Ecological Studies on Cultivation of Tropical Bamboo Forest in The Philippines

By

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Summary : Understanding of the ecology and distribution of the tropical bamboo forests is a prerequisite for the cultivation of bamboo forests and the improvement of forest production. The site conditions of bamboo forests, which are distributed in tropical regions were therefore studied first. Secondly, the production structure of some useful tropical bamboo species was drawn using the data of fundamental studies including growth periods of bamboo shoots, culm analysis, relationship between D. B. H. and the length of culms, the relative growth relationship between dry weight of culm and D^2H, and moisture contents. Thirdly, standing crops and annual production were estimated from these results, i. e., standing crops of *Bambusa blumeana*, *Bambusa vulgaris* and *Schizostachyum lumampao* on a dry weight basis were found to be about 180 tons, 130 tons and 80 tons per hectare respectively, and each annual production was about one fourth of the standing crops. Bamboo species which propagate by non clump-forming type are suited for offset, while clump-forming type bamboos are suited for cuttage. Both the selection of cutting materials and the method of cutting to obtain the most effective cuttage were subsequently investigated. The lower portions of young and large culm which were grown in the latter half of the rainy season proved to be the best material for cuttage. The best method of cutting was found to be a section of material culm having one node at the center of it and laid horizontally under the ground at about 20 cm in depth. It was also clarified that if a bamboo forest is cultivated with culm cuttage, culms can be felled within five years after planting. Seed obtained after bamboo flowering can be used for propagation by seedling, but sexual propagation was less efficient than vegetative method in bamboos.

Further research works on bamboo cultivation are recommended.

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Introduction

In the coming 21st century, the perennial problem of mankind will be the production of enough food for the worlds' ever-increasing population. Today, man has realized an equally important problem, that of managing and maintaining the world' natural resources. Among these is the tropical forest including bamboo forests which have to reckon with many difficulties such as variability in structure, species and growth habits. Yet, if it is managed for sustained-yield, the tropical forest can be an inexhaustible source of goods and services. More often than not, some bad practices contrary to sustained-yield principles are perpetuated in the tropics due to negligence and lack of knowledge. Prominent among these is harvesting more than what the forest resouce can produce. As a result, reproduction can not keep up with exploitation. It has been proved that if exploitation can be controlled and combined with natural and artificial regeneration, a productive tropical forest can be restored and made productive.

Narrowing our considerations from tropical forests in general to bamboo in particular, bamboo adapt very well in places where trees naturally grow. More than 1,200 species of bamboo are growing over a total of 14 million hectars of land throughout the world, and about 80 per cent of that area is distributed in the Southeast Asian tropical region. Climatic conditions such as high temperature and humidity including favorable edaphic conditions of generally sandy loam to clay loam are conducive to the growth and proliferation of bamboos in the region.

Mature bamboo culms are traditionally used for house construction, various agricultural tools, fish pens and fish traps. The pulp and paper industry depends on bamboos for raw materials. Some bamboo species are good for landscaping, as windbreaks and hedges. Furthermore, the bamboo forest can be used as a reforestation crop. Despite the present rapid strides of plastics and other synthetics as raw materials for various purposes, bamboos continue to be an indispensable material for man's needs.

Recently, the Philippine Council for Agriculture and Resources Research (PCARR) approved two projects for implementation, namely : (1) Studies on some aspects of the utilization of bamboo, and (2) Research on the production and harvesting of various bamboo species. These projects are admirable. Nevertheless, more research is needed to fully unveil and develop the economic potentials of bamboos.

In a symposium held at the FORPRIDECOM Conference Hall on September 29, 1976 the importance of bamboos to everyday life was stressed. It has been accepted that bamboos as raw materials for processing are easier to work on than lumber.

As the quality of the product is improved, the commercial value is increased.

Its economic potential is so great that it would be advantageous to regenerate, maintain and fully utilize this minor forest products resource.

Bamboo species like *Bambusa*, *Dendrocalamus* and *Schizostachyum* genera which grow in the tropical region belong to the clump forming type. Characteristic of this type of bamboo is that the bigger buds at the lower portion of culm located under the ground surface sprout directly above the ground and grow into culms, forming a clump of culms with short rhizomes. Some studies on the propagation of this type of bamboos and its maintenance in plantation were conducted[7)32)]. However, bamboo ecology and breeding were never studied in detail till now. Additional knowledge along these lines may lead to bigger discoveries.

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I. The ecological distribution and characteristics of some Philippine bamboos

1. Distribution of Bambuseae in tropical regions as a background of Philippine bamboos

On a world-wide basis, native species of bamboos occur in all continents except Europe and North America[11]. The genus *Bambusa* has the largest number of species that occur principally in the tropics and mild climates, though a few are native to the temperate regions. The genus *Oxytenanthera* is found in Africa and Asia; *Schizostachyum* in Madagascar, Asia and some of the Pacific Islands including Hawaii; and *Cephalostachyum* and *Ochlandra* are both in Madagascar and Asia. No genus occurs in more than one sector of the tropics and some are narrowly distributed. About 90 per cent of the 47 or so genera are either in Asia or in Latin America, the species being more numerous in the former. The occurrence of bamboo in tropical Africa is remarkably small, only about 8 genera and 14 species (Appendix 1).

Bamboos comprise a large portion of the tropical forest in Southeast Asia notably in Burma, Cambodia, India, Indonesia, Laos, Malaysia, Papua New Guinea, Bangladesh, the Philippines, Sri Lanka and Vietnam. Genera found in these countries include *Arundinaria*, *Bambusa*, *Thyrsostachys*, *Gigantochloa*. *Dendrocalamus*, *Ceplortachys* and *Melocanna*. In temperate countries in Asia, such as China and Japan, *Phyllostachys* and *Sasa*[37] are the most common genera.

In Latin America, the genus *Guadua* is most prominent and at higher altitudes the genus *Chusquea* is the most dominant. Only two species are native to North America, namely *Arundinaria gigantea* and *A. tecta*[3].

2. Limiting factors on the distribution of bamboos

(1) Latitude

All the bamboo species of the world except *Sasa** naturally grow within 40 degrees on either side of the equator, particularly in the area of the Tropic of Cancer on the northern side and in the Tropic of Capricorn on the southern side. They are gregarious in two categories, namely : (1) bamboo forest in extensive areas, and (2) in groups or colonies. Bamboos that grow together in the first category are more or less confined wihthin 15～25 degrees of either side of the equator, including the southern part of the Peoples' Republic of China, Burma, Thailand, Laos, Vietnam, India and Bangladesh, all in Southeast Asia. In the western world, more grow in Nicaragua, the Honduras, Guatemala and Mexico. On the other hand, only colonies of bamboos occur in Peru, Chile, Paraguay, Bolivia, Madagascar, Mozambique and Rhodesia in areas reaching to 40 degrees south of the equator where the species becomes limited.

Based on the growth habits, the sympodial or clump-forming type represented by the genera of *Bambusa*, *Schizostachyum* and *Dendrocalamus* occur mostly northward from the equator

* *Sasa* refers to bamboos, consisting of 6 genera, that reach a maximum height of 5 meters. They grow in the temperate zone. Of the 6 genera, leaves of 2 can be used as a feed for cattle. They are a very persistent nuisance in forest plantations.

to about 30 degrees latitude. The monopodial or non clump-forming type represented by the genera *Phyllostachys*, *Semiarundinaria*, and *Sasa* predominates beyond 30 degrees latitude. The intermediate type of *Arundinaria* and *Melocanna* overlap with both sympodial and monopodial type at the environs of 30 degrees latitude north of the equator (Fig. 1). The Philippine Archipelago is located from 5～20 degrees north latitude of the equator. This country is within the region with climatic conditions that are most favorable for the growth of ***Bambusa***, ***Schizostachyum*** and ***Dendrocalamus***. The species are generally scattered from north to south in the islands. Only one species of *Phyllostachys* 〔*P. nigra* var. *henonis* (MITF.) STAPF. ex RENDLE〕 grows favorably in the Philippines. Other *Phyllostachys* species that were introduced survived, but did not grow as expected. The region of Central and Northern Luzon in the Philippines lies between 15～20 degrees north latitude. The area is very suitable for the growth and development of bamboos. At present, most lands in Central Luzon are tilled for the cultivation of rice, corn, sugar cane, coconuts and other important annual crops. Although bamboos are found in every locality, these are confined to marginal lands, along stream and river banks, in the backyards of the farmers' houses and on the hillsides. It is evident that extensive bamboo plantations occurred in the area about a century ago.

(2) Altitude

Bamboo grows from tropical to temperate forest at about sea level to 2,800～3,200 meters elevation for *Arundinaria maling* in Eastern Nepal. The genus *Chusquea* which has adopted to grow under frost conditions thrives at a maximum altitude of 3,650 meters in Chile[12] and to an elevation of about 5,000 meters in the Andes mountain ranges in this Latin America[24].

Altitude also affects the distribution of bamboo with respect to form or type. The sympodial types were observed to predominate in low and medium altitudes, while the monopodial type occur more abundantly at high elevations. In Central Luzon, the largest among the islands of the Philippines, the sympodial types, namely those belonging to the genera ***Bambusa***, ***Dendrocalamus*** and ***Schizostachyum*** are found in the lowlands. At about 1,500 meters altitude, some species of *Phyllostachys*, the *P. aurea* grow very well.

(3) Temperature

Altitude and temperature are related and it is difficult to separate one from the other. For example, some species of *Phyllostachys* that grow at high elevations in the tropics occur

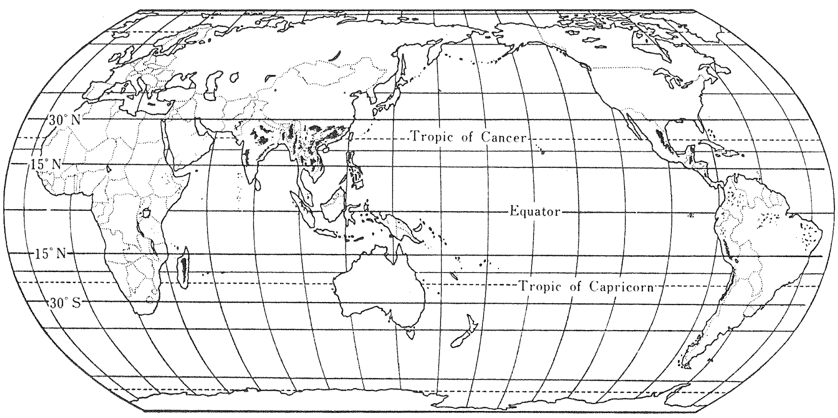

Fig. 1 Distribution map of tropical bamboo in the world with respect to latitude.

also at low elevations in the temperate countries. It was observed that *Phyllostachys aurea* grows well in the vicinity of Baguio at an altitude of 1,500 meters with about 18～26 centigrade temperature. The same species grows in the high elevations of about 800～1,000 meters in Malaybalay, Bukidnon, also with a mild climate. It is interesting to note that *Phyllostachys aurea* occurs also in Kyushu, Southern Japan at an elevation of about 50 meters, where the temperature is similar to Baguio City and suburbs.

Bamboo generally grow well in places with temperatures ranging from 8.8～36 degrees centigrade. However, there are extreme exceptions : *Phyllostachys nigra* var. *henonis* grow in Japan with a minimum temperature of −18 degrees centigrade, and certain bamboo species in India, have become adapted to temperatures as high as 40 degrees centigrade. Incidentally, it can be presumed that tropical bamboo species are inferior to temperate bamboo species for susceptibility and photo sensitivity. For instance, the *Bambusa* which has been planted in Japan, grows faster than temperate bamboo species do during the summer nights when temperatures are higher. This could be explained by the fact that there is a closer affinity in temperature between Japan in the summer season and the native place of growth.

Otherwise, some seedlings of *Phyllostachys pubescence* were planted in the University of the Philippines, College of Foresty in Los Baños, Laguna but the height growth was limited to only about 100 cm in 2 years. It was thought that at night the plant respired and made use of the energy generated during the day.

However, in places with high temperatures during both the day and night, the respiration at night was active and growth was retarded.

(4) Rainfall

Rainfall, a component of climate definitely affects the distribution of bamboos because of its necessity in the growth process. However, there is not a single environmental factor that limits more the growth of bamboos or other plants than rainfall. Until now, reports concerning the relationship between growth of shoots and precipitation were very few[29)36)37)]. The estimated maximum annual rainfall ranges between 1,270～4,050 mm[12)]. The west and south coast of Northern Luzon have comparatively distinct dry and rainy seasons. During the dry season when soil moisture is scanty, the bamboos adapt by shedding leaves thereby reducing transpiration. Then, at the first splash of rain, usually in the later part of May, new buds emerge as a result of more moisture in the soil. Soon the bamboos are crowned with leaves again. This shows that vegetative growth in bamboos are more affected by soil moisture as a result of rainfall than by temperature. Bamboos also retain their green leaves if they are irrigated.

During the dry season those bamboos growing along creeks, streams and lakes retain their leaves all the year round.

(5) Soil

Bamboos grow best on well-drained sandy-loam to clay-loam derived from the river alluvium or from the underlying rocks. Seldom can one find bamboos in swampy places or in wet stream beds. Soils that are suitable for bamboo growing vary in color from yellow, reddish yellow, to brown yellow. A pH of about 5～6.5 is most suitable for bamboos as well as for many other plants. Saline soils along salty bodies of water are not good for the growth and development of bamboos.

In Cardona, Rizal and the vicinities which are about 38 km northeast of Manila, bamboos grow on well-drained stony soils which vary in colour from dark-brown to light red.

Along the west coast of Northern Luzon, the soil shows (based on standard color chart) a dull reddish brown (Hue 5 YR 5/3) and dull yellowish brown (Hue 10 YR 5/4).

In other countries, individual species of bamboo were observed to have well-defined habitats and for this reason the different species were considered as soil indicators. For example, the presence of *Bambusa polymorpha* in Burma is an indication of moist, fertile well-drained soil. *Dendrocalamus strictus*, on the other hand, is associated with dry soil ; and *Cephalostachyum pergracile* indicates the intermediate type of the dry and more moist sites. *Bambusa tulda* occurs on stream bed alluvial flats ; *Oxytenanthera albociliata* on low plateaus or hills on sandy lateritics soil ; *Dendrocalamus longispathus* on the edges of damp ravines ; and *Teinostachyum helferi* in very damp valleys in evergreen forests. In India, *Dendrocalamus strictus* grows well in open stony hillsides, and extends into areas of drier conditions than to other species. *Bambusa arundinacea* occurs on rich and moist sites such as alluvial stretches along streams[12)].

