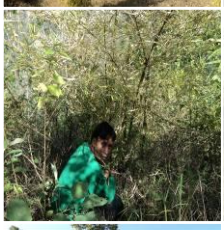
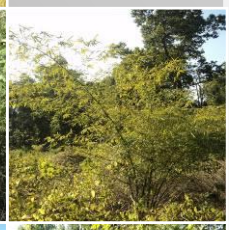
2010-11

# To Study the Growth and Survival of Bamboo Plantation in Different Parts of Uttarakhand


## *Final Report 2010-11*

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# 2. LIST OF TABLES



## LIST OF FIGURES

# TABLE OF CONTENTS

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of variance |
| CD | Critical Difference |
| CEDAR | Centre for Ecology Development and Research |
| UBFDB | Uttarakhand Bamboo and Fibre Development Board |
| Kg $ha^{-1}$ $yr^{-1}$ | Kilogram per hectare per year |
| mm | Millimeters |
| msl | Mean Mea Level |
| GPS | Global Positioning System |
| Ha | Hectare |

**B**amboo is woody grass belonging to the sub family Bambusoideae of the family Poaceae. Bamboo is fast growing species and therefore, known as **"Green Gold"**. This green gold is sufficiently cheap and plentiful to meet the vast needs of human populace from the "*child cradle to the dead man's bier*" that is why sometimes known as "*poor man's timber*." Worldwide there are more than 1,250 species under 75 genera of bamboo, which are unevenly distributed in the various part of the humid tropical, sub tropical and temperate region of the earth (Subramaniam, 1998). India is very rich in bamboo diversity. There are 124 indigenous and exotic species under 23 genera, found naturally and or under cultivation (Naithani, 1993). An estimated 8.6 million ha forest area of the country contains bamboo (Rai and Chauhan, 1998). Bamboo generally forms the understory in the natural forests. It is found to grown practically in the tropical sub-tropical and temperate region where the annual rainfall ranges between 1,200 mm to 4,000 mm and the temperature varies between $16^{o}$C and $38^{o}$C. The most suitable conditions for the occurrence of bamboo are found between 770-1,080 meter above sea level (msl). However, two thirds of the growing stock of bamboo in the country is available in the north-eastern states with supports about 50% of the total genetic resources of bamboo being tropical moist region.

Bamboo plantations conserve soil and water, improve soil fertility and local climate, Liese (1992) pointed out that 2.5 billion people depend on or use bamboo materials valued of US$ 7 billion per annum. India is one of the leading countries of the world, second to China in bamboo production with 32, 30,000 tonnes per year (Pathak, 1989). Climatically bamboo prefers regions of high rainfall ranging from about 1270 mm to about 6350 mm or even more. Rainfall plays a very important and dominating role in the distribution and growth of different species.

Bamboos are multipurpose plants, widely harvested from natural forest and also cultivated. Their uses are dependent upon the characteristics of individual species such as culm strength, flexibility and size. Their contribution to the ecology of an area derives from their ability to recycle nutrients efficiently (Rao & Ramakrishnan, 1990), their ability to protect against soil erosion, and the high nutritive value of their leaves and shoots. As economically and ecologically important plants, they merit serious attempts to conserve their diversity.

Bamboos are distributed throughout the Himalayas, with a variety of different genera adapted to different ecological zones, and an as yet unknown number of species, subspecies and varieties. These are often limited in distribution to a narrow geographic or topographic area. Because of their infrequent flowering their taxonomy has been rather neglected.

In the hottest and driest outer limits of the Himalayas such as the Siwalik Hills, a limited range of species occurs, including such relatively drought-tolerant species as *Dendrocalamus strictus* and *Bambusa bambos*. Inner valleys of such areas can be classified as semi-arid, and water stress severely limits the distribution of bamboos. The subtropical middle hills of the Western Himalayas are also relatively dry and contain only a few species of bamboo from the genera *Bambusa*, *Dendrocalamus*, and *Drepanostachyum*. The temperate forests are home to a few more, from the genera *Himalayacalamus*, *Thamnocalamus*, and *Yushania*. They are naturally restricted to cooler, damper sites but are also sporadically cultivated. As they are at the end of their natural range, they are particularly sensitive to environmental degradation. Deforestation, fire or overgrazing can eliminate all bamboos rapidly under such conditions. Reduction in canopy cover can lead to death of even well-established.

Uttarakhand Bamboo and Fiber Development Board (UBFDB) has undertaken major plantation programs in emerging as a major source of raw material for several processed products primarily due to its fast growth, wide spread occurrence and its multiple uses.

Although plantations are carried out throughout the Uttarakhand State, the most significant concentrations are in the Lansdown, Kalagarh and Badrinath Forest Divisions (Table 1). In the foothills, in the Siwalik Hills, and in adjacent plains areas, the dominant species is *Dendrocalamus strictus*. *Bambusa bambos, Bambusa nutans and Dendrocalamus hamiltonii* are cultivated on private lands, especially on lower slopes and valleys. In the hills, the dominant group of species planted is locally known as Ringal, typically thin, reedy, shrubby, thorn less and clump forming. Ringal grows on steep mountain slopes, within temperate zones, at an elevation of 1800-2400m in the Garhwal and Kumaon Hills. It is distributed over 66,000 hectare at elevations between 1800 – 2500 meters.

**Table 1.1.1. Availability of bamboo in Uttarakhand (in hectares)**

| Forest Division | Bamboo/Ringal availability |
|---|---|
| **Garhwal Region** | |
| Lansdowne | 27,546 |
| Dehradun | 1,449 |
| Badrinath | 44,848 |
| Kalagarh | 15,714 |
| **Kumaun Region** | |
| Ramnagar | 14,221 |
| Haldwani | 14,777 |
| North Pithoragarh | 7,395 |
| South Pithoragarh | 811 |
| East Almora | 3,807 |
| Nainital | 8,842 |
| **Total** | **139,410** |

***Source: National Mission on Bamboo Applications***

UBFDB has undertaken plantations in five forest divisions of Uttarakhand. These forest divisions are Dehradun, Terai Central, Terai West, Lansdowne forest division and Nainital forest division. The UBFDB has established extensive nurseries and undertaken plantations in different areas of Uttarakhand. Total bamboo plantation carried out by UBFDB is 1752 ha, 981 ha of bamboo plantations and 771 ha of Ringal Plantation (UBFDB, 2009).

Centre for Ecology Development and Research (CEDAR) with the financial assistance of Uttarakhand Bamboo and Fiber Development Board (UBFDB) has been assigned the task of evaluating the growth, survival and productivity of bamboo plantation in different parts of Uttarakhand. The present study attempts to provide scientific assistance to the UBFDB in collecting information essentially on growth parameters and survival rates of bamboo plantations in undertaken by UBFDB in different parts of the state. The present investigation is being carried out with the following objectives.

