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Evaluation of Growth, Morphology, Biomass Production of Commercial Bamboo Species under Rainfed Condition on Agricultural Wastelands

V. M. Ilorkar* and P. D. Raut

AICRP on Agroforestry, Agroforestry Farm, PDKV- College of Agriculture Nagpur, India

**Corresponding author*

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A B S T R A C T

Investigations on growth, morphology, biomass production of ten commercially important bamboo species was undertaken under rainfed conditions on agricultural wastelands. The study showed that at the end of 6th year maximum total biomass (ton/ha) was produced by *Bamboosa bambose* (261.89) followed by *Bamboosa balcoa* (224.40) followed by *Dendrocal musstocksii* (171.38) followed *Bamboosa tulda* (161.96). The lowest biomass production was estimated in *Bamboosa multiplex* (70.62) .Growth characters culm height, emergence of new culms, total number of culms showed significant variation with respect to different bamboo species. A first harvesting (50% removal of culms) was carried out at 6th year. In this first harvesting the maximum biomass yield (ton/ha) was recorded by *Bamboosa bambose* (42.37) followed by *Bamboo sabalcoa* (41.80) followed by *Dendrocal musstocksii* (35.09) followed *Bamboo satulda* (28.61). The lowest biomass yield was estimated in *Bamboosa multiplex* (11.77). The Cost of cultivation and monetary returns were worked out. A more than two benefit-cost ratio was worked out for *Bamboosa balcoa* (2.44) followed by *Dendrocal musstocksii* (2.39) and *Bamboosa bambose* (2.25) .Suggested these three species for commercial plantation in this region.

Introduction

Present demand for bamboo is estimated to 26.9 million ton as against the supply of 13.47 million tonne. Demand is drastically increasing due to industrial revolution like pulp for paper and rayon, laminated bamboo, parquet flooring, ply bamboo, bamboo composites, and charcoal coupled with mechanization of traditional sector like shoot processing, chopsticks, agarbatti, toothpick production and bamboo handicrafts. According to estimates, bamboo-based activities could easily generate 8.6 million additional jobs in India and thus enable 5.01 million families to cross the poverty line. Therefore, there is good scope of bamboo based agroforestry systems in the country (Patil, *et. al*. 1994) and (Patel *et al*., 2019).

Section of appropriate combination of suitable bamboo species, silvicultural practices and water conservation technique can however increase the productivity of bamboo to meet out the challenges of growing demand (Ilorkar, 2016) and (Kumari Reena, 2018).

Materials and Methods

A field experiment was conducted at AICRP on Agroforestry, PDKV, College of Agriculture, Nagpur. Thirteen different bamboo species were collected from State Forest Department, Tropical Forest Research Institute, Jabalpur, Forest Research Institute, Dehradun in the year (2013-14). The collected bamboo species were planted in field at 3 x 3mt spacing in a randomized block design. Six plants per replication were maintained and three plants across the diagonal were taken for observation. The plantation raised on shallow to medium deep (40cm), clay loam soil. Soil fertility ranges from medium to low. The mean annual rainfall at Nagpur is 1140 mm. The maximum temperature is recorded during summer 47 ^{0}C. Winter is dry and cool.

Standard agronomic practices recommended by National Bamboo Mission (BTSG-KFRI, 2015) were followed for bamboo cultivation and maintenance. Observations on growth, morphology, biomass productivity were recorded in the month of March. Data were analyzed statistically. Biomass Productivity estimated, cost of production, monetary return and Benefit Cost ratio was calculated from the data. The selling price of bamboo was assumed Rs. 5000/ton.(BILT, 2019) Presented in following tables (1 to 4).

Results and Discussion

Observations on growth characters Culm Height (cm), Number of New culm /clump/year, Total Number of culm /clump/year are given in table 1.

Culm height (cm): The culm height for three successive years was measured (2018, 2019 & 2020). Pooled mean was worked out. The culm height varied from 114.33 to 506.67. The highest culm height 506.67 was recorded for bamboo species *Bamboosa bambose*. Height variations' were found significant.

Number of new culm /clump/year: The number of new culm produced for three successive years was measured (2018, 2019 & 2020). Pooled mean was worked out. The new culms varied from 2.00 to 13.67. The highest number of new culm 13.67 was recorded for bamboo species *B. multiplex.* Variations' were found significant.