Bamboos grow bigger, both in diameter and height, in places with high humidity and with fertile soil. Bamboos which grow in moist soils generally have leaves of bigger dimension than those species growing in drier sites. Likewise, this holds true for bamboos in sites with more moisture due to rainfall than in sites with drier soils.

3. Ecological characteristics of Philippine bamboos

Some of the more common bamboo species of the Philippines such as *Bambusa blumeana*, *B. vulgaris* and *Dendrocalamus merrillianus* are found growing singly or oftentimes in groups of clumps within the vicinity of residential areas. Sometimes these species are found along creeks and river banks. The presence of *Dendrocalamus merrillianus* is indicative of drier soils, based on the fact that the species occurs only in Central and Northern Luzon which have distinct dry and wet seasons. *Schizostachyum lumampao* and *S. lima* usually grow farther away from towns and villages. Both genera generally occur in the hills but the former which is more sylvan extends deeper into the forest. *S. lumampao* is the most popular species in Zambales and Bataan. Many clumps of *Gigantochlos levis* are growing in Aklan and Capiz, Panay.

For the taxonomy of Philippine bamboo, Gamble[13)] and Brown[5)] reported their studies, and these reports are still used today in this country. Brown described three types of bamboo namely : (1) Symposial type where the rhizomes elongate upward on the ground ; (2) Monopodial type which expands by creeping rhizomes ; and (3) Climbing type like vine. The sympodial and monopodial type of culms are called erect bamboos. The elongation term of erect bamboo is less than 100 days. Climbing bamboos grow for a much longer period than the erect ones. These species are strictly sylvan and are considered more of a liability than an asset because they interfere in the growth and development of desirable tree species. At present, the climbing bamboos are of minor commercial importance.

At present, there are 12 genera and 43 species in the Philippines (See Appendix 2). The following species, introduced from other countries were observed by the author :

1. *Phyllostachys bambusoides* var. *aurea* Makino
2. *P. nigra* var. *henonis* (Mitf.) Stapf. ex Rendle
3. *P. pubescens* Mazel ex H. de Lehaie
4. *Bambusa floribunda* Nakai
5. *B. ventricosa* McClure
6. *Thyrsostachys siamensis* Gamble

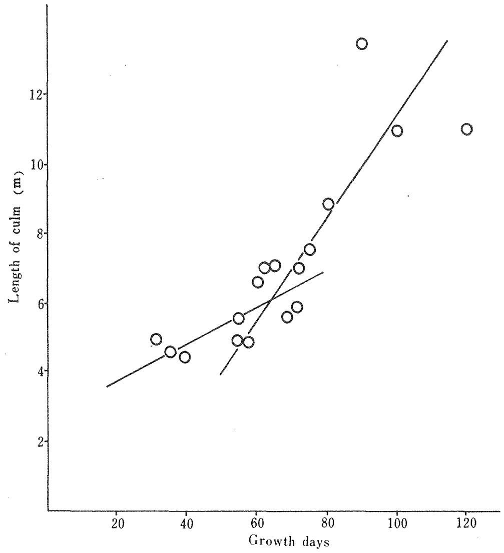

Fig. 2　Relationship between culm length and growth days on *Bambusa vulgaris.*

4. Factors affecting bamboo production

(1) Growth period of bamboo shoots

Bamboo shoots start to grow during the wet or rainy season. In the tropical region, the dry and wet seasons of the year are clearly distinct from one another. The availability of soil moisture and the decreased temperature during the rainy season influence the emergence of shoots. Therefore, data on the rate of growth and quality of shoots are needed for the improvement of silvicultural techniques.

The species used in this study are *Bambusa vulgaris* and *B. vulgaris* var. *striata.*

The tapering of shoots was measured weekly with a plastic measurement tape. The shoots of *Bambusa vulgaris* had a 30～120 days growth period. In Japan, the growth period for *Phyllostachys, Semiarundinaria* is about 30～80 days, and for *Arundinaria,* 40～50 days. In *Bambusa vulgaris,* growth days relate to the length of culm (See Fig. 2). The short growth days have a tendency to produce shorter culms. Dr. Shigematus found that the length of the culm and growth days could be correlated with the linear regression equation as follows :

$$y=a+bx$$

where y=growth days

$a=y$ intercept, constant number

b=slope, constant number

x=culm elongation or height growth attained

In the case of the Japanese species of *Phyllostachys, Sinobambusa,* the value of b is small, which means that the rate of growth of the shoot is slow. In contrast to *Bambusa* species, b tends to have a larger value. Results of the experiment conducted in the provisional nursery of FORPRIDECOM, showed a precise relationship between growth period and elongation. Tropical bamboo species have long periods of growing sprout, resulting in very few leaves on the mother culm. The bamboo sprout eventually grow faster and the amount of elongaiton is bigger in the later part of the rainy season.

In 1976, it was observed in *Bambusa vulgaris* that the first shoot emerged on April 1, and the last which attained its maximum height on January 11, 1977 was observed on November 2. The growth period therefore, of *Bambusa vulgaris* was considered from April 1, 1976 to January 11, 1977 (281 days) for the particular growth season. The shoots that emerged during the months of April and May (early growers) were found to attain lower height growth than those that appeared during October to November (late growers). Furthermore, the early growers had shorter growth days* than the late growers but the difference was not signifi-

* Growth days is the number of days from the time a shoot emerged until cessation of its height growth.

cant.

In order to gain more insight on the effect of late growth on the development of shoots, the emerging period from April 1 to November 2 was divided into 3 categories, namely :

(1) Early growth, those that emerge and grow during April and May,

(2) Intermediate growth, those that emerge and grow during July and August, and

(3) Late growth, those that emerge and grow during October and November.

The test shoots for the three periods were marked and their heights were mesured every seven days. The results are shown in Fig. 3 and 4.

During the latter part of the dry to the early part of the rainy season (April to May), three shoots were sampled for early growers, five shoots for intermediate and seven shoots for the late growers. The growth days were all equated to 100%. The time interval between points on a curve is equivalent to 7 days. The highest point at the curve shows the peak of

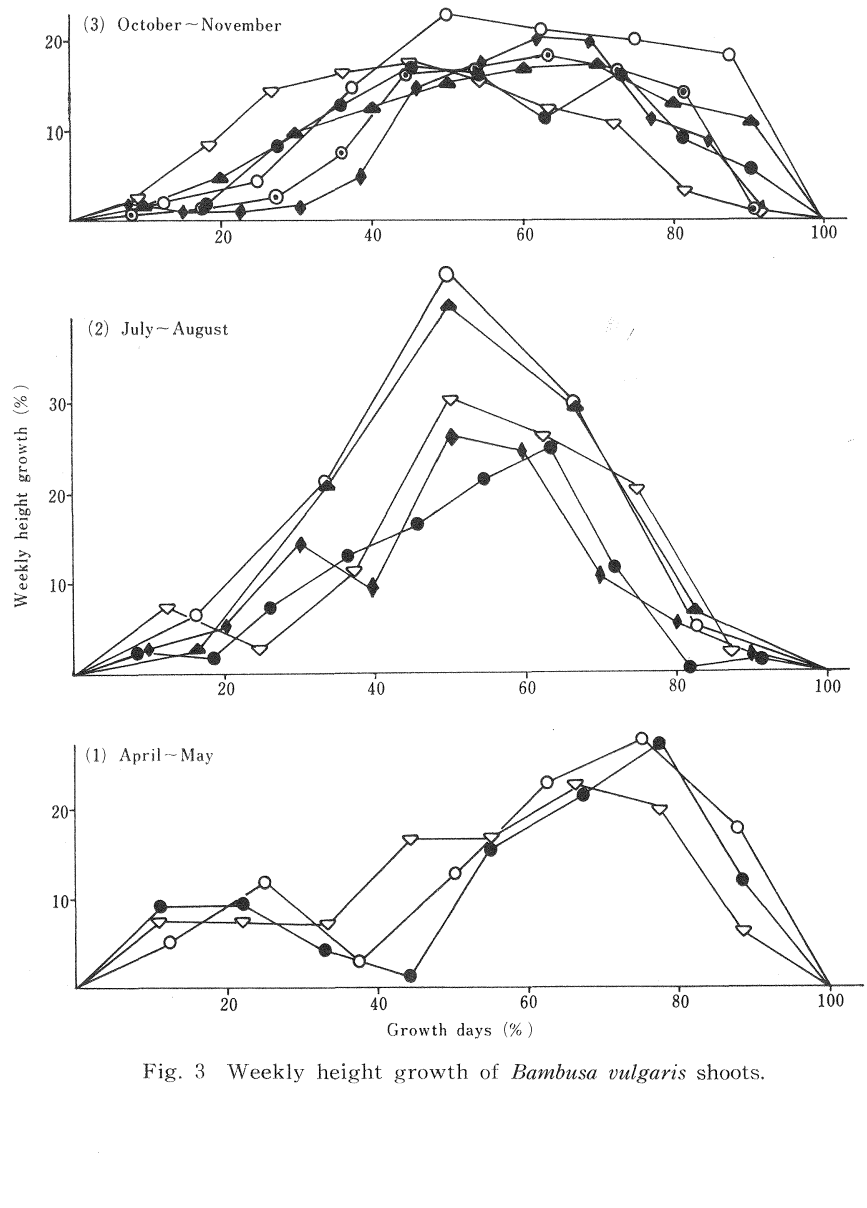

Fig. 3 Weekly height growth of *Bambusa vulgaris* shoots.

growth rate; an ascending segment of the curve shows an increasing rate of height growth.

A high rate of growth can be observed at the point of 70 to 80% during the growth days of the shoots that emerged during April to May. The peak of growth rate for the intermediate period (July to August) can be seen mid-way or at 50% during the growth days. On the late grower, the rate of growth is slow and the point of rapid growth is not distinct. This can be attributed to the decreasing availability of soil moisture that slowed down the growth of bamboo shoots during the latter part of the rainy season and the onset of the dry season. Moreover, compared with those that grew earlier the shoots that grew late on October and November varied widely with respect to their growth behavior. The season for the growth of tropical bamboos is very long, about 7～8 months. During this period, a young culm of *Bambusa vulgaris* that is capable of producing rhizomes, produces from 3～4 shoots during the growth season (Section II-2-(3)). For this reason, growth type, growth days and the length of culm vary during early and late growth. In contrast, Japanese species of *Phyllostachys* have at most a short growth season of only about 2 months.

As to mortality, about 50% of the shoots that emerged from a plantation of *P. pubescens*, die upon reaching a height of 30 cm, which is attributed to the severe competition among the shoots for nutrients. The fittest usually survive but the weak, die. In the natural bamboo

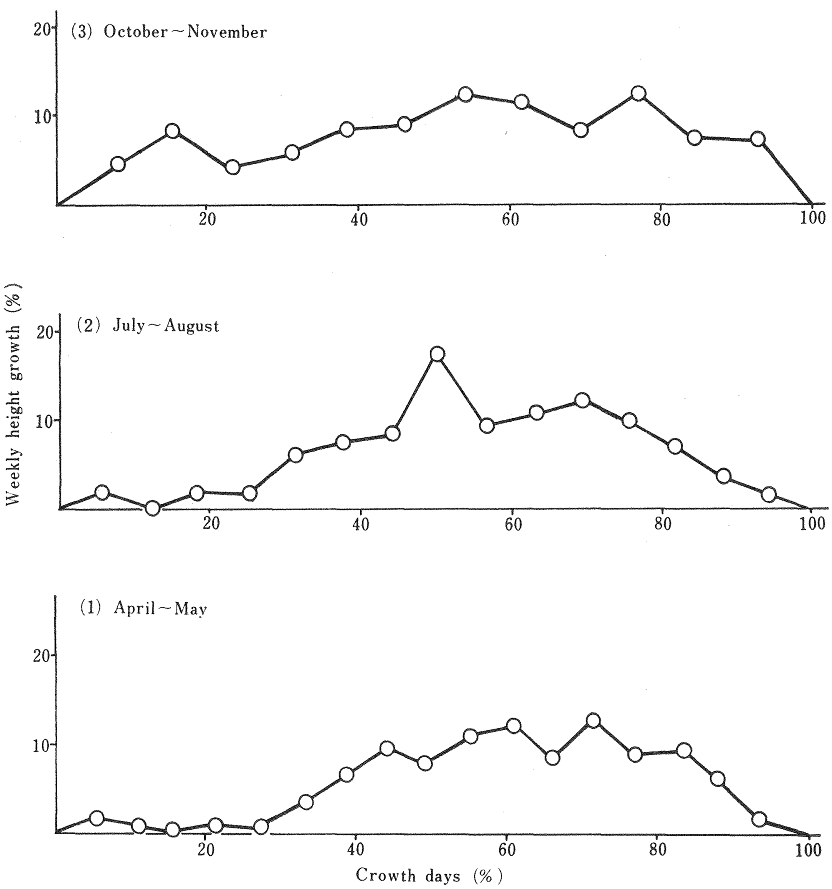

Fig. 4 Weekly height growth of *Bambusa vulgaris* var. *striata* shoots.

forest in Cardona, Rizal, Philippines, there are also cases of mortalities but there has not been a formal study to determine the percentage of those that survive.

(2) Culm analysis

The general form of a bamboo culm shows a hollow portion inside with big diameter at the base which decreases to the top. The culm-wall thickness, likewise, vary from very thick at the base to thin at the top. To determine the variation of diameter and wall thickness along its length, it is necessary to cut the culm at intervals of one meter. The diameter and wall thickness were measured at the lower end of segment with the use of a caliper. The point with maximum diameter and wall thickness varies with species (Fig. 5). The maximum diameter of *Bambusa blumeana* is about six meters above the ground, *Bambusa vulgaris*, 4 meters, *Schizostachyum lumampao*, 5 meters, and *Schizostachyum lima* 2 meters. Thus, the maximum diameter along the length of the culm is not at ground level.