**Objectives:**

1. To undertake scientifically sound data on height and diameter etc of bamboo species in different plantation areas of Uttarakhand.
2. To estimate the productivity rates of bamboo species of the studied sites.
3. To provide information on survival rates of species
4. To access the impact of altitudinal variations on growth, survival and productivity rates of the species
5. To project the approximate rotation age of the different bamboo species in consideration

The present investigation was carried out in 24 randomly selected sites in both Garhwal and Kumaun region of Uttarakhand state. The criteria of selection of the sites were based on the physiographic region, plantation age, altitudinal gradient forest/land use type. Out of 24 sites, 15 were in Garhwal region and the rest 9 were in Kumaun region (Figure 2.1.1.). The present investigation was undertaken between 194 m msl to 1474 m msl in both Garhwal and Kumaun region. Most sites undertaken in the study were in the subtropical region as most study undertaken under the bamboo plantation. However, to understand the production, growth behaviour and survival rate of the bamboo species, some of the study sites have also been selected in the temperate region. To precise the location of the study sites GPS coordinates was also marked during the field survey.

**Table 2.1.1 Selected study sites in Uttarakhand**

| S.No. | Sites | Forest Range | Area (ha) | Forest/Vegetation Type | Coordinates | Elevation (m msl) | Aspect | Plantation Year |
|---|---|---|---|---|---|---|---|---|
| | | | | Garhwal Region | | | | |
| 1. | Jhatri 1 | Matiyali | 5 | Chir Pine | N 29$^0$52'.203'' E 78$^0$34'.805'' | 985 | NW | 2006-07 |
| 2. | Jhatri 2 | Matyali | 10 | Chir Pine | N 20$^0$51'.829'' E 78035'.313'' | 1000 | SW | 2007-08 |
| 3. | Boregaun | Bhrigukhal | 10 | Chir Pine | N29$^0$54'.557'' E078$^0$27'.706'' | 1120 | NW | 2006-07 |
| 4. | Harsu | Bhrigukhal | 15 | Chir Pine | N29$^0$53'.520'' E079$^0$27'.290'' | 1050 | SW | 2007-08 |
| 5. | Dabri | Rikhnikhal | 10 | Exposed Site | N29$^0$50'.550'' E078$^0$40'.900'' | 1307 | NW | 2006-07 |
| 6. | Dabri Palli | Rikhnikhal | 15 | Exposed site | N29$^0$46'.550'' E078$^0$50'.900'' | 1345 | SE | 2007-08 |
| 7. | Papadiyan | Langha | 10 | Sal Forest | N 29$^0$ 52'.501'' E 078$^0$34'.805'' | 642 | SW | 2007-08 |
| 8. | Mehndipur | Timli | 10 | Sal Forest | N 30$^0$23'.807'' E 077$^0$44'.700'' | 454 | SW | 2007-08 |
| 9. | Sahpur/ Kalyanpur | Timli | 10 | Mix Forest | N 30$^0$25'.013'' E 077$^0$41'.548'' | 443 | NW | 2007-08 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **10.** | **Chauhadpur** | Ambadi-3 | 10 | Mix Forest | N $30^0$28'.239'' E $077^0$48'.417'' | 475 | NE | 2007-08 |
| **11.** | **Mehuwala-Khalsa** | Chauhadpur | 10 | Mix Forest | N $30^0$28'.864'' E $077^0$49'.138'' | 494 | SW | 2007-08 |
| **12.** | **Pindadhar** | Narendranagar | 20 | Sal Forest | N $30^0$22'.111'' E $077^0$50'.136'' | 848 | NW | 2007-08 |
| **13.** | **Silondi Pakha** | Narendranagar | 15 | Chir Pine | N $30^0$06'.089'' E $078^0$27'.490'' | 777 | SW | 2006-07 |
| **14.** | **Malli Bhangoli** | Narendranagar | 15 | Degraded Forest (Khair & Pine) | N $30^0$16'.868'' E $078^0$22'.280'' | 942 | NW | 2007-08 |
| **15.** | **Bemar** | Narendranagar | 10 | Mixed Forest dominant by Lantana | N $30^0$15'.368'' E $078^0$22'.139'' | 954 | North Facing | 2007-08 |
| | | **Kumaun Region** | | | | | | |
| **16.** | **Bailpadaw (Plot 56 a)** | Bannakhoda | 15 | Exposed | N $30^0$15'.374'' E $078^0$22'.142'' | 272 | NW | 2009-10 |
| **17.** | **Bailpadaw (Plot 46 a)** | Bannakhoda | 36 | Exposed | N $29^0$16'.710'' E $079^0$10'.072'' | 270 | NW | 2009-10 |
| **18.** | **Guljarpur Plot (19)** | Judka | 7 | Exposed | N $29^0$16'.649'' E $079^0$03'.898'' | 232 | NE | 2009-10 |
| **19.** | **Guljarpur Plot (20)** | Judka | 5 | Exposed | N $29^0$16'.654'' E $079^0$03'.853'' | 200 | SW | 2009-10 |
| **20.** | **Guljarpur Plot (21)** | Judka | 6 | Eucalyptus | N $30^0$16'.716'' E $079^0$10'.073'' | 194 | N | 2009-10 |
| **21.** | **Guljarpur Plot (22)** | Judka | 6 | Water stream, Open Forest | N $29^0$16'.595'' E $079^0$03'.894'' | 220 | SE | 2009-10 |
| **22.** | **Ragargar** | Salt | 10 | Chir Pine | N $29^0$16'.683'' E $079^0$03'.760'' | 1474 | S | 2010-11 |
| **23.** | **Kangari** | Salt (Manila) | 10 | Open Forest (Chir Pine) | N $29^0$44'.911'' E $079^0$11'.535'' | 1176 | N W | 2008-09 |
| **24.** | **Simaldhar** | Salt | 10 | Chir Pine | N $29^0$41'.461'' E $079^0$14'.198'' | 1388 | N | 2010-11 |

After an initial survey recommended by Uttarakhand Bamboo and Fibre Development Board (UBFDB), existing baseline data was collected and analyzed. Circular quadrat method was used to study the growth, survival and productivity rates of bamboo species in the selected sites. Five randomly selected circular quadrats of 5.64 m were laid down in each site to fulfill the objectives of the project:

### 3.1.1. Growth Study

The growth of bamboo species in the selected sites was estimated using the following standard methods:

#### 3.1.1.1. Height (meter)

Height of bamboo species in selected sites was estimated using Clinometer.

#### 3.1.1.2 Diameter (mm)

Diameter of the selected species was measured using Variner caliper (Mitutoyo electronic digital caliper).

### 3.2.1 Estimation of Productivity

Harvesting method was used to estimate the productivity (Mishra, 1968). Five random bamboo clumps of different diameter class were selected and harvested. Fresh weight of these harvested bamboo species was estimated and the productivity was estimated using the following formula:

$$\text{Productivity (Kg/ha)} = \frac{\text{Average Bamboo production in the selected quadrats}}{} \times 100$$

### 3.3.1 Quantitative analysis

Apart from the estimation of productivity, the important quantitative analysis such as density and survival rates of planted bamboo species were determined as per Curtis and McIntosh (1950).

