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Effect of different bamboo species on growth attributing characters grown on Entisol of semi-arid climate

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Abstract
A long-term field experiment initiated in the year 2018-19, was selected for conduct of present study in order to determine the effect of different bamboo species on growth attributing characters after 2nd year of bamboo plantation grown on Entisol of semi-arid climate during the year 2020-21. The treatment of *Bambusa tulda* recorded highest number of culms per clump (59.32), culm density (49413.56 culms ha^{-1}), number of new culms per clump (13.80) and clump girth (717.27 cm) over rest of tested bamboo species. Whereas, bamboo species *Dendrocalamus strictus* recorded highest culm height (6.39 m), basal diameter of culm (8.16 cm), Diameter at breast height (7.13 cm), culm girth at 5th internode (16.53 cm) and internodal length (27.51 cm) as compared to other bamboo species. The treatment of *Bambusa* bamboos recorded highest number of internodes per culm (28.34). From the present study it is clear that tested bamboo species showed significant variation in growth attributing characteristics among themselves after 2nd year of plantation grown on Entisol of semi-arid climate.

Keywords: bamboo, *Bambusa balcooa*, *bamboos*, *nutans*, *tulda*, basal diameter, culm density, culm height, culm girth at 5th internode, DBH, *Dendrocalamus asper*, *brandisii*, *strictus*, entisol, internodal length, semi-arid

1. Introduction
Bamboos are the fastest growing tall woody grass, taxonomically belongs to the family Poaceae of sub-family Bambusoideae. Bamboo often known as 'the grass of hope' (PIA, 2008) [10], is a miracle plant with over 1500 documented uses (Ranjan, 2001) [12]. This 'green gold' introduces itself as a prime and plentiful resource that can be used to meet a variety of livelihood needs while also providing numerous environmental benefits to rural communities and commonly known as "poor man's timber" (Ram *et al*., 2010) [11]. According to Bakshi (2010) [2], bamboos grow abundantly almost all over India, except in Kashmir Valley and harbouring about 136 species from 22 genera. Sungkaew *et al*. (2009) [15] has categorized Bambusoideae into three main lineages *viz*., Arundinarieae (temperate woody bamboos), Bambuseae (tropical woody bamboos) and Olyreae (herbaceous bamboos). Based on morphology, bamboo species are grouped as amphipodial, monopodial and sympodial (Maoyi and Banik, 1996) [8]. Bamboos with single stem (leptomorph) are also called as monopodial bamboo whereas those with densely clumped (pachymorph) are also known as sympodial bamboos. Furthermore, bamboo plays an important role in maintaining and improving the nutrient status of the soil (Kleinhenz *et al.* 2001) [6]. The species of bamboo has tremendous capacity to rapidly regenerate after disturbance and has been reported to grow well in degraded areas under conditions of impoverished soil nutrients and water stress (Tripathi and Singh, 1994) [16], as well as makes efficient use of the available nutrients and build up relatively fertile soil around the clumps (Singh and Singh, 1999) [13]. Bamboo due to its fast growth and extensive root system improves physical, chemical and biological properties of soil, controls soil erosion and is considered suitable for rehabilitation of degraded lands within a short span of time (Sujatha *et al*., 2008) [14].
Bamboos are blessed with a unique rhizome-dependent system, which is highly dependent on local soil and climate conditions. However it has been observed that there has been considerable variation in growth performance of different bamboo species when grown under different agroclimatic regions. Hence, it is essential to understand the impact of climatic parameters on growth of bamboo species so as to ensure that appropriate species are matched with site conditions.

In this context, the present study was conducted in order to determine the effect of different bamboo species on growth attributing characters grown on Entisol in a semi-arid climate after the 2nd year of bamboo plantation, which may eventually aid in the identification of suitable bamboo species for the region.