Culm-wall thickness starts from about 3.5 cm at the ground level for *Bambusa blumeana*; 1.5 cm, for both *Bambusa vulgaris* and *Schizostachyum lumampao*; and 0.8 cm for *Schizostachyum lima*. Culms with thin walls can be easily moulded into quadrangular shapes as in the case of *Bambusa vulgaris* (Photo 1), *Schizostachyum lumampao*; but the formation of artificial shapes

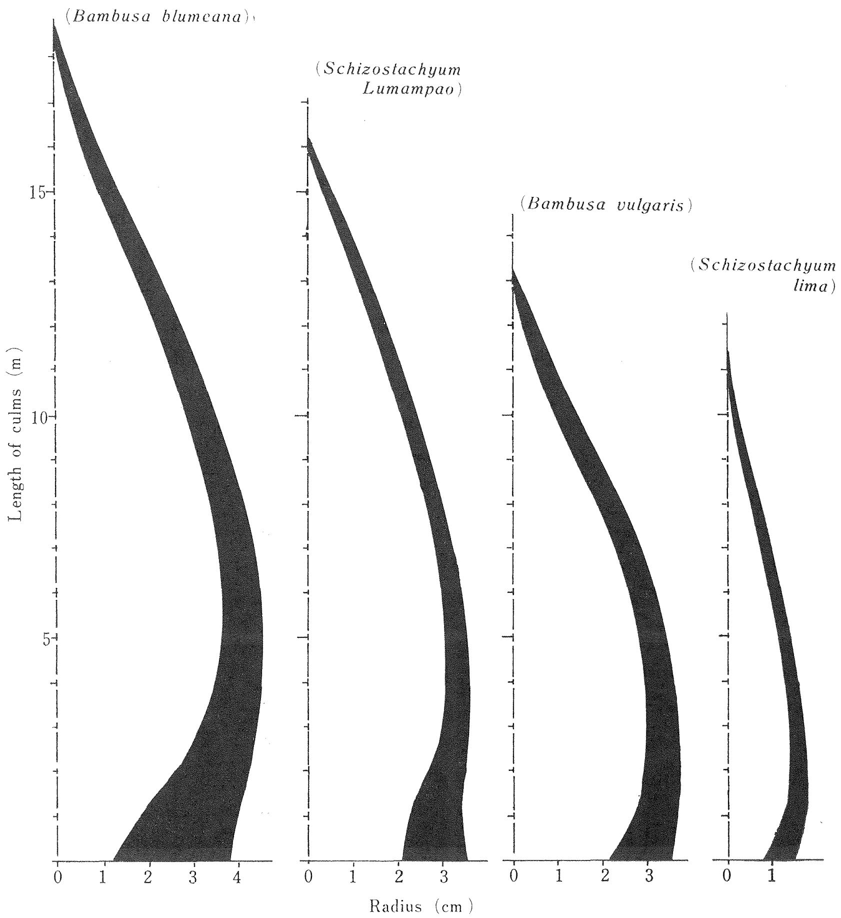

Fig. 5 Vertical section of bamboo culms.

Table 1. Characteristics of some bamboo spceies

Characteristics	Species*			
	Bambusa blumeana	*Bambusa vulgaris*	*Schizostachyum lumampao*	*Schizostachyum lima*
Length of culm (m)	16.2	12.4	14.2	12.8
Green weight of culm (kg)	32.1	16.4	11.9	2.7
Number of node (pc)	65	43	28	21
Wall thickness of culm at the bottom (cm)	2.5	1.7	1.0	0.7
Wall thickness of culm at eye height (cm)	1.7	1.1	0.7	0.4
Diameter at breast height (cm)	7.5	7.0	7.3	3.2
Maximum internode length (cm)	49.4	35.1	79.3	116.1
Green weight of branches (kg)	7.05	5.30	1.20	0.40
Number of branches (pc)	30	32	14	12
Green weight of leaves (kg)	1.52	2.87	0.67	0.30

* Average of 10 culms each

would be difficult for *Bambusa blumeana* because of its thick walls. Thick-walled culms are also more resistant to insect attact mainly because it takes a longer time for destructive agencies to destroy them. All the research materials were taken from the Makiling forest with the exception of *Schizostachyum lumampao* which was collected from the forest of Tanay, Rizal. Unfortunately, no research materials on *Dendrocalamus merrillianus* was available for culm measurements. This species has thick culm-wall.

For all the species studied, the length of internode is shortest near the ground level. This increases to a certain point then shortens gradually fowerd the top. The longest internode for all species was found at about 2～3 meters above the first branch of the clear culm. The maximum diameter appears well below the longest internode.

(3) The relationship between the diameter at breast height (D. B. H.) and the length of culms

Monopodial type of bamboo have many relationships between the diameter at breast height or circumference and culm length[38], while sympodial type have very few[44]. This relstionship is applied to four species, namely : *Bambusa blumeana*, *B. vulgaris*, *Schizostachyum lumampao* and *S. lima*. The data obtained in this relationship is used for estimating scale in culm production and stand condition of bamboo forests.

The three species, namely : *Bambusa vulgaris*, *B. blumeana* and *S. lumampao* have an exponential equation function like a linear straight line, as shown in Fig. 6. *Schizostachyum lima* which grows in the same area does not have this kind of relationship. *Bambusa blumeana* has a high rate of growth, bigger diameter and longer culms than *Bambusa vulgaris* and *S. lumampao*. On the other hand, *S. lima* varies in culm diameter and length, and has irregular length of internodes. The shorter ones have been observed to be more susceptible to insect infestation.

Generally, *Bambusa blumeana* grows on well-drained lowland soils. Therefore, survey plots

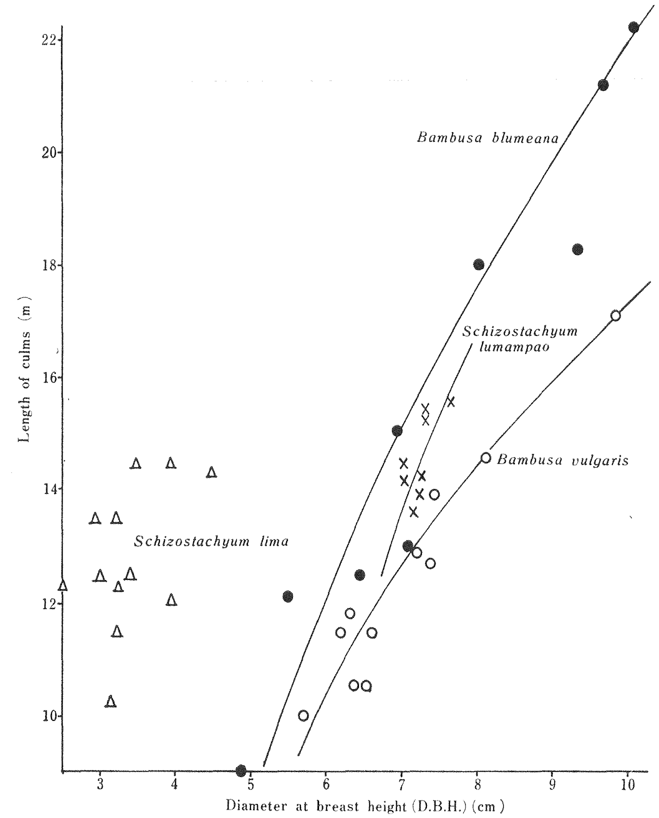

Fig. 6 The relationship between diameter at breast height and length of culms of different bamboo species.

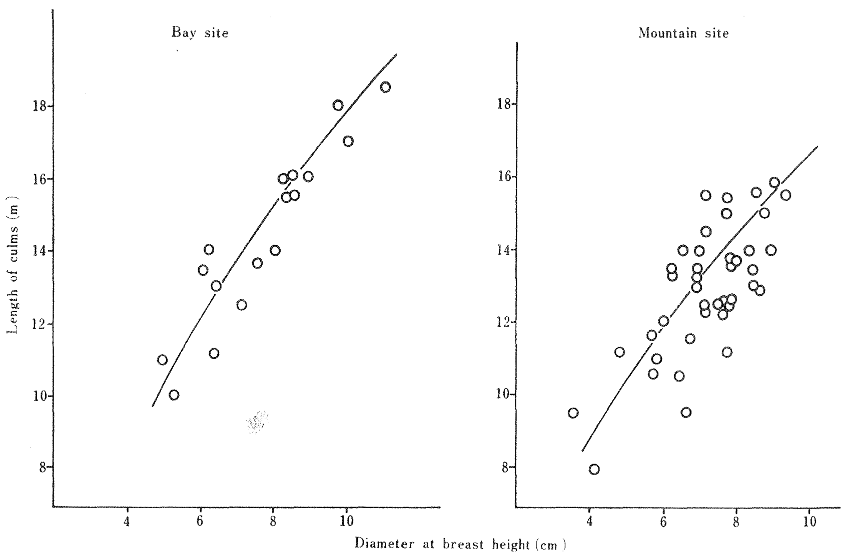

Fig. 7 Relationships of D. B. H. to length of culms (*Bambusa blumeana*) located at bay and mountain sites in Cardona, Rizal, Philippines.

were set at different elevations. Representative samples of *Bambusa blumeana* with different diameters at breast height were measured with a tape measure and lengths of culms were measured with a K-type hypsometer. The relationship between diameter at breast height (D. B. H.) and the length of culms of *Bambusa blumeana* near Laguna de Bay and mountain sites in both Cardona, Rizal, Philippines is shown in Fig. 7. Observations of the growth habits showed that *B. blumeana* have bigger diameters and longer culms near the bay sites than on mountain sites. Relationship of D. B. H. to the length of culms on small-sized bamboos showed almost the same trend at bay and mountain sites.

(4) The relationship of dry weight of culm to its diameter and length (D^2H)

For the purpose of estimating crops and the productivity of forest ecosystem, it is necessary to set up survey plots, and then measure D. B. H. and length in these plots. For more detailed information, felling of the standing crop is required. In general tree forests, the dry weight of trunk covers about 60～70% of the whole standing crop (trunks, branches leaves and roots). The volume of trunks is in direct proportion by section area multiplied by the height (D^2H). If the specific gravity of trunks is constant, the weight of trunks is also in direct proportion to (D^2H). This relationship is shown below;

$$W = A(D^2H)h$$

where : W = weight of trunks

A = coefficient depend on species or forest

h = relative growth coefficient

The same relationship is applied to bamboos[43]. The standard form of bamboo culm is the same for any of the species. So, weight of culm could be estimated to (D^2H). Bamboo culm does not increase in height after the elongation of the shoot has ceased. Consequently, a bamboo forest is considered to consist of culms of the same age. There is a relative growth relationship (Fig. 8) between dry weight of culms and D^2H in *Bambusa blumeana* and *B. vulgaris*, with linear regression of ($\log W_c = 0.81342 \log D^2H - 1.25577$) and ($\log W_c = 0.77024 \log D^2H - 1.24067$), respectively. The results of this study is statistically analyzed and discussed in Section I-4-(7).

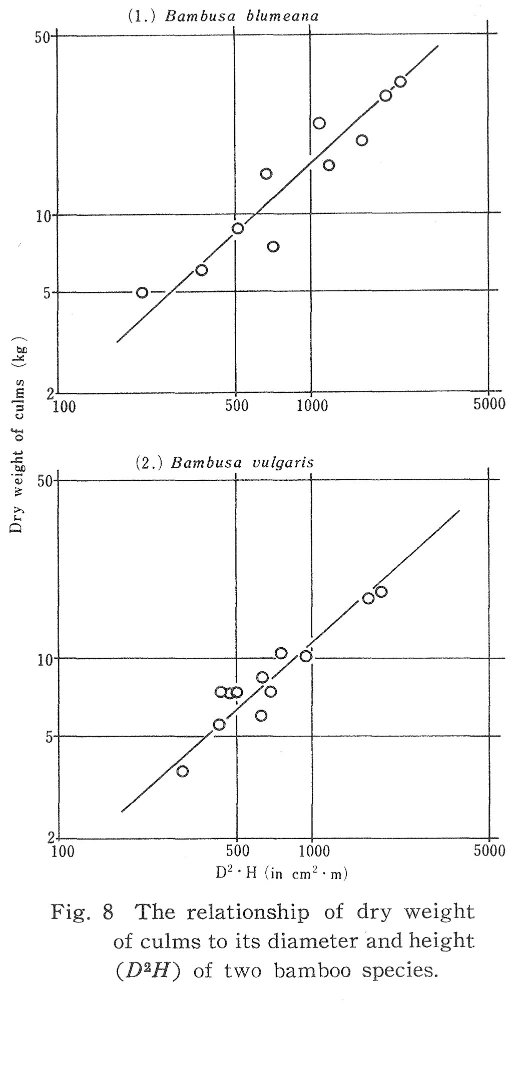

Fig. 8 The relationship of dry weight of culms to its diameter and height (D^2H) of two bamboo species.

(5) Moisture contents of some bamboo species

Moisture contents of some bamboo species were determined in specimens (1-meter long) representing the butt, middle and top portions of the culm. Green weight was taken immediately after cutting

Table 2. Moisture content of culms of some bamboo species

Species	Number of culms	Moisture content (%)			
		Culm portion			
		Butt	Middle	Top	Average
Bambusa blumeana	9	55.96	51.48	46.09	51.18
Bambusa vulgaris	11	47.73	44.18	43.46	45.12
Schizostachyum lumampao	6	52.21	49.41	30.06	43.89
Schizostachyum lima	11	51.98	37.76	38.71	42.82

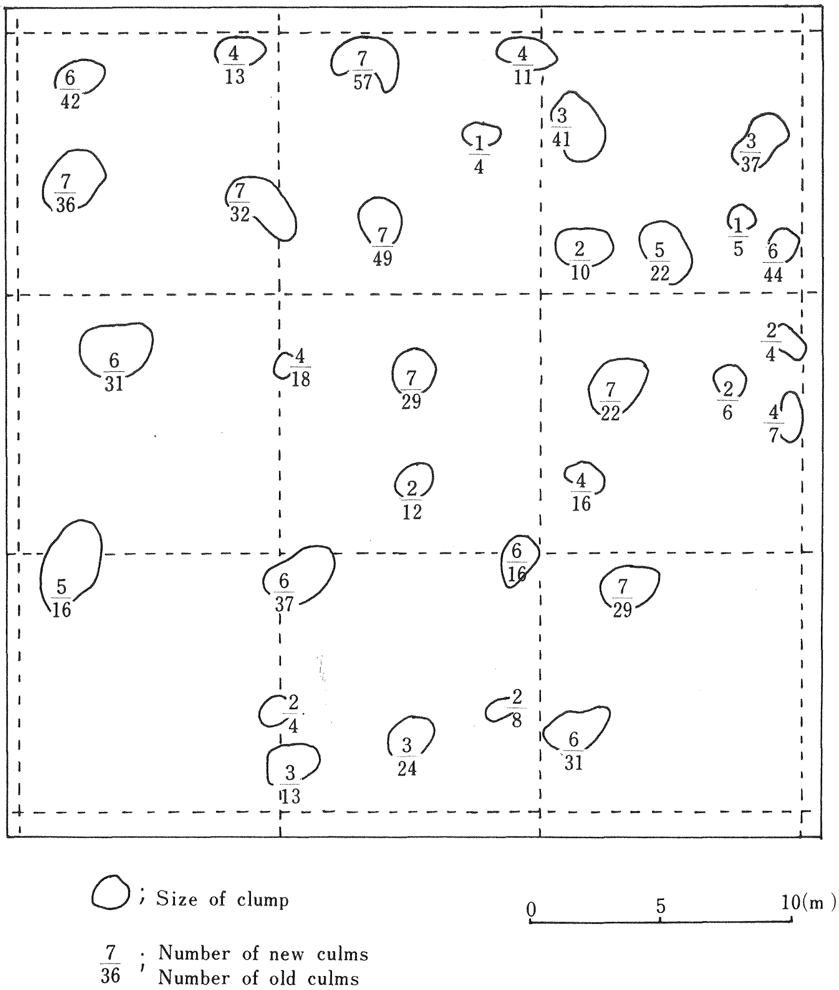

Fig. 9 Distribution map of *Bambusa blumeana* in Cardona, Rizal, Philippines.

and then oven-dried at 105°C for three days until constant weight was attained. The percentage moisture content is derived as follows :

$$MC=\frac{W_g-W_d}{W_g}\times 100$$

where : W_g=green weight

W_d=dry weight

The butt portion of culms of the different species studied have higher moisture content values than the middle and top as shown in Table below.