Total number of culm /clump/year: The number of new culm produced for three successive years was measured (2018, 2019 & 2020). Pooled mean was worked out. The total culm varied from 6.00 to 80. 00. The highest number of total culm80. 00 were recorded for bamboo species *B. multiplex.* Variations' were found significant. Observations on Morphological Characters number of branches, Culm diameter, Wall thickness, number of internodes, inter nodal distance are given in table 2.

Number of branches/culm: The number of branches produced for three successive years were recorded. The total number of branches produced varied from 26.00 to 91.00. The highest number of branches 91. 00 were produced for bamboo species *Bamboosa bambose.*

Culm diameter at Base (mm): The Culm diameter leading culm at the base of the culm was recorded. The Culm diameter varied from 12.00 to 40.27. The highest Culm diameters 40.27was recorded for bamboo species *Bamboosa bambose.*

Wall thickness at base (mm): The Wall thickness at Base of the culm was recorded. The Wall thickness of culm varied from 0.80 to 15.95. The highest Wall thickness 15.95was recorded for bamboo species *Bamboosa bambose.*

Table.1 Growth characteristics of different bamboo species planted on waste land under rainfed condition

S.N.	BAMBOO SPECIES	CULM HEIGHT CM				NO. OF NEW CULMS /CLUMP /YEAR				TOTAL NO. OF CULMS /CLUMP/YEAR			
		2018	2019	2020	Poled mean	2018	2019	2020	Pooled Mean	2018	2019	2020	Pooled mean
T1	*Dendrocalmus strictus (control)*	310	320	542	**390.67**	2	2	2	**2.00**	4	6	8	**6.00**
T2	*Bamboosa vulgaris*	300	310	523	**377.67**	3	3	4	**3.33**	7	9	10	**8.67**
T3	*Bamboosa bambose*	380	490	650	**506.67**	6	7	2	**5.00**	16	20	24	**20.00**
T4	*Dendrocalmus asper*	225	235	572	**344.00**	4	2	3	**3.00**	9	11	14	**11.33**
T5	*Bamboosa multiplex*	90	105	148	**114.33**	20	7	14	**13.67**	50	83	107	**80.00**
T6	*Dendrocal musstocksii*	354	385	623	**454.00**	5	8	4	**5.67**	12	18	20	**16.33**
T7	*Bamboosa tulda*	275	285	693	**417.67**	4	5	2	**3.67**	8	12	18	**12.67**
T8	*Bamboosa nutans*	285	295	555	**378.33**	3	4	3	**3.33**	7	9	10	**8.67**
T9	*Bamboosa balcooa*	280	291	650	**407.00**	4	3	3	**3.33**	8	12	20	**13.33**
T10	*Bamboosa brandice*	310	320	542	**390.67**	4	2	2	**2.00**	7	10	12	**6.00**
	F Test	**SIG**	**SIG**	**Sig**	**Sig**	**Sig**	**SIG**	**Sig**	**Sig**	**SIG**	**SIG**	**Sig**	**Sig**
	SE ±	55.10	55.10	68.08	59.43	0.67	0.81	1.20	0.89	2.10	2.10	6.07	**3.42**
	Cd @ 5%	**152.54**	**152.54**	**204**	**182.97**	**1.81**	**2.26**	**3.61**	**2.26**	**7.09**	**7.09**	**18.20**	**10.17**

Table.2 Morphological characters of bamboo spp. on waste land under rainfed condition

Sr.No.	Name of *Bamboo* spp.	Culm Height cm	No. Branches	Base Dia mm	Dia 5ft. mm	Dia 10 ft mm	Dia 15ft. mm	Wall Thickness mm	No. of Internodes	Inter nodal dist. cm
T1	*Dendrocalmus strictus (control)*	542	84.00	37.39	28.95	21.75	13.44	13.00	23	21.32
T2	*Bamboosa vulgaris*	523	57.00	39.10	34.61	27.13	15.02	12.12	23	38 .21
T3	*Bamboosa bambose*	650	91.00	40.27	35.23	30.32	25.30	15.95	27	27.32
T4	*Dendrocalmus asper*	572	63.00	33.20	28.84	20.72	10.54	12.58	21	30 .42
T5	*Bamboosa multiplex*	148	26.00	12.00	9.60	9.62	6.54	0.80	7.0	8.98
T6	*Dendrocal musstocksii*	623	84.00	38.34	27.07	19.62	15.14	16.00	28	29 .87
T7	*Bamboosa tulda*	693	69.00	40.37	33.20	22.14	10.00	12.81	23	30 .32
T8	*Bamboosa nutans*	555	63.00	30.86	25.49	14.61	11.11	11.72	20	31 .67
T9	*Bamboosa balcooa*	650	66.00	37.49	28.94	21.24	12.90	14.38	20	30.32
T10	*Bamboosa brandice*	542	81.00	38.12	32.27	29.63	13.71	15.18	24	27.34

