SHOOT-CULM HEIGHT GROWTH OF THE MOST COMMERCIALLY IMPORTANT BAMBOO SPECIES OF MYANMAR

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ABSTRACT

This paper presents the height growth development of new shoots (culm development) of the selected bamboo species, viz., Kyathaung-wa (*Bambusa polymorpha*), Tin-wa (*Cephalostachyum pergracile*) and Hmyin-wa (*Dendrocalamus strictus*) were observed and recorded. The height growth of the new shoots was found to be successive along the culm length. It was found that the growth rates of height were different for each species and the time taken to reach the specific height for species concerned was also different.

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1. INTRODUCTION

Bamboo is a wonderful gift of nature. Bamboos are giant, woody, grasses which are versatile and are fast growing and high yielding renewable resources.

There are 75 genera and 1250 species distributed in tropical, subtropical and temperate zones of the world (Sharma, 1980). Tropical Asia has been referred to as the center of bamboo diversity with as many as 45 genera and 750 species (Biswas, 1988). Myanmar is also endowed with extremely rich species and generic diversity of bamboo with about 100 species distributed among 17 genera (Hundley & Chit Ko Ko, 1986). Among the species of giant bamboos like *Dendrocalamus* and *Bambusa*, Myanmar may be the home and center of diversity for the said species (Htun, 2002). There are 14 species of bamboos in Myanmar which are commercially important in one way or another or in one locality or another depending on their uses (Htun, 1999) (Appendix I.). Among them Kyathaung-wa (*Bambusa polymorpha*, Munro.), Tin-wa (*Cephalostachyum pergracile*, Munro.) and Hmyin-wa (*Dendrecalamus strictus*, Nees.) are the three species which are the most important commercial species recorded.

Bamboo is widely regarded as the most important of the "non-timber" forest products in Myanmar and also through out the tropical Asia. The rural Myanmar people cannot imagine existence without bamboo. It has high value in a wide range of applications as structural material, fiber and food. And also used for tools and implements for agriculture, pulp for paper, household utensil and for handicrafts.

Bamboo with a wide diversity of species are found in almost all forest types of Myanmar, from sea level to the high mountains of 4,000 m. They are usually found growing mixed with other species and they formed understorey in high forests. Almost pure bamboo forests are also found. The sizes or lengths or characteristics of species may be different depending on the ecological conditions in which the species grow.

With the practice of shifting cultivation there was decrease in diversity of other species, which might increase the density of bamboo population. As example the abandon taungya areas are almost always filled in by Bamboo or *Imperata* grass.

Bamboos are perennial woody members of the family GRAMINAE (Poaceae). It is also placed in the subfamily Bambusoides.

Bamboo is one of the fastest growing plant in the plant kingdom. The new shoot-culm starts to emerge from the soil mostly at the beginning of the rainy season. Shoot elongation occurs during day and also in the night. The height of the culm results in mainly by elongation of the internodes. Internodal elongation begins at the basal portion of the culm and then gradually proceed at the top because of the intercalary meristem present at the node. In tropical countries elongation and growth occur more during the night (Osmaston 1918). An emerging culm reaches full height of the specific species within 2- 4 months (McClure 1966, Ueda 1960) in one year time. But all emerging culms do not always develop into fully grown culms always.

The age of an individual culm is not related to clump age, as they sprout every year from the rhizome, which may be older in years. Culms are tender during the first year. They grow tough during the second year and are hard and mature in the third year, when they acquire full density and strength. After this age they start changing colour.

The age of a culm for harvesting is difficult to determine. Generally, culms that are 3 – 5 years old are considered “mature” (Liese, 1985). However, presence or absence of culm sheaths and nodal rootings, bud break and branching pattern, and colour of culm are diagnostic morphological characters for determining the age of culms (Banik, 1993 b). The age of culm should be determined for various utilization and selected culm felling in management of bamboo forest.

2. LITERATURE REVIEW

2.1. On Bamboo Growth in Genera

McClure (1966) stated that two major rhizome types are found in bamboos: pachymorph and leptomorph. All clump- forming bamboo species have pachymorph rhizomes, where as the entire non- clump forming species gave leptomorph rhizomes.

Shigenmatsu (1960) mentioned that the pachymorph rhizome is typically a summer sprouting type for which mainly soil moisture and temperature is the limiting factor.

Watanabe (1986) mentioned that, between the single-stemmed (leptomorph) and the densely clumped (pachymorph) forms, there are intermediate types (woody – pachymorph – diffuse) forming somewhat open clumps.

Bamboo growth is characterized by its increment in weight, length, volume and quality of the rhizome system underground and the culm above. The increase of culms, branches and rhizome in diameter and wall – thickness could have been achieved during the same period when the length growth of shoots and rhizomes occur because bamboo lacks secondary meristem. In other words, there is no increase in size with age once the growth in height has completed. Afterwards, the culms mature gradually and their weight and quality are continuously increased. (Zhou, 1983)

Xiao, (1986) observed that the sympodial bamboo (pachymorph rhizome), the rhizome couldn’t run for a long distance, the culm base is the main part of the rhizome. The buds on a culm base sprout and elongate their rhizome neck, and then the shoot grow erectly from the ends of clump. The buds on the middle and lower part of a stump usually are more vigorous and sprout earlier, and also have longer rhizome necks and could produce bigger shoots than those on the upper parts of the stump. The buds on a culm base of 1 or 2 years old usually are vigorous and could produce 1- 2 shoots while the buds at 3- 4 years old a culm base almost lose the capacity to produce rhizome. Xiao, (1986) stated that the culms, growing in an earlier stage of a year, usually can produce some new shoots from its base again in the current year, which are called the second- time shoots.