#### 3.3.1.1 Density

To study the numerical strength of bamboo species in selected sites, density/ha was estimated using following equation:

$$\text{Density} = \frac{\text{Total Number of Individuals of a species in all Quadrats}}{\text{Total number of Quadrat Studied}}$$

#### 3.3.1.2. Survival Rate (%)

The survival percentage of the selected species was measured using following formula

$$\text{Survival Rate (\%)} = \frac{\text{Total number of individuals counted during the survey}}{\text{Total number of individuals planted}} \times 100$$

## 3.4. Statistical Analysis

The data related to height, diameter and productivity of bamboo species were analyzed by using the SPSS programme for Windows version 15.0. Multiple comparison and two way analysis of variance (ANOVA) procedures are used to compare the differences between the samples. LSD test are performed to determine the significance of the samples mean at $P < 0.05$. The significant differences would be statistically analyzed by ANOVA. CD (Critical Difference) was calculated using Scheffe's method (Scheffe, 1959). Pearson's correlation coefficient was also applied to establish relationship between various attributes viz., productivity, altitude, study sites etc.

## 4.1 Growth Study

Growth study of bamboo species was studied at all the sites during the month of December to February. The data was collected and subjected to the statistical analysis using the ***statistical package- SPSS.*** The findings of the analysis are given below.

**Table 4.1.1. Height growth and Diameter of the dominant bamboo species in the selected sites**

| Site | Dominant Species | Plantation Year | Height (meters) | Collar Diameter 1 (mm) | Collar Diameter 2 (mm) | Collar Diameter 3 (mm) | Average Diameter (mm) |
|---|---|---|---|---|---|---|---|
| | | | **Garhwal** | | | | |
| **Jhatri 1** | *D. strictus* | 2006-07 | 0.91±0.27 | 3.46±0.65 | 2.23±0.24 | 2.09±0.23 | 3.05±0.65 |
| **Jhatri 2** | *D. strictus* | 2007-08 | 1.23±0.27 | 4.64±0.72 | 2.98±0.60 | 2.05±0.27 | 3.20±0.50 |
| **Boregaon** | *D. strictus* | 2006-07 | 1.44±0.30 | 6.17±1.09 | 4.16±0.78 | 2.66±0.53 | 5.06±0.89 |
| **Harshu** | *D. strictus* | 2007-08 | 1.48±0.36 | 6.32±1.31 | 4.59±1.00 | 2.32±0.44 | 5.08±1.10 |
| **Dabri** | *D. strictus* | 2006-07 | 1.08±0.28 | 5.80±1.11 | 3.54±0.71 | 1.99±0.31 | 3.85±0.66 |
| **Dabri Palli** | *D. strictus* | 2007-08 | 0.90±0.25 | 5.56±1.31 | 2.73±0.67 | 1.50±0.40 | 3.12±0.72 |
| **Papdiyaan** | *D. strictus* | 2007-08 | 1.16±0.19 | 8.57±1.54 | 6.85±1.44 | 5.35±1.01 | 6.81±1.29 |
| **Mehandipur** | *D. strictus* | 2007-08 | 2.04±0.20 | 21.41±1.59 | 16.33±1.43 | 12.33±1.23 | 16.40±1.36 |
| **Shahpur (Kalyanpur)** | *B. bambos* | 2007-08 | 1.61±0.30 | 12.17±1.88 | 8.60±1.35 | 7.89±1.08 | 9.30±1.33 |
| **Ambadi** | *B. bambos* | 2007-08 | 2.38±0.40 | 27.15±1.53 | 23.59±1.46 | 20.60±1.50 | 23.78±1.45 |
| **Mehuwala Khalsa** | *D. strictus* | 2007-08 | 1.38±0.18 | 13.63±1.40 | 9.49±1.33 | 6.58±1.30 | 10.08±1.29 |
| **Pinda Dhar** | *D. strictus* | 2007-08 | 1.30±0.26 | 19.30±1.96 | 16.24±1.78 | 12.12±1.83 | 15.61±1.78 |
| **Silondi Pakha** | *D. hamiltonii* | 2006-07 | 0.89±0.24 | 15.60±2.66 | 13.47±2.30 | 10.96±2.08 | 13.04±2.27 |
| **Malli Bhangeli** | *D. strictus* | 2007-08 | 0.85±0.18 | 12.04±2.47 | 8.57±1.45 | 7.73±1.33 | 9.67±1.77 |
| **Bemar** | *D. strictus* | 2007-08 | 0.73±0.23 | 11.73±2.73 | 7.94±1.56 | 6.00±1.00 | 9.49±1.96 |
| | **Average** | | **1.29±0.11** | **11.57±1.72** | **8.75±1.55** | **6.81±1.34** | **9.17±1.49** |
| | | | **Kumaun** | | | | |
| **Bailpadaw Block (Plot (56 a)** | *D. strictus* | 2009-10 | 0.94±0.24 | 11.53±1.50 | 7.26±1.59 | 11.54±1.07 | 10.35±0.80 |
| **Bailpadaw Block (Plot (46 a)** | *D. membranacea* | 2009-10 | 1.11±0.22 | 18.25±1.67 | 16.50±1.30 | 14.82±1.26 | 16.39±1.43 |
| **Guljarpur Block (Plot 19)** | *D. membranacea* | 2009-10 | 0.89±0.32 | 14.88±1.63 | 13.33±1.67 | 12.41±1.35 | 13.19±1.49 |
| **Guljarpur Block (Plot 20)** | *D. hamiltonii* | 2009-10 | 1.00±0.27 | 20.01±2.58 | 17.67±2.45 | 17.22±2.05 | 17.82±2.36 |
| **Guljarpur Block (Plot 21)** | *D. hamiltonii* | 2009-10 | 2.14±0.62 | 26.03±2.79 | 23.28±2.57 | 21.05±2.30 | 23.44±2.49 |
| **Guljarpur Block (Plot 22)** | *D. hamiltonii* | 2009-10 | 3.81±0.61 | 29.72±3.24 | 26.29±2.95 | 23.76±2.64 | 26.58±2.89 |
| **Ragargar** | *D. hamiltonii* | 2010-11 | 3.06±0.51 | 26.09±3.46 | 23.30±2.88 | 20.98±2.68 | 23.44±2.93 |
| **Kangari** | *D. strictus* | 2008-09 | 1.94±0.35 | 21.49±2.92 | 19.63±2.37 | 17.15±2.24 | 19.41±2.42 |
| **Simaldhar** | *D. strictus* | 2010-11 | 1.36±0.18 | 17.88±1.77 | 15.79±1.86 | 14.02±1.56 | 15.88±1.69 |
| | **Average** | | **1.81±0.33** | **20.65±1.83** | **18.12±1.83** | **16.99±1.33** | **18.50±1.65** |
| ***Significance*** | | ***NS*** | *** | *** | *** | *** | *** |
| ***CD*** | | | ***714.18*** | ***0.054*** | ***0.048*** | ***0.044*** | ***0.51*** |

***Significant at *P*<0.001 NS-Non-significant *Values are mean of replicates ± standard error*

The analysis of variance (ANOVA) exhibits that the variation in height and diameter of bamboo species between the sites were observed to be highly significant (*P*<0.001*)*, whereas, the agewise variation in height and diameter of bamboo species was found to be non-significant. *Dendrocalamus hamiltonii*, exhibited the maximum height growth of 3.81±0.61 meter in Guljarpur Block (Plot 22) in Tarai range of Kumaun region. In Garhwal region the maximum height growth was recorded in Ambadi, where *Bambusa bambos* exhibited the maximum height growth of 2.38±0.40 meter. However, *Dendrocalamus strictus* showed the lowest height growth of 0.73±0.23 meter in Bemar (Table 4.1.1 & Figure 4.1.1).

