, cultivation and research status of bamboo in Eastern Africa. *KEFRI Ecol Ser Monogr*. 1988;1:1–19.
- Kigomo BN, Savill PS, Woodell SR. Phenological patterns and some aspects of reproductive biology of *Brachylaena huillensis* O. Hoffm. *Afr J Ecol*. 1994;32:296–307.
- Kigomo BN. Guidelines for establishment and management of bamboo in Kenya. *Forestry Research Institute Occasional (Management)*. 1995.
- Numata M. The relationship of limiting factors to the distribution and growth of bamboo. In: Numata M, editor. *Ecology of Grasslands and Bamboo-lands in the World*. 1979;258–275.
- Widmer Y. *Life history of some Chusquea species in old growth oak forest in Costa Rica*. 1997.
- Bamboo for the environment. Development and trade International Bamboo Workshop. INBAR. 2006.
- Jiang Z. Grasp the opportunity, Drum up future to push our country bamboo industry development. *J Bamboo Res*. 2002;21(1).
- Swaine MD, Lieberman D, Hall JB. The effect of fire exclusion on savannah vegetation at Kpong, Ghana. *Biotropica*. 1992;24(2a):166–172.
- Amare G. Bamboo and reeds in Ethiopia. *Ethiopian Forestry Action Plan*. 1992.
- Anonymous. *Study of sustainable bamboo management*. 1997.
- Behari B, Rashmi A, Singh AK, et al. Vegetation development in a degraded area under bamboo based agro-forestry system. *Indian Forester*. 2000;126(7):710–720.
- Bernard K. Guidelines for Growing Bamboo. A handbook of the Guideline for Establishment and Managing Plantations of Bamboo in Kenya. *Kenya Forestry Research Institute*. 2007.
- Bewketu Z Kassa. *Bamboo: an alternative building material for urban Ethiopia*. 2009.
- Bumarlong A, Yagi H. Rehabilitation of denuded forest lands in the Philippines using bamboos. *JIRCAS Int Symp Ser*. 1984;1:72–77.
- China Biodiversity and National Condition Research*. 1998.
- Ethiopian Forestry Action Program: Synopsis Report, Ministry of Natural Resources Conservation and Development*. EFAP. 1994.
- Ensermu Kelbessa, Tamrat Bekele, Alemayehu Gebrehawt, et al. *The Socio-Economic Case Study of the Bamboo Sector in Ethiopia: An Analysis of the Production-to-consumption system*. 2000.
- Ministry of Natural Resources Development and Environmental Protection, Ethiopia*. Ethiopia: Forestry Action Program 1994.
- Isagi Y, Kawahara T, Kamo K, et al. Net production and carbon cycling in a bamboo *Phyllostachys pubesuzns* stand. *Plant Ecology*. 1997;130(1):41–52.
- Jiping L. An outline of bamboo resources and research in the world. In: Jiping L, editor. *Farm Forestry Training Courses on Bamboo Production and Utilisation*. Nanjing Forest Univ, Nanjing, China. 1987;82–95.
- Kajembe GC. *Indigenous management systems as a basis for community forestry in Tanzania: A case study of Dodoma urban and Lushoto districts*. 1994.
- Guidelines for Growing Bamboo*. KEFRI: Nairobi; 2007.
- Khosrow G. Bamboo as Reinforcement in Structural Concrete Elements. *Cement and Concrete Composites*. 2005;27(6):637–649.
- Lugt Van der P, AAJF Dobbeltstein, JJA Janssen. An Environmental, Economic and Practical Assessment of Bamboo as a building material for supporting structures. *Construction and Building materials*. 2006;20(9):648–656.

45. Luso Consult. *Study on Sustainable Bamboo Management*, Commissioned by GTZ. 1997.
46. Martin GJ. *Ethnobotany: A conservation manual*. Chapman and Hall: London; 1995.
47. Melaku Tadesse. *Bamboo and Rattan Trade Development in Ethiopia*. Ministry of Agriculture and Rural Development Addis Ababa, Ethiopia. 2006.
48. Mooney HF. *A report on the bamboo forests of Wellega Province with view to their possible utilization for pulp*. 1955.
49. Nath S, Das R, Chandra R, et al. Bamboo Based Agroforestry for Marginal Lands with Special Reference to Productivity, Market Trend and Economy. *Institute of Forest Productivity*. 2009;1–25.
50. Newcombe KJ. An economic justification for rural Afforestation: The case of Ethiopia. *The Annals of Regional Science*. 1987;21(3):80–99.
51. Ntirugulirwa Bonaventure. *Enhancing Bamboo Production and Utilization in Rwanda*. 2006.
52. Phillips S. Poaceae (Gramineae). In: Edwards S, Hedberg I, editors. *Flora of Ethiopia and Eritrea*. 1995.
53. Qiu GX, Shen YK, Li DV, et al. Bamboo in subtropical eastern China. In: Long SP, Jones MB, Roberts MJ, editors. *Productivity of Grass Ecosystems of the Tropics and Subtropics*. 1992.
54. Ramanayake SMSD, Yakandawala K. Incidence of flowering, death and phenology of development in the giant bamboo (*Dendrocalamus giganteus* Wall. Ex Munro). *Ann Bot*. 1998;82(6):779–785.
55. Scurlock DC, Dayton DC, Hames B. Bamboo: an overlooked biomass resource? *Biomass and Bioenergy*. 2000;19(4):229–244.
56. Sharma BD, Hore DK, Pandey G, et al. Genetic resources of bamboos in the NE region of India. *Indian J Forestry*. 1992;15(1):44–51.
57. Sharma YML. *Inventory and resource of bamboos*. In: Rao AN, Dhanarajan G, et al, editors. *Proc Int Bamboo Workshop on Recent Research on Bamboo*. Hangzhou, China. The Chinese Academy of Forestry, China and International Development Research Centre (IDRC), Ottawa, Canada, 1996.
58. Masresha Fetene. *Forests of Sheka: Multidisciplinary case study on impacts of land use /land cover changes/ in south West Ethiopia*. 2007.
59. Tesfaye Hunde, Seyoum Kelemwork. Suitability, Status, Distribution and Biology of Bamboo Resources in Ethiopia. *Jornal of United Nations Environment Programme*. 2006.
60. Virtucio FD. Pulp Yield and Physico- mechanical Properties of Six Philippine Bamboo Species and the Implications on Optimal Harvesting Age. *Ecosystem Research and Development Bureau*. 1990.
61. Wimbush SH. The African Alpine Bamboo. *The East African Agricultural Journal*. 1947;13(1):56–60.
62. Yang Y, Zhang H. Prospects for bamboo-based products as replacement for wood in Yunnan. *Proc Fourth International Workshop on Bamboo in Pacific Asia. FORSPA*. 1994;273–277.
63. Zhang Kunmin, Hao Jiming. *Theory of Sustainable Development*. Beijing: China. 1997.