Growth performance and culm production of bamboo at the eastern Terai, Nepal

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The results of growth trial of five bamboo species (*Bambusa nutans* subsp. *cupulata*, *Bambusa nutans* subsp. *nutans*, *Bambusa tulda*, *Bambusa balcooa*, and *Dendrocalamus giganteus*) at Belbari of Morang District in the eastern Terai of Nepal, indicated that the species survival were more consistent after one and half year. At 5.5 years. The locally growing species *B. nutans* subsp. *cupulata* had the highest survival (86%) followed by *B. nutans* subsp. *nutans* (76%) indicating that success could be achieved through the use of planting material from single node culm cuttings. *Bambusa nutans* subsp. *cupulata* was best in culms production and growth (diameter and height), followed by *B. nutans* subsp. *nutans*. Merchantable culms can be obtained on an annual basis for a considerable length of time only after 5.5 years of planting. *Bambusa nutans* subsp. *cupulata* is best for planting at conditions similar to Belbari followed by *B. nutans* subsp. *nutans* and *B. tulda*.

Keywords: Bamboo, growth, culm production, Nepal

Bamboo is one of the important natural resources of Nepal. Occurrence of bamboo are more common in the eastern half of the country from Dhaulagiri to Sikkim boarder (Stapleton 1994), as high as 4000 m. Very little survey of bamboo species had been done in the past, making it difficult to state all the genera and species found in the country. At present, five genera and more than thirty species of bamboo have been recorded in Nepal (Das 1988) and principal among them are *Bambusa* and *Dendrocalamus* sps.

Bamboo have intimately been associated with human beings since ancient times. In Nepal, bamboo are an important component of overall livelihood strategies of the rural households. It plays an important role in uplifting the socio-economic condition of the rural people and national economy as well. It is an integral part of the rural life and it is extremely difficult to imagine the rural economy without them. They are in great demand not only for construction purposes but also for fodder and many other uses such as new shoots as vegetables, woven products such as mats and baskets, handles for agricultural implements, fencing and scaffoldings, etc. Well over a thousand economic applications of this plant in the welfare of mankind has been compiled by many scientists around the world (Banik 1988). There is a growing demands for bamboo and its products not only in the urban centres (Poudyal 1991) but also in the rural areas of Nepal. Bamboo stems (culms) and its various products are readily sold and bought in the market and is an important source of income for many bamboo growers and basket makers of Nepal (Das 1998).

For their characteristically fast growing nature and usually with strong, straight and smooth culms which are light and easy to split for various uses, people are interested to cultivate them on their fallow land and homesteads. Despite the modernisation in the industrial sector, the demand of bamboo is ever increasing. As the forest products are getting scarcer, more people are using bamboo as a replacement for many forest products and have shown a great interest in bamboo planting both in the Terai and the Midhills (Das 1992 and 1998).

The availability of bamboo seed is low because of its very low viability. As soon as seed are collected they should be sown (Chaturvedi 1986; Napier and Robbins 1989).

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Bamboo are traditionally propagated by farmers from offsets with rhizomes. Two meter tall offsets with undamaged dormant buds at rhizomes from two year old culms are selected as planting materials. The planting is done in June just before the monsoon rain (Stapleton and Tamrakar 1983). It is difficult to get such planting stock as farmers are reluctant to provide as this can damage the production of new shoots and is unfeasible for any large scale planting.

The general practice of growing bamboo in the nursery is from seed or single node culm cuttings (Napier and Robbins 1989). As the bamboo seed is not normally available for raising seedlings, more priority has now been given to culm cutting propagation techniques in several countries. A number of successful single node culm cuttings propagation trials were carried out by the Forest Research Division of the Forest Research and Survey Centre (FORESC).

The propagation of some bamboo species from single node culm cuttings in nursery is although found successful, their field performance is still not known. The present paper communicates the results of growth performance, survival and culms production per year in the field of the following five major bamboo species. For detail descriptions of these species see Stapleton (1994).

Materials and Methods

A bamboo growth trial was established in July 1991 by the Forest Research Division at Belbari (alt. 155 m msl), Morang District, in the eastern Terai of Nepal. It falls under the sub-tropical zone. The recorded average maximum and minimum temperatures were 30°C and 18.2°C respectively. The absolute maximum temperature was 39° C (May, 1994) whereas absolute minimum temperature was 4.4° C (January 1993). The mean annual rainfall was 1737 mm (Department of Hydrology and Meteorology 1997). It has a flat terrain consisting of loamy and silt loam soils with a pH range of 6 to 6.3. Percent N ranges from 0.02 to 0.1 and organic C % from 0.2 to 2. There was a *Shorea robusta* forest 3 to 4 years before establishment trial plot. Due to heavy exploitation, the forest is now converted into open land. Two of the five species (*B. nutans* subsp. *cupulata* and *B. nutans* subsp. *nutans*) were propagated from Hetauda nursery, Makwanpur District and the rest were propagated at Tarahara. Propagation was done using single node culm cutting (source of cuttings are given in Annex).