In *S. lima*, the top portion is quite a bit higher than the middle, probably due to some defects caused by insect attack. The average moisture content of the four species are : *B. blumeana* (51.18%), *B. vulgaris* (45.12%), *S. lumampao* (43.89%), and *S. lima* (42.82%). The longer culms have higher moisture content. In *B. vulgaris*, the same trend in moisture content and height is true for branches such as : butt (67.97%), middle (53.52%), and top (42.91%). This trend is also true for *Gigantochloa aspera*[11].

(6) Distribution of clumps in natural bamboo forests

In order to have an estimate of standing crop, it is important to know how to grow and keep the natural ecological state of bamboo forest. These two factors necessary in bamboo cultivation are affected by density, planting distance and felling control.

Distribution of clumps per unit area and number of culms per clump is shown in Fig. 9. Due to limited time, only a few surveys were conducted. The results are as follows :

A *Bambusa bulmeana* forest in Cardona, Rizal was surveyed and found not fully tapped as yet. There were 32 clumps per hectare, with an average of 22.5 culms per clump, or a total of 7,200 culms per hectare. About 24.5% of the standing culms consisted of newly grown culms. Accordingly, it is important to know that this forest will have to consist of 1～4 year of culms. One-year old culms have sheaths at the basal portions of branches and culms ; 2-year old culms, at basal portion of culms only. The 3-year old culms, are green to light green ; and 4-year old culms, yellow.

Another plot survey of *B. blumeana* and *S. lumampao* was conducted in a different area in Cardona, Rizal. It was found that for *B. blumeana* the distribution of clumps is 28 per 0.10 hectare ; the number of culm is 25 per clump ; or a total of 7,000 culms per hectare. The estimated number of culms per hectare of *S. lumampao* is about 10,000.

Furthermore, a survey of *B. blumeana* at Bato Lake in Camarines Sur showed that the distance between clumps was 6 meters. The distribution of clumps per unit area is shown in the following expression :

$$N=\frac{A}{a\times b}$$

where : N=number of clumps

A=unit area

a=distance between clumps

b=distance between rows

Using the above expression, if there are 280 clumps per hectare and one clump gives about 30 culms, there would approximately be 8,400 culms per hectare.

Based on the different surveys conducted, an estimate of a natural forest of *B. blumeana* was placed at about 7,000 to 8,400 culms per hectare.

There was no suitable area for a suvey on *B. vulgaris*. However, a small scale observation was conducted in the Makiling area and it was observed that the clump distribution was every 6 to 7 meter with 30 to 40 culms per clump; or a total of 9,000 to 10,000 culms per hectare.

(7) Production and growing stocks of bamboo

Generally, the main objective in forestry, is to get the maximum amount of production per unit area. Bamboo forest management has the same purpose as in forestry, the use of land for maximum production.

Tropical bamboos are considered in two respects : 1) as an individual plant (small ecosystem) and 2) as clump to clump relation (forest ecosystem). With those two categories, the foundation of material production is influenced by factors such as the space supply for photosynthesis, the amount of sunlight reaching the leaves, and the absorption of nutrition by the roots. The stratified clip technique was used to make production structure and to estimate the standing crop of culms, branches and leaves. Data for production structure was collected-sized bamboo culms, cut at 30 cm from the ground level. Representative 1-meter long samples were cut and measured. Other pertinent data like weight of culms, branches

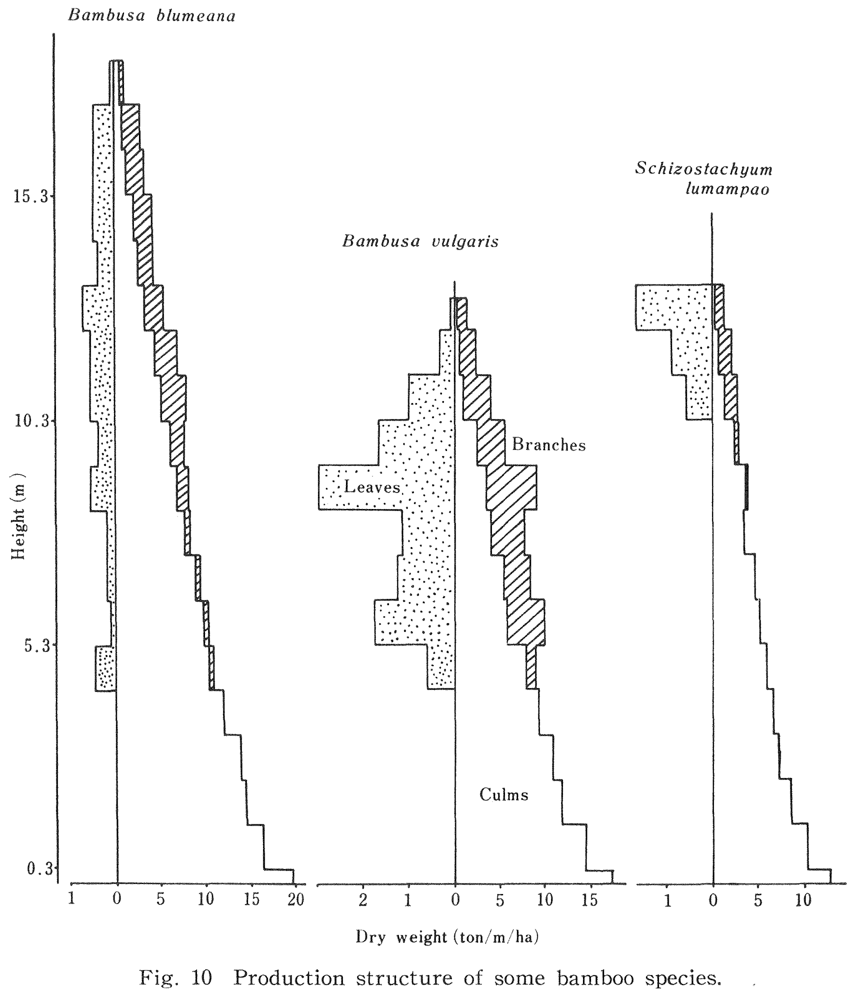

Fig. 10 Production structure of some bamboo species.

Table 3. Production dry weight ratio of culms, branches and leaves of different bamboo species

Species	Production dry weight ratio (%)		
	Culm	Branches	Leaves
Bambusa blumeana	83.53	12.75	3.72
Bambusa vulgaris	69.39	22.17	8.44
Schizostachyum lumampao	88.75	7.02	4.23

Table 4. Standing crop of some bamboo species

Species	Standing crop production (Dry weight: tons/ha)			
	Culms	Branches	Leaves	Total
Bambusa blumeana	120±10	18±5	5±1	143±16
Bambusa vulgaris	75±5	22±2	9±1	106±8
Schizostachyum lumampao	60±5	4±1	2±1	66±7

and leaves, total culm length, moisture content, etc. were also determined. The production structure of surface substances expressed in dry weight per hectare is shown in Fig. 10.

The production dry weight ratio of culm to branches and leaves is shown in Table 3 below :

B. blumeana was observed to have small leaves which were thinner and lighter in weight but nonetheless produced a great number of successive culms. Compared with *B. blumeana*, *B. vulgaris* had thick and heavy leaves which were wide. The leaves were not considered as effective in successive culm production. Furthermore, *B. vulgaris* had long branches and the produstion of surface substance was not so small but the ratio of culm per surface substances was only a few. On the other hand, *S. lumampao* had a considerable amount of leaves. Besides, it produced a great number of culms. Therefore, it is clear that high density plantation of *S. lumampao* is made possible through space distribution of leaves. *S. lumampao* grows in shaded areas. *B. blumeana* definitely needs more sunlight.

Clump-forming type of tropical bamboo species have fewer roots and shorter rhizomes than the non-clump forming type.

Rhizomes and roots below ground level were not included in determining the production structure. However, the amount of root is roughly estimated as 30% of the total culm weight ratio is about 60～70% of the total production.

The standing crop production of some bamboo species is shown in Table 4 below :

As mentioned earlier, only parts (culms, branches and leaves) above ground level were considered in this study. In comparing three species (*B. blumeana*, *B. vulgaris* and *S. lumampao*), *B. blumeana* had fewer culms per hectare but produced bigger solid volumes per culm than the other two species (*B. vulgaris* and *S. lumampao*). On the other hand, *S. lumampao* had thin-walled culms, so that culm production was small.

As mentioned in Section I-4-(6), 24.5% of the standing crop was composed of young (1-year old) culms and annual growth was estimated at about 25%. The annual growth of *B. blumeana* was 1,900 culms per hectare, *B. vulgaris* (2,250 culms/ha) ; *S. lumampao* (2,500 culms/

ha); or annual yield of culms (dry weight) of 30, 20 and 15 tons per hectare, respectively.

Generally, one-third of culm production is used for pulp, and about 9 tons of pulp per hectare of *B. blumeana* could be produced annually. A large-scale production will need about 2,000 hectares of forest land planted with *B. blumeana* to produce about 50 tons of pulp daily. For *S. lumampao*, a minimum of about 4,000 hectares of forest land is necessary to produce the same amount of pulp as in *B. blumeana*.

II. The propagation of Philippine bamboos

Knowledge of the different methods of propagation is necessary in determining the speculative requirements for large scale bamboo plantation not only as raw materials for pulp and paper manufacture but also for reforestation crop to minimize soil erosion.

Some bamboo species produce seeds which germinate readily. However, because of the infrequent blooming of most bamboos and the fact that a large number of species are sterile when they bloom, propagation by seedlings (sexual propagation) is impractical although quite probable. However, rhizome cutting (offset), culm cutting, layering and grafting (asexual propagation) could be done.

Rhizome cuttings are widely used in non-clump forming bamboo while culm cuttings are used in the clump-forming type. Layering is used only in some bamboo species; Grafting is not possible. On the other hand, seedlings can be used in any type of bamboo species, only they require the flowering and production of seed from the mother plant; otherwise, breeding is not possible. The genetic quality of plants is an important thing to consider in any kind propagation.

1. Propagation by rhizome cuttings (offset)

Propagation of the non clump-forming type of bamboo is usually effected by some methods of rhizome cutting. The rhizomes extend horizontally underground for some distance with new sprouts from the rhizomes having about 4～10 buds at intervals. Eventually after three months or more, the new sprouts will grow into mature culms. The rhizomes below can be severed from the mother plant and the culm is cut 30 cm above the ground level. The cut material is planted immediately to avoid drying up to the roots. One- or two-year old culms of big diameter were selected as planting materials.

With this method of propagation, new generation plants with true-to-type genetic qualities could be produced faster than by either cuttings or seedlings. One drawback of this method is the risk of impairing the health and vigor of the mother plant on account of the reduced water supply and suppressed transpiration. Furthermore, it takes a long time to dig the rhizomes and roots, hence, less planting materials can be obtained through this method of propagation. Lastly, this method is only applicable to bamboo species transplanted for ornamental purposes.

2. Propagation by culm cuttings

The clump-forming type of tropical bamboos can be regenerated by use of cuttings. In the Philippines, quite a few investigations were done on this aspect. CURRAN, H. M. and F. M. FOXWORTHY (1916)[8] and LOGAN, J. B. (1918)[21] investigated cuttings of *Bambusa spinosa* ROXB.; while TAMOLANG, F. N. and A. C. CABANDAY (1956)[32] and CABANDAY, A. C. (1957)[6] conducted studies on cutting and layering of *Bambusa blumeana*. According to CABANDAY[6], the percentage of survival for unsplit cutting was 60.8% and for split cutting, 59.7%. There was really not

Table 5. Effect of cutting age on growth of roots

Characteristics	Treatment by age			
	I	II	III	IV
Rate of rooting (%)	30.0	50.0	20.0	10.0
Length of rooting (cm)	3.5	3.5	2.5	1.3
Number of roots (pc)	3.2	3.5	2.1	1.5

much difference between the two methods.

Culm cuttings generally need ample water in the nursery bed. During the dry season, irrigation is necessary to augment the meager water supply. There is a need of knowing, the best method of cutting and to this effect, an experiment was conducted at a provisional nursery at FORPRIDECOM, using *B. vulgaris* unsplit culm cuttings.

(1) Method and selection of materials

(a) Age of materials

The right choice of planting materials is the first problem in propagation through cuttings. Generally, a better rate of rooting in trees could be obtained from materials coming from young mother plants. An experiment to this effect was conducted and the results obtained were evaluated as to its possible application to tropical bamboos. Observations of results were based on the following treatments : (I) culm that developed just after branches elongation, (II) six months after culm elongation, (III) one-year old culm, and (IV) two-year old culm.

