Recent Research on Bamboos

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FOREWORD

In early 1980, IDRC organized the first ever workshop on "Bamboo Research in Asia" in Singapore. About 22 forestry scientists participated in the meeting where 19 papers were presented for discussion. That ground-breaking meeting had the following objectives:

- To review the existing knowledge on the cultivation and utilization of bamboo in Asia;
- To consider the most important problem and constraints preventing the greater use of the bamboo resource in the region; and,
- To identify regional research needs and priorities on bamboo cultivation.

We in IDRC are happy that five years later we are able to convene this second workshop on Bamboo Research in Asia in Hangzhou, China, in collaboration with the Ministry of Forestry, China, the Chinese Academy of Forestry, The Nanjing University of Forestry, and the IUFRO. The world of bamboo reserach has changed much since 1980. This is largely reflected in the papers presented. In this second meeting some 80 scientists from various parts of the world participated and over 50 papers were presented for discussion. Of these at least 15 papers are the results of research supported jointly by IDRC and national research institutes; over 20 papers come from the People's Republic of China reflecting the long tradition and interest this great nation has in Bamboo. We will not be surprised if this is not the first meeting in Forestry in which so many Chinese scientists have participated.

The papers themselves reflect both the progress and the degree of comprehension we have achieved in understanding bamboo production and utilization. The problems identified in 1980 have not all been resolved, but it is heartening to note that many solutions and innovative approches to improve the lot of bamboo growers, manufacturers and users have been worked out. Even more heartening is to note the awakening of interest on Bamboo Research in Asia.

On behalf of IDRC, the Ministry of Forestry and the Academy of Forestry, People's Republic of China, we wish to express our gratitude to all the people who ensured the success of this workshop. We are specially grateful to the enthusiastic team of organizers from the Chinese Academy of Forestry's Subtropical Forestry Research Institute in Zhejiang Province who devoted so much of their time and effort for making the workshop into such a lively and productive forum. Finally our thanks are also due to all of the participants who have come from all over the world to contribute to the second workshop on Bamboo Research in Asia.

IDRC is hopeful that much good will result from this workshop. The Centre will continue to give serious consideration to any request from the developing nations of the world for support to conduct bamboo research. We, like the great Chinese poet, believe "a meal should have meat, but a house must have a bamboo. Without meat we become thin; without bamboo we loose serenity and culture in itself" (Su Dong Po — 10th Century Chinese Poet).

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Preface to the Second Edition

INBAR/IDRC has been at the forefront of the research and development in bamboo since the eariy eighties. tDRC organized the first ever workshop on 'Bamboo Research in Asia" in 1980. In 1985 in collaboration with the Chinese Ministry of Forestry, The Chinese Academy of Forestry, the Nanjing University of Forestry, and the International Union of Forestry Research Organizations (IUFRO). the second Intemational Bamboo Research Workshop was organized in Hangzhou, China. This workshop was the largest gathering of bamboo scientists in the world up to that date and provided a forum for wide-ranging exchanges of the latest information and ideas on bamboo research in Asia.

Since then, the IDRC Bamboo and Rattan Network(predecessor of INBAR) and after 1993, INBAR, have been involved in organizing the third, fourth, and fifth international meetings, held in Cochin, India; Chiangmal, Thailand; and Bali, Indonesia in 1988, 1991 and 1995, respectively. Proceedings of these workshops, **two** of them in reprints, have been published jointly by INESAR, IDRC and FORSPA. They continue to be great demand by bamboo enthusiasts around the globe.

The Hangzhou proceedings has been a very informative and path breaktng document in its content and presentations and scientists, field workers, and general bamboo lovers continue to request it. Responding to this popular interest, we are happy fo bring out a section edition of the Hangzhou proceedings Recent Research on Bamboos', together with the Chinese Academy of Forestry, China. We are confident that a large number of readers will now have easy access to this wealth of information of meet their growing interest in bamboo.

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DEDICATION

It is with deep regret that we record the sudden tragic death of Mr Haryanto Yudodibroto who was involved in a car accident on May 19, 1986. He was an Associate Professor in the Faculty of Forestry of Gadja Madah University, Yogyakarta, Indonesia, His contribution to bamboo research in Indonesia was considerable and he was an active participant in the Workshop. The demise of an experienced colleague in bamboo research is deeply regretted and this volume is dedicated to cherish his memory.

Bamboo Resources and Country Reports

Inventory and Resource of Bamboos

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Abstract

After detailing the general importance of bamboos in the Asia Pacific Region the occurrence and importance of bamboos in different contries are discussed. Assessment of bamboos is made only in such countries where pulp and paper mills are established and one recent example is cited. The bamboos in the villuges of Bangladesh has been assessed. In view of the likelihood of gregarious flowering of bamboo and death of clumps, whether a total country wise assessment of bamboos is necessary and would be useful is an aspect to be considered. Assessment of bamboo resources in the rural sector is, however, desirable as bamboos form cm important component in the rural sector for establishment of cottage and rural industries. Further recommendations are made to enrich bamboo plantations and resources.

General

Bamboos form the single most important item of forest produce used by the rural communities in Asia and the Pacific, from the.cradle to the coffin. Though once called the poor *man's, timber* it is no longer so. Its use as a long fibre raw material in the pulp and paper industry is well known and is one of the much sought after raw material in the tropics. Its use in housing, agricultural, horticultural pursuits, fishing industry, basket making, transport system both on land and water, handicrafts and production of edible shoots warrant reconsideration of the classification of bamboos as a 'Minor Forest Produce' in some countries and in others as 'non commercial species'. It deserves an improved status in the forestry parlour and greater study in depth. Significant awareness on the importance of bamboos has been created during the last decade, though work was done earlier on the scientific aspects of bamboos by several scientists. Bamboos continue to hold their important place in the rural economy of the developing countries especially in the Asia Pacific region. The usage of bamboos in rural and cottage industries is far more than their use. in the pulp and paper industry. Its high calorific value of 4600 to 5400 Cal/kg makes it eligible as an energy crop, except that it burns quickly. If a device could be found to make it burn slow, its use as an energy resource would be immense especially due to its fast growth. Bamboos are also used in the ceramic industry (FAO, 1978; Sharma. 1982).

Country Wise Occurrence

It is reported that over 75 genera and 1250 species of bamboos occur in the world (FAO, 1978). The tropical belt is characteristic of a large number of species. The occurrence of species in some of the countries in the Asia Pacific Region is given below. The species of bamboo that figure prominently and used both by the people and paper industry are:

Species of Melocanna, Bambusa and Dendrocalamus in India, Melocanna and Bambusa species in Bangladesh, species of Bambusa and Dendrocalamus in Burma, Thyrsostachys, Bambusa and Dendrocalamus species in Thailand,, Dendrocalamus and Gigantochloa species in Indonesia, Schizostachyum, Gigantochloa, Bambusa species in Philippines, Phyllostachys species in China, Japan and Korea.

India (About 130 species): Bamboos have a wide range of distribution forming an understorey in several forest types, except in Jammu and Kashmir. The tropical moist deciduous forests of North and South India,

Dendrocalamus hamiltonii along Melak river Nagaland, India

the deciduous and semi-evergreen regions of North Eastern India are the home of bamboos. The forest area over which bamboos occur in India, on a conservative estimate, is 9.57 million hectares. This is about 12.8 percent of the total forest area of the country (Bahadur and Verma, 1980; Sharma, 1980). Out of the total estimated production of nearly 5 miilion tonnes about 3.5 million tonnes are required by the pulp and paper industry. only a few species like Bambusa *arundinacea,* B, tulda, Dendrocalamus *hamiltonii,* D, strictus are commercially utilised for pulp and paper though other species are used for cottage/rural industries. One of the disturbing factors contributing towards wholesale destruction of bamboo wealth is shifting cukivation * (Jhum is the term used for slash and burn technique for temporary agricultural pursuits by landless people) in the N. E. hill regions.

Bangladesh (33 species): The hill forests contain most of the species of bamboos. The bamboos in Chittagong hill tracts committed to Karnaphuli Paper Mills at Chandagona are heavily depleted, with the result the mills are now augmenting their supplies from the bamboos growing in village groves. A large number of villages in Bangladesh contain several important species of bamboos. According to the National Statistics of village trees and bamboos of Bangladesh (1980-81) there were nearly 190 million mature or older bamboos and 558 million immature or young bamboos, in homestead blocks. Even in these rural areas and homesteads, trees and bamboos are being cleared due to fragmentation of holdings, The village cannot expand as

Dendrocalamus hamiitonii with new shoots japo-Nagaland, India

they are surrounded by agricultural lands all round. Shifting cultivation also has contributed towards the depletion of bamboo resources.