As regards to the diameter, *Dendrocalamus hamiltonii* again showed the highest diameter (26.58±2.89 mm) in Guljarpur Block (Plot 22), while *Dendrocalamus strictus* exhibited the lowest diameter (3.05±0.65 mm) in Jhatri 1 site in Garhwal (Table 4.1.1 & Figure 4.1.2).

**Figure 4.1.1. Height growth of Bamboo species in selected Sites**

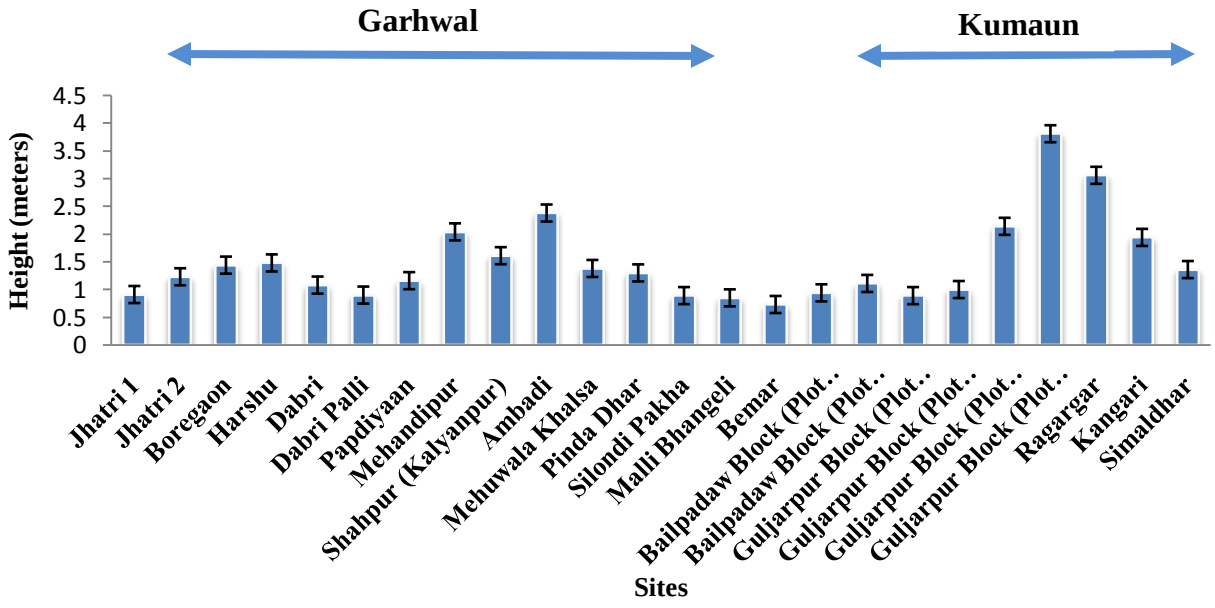
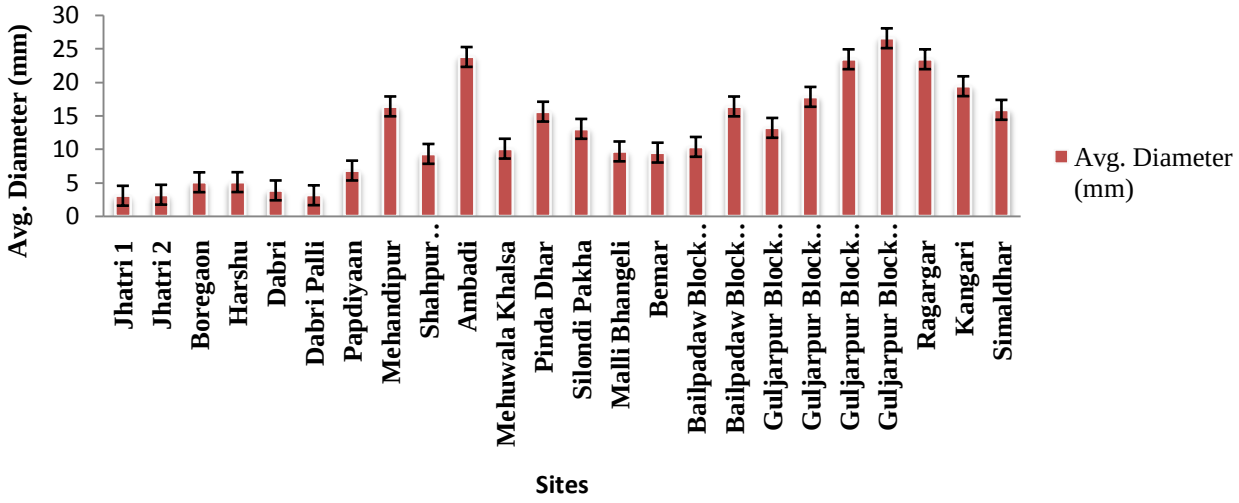


**Figure 4.1.2. Average Diameter of Bamboo species in selected Sites**




On comparing the average height growth and diameter in Garhwal and Kumaun regions, it was found that in Kumaun region the height and diameter of bamboo species were significantly higher than Garhwal region. In Kumaun the average height of bamboo species was estimated to be 1.81±0.33 meter while it was found to be 1.29.58±0.11 meter in Garhwal (Figure 4.1.3). Similarly the average diameter in Kumaun region was found to be 18.50±1.65 mm, whereas it was observed to be 9.17±1.49 mm in Garhwal (Figure 4.1.4.).