2. Material and Methods

2.1 Experimental site

A long term field experiment entitled, "Performance of different bamboo species on growth and yield of bamboo" was initiated in the year 2018-19 at National Agricultural Research Project, Dryland Sub-Centre (Agroforestry), M. P. K. V., Rahuri, Dist. Ahmednagar (M.S.). The same field experiment was selected for conduct of present study in order to determine the effect of different bamboo species on growth attributing characters after 2nd year of bamboo plantation grown on Entisol of semi-arid climate during the year 2020-21. The geographical location of experimental site is N 19º 31′ 996″ to N 19º 32′ 073″ latitude and E 74º 63′ 920″ to E 74º 64′ 042″ longitude, at the altitude of 608.4 to 616.1 meter above mean sea level. Agro-climatically the experimental site belongs to scarcity zone of Western Maharashtra, comes under hot semi-arid region with dry summer and mild winter at an average annual rainfall less than 750 mm. Out of the total annual precipitation about 70% is received during June to September (South-West monsoon), while the remaining precipitation is received in the months of October and November (North-East monsoon). During crop growth period of different bamboo species for the year 2020-21, it was observed that the average maximum and minimum temperature ranged between 27.0 to 38.5°C and 13.0 to 25.7°C, respectively. The total rainfall received was 1345.8 mm in 66 rainy days (15 months). The average morning and evening relative humidity ranged between 61.1 to 91.1% and 19.3 to 66.5%, respectively. The average wind speed ranged between 0.74 - 4.37 km hr^{-1}. The average bright sunshine hours and open pan evaporation ranged between 3.2 to 10.1 hrs. and 3.0 to 13.4 mm, respectively.

2.2 Soil of experimental site

The soil of experimental site is grouped under Entisol order and belongs to Rahuri soil series. The experimental soil had a sandy clay texture, was slightly alkaline in reaction (pH 8.01), had low EC (0.21 dSm^{-1}) and $CaCO_3$ content (3.37%), was medium in organic carbon (6.70 g kg^{-1}), low in available nitrogen (178.70 kg ha^{-1}), very low in available phosphorus (6.10 kg ha^{-1}) and very high in available potassium (403.20 kg ha^{-1}) content. The average depth of experimental soil is upto 45 cm.

2.3 Experimental setup

The field experiment was laid out in Randomized Block Design comprising 3 replications and 7 treatments of different bamboo species *viz.*, T_1: *Dendrocalamus brandisii*, T_2: *Bambusa nutans*, T_3: *Bambusa balcooa*, T_4: *Dendrocalamus strictus*, T_5: *Bambusa tulda*, T_6: *Bambusa bamboos*, T_7: *Dendrocalamus asper*. Bamboo seedlings of uniform size and age were planted during October, 2018 in the pits of 45 cm × 45 cm × 45 cm. The gross plot size for the field experiment was 20 m × 15 m, and the net plot size was 12 m x 09 m. The optimum spacing adopted was 4 m x 3 m so as to accommodate 833 clumps per ha. The recommended dose of chemical fertilizers, 160:40:200 kg N, P_2O_5 and K_2O ha^{-1} $year^{-1}$ was applied as split dose through commercial grade urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Well decomposed farm yard manure was added @ 25 kg $clump^{-1}$ (*i.e.* 20.8 t FYM ha^{-1} yr^{-1}) as a source of organic manure. Irrigation to bamboo plantation was given at regular intervals as required.

2.4 Biometric observation

Five representative clumps of each bamboo species were randomly selected and identified with the help of colour paint marking as suggested by Shanmughavel and Francis (2003) [5]. The biometric observations for growth attributing characters were recorded on marked clumps for different bamboo species.

2.4.1 Number of culms per clump

The number of culms per clump was determined species-wise by counting all culms of a randomly selected and marked clump.

2.4.2 Culm density

Culm density was computed by multiplying average number of culm per clump with 833 (*i.e.* number of clumps per hectare) and expressed as culm ha^{-1}.

2.4.3 Number of new culms per clump

Culms from the 1st and 2nd year were marked with different colour. The number of new culms per clump was determined by counting culms produced after 2nd year.

2.4.4 Culm height

The culm height of five representative culms was measured species-wise by using a standard measuring tape and expressed in meters.

2.4.5 Basal Diameter of culm

Diameter of the culm at the base of the culm below the first internode was measured in cm using Vernier callipers.

2.4.6 Diameter at breast height

Diameter at the 5th internode from the base of culm was measured in cm using Vernier callipers.