2.2. On Shoot – Culm Height Growth

Ueda, (1960) studied the emerging of the new shoots, the shoot starts to emerge from the soil mostly at the beginning of the rainy season. Shoot elongation continues both during the day and the night. The genus *Phyllostachys* in Japan grows more during the day, where as Osmaston, (1918) stated that the shoot elongation, in the tropical regions, bamboos grow more during the night. The daily (24.hours) extension growth amounts to about 10- 30 cm, but reaches 58 cm for *Dendrocalamus giganteus*, and up to 121 cm per day for *Phyllostachys reticulata***.**

Banik, (1993a) reported that maximum elongation per day was 44 cm in *Melocanna baccifera*, 66 cm in *Bambusa vulgaris* and 77 cm in *Bambusa balcooa.*

Banik, (1991) observed that in Bangaladesh a bamboo clump starts producing culms generally either from May or June and may continue for up to 6- 7 months. Each species of bamboos has a definite periodicity for culm emerge. The total culm elongation period were observed to be 75- 85 days for *Bambus balcooa* and *Bambusa vulgaris*, and 55- 60 days for *Melocanna baccifera*.

Xiong, (1989) described that the growth of young culm can be characterized by the growing proceeding from bud differentiation in the soil to culm maturity and ageing in air. Underground shoot growth means that a bud in the soil differentiates and sprouts up to the soil surface. The growing situation varies with species and sprouting time, etc. Both in sympodial and in monopodial bamboos, the shoot- culm growth stage lasts from the emergence of shoots from the soil to the producing of branches and leaves, in which culm- shaped has been formed. A shoot in the soil grows slowly in height during the first a few days; it grows a few centimeters in height in a 24-hour period. After the slow growing period, the growth of shoots in height enters the fast- growing –period in which its increment may reach over 10 cm or more, even 100 cm in a 24 hour period. After the fast- growing- period the height growth declines rapidly and stops finally. This period varies with species. In monopodial bamboo it is shorter than that in sympodial bamboos, which spends 90 to 120 days in this period. Meanwhile, there is a period of 50 to 60 days in some large size species while 30 – 40 days in middle or small –size species.

Chimera (1987) observed clump forming type of bamboo have longer growth period of bamboo shoot than non clump forming type of bamboo in genera, for instance, *Bambusa vulgaris* has 40 – 100 days growth period but *Pyllostachys* and *Semiarundinaria* genera have 30 – 80 days growth period, and *Arundinaria* and *Leleba* genera which grow between temperate and subtropical region have 40–50 days only. He also observed the culm length and diameter in a clump of tropical bamboo are relatively uniformity, but the shoots of non-clump forming type of bamboo species have different size of culm affected by ages of rhizome, arrangement of shoot, etc.

Xiong et al. (1974) further studied in internode growth of shoot- culm, as a result of internode growth, an elongation zone is compared of about ten internodes or more in the upper part of shoot. In an elongation zone, when the internodes at the lower part enters fast growing period those in the upper part still stay in slow-growing –period. As the lower part in this zone matures and stops growing, the upper part will grow fast. Meanwhile, the elongation zone moves upwards till the height growth finishes and internodes will become smaller in diameter one by one. The increase in diameter and wall thickness of internodes is achieved during the same time when an internode elongates. In a new culm, the size in diameter and wall-thickness becomes smaller and thinner upwards one internode by one.

Tomar (1963) observed the growth of *Bambusa arundinacea*, the internodes become visible above the edges of the sheaths after they have completed about 65 per cent of their potential length. Basal portion of an internodes is the most active region and continues growing until maximum growth is reached. Removal of culm-sheaths from young internodes reduced the potential length of these internode.

The two phases of culm growth and development characteristic of woody bamboos (McClure 1966; Clark and Fisher 1987) are presumed to be an adaptation for competition for light in the forest setting. New shoots emerging from the ground are clothed with overlapping bracts, known as culm leaves or culm-sheath, that protect and support the tender, elongating internodes. The new shoots remain unbranched until they reach more or less their mature height, by which time hardening of the internodes has begun and branching may be initiated. The culm leaves begin to dry out and either persist until they disintegrate or fall off, often as a result of branch development.

The culm proper begins more or less at soil level and is usually recognizable by the length of internodes relative to the length of those of the rhizome (McClure, 1966).

Pearson et al. (1994) found that internode diameter decreases linearly from the base to the apex in *Chusquea culeou*.

Along the length of a culm, the lower most few internodes are fairly short, those in the midsection are more elongated, and those toward the apex become shortened (McClure 1966; Pearson et al. 1994).

Pearson et al. (1994) presumed that the production of shoots is seasonal in temperate climates and may be more closely correlated with precipitation patterns in tropical habitats. The occurrence of fire also affects the timing and vigor of shoot production in both temperate and tropical climates.

Chaturvedi (1988) stated that the new rhizomes are produced from the previous year’s rhizomes and the number of new rhizomes formed may vary from one to many. Unlike a tree, bamboo does not acquire more girth as it grows: the new sprouts emerge with full diameter. It reaches full height in 60 to 120 days. Height growth is caused by the successive elongation of the internodes. The basal internode is the first to grow and the top- most one the last. However, several internodes from the bottom upwards grow simultaneously and 40–50 percent of the daily increment in height is contributed by only four to six internodes. The internodes are enclosed in sheaths. It is usually after completion of 65-75 percent of their height that the internodes become visible above the edge of sheaths. Early exposure of internode from the sheaths results in stunted growth of the culm.

Forms of culms as the growth types were studied by Shigematsu, (1960) with the growth rate, the growth curve, the vigor of the bamboo shoot, and the influencing meteorological factors. The height of growth was measured in 19 species (8 genera) of bamboo, and special patterns of growth types were clarified. The clear length, the number of nodes, the weight of culm, branches, and leaves and the width of bamboo crown are important. A better growth bamboo has a longer clear length, and the form may be as an open umbrella with a long stick.

2.3. Environmental Factors Affecting for Bamboo Growth

The following environmental conditions are the major requirements for optimum growth of bamboo species (Uchimura 1987).

2.3.1. Elevation and temperature

The majority of clump- forming bamboos grow at temperature ranges from 7° C (sometimes 2° – 3° C) – 40° C. In general, high temperature accelerates the growth of bamboo while low temperature in habit it. The clump – forming types are generally present in the humid tropics mainly in places where the average temperature is higher than 20°C, and where the altitude is less than 100 m above the sea level.

2.3.2. Rainfall

Numata (1987) stated that high temperature and humidity requirements are common characteristics of plants originating in the monsoon areas of South-East Asia. As the water requirement of bamboo is high, the amount of rainfall is also a limiting factor to distribution and the growth of bamboo. Rainfall is an important factor and 1,000 mm seems to mark the minimum annual precipitation required. Gamble (1896) reported that distribution of bamboos in India was related to the rainfall, the most common range being 1270 to 4000 mm per year. For active growth of clump- forming type of tropical bamboos, more than 200 mm and monthly rainfall is required for at least 3 months (Poudyall 1992).