Thailand (50 species): Bamboos occur as associates of the deciduous forests of the north and as undergrowth in the evergreen and mixed deciduous forests, Sometimes bamboos occur as pure stands. Though barn boos are not exploited by Government agencies, people are allowed to remove bamboos freely from forests without any regulations in cutting. Over 50 million bamboo culms are extracted annually. This system would lend to depletion of bamboo resources in the long run, Thyrsostachys siamensis is grown in homesteads and is the main source for the cottage and rural industries. No assessment of the bamboo resources has been made either in Government Forests or in the homestead areas.

Large clumps of *Dendrocalamus* hamiltonii Jaoo Nagaland, India

Burning of forest containing bamboo for Jhum Nagaland, India

Malaysia (12 species): Bamboos occur gregariously or in isolated patches, along stream and river banks, heavily worked out forests in low lands, hill sides, and tops of ridges. The complete opening up of the canopy of forests and fires induce their development. About 2.5 tonnes of bone dry bamboos per acre is reported to be available from the Malaysian forests. Little attempt has been made to cultivate bamboos, as they are freely available in natural forests. Bamboos are extracted on the strength of licenses issued by Forest Department and the revenue collected is relatively small. Besides bamboos are generally regarded as a weed interfering with the normal regeneration and development of the timber species. Assessment has not been made of the bamboo resources of the country.

Philippines (55 species): Large tracts of bamboos occur in the northern provinces, confining themselves to the marginal lands, courses of streams and rivers. Several climbing species of bamboos like Dinochola sp. form dense tangles, in the forest especially in the Southern region. Bamboos occur over an area of 7924 hectares which is 0.03 percent of the land area. A survey carried out during 1981 in the forest areas revealed that there were 353 million clumps of bamboos (Source – Bureau of Forest Department). This does not include bamboos on private lands and they are considerable. The consumption of bamboos in the cottage/rural industries sectors and for fish pen industry is on the increase, but resources have dwindled, There is no control over the removal of bamboos by people as they are free to remove them for their local needs.

Indonesia (31 species): Bamboos occur in forests which have been opened up as a result of heavy exploitation. The climbing species like Dinochold is very rampant in such areas. More than 90 percent of bamboos are in village lands and homesteads, mostly cultivated by people. Bamboo groves are converted into Agathis/Pine plantations. No assessment of the growing stock of bamboos either in the Government owned forests or in the village lands or in homesteads have been made.

Papua New Guinea (26 species): Bamboos occur generally in savannahs of the Western Provinces. People plant thick walled bamboos for housing and other needs, in the villages, in low lands and high lands. Assessment of bamboo resources either in forests or

Forest cleared for Jhum. Nagaland, India

Jhum cultivation in progress — Destruction of rich bamboo area. Nagaland, India

viliage lands or on farm lands has not been made. Nearly 144000 hectares are private forests owned mostly by farmers and 13 genera, 670 species are reported. No assessment is made of the total quantity of bamboo available.

China (300 species): Bamboos occur over 2.9 million hectares. No information is available of the total assessment. Intensive work has been done in various parts of China on cultivation and management of bamboos and the papers in this volume provide plenty of information .

Assessment Of Bamboo Resources

Bamboo generally forms an understorey/ mixture with other tree species in the tropical natural forests. There are no pure natural bamboo stands except the dense Phyllosta chys sp. in the temperate countries. Bamboos occur as a pure crop (a successional species) as a result of clear felling of natural forest of mixed species – either for regeneration purposes or in abandoned areas where shifting cultivation has been practiced in a large number of tropical countries.

Assessment of bamboos ie., involving information on the extent of area over which bamboo species occurs, their density/ stocking and their extent and proportion, total availability. have not been made in any country, except when their availability has to be known for establishing paper and pulp industries. The assessment is either done by ground or serial survey. Being an understorey in the natural forest, it is difficult to obtain a clear picture by aerial survey. The density has to be determined only by ground surveys and sample enumerations. This is how surveys have been carried out in India, Bangladesh and Burma over specific forest areas where bamboos are leased/proposed to be leased to a pulp industry. In Bangladesh UNIP recently assisted in the determination of the extent of bamboos in the villages (Sharma, 1980; Hammer Master, 1981). It was found to contain 190 million mature and 558 millions of immature or young bamboos. This again appears to have been necessitated by the shortage of bamboos experienced by the Karhaphuli Paper Mills in the Chittagong Hill tracts.

In many states in India bamboo wealth has been assessed either as an independent programme or at the time of preparation of working plans specifically when such informa-

Jhum cultivated and abandoned area taken *for bamboo* planting with intervening paddy by Nagaland Pulp and Paper Co, India.

Bamhusa tulda rhizomes planted at 6.5 m × 6.5 m amidst paddy cultivation. Nagaland, India.

tion is needed for feeding a paper mill. These assessments have, however, been upset by subsequent gregarious flowering and subsequent death of bamboo clumps following seeding. The resulting regeneration takes time to establish and has to face factors like grazing and fires and need for tending the regeneration for further development.

Thus the extent of availability of bamboo resources has to be determined more precisely in the countries of the Asia Pacific region.

The possible reasons why country wise inventories of bamboos have not been initiated could be

i) A total inventory of bamboo wealth may indicate only the extent of availability of all species and the assessment of the utilisable species has also to be part of total inventory.

ii) Bamboo occurs as an understorey in the forest. The inventories made hitherto by Forest- Departments generally concentrate on the tree species only, unless an assessment is needed for supply to pulp industry and such assessments are done over areas leased to the industry.

iii) In countries like India, Bangladesh, Burma the figures of inventories made at considerable expense are. upset by gregarious flowering and seeding resulting in the death of bamboo clumps (sympodial bamboo) upsetting all industrial planning and supplies to rural and cottage industries.

iv) The methodology for conducting inventories has also not been standardised especially when we are dealing with sympodial species of bamboos.

v) The sympodial species of bamboos present difficulties due to very close or dense collection of culms in the clumps, sometimes congested. Thorny species like *Bambusa arundinaced* and *Bambusa blumeana* pose additional difficulties in approaching the clumps due to thorns and a thorough clearing of side branches is needed to get near the culms.

Planting of rhizome in 1 m diameter pits — Agroforestry, Nagaland, India.

In view of these difficulties and since many of the countries in the region rarely use bamboo for pulping is it really necessary, to attempt a total inventory of bamboo resources? These assessments of bamboo become necessary when a pulp and paper industry is planned. However detailed surveys do become useful when planning has to

I m diameter pit. 1/2 m deep for Bambusa tulda between paddy crop (Agroforestry) Nagaland Pulp and Paper Co. Nagaiand India.

be done by Forest Department Extension workers for distribution of seedlings and planning of bamboo based rural or cottage industries.

Bambusa tulda as a dense wind belt around cultivation. Assam, India

Wind belt of *Bambusa tulda* around a farm Assam. India

In India the gregarious flowering followed bv seeding has completely jeoparadiesed the planning of sustained supplies of bamboos to the pulp and paper industry and supplies to the rural and cottage industries. The same is the case in Burma, where bamboo resources are dwindling though there are not many paper mills in that country. The free removal of bamboos from the forests by the people in Thailand has already created shortage of bamboo and this position is likely to be aggravated soon. The regenerations development of the bamboo resources is left in the hands of the people. There is need, however. for an intensified technological guidance to the people to grow bamboos on private lands, The depletion of resources even in the reserve forests as a result of free, removal of bamboos has to be guarded against and augmentation of the bamboo resources is a necessity if sustained supply is to be ensured. In Malaysia since bamboo is considered as a nuisance interfering with the regeneration of main timber species not much work is done in the field of development of bamboo resources. In Indonesia, except for the private farmers raising bamboo, no serious effort has been made in the forestry sector to develop bamboo resources. The raising of Agathis is prefered to the development of bamboo resources. In the Philippines the bamboo resources have dwindled to a considerable degree partly due to the utilisation of bamboos in the fish pen and cottage industries. These industries are virtually threatened so far as the raw material needs are considered.