2.4.7 Culm girth at 5th internode

Culm girth at 5th internode was measured in cm using standard measuring tape.

2.4.8 Clump girth

A standard measuring tape was used to measure clump girth in both north-south and east-west directions. The clump girth in cm was calculated by averaging this data.

2.4.9 Internode length

The length of internode at the 5th internode from culm base was measured using a standard measuring tape and recorded in cm.

2.4.10 Number of internodes per culm

The number of internodes per culm was estimated by counting all internode of culm from the base to the tip of representative culms.

2.5 Statistical Analysis
The experimental data generated from present study were analysed statistically by applying the technique of "Analysis of variance" i.e. ANOVA table as described by Panse and Sukhatme (1985) [9].

3. Results and Discussion

3.1 Effect of different bamboo species on growth attributing characters

After the 2nd year of plantation grown on Entisol in a semi-arid climate, the tested bamboo species showed significant variation in growth attributing characters among themselves (Table 1 and Fig. 1-5).

3.1.1 Number of culms per clump

Table 1 and Fig. 2 depicts that, *Bambusa tulda* recorded highest number of culms per clump (59.32) followed by *Bambusa nutans* (44.68) and *Dendrocalamus brandisii* (36.20). Whereas, *Bambusa bamboos* recorded lowest number of culms per clump (10.48) followed by *Bambusa balcooa* (13.72) and *Dendrocalamus strictus* (15.24) on Entisol. Similar findings were also reported by Venkatesh *et al.* (2005) [17].

3.1.2 Culm density (culms ha^{-1})

Perusal of Table 1 and Fig. 3, it was observed that, *Bambusa tulda* recorded highest culm density (49413.56 culms ha^{-1}), followed by *Bambusa nutans* (37218.14 culms ha^{-1}). While, lowest culm density (8729.34 culms ha^{-1}) was found in *Bambusa bamboos* (Kumar *et al.*, 2005) [4] followed by *Bambusa balcooa* (11428.76 culms ha^{-1}) and *Dendrocalamus strictus* (12694.92 culms ha^{-1}) on Entisol in a semi-arid climate.

3.1.3 Number of new culms per clump

Table 1 and Fig. 2 depicts that on Entisol under semi-arid climate, *Bambusa tulda* recorded highest number of new culms per clump (13.80), which was statistically at par with *Bambusa nutans* (12.93) and *Dendrocalamus brandisii* (11.80). Whereas, *Bambusa bamboos* recorded lowest numbers of culms per clump (5.33) closely followed by *Bambusa balcooa* (5.67) and *Dendrocalamus strictus* (5.80).

3.1.4 Culm height (m)

Culm height is primarily governed by the genetic makeup of the species, but it is also influenced by row spacing, prevailing climatic conditions and management practises. Perusal of Table 1 and Fig. 4, it was observed that the treatment, *Dendrocalamus strictus* recorded numerically highest culm height (6.39 m), which was found statistically at par with *Bambusa balcooa* (6.33 m), *Bambusa nutans* (6.05 m) and *Bambusa bamboos* (5.97 m). While, lowest culm height was recorded in *Dendrocalamus asper* (3.82 m) closely followed by *Dendrocalamus brandisii* (3.93 m) on Entisol in a semi-arid climate.

3.1.5 Basal diameter of culm

After 2nd year of plantation as depicted in Table 1 and Fig. 1, the treatment *Dendrocalamus strictus* recorded highest basal diameter of culm (8.16 cm), which was statistically at par with *Bambusa bamboos* (7.19 cm) and *Bambusa balcooa* (7.01 cm). While, lowest basal diameter of culm (2.96 cm) was observed in *Bambusa tulda* followed by *Dendrocalamus brandisii* (3.14 cm) and *Dendrocalamus asper* (3.92 cm) on Entisol in a semi-arid climate. The results are in line with the findings of Shanmughavel and Francis (2003) [5].