Numata (1987) further observed that the best growth condition for bamboo is to be maintain six months with 100 to 200 mm monthly rainfall. This is quite different to non-clump forming type of bamboo which need only 240 mm or so rainfall at the time of sprouting. Growth process is close relationship between growth of shoots and precipitation on this connection, tropical bamboo need much rainfall than the bamboo which grow in temperate region. Some of bamboo species such as *Bambusa blumeana*, *Dendrocalamus strictus* etc. have strong drought resistance, otherwise, *Bambusa polymorpha* and *Gigantochloa asper* prefer wetty site.

2.3.3. Soils

Most bamboos are found in well drained, sandy to clayey loam soils, derived from river alluvium of flat or gentle slop areas. *Bambusa polymorpha* and *Bambusa bambos* grow on well drained and fertile soil under forest trees while *bambusa tulda* and *Oxytenanthera olbociliata* are best suited for sandy soil (Uchimura 1987).

Qureshi et. al. 1969. discussed that the soil pH of about 5.0 – 6.5 is the most suitable for bamboo, but some species may grow even at pH 3.5. Saline soil is not suitable for bamboo growth. A wide range of textural variation and soil depth, however, do not interfere in the normal growth of bamboo, provided the drainage, rainfall and temperature conditions are favorable.

According to Uchimura (1980), although bamboo prefers well-drained and aerated soils, it can also grow in swampy or wet areas. Soils high in nitrogen and oxides of phosphorous, potassium, calcium silicon best promote the growth of bamboo culms.

He and Ye (1987) investigated that soil nitrogen content was the most important factor affecting growth of bamboo.

Uchimura (1987) stated that the topsoil, which are suitable for bamboo vary in color from yellow, clear reddish yellow to brown yellow, and color of heart-soils are clear red, yellow, brown to blue gray and the bamboo species of culm which on the wet and fertile soils are usually taller in length and wider in diameter than that of dry and poor soil.

Stamp (1926) classified climax community of Myanmar vegetation as an index of rainfall, bamboo forest is in the midst of regenerative vegetation because climax is dominated by tree vegetation, however, wet teak forest were is 1,500 to 2,300 mm annual rainfall and mother soil constructed by sand stone or sandy shale, is occupied with *Bambusa polymorpha* and *Cephalostachyum pergracile*, but *Dendrocalamus strictus* become index of clay soil in the dry teak forest.

3. OBJECTIVES

The management of natural forest includes management of bamboos in that culm-selection-felling must be understood. Bamboos are exploited at round about 3 years in age. The identification and estimation of age of bamboo are necessary. Culm age can be determined by studying morphological characters of culms, culm-sheaths, and branch complements of the bamboo. Therefore, the development nature of new culm-shoots must be studied.

The objectives of the research are as follows:

1. To study the new shoots – culm growth pattern and time required to reach the specific height among the three bamboo species,
2. To investigate the number of node per culm and to determine the specific length of internodes and the culm length of each species.
3. To observe the development of new shoots in terms of green weight and solid volume.

4. MATERIALS AND METHODS

4.1. Materials

4.1.1. Selected bamboo species

The following materials are selected for study.

(1). *Bambusa polymorpha* Munro. (Kyathaung-wa)
(2). *Cephalostachyum pergracile* Munro. (Tin-wa)
(3). *Dendrocalamus strictus* Nees. (Hmyin-wa)

4.2. Description of Study Site

The experiments were conducted at the compartment No. (9) and (18) of Ngalaik Reserved Forest in Pyinmana township. It is situated approximately 19° 56´ N and 95° 56´ E. at an elevation of 170- 225 m above sea level. This ridge belongs to northern part of Bago Yoma. The soil is sandy loam and has 5.76 - 6.77 p^H.

4.2.1. Topography

The study area is a ridge of Bago Yoma, which ridges generally stretch in north-south direction.

4.2.2. Soil

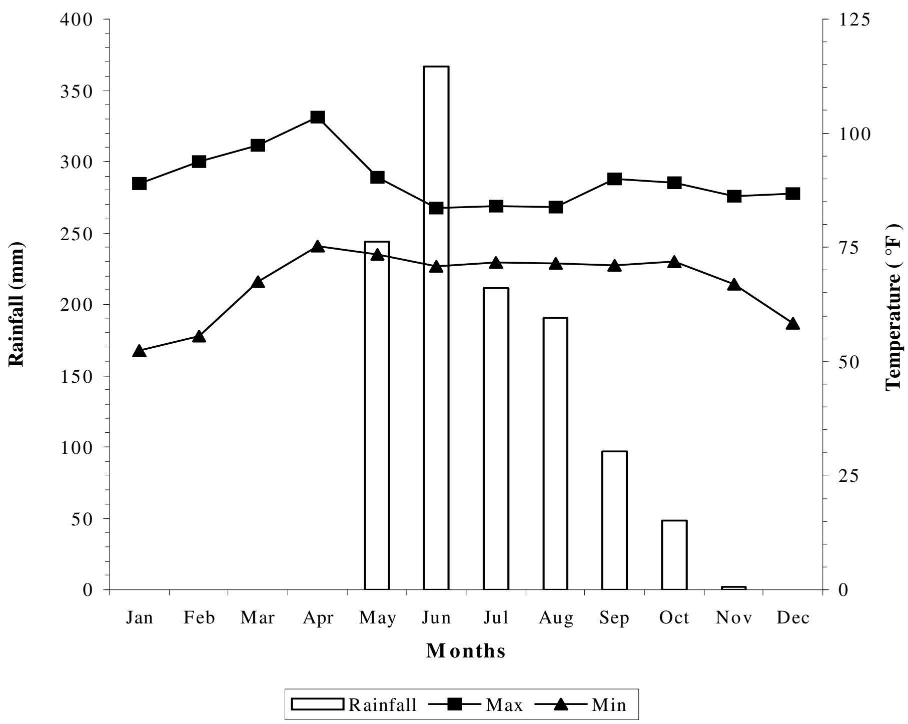
The soils are mostly yellow brown mountain forest soils of tropical monsoon forests. The samples were analyzed at the F.R.I. The data related to dry weight of the soil sample are given in the Table 1.