**Figure 4.1.3. Variation in Average Height Growth in Garhwal and Kumaun Region**

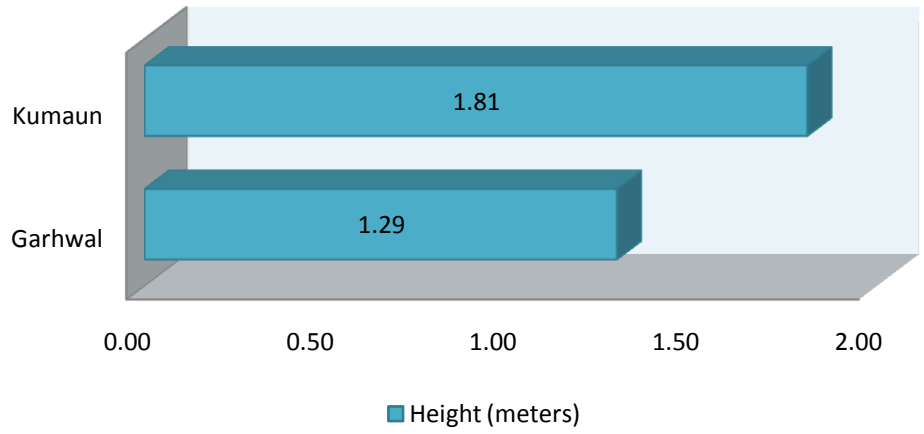


**Figure 4.1.4. Variation in Average Diameter in Garhwal and Kumaun Region**

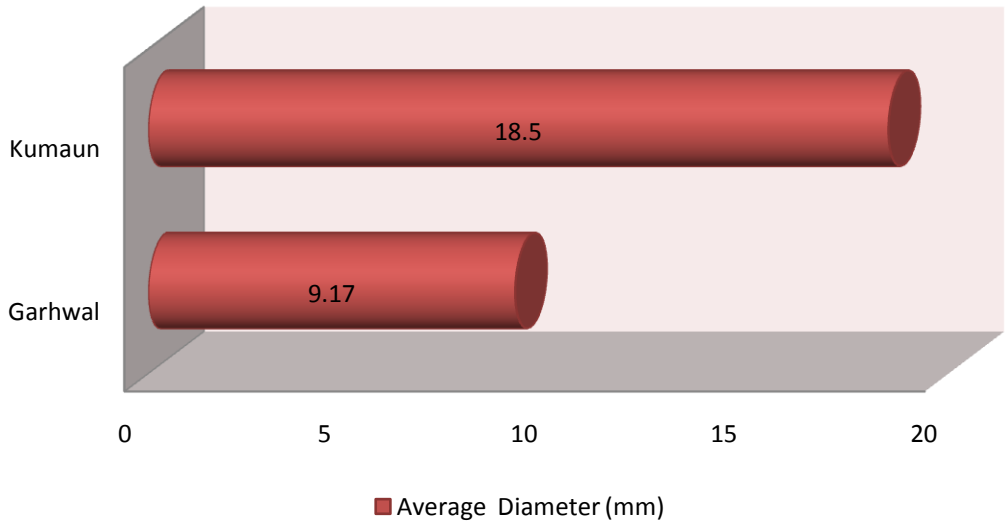



**Figure 4.1.5. Average Height Growth of Different bamboo species in Garhwal & Kumaun**

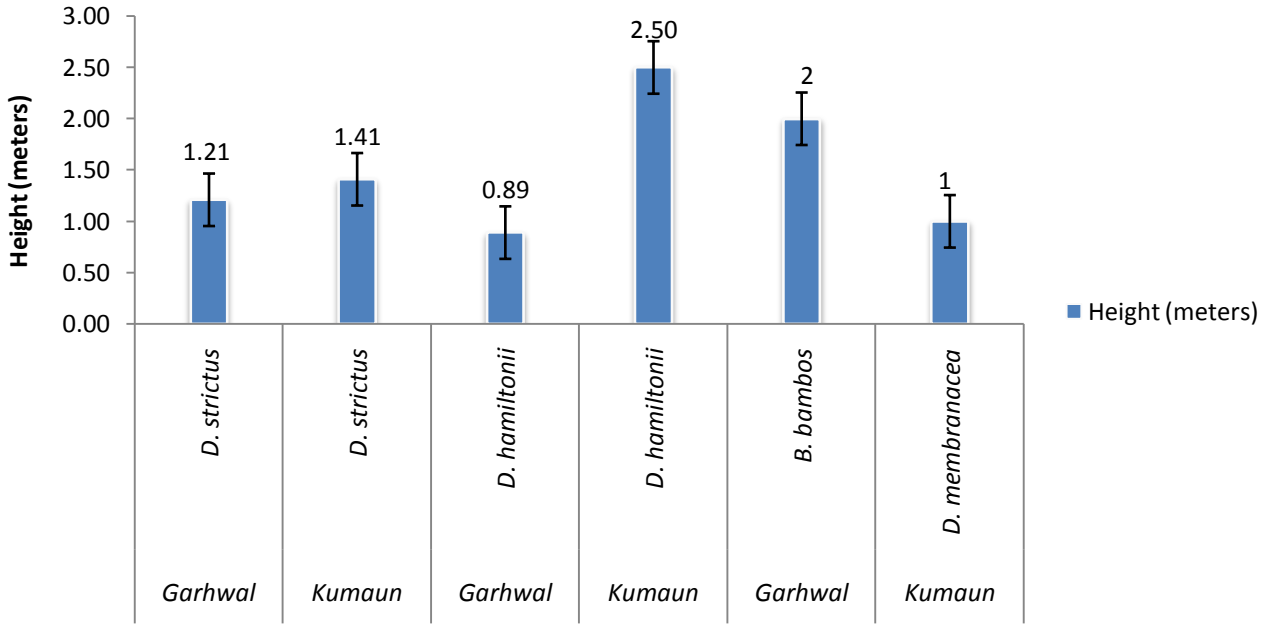
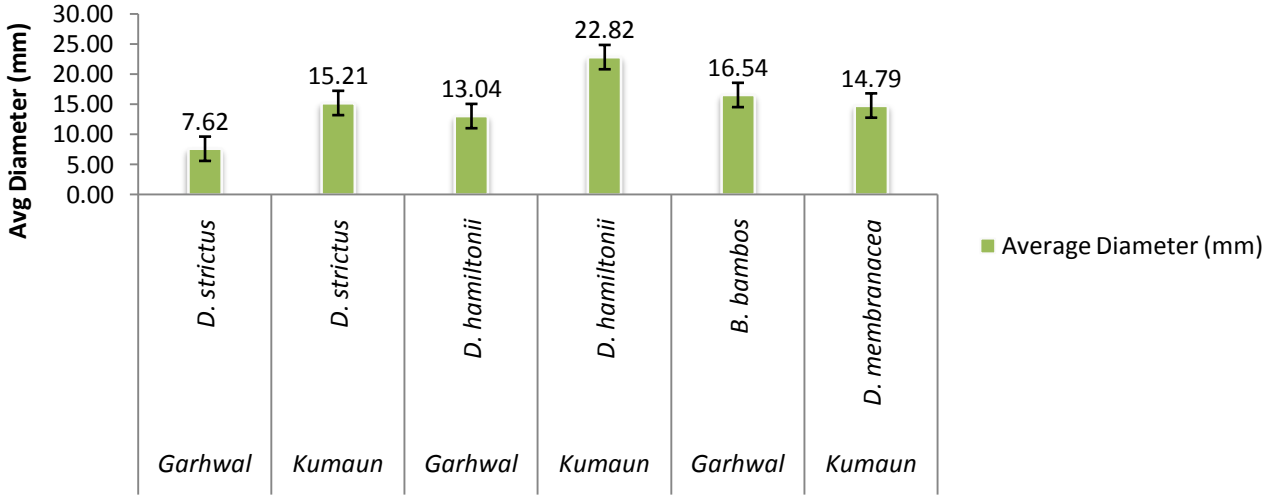


**Figure 4.1.6. Average Diameter of Different bamboo species in Garhwal & Kumaun**




On comparing the average growth performances of different bamboo species in Garhwal and Kumaun region it was observed that *D. hamiltonii* exhibited the maximum average height (2.50±0.61 meter) in Kumaun followed by *B. bamboos,* which showed an average height of 2.00 ±0.38 meters in Garhwal (Figure 4.1.5). Likewise, the maximum average diameter was also recorded for *D. hamiltonii*, which showed an average diameter of 22.82±1.82 mm in Kumaun followed by *B. bamboos* (16.54±7.24 mm) in Garhwal (Figure 4.1.6).