Natural regeneration of bamboos by means of seed consequent on gregarious flowering is evident in the case of Bambusa arundinacea and Dendrocalamus strictus

2 Seasons *Dendrocalamus strictus* planted for soil erosion control. Neyveli Lignite Corporation Ltd., India.

Well maintained clump of *Bambusa tulda* by farmers, Nagaland, India.

which are flowering at frequent intervals all over India/Banladesh/Burma. The development of the seedling regeneration into clump stage takes 6 to 10 years and depends how well they are protected from grasing and fire, In all these natural regeneration areas it is necessary to adopt soil and moisture conservation measures and fertilizer treatment to the promising and selected seedlings of a specified number per hectare. To enable the seedlings to develop into clump stage, it is necessary to keep the culms spaced out. This will also prevent congestion and provide adequate space for the free use of implements while working.

Great strides have been made in India on the artificial regeneration of bamboo by different methods compelled by circumstances arising out of infrequent flowering and seeding and acute demand for bamboo in the industrial and rural sectors. The cultivation of bamboos by farmers generates increased resources, with small inputs, reduced after care, low technology and reduced pest control measures. It is already being done in Bangladesh, Burma, Thailand, Indonesia China and Japan. It is time that the developing countries intensify cultivation of bamboos by the small and marginal farmers. Plantations of bamboos have not been attempted so far in Burma except on an experimental scale. But *Dendrocalamus longispathus, Bambusa vulgaris, Dendrocalamus calostachys, Dendrocalamus giganteus* and *Thyrsostachys siamensis* have been planted by villagers in the country side for domestic uses. In the context of development of rural economies bamboo should be one of the species which should be given adequate importance in the Social Forestry/Ago Forestry practices as well as in waste land development. There are over 160,000 hectares of bamboo piantations in India. The areas cleared for shifting cultivation in the hill regions could be reclaimed by planting bamboo at frequent intervals along the slopes and permitting cultivation in the intervening space with either agricultural/horticultural/forestry crops, This type of agroforestry with bamboos can be used not only to protect the hillsides from erosion but also to increase the resources (Hammer Master, 198 1).

Bamboo resources should, however, be developed at village level. People in North Eastern India, Bangladesh, Thailand, Philippines and Indonesia raise large quantities of bamboos of different species in and around their homesteads for their local requirements and to serve as a wind belt. If planting of bamboos by farmers along the fringes of their farms, along water courses and homesteads is encouraged it would lead to the creation of enormous bamboo resource/raw materiaf in the rural sector of all the countries.

Suggestions For Increasing Bamboo Resources

1. In the case of sympodial bamboo species felling should be regulated by 'Culm Selection System'.
2. A certain proportion of older culms to the number of new culms shoutd be retained in the clump to provide stability to the new culms.
3. Peripheral cuttings or cutting of top portions of culms only in the case of thorny species like *Bambusa arundinacea* and Bambusa blumeana would make the clumps congested. Two methods of cuttings of congested clumps/dense overcrowded clumps are indicated. (Figs. l-3)
4. The culms in a clump should be thinned out from the very inception and culms spaced. This prevents congestion, provides for space for working and allows adequate space for new shoots to come UP.
5. Moisture conservation techniques (vide diagram) followed by fertilizer application should be adopted in the case of new regenerations consequent to flowering.
6. In the older clumps, cultural operations like removal of dead and crooked stems, spacing of clumps, moisture conservation methods and fertilizer application have to be resorted to (Fig. 4).
7. In view of the dwindling resources of bamboos, captive plantations should be planned to meet the needs of the rural and cottage industries with appropriate planting technique, after care and fertilizer treatment.
8. Bamboos should be the principal species to be planted in the foreshore areas of reservoirs between the high flood level and mean flood level.
9. Intensive planting of bamboos should be encouraged in the agricultural sector and in homesteads, by providing the planting materials and technology to the farmers by Forestry Extension Service.
10. Bamboo,should be one of the principal species for peripheral and contour strip planting in shifting cultivation areas as they would act as good wind belts and arrest soil erosion. (Figs. 5 & 6).
11 There is considerable scope for work connected with the classification and identification of bamboos. distribution and up dating their nomenclature.
12. International funding should be made available to the poor countries taking up the development of bamboo resources.

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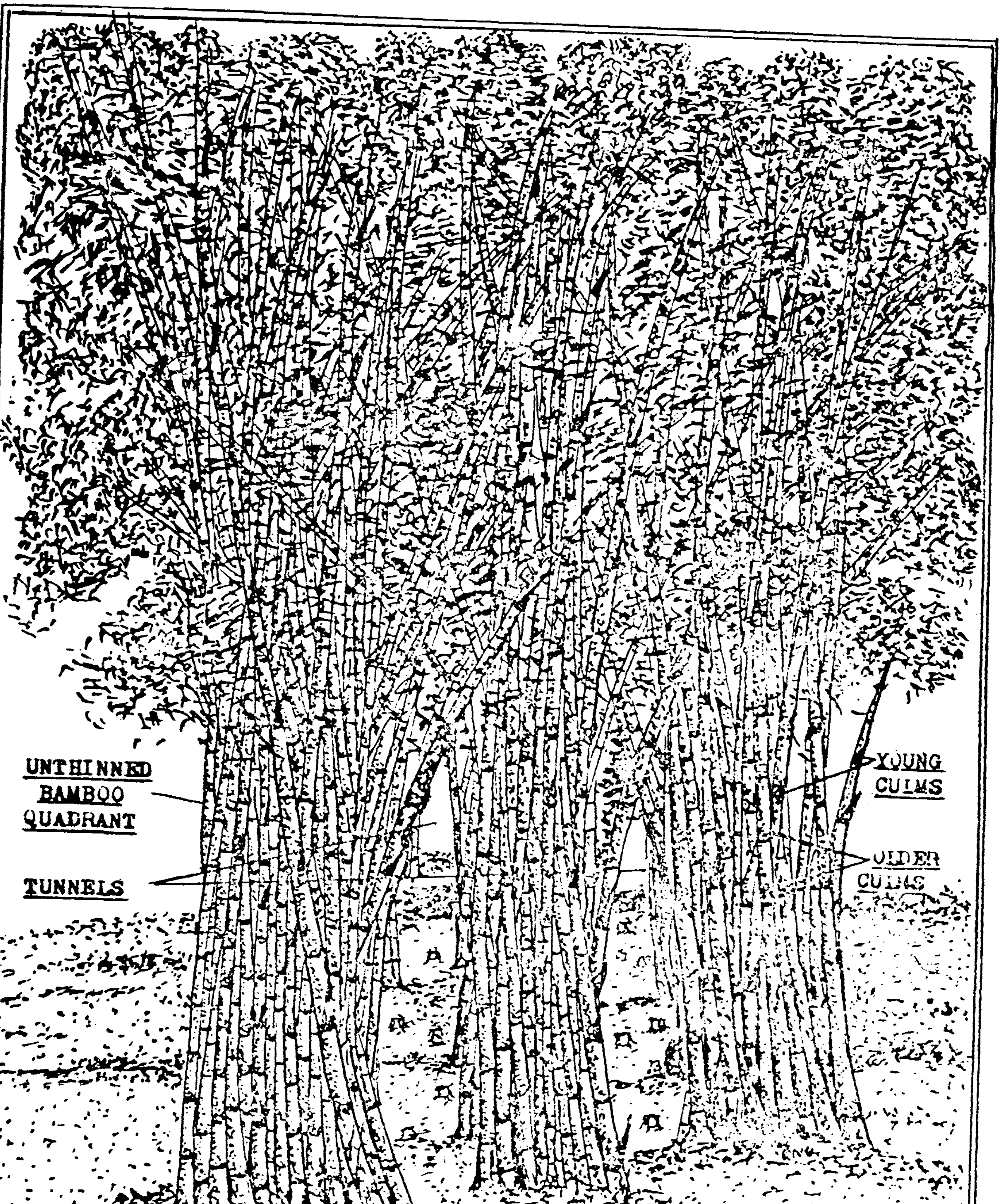
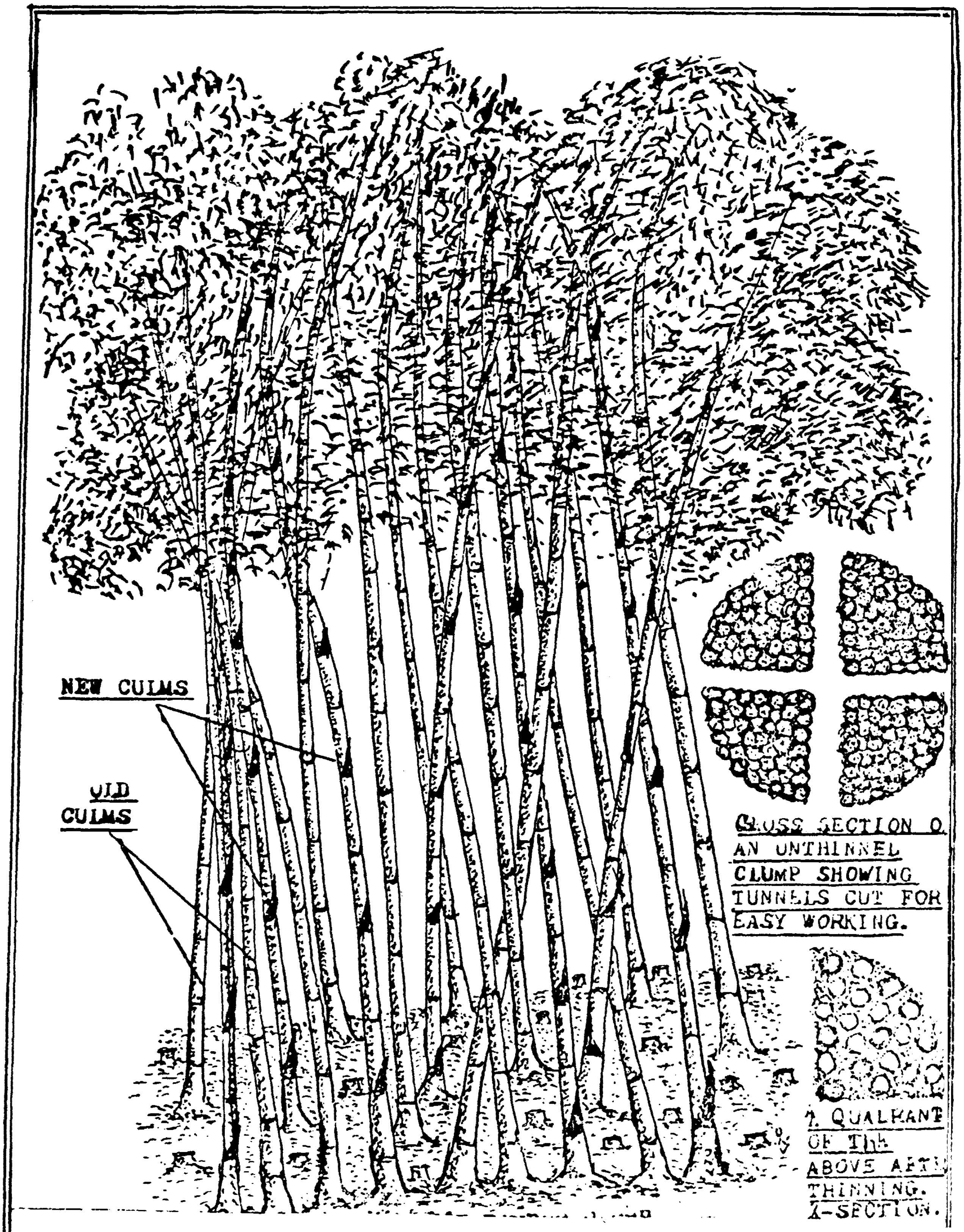