The cuttings were planted in each pit (size: 40 cm x 25 cm) at a spacing of 5 m x 5 m. A total of 200 cuttings of *Bambusa nutans* subsp *nutans*, 150 cuttings of each *Bambusa tulda* and *B. nutans* subsp. *cupulata*, and 100 cuttings of *B. balcooa* and 50 cuttings of *Dendrocalamus giganteus* were planted in blocks. Thirty four cuttings of *D. giganteus* were replanted in open patch in July 1993. Total number of new shoots in each clump of each species appearing in every winter were recorded. Diameters (D_{30cm} at 1.5 and 2.5 years and Diameter at breast height at 1.3 m at 3.5, 4.5 and 5.5 years) and heights of the largest new shoot were measured in the winter season. Soil heaping was carried out in each clump in March 1993. The oldest culms (planted cuttings and first year shoots) were cut and removed by watcher in the winter of 1996. The collected data were compiled and analysed to know the bamboo species best in terms of growth, survival and culms production.

Table 1: Survival percent of five bamboo species

Species	Local name	Survival (%)				
		1.5 years	2.5 years	3.5 years	4.5 years	5.5 years
Bambusa nutans subsp. *cupulata*	Mal bans	96	86	86	86	86
Bambusa nutans subsp. *nutans*	Tharu bans	78	76	76	76	76
Bambusa tulda	Japhta bans	68	68	67	67	67
Bambusa balcooa	Dhanu bans	73	68	68	66	66
Dendrocalamus giganteus	Rakshasi bans	58	75*	58	56	56

* survival percent at 2.5 years is more than survival percent at 1.5 years. Since 34 cuttings were planted in July 1993 and survival percent includes these cuttings also.

Results and discussions

The local species *Bambusa nutans* subsp. *cupulata*, showed the highest survival (86%) followed by *B. nutans* subsp. *nutans*. The others have survival less than 70 percent at 5.5 years (Table 1). Four species except *B. nutans* subsp. *cupulata* attained low survival percent at 1.5 years. Transportation of cuttings from a considerable distance might have some bearing on the survival. Consequently, there may have been root shock during and after planting as some of the cuttings died within 6 months. After 1.5 years, *Bambusa nutans* subsp. *cupulata*, *Bambusa balcooa*, *Bambusa tulda* and *Bambusa nutans* subsp. *nutans* established well. However, survival percent of *Bambusa nutans* subsp. *cupulata* dropped from 96 to 86 at 2.5 years. The reason of mortality is not clearly known. Normally, once established, bamboo clumps will not die unless there are natural calamities and/or diseases.

The exceptional reduction in survival percent (from 75 to 58 at 3.5 years) of *D. giganteus* could possibly be minimised by taking proper care in transporting cuttings from nursery to the planting site and during planting.

Culms production between species was not different at 1.5 years during which bamboo might have not well established. At 3.5 years, culms production of *B. nutans* subsp. *cupulata* was found higher than other four bamboo species (Table 2) and the similar trend was observed at 4.5 and 5.5 years. *Dendrocalamus giganteus* and *B. balcooa* were less productive than other species (Table 2).

The diameter and height of the largest new culms increased with the increase in age of the bamboo planting (Table 3). This trend is expected to continue for few more years unless culms will attain full size and production will be optimum. In the early stage, culms were smaller and production was also low. Also, sprouting of new shoots increased with the increase in diameter and height of new shoots.

The diameter and height growth of *B. nutans* subsp. *cupulata* was highest followed by *B. tulda* and *B. nutans* subsp. *nutans*. In comparison to other species, the growth performance of *D. giganteus* was very poor, which is important finding considering that the species has the highest growth rate and size (maximum diameter of 30 cm and maximum height of 25 m) in Southeast Asia (Stapleton 1994). The present results indicate that the site condition of Belbari where ground water table is quite high is not suitable for *D. giganteus* and it should not be planted without sites improvement.