Table (1) Physical Properties of the Soil Smaples of the Investigated Stands

Texture	Soil sample from 50 cm	
	Kyathaung-wa & Tin-wa	Hmyin-wa
Sand %	81	61
Silt %	9	18
Clay %	13	19
Moisture Content	6.75	6.45
P^H	5.76	6.77
Remark	Sandy loam	Sandy loam

Analysis of soil samples revealed the acid nature of soils. Soil pH ranged from 5.76 to 6.77 at the depth of 50 cm site respectively.

Figure (1) The Climatogram of Moeswe, Pyinmana Township (Year 2001)



4.3. Methods

4.3.1. Shoot-culm height growth measurement

Twenty new-shoots of each bamboo species were randomly selected and measurement of daily height growth was made. The selection and measurement were done in the selected site in Ngalaik Forest Reserve in Pyinmana Township.

The plot size for the investigation was (20 x 20) m for each species. From sample plot 20 new-shoots of the year were selected randomly and cut.

For measuring the length and diameter and to calculate the solid volume, each culm was cut into 4 equal parts. The thickness of the culm wall was obtained by subtracting the hollow diameter from the outer diameter. Fresh weight of the whole culm was also measured.

The solid volume of each section was calculated using the following Leuvina′s formula (1985) :

$$V = \frac{[(B_a - B_h) + (b_a - b_h)]\, L}{2}$$

Where;

V = Solid volume cubic centimeter of the section.

B_a = Area in square centimeter at the basal end of the section.

B_h = Area in square centimeter at the basal end of the hollow section.

b_a = Area in square centimeter at the apical end of the section.

b_h = Area in square centimeter at the apical end of the hollow section.

L = Length in centimeter of the section.

Total green weights in kilogram were derived by summing up the value of each section.

4.4. Data Analysis

Data on length, diameter and volume of the new shoots were subjected to Analysis of Variance (ANOVA) using IRRI STAT software programme. Means were compared using Duncan' s Multiple Range Test (DMRT).

5. RESULTS AND DISCUSSION

5.1. Height, Weight and Solid Volume of the Three Bamboo Species

5.1.1. Emerging of new-shoots

The new shoots started to emerge from the soil mostly at the beginning of the rainy season. The starting emerging times were different among the species. That was first week of May for *B. polymorpha*, second week of May for *D. strictus* and after second week May for *C. pergracile*. *B. polymorpha* was earlier about two weeks than the other, out of which *C. pergracile* was later, which continued to July-August.

Results on the percentage of survival and new shoot production capacity from rhizome were presented in (Table 2). The results showed that the survival percent ranged from 85.52 % to 77.68 % and mortality per cent ranged from 14.18 % to 22.32 %, which varied from species to species.

Table (2) New Shoot Production Capacity of Rhizome in Growing Season (20 Sample Clumps)

Species	Total shoot	Average Shoots/clump	Mortality %	Survival %
B. polymorpha	141	7	14.18	85.82
C. pergracile	112	5	13.73	86.27
D. stritus	102	5	22.32	77.68

Capacity to develop new shoot productions of *B. polymorpha* was found to be higher in number than *C. pergracile* and *D. strictus*, which may be due to the differences in species and may also be due to clump congestion. Among the selected bamboo species *C. pergracile* had highest survival rate which had the thin-wall culms.

Banik (1983) stated that all emerging culms do not develop into fully grown culms. The natural mortality of emerging culms tends to be high (28-69%) in thick walled and tall species and low (9-37%) in thin-walled and shorter species. Mortality percent of emerging culms is higher (50-60%) in September and October when average rainfall is low. According to Banik statement which contradicted my research findings.

The data showed that the mortality percent of the new shoots were 14.18% in *B. polymorpha*, 13.73% in *C. pergracile* and 22.32% in *D. strictus* respectively when the average rainfall was 222 mm in May to August. Eco-physiological conditions – such as clump congestion, soil moisture, food storage and genetic make-up of each species seem to influence the rate of mortality of emerging culms.

The new shoots emerged during at May and continued to July – August in the observed locality but which can be different in other localities. Ueda (1960) also studied the emergence of new shoots for tropical bamboos, the shoots to emerge from the soil mostly at the beginning of the rainy season of tropical region. Pearson et. al. (1994) stated that the production of shoots was seasonal in temperate climates and may be more closely correlated with precipitation patterns in tropical habitats.

The present results of emerging time were found to be close to above mentioned literatures.

5.1.2. The growth rate of new shoot elongation

The growth rates of culms in terms of culm height were found to be significantly different. Culm height measured from soil level to reach the specific height varied in observation.

The specific culm-height reached for one year growth at 18 weeks (120-125 days) for 14-15 m in *B.polymorpha*, 16 weeks (100-110 days) for 13-14 m in *C. pergracile* and 13 weeks (80-91 days) for 12-13 m in *D. strictus* (Figure.2) (Table 3). About 13 weeks after emerging shoot, the height of selected bamboo species had the nearly same height, when the *D. stricus* reached their specific height.

The maximum length-growth per day for different species, 27.74 cm (with mean of 11.82 cm) for *B. polymorpha*, 19.64 cm (with mean of 11.83 cm) for *C. pergracile* and 34.76 cm (with mean of 13.72 cm) for *D. strictus* were recorded. The daily height elongation rate of the new shoots of different species were similar pattern in diagram, (Figure 2) in that they start slow and faster after sometime and than slowed down in the end (Figure 3).

Table (3) Comparison for Means Height of New Shoot among Different Bamboo Species of Observation after Shoot Emerging from the Soil.