WORKING OF BAMBOO CLUMP

Diagram showing a bamboo clump with two tunnels formed at right angles to facilitate easy working of each quadrant on thinning principle.

Fig. 1: Methods of cutting clumps.



WORKING OF THE BAMBOO CLUMP

A DIAGRAM SHOWING A QUADRANT OF THE BAMBOO CLUMP AFTER THINNING. AN OLDER CULM SHOULD BE LEFT NEAR EACH ONE OF THE NEW CULMS FOR SUPPORT.

Fig. 2: Methods of cutting clumps.

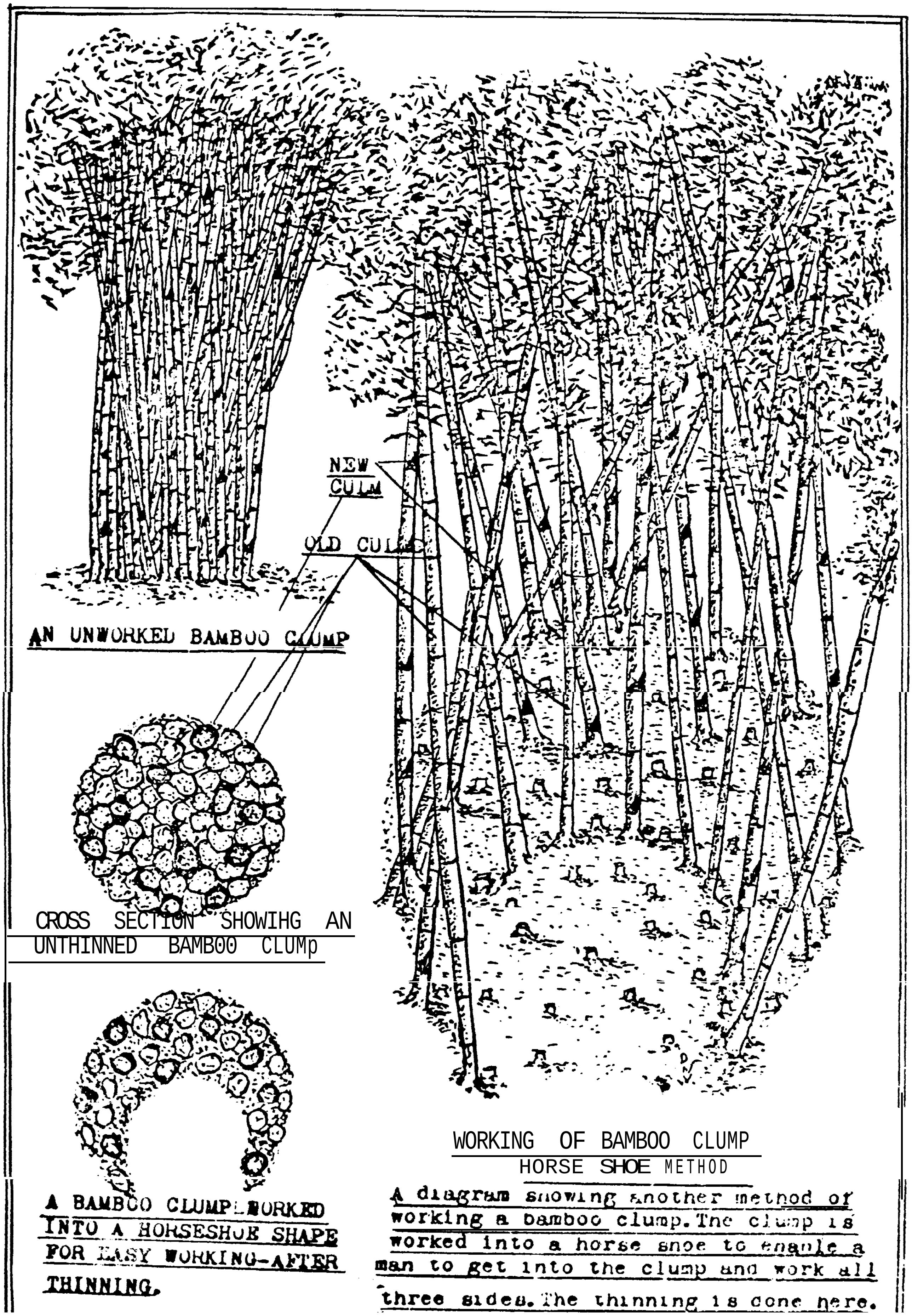
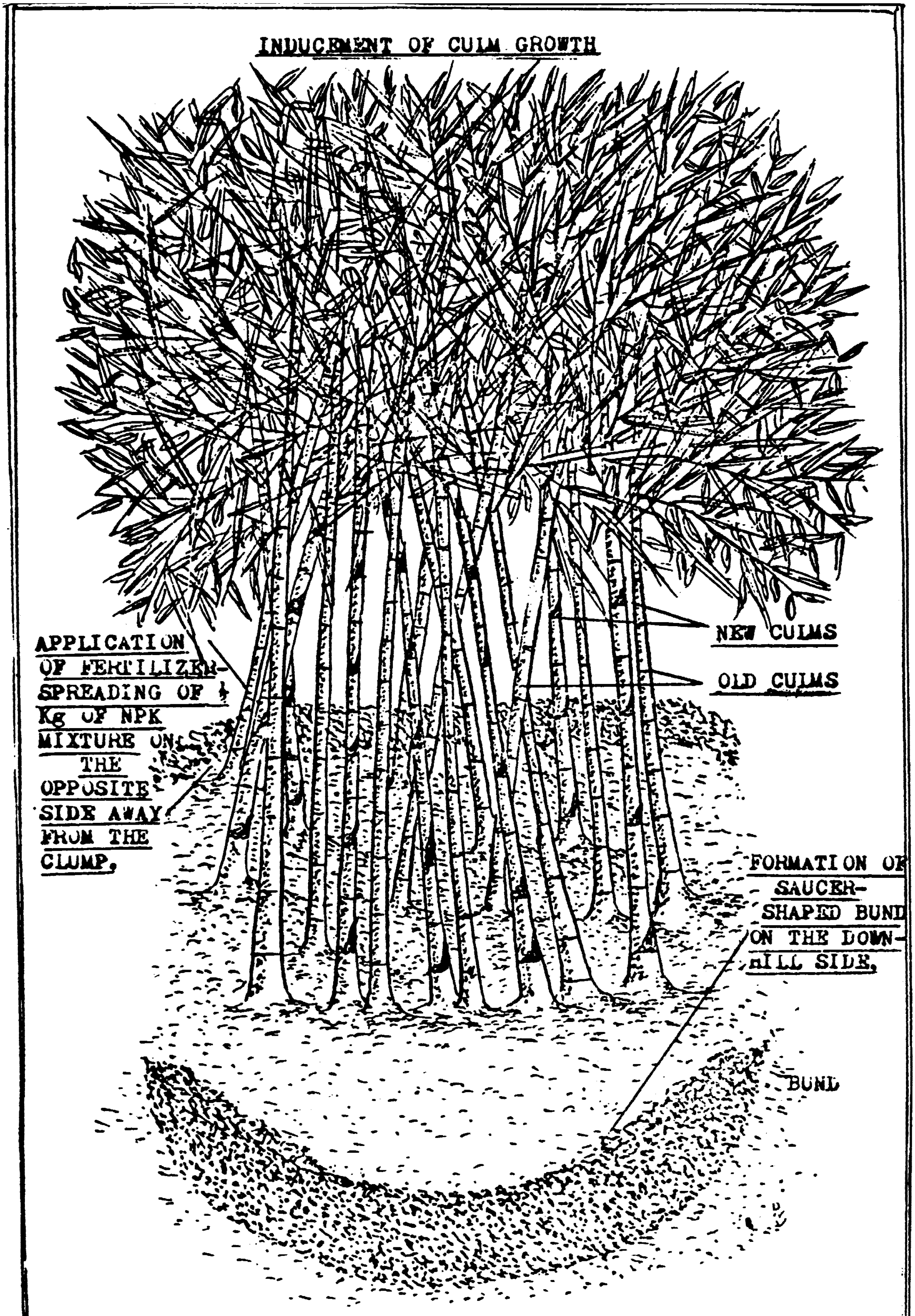


