Growth performance and biomass accumulation of four introduced bamboo species in south-western Ethiopia

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Abstract

Ethiopia has two indigenous bamboo species and no exotics, covering 0.6 to 1.0 million ha at 2400-3500 masl and 500-1800 masl. From 1800 to 2400 masl, there are no bamboo species, and the two native species are dwindling because of over-exploitation, gregarious flowering, shifting cultivation and extensive forest fires. Introduction of different species and evaluation of their growth performance is required in different agro-climatic zones of the country. Accordingly in 2010/2011 four potential bamboo species, *Dendrocalamus hamiltonii, Bambusa vulgaris*, *Dendrocalamus membranaceus* and *Guadua amplexifolia* were introduced and evaluated for their growth performance and biomass accumulation on-station at Jimma Agricultural Research Centre. *D. hamiltonii* showed best performance with average DBH, height and basal area 3.44±0.213 cm, 10.58±0.47 m, and 9.71±1.25 cm respectively. *B. vulgaris* had the greatest number of culms/clump (66±5) and shows lower performance in diameter of culms (1.9±0.92 cm) and basal area (2.91± 0.26 cm2). *D. membranaceus* performed well in average number of nodes per clump (19±0.63) and *G.amplexifolia* shows lower performance in culm number, height and number of nodes 7±1, 3.167±0.20, 13±0.60 respectively. The grand total biomass for the species *D. hamiltonii, B. vulgaris, D. membranaceus* and *G. amplexifolia* measured 82.16±0.94, 77.22±2.15, 75.18±1.95, and 11.90±0.45 kg respectively. Among the four species *D. hamiltonii* showed the highest total biomass accumulation of 82.16±0.94 kg/clump of which culm, branch, leaf and rhizome parts contributed about 50.32%, 16.77%, 20.25%, 12.66% respectively. Among the four species *D. hamiltonii* showed faster growth performance and *D. membranaceus* the second fastest. The results indicated that *D. hamiltonii* and *D. membranaceus* are good potential bamboo species for cultivation in Ethiopia.

Key words: Bamboo, biomass, species, growth performance

Theme: Propagation, Plantations & Management

Introduction

Bamboo plants grow in the tropical and temperate regions, being predominant in the former, particularly in Southeast Asia (Banik 1985). More than 1,500 bamboo species are found in the world (Ohrnberger 1999), covering more than 14 million ha of land. About 40 of these species occur naturally or are introduced in Africa, on over 1.5 million ha (Kigomo 1988) of land, and two of these species are indigenous to Ethiopia: *Oxytenanthera abyssinica* (A. Richard) Munro (lowland bamboo) and *Oldeania alpina* (K. Schum.), Stapleton (highland bamboo). The Ethiopian natural bamboo forest is about 1 million ha, which is about 7% of the world total and 67% of the African bamboo forest area (Kassahun 2003). According to the literature reviewed and field observations undertaken, Ethiopia had only the two indigenous bamboo species and no exotics at all. About 130,000 ha of Oldeania *alpina* and about 850, 000 ha of *Oxytenanthera abyssinica* are found scattered in the south, south-west and central parts of Ethiopia. Altitudinal range of the two aforementioned species is 2400- 3500 masl and 500-1800 masl, respectively. However, in between 1800 – 2400 masl, there were no native or exotic bamboo species in the country. They were in more or less pure, fully stocked natural forest conditions. However, they are being cleared at an accelerating rate for agricultural land expansion, burned to promote more tender grass growth for grazing, and to drive out or kill allegedly harmful insects. Large-scale coffee and tea plantations and urban expansion are also emerging as real and potential threats (Kassahun 2003). The bamboo resource in natural habitats is dwindling, due to over-exploitation, gregarious flowering, shifting cultivation and extensive forest fires. Sustained availability and utilisation can be ensured by proactive bamboo cultivation (Shanmughavel, P. et al. 1995). In addition broadening of the genetic base of the resource is indispensable, to reduce disruption in supply caused by flowering. These all requires introduction of different potential species from other parts of the world and evaluation of their growth performance in different agro climatic zones of the country. To assess and evaluate the growth performance of species, it is important to study the productivity dynamics of the species (George 1977). Biomass studies are important to judge the performances of the species in terms of biological and total biological production and to assess the nutrient during the harvest (Negi 1984). The main objectives of this investigation were to estimate allocation of biomass to above ground, below ground and overall biomass components and to evaluate the performances of different bamboo species introduced from Asia and Latin America.