Species	Mean Culm Height (cm) at Successive Week								
	1 WAE	2 WAE	3 WAE	4 WAE	5 WAE	6 WAE	7 WAE	8 WAE	9 WAE
B.polymorpha	9.19	17.53	29.84	63.66	119.18	219.21	367.57	524.39	692.65
C. pergracile	14.09	41.70	103.5	205.13	316.99	425.29	547.61	674.24	795.57
D. strictus	20.08	79.92	209.03	390.66	592.35	762.71	918.87	1048.67	1137.34

Species	Mean Culm Height (cm) at Successive Week								
	10 WAE	11 WAE	12 WAE	13 WAE	14 WAE	15 WAE	16 WAE	17 WAE	18 WAE
B.polymorpha	867.36	1021.75	1147.31	1252.15	1335.78	1408.08	1459.98	1484.93	1488.71
C. pergracile	938.4	1046.07	1147.52	1220.81	1280.0	1318.30	1324.99		
D. strictus	1198.51	1233.82	1248.62	1249.99					

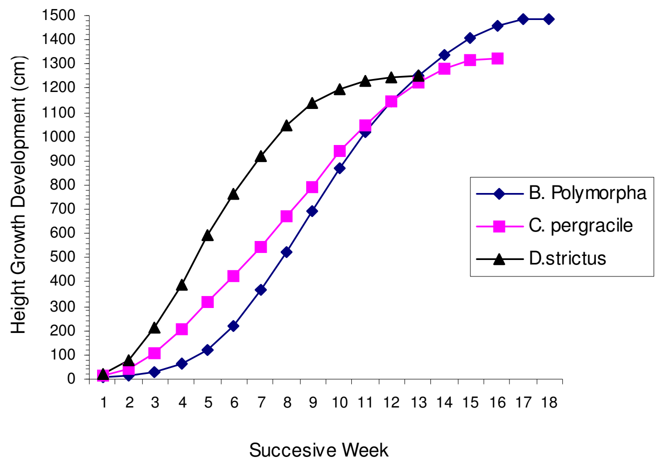


Figure 2. Mean Weekly Height Growth Development of the New Shoot of Three Bamboo Species

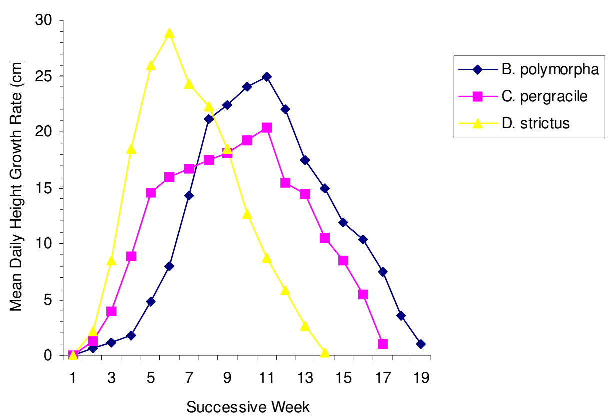


Figure 3. Mean Daily Height Growth Rate of the Three Bamboo Species

The growth and development in terms of culm height growth of three bamboo species indicated that there were marked differences among the different bamboo species (Fig 3). In that, the height growth of *D. strictus* was greatest. It was also noted that time taken for *Dendrocalamus strictus* to get its specific height was faster than the other *B. polymorpha* and *C. pergracile*, which taken place in 13 weeks after emerging from the soil (Fig 2).

The weekly elongation patterns of the new shoots of different species showed similar in diagram (Fig 2 & 3). Elongation pattern which was slow at the beginning and faster after a few days and then slowed down when the culms approached the specific length and when branches started to develop. These results are similar for the different bamboo species. This observations were similar with those of Ueda (1960) and Xiong et.al. (1974).

In this study, Its was found that required time to reach the specific height for three bamboo species was different viz. for *D. strictus* it took about 80-91 days, for *C. pergracile* 100-110 days and for *B. polymorpha* about 120-125 days. This period may be varied with species as well as localities. The similar findings were reported by Chimera (1987), Xiong (1989) and Banik (1991). In their works on *Bambusa* species, such as *B. balooca* and *B. vulgaris* average about 55-60 days, and 50-60 days in some large size species while 30-40 days in middle or small size.

The maximum length-growth per day for different species were different in the cited literatures. The highest elongation growth taken place during 5 weeks in *B. polymorpha* and 11 weeks in *C. pergracile* and *D. strictus* respectively, and then after the period of highest elongation, the growth rate of the selected bamboo species were linearly decreased and stopped. Osmaston (1918) and Banik (1993a) stated that the shoot elongation of the daily extension growth amount to about 10-121 cm per day and they cited the some bamboo species, such as *Dendrocalamus giganteus*, *Phyllostachys reticulata*, *Bambusa balcooa*, *Bambusa vulgaris* and *Melooanna baccifera.*

5.1.3. Culm length

In the length growth of the selected species, the results showed that there were not varied significantly at 0.05 % level. The different means of culm length ranged from 11.52 to 13.71 m. *B. polymorpha* gave the best length performance (13.71 m) compared to *D. strictus* the shortest length (11.52 m) (Table 4). However, the ANOVA (Appendix II, Table 1) indicated that, the culm length development were significant at the 5 % level in term of culm length.

Table (4) Means Comparison for the Total Length of Culm among the Three Bamboo Species (m) (Ave. 20 Rep)

Species	Ranks	Means
B. polymorpha	3	13.7135 b
C. pergracile	2	12.3660 ab
D. strictus	1	11.5150 a
Mean		12.5150

A common letters are not significantly different at the 5 % level by DMRT.

According to the base of the original data, internode lengths of the three species were the similar pattern and indicated that the internode of the mid section of culms growth in length were longer than internodes of the lower and apex portion. The longest internodes had between 10-20 internode and about 71.81 cm long in *B. polymorpha,* 5-15 internode and about 61.75 cm long in *C. pergracile* and 10-20 internode and about 36.41 cm long in *D. strictus* (Figure 10).

5.1.4. Diameter of culm

Means diameters of breast height were significantly different at 5 % level by DMRT. But ANOVA of D.B.H of selected species (Appendix II, Table 2), diameter growths were highly significant at the 1 % level. The means of diameter of culm at breast height ranged from 4.75-6.76 cm. The biggest was *B. polymorpha*, the middle was *C. pergracile* and the smallest was *D. strictus* (Table 5).

Table (5) Means Comparison for the D.B.H of Culm among the Three Bamboo Scies (cm) (Ave. 20 Rep)

Species	Ranks	Means
B. polymorpha	3	6.7570 c
C. pergracile	2	5.5070 b
D. strictus	1	4.7455 a
Mean		5.66983

A common letters are not significantly different at the 5 % level by DMRT.