The experiment was started in October, 1976 in a provisional nursery at FORPRIDECOM. The materials were cut at midsection of two internodes with a node at the center. Sampling of materials started from the base up to the 3-cm diameter portion of the culm. The specimens were then planted in a slanting position with the node covered with soil. Daily watering was necessary. Observations were done 30 days after planting and results are shown in Table 5 below :

Samples taken from some culms which emerged just after branches elongation produced soft tissues and had high moisture content (MC). These samples do not make good planting materials. Samples taken from a 6-month old culm produced longer roots, and had a high percentage rate of rooting, thereby producing the best planting materials. The elongation of new buds in a 1-year old culm was better than in the others, but the rate of rooting was poor. On the other hand, samples from 2-year old culms produced short and fewer roots and had the lowest rate of rooting. The results tended to show that samples taken from a 6-month old culm had the best growth rate because its branches and leaves were already fully developed.

(b) Method of cutting

One important factor to be considered in an effective method of cutting is the ease of water absorption through the cut portion of the material. Since this involves a long range field of study, a preliminary observation on *B. vulgaris* was conducted using three trials. Each trial had different treatments as to the position of planting and application of water and soil at the upper and basal hollow portions of the cutting materials, respectively. Watering was done daily in all treatments, and growth development was observed.

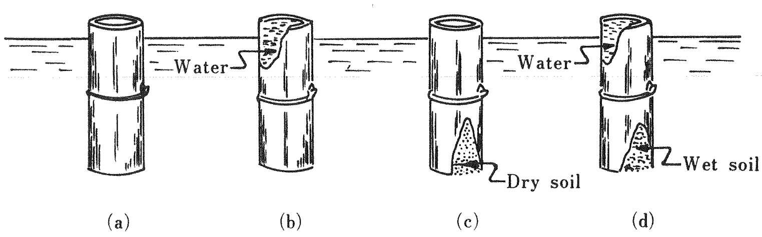

Fig. 11 The first trial of culm cutting.

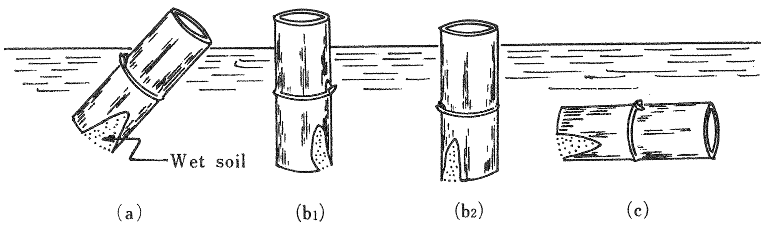

Fig. 12 The second trial of culm cutting.

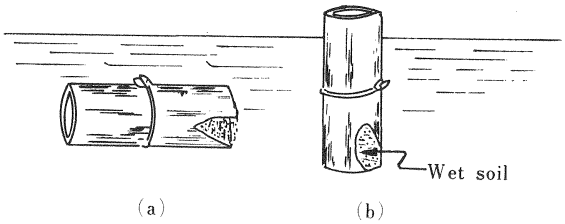

Fig. 13 The third trial of culm cutting.

Table 6. Effect of age and planting position of cuttings on the growth development of *Bambusa vulgaris*

Characteristics			Planting position/Age			
			Horizontal		Vertical	
			3 Mos.	12 Mos.	3 Mos.	12 Mos.
Culms	Average length	(cm)	162.1	164.4	130.8	128.2
	Diameter	(cm)	1.13	1.10	0.79	0.93
	Green weight	(gm)	67.5	128.9	40.3	57.7
	No. of new shoots	(pc)	1.9	2.5	1.5	2.0
	No. of buds	(pc)	3.0	3.2	2.2	2.6
Roots	Total length	(cm)	1267.0	1392.0	808.0	332.0
	Total green weight	(gm)	41.9	55.9	26.2	25.6
	Total number	(pc)	54.7	93.3	49.9	59.3
Leaves	Total green weight	(gm)	42.4	50.3	21.8	39.1
	Total number	(pc)	132.6	133.5	68.7	96.1

In the first trial above, (a) is the control; in (c), water does not penetrate through that portion with dry soil. In treatments (b) and (d), the water put in the upper hollow portions have no effect on water absorption of the materials. Based on observations, treatment (d) is the best because there is a continuous water absorption due to the presence of wet soil at the basal hollow portion of the cuttings. (Photo. 2)

In the second trial above, treatments (a) & (b_1) the top soil is usually washed-off during heavy rains thereby subjecting the nodes to sudden exposure to intense sunlight which affects growth. However, treatment (b_2) is better than (b_1) because its upper internode is cut longer than the lower internode and the node is located deeper in the ground. Further observations on its growth development show that culm length of b_2 (54.8 cm), is longer than b_1 (33.2 cm) and the number of leaves in b_2 (5.1 pc.) is more than in b_1 (4.3 pc.). Treatment (c) is found to be the best in the second trial due to the presence of wet soil in the basal hollow portion of the cutting. It is easier to plant in a horizontal position and that the nodes are protected from exposure to extreme conditions.

In the third trial above, treatment (a) is better than (b) and considering all the foregoing factors in the first 2 trials, treament (a) is the best of all treatments. Observations on the third trial using *B. vulgaris* was done 5 months after planting and the results are shown in Table 6 below :

In all treatments the rate of rooting is 100%. The growth of the second generation materials is heavier in the 12 months cuttings. To this effect, the distribution of green weight and D^2H is shown in Fig. 14 & 15. The D^2H and green weight is greater in the horizontal (12 months cutting better than 3 months) than the vertical (both in 3 and 12 months cuttings).

Cutting method then has no effect on the age and rooting ratio on materials.

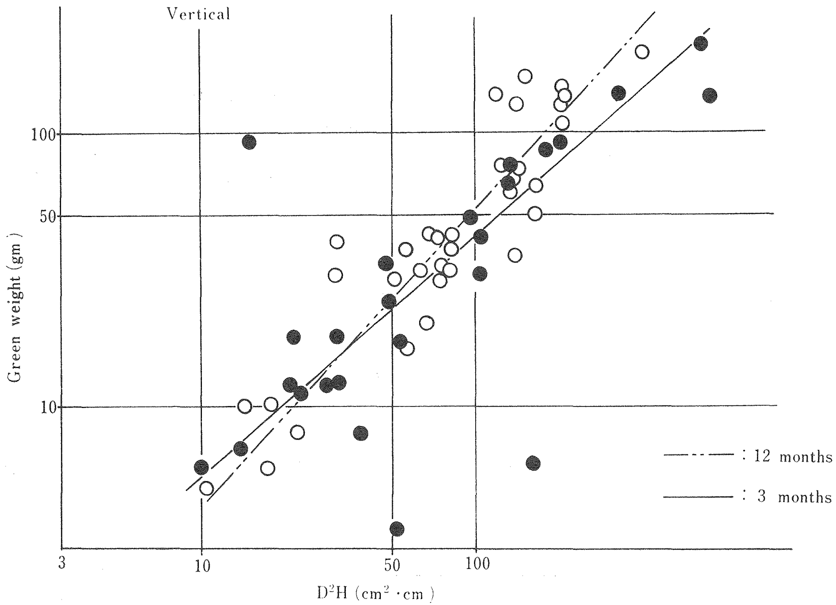

Fig. 14 Regeneration of culms after cutting.

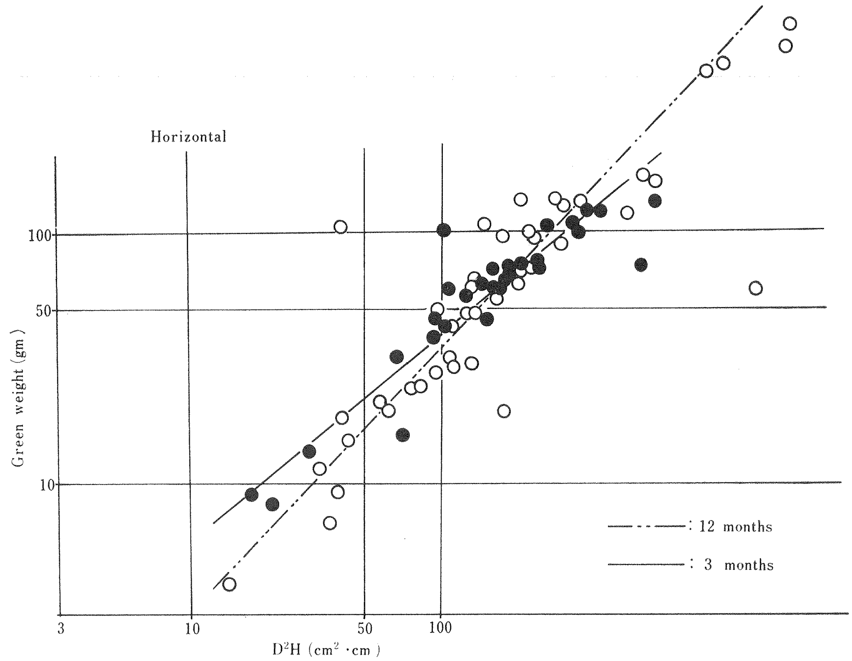

Fig. 15 Regeneration of culms after cutting.

Table 7. Effect of cutting period on the growth development of *Bambusa vulgaris* during rainy season

Characteristics			Cutting period	
			Early rainy season (May)	Late rainy season (October)
Culms	No. of branches	(pc)	1.53	2.43
	Length	(cm)	132.26	150.23
	Diameter	(cm)	0.94	1.02
	Green weight	(gm)	43.73	34.13
	No. of buds	(pc)	2.30	3.16
Roots	No. of roots	(pc)	44.15	84.38
	Length	(cm)	771.70	1076.96
	Green weight	(gm)	25.35	50.11
Leaves	No. of leaves	(pc)	71.20	105.20
	Green weight	(gm)	22.63	41.08

(c) Period of collecting samples during rainy season.

As previously mentioned, *Bambusa vulgaris* grows in three stages during the rainy season as affected by the rate of the nutrition supply. With regard to the growth period of bamboo shoots propagated through the use of cuttings as mentioned in Section I-4-(1), the weekly height growth differed in form and so with the growth period.

In this study, the period of collecting cutting materials is as follows : 1) early rainy season growth (samples were collected in the mid May); and 2) late rainy season growth (samples were collected in mid October).

The materials were cut at midsection of two internodes with a node at the center. Wet soil is placed in the basal hollow portion of the material and then planted horizontally underground. Observations were made 6 months after planting and the results are shown in Table 7.

The rate of rooting is 100% in all treatments. However, better growth development occurred in the late rainy season planting.

(d) Portion of material and growth of second generation for culm cuttings.

If supply is limited, the selected culm is fully utilized. However, if supply is abundant, the best ones are selected. The materials selected from the different portions should show better qualities than the original mother culm.

An experiment using *B. vulgaris* was started December, 1976, using three treatments, as follows:

1) Three samples representing the 2nd, 3rd and 4th node of the butt portion, with an average diameter of 7.1 cm.

2) Three samples representing the 12th, 13th and 14th node of the middle portion, with an average diameter of 6.7 cm. The internode is longest in there portions.

3) Three samples representing the 23rd, 24th and 25th node of the top portion (about 2 meter from the top end), with an average diameter of 4.5 cm.

The specimens were cut at the midsection of two internodes with one node at the center. The basal internode (butt portion of the sample) is filled with wet soil while the upper internode (top portion of the sample) is left empty. The specimens were then planted horizontally about 20 cm underground. The specimens were watered daily. Observations were made 70 days after planting, the results are shown in Table 8.

The rate of survival in all treaments is 100%. The buds attached to the basal portion of the culm will eventually become the second generation material. The number and size of buds determine the growth of the second generation stock.

Samples taken from the butt portion of the culm were observed to have better growth rates than those taken from the middle and top portions of *B. vulgaris* and *Dendrocalamus*

Table 8. Growth development characteristics of cuttings taken from different portions of culm

Characteristics			Culm portion		
			Butt	Middle	Top
Culms	Diam. near ground	(cm)	1.00	0.89	0.62
	Length	(cm)	164.50	120.0	100.5
	Green weight	(gm)	88.8	57.1	29.3
	No. of buds	(pc)	6.9	3.8	1.3
Roots	Numbers	(pc)	73.8	49.9	27.4
	Total length	(cm)	987.3	620.0	289.3
	Green weight	(gm)	36.7	18.8	7.8
Leaves	Numbers	(pc)	189.8	48.4	8.8
	Green weight	(gm)	43.7	18.0	1.9

strictus. Samples from the middle portion of the culm showed good growth for *B. arundinacea* and *B. blumeana*.

(2) Treatment with plant growth hormones

The most simple and orthodox method of cutting is by immediate planting of cut samples having some nodes or by immersion of the butt portion of cutting materials in water for 24 hrs and then planting them in soil. These ordinary method of planting have low rooting rate and, therefore, need improvement through the use of plant hormones. Two trials were made of this experiment, using *B. vulgaris*, with the following treatments :

1) 100 ppm α-N. A. A. (Alpha- Naphthalene Acetic Acid)
2) 100 ppm α-I. A. A. (Alpha- Indole Acetic Acid)
3) 100 ppm I. B. A. (Indole Butyric Acid)
4) Control (water only)

The first trial was conducted on June 30, 1976, and replicated thrice. The materials with an average top-end diameter of 4 cm were cut at midsection of two internodes with a node at center. Samples taken from the middle towards the top portion of culms, contained branches which were left intact (about 20 cm long) so as not to destroy the next node. The basal

Table 9. Growth hormone treatment and suvival ratio of *Bambusa vulgaris* cuttings

Growth hormones	Survival (%)	
	100 days after cutting	150 days after cutting
α-N. A. A.	36.60	33.34
α-I. A. A.	30.00	26.67
I. B. A.	23.30	46.16
Control	16.60	17.24

Table 10. Growth development of culms, roots and leaves of *Bambusa vulgaris* by treatment of growth hormones

Characteristics			Treatment			
			I. B. A.	α-I.A.A.	α-N. A. A.	Control
Culms	Average number	(pc)	1.6	1.8	1.3	1.6
	Total length	(cm)	263.5	185.0	157.9	193.0
	Green weight	(gm)	154.6	69.6	54.4	100.6
	Average diameter*	(cm)	0.9	0.7	0.7	0.9
	Moisture content	(%)	62.85	51.42	49.25	57.85
Roots	Total number	(pc)	77.6	37.1	48.3	51.4
	Total length	(cm)	1023.1	501.0	732.0	622.0
	Green weight	(gm)	32.3	17.3	22.8	23.3
	Moisture content	(%)	62.05	68.54	66.49	60.09
Leaves	Av. total number	(pc)	82.8	113.9	92.2	104.6
	Green weight	(gm)	27.1	40.2	37.1	36.3
	Moisture content	(%)	58.76	62.70	55.51	64.60

* Diameter taken at second internode from the basal portion of the culm

portion of the cuttings were then dipped for 24 hrs in the hormone solutions. These were then planted in a vertical position with wet soil placed inside the hollow portion of the basal internode. The cuttings were watered daily. Observations were made twice (100 and 150 days after planting), and the results are shown in Table 9.