3.1.6 Diameter at breast height (DBH)

Perusal of Table 1 and Fig. 1, it was observed that *Dendrocalamus strictus* recorded highest diameter at breast height (7.13 cm), which was statistically at par with *Bambusa bamboos* (6.38 cm) and *Bambusa balcooa* (6.35 cm) (Venkatesh *et al.*, 2005) [17]. While, lowest DBH (2.51 cm) was recorded in *Bambusa tulda* followed by *Dendrocalamus brandisii* (2.98 cm), *Dendrocalamus asper* (3.38 cm) and *Bambusa nutans* (3.49 cm). Similar findings were also reported by Shanmughavel and Francis (2003) [5] and Kim *et al.* (2018) [3].

3.1.7 Culm girth at 5th internode (cm)

Table 1 and Fig. 1 depicts that on Entisol under semi-arid climate, *Dendrocalamus strictus* recorded highest culm girth at 5th internode (16.53 cm), which was statistically at par with *Bambusa bamboos* (15.99 cm) and *Bambusa balcooa* (14.73 cm). Whereas, *Dendrocalamus brandisii* recorded lowest culm girth at 5th internode (6.59 cm), closely followed by *Bambusa tulda* (7.00 cm), *Dendrocalamus asper* (7.87 cm) and *Bambusa nutans* (8.34 cm). The results are in corroborative with the findings of Angom *et al.* (2018) [9].

3.1.8 Clump girth (cm)

After 2nd year of plantation as depicted in Table 1 and Fig. 5, the treatment *Bambusa tulda* recorded highest clump girth (717.27 cm), which was found statistically at par with *Bambusa nutans* (682.07 cm) and *Dendrocalamus strictus* (638.33 cm). Whereas, *Bambusa balcooa* recorded lowest clump girth (478.47 cm) followed by *Dendrocalamus brandisii* (530.93 cm) and *Dendrocalamus asper* (539.73 cm), on Entisol.

3.1.9 Internodal length (cm)

Perusal of Table 1 and Fig. 1, it was observed that the treatment, *Dendrocalamus* strictus recorded highest internodal length (27.51 cm), which was statistically at par with *Bambusa* balcooa (25.31 cm) and *Bambusa* nutans (23.03 cm). While, lowest internodal length (16.64 cm) was recorded in *Dendrocalamus* asper followed by *Dendrocalamus* brandisii (17.19 cm) and *Bambusa* tulda (17.94 cm), after 2nd year on Entisol under semi-arid climatic condition. The results are in line with the findings of Kumari *et al.* (2017) [7].

3.1.10 Number of internodes per culm

After 2nd year of plantation as depicted in Table 1 and Fig. 2, the treatment, *Bambusa bamboos* (28.34) recorded highest number of internodes per culm (28.34), which was statistically at par with *Bambusa nutans* (26.27) and *Bambusa tulda* (26.03). Whereas, *Dendrocalamus brandisii* recorded lowest number of internodes per culm (22.86) closely followed by *Dendrocalamus* asper (22.95) and *Dendrocalamus* strictus (23.22), on Entisol under semi-arid climate. The results are in line with the findings of Venkatesh *et al.* (2005) [17] and Shanmughavel and Francis (2003) [5].

Table 1: Effect of different bamboo species on growth attributing characters after 2nd year of plantation grown on Entisol of semi-arid climate

Tr. No.	Treatment	Growth attributing characters									
		Number of culms per clump	Culm density (culm ha^{-1})	Number of new culms per clump	Culm height (m)	Basal diameter of culm (cm)	Diameter at breast height (DBH) (cm)	Culm girth at 5th internode (cm)	Clump girth (cm)	Inter-nodal length (cm)	Number of Inter-nodes per culm
T_1	*Dendrocalamus brandisii*	36.20	30154.60	11.80	3.93	3.14	2.98	6.59	530.93	17.19	22.86
T_2	*Bambusa nutans*	44.68	37218.44	12.93	6.05	4.03	3.49	8.34	682.07	23.03	26.27
T_3	*Bambusa balcooa*	13.72	11428.76	5.67	6.33	7.01	6.35	14.73	478.47	25.31	25.00
T_4	*Dendrocalamus strictus*	15.24	12694.92	5.80	6.39	8.16	7.13	16.53	638.33	27.51	23.22
T_5	*Bambusa tulda*	59.32	49413.56	13.80	4.67	2.96	2.51	7.00	717.27	17.94	26.03
T_6	*Bambusa bamboos*	10.48	8729.84	5.33	5.97	7.19	6.38	15.99	576.80	21.06	28.34
T_7	*Dendrocalamus asper*	19.68	16393.44	9.27	3.82	3.92	3.38	7.87	539.73	16.64	22.95
	General mean	28.47	23719.08	9.23	5.31	5.20	4.60	11.01	594.8	21.24	24.95
	SEm ±	1.98	820.40	0.58	0.18	0.47	0.44	0.62	34.20	1.23	1.31
	CD at 5%	5.99	2468.00	1.80	0.60	1.46	1.35	1.93	105.38	3.73	3.98