There were positively correlated between diameter at breast height and the total length of culm for all the selected species. Based on the regression equations, the total length of culm can be estimated when the D.B.H. of culm only is known. This observation agreed with the Numata's statement (1987), he observed that the total length of some tropical bamboo species were closely related with their diameter.

5.1.5. Correlation between D.B.H and length

The relationship between D.B.H. and length growth of each species were determined in this study. Based on the regression equations (Table 6) generated from sample culm data. For correlation between D.B.H and length of each species, in *B. polymorpha* had positively and highly correlated, in *C. pergracile* had also positively correlated and in *D. strictus* had positively related (Figure 4 ,5 & 6).

Table (6) Regression Equations to Estimate the Total Length of each Bamboo Species

Species	Equations[a]
B. polymorpha	Y = 1.7939 X + 1.5967 (r^2 = 0.803 * *)
C. pergracile	Y = 1.9380 X + 1.6934 (r^2 = 0.6930 *)
D. stricus	Y = 1.2108 X + 5.7693 (r^2 = 0.1564 *)

[a] where: Y = Total length of culm in m
X = Diameter at breast height of culm in cm
r^2 = Correlation coefficient
*= significant at the 5 % level
**= highly significant at the 1 % level

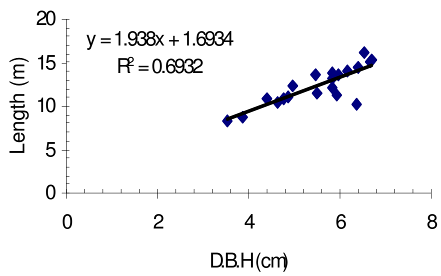


Figure 4. Correlation and Regression of Diameter and Length of *Bambusa polymorpha*.

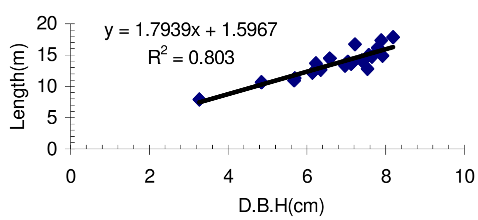


Figure 5. Correlation and Regression of Diameter and Length of *Cephalostachyum pergracile*.

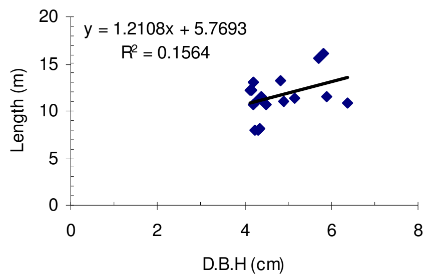


Figure 6. Correlation and Regression of Diameter and Length of *Dendrocalamus strictus*.

5.1.6. Total green weight of culm

Mean comparison of total green weight of culm indicated that the *D. strictus* and *C. pergracile* were not significantly different in this experiment, and were highly significant at 1 % level by the one way ANOVA (Appendix II, Table 3). Comparison of means weight of the different species were 15.91 kg for *B. polymorpha*, 10.95 kg for *C. pergracile* and 11.21 kg for *D. strictus* (Table 7).

Table (7) Means Comparison for the Total Green Weight of Culm among the Three Bamboo Species (kg) (Ave. 20 Rep)

Species	Ranks	Means
B. polymorpha	3	15.91 b
C. pergracile	1	10.947 a
D. strictus	2	11.210 a
Mean		12.689

A common letters are not significantly different at the 5 % level by DMRT.

5.1.7. Solid volume of culm

The effects of species on solid volume were found to be highly significant at the 1 % level by ANOVA (Appendix II, Table 4). The highest and lowest means of solid volume were observed in *B. polymorpha* (17884.70 cu cm) and in *C. pergracile* (8831.83 cu cm) respectively (Table 8), which were significantly different at the 5 % level by DMRT.

Table (8) Means Comparison for the Solid Volume of Culm among the Three Bamboo Species (cu cm) (Ave. 20 Rep)

Species	Ranks	Means
B. polymorpha	3	17884.70 c
C. pergracile	1	8831.83 a
D. strictus	2	10698.70 b
Mean		12538.41

A common letters are significantly different at the 5 % level by DMRT.

5.1.8. Weight-volume equations

The relationship between green weight and solid volume of the different bamboo species (Table. 9) was also determined It was found that the average number of bamboo per 1,000 kg (1 ton) in fresh weight and the equivalent solid volume of the three species varied.

Based on the regression equations (Table. 10) generated from sample culm data, it was noted that the highest total solid volume (Table. 11) was given by *Bambusa polymorpha*, *Dendrocalamus strictus* and *Cephalostachyum pergracile*.

Table (9) Average Green Weight and Solid Volume of the Different Species per Culm Base on the Sample Culms

Species	Weight (kg)	Volume (cu cm)
Bambusa polymorpha	15.91	17884.70
Dendrocalamus strictus	11.21	10698.70
Cephalostachyum pergracile	10.95	8831.83

Table (10) Regression Equation to Estimate the Total Volume per Culm of each Bamboo Species

Species	Equation[a]
B.polymorpha	$Y = 1196.4 X - 2550.6$ $r^2 = 0.3473$ *
C. pergracile	$Y = 1536.7 X - 7640.1$ $r^2 = 0.7578$ **
D. strictus	$Y = 1688.4 X - 8228.8$ $r^2 = 0.7624$**

[a] where: Y= volume in cu cm
X= weight in kg
r^2= correlation coefficient

* significant at 5 % level

** highly significant at 1 % level

Table (11) Average Number of Bamboo Culms and the Equivalent Solid Volume per Metric Ton (Fresh Weight) of the Three Bamboo Species

Species	Number/1000 kg Range	Mean	Equivalent Solid Volume (cu cm)
B. polymorpha	44-138	63	1126736.1
D. strictus	57-183	89	952184.3
C. pergracile	68-120	91	803696.5

According to the result of correlation and regression between total green weight and solid volume, they were positively correlated in *B. polymorpha* at the 5 % level and highly and positively related in *C. pergracile* and *D. strictus* at the 1 % level. (Figure 7, 8 & 9).