### 4.2. Estimation of Productivity

The analysis of variance (ANOVA) exhibits that the variation in productivity of bamboo species between the sites and altitude were observed to be highly significant ($P<0.001$) (Table 4.1.1).

**Table 4.2.1. Bamboo productivity (Kg $ha^{-1}$ $yr^{-1}$) in different sites**

| S.No. | Site | Species | Altitude (m msl) | Productivity ($kg^{-1}ha^{-1}$) |
|---|---|---|---|---|
| | | **Garhwal Region** | | |
| 1. | Jhatri 1 | *D. strictus* | 985 | 254±32.34 |
| 2. | Jhatri 2 | *D. strictus* | 1000 | 283.60±63.30 |
| 3. | Boregaon | *D. strictus* | 1120 | 210±32.86 |
| 4. | Harshu | *D. strictus* | 1050 | 376±79.54 |
| 5. | Dabri | *D. strictus* | 1307 | 144±19.90 |
| 6. | Dabri Palli | *D. strictus* | 1345 | 145±27.75 |
| 7. | Papdiyaan | *D. strictus* | 642 | 914±65.54 |
| 8. | Mehandipur | *D. strictus* | 454 | 1540±129.81 |
| 9. | Shahpur (Kalyanpur) | *B. bambos* | 443 | 1361±84.39 |
| 10. | Chauhadpur | *B. bambos* | 475 | 1930±149.67 |
| 11. | Mehuwala Khalsa | *D. strictus* | 494 | 1670±94.34 |
| 12. | Pinda Dhar | *D. strictus* | 848 | 528±68.29 |
| 13. | Kandarkhet | *D. hamiltonii* | 777 | 720±71.76 |
| 14. | Malli Bhangeli | *D. strictus* | 942 | 390±95.39 |
| 15. | Bemar | *D. strictus* | 954 | 534±64.08 |
| | **Average Productivity** | | 985 | **733.30±156.04** |
| | | **Kumaun Region** | | |
| 16. | Bailpadaw (Plot 56 a) | *D. strictus* | 272 | 2290±289.14 |
| 17. | Bailpadaw (Plot 46 a) | *D. membranacea* | 270 | 1970±121.82 |
| 18. | Guljarpur Block (Plot 19) | *D. membranacea* | 232 | 1955±214.2 |
| 19. | Guljarpur Block (Plot 20) | *D. hamiltonii* | 200 | 2256±146.75 |
| 20. | Guljarpur Block (Plot 21) | *D. hamiltonii* | 194 | 2102±139.48 |
| 21. | Guljarpur Block (Plot 22) | *D. hamiltonii* | 220 | 1707±171.83 |
| 22. | Ragargar | *D. hamiltonii* | 1474 | 410±36.74 |
| 23. | Kangari | *D. strictus* | 1176 | 233±50.98 |
| 24. | Simaldhar | *D. strictus* | 1388 | 154±33.26 |
| | **Average Productivity** | | | **1453±303.206** |
| **Significance** | | *** | *** | |
| **CD** | | **0.20** | **4.32** | |

***Significant at *P*<0.001 *Values are mean of five replicates ± standard error*

**Table 4.2.2 Pearson's Correlation coefficient Between Sites, Altitude and Productivity**

| | Site | Altitude | Productivity ($Kg^{-1}ha^{-1}$) |
|---|---|---|---|
| **Site** | 1 | | |
| **Altitude** | -.177 | 1 | |
| **Productivity (kg/ha)** | .246(**) | -.846(**) | 1 |

***Correlation is significant at the 0.01 level (2-tailed).*

**Figure 4.2.1 Average Bamboo Production in Garhwal and Kumaun Regions**

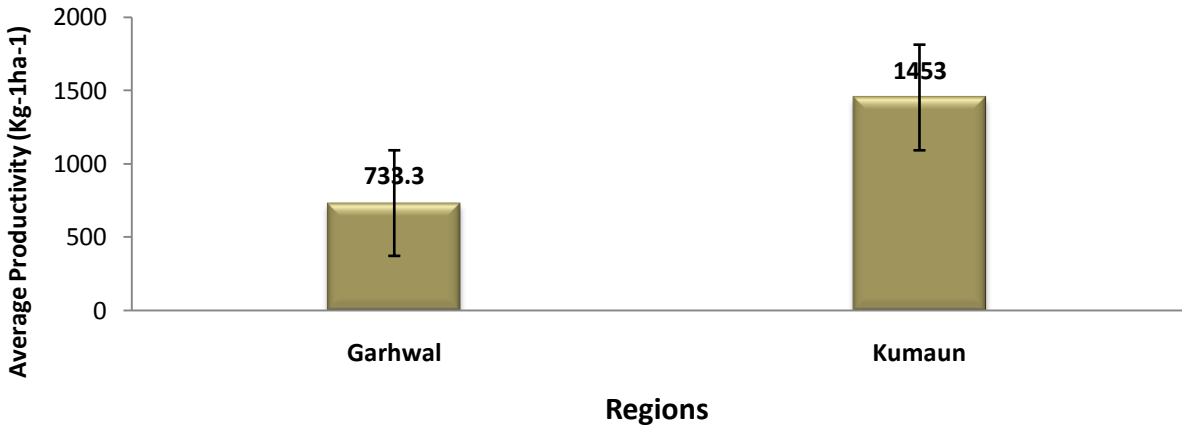
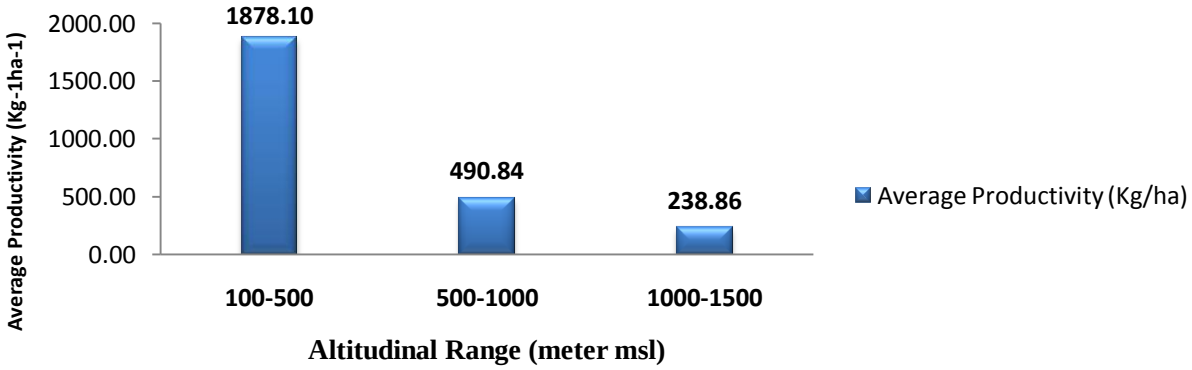