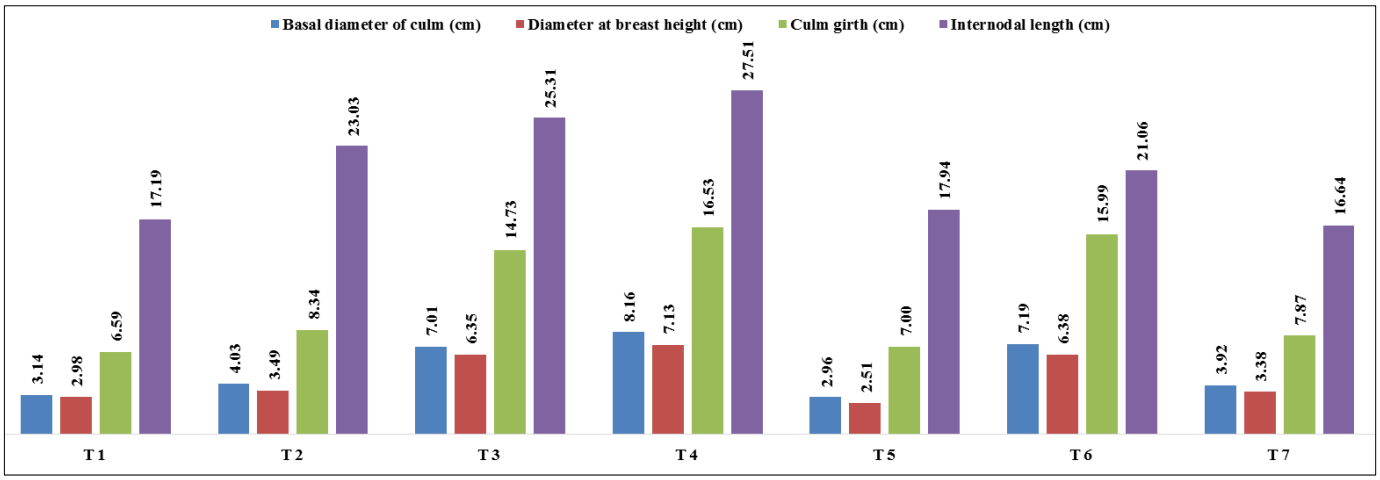

Fig 1: Effect of different bamboo species on basal diameter, diameter at breast height, culm girth and internodal length