At 5.5 years, the total number of culms per hectare for two species would be 7998 for *B. nutans* sub sp. *cupulata* (23.25 culms per clump; stocking: 344 clumps per ha); 6299 for *B. nutans* subsp. *nutans* (20.72 culms per clump; stocking: 304 clumps per ha). The coefficient of variation (CV) in mean total number of culms for five species and new shoots production for four species is more than 40 percent (Table 4). However, such variation is slightly less in *B. nutans* subsp. *nutans* and more in *B. balcooa*. It clearly states that each bamboo clump does not have the same capacity of culms production. It is mainly governed by the number of culms capable of producing new shoots in a clump, condition of the cutting material at planting, and number of sprout shoots and finally the site conditions. The least variation in diameter growth of the largest new shoot at 5.5 years was for *B. nutans* subsp. *cupulata* followed by *B. nutans* subsp. *nutans* and *B. tulda* (Table 4). Two species namely *B. balcooa* and *D. giganteus* largely varied in diameter growth of new

Table 2: Mean total number of culms and new culms per clump of five bamboo species in different years

Species	Age (years)							
	1.5		2.5		3.5		4.5	
	Total culms	New culms	Total culms	New culms	Total culms	New culms	Total culms	New culms
Bambusa nutans subsp. *cupulata*	3.7	1.7	7.6 (105.4)	3.7 (117.6)	15.2 (100.0)	4.8 (29.7)	15.8 (3.9)	5.8 (20.8)
Bambusa nutans subsp. *nutans*	3.8	1.4	6.9 (81.6)	3.4 (142.9)	9.5 (37.7)	2.7 (-20.6)	12.9 (35.8)	4.9 (81.5)
Bambusa tulda	3.6	1.4	5.3 (47.2)	2.2 (57.1)	7.1 (34.0)	1.9 (-13.6)	9.8 (38.0)	3.6 (89.5)
Bambusa balcooa	2.6	1.2	3.5	1.3	3.8	1.0	4.5	1.7
Dendrocalamus giganteus	3.0	1.3	3.8	1.6	3.4	1.3	3.6	1.4

Figures in brackets are the percent increase or decrease in mean total number of culms and new culms each year.

culms at 5.5 years. *Bambusa nutans* subsp. *cupulata* is slightly bigger in size of the new culms than *B. tulda* at 5.5 years.

The diameter varied from 23.9 percent for *B. nutans* subsp. *cupulata*, 20.5 percent for *Bambusa nutans* subsp. *nutans* and 28.6 percent for *B. tulda* (Table 4). Similarly for *B. balcooa* and *D. giganteus* diameter variation was 32.3 percent and 40 percent respectively. Average production of new culms of *B. nutans* subsp. *cupulata* at 5.5 years was 12.6 percent more than *B. nutans* subsp. *nutans* and 55.9 percent than *B. tulda*. For the same year, the average number of total culms production per clump in *B. nutans* subsp. *cupulata* was 12.2 percent and 62.4 percent more than *B. nutans* subsp. *nutans* and *B. tulda* respectively. *B. nutans* subsp. *nutans* attained 44 percent and 31.2 percent more mean total number of culms and number of new culms than *B. tulda*. Average culm size in terms of diameter in *B. nutans* subsp. *cupulata* and *B. tulda* are found more or less similar. (Table 4). However, there was great variation in culms production between these two species.

Increment on number of new culms per clump was calculated on an annual basis. For *B. nutans* subsp. *cupulata*, an increase in mean total number of culms production was found higher at 2.5 years and 3.5 years. Annual increment of mean new culms production per clump ranged from 20.8 percent to 30 percent at 3.5, 4.5 and 5.5 years, however the highest increment was at 2.5 years (Table 3). For *B. nutans* subsp. *nutans*, annual mean increment in total number of culms was higher at 2.5 and 5.5 years than at 3.5 and 4.5 years in which case average increase in total culms was almost the same in both years (Table 3). Annual average increase in new culms was the highest at 2.5 years, then reduced at 3.5 year and then again increased. It could be said that the same trend was not found in annual new culms production.

The average production of total new culms per clump was not increased in the same trend. It may be due to variation in rainfall and temperature which play a vital role in producing new shoots, capacity of older culms to produce new culms and the site type. Comparing the production of total culms at 1.5 years with the other years, it was found that annual percentage increase in total culms production was 105.4 percent (2.5 years), 310.8 percent (3.5 years), 327 percent (4.5 years) and 528.4 percent (5.5 years) for *B. nutans* subsp. *cupulata*; and 81.6 percent (2.5 years), 150 percent (3.5 years), 239.5 percent (4.5 years) and 445.3 percent (5.5 years) for *B. nutans* subsp. *nutans*; and 47.2 percent (2.5 years), 97.2 percent (3.5 years), 172.2 (4.5 years) percent and 297.8 percent (5.5 years) for *B. tulda* (calculation based on Table 2 and 4). The above figures reflect the rapid increase in culms production of *B. nutans* subsp. *cupulata* after 1.5 years.