On the average, the cuttings treated with hormone solutions showed better percentage of survival than the control. I. B. A. showed the highest percentage of survival at 150-day observation, and had also produced longer culms and roots. Cuttings with a high percentage of survival were less attacked by termites. In this trial, termites affected the survival of the cuttings.

The second trial was planted October 6, 1976. During this period, the planting materials reached its maximum growth development. The method of hormone treatment and the cutting of materials are the same as in the first trial, except the method of planting was done horizontally. Observations were made 6 months after planting. The results are shown in the Table 10.

The total lengths of culms and roots of *Bambusa vulgaris* were obviously greatest with the I. B. A. treatment. The same result was true for *Dendrocalamus longispathus*[48].

Furthermore, this trial was not attacked by termites.

It is difficult to compare these two trials because different methods and periods of cutting were used. However, it is safe to recommend latter rainy season planting with I. B. A. hormone treatment, and horizontal planting.

(3) Expansion of clump and growth of standing crop.

Different species have different rates of rooting. Species with low rates of rooting will eventually improve through progressive cutting techniques. Generally, the growth of newly developed culms can always be improved for possible growth expansion and regeneration. The cutting method of propagation is recommended for the clump-forming type of tropical

Table 11. Growth of culms, branches and leaves of *Bambusa vulgaris* propagated by cutting

Characteristics		Stage of culm development						
		First year				Second year		
		1	2	3	4	5	6	7
Culms	No. of culm (pc)	1	2	2	3	3	5	2
	Length (m)	1.20	2.43	4.26	5.43	6.28	8.44	8.85
	Diameter* (cm)	0.95	1.15	2.20	3.01	4.10	4.89	4.88
	Green weight (gm)	10.5	69.6	445.0	1522.2	2651.0	5650.1	5414.9
	Moisture content (%)	10.15	10.29	32.21	41.47	43.66	45.46	51.27
	No. of node (pc)	8	12	21	30	33	38	35
Branches**	Maximum length (m)	—	0.91	1.49	2.45	2.53	3.45	3.93
	Green weight (gm)	—	54.7	360.6	1300.5	1743.2	3923.6	3805.7
	Moisture content (%)	—	9.44	34.10	48.40	50.62	54.00	60.00
Leaves**	No. of leaves (pc)	—	—	306	2281	3566	6442	4753
	Green weight (gm)	—	—	29.5	354.6	693.9	2135.9	1623.1

* Diameter taken at 30 cm above the ground level

** No data available at the initial stages of development in the first year of observation bamboo.

An experiment was conducted in April, 1975 using *B. vulgaris* planted in a provisional nursery at FORPRIDECOM. Observations were made in 4 stages for the first year and an another 3 stages for the second year. Observations were made within a span of 2 years to give time for growth before the clump was dug up. The results are shown in Table 11 and Fig. 16.

As shown in Table 11, two weeks after planting (1st stage), new sprouts and leaves developed while those leaves from the old branches were shed off. One month later (2nd stage) the culm length doubled and the diameter increased considerably. Two months later (3rd stage) the culm length had increased to 3.5 times while the diameter had doubled. At this stage, the buds of the rhizomes developed into new culms, so the number had increased, resulting in the expansion of the clump (Photo. 3).

The 4th stage is the last observation made during the first year and this was about 2 months after stage 3. At this stage, more culms were developed through rhizome branching. However, those which developed during the first stage died due to depletion of nutrients resulting from the successive production of culms and branching of rhizomes toward the 4th stage. During the first year of abservation, no shoots appeared during the dry season.

In the second year observation, the rainy season had commenced and shoots started to develop somewhere in April to May (stage 5), thereby repeating all the stages of development of the first year up to the 7th stage of the second year. By this time, the culm attained maximum diameter about 5 times and culm length about 7 times more than in stage 1, the leaves had dropped; and culms had started to decay.

At the start of the 3rd year, a clump was dug. Shoots were observed to have developed. The diameter (about 5.75 cm) of the shoots were found to be the same as the mother culm. The length and weight of branches, number and weight of leaves, and their moisture contents had increased progressively from the first stage up to the 7th in the second year of observation.

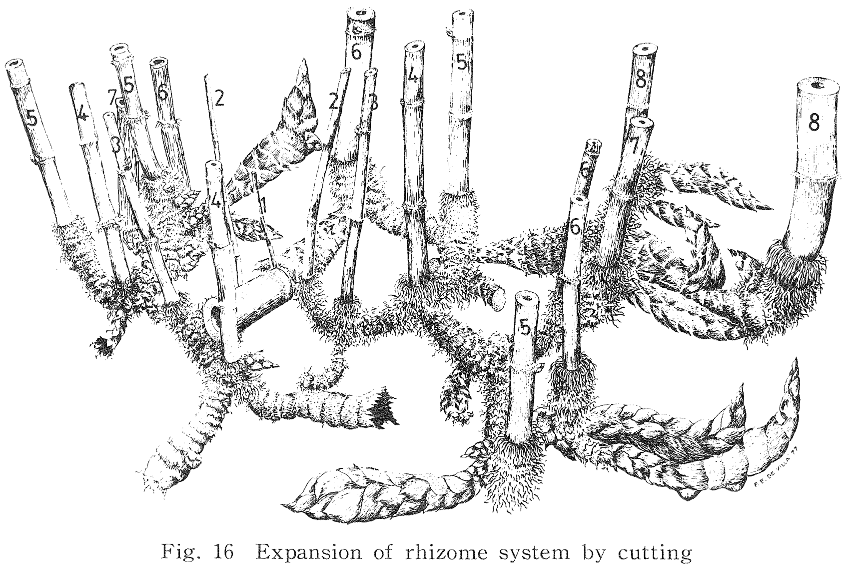

Fig. 16 Expansion of rhizome system by cutting
(Number 1～8 show the stage of culm elongation).

Three years after cutting, the culms developed completely. An estimate of culm production could be made in 5 years' time with yearly harvesting there after.

With the foregoing results, bamboo plantation can be regenerated with the use of cuttings. Samples with one or two nodes taken from the butt and middle portions of a culm are ideal sources of cuttings. Species with low rate of rooting can be improved with the application of I. B. A. plant hormones. The best age of selecting cutting materials is either about 6 months after culm elongation or less than 12 months from cutting. The cutting are best planted horizontally during the late rainy season period.

These experiments however, must be studied further. Regeneration by cutting is speedy. Therefore, this method of cultivating bamboo should be adopted.

3. Propagation by seedlings

(1) Flowering of bamboos

Generally, bamboos can be regenerated by an asexual method of propagation. However, sexual propagation by seed is also feasible although not quite practical due to the great length of flowering cycles, which in most cases, is very rare. An interesting and curious thing about bamboos is that some species generally die soon or one year after flowering. Others do not die but their vegetative growth slows down during flowering.

Although many investigations have been undertaken, the phenomenon of bamboo flowering has not as yet been fully explained. Brandis[4] divided 3 types of flowering of tropical bamboos, as follows :

1) Annual : Species like *Arundinaria wightii*, *Bambusa lineata* and *Ochlandra stridula* flower once or sometimes twice a year and remain alive.

2) Periodic and gregarious : Species of *Bambusa polymorpha*, *Bambusa arundinacea*, and *Melocanna bambusoides* flower periodically and gregariously. After fruiting, the culms and rhizomes soon die.

3) Irregular, sporadic and gregarious : Species of *Oxytenanthera olbociliata*, *Dendrocalamus strictus*, *Dendrocalamus hamiltonii* and *Cephalostachyum pergracile* flower irregularly, sporadically and sometimes gregariously. After fruiting, the culms and rhizomes die.

Flowering is very common in places where the different species of the first type are grown and for this reason, flowering is not a problem. There is a continuous maintenance of the species. In types 2 & 3, the species die soon after flowering, so the species are not maintained.

Furthermore, bamboo flowering can be classified into 2 types based on the extent of flowering per unit area. The first type is the wide area flowering (gregarious or simultanious). In February 1961, *Melocanna baccifera* and *Bambusa arundinacea* of Assam and Kerara in India, respectively, were observed to have flowered gregariously. According to observations, it would take about 10 years before a wide area bamboo plantation could be recovered. During this period, culm havesting is not advisable. The second type is sporadic flowering where bamboo culms do not flower at the same time. For this reason, culm production in a certain area is decreased because those culm which have flowered earlier soon die.

Several theories formulated about flowering are, as follows :

1. Pathological theory. Destruction of bamboos through causal organisms like nematodes, fungus, insect pest and parasites brings about this phenomenon of flowering.

2. Periodical theory. A cycle of bamboo regeneration through asexual method by rhizome and culm elongation reaches maturity thus, flowering results.

3. Mutation theory. Bamboo regeneration through any methods of asexual propagation is considered as mutation, resulting in flowering of bamboos.

4. Nutrition theory. Flowering and fruiting are usually the results of a physiological disturbance arising chiefly from the poor growth of the vegetative cells, brought about by an imbalance of carbon-nitrogen ratio.

5. Man-made theory. Clear cutting and fire are man-made practices that can induce bamboo flowering.

All of these theories are only observations and in order to determine which of the theories are profitable for each the different species, there is a need to know the meteorological factors or conditions that induce artificial flowering with the use of special equipment (growth cabinet).

There is an assumption that there is less nutrient supply in continuous asexual propagation of bamboos. This could result in the accumulation of certain substances which bring about the production of flower buds. However, this aspect should be subject to further studies.

Some species which were observed to have green leaves after flowering produced sterile seeds; those species with defoliated culms after flowering produced viable seeds.

Although some Philippine bamboo species were reported to have flowered and produced seeds, there is no record of gregarious extent of flowering.

(2) Cultivation of seedlings

Regeneration of bamboo after flowering is different by species. In *Phyllostachys reticulata* genus *Phyllostachys*, plants die soon after flowering. A few seeds with low rates of viability are produced. However, new sprouts are developed from the basal part of culms or in the rhizomes, elongating into abundant growth of small culms and resulting in successive growths of bigger culms in the following years. In the case of *P. edulis*, more seeds are produced but there is no development of small culms from the rhizome. In *Sasa nipponica* Makino and *S. paniculata* Makino, the mother culms die soon after flowering. An abundance of seeds with high rates of viability are produced, hence, seedlings are made naturally available. However, such a viability rate becomes quite reduced after 2 weeks.

Generally, the non-clump forming type of bamboos produce flower buds in early August to late November, usually flower in early April to July and produce seeds in August to September or approximately about one year from the production of flower buds. In tropical bamboos as in *B. arundinacea* and *S. lumampao*, an abundance of seeds with a high rate of viability are produced, but soon after flowering, the culms die. In *S. zollingeri* Steud. (Photo. 4), flowering does not occur at the same time, so only those culms which have flowered earlier die, therefore, others remain alive up to that time they have flowered. In this species, the few seeds that are produced are likely to be sterile; hence, only a few are capable of germinating.

Generally, tropical bamboos that usually flower from November to February produce seeds from May to August. However, not all species do flower and produce seeds at the same time during the year. For this reason, seeds introduced from other countries are used for studies on the cultivation of seedlings. Several observations are made on the following species :

a) *Bonkawe*

The flowering of *Bonkawe* in Cardona, Rizal, Philippines, sometime in middle September, 1976 was seen for the first time. The seeds were already matured and the mother culms had died. Natural seedlings with 2～3 leaves had started to grow 3～4 weeks after germination.

These seedlings together with non-flowering culms were then collected and planted in the provisional nursery at FORPRIDECOM. It was observed that the non-flowering culms flowered in April 1977 and produced matured seeds in June 1977. The matured seeds, brown in color, readily germinated on the ground. Each seed was round and 4～7 mm in diameter (Photo. 5). Those seeds attached to the top portion of branches were smaller than thost at lower portion of branches.

The growth of seedlings was observed in pots and in nursery plots. About 2～3 leaves appeared in the potted seedlings during the first month and about 1～2 slender culm developed every month. After the tenth month, the seedlings grew to 4.1 mm in diameter, reached a height of 28.8 cm and produced an average number of 27 culms per clump. The culms grew bigger (the newly developed clums were bigger than those previously developed) and the roots were crowded inside the pot after 10 months. Those seedlings planted in nursery plots attained a height of 105 cm and diameter of 8.1 mm and were ready to be transplanted to the field. The potted seedlings were found to be smaller in size and height than those seedlings planted directly in nursery plots. So, it is advisable to transplant potted seedlings 3 months from the time of planting.

b) *Schizostachyum lumampao* (Blanco) Merr.

Towards the middle of 1976 at UPLB campus, a species of *S. lumampao* (Photo. 6) flowered. The date of flowering was not certain but the presence of many seedlings on the ground showed a high germination rate of the species. Seedlings were also found to have germinated on the basal portion of branches, which after 10 months attained a maximum diameter of 2.4 mm and height of 21.7 cm. As compared to *Bonkawe*, *S. lumampao* had slow growth and poor root development, but an early recovery of leaves.

c) *Bambusa arundinacea* Willd.

Seeds that had actually dropped to the ground were collected from ten culms on February 11, 1977 at Prachinburi, Thailand (Photo. 7). The stand condition and culm characteristics of this species fit the growth condition of the same species in the Philippines. It was observed that soon after flowering, the mother plants die. Many seeds were gathered and brought to the Philippines for trial planting.

The seeds were like wheat with a 74.1% rate of viability. The seeds which were sowed germinated after one week. Two weeks later, the seedlings with 2 leaves had attained a height of 3 cm. At 5 weeks, the seedlings had 5～7 leaves. They attained a height of 7 cm and at this stage, 2 culms had developed. At 8 weeks, additional culms had developed. The seedlings which had now sprouted had about 8 leaves. Each seedling had different growth development, depending upon the size of seed planted. Big-sized seeds grew faster than the small ones. Observation was done five months from sowing time. Growth development was found very favorable and these seedlings appeared suitable for planting on mountain sites.

d) *Thyrsostachys siamensis* Gamble.