**Figure 4.2.2. Variation in Average Bamboo Production along Altitudinal Gradient**



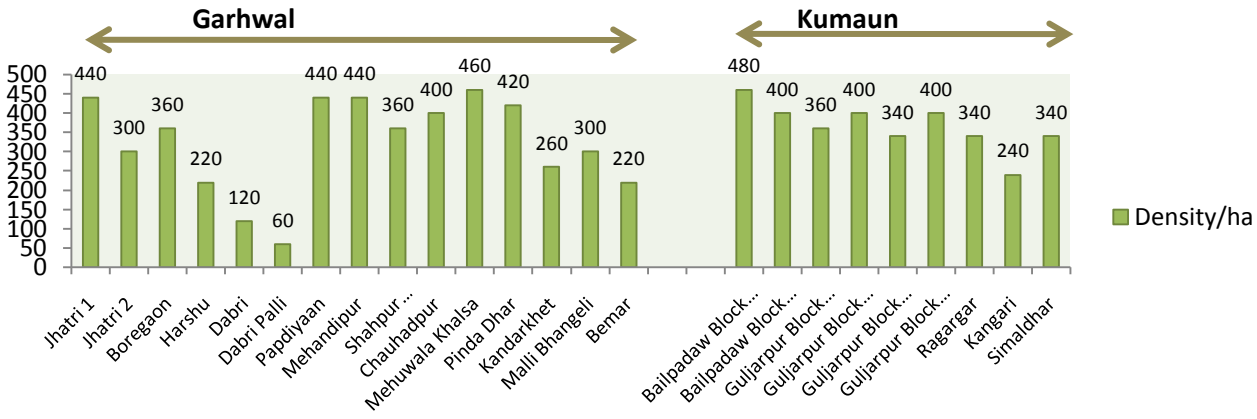

The results reveal that maximum bamboo production (2290±289.14 $Kg^{-1}ha^{-1}$) was estimated in Bailpadaw (Plot 56 a) in Kumaun region, which is largely dominated by *Dendrocalamus strictus,* whereas the lowest bamboo productivity (144±19.90 $Kg^{-1}ha^{-1}$) was observed in Dabri (Garhwal region). This site was also dominated by *Dendrocalamus strictus* (Table 4.2.1). The growth and productivity of any species depends on several environmental factors but altitude along with some other factors viz., aspect, soil type, topography etc might be some major factors controlling the growth and productivity of the same species in different sites. On comparing the productivity of bamboo species in different altitudinal range, it was found that the average productivity of bamboo species was found maximum between 100-500 meter msl

and the productivity decreases with increasing elevation (Figure 4.2.2). The Pearson's correlation coefficient also exhibits that there is a significant negative correlation (r= -.846) between the productivity and altitude (Table 4.2.2), which indicates that the average productivity of bamboo species decreases with increasing elevation. On comparing the average bamboo productivity in both Garhwal and Kumaun regions, it was observed that the average bamboo productivity was higher in Kumaun region (1453±303.08 $Kg^{-1}ha^{-1}$), while in Garhwal it was estimated to be 733.30±156.04 $Kg^{-1}ha^{-1}$ (Figure 4.2.1).

### 4.3. Estimation of Density of Bamboo Species

The results of the present investigation reveal that density of bamboo species was found to be highest (480 clumps/ha) in Bailpadaw block (Plot 56 a) in Kumaun region followed by 460 clumps/ha in Mehuwala Khalsa in Garhwal region.

**Figure 4.3.1. Density/ha of Bamboo Species in the Selected Sites**

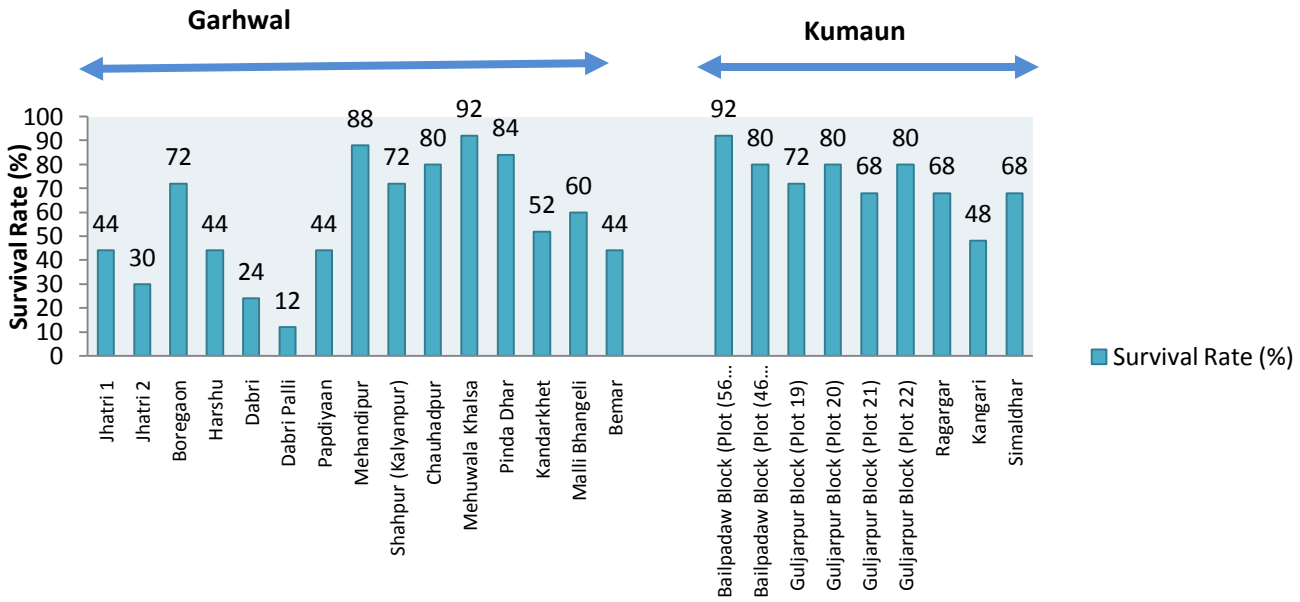



The dominant species in both the sites was *Dendrocalamus strictus*. The lowest density was observed in Dabri Palli in Garhwal, where only 60 clumps/ha of *Dendrocalamus strictus* were found during the field sampling.

### 4.4. Survival Percentage

Mehuwala Khalsa (Garhwal region) and Bailpadaw Block (Plot 56 a) were the two sites where *Dendrocalamus strictus* exhibited the highest survival rate of 92% followed by 88% in Mehndipur site in Garhwal region. The lowest survival rate was observed in Dabri Palli, where *Dendrocalamus strictus* showed only 12% of survival rate.

**Figure 4.4.1. Survival Rate of Bamboo Species in Different Sites**



For centuries, bamboos have played an important part in the daily life of the people in many tropical countries, particularly in Asia. India has the World's richest resources of bamboo, claiming about 130 species occurring over an area of 10.05 million ha, which is about 12.8% of the total forest area of the country (Shanmughavel and Francis, 2003).