Materials and Methods

Study Site:

The study site is located at Jimma Agricultural Research Centre, located at latitude of $7^0$46' N, longitude of $36^0$0'E and altitude of 1753 meter above sea level. The centre has maximum of 26.2^0C and minimum 11.3^0C temperature and receives 1529.5 mm average rainfall per annual. The major soil type of the centre is chromic nitosol, with cambisol of upland and fluvisol of bottom land, with total land holding of 183 hectare. The centre is situated in a sub-humid tepid to cool mid-highland agro-ecological zone.

Bamboo Plantation:

The plantation was established to evaluate the performance and adaptation of four introduced bamboo species (*Bambusa vulgaris* var. *vulgaris, Dendrocalamus hamiltonii, Guadua amplexifolia* and *Dendrocalamus membranaceus*, in 2010 & 2011. Planting materials were prepared at Debrezeyit Agricultural Research Centre, and become ready for the 2010/2011 rainy season. 16 plants were planted per plot, and the experiment was replicated 4 times (48 seedlings per species per site). The experimental design followed was a Completely Randomized Block Design (RCBD) with 4 replications. The seedlings were planted at a spacing of 4 x 4 m. The data was summarizing using SPSS software and was analysed using descriptive statistics and MS Excel.

Growth Study

Four growth study measurements were taken from all clumps and the average measurement was used for calculations. The number of culms in these clumps was counted and all observations were made for the basal area, DBH, height and number of nodes for all the species.

Biomass Estimation

In order to estimate the total biomass, four plots/clumps were selected randomly from each block. For reasons of economy, time and labour, the rhizome was excavated only from one clump/plot for all species. After felling, the clumps were subdivided into leaves, branches, stems and rhizome and grouped in to three age classes:<1 yr, 1-2 yrs, >2 yrs. Fresh weight of the components was estimated in the field and sub samples from each component were brought to the laboratory in plastic bags. The culm was divided into three parts: bottom, middle, and top. Sub samples were taken from the four

plots randomly: 200 g of culm from the second internodes of the bottom, middle and top parts. 100 g of branch and 100 g of leave were taken in each of the age class from the field immediately after felling and dried in an electric oven at 85 ºC until constant weight was reached. With these data, the ratio of dry weight to fresh weight was obtained for each sample; this ratio was used to obtain the values of dry matter (DM) for each component of the species. From the oven-dry weight of the samples, the total grand total biomass of each clump group was calculated by multiplying the average number of the bamboos of each clump with the average dry weight of the sample, following Shanmughavel, P. et al. (1995). Total above ground dry weight of the culm and clump was obtained from the sum of the dry weight of the components, that is dry weight of stem + dry weight of branch + dry weight of leaf. Overall biomass of the species was obtained from the sum of the dry weight of all the components.

Results

Growth Study

The number of culms produced from 4 year old clumps for each species was counted and are presented in Table 1. Average number of culms, height, DBH, Basal area and number of nodes for *Dendrocalamus hamiltonii, Bambusa vulgaris, Dendrocalamus membranaceus* and *Guadua amplexifolia* were 26±2, 10.58±0.47, 3.44±0.213, 9.71±1.25, 18±0.89, 66±5, 6.77±0.264, 1.9±0.92, 2.91± 0.26, 14±0.61, 42± 3, 7.208±0.304, 2.716±0.145, 5.97 ±0.60, 19±0.63, and 7±1, 3.167±0.20, 2.83±0.189, 6.59± 0.78, 13±0.60 respectively.

Biomass Production in Clump Basis

It is seen in Table 2 that the total biomass accumulation of *Dendrocalamus hamiltonii, Bambusa vulgaris, Dendrocalamus membranaceus* and *Guadua amplexifolia* per clump were 82.16±0.94, 77.22±2.15, 75.18±1.95 and11.90±0.45 kg respectively. For stem, branch, leaf and rhizome the average dry weight per clump for *Dendrocalamus hamiltonii* was 41.34±0.6, 13.78±0.26, 16.64±0.26, and 10.40±0.88 kg respectively. *Bambusa vulgaris, Dendrocalamus membranaceus and Guadua amplexifolia* had 36.3±1.2, 15.84±0.35, 18.48±0.8, and 6.6±0.75 kg, 31.50±1.32, 15.54±0.3, 29.74±0.48, 8.4±0.06 kg, 2.24±0.14, 2.24±0.15, 2.03±0.16, 5.39± 0.67 of culms, branches, leaves and rhizomes in kg respectively.