The seeds collected from Thailand 4 years age were put in a cold storage with 5°C temperature and were planted in pots on April 1975. (Photo. 8)

The seed resembled that of a glutinous rice grain. Four months after they were sowed in pots, the seedlings attained a height of 20 cm. These were transplanted in nursery plots. In two years, seedlings were found robust and had attained a height of 3.7 meters and an average basal culm diameter of 2.4 cm. This species is currently used as raw materials for pulp and paper manufacture in Thailand. Should a bamboo forest be established, there is a need for a wide area plantation using 5 cm diameter culms to produce 4.0 tons of culm per hectare annually[43].

e) *Phyllostachys pubescens* MAKINO.

The seeds collected in Japan in August 1974 were planted in Philippines in April 1975.

The seed had the shape of a grain of rice which is long and slender. The seeds were sown in pots and after 4 months, the seedlings had attained a height of 25 cm. These were planted in nursery plots. After 2 years, the seedlings resembled those of shrubs with short growth but with very unusual robust leaves (Photo. 9), thereby producing an abnormal growth resembling the characteristics of a clump-forming (sympodial) type of tropical bamboos. Six months later, new culms developped from the rhizome buds showing a monopodial type of regeneration. Generally, *Phyllostachys* species are a non-clump-forming (monopodial) type of bamboo. These species clearly prefers to have favorable growth in elevated areas[39]. Based on observations, it will take about 10 years to get a good stand of bamboo forest planted of this species.

As mentioned earlier, regeneration by use of seedlings in much slower than by use of cuttings. However, growth development of seedlings is highly affected by the rate of fertilizer application. To this effect, a fertilizer test was conducted on *Bonkawe* and *S. lumampao* on September 23, 1976; and another on *B. arundinacea* on March 23, 1977. The fertilizer used was a mixed fertilizer of N : P : K elements at the rate of 2 : 2 : 1 ratio with the following treatments : a) control, b) × 1 (50 kg/0.1 ha) and c) × 2 (100 kg/0.1 ha). Twelve potted seedlings were used for *Bonkawe* (Photo 10) and 20 each for *S. lumampao* and *B. arundinacea.* Progress the experiment still continuous, but preliminary observations have been made and are shown in Table 12.

Observations were done 280 days after fertilizer treatment on *Bonkawe* and *S. lumampao,* and 110 days for *B. arundinacea.* Generally, the growth development of *Bonkawe* and *S. lumampao* are better in all fertilizer treatments than in the control. However, at the present stage of the experiment, fertilizer treatments have had no effect on the growth development of *B. arundinacea.*

Table 12. Fertilizer test of some bamboo species

Characteristics		*Bonkawe*			*S. lumampao*			*B. arundinacea*		
		×2	×1	Control	×2	×1	Control	×1	×2	Control
Culms	Number (pc)	22	13	27	28	22	26	7	5	6
	Average length (cm)	43.3	39.1	28.8	34.7	28.0	21.7	40.0	34.0	35.0
	Maximum length (cm)	95.8	72.3	56.3	59.7	54.7	58.7	71.0	69.2	64.0
	Base diameter (mm)	4.5	5.0	4.1	2.3	2.3	2.4	3.8	4.2	4.2
	Dry weight (g)	55.5	53.9	36.3	43.5	36.9	31.6	4.1	2.2	3.7
Roots	Dry weight (g)	38.2	26.8	22.3	24.5	21.9	17.1	1.5	1.8	1.9
Leaves	Number (pc)	149	140	165	494	342	309	88	131	125
	Dry weight (g)	18.7	21.0	16.0	18.7	13.8	12.1	2.1	2.6	1.9
Standing crop (g)		112.4	101.7	74.6	86.7	72.6	60.8	7.7	6.6	7.3

III. Cultivation of bamboo forest and research work on tropical bamboo in the future

In the tropical regions, particularly in Southeast Asian countries, bamboos grow everywhere and are widely utilized for house construction, pulp and paper manufacture, agricultural implements, tools in fishery and forestry, for various industries like basket-making, and as musical instruments like the bamboo organ. For this reason, a growing interest in bamboos has been generated becaused of their wide-spread distribution, ease of propagation and rapid rate of growth. So far, however, not much research work has been done on bamboo production and utilization and no record of studies on bamboo cultivation are available. Quite a few investigators attempted to study the subject but only to a limited extent.

Nowadays, bamboo forests play an important role not only in the preservation of our natural wealth but also as a reforestation crop to minimize soil erosion and for flood control. These speculative requirements are important in considering the end uses to which bamboos may be put to best advantage. For example, if one wants to take manufactured materials, quality controls of the product are considered more than just mere bamboo culm production. In the aspect of pulp and paper manufacturing, it is necessary that production of bamboo culms with long fibers, wide diameter and less silica content, be considered. Furthermore, if bamboo forests are intended for watershed management, proper selection of species with good rooting systems or rhizome expansion should be given priority.

In any standing crop, the natural distribution of a plant shows its suitability for cartain purposes and ecological factors are then considered. For instance, as previously mentioned, flat of fairly rolling areas are suitable for bamboo growth. Some bamboo species prefer comparatively swampy lowland areas while other species prefer which is quite dry.

Bamboo plantations must be planted with the right kind of species and to some extent, the search for and the subsequent introduction of outstanding bamboos from other countries for trial and study should continue. This study should stress such variables as forest stand and bamboo species. In an experimental forest, many species are planted. These provide the planting stock for future use.

In bamboo plantations, experimental procedures like planting, tending or cultivation and harvesting are important. Bamboo planting is a different form of tree planting in that the bamboo site is only planted once. Tree planting on the other hand, makes use of the same site over and again.

In tropical bamboos, planting stock is limited to the use of culm cuttings and seedlings. Culm cutting is an asexual method of bamboo regeneration wherein the genetic qualities of the mother plant is being transferred to the second generation plants. So proper selection of materials (big diameter, longer culms with high qualities); sampling method; and period and condition of growth are important factors in bamboo culture. The planting materials are grown in the nursery bed and maintained there until rooting stage, and within a year these are transplanted (out-planting) in the field. If the mother culm happens to be near the place of transplanting, direct planting is done. Another important thing to consider in culm cuttings is the survival rate of rooting. Since rooting rate differs with species, there is a need for further studies as to the techniques in hormone treatment and in breeding.

Inasmuch as bamboo seldom bloom or produce seeds, regeneration by sexual method is economically impractical to supply commercial demands. The period of flowering differs by species. Seed collection is best done when the seeds mature in the mothe plant. Branches are cut before the natural falling of seeds. Natural drying of seeds follows. Since only a few studies were conducted in this aspect, future viability studies are then recommended.

Seedlings planted in pots were found to have more delayed growth than those planted directly in the nursery. Potted seedlings are transplanted to the field after one year. Seedlings in the nursery which grow 50～100 cm in height are ready for transplanting in the field within 6 months.

Preferably the period of planting should be during the late rainy season. The planting material should be placed 10～20 cm below the gronud and then covered with soil. Some leaves are removed before planting and the top part of culm is cut about 40～50 cm from ground level in order to obviate wilting due to exposure to too much sunlight. Further studies on the effect of light intensity on the growth of culm from seedlings is suggested.

A trial planting which concerns the ecological study of the different bamboo species planted in flat areas, as affected by planting density and soil preparation are shown in Table 13 below.

Table 13. Effect of distance of planting and the number of planting stocks on the size of clump of different bamboo species

Species	Planting distance (m)	Number of planting stocks per hectare (pc)	Remarks
Schizostachyum lima	5×5	400	Species which consist of smaller culms and clumps
S. lumampao	5×6	333	Species with small culms and clumps
Bambusa blumeana, *B. vulgaris*	6×6	278	Species with average size of culms and clumps
Dendrocalamus latiflorus, *Gigantochloa levis*	6×7	238	Culm has space between each other within a clump
G. aspera	7×7	204	Species having big culms and clumps

Weeding is one of the problems in tending within the first 2～3 years after planting, especially during the rainy season. During this period, spot weeding is done 2～3 times a year.

Forest fertilization has been tried extensively in Japan and was found effective for bamboos. In the future, fertilization studies should include dosage and time of application, and tests on individual and mixed combinations of N-P-K elements.

Generally in tree forestry, harvesting is done by felling trees, thereby leaving no standing crop. In bamboos, after selective harvesting, new plants will still develop. Consequently, the harvesting method could be a part of tending. Nowadays, the harvesting method is practiced indiscriminately resulting in reduced productivity and decreased production of new culms. Over-cutting affects the mother culm in such a way that there is reduced assimilation and deficient nutrition resulting always in reduced production. In the Bataan and Zambales provinces, it was observed that indiscriminate harvesting adversely affects culm production of *S. lumampao.*

Bambusa blumeana have small spiny branches which are intertwined at the lower basal portion of the clumps. The culms are traditionally cut about two meters from ground level. The uncut portion at the base is durable and strong and has a high utilization value because of its thick walls. Harvesting of this thick-walled culm is made easier if the spines are trimmed in advance.

The ideal method of harvesting is selective cutting after two years and culm harvesting be distributed evenly around the clump, keeping a certain distance between culms.

Clump-forming type of bamboo have buds which grow into new culms and within two years no growth of additional culms occur. Selective cutting can be applied to species like *D. strictus*, *B. vulgaris*, *S. lumampao* and *G. levis* while partial clear cutting can be applied to *B. blumeana* and *D. merrillianus*.

A test on the effect of the period and quantity of harvest and divided harvesting of clump in relation to bamboo growth must be investigated further.

In bamboo flowering, factors such as differentiation of flower buds, causes of flowering structures in different species, and recovery test after flowering also need further study.

In the near future, utilization of bamboo will be developed in order to meet the current and future demands of these materials. Generally, rectangular or squared bamboo could be used as decorative elements as flower vases, and also be utilized in some parts in house construction and furniture.

These studies would be an important guideline in giving solutions to various research problems of bamboo cultivation towards the attainment of an efficient and comprehensive implementation of bamboo exploitation and management in the Philippines and other tropical countries.

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Appendix 1. Number of genera, species and area of bamboo forest in some countries

Country*1	Genera	Species*2	Area (1,000 ha)
Africa	8	14	?
Bangladesh	?	?	100
Burma	?	42	2,000
Cambodia	?	?	400
India	13	136	5,000
Indonesia	9	31	50
Japan	14	635	150
Latin America (Nicaragua)	9	180	? (4)
Madagascar	9	30	?
Malaysia	8	52	100
New Guinea	?	8	?
Philippines	12	49	200
The Peoples' Republic of China (: Continental China)	26	235	2,500
Sri Lanka	?	10	?
Republic of China (: Taiwan)	21	130	110
Thailand	10	34	1,000
Vetnam	?	?	100

*1 Approximate data collected on following references ; 3), 13), 15), 33), 36) & 40).

*2 Genera and species include native and cultivated bamboos.

Appendix 2. List of Philippine bamboos

Scientific name	Common name
1. Erect Bamboo	
Arundinaria	
Arundinaria niitakayamensis HAYATA	
Bambusa	
Bambusa arundinacea WILLD.	India Bamboo
B. blumeana SCHULTES f.	Kauayan-tinik, Spiny-bamboo
B. cornuta MUNRO	Lopa
B. merrillii GAMBLE	Merrill bamboo
B. nana ROXB.	
B. tulda ROXB.	Spineless India bamboo
B. vulgaris SCHRAD. ex WENDL.	Kauayan-kiling, taiuanak
B. vulgaris var. *striata* (LODD) GAMBLE	Yellow bamboo, kauaxau-dilau
Dendrocalamus	
Dendrocalamus merrillianus (ELM.) ELM.	Bayog
D. curranii GAMBLE	
D. latiflorus MUNRO	Botong
D. parviflorus HACK	
Gigantochloa	
Gigantochloa aspera KURZ	Giant bamboo
G. levis (BLANCO) MERR.	Bolo
G. scribneriana MERRILL	
Guadua	
Guadua philippinensis GAMBLE	Guadua
Leleba	
Leleba floribunda NAKAI	
L. ventricosa MCCLURE	Budda bamboo
Phyllostachys	
Phyllostachys nigra MUNRO	Polevault bamboo
P. bambusoides var. *aurea* MAKINO	
P. pubescens MAZEL ex H. LEHAIE	
Schizostachyum	
Schizostachyum lima(BLANCO) MERR.	Anos
S. brachycladum KURZ	
S. hirtiflorum HACK	
S. lumampao (BLANCO) MERR.	Buho
S. textorium (BLANCO) MERR.	Kalbang
S. zollingeri STEUD.	Buhong-dilau, yellow buho
Thyrsostachys	
Thyrsostachys siamensis GAMBLE	
2. Climbing bamboo	
Cephalostachyum	
Cephalostachyum mindorense GAMBLE	
Dinochloa	
Dinochloa aguilarii GAMBLE	
D. ciliata KURZ	
D. elmeri GAMBLE	
D. luconiae (MUNRO) MERR.	
D. pubiramea (MERR.) GAMBLE	
D. scandens O. KUNTZE	
D. scandens var. *angustifolia* HACKEL ex MERR.	
Schizostachyum	
Schizostachyum acutiflorum MUNRO	
S. curranii GAMBLE	
S. dielsianum (PILGER) MERR.	
S. diffusum (BLANCO) MERR.	
S. fenixii GAMBLE	
S. hallieri GAMBLE	
S. luzonicum GAMBLE	
S. merrillii GAMBLE	
S. mucronatum HACK	
S. palawanense GAMBLE	
S. toppingii GAMBLE	

フィリピンにおける熱帯産タケ林の育成に関する生態的考察

内　村　悦　三[(1)]