Fig. 3: Methods of cutting clumps.



Fig, 4: Spacing of Bamboo clumps.

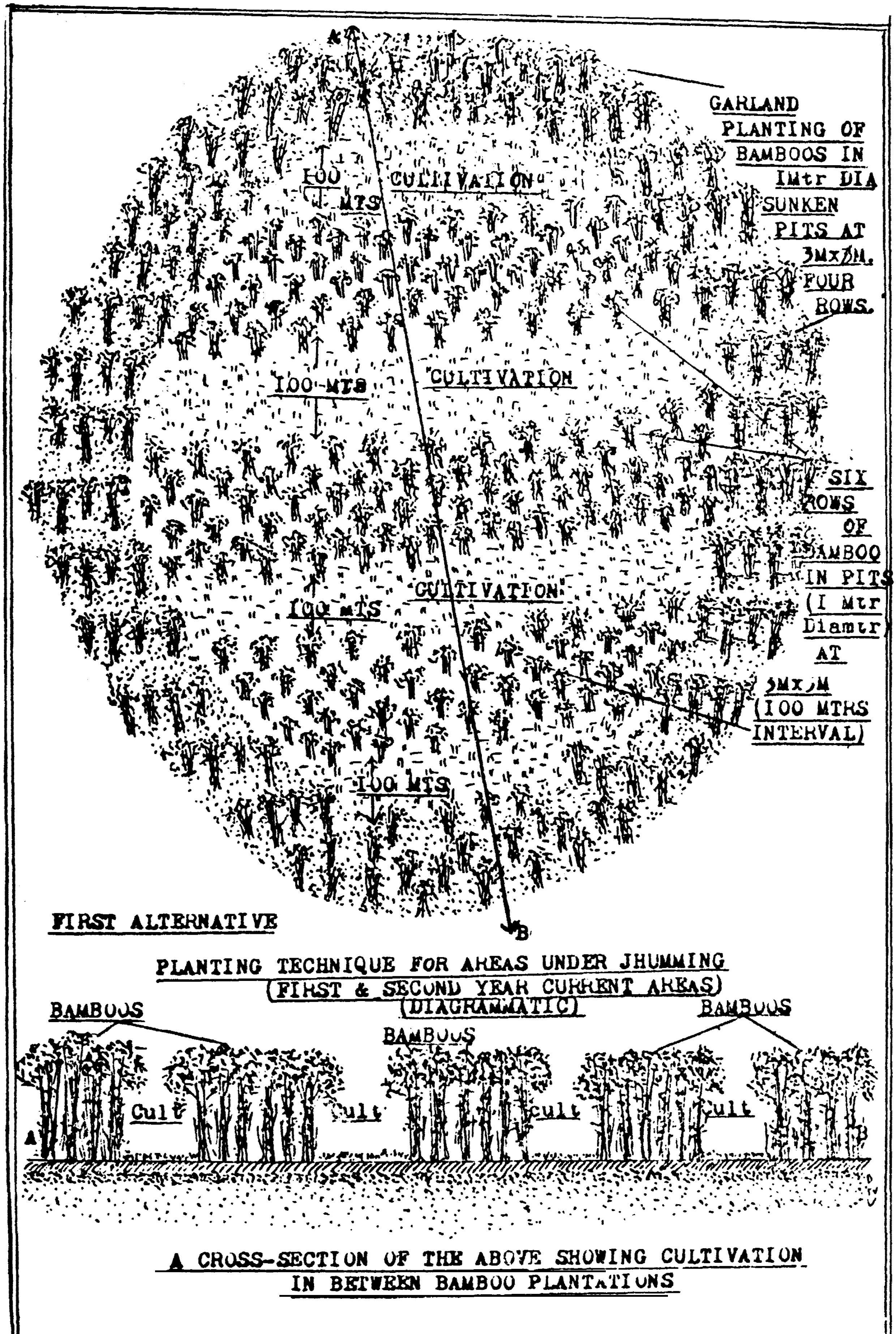


Fig. 5: Contour strip planting.