Percentage Contribution of Biomass Components

With regard to contribution of different plant components to total shoot weight (total above ground biomass) the culm contributes maximum in the entire clumps (50.32, 47.02, 35.14, and 18.82) % for *Dendrocalamus hamiltonii, Bambusa vulgaris, Dendrocalamus membranaceus and Guadua*

amplexifolia respectively. The contributions of branch, leaf and rhizome biomass were 16.77, 20.25, 12.66 %, 20.15, 23.93, 8.54%, 22.14, 27.68, 15.02 % and 18.82, 17.06, 45.30% per clump for *Dendrocalamus hamiltonii, Bambusa vulgaris, Dendrocalamus membranaceus and Guadua amplexifolia* respectively. (Table 4 and Figure 3)

Discussion

Growth Study

The productivity of bamboo was assessed on the basis of the number of new culms produced annually. At a given site, the production of new culms depends mostly on the degree of congestion, the clump age, and the rainfall of the previous year (Shanmughavel, 1995). Among the four species, *Dendrocalamus hamiltonii* showed best performance with average DBH, height and basal area 3.44±0.213 cm, 10.58±0.47 m, 9.71±1.25 cm respectively. *Bambusa vulgaris* had the greatest number of culms per clump (66±5) and showed lower performances in diameter of culms and basal area. *Dendrocalamus membranaceus* performed well in average number of nodes per clump (19±0.63), while *Guadua amplexifolia* showed lower performance in culm number, culm height and number of nodes 7±1, 3.167±0.20, 13±0.60 respectively. But even though *Guadua amplexifolia* showed lower performance in our study however, it showed good performances in average basal area (6.59± 0.78 cm) as it was compared to *Dendrocalamus hamiltonii* of 13 years old (P. Shanmughavel and K. Francis, 2003) which is between 5 to 5.5 cm. Our result showed lower performance in DBH at breast height, compared to the finding of Bharat Rai and Bijay Kumar Mallik (2013) on a six year old *Melocanna baccifera* plantation with value of 7 cm on average. *Dendrocalamus hamiltonii* measured higher value on average height (10.58±0.47 m) as compared to the finding of Bharat Rai and Bijay Kumar Mallik (2013) of 8 ±4 m, see Figure 1 and Table 1.

The grand total biomass of the species was calculated on the basis of the average number of culms/clump multiplied by the average total biomass of sample culm according to which the grand total biomass for the species *Dendrocalamus hamiltonii, Bambusa vulgaris, Dendrocalamus membranaceus* and *Guadua amplexifolia* measured (82.16±0.94, 77.22±2.15, 75.18±1.95, 11.90±0.45 kg in clump base respectively). Among the four species *Dendrocalamus hamiltonii* showed higher number of total biomass accumulation which is 82.16±0.94 kg/clump to which culm, branch, leaf and rhizome parts contributed about 50.32%, 16.77%, 20.25%, 12.66% respectively. *Guadua amplexifolia* had the lowest total biomass accumulation on each components (11.90±0.45 kg/clump) to which culm, branch, leaf and rhizome parts contributed about 18.82%, 18.82%, 17.06%, 45.30% respectively. For all species except *Guadua amplexifolia* the biomass accumulation of culm contribution was highest and leaf biomass contribution the second highest. For the species *Guadua*

amplexifolia, rhizome biomass covers the higher percentage contribution for the total biomass accumulation (45.30%). *Dendrocalamus membranaceus* showed higher biomass accumulation on leaf biomass component (27.68 %) compared to the other species biomass contributions (Table 3, Table 4, Figure 2, Figure 3).