One-year old culms were not of salable size, for they were very small to be used for constructional purposes. However, they can be used for firewood and fencing. Merchantable culms could be obtained only after five years of planting.

The study showed that after planting of cuttings, one will not get good sized merchantable culms before 5.5 years. After this, merchantable culms could be obtained on an annual basis for subsequent years. In one hectare, production of merchantable culms will be about 1273, 1651 and 1995 for *B. nutans* subsp. *cupulata*, 1034 culms, 821 culms and 1490 culms for *B. nutans* subsp. *nutans* and 590 culms, 509 culms at 5.5, 6.5 and 7.5 years respectively.

Clumps once established, will continue to provide a sustained yield of culms and fodder on an annual basis for a considerable lengths of time and allows harvesting annually. In the case of species grown for structural uses, culms in their second year (2+ year)

Table 3: Diameter (cm) and height (m) of the largest new culms of five bamboo species in different years

Species	Age(years)							
	1.5		2.5		3.5		4.5	
	D_{30}	Height	D_{30}	Height	DBH	Height	DBH	Height
Bambusa nutans subsp. *cupulata*	2.2	3.8	3.5	6.2	4.1	9.1	4.6	10.5
Bambusa nutans subsp. *nutans*	1.7	2.8	2.8	4.5	3.0	5.6	3.9	8.0
Bambusa tulda	2.0	3.5	2.8	4.8	3.1	6.0	4.2	8.7
Bambusa balcooa	1.1	2.0	2.0	2.9	2.1	4.1	3.1	8.3
Dendrocalamus giganteus	0.7	1.2	0.8	1.2	1.4	1.8	1.5	2.2

Table 4: Average number of culms and new culms per clump and coefficient of variation (%) of five bamboo species at 5.5 years.

Species	Total culms+	CV	New culms+	CV	DBH (cm)*	CV
Bambusa nutans subsp. *cupulata*	23.25 (47.2)	51.5	7.54 (30.0)	56.6	5.7 (23.9)	16.2
Bambusa nutans subsp. *nutans*	20.72 (60.6)	46.0	6.69 (36.7)	42.5	4.7 (20.5)	17.4
Bambusa tulda	14.32 (46.1)	50.9	4.84 (34.4)	46.6	5.4 (28.6)	22.8
Bambusa balcooa	6.47	68.1	2.03	67.7	4.1 (32.3)	37.6
Dendrocalamus giganteus	4.06	52.5	1.0	-	2.1 (40.0)	67.7

+Figures in brackets are the percent increase or decrease in mean total number of culms and new culms each year
* Figures in brackets are the percent increase in diameter growth of new culms at 5.5 years as compared to 4.5 yea

or preferably third year (3+ year) can be cut and the younger culms can be left in clumps for further maturity and to facilitate production of new shoots.

Conclusion

Bambusa nutans subsp. *cupulata* is the best species in terms of culms production, diameter and height growth, followed by *B. nutans* subsp. *nutans* and *B. tulda*. *Dendrocalamus giganteus* has shown very poor growth and survival which is followed by *B. balcooa*. Considering the results of this study, these two species are not recommended for planting under situations similar to Belbari. *Bambusa nutans* subsp. *cupulata*, *B. tulda* and *B. nutans* subsp. *nutans* raised from single node culm cuttings are successful in the field.

Recommendations

- Based on the present results and the conditions prevailing at Belbari, *B. nutans* subsp. *cupulata* can be incorporated in planting programmes. Also, further research on *D. giganteous* and *B. balcooa* is needed for achieving their higher rate of culm production and survival.
- Culms of *B. nutans* subsp. *cupulata* with strong branches should be selected for single node culm cuttings, otherwise rooting success is doubtful.
- To increase the success rate care must be taken during transportation of cuttings from nursery to the planting site and during planting in the field. It is better to have nursery adjoining to plantation sites.
- For its minimal cost required in managing clumps, bamboo planting should be encouraged
- Proper techniques of raising cuttings in the nursery, pitting, planting and management should be implied to achieve higher success rate and production.

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Annex : Source of bamboo cuttings

Species	Local name	Source
Bambusa nutans subsp. *cupulata*	Mal bans	Belbari, Morang District
Bambusa nutans subsp. *nutans*	Tharu bans	Hetauda, Makawanpur District
Bambusa tulda	Jhapta/Japhta bans	Near to Inarawa, Sunsari District
Bambusa balcooa	Dhanu bans	Belbari, Morang District
Dendrocalamus giganteus	Rakshasi bans	Near to Chandragadhi, Jhapa District