摘　　要

タケは熱帯から温帯にかけて広範囲に生育しており，その種類も多い。なかでも南北両回帰線にはさまれた低海抜高の熱帯にはクランプ型(連軸型もしくは株立ち型)のタケ類がみられるほか，高海抜高地帯ではノン・クランプ型(単軸型もしくは散稈型)のタケ類がみられるなど分布と生態の上から極めて興味深い地域ということができる。熱帯地域のうちでも北緯15°から25°に拡がる熱帯アジアの一部には大面積の天然性タケ林がみられ，各国で紙やレーヨンパルプ資源のほか農林水産業資材，構築材料などとして大量に使用されており，さらに良質材は雑貨用品や工芸品として加工されている。ところが搬出の容易な農家林や資材用の林分では過伐や保育を無視した伐採がおこなわれている。したがって，森林資源を確保し，環境の保持をおこなうためにも先進の育林技術を導入して施業の改善をはかり，あわせて有用種の造成林分の育成を望む声が各国で高まりつつある。本報告はこうした情況下にあり，かつタケの研究と利用に深い関心を示したフィリピン国林産研究所（FORPRIDECOM）と農林水産省熱帯農業研究センターの研究協力のもとで昭和50年8月より2か年間現地で実施した研究成果の一部をとりまとめたものである。なお表題に示した熱帯産タケ類とは数理気候のうえで定義づけられている熱帯で，しかも月平均気温18℃以上の地域に自生しているタケ類であり，そのほとんどがClump forming type（連軸型）のものである。

本報告では，まず，タケの分布を他の地域における熱帯産タケ類の立地条件と対比し，その生態上の特徴を究明した。すなわち，立地要因を緯度，標高，気温，土じょうなどから考察した結果，フィリピンにおけるタケの林分は農業開発によりかなり破壊されており，本来の林分形態が北部ルソンでみられるに過ぎないことが明らかになった。一方，これまでフィリピンには8属30種のタケが確認されていたが，今回の調査により数種の導入種を見出すことができ，なかでも幾種かはすでに現地に適応して林分となっている。こうしたことから現在少なくとも12属48種は生育していることがわかった。しかし，分布範囲が広いわりに，生産量や利用度の高い有用種はごく少なく，それらですら生態的特性の未知の点が少なくない。いま有用種の分布についてみると，熱帯産タケ類では日照量と降水量に影響されていることが明らかで，とくに雨期と乾期が明確な地域や裸地化した場所では *Bambusa blumeana* が優占種となる。*Bambusa vulgaris* や *Schizostachyum lumampao* は樹木と混生し，傾斜地や小さな尾根近くの日陰地でよく生育している。さらに *Gigantochloa levis* は谷筋もしくは湿度の高い日陰地で生育が良い。ただ *B. blumeana* は前記のほか湿度の高い低地でも林分をなしていてその適地は広い。

成長過程に関する基礎的調査　*B. vulgaris* および *B. vulgaris* var. *striata* を供試材料として実施したところ，成長日数の長いタケでは稈の総成長も長くなる傾向がみられ，成長曲線は降水量と養分補給に

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(1) 関西支場

関係する。すなわち，雨期の初めに発生するタケは成長日数が短く，稈長も短いが後半に発生するものほどそのいずれもが長くなる。こうした傾向は短期間に集中的にタケノコを発生する散稈型の温帯産タケ類と異なった特徴といえる。さらに熱帯産タケ類は一般に温帯産のものに比べて成長日数が長く，形状比も胸高直径の増加とともに大きくなる。一方稈の形状は種類によって異なるが，概して地ぎわが肉厚の種類でも地上3m附近から急激に稈壁が細くなる傾向がみられる。

生産量　熱帯産タケ類の蓄積量の推定や林分構造を知るための資料として地上部各部分の含水率を求めたところ，稈については一般に基部で高く，中央部に相当する樹冠の下部から先端部へ移るにつれて減少する。つぎに D^2H と稈乾重量との間には相対成長関係が認められた。一方，天然林におけるクランプ配置とクランプを構成するタケの生育状態にもとづき生産構造図を求めた。その結果，*B. blumeana* や *S. lumampao* では地上物全体に占める稈の割合は多く，*B. blumeana* では枝葉量の垂直的配分が比較的均等であるが，*B. lumampao* ではこれが稈の上方部に集中しており，限られた光を十分に利用していることがわかった。*B. vulgaris* については稈の生産量に対して枝葉量が多く，このため稈はクランプの外側へ倒れるように拡がり，全体として大きな樹冠を構成している。地下茎や根茎量は温帯産のものに比べて少なく，稈重量のほぼ30％を示し，全生産量に対する稈の重量比は60～70％となる。

これらの結果から現存量は地上部合計でヘクタールあたりの乾重量（トン）が *B. blumeana* で143，*B. vulgaris* で106，*S. lumampao* で66となり，年生産量は同様に30，20，15，また本数で1,900，2,250，2,500と推定される。

熱帯産タケ類の増殖　タケ類は突然に有性繁殖するが，通常は無性繁殖で更新している。このため増殖にはこれら両者を利用しうるが，有性繁殖の場合は開花結実が前提となる。一方，無性繁殖法としては株分け，さしき，とりきがあり，いずれも母材の形質がそのまま受継がれるという利点がある。ただ温帯産のタケ類では地下茎が長く，しかも稈がランダムに生育しているため株分けをおこなっても母材におよぼす影響は少ない。しかし熱帯産のタケ類では地下茎が短く，稈の下部の芽子がそのまま稈に生育するため，株分けを実施すれば限られた母材から大量に増殖することができないばかりか，母材を傷つけ痛めるなど悪影響も大きい。したがって熱帯産のタケ類ではさしきやとりきが可能であるため，むしろこうした増殖法の技術を体系化することが必要と思われる。ただ，この両者を比較した場合実用性の高いさしきの方がより大切であると思われるので本稿ではさしき試験についてのべることにした。

供試材料は *B. vulgaris* を使用し，（1）さしき材料の年齢に関する試験，（2）さしつけ方法別試験，（3）材料採取時期試験，（4）材料の部位と活着後の生育調査などを実施した。これらの結果，養分補給量の多い雨期の後半に発生する生育良好な，しかも成長完了後1年未満の若い稈を用いること，さらに活着率の高い稈の基部もしくは中央部にいたる部分が材料としての最適条件を具備したものということができ，先端部やその附近では活着率が低下する。活着後における地上稈の生育は基部，中央部，先端部の材料採取順に悪く，各部位における差は大きい。

さしつけには中央部に1節をつけ，その前後の中央部を切断するのみで材料となるが，空洞内に泥土を入れ，地中20cm程度に水中にさしつける。これは水平ざし（埋稈）が垂直ざしや斜ざしよりも生育，発根量などがすぐれたという結果によるものであり，垂直ざしをおこなう場合でも節の位置を地中深くさしつける必要がある。

さしきの発根率はタケの種類により異なるが発根率の低い種類ではホルモン処理が必要であり，*B.*

vulgaris では I. B. A. 処理による効果が認められた。なおこの種のさしき試験については さらに追究すべき問題点が多い。

一方，有性繁殖に関しては数種の熱帯産タケ類の開花過程と実生苗の生育状況，施肥試験などについて述べたが，これらはタケの種類のほか種子によっても生育状況が相違した。しかし，開花後クランプ全体が完全に枯死する種類では種子の結実量が多く，その発芽率も高い。反面，クランプの一部が未開花で生育を続ける種類は結実量が極めて少なく， 発芽率も低い。 また開花時期は多くの場合 11 月から 2 月頃にかけてみられ， 5 月から 8 月にかけて結実する。

熱帯産タケ類の育成　さしきによる育成過程についての調査結果はこれまで全くなかったので，タケの更新とクランプの拡がりを追跡した。すなわち，さしき後 2 か年経過したクランプの掘取り調査をおこなったところ，タケノコの発生は初年度 4 回おこなわれており，第 1 回はさしつけ後 2 週間目に，第 2 回はその後 1 か月目に，第 3 回はさらに 2 か月目に，そして第 4 回はさらに 2 か月後に発生している。このように地上茎は発生過程とともに直径， 稈長 を 増大し， 満 1 年後に最初に発生した稈に 比べて直径で 3.2 倍，稈長で 4.5 倍を示した。第 2 年度にはさらに稈の更新がすすみ，稈の発生はほぼ 2 か月目ごとにおこなわれ，地下茎の分岐も認められた。そして年度最後の段階では直径はもとの 5.1 倍，稈長は 7.4 倍となり，さしき材料と同一形状にまで生育した。こうした調査の結果，さしき後 5 年目には利用可能な稈生産がおこなえるものといえる。これに対して実生苗による更新はさしきに比べて遅い。ただ，施肥などの効果が認められるので，今後こうした処理を併用した育成技術も追究する必要がある。

最後に各種の調査および試験結果から熱帯産タケ類の 研究や育成に 関する問題点にふれ， 2，3 の指針をのべた。

Photo. 1
Artificial square bamboo
(*Bambusa vulgaris*).

Photo. 2
Experiment of culm cuttings (*Bambusa vulgaris*).

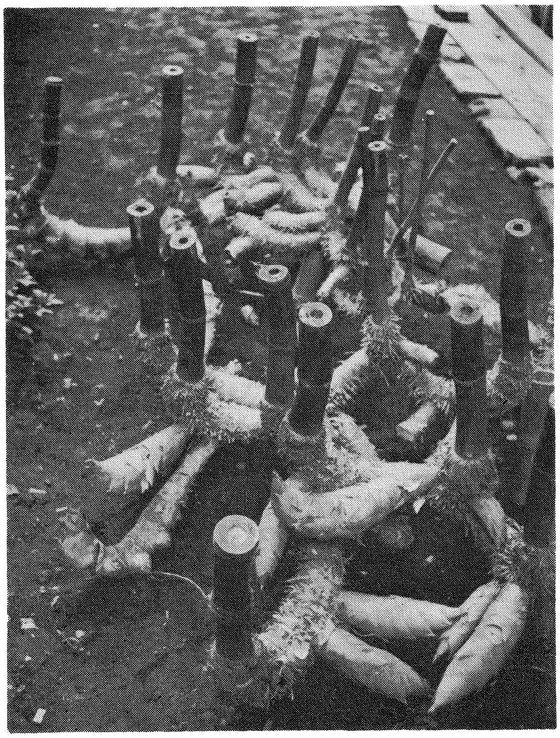
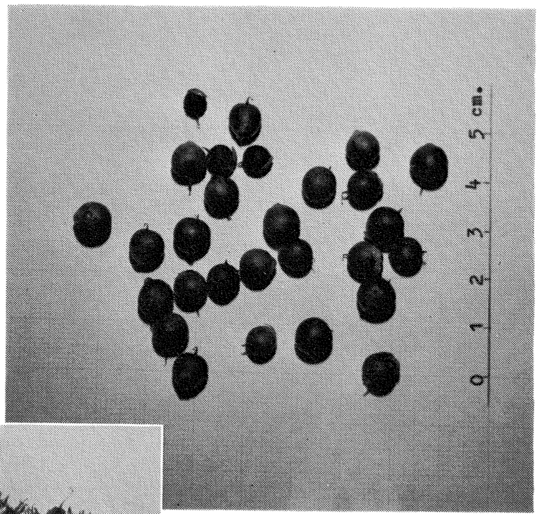
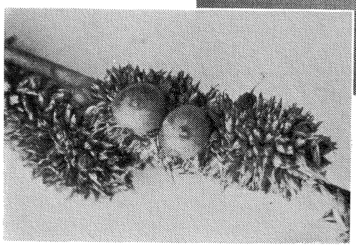


Photo. 3
Development of bamboo after 2 years by culm cutting (*Bambusa vulgaris*).

Photo. 4
Flowering of *Schizostachyum zollingeri*.





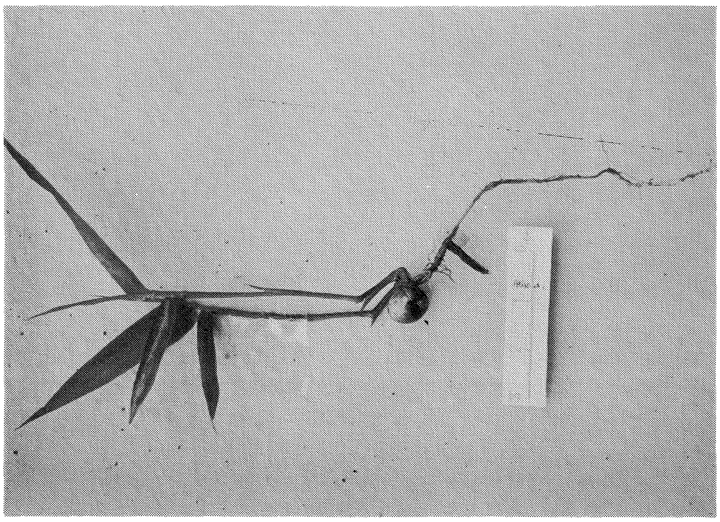


Photo. 5 Seeds and seedlings of *Bonkawe.*

Photo. 6
Flowering of *Schizostachyum lumampao.*

Photo. 7
Seeds of *Bambusa arundinacea* collected in Thailand.

(a) Growth of seedlings after 3 months.

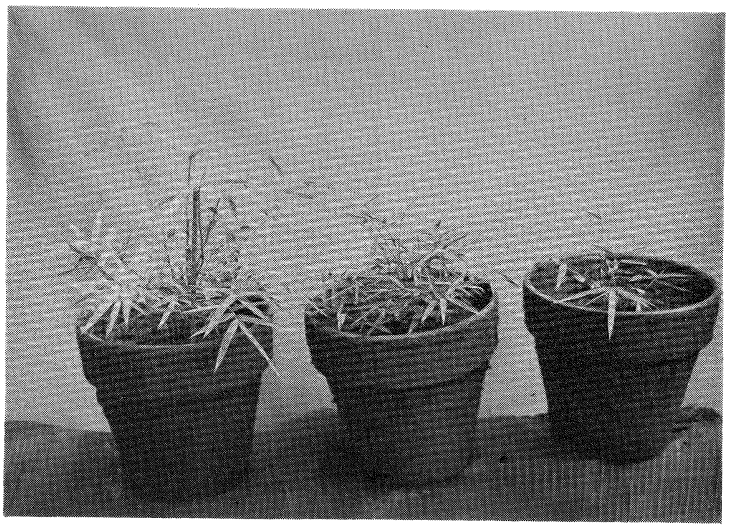
(b) Growth of seedlings after 2 years.

Photo. 8 Plantation of *Thyrostachys siamensis.*

(a) Growth of seedlings after 3 months.

(b) Growth of seedlings after 2 years.

Photo. 9 Plantation of *Phyllostachys pubescens.*



(× 2)　(× 1)　(Control)

Photo. 10
Fertilizer application test (*Bonkawe*) after 50 days.