The grand total dry matter production of the species *Dendrocalamus hamiltonii, Bambusa vulgaris, Dendrocalamus membranaceus* and *Guadua amplexifolia* measured 82.16±0.94, 77.22±2.15, 75.18±1.95, 11.90±0.45 kg in clump base respectively, at the age of 4. Compared to other studies of biomass production, where the annual yield of air dry bamboo per hectare of 3-4 years plantation was found to be 6-7 t for *Bambusa vulgaris* (Chinte et al. 1965), 1 t for *Gigantochloa asper* (Chinte et al. 1965), 1954 to 2354 kg DM for *Dendrocalamus hamiltonii* clump at the age of 13 (P. Shanmughavel et al. 2003) and for six year old *Melocanna baccifera* plantation 1.95 ton to 3.63 ton (Bharat Rai et al. 2013) our results were higher, but they were lower than *Bambusa bambos* (Shanmughave et al. 1995) 297 ton, *Gigantochloa scortechinii* from Malaysia 71.9 t/ ha in natural stand and 36.67 t/ha in a 3 year old plantations (Othman 1992). Total biomass estimates of *Dendrocalamus hamiltonii, Bambusa vulgaris and Dendrocalamus membranaceus* measured 51.4 t/ha, 48.5 t/ha, 46.8 *t/ha,* respectively at their earlier stage, is also comparable to above ground biomass of mature stands of indigenous species *Arundinaria alpina* 51-99 t/ha (LUSO, 1997), 110 t/ha (Kassahun Embaye 2003), 99 t/ha (Yigardu Mulatu and Masresha Fetene 2012) and *Oxytenanthera abyssinica 20* t/ha (LUSO, 1997). Adaptability for all species was found to be 100%; pest and disease assessment does not show any problem so far.

The study and observation made showed clearly that *Dendrocalamus hamiltonii* is the fastest growing species of bamboo followed by *Dendrocalamus membranaceus*. The results indicated that *Dendrocalamus hamiltonii* and *Dendrocalamus membranaceus* are good potential bamboo species for cultivation in Ethiopia. These species could be scaled-up for various end uses human food (*D. hamiltonii*) and animals feed, for industrial purposes, for carbon sequestration (because of their high biomass), for soil and water conservation and recreation in Ethiopia, Jimma and similar agro-climatic zones. Field evaluations made with farmers and DA's and experts also showed that *Bambusa vulgaris is* a recommendable species for scaling-up. Strengthen research on utilization of these specie should required.

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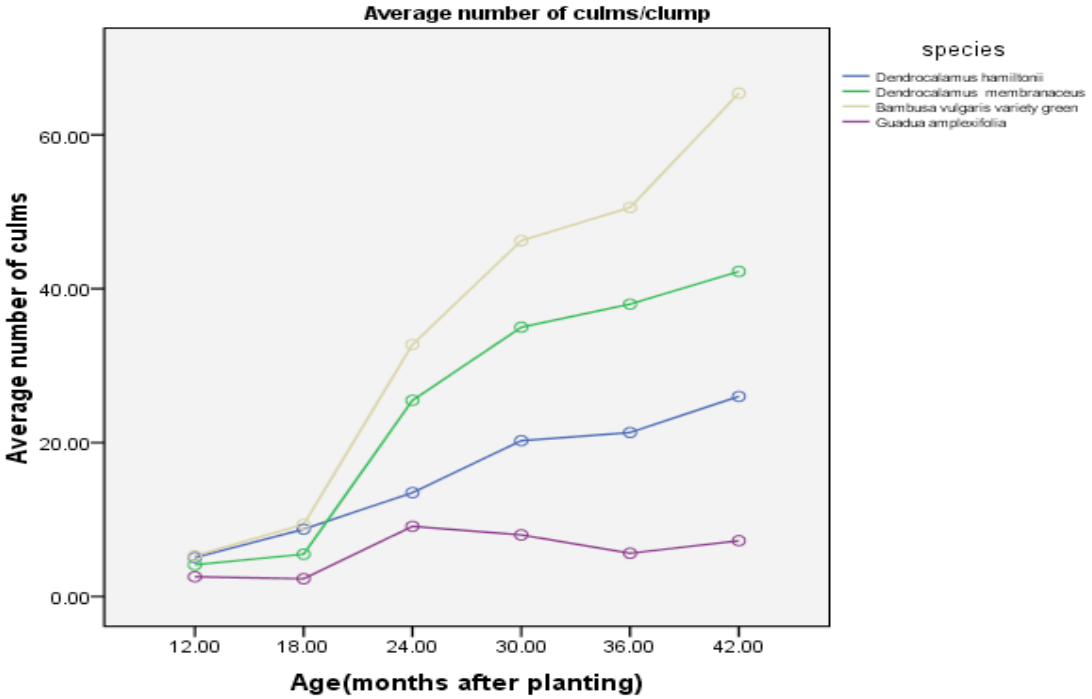