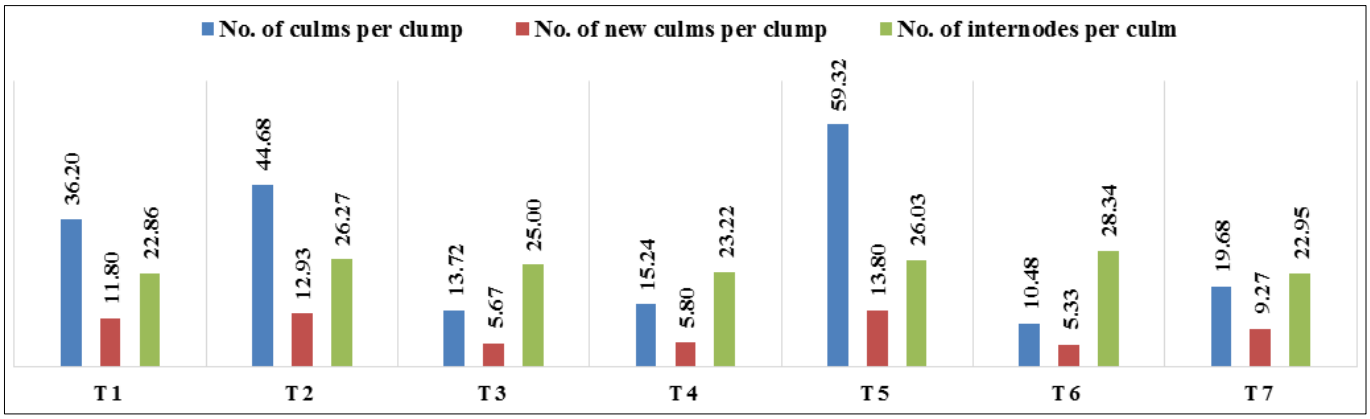

Fig 2: Effect of different bamboo species on no. of culms per clump, no. of new culms per clump and no. of internodes per culm

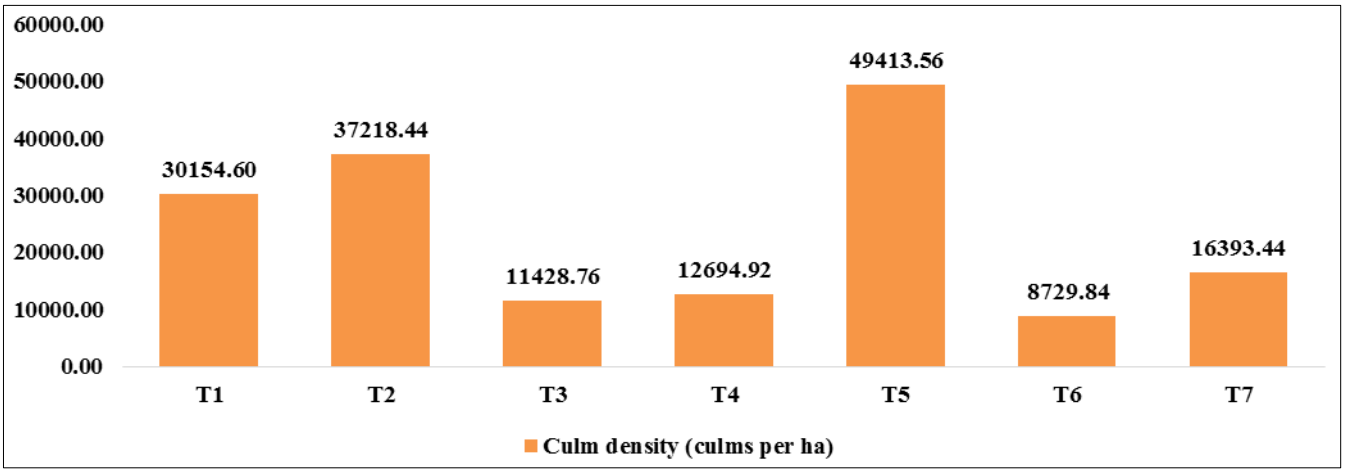

Fig 3: Effect of different bamboo species on culm density (culm ha^{-1})

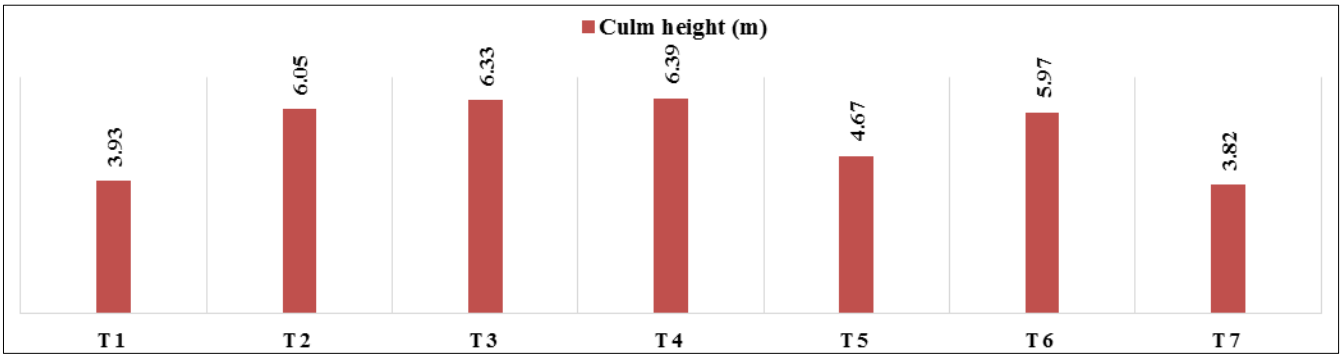

Fig 4: Effect of different bamboo species on culm height (m)