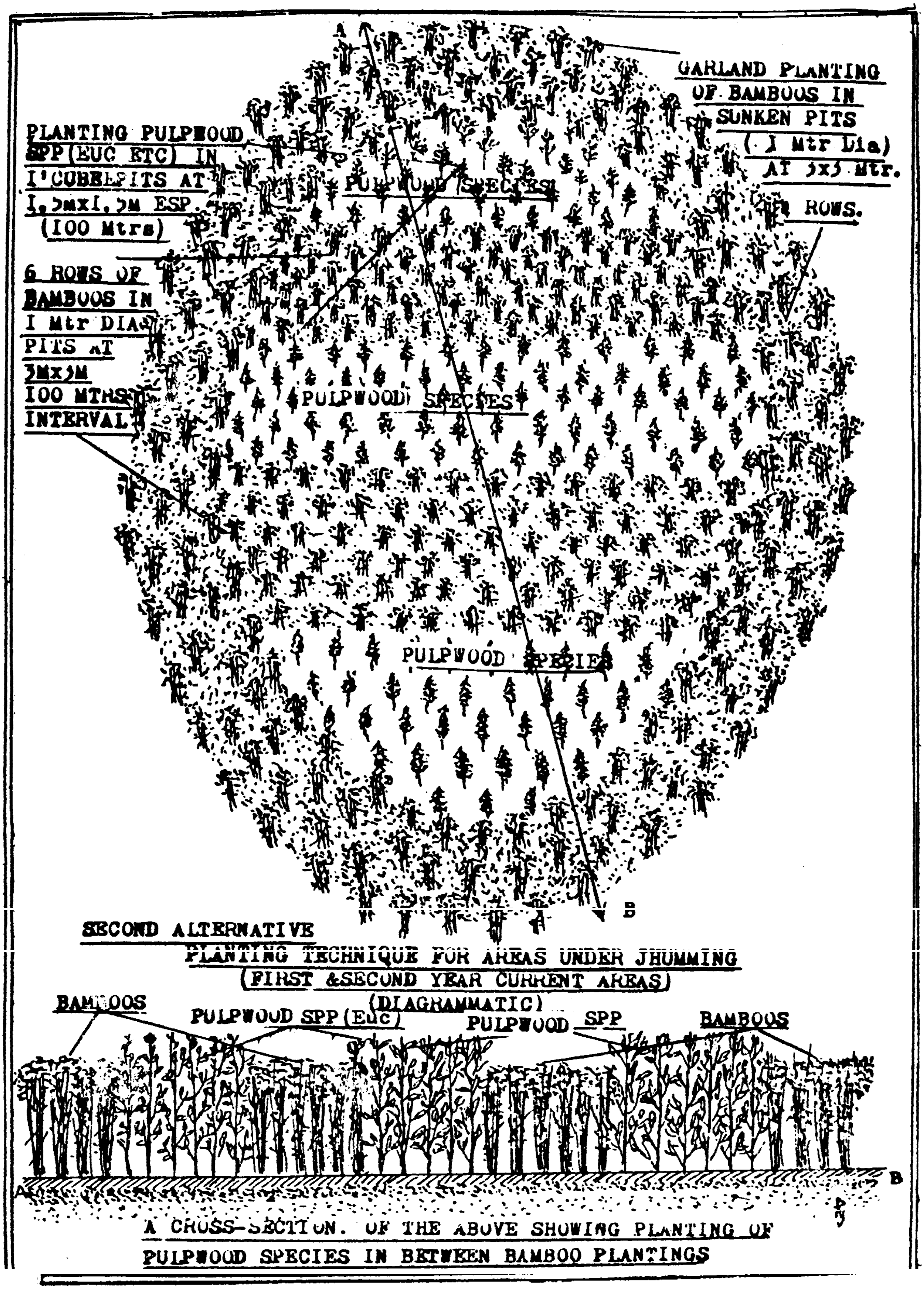


Fig. 6: Contour strip planting.

Bamboo Research in China

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Abstract

Bamboo research in China is discussed with reference to resource and production. The authors further describe current research activities and chart future directions.

China is one of the most important bamboo producers in the world and bamboo is closely bound with the life of the Chinese people throughout history. In the ruins of Zhejiang's Hemudu which was built more than 4,800-5,200 years ago during the New Stone Age and in the ruins of Zhejiang's Shishan of 4,200-5,300 years ago, bamboo mats, baskets and other bamboo-weaving articles have been unearthed. And in the Yin Dynasty ruins in Henan's Anyang (16th – 11th century B.C.), there are six bamboo articles with (bamboo brush) written records among the excavated inscriptions on bones and tortoise shells. In "Shijing", a collection of poems from early years of the Western Zhou Dynasty to the spring and autumn period (11th – 5th century B.C.), records of people eating bamboo shoots can be found. Historical and cultural events were already being recorded mainly on *bamboo slips as early as the spring and autumn period (770 – 476 B.C.). Since the Western Jin Dynasty of more than 1,700 years ago (256 A. D.) , people started to make paper with bamboo saplings and such bamboo-made paper became world-famous by the. Tang Dynasty. The bamboo-made bows and arrows used to be important weapons in ancient wars. In "Zhouli" written in the 3rd century B.C., there are records of many. types of bows and arrows, such as "Round Bow", "Six Bow", "Wang Bow", "Pincer Bow", "Inclosure Bow", "Tang Bow" and "Large Bow". China has a rich array of traditional musical instruments with national characteristics and long history. According to the records of the Zhou Dynasty (11th – 3rd century B.C.) alone, there are over 70 varieties of musical instruments, including seven types of bamboo musical instruments, such as xiao (Chinese vertica), sheng (Chinese wind pipe), dizi (8-holed Chinese bamboo flute) and other ancient wind instruments. Bamboo has played great indelible role in China's historical and cultural development. Su Dongpo, the famous poet of the Song Dynasty, said: "There ***are*** bamboo tiles for shelter, bamboo hats for shading, bamboo paper for writing, bamboo rafts for carrying, bamboo skin for clothing, bamboo shoes for wearing, bamboo shoots for eating and bamboo fuel for fires. Indeed, we cannot live without bamboos for a single day." This is a succinct summary of the close relationship between bamboos and people.

Bamboo Resources

China has about 400 out of 1,300 or more bamboos known in the world. Over 1,000 years ago (317 – 420 A.D.), in the Jin Dynasty, Dai Kaizhi recorded in his "Zhupu" (bamboo manual), the first monograph of bamboos in the world – 61 types of Chinese bamboos. Later on, there is further description of bamboo varieties, distributions, shapes, characteristics, habits and cultivation techniques in Jia Sixie's "Qiminyaoshu" (530 A.D.), Zan Ning's "Zhupu" (the late 10th century) of the Song Dynasty, Li Kan's "Zhupuxianglu" (1312 A.D.) of the Yuan Dynasty, Wang Xiangjin's "Qunfangpu" (1621 A.D.) and Xu Guangqi's "Nongzhengquanshu" (1639 A.D.) of the Ming Dynasty and Wang Ying's "Guangqunfangpu" of the Qing Dynasty.

The contemporary classified research work by the Chinese scholars started in the 1930s. In 1940, Professor Geng Changli published an article concerning two new types of bamboo originating from China — *Brachystachyum.* However, the wide ranging and systematic investigation and classified research on China's bamboo resources started from the mid 1970s. Through the efforts of the Chinese researchers in bamboo classification, 266 new species (including varieties and forms) and four new genera have been discovered in addition to the other genera.

Current Situation of Bamboo Production

According to statistics, China's present total *area of bamboo forest has reached 3.4 million hectares, making up nearly 3% of China's total area of forest and one quarter of the world's total area of bamboo forest. China's bamboo is mainly distributed along the Changjiang (Yangtze) River basin and in hilly area, downland and plain of torrid and subtropical zones, 3,000 m above sea level south of the Changjiang River. The annual bamboo output is about 6-7 million tons. The primary species is Phyl/ostuchys heterocycla var. *pubescens* which makes up 2/3 or more of China's total area of bamboo forest. Other major species are Ph. glauca, *Ph.* bambusoides, *Ph.* viridis, Ph. nigra var. Henonis, *Bambusa* textilis, B. rigida, B. *pervariabilis, B. multiplex, Sinocalamus latiflorus,* Neosinocalamus affiis, *Pleioblastus amabilis, Pseudosasa* amarus, etc.

Since the founding of the People's Republic of China, thanks to the great attention paid by the Party and State to the bamboo production, continuous progress has been made in this field:

1. Increased bamboo resources and output – Table 1. shows the development and change in China's bamboo forest area, storage and annual production from 1950, the year after liberation, to 1980. During these 30 years, the total area of bamboo forest increased 70% or more with an annual average increase of 1.78%) among which the forest of Phyllostachys heterocycla var. pubescens increased 81.4% with a yearly average increase of 2%.