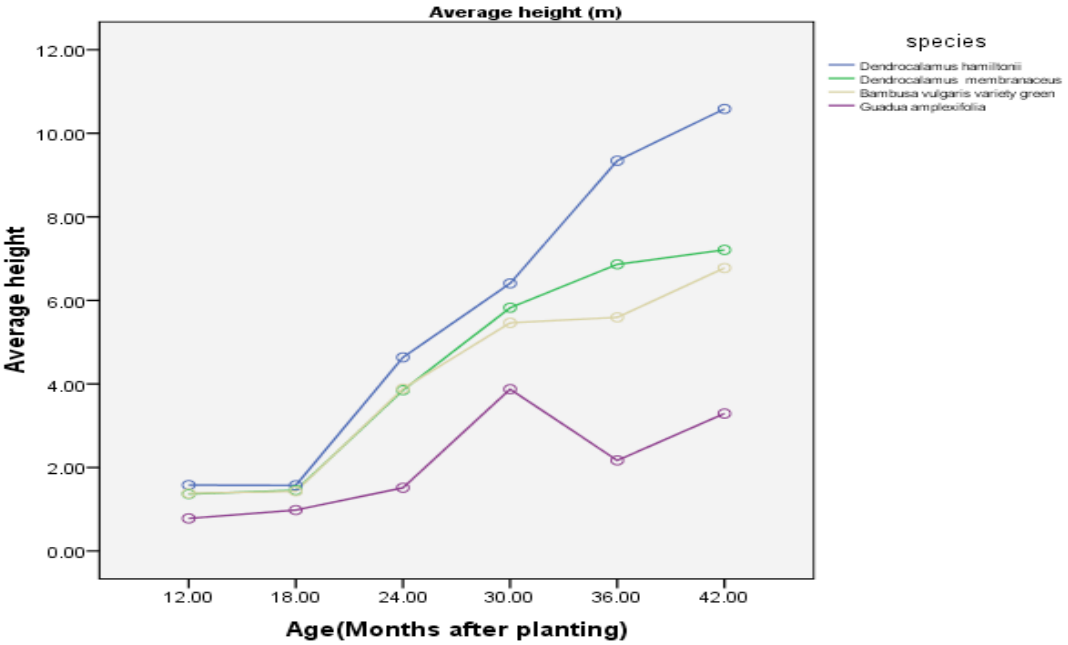

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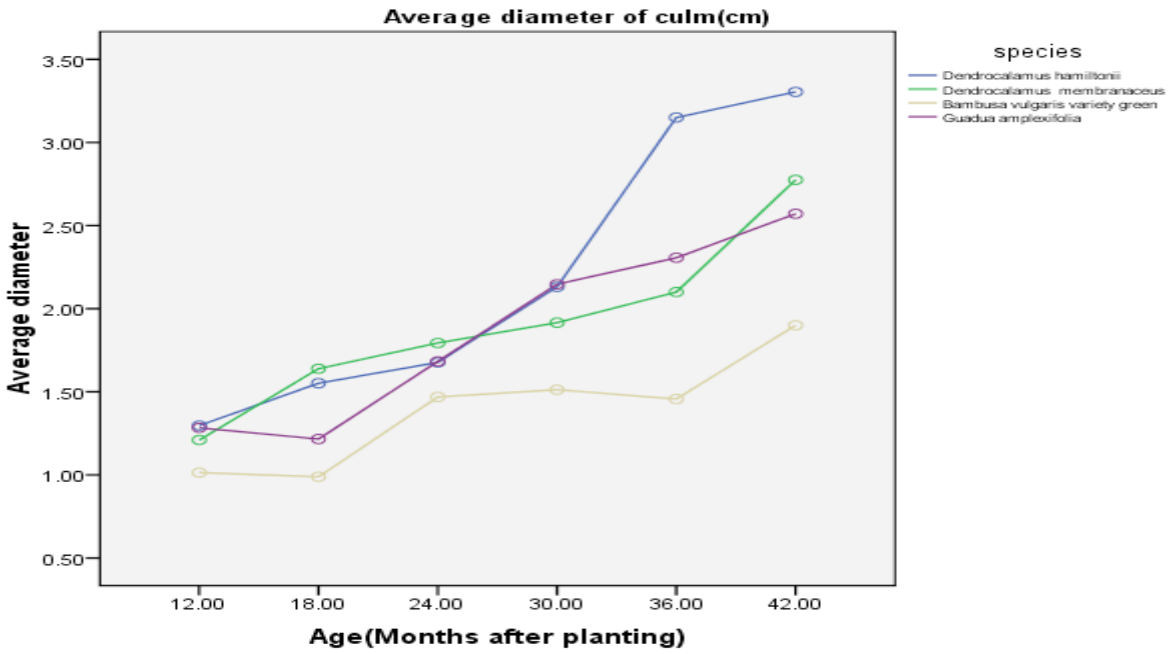