In this research, green weight and solid volume of each selected species were directly correlated between them. Leuvina et.al. (1985) observed that some tropical bamboo species of Phillippine had the correlation between green weight and solid volume.

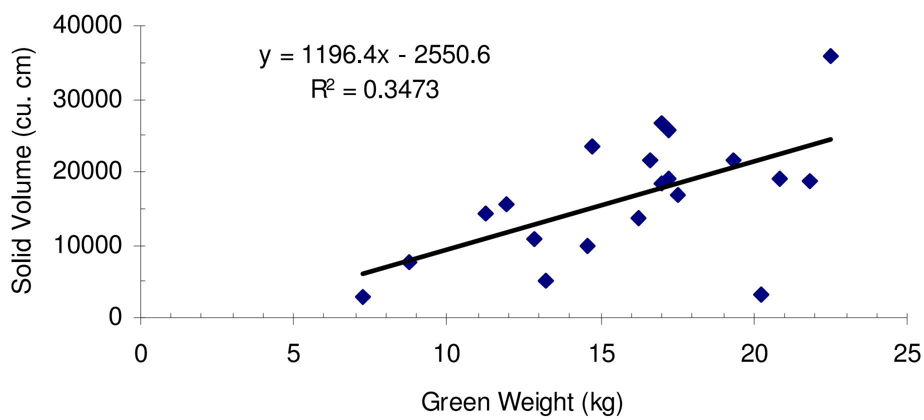


Figure 7. Regression between Green Weight and Solid Volume of *Bambusa polymorpha*.

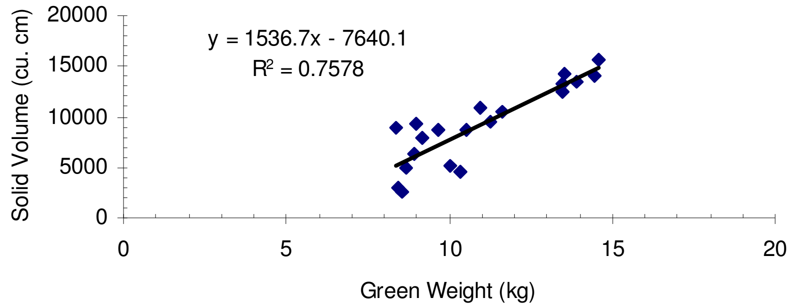


Figure 8. Regression between Green Weight and Solid Volume of *Cephalostachyum pergracile*

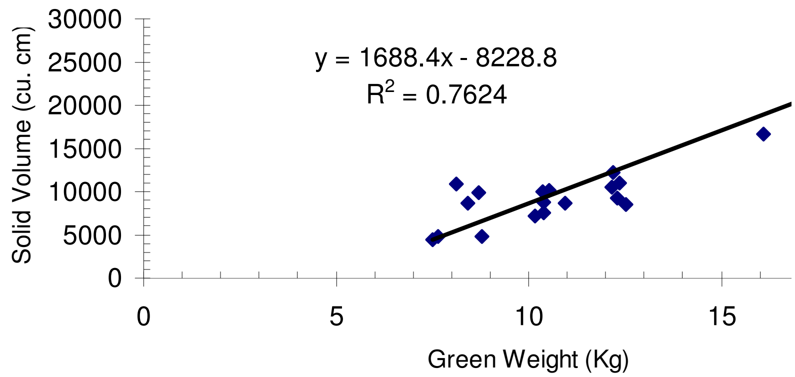


Figure 9. Regression between Green Weight and Solid Volume of *Dendrocalamus strictus*.

5.1.9. Diameter and length of internodes of the culm

The diameter growths of internodes in different three bamboo species were also similar in pattern. It was found that growth of internode diameter decreased linearly from the base to the apex in all selected species (Figure 11).

The average internode length of *Bambusa polymorpha* is the longest and the *Dendrocalamus strictus* is the shortest of the three species. The highest number of internode per culm is found in *Dendrocalamus strictus* among the selected species. These variations may be due to the difference in species. In my research finding, the internodes of the selected species are short at the basal portion, longer in the middle and again shorter towards the tip. It may be due to seasonal effect or the physiology of plant. This findings are similar to the statement of McClure(1966), Chaturvedi (1988) and Pearson et.al.(1994),they found that along the length of a culm, the lower most few internodes are fairly short, those in mid-section are more elongated, and those toward the apex become shortened.

According to the results of the diameter growth, the growth of internode diameter decreased linearly from the base to the apex in all selected species.

The similar results can be agreed with the findings of Person et. al (1994), he found that internode diameter decreases linearly from the base to the apex in *Chusquea culeou.*

This research on bamboo shoot elongation can be of use to bamboo management work of forest department because it focused on shoot emergence, rate of elongation in height, estimation of specific height of three commercially important species. e.g., *Bambusa polymorpha*, *Cephalostachyum pergracile* and *Dendrocalamus strictus.*

The site location for the research appropriates the ecological requisite as all the three selected species grow naturally in this area. The species chosen are of clump forming types. The whole research program encompassed, time and season of culm height growth, duration or time taken to reach each specific height, length of internodes of the three species, which can contribute to the silvicultural aspects of the bamboos.

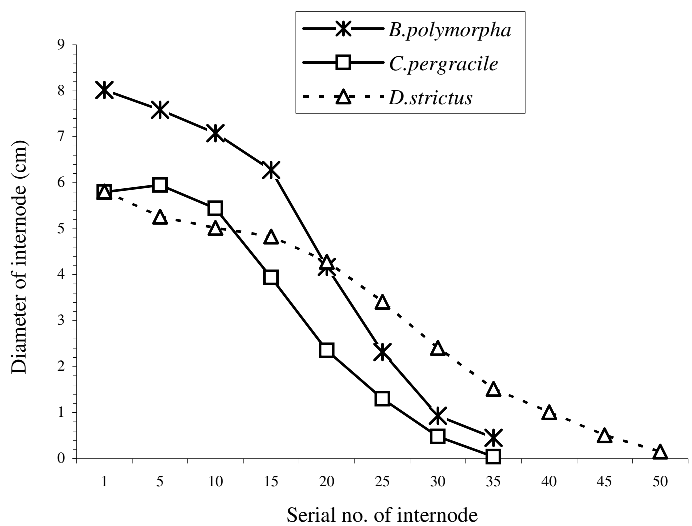


Figure 10. Diameter of the internode at different portions in the culms of three bamboo species