Table.3 Biomass production, yield /ha of different bamboo species on waste land under rainfed condition

Sr. No.	Name of Bamboo Sp.	No. of culm/ clump	Biomass kg /culm					Biomass		Biomass Yield tonn /ha
			Stem	Branch + leaves	Rhizome	Root	Total	Kg /clump	Tons /hectare	
T1	***Dendrocalmus strictus(control)***	**8**	**2.80**	1.41	2.1	0.70	**7.01**	56.08	**61.69**	**12.32**
T2	***Bamboosa vulgaris***	**10**	**3.12**	4.1	2.34	0.78	**10.34**	103.40	**113.74**	**17.16**
T3	***Bamboosa bambose***	**24**	**3.21**	3.5	2.40	0.80	**9.92**	238.08	**261.89**	**42.37**
T4	***Dendrocalmus asper***	**14**	**2.47**	1.85	1.85	0.61	**6.79**	95.06	**104.57**	**19.02**
T5	***Bamboosa multiplex***	**107**	**0.20**	0.2	0.15	0.05	**0.60**	64.20	**70.62**	**11.77**
T6	***Dendrocal musstocksii***	**20**	**3.19**	1.41	2.39	0.79	**7.79**	155.80	**171.38**	**35.09**
T7	***Bamboosa tulda***	**18**	**2.89**	2.4	2.16	0.72	**8.18**	147.24	**161.96**	**28.61**
T8	***Bamboosa nutans***	**10**	**2.21**	2.5	1.65	0.55	**6.92**	69.20	**76.12**	**12.16**
T9	***Bamboosa balcooa***	**20**	**3.38**	2.6	2.85	0.95	**10.20**	204.00	**224.40**	**41.80**
T10	***Bamboosa brandice***	**20**	**2.62**	1.26	1.96	0.65	**6.50**	78.00	**85.80**	**17.29**

Table.4 Biomass yield, gross monetary return, cost and B/C ratio of bamboo production on waste land under rainfed condition

Sr. No.	Name of Bamboo spp.	Biomass. Yield tons/ha	Gross Monetary Return Rs/ha	Net Monetary Return Rs/ha	Establishment Cost Rs/ha	Maintance 1 To 5yrs. Rs/ha	Harvesting Cost Rs/ ha	Cost of Production Rs /ha.	B/C Ratio
T1	*D. strictus*	**12.32**	61600	14940	33000	7500	6160	46660	**1.32**
T2	*B. vulgaris*	**17.16**	85800	23220	44000	10000	8580	62580	**1.37**
T3	*Bamboosa bambose*	42.37	211860	117632	33000	12500	48727	94228	**2.25**
T4	*D. asper*	**19.02**	95095	40085	33000	12500	9509	55010	**1.73**
T5	*B. multiplex*	**11.77**	23540	-16814	33000	5000	2354	40354	**0.58**
T6	*D. stocksii*	**35.09**	178959	103932	49500	15000	10527	75027	**2.39**
T7	*B. tulda*	**28.61**	143055	66166	44000	10000	22888	76889	**1.86**
T8	*B. nutan*	**12.16**	60775	-2949	44000	10000	9724	63724	**0.95**
T9	*B. balcooa*	**41.80**	213180	125640	55000	20000	12540	87540	**2.44**
T10	*B. brandicee*	**17.29**	86460	26168	33000	10000	17292	60292	**1.43**

Number of internodes: The number of internodes per culm was recorded. The number of internodes per culm varied from 7.00 to 28.00 The highest number of internodes per culm 28.00were recorded for bamboo species *Dendrocal musstocksii.*

Inter nodal distance (cm): The inter nodal distance per culm were recorded. The intermodal distance per culm varied from 8.98 to 38.21 the largest inter nodal distance in culm 38.21 were recorded for bamboo species *Bamboosa vulgarise.* Observations on Biomass Productivity –biomass of stem, branch + leaves, root, rhizome, total biomass/clump , biomass /ha and biomass yield /ha are given in table 3.