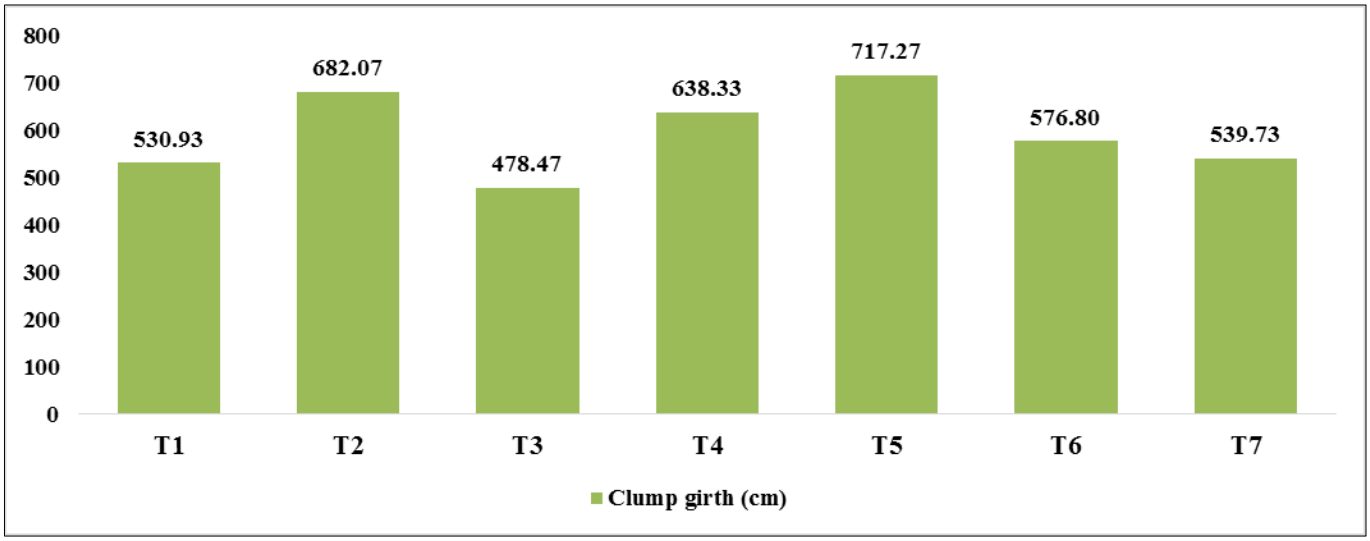

Fig 5: Effect of different bamboo species on clump girth (cm)

4. Conclusion

In the present study, *Bambusa tulda* showed its dominance over other tested bamboo species in terms of number of culms per clump (59.32), culm density (49413.56 culms ha^{-1}), number of new culms per clump (13.80) and clump girth (712.27 cm). *Dendrocalamus strictus*, on the other hand, displayed its supremacy over other bamboo species in respect to culm height (6.39 m), basal diameter of culm (8.16 cm), DBH (7.13 cm), culm girth at 5th internode (16.53 cm) and internodal length (27.51 cm). While, *Bambusa bamboos* showed its superiority over other in case of number of internodes per culm (28.34) after 2nd year of bamboo plantation grown on Entisol of semi-arid climate. Growth and developmental characteristics of individual bamboo species are greatly influenced by their genetic makeup, prevailing climatic conditions, genotype and environmental interactions. As well as above ground bamboo biomass and dry matter accumulation increases significantly concomitant with diameter at breast height (DBH) and culm height which in turn contributes its major portion towards the total bamboo biomass.

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