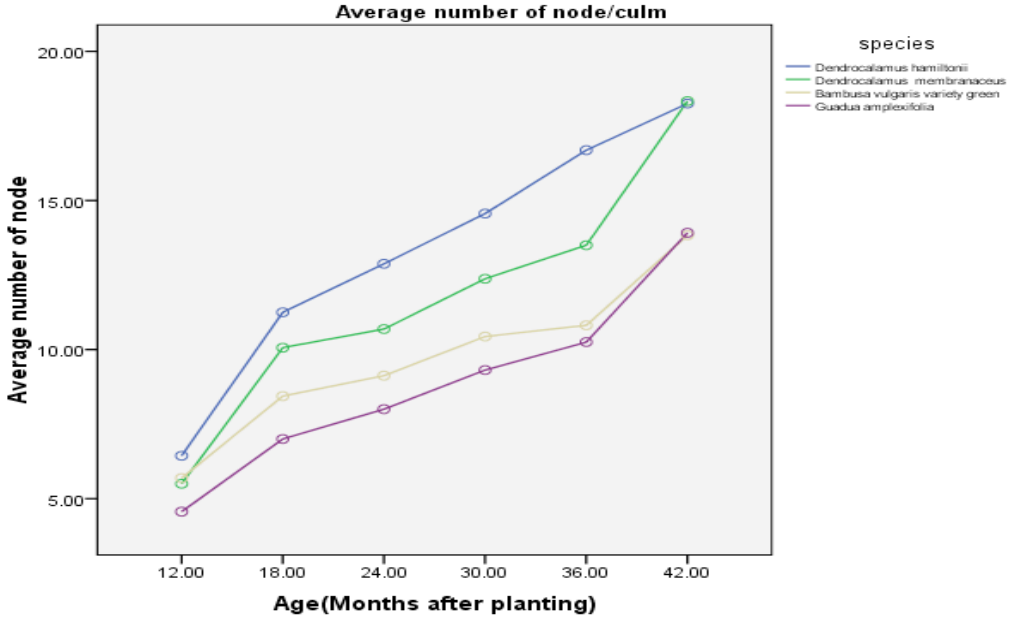

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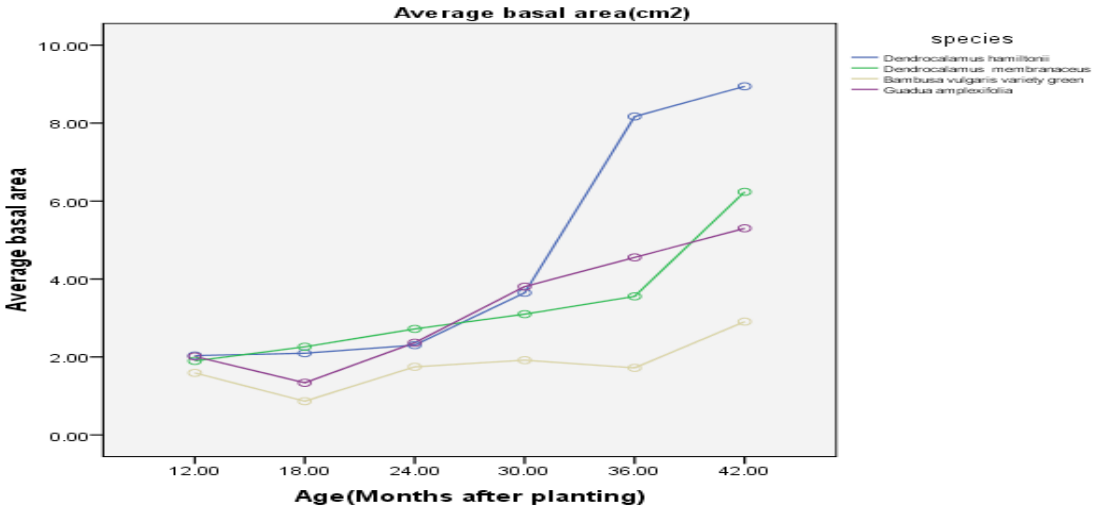