2. Increasingly intensive bamboo management and growth of per unit bamboo output – In the early days after liberation, China's bamboo forest mostly lay waste. People cut bamboo without planting. Later extensive cultivation was practised, causing old bamboo plants to fill the forest with an extremely high output. With the rejuvenation and progress in the national development, bamboo has become an important raw material in China's industrial and agricultural production as well as in people's life and the management of bamboo forest has become increasingly intensive. The managerial level of bamboo forest can be shown from three main aspects. The first concerns the bamboo forest with high output, high level of intensive management and practice of appropriate cultivation and felling, prevention and control of plant diseases and elimination of pests, scarifying and applying fertilizer to the soil etc. The per hectare annual output can reach 10-12 tons or more. The second concerns the bamboo forest with comparatively high level of intensive management and fairly general practice of appropriate cultivation and felling, levelling off hilltops and weeding, prevention and control of plant diseases and elimination of pests etc. The per hectare annual output is around 7.5 tons. The third concerns the bamboo forest with extensive management and very low density or the problem of going out of cultivation. The per hectare annual output is only 1.5-3 tons. In the early days after liberation, the first and second kind of bamboo forest only amounted to less than 3% of the total bamboo forest area and now it is making up 1/3 of the total. Owing to the scientific management of bamboo forest, the per unit bamboo output has increased (Tables 1,2)

3. Bamboo shoot production and comprehensive utilization of bamboo by-product – In China, over a hundred kinds of bamboo shoots are eaten as delicacies. Following species are planted mainly for the usage of bamboo shoots: *Phyllostachys heterocycla var. pubescens, Ph. praecox, Ph. dulcis, Ph. iridescens, Sinocalamus latijlorus, Dendrocalamopsis oldhami, D. beecheyana* var. *pubescens, Oreocalamus szechuanensis* etc. Apart from fresh ones, bamboo shoots can be processed into dried bamboo shoots and preserved. In recent.years, the bamboo shoot

Table 1. Development of Bamboo Resources.

Year	Total		Ph. heterocycla var. *pubescens*			
	Area (10,000/ hectare)	Storage (10,000/ ton)	Area (10,000/ hectare)	Annual Felling t10,000/ pole)	Storage	
					Number (10,000/ plant)	Weight (10,000/ ton)
1950	about 200		about 133.33			
1957		4,563.30	149.44	16,052.1	237,533	3,563.3
1965	230.55	5.501.12	161.29	13,975.0	292,148	4,382.22
1975	270.47	6.369.31	199.62	18,309.3	354,274	5,314.11
1980	340.18	7.168.84	241.87	24,800	379,589	5,693.84,

Note: The average weight of each *Ph. heterocycla* var. *pubescens* culm is 15 kg.

Table 2. Quantitative Output of Main Bamboo Species.

Name	Producing Area	Density (plant/mu)	Average Diameter (cm)	Storage (kg)	output of New Bamboo (kg/mu)
Phyllostachys heterocycla var. pubescens	Gangkou Farm under Lingfengsi Forestry Centre, Anji, Zhejiang	411	11.96	15,895	1,816
	Shimen, Fenghua, Zhejiang	332	14.2	18,007	1,801
	Moganshan, Deqing, Zhejiang	504	10.8	16,013	1,610
Ph. *glauca*	Xinghua Bamboo Garden, Loning, Henan	1,990	6.18	27,860	5,572
Pseudosasa amabilis	Aozhenglibo, Huaiji. Guangdong	1,886	3.7		
Bashania fargesii	Liqianping, Hongyu, Zhenba, Shaanxi	2.615	2.6	4,855	1,306
Sinocalamus latiflorus		321		3,806	1,901
Si. *oldhami*		1,035		5,589	2,795
Lingnania wenchouensis	Mabu, Pingyang, Zhejiang	1,026 (18 thickets)	6.9		2,520

Note: One hectare = 15 mu.

production has achieved a very rapid development as there is a sharp increase of demand for bamboo shoots in people's life and foreign trade. Farmers in many places have grown large areas of bamboo for bamboo shoots, and large areas of *Phyllostachys heterocycla* var. *pubescens* forest for construction materials have been changed for bamboo shoots or dual-purpose of bamboo materials and bamboo shoots. The per unit bamboo shoot output has raised very rapidly with, the emergence of such high-yielding varieties as *Ph. praecox* fdrest and *Phyllostachys heterocycla* var. *pubescens* forest, producing 20-30 tons of fresh bamboo shoots per hectare a year. According to the statistics in 1981, FuJian, Jiangxi, Hunan and Zhejiang four provinces alone produced 9,692 tons of dried *Phyllostachys heterocycla* var. *pubescens* shoots and 115, 398 tons of fresh bamboo shoots. According to the preliminary estimates, China's annual bamboo shoot output can reach about 1 million tons.

Since bamboo has many uses and is easy to process, it is used by a great number of departments and through many channels. It is, therefore, difficult to make accurate estimation of its range of usage and proportion. However, its continued economic contribution to China is undeniable.

With the development of the bamboo processing industry there has been a proportionate increase in the utilization of bamboo as pulp and veneer board and a decrease in its use in the raw (culm) form. Judging from the present trend of development, one may conclude that bamboo pulp and paper-making in particular will develop into an important industry in China.

Research Work

The bamboo researches constitute an important force in the contingent of forestry sciences and technologies. The Chinese Academy of Forestry Sciences, Nanjing Forestry College, Zhejiang Forestry College, Zhejiang Provincial Institute of Forestry Sciences and some other research institutes of forestry sciences and forestry colleges have all set up bamboo research divisions. Also, there are special bamboo researchers in almost all the important bamboo producing-provinces, district forestry research centres and forestry colleges. Under the leadership of the Party, research was centred on ways to explore, expand, protect and comprehensively use the bamboo resources. A great deal of experiments have been carried out and demonstrations, have been held to popularise, bamboo production and multiple uses.

1. **Research on basic aspects**— Systematic investigations have been carried out to find out various resources of bamboo plants in China and fairly in-depth research work has been done in the field of bamboo classification, which has helped us to sort out, on a preliminary basis, the data on Chinese bamboo classification, discover and name a large number of new bamboo genera and species. Preparations are being made for the publication of the special volume of bamboo section of the Chinese flora.

Efforts have also been made to collect widely various kinds of bamboo present in China and set up a number of bamboo gardens so as to let them play a role in protecting and expanding Chinese bamboo resources and promoting work in bamboo scientific research, education, production and academic exchanges. Following are those gardens with a fairly large and wide collection of bamboo plants: Anji Bamboo Garden collectively set up by the Institute of Subtropical Forestry under the Chinese Academy of Forestry Sciences, Lingfengsi Forestry Centre of Anji County and the Forestry Bureau of Anji County, Hangzhou Botanical Garden, Bamboo Sample Garden of Nanjing Forestry College, Bamboo Garden of Guangxi Institute of Forestry Sciences and Wangjiang Park in Chengdu. At the same time, observations, experiments and research have been carried out to find out the growing pattern, biological characteristics and ecological habits of some of the fine Chinese economic bamboo plants, such as *Phyllostachys* heterocycla var. *pubescens,* Ph. *praecox,* Pseudosasa amabilis, Ph. *nuda,* Ph. viridis, Ph. glauca, Bashania *fargesii,* Neosinocalamus *affinis* etc., in order to provide theoretical basis for their fast growth and high-yield breeding. Furthermore, observations, experiments and research have been carried out on the bloom of bamboo plant and certain regular patterns of blooming and yielding of bamboo have been discovered and records made.

Since 197Os, Bamboo Research Division of Nanjian Forestry College and some other research institutes have conducted researches on the relationship between production and colony formation of bamboo forest, probed into the close link between production and index of bamboo leaf area, started observations and researches on permanent sample plot on the material circulation of ecological system and energy transformation of bamboo forest and determined various organs' combustion value of some of the major bamboo plants in China.

2. **Research on technology of breeding and fast-growth and high-yield cultivation** – In the early 1950s, systematic research work was carried out in Guangxi and Guangdong Institutes of Forestry Sciences on the techniques of pole and node burying and secondary branch insertion and other breeding techniques of asexual reproduction concerning such thick-growing bamboo as Bambusa textilis, B. pervariabilis and Lingnania chungii. The experience has helped us to develop exclusively thick-g&wing bamboo in the south. In the early 1960s. the Ph. *heterocycla* var. *pubescens* forest witnessed large area ot blooming and yielding which led to the successful research work in many places on the breeding technique in the same species. As far as the research on high-

yielding technique is concerned, there are fairly successful results in various bamboo-producing regions, with more intensive research work on Ph. heterocycla var. pubescens. As for *Ph. heterocycla* var. *pubescens,* cultivation density and felling, technique of dispersing bamboo shoots, soil-loosening and weeding,. research and manufacture of compound fertilizer and the system of fertilizer-applying in bamboo forest and systematic researches have been or are being conducted and many useful results have been obtained. Through the experiments and researches on high-yielding bamboo techniques, a number of high-yielding bamboo forests have been established. Experience has been gained in breeding high-yielding varieties in different counties. On Huaiji County, Guangdong Province, progress has been made in breeding *Pseudosasa amabilis.* In Guangning County, Guangdong Province, there have been useful experiments in breeding *Bambusa texti/is.* And in Loning County and Bo'ai County, Henan Province, results have been achieved in breeding *Ph.* glauca and the high-yielding *Sinocalamus latiflorus.*