In India, Bamboos occur extensively in the managed ecosystems, both as plantations (Chandrashekara, 1996) and in agroforestry (scattered clumps, hedgerows on farm boundaries etc., Kumar, 1997; Divakara et al., 2001). It has a long history as an exceptionally versatile and widely used resource. Important traditional uses include paper and pulp, fuel, food, feed, house construction, scaffolding, making several articles of everyday use (Sharma, 1987), controlling soil erosion and facilitating on-site nutrient conservation (Christanty et al., 1996). In a rapidly changing world, however, households develop a myriad of livelihood options and in several cases bamboos are considered to be an important livelihood strategy of rural people. Coincidentally, bamboo is being elevated from a raw material known as the "*poor man's timber",* to the status of the "*timber of the 21st century*" (http://agricoop.nic.in/ bamboo/bamboomission.htm) sustained availability can be ensured only by elaborate bamboo cultivation.

Bamboos are distributed throughout the Uttarakhand, with a variety of different genera adapted to different ecological zones, and an as yet unknown number of species, subspecies and varieties. Uttarakhand Bamboo and Fiber Development Board (UBFDB) has undertaken major plantation programs in emerging as a major source of raw material for several processed

products primarily due to its fast growth, wide spread occurrence and its multiple uses. The UBFDB, in collaboration with State Forest Department has established extensive nurseries and undertaken plantations of different bamboo species in different areas of Uttarakhand. In the present study we have assessed the growth behaviour, survival rate and productivity of bamboo species in different parts of Uttarakhand.

In the present study we have found four species of bamboos viz., *Dendrocalamus strictus, Dendrocalamus hamiltonii, Dendrocalamus membranacea and Bambusa bambos* in both Garhwal and Kumaun region of Uttarakhand. Though, *Dendrocalamus strictus* was the dominating species in almost every site studied during the present investigation, it showed the lowest growth (0.73±0.23 meter) in comparison to the other species while, *Dendrocalamus hamiltonii* showed the maximum growth of 3.81±0.61 meter (Table 4.1.1 & Figure 4.1.1). Growth performances of any species depend on several factors viz., site conditions, microclimate, soil type, altitude, slope, aspect and topography etc. In the present study we have observed that *Dendrocalamus hamiltonii* was mainly planted in the foothills and Tarai regions whereas *Dendrocalamus strictus* has been promoted in almost all altitudinal zones. The variation in the growth performance of these two species of same genera might be due to the variation in the altitudinal gradient because altitude in combination with climatic factors (rainfall, temperature and other environmental factors) governs the growth nature and type of any vegetation (Golley et al., 1975). Altitude, temperature and rainfalls are constraints to bamboo growth, and the genera and species are sensitive to changes in these and other environmental factors (Stapleton, 2004).

In Uttarakhand, *Dendrocalamus strictus* is mainly planted between 400-1475 m msl, and it was found during the field surveys that all most every site dominated by *Dendrocalamus*

*strictus* is severely affected by open grazing by domestic animals, and damages caused by wild boar and porcupine, which are unfavorable for the survival and growth of the species. In some sites (Pindadhar and Harsu) of Garhwal region, the State Forest Department has used *Lantana* as a natural barrier to protect the bamboo species from these wild animals, this strategy of protecting the plantations have shown promising results as the growth and survival of these sites were higher than others sites viz., Silondi Pakha, Malli Bhangeli, and Bemar (Table 4.1.1).

Earlier studies indicate that a 3 year plantation of bamboo species may yield 3000-4000 kg $ha^{-1}$ in the first cut 5000-6000 kg $ha^{-1}$ and 8000 kg $ha^{-1}$ (Higuchi, 1981; Banik, 1988; Othman, 1992; Shanmughavel et al., 1997). In the present study we examined that the maximum bamboo productivity was 2290±289.14 $Kg^{-1}ha^{-1}$ in Bailparaw Block (Plot 56 a). The productivity values obtained in the study are closer to what has been observed in earlier studies

As regards to the density of bamboo species, it was observed to be maximum in Bailpadaw block (Plot 56 a) in Kumaun region, where 480 clumps $ha^{-1}$ were recorded during the field survey followed by 460 clumps ha-1 in Mehuwala Khalsa in Garhwal region. The higher density also supported higher survival rate of bamboo species in Bailpadaw, where 92% of survival rate was recorded followed by 88% in Mehndipur site, this can be attributed to low anthropogenic pressure and better microclimatic conditions of the sites.

**Key Recommendation**

1. The growth and productivity of bamboo species have yielded satisfactory results in Tarai and foothills regions but in the higher elevation the bamboo species, mainly *Dendrocalamus strictus* have shown lower growth in comparison to the sites in lower eleavation. Keeping in view the growth and productivity of *Dendrocalamus strictus* in

higher elevation it is suggested that high altitude species of bamboo, if any, are promoted in higher elevations.

2. Locality factors such as aspect, slope and microclimatic conditions need to be carefully considered for best productivity of different species bamboo.
3. Detailed physico- chemical analysis of soil should be carried out before plantation of any bamboo species to understand the nutrient availability and soil properties of the site.
4. It is also evident that anthropogenic pressure viz., open grazing and some wild animals like porcupine, wild boar and rodents have caused severe damage to the bamboo plantation. It is therefore suggested to take some physical and biological measures to protect the plantation from such pressures.
5. It is important to extensive research on growth and productivity of different bamboo species along different moisture and altitudinal regimes.
6. Owing to its high carbon sequestration rates, it is recommend voluntary markets are approached for possibility of carbon trading under CDM mechanism of Kyoto Protocol.

7. It would timely to evaluate and develop linkages for different species of bamboo to check forest degradation, enhancement of carbon stocks in natural forests and its role in conservation of biodiversity and sustainable development so that it can be used to obtain carbon credits under REDD+ scheme of UNFCCC presently being hotly debated in the international arena.
8. Due to high scarcity of fodder in the region some fodder species of bamboo such as *Bambusa arundinacea*, *Bambusa oldhamii* and *Arundinaria cannavieira* need to be promoted in the region.

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***Annexure***

## Bamboo Growth and Survival Format

Site: Area Under plantation (ha) Year of plantation:

Adjoining forest/landuse type: Soil colour:

Soil type & texture:

Altitude: Aspect: Slope:

GPS Coordinates of Plots:

Botanical Name of the Species: Common Name:

Orignal Planting Density (clumps/ha):

| **`Growth Parameters** | **Circular Quadrat Method (5.64 m)** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| Average Height of the Species (m) | | | | | |
| Average Diameter at the $5^{th}$ internode (cm): | | | | | |
| Total Number of Clumps: | | | | | |
| Total Number of Clums: | | | | | |
| Total Number of new clums: | | | | | |

| **Estimation of Productivity (kg)** | | | | |
|---|---|---|---|---|
| Site | Height (meter) | Diameter (meter) | Fresh Weight (kg) | Dry Weight (kg) |
| | | | | |
| | | | | |
| | | | | |

No. of Harvesting/year (if any) Season:

Grazing & Collection of Fodder (Yes/No)

Remarks (If any)