Figure 1. Growth and development of four introduced Commercial bamboos species at Jimma

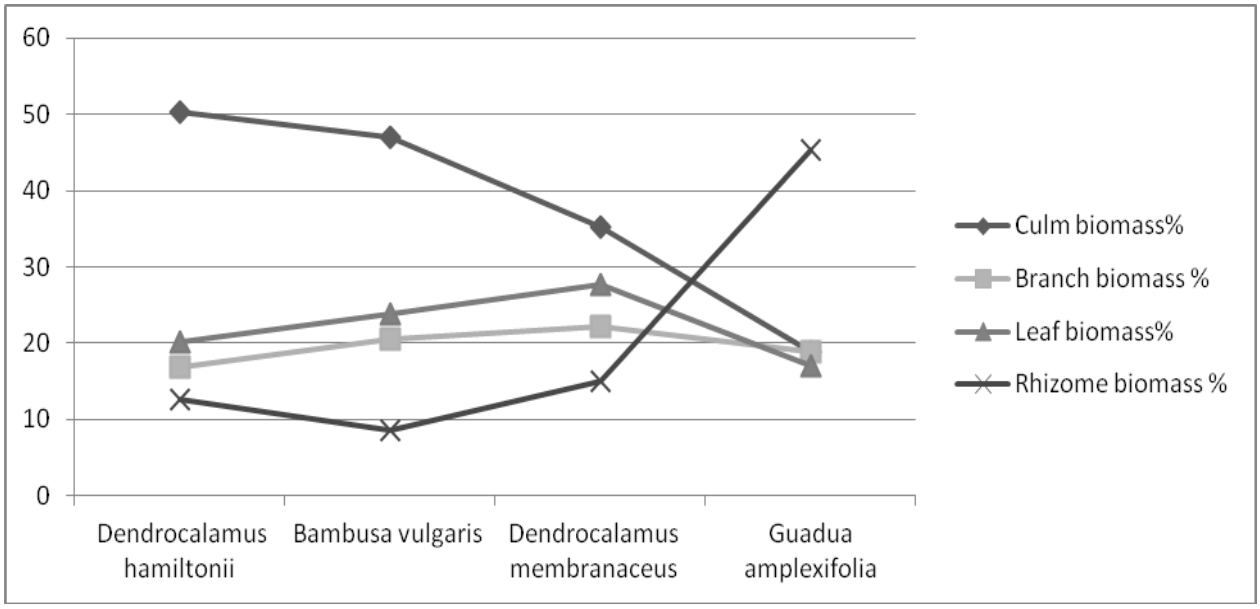

Figure 2. Percentage contributions of each component for individual species

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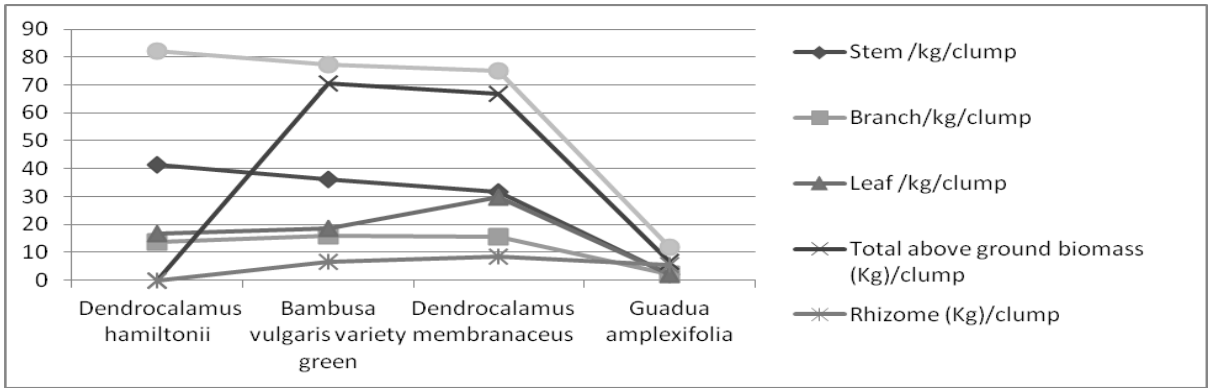

Figure 3 Collection of biomass in clump base

Table 1 Characteristics of *Dendrocalamus hamiltonii* ,*Bambusa vulgaris, Dendrocalamus membranaceus* and *Guadua amplexifolia*

Age in Year	Growth Characters	Species			
		Dendrocalamus hamiltonii	*Bambusa vulgaris*	*Dendrocalamus membranaceus*	*Guadua amplexifolia*
4	Average number of Culm /clump	26±2	66±5	42±3	7±1
	Average Height (m)/clump	10.58±0.47	6.77±0.264	7.208±0.304	3.167±0.20
	Average DBH(Cm)/clump	3.44±0.213	1.9±0.92	2.716±0.145	2.83±0.189
	Average BA(Cm)/clump	9.71±1.25	2.91± 0.26	5.97 ±0.60	6.59± 0.78
	Average No. of nodes /clump	18±0.89	14±0.61	19±0.63	13±0.60

Table 2 collection of biomass in culm base

Age (years)	Species name	Biomass (Kg/Clump)	Total above	Rhizome (Kg)/culm	Total grand

		Stem /kg/culm	Branch/kg/culm	Leaf /kg/culm	ground biomass (Kg)/culm		biomass (Kg)/culm
4	*Dendrocalamus hamiltonii*	1.59±0.30	0.53±0.13	0.64±0.13	2.76±0.52	0.40±0.44	3.16±0.47