Stem biomass (Kg): The stem biomass per culm were recorded. The stem biomass per culm varied from 0.20 to 3.38 The highest stem biomass per culm 3.38 were recorded for bamboo species *Bamboosa balcooa followed by Bamboosa bambose 3.21 and Dendrocal musstocksii 3.19.*

Total biomass/clump (Kg): Total biomass/clump were recorded. The Total biomass/clump varied from 64.20 to 238.08. The highest total biomass/clump 238.08 was recorded for bamboo species *Bamboosa bamboose followed by Bamboosabalcooa 204.00 and Dendrocal musstocksii 155.80.*

Biomass tonn/ha: Total biomass/ha were recorded. The biomass/ha varied from 70.62 to 261.89. The highest total biomass/ha 261.89 was recorded for bamboo species *Bamboosa bamboose 261.89 followed by Bamboosa balcooa 224.40 and Dendrocal musstocksii 171.38.*

Culm biomass yield tonn/ha: For maintaining the sustainability of bamboo plantations the fifty percent harvestable biomass yield is allowed as per silvicultural rules (Tewari, 1994). The biomass yield tons /ha were recorded.

The biomass yield /ha varied from 11.77 to 42.37. The highest total biomass yield /ha 42.37 was recorded for bamboo species *Bamboosa bamboose followed by Bamboosa balcooa 41.80 and Dendrocal musstocksii 35.09.*

Observations on Monetary returns –Gross, monetary return, Net monetary returns, Cost of establishment, maintenance cost for 5 years, harvesting cost, total cost /ha and benefit Cost ratio were worked out and are given in table 4.

Gross monetary return Rs/ha: Considering the biomass yield the gross monetary return Rs/ha from each bamboo spp were worked out. The gross monetary return varied from Rs. 23540 to 213180. The highest gross monetary returnRs /ha 213180 was worked out for bamboo species *Bamboosa balcooa followed by Bamboosa bambose Rs. 211860 and Dendrocal musstocksii Rs.178959.*

Net monetary return Rs/ha: Considering the biomass yield the netmonetary return Rs/ha from each bamboo spp were worked out. The net monetary return varied from Rs. (-) 2949 to Rs.125640. The highest net monetary return Rs /ha 125640 was worked out for bamboo species *Bamboosabalcooa followed by Bamboosa bambose Rs. 117632 and Dendrocal musstocksii Rs.103932.*

Cost of establishment Rs/ha: The Cost of establishment Rs/ha from each bamboo spp were worked out. The Cost of establishment varied from Rs. 33000 to Rs.55000. The highest Cost of establishment Rs /ha 55000 was worked out for bamboo species *Bamboosa balcooa* (because of higher cost of tissue culture origin planting material) followed by *Dendrocal musstocksii* Rs.49500.

The lowest cost Rs.33000 was worked out for *Bamboosa bambose* and three more spp.

Cost of production Rs/ha: Considering the cost establishment + cost of maintenance for five years + cost of harvesting and transportation the cost of Production was worked out. The Cost of production varied from Rs. 46660 to Rs.94228. The highest Cost of production Rs /ha 94228 was worked out for bamboo species *Bamboosa bambose (because of higher cost of harvesting) followed by Bamboosa balcooa Rs.87540. The lowest cost Rs.*46660 *was worked out for Dendrocal musstrictus.*

Benefit /Cost ratio: Considering the cost of production vs gross monetary returns the benefit-cost ratio (B/C) of cultivation of ten bamboo spp. was worked out. The benefit-cost ratio varied from 0.581 to 2.44. The highest benefit-cost ratio 2.44 was worked out for bamboo species *Bamboosa balcooa (Bhima)* followed by *Dendrocal musstocksii (Manga)* 2.39 and *Bamboosa bambose (Katang)* 2.25.

In conclusion the basis of six years filed experimentation, assessment of growth and morphological characters, estimation of biomass productivity, cost of production and calculation of higher Benefit /Cost Ratio (> 2) it can be concluded that three bamboo spp. namely *Bamboosa balcooa (Bhima)* 2.44 followed by *Dendrocal musstocksii (Manga)* 2.39 and *Bamboosa bambose (Katang)* 2.25 are suitable for cultivation on waste and wastelands under rainfed conditions (Patel *et al.,* 2017).

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