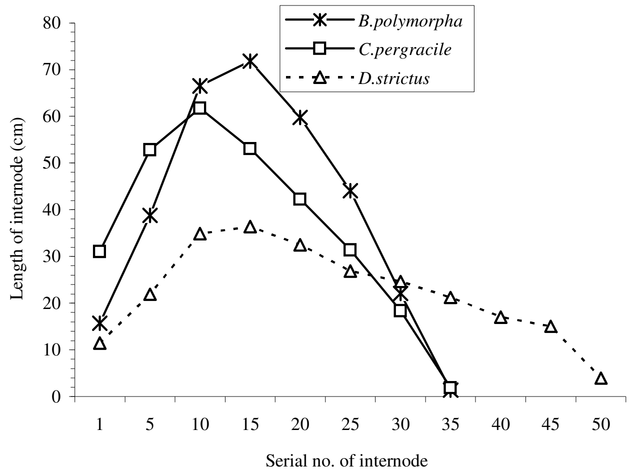


Figure 11. Length of the internode at different portions in the culms of three bamboo species

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The results of the experiments indicated that the following conclusions could be drawn.

(1) The results showed that the specific height growth experiments *Bambusa polymorpha*, *Cephalostachyum pergracile* and *Dendrocalamus strictus* can reached their specific height growth of culm within one growing season. The duration of reaching the specific height varied with species.

(2) New shoots emerged in May at the start of rainy season. The *Bambusa polymorpha* emerged earlier than the other two, which are smaller in size.

(3) New shoots of the selected bamboo species grew on the out side of the clump centrifugally.

(4) The daily mean growth elongation measured, showed that the *Bambusa* grows slower and the *Cephalostachyum* a little faster and the *Dendrocalamus* the fastest.

(5) The pattern of the height growth and culm development of the different species are similar, in that they start slow and faster after sometime and then slow down in the end.

(6) The diameter of the culms of the three bamboo species decreased linearly from the base to apical tip.

(7) The length of internodes at the middle portions of the culms were longer than those at the base or apical portion.

(8) Shoot-culm height growth started at the basal internodes and then to the upwards continuously.

(9) The total length of the culm and the D.B.H. are correlated. The length of the specific height for the first year growth can be estimated by measuring the D.B.H. of the culm.

(10) Of the three bamboo species studied, *B. polymorpha* was observed to have the biggest diameter and the longest culms.

(11) *D. strictus* had the smallest average diameter but the thickest wall.

(12) *C. pergracile* was found to be the second large species, but had very thin culm-wall.

(13) Significant linear positively relationship between green weight growth and solid volume of the sample culms for all the species studied.

6.2. Recommendations

According to the results obtained in this research, the following recommendations should be made.

(1) Environmental factors affecting bamboo growth, such as rain fall, relative humidity, temperature, which influence on new shoot production capacity of some commercial species should be studied.

(2) Fertilizer affect on bamboo growth with treatment in different ratio of Nitrogen, Potassium and Calcium should be tested, when commercial plantations of bamboo are to be established.

(3) The bamboo resources are one of the most important non-wood forest products for rural people, which must be properly managed. The phenomenon of the emergence and shoot-culm growth must be thoroughly studied which are the factors influence the clump formation and yield of culms per clump.

(4) Bamboo should be harvested only at the end of growing season, that is, sometime around end of December, to ensure the progressive development and to give strength to the regenerating new shoots.

Appendix I

Some Important Commercial Bamboo Species in Myanmar

No	Botanical Name	Myanmar Name
1.	*Bambusa arundinacea* (Retz.) Willd.	Kyakat-wa
2.	*Bambusa longispiculata* Gamble.	Tabindaing-wa
3.	*Bambusa polymorpha* Munro.	Kyathaung-wa
4.	*Cephalostachyum pergracile* Munro.	Tin-wa
5.	*Dendrocalamus brandisii*	Kyalo-wa
6.	*Dendrocalamus giganteus*Munro.	Wabo-gyi
7.	*Dendrocalamus hamiltonii*	Wabo-myetsangye
8.	*Dendrocalamus longispathus* Kurz.	Wanet
9.	*Dendrocalamus membranaceus* Munro.	Waphyu
10.	*Dendrocalamus strictus* Nees.	Hmyin-wa
11.	*Dinochloa m' clellandi* Gamble & Kurz.	Wanwe
12.	*Melocanna bambusoides* Train.	Kayin-wa
13.	*Oxytenanthera nigrociliata* Munro.	Waya
14.	*Thyrsostachys siamensis* Gamble.	Htiyo-wa

Appendix II

Table (1) Balanced Analysis of Variance for Total Culm Length of the Three Bamboos Species (m)

Sources of Variance	DF	Sums of Squares	Means Squares	F-ratio
Bamboo Species (s)	2	49.15573	24.57787	4.92 *
Error	57	284.62163	4.99336	
Total	59	333.77736		

cv = 17.8%
* = significant at 5% level

Table (2) Balanced Analysis of Variance for D.B.H of The Three Bamboos Species (cm)

Source of Variance	DF	Sums of Squares	Means squares	F-ratio
Bamboo Species (s)	2	41.256763	20.628382	22.12 **
Error	57	53.153535	0.932518	
Total	59	94.410298		

cv = 17.0%
* * = significant at 1% level

Table (3) Balanced Analysis of Variance for Total Green Weight of the Three Bamboos Species (kg)

Sources of Variance	DF	Sums of Squares	Means Squares	F-ratio
Bamboo species	2	311.93692	155.96846	15.22 **
Error	57	584.10982	10.24754	
Total	59	896.04674		

cv = 25.2%
* * = significant at 1% level

Table (4) Balanced Analysis of Variance for Solid Volume of the Three Bamboos Species (cu cm)

Source of Variance	DF	Sums of Squares	Means Square	F-ratio
Bamboo Species (s)	2	0.913847 E+09	0.456923 E+09	11.31* *
Error	57	0.230201 E+10	0.403862 E+08	
Total	59	0.230201 E+10		

CV =51.0 %

* * = significant at 1 % level

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