	Bambusa vulgaris	0.55±0.24	0.24±0.07	0.28±0.16	1.07±0.42	0.10±0.15	1.17±0.43
	Dendrocalamus membranaceus	0.75±0.44	0.37±0.10	0.47±0.16	1.59±0.65	0.20±0.02	1.79±0.65
	Guadua amplexifolia	0.32±0.14	0.32±0.15	0.29±0.16	0.93±0.38	0.77±0.67	1.70±0.45

Table 3 Biomass allocations of *Dendrocalamus hamiltonii, Bambusa vulgaris variety green, Dendrocalamus membranaceus and Guadua amplexifolia* in clump base.

Age (years)	Species name	Biomass (Kg/Clump)			Total above ground biomass (Kg)/clump	Rhizome (Kg)/clump	Total grand biomass (Kg)/clump
		Stem /kg/clump	Branch/kg/clump	Leaf /kg/clump			
4	*Dendrocalamus hamiltonii*	41.34±0.6	13.78±0.26	16.64±0.26	71.76±1.12	10.40±0.88	82.16±0.94
	Bambusa vulgaris variety green	36.3±1.2	15.84±0.35	18.48±0.8	70.62±2.10	6.6±0.75	77.22±2.15
	Dendrocalamus membranaceus	31.50±1.32	15.54±0.3	29.74±0.48	66.78±1.95	8.4±0.06	75.18±1.95
	Guadua amplexifolia	2.24±0.14	2.24±0.15	2.03±0.16	6.51±0.38	5.39± 0.67	11.90±0.45

Table 4. Percentage contribution of each component for individual species

Species name	Culm biomass %	Branch biomass %	Leaf biomass%	Rhizome biomass %
Dendrocalamus hamiltonii	50.32	16.77	20.25	12.66
Bambusa vulgaris	47.02	20.51	23.93	8.54
Dendrocalamus membranaceus	35.14	22.14	27.68	15.02
Guadua amplexifolia	18.82	18.82	17.06	45.30