3. Experiments and researches on introduction of new varieties and breeding– China has a great number of fine economic bamboo varieties and many have fairly good adaptability. However, a few of the fine economic varieties are distributed very narrowly. In order to widen their distribution, experiments have been carried out in the past few decades on introduction of new varieties. In some provinces and regions in the North where the bamboo varieties are comparatively fewer, experiments have been conducted to introduce the bamboo varieties in the south to the north and certain results have been achieved. For example, *Ph. uiridis* and *Ph. glauca* have started to grow along Beijing and Dalian and *Ph. heterocycla* var. *pubescens* has gradually adapted itself in Laoshan and Wendeng of Shandong Province. The breeding zone of *Pseudosasa amabilis* which originated in the south of China has expanded to the broad area along the Changjiang River basin. The range of distribution of some of the fine thick-growing bamboo varieties, such as *Bambusa textilis, B. multiplex, B. pervariabilis, B. rigida, Neosinocalamus affinis* (Rendle) Keng f etc., are also moving to the north. Some of the fine foreign bamboo varieties, such as Dendroculamus *giganteus and Melocanna* bambusoides, have also been successfully introduced to China. Because of the experiments in this field, there has been greater understanding of the theory of introduction of new bamboo varieties and ecological habits of some bamboo varieties', more technical progress in this aspect and plenty of successful experiences.

Research on bamboo breeding was started in China in the early 1970s. The Institute of Forestry Sciences in Guangdong Province has taken the lead in conducting experiments to improve thick-growing varieties of *B. pervariabilis, Sinocalamus latiflorus, B. sino spinosa, D. beecheyanus, Bambusa textilis* and scattered *Ph. heterocycla* var. *pubescens* through hybridization and has selected some promising hybrids,

4. Researches on the prevention and control of plant diseases and elimination of pests – The main pests in the bamboo forests of China are *Ceracris kiangsu, Atrachea vulgaris, Otidognathus davidis, Pantuna sinica, Artona funeralis, Algedonia coclesalis,* etc. There used to be serious plague of insects in some bamboo producing areas at various times. Through researches and studies, the history, occurrence and development pattern of these pests have been learnt, and fairly effective methods of controlling the pests have been followed bringing them under control.

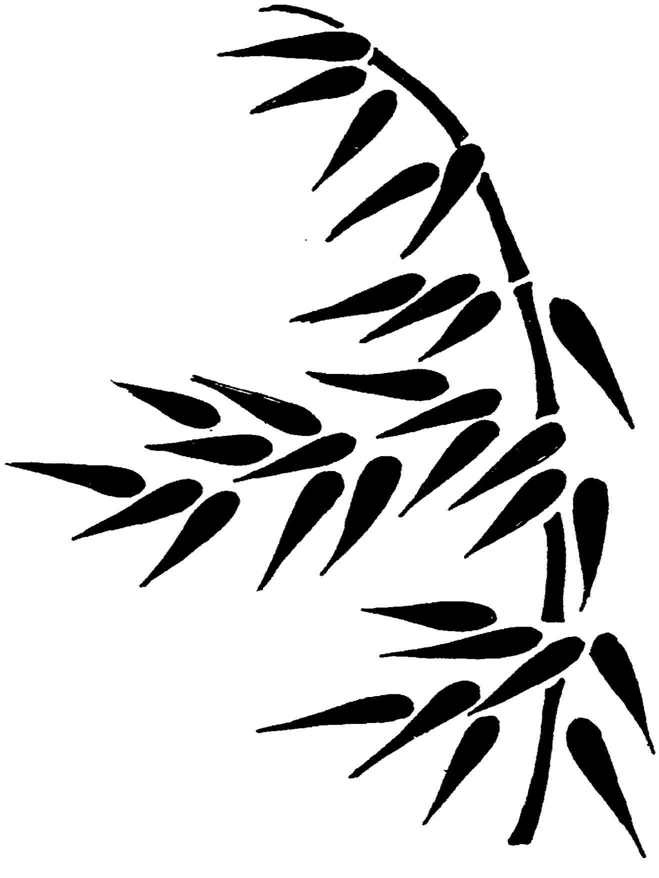
The most serious bamboo disease is *Ceraptosphaeria phyllostachydis* Zhang *sp. nov.* This disease was first discovered in the early 1960's along the coastline in the south-east part of Zhejiang Province. The disease became serious in the 1970s in northwest Zhejiang and spread rapidly to Shanghai, Jiangsu and Jiangxi Provinces and other districts. Owing to concerted efforts on prevention and control the disease was under control within a very short period of time _

The problem of moulding and moth-eating of bamboo materials and bamboo-made products has seriously lowered the value and length of bamboo usage and may cause great economic losses. The main insects threatening bamboo materials are *Dinoderus minutus* and powder-post beetle. At present many institutions have achieved fairly successful results in the treatment of bamboo-made products against moulding and insects.

5. Research on the comprehensive utilization of bamboo materials and bamboo by-products – Analysis has been made to determine the various nutrients, including sugar, protein, fat, vitamin, various mineral nutrients and 17 free amino acids, and their proportion in bamboo shoots of Ph hetero-*cycla* var. *pubescens, Ph. iridenscens, Ph. praecox, Ph. nuda, Sinocalamus latiflorus,' Dendrocalamospsis beecheyanus* var. *pubescens, D. oldhami* and *D. beecheyanus.* This helps the further usage of bamboo shoots.

Researches have been carried out to determine the fiber content, length and width of fiber. This data will be useful in paper-making industry. The technique of bamboo paper-making is improving arid a number of bamboo pulp and paper-making factories are under construction which will increase the usage of bamboo materials

Thus, in the last few years, China has made great strides in bamboo research and production. Though our efforts are still low compared to others, China's foresters have accorded a high priority to this.plant and we anticipate further and rapid development in the years to come.



Bamboo Development in China

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Abstract

The recent advances made in* China *with regard to bamboo cultivation, establishment of industries, bamboo research, the cooperative efforts of the government and the scientists ure briefly outlined.

Bamboos are an important part of forest resources. In China there are about 300 bamboo 'species belonging to more than 30 genera. The total area of bamboo land is about 5.5 million hectares, 3.5 million ha. for commerical bamboo stands and 2.0 million ha. for alpine bamboo thickets. Annual production of culms amounts to more than 5.0 million tons. As an important material, bamboos are widely used in fisheries, industry, construction, paper making, handicrafts and daily items. Tender shoots of bamboo species are nutritious and used as delicious vegetable. With colourful culms and evergreen leaves bamboos are beautiful plants for landscaping. Their extensive rhizome-root system is very useful for soil conservation.

Chinese civilization is closely associated with bamboos. Several thousand years ago our ancestors knew how to use bamboo material. Bamboos were split into slices for recording and writing. Bows and arrows made of bamboos were highly effective weapons for fighting wars. Bamboos have been used to make cheap and handy agricultural implements for long time. Paper making from bamboo pulp has been reputed for more than 1700 years. So many items of Chinese daily life are still made of bamboos even today. Chinese people are proud of their historical association with production and utilization of bamboos.

Unfortunately, bamboo development did not progress much in the past 100 years because of external aggression, internal bureaucracy and backward economy. Since 1949, the Chinese government has paid more attention to bamboo development as indicated by a 70% increase in bamboo area under cultivation. Particularly appreciable advancement of the bamboo industry has been recorded in recent years. Bamboo production has gradually changed with many improvements. About 10% of bamboo plantations are under intensive management with increased production. For instance, bamboo plantations in Moganshan is one of the best, where culm yield reaches over 30 tons per hectare annually. Similarly, processing of bamboo culms has also improved from hand work to industrial practices. We now have more than 100 factories all over the country engaged in the production of various bamboo plywoods or bamboo particle boards. Their capacity is relatively small, not more than ten thousand tons mostly. Substituting bamboos for timber wood becomes more interesting and practical in China because of our poor forest resources. The Central Government has recently financed the establishment of four bamboo paper mills, each with a production capacity of thirty thousand tons annually. Bamboo shoot production has increased over one million tons in recent years. More scientists are now engaged in different aspects of bamboo research and have made valuable contributions to bamboo development. A national organization for bamboo workers known as the Chinese Bamboo Association (CBA) was established with the approval of the Forestry Ministry in 1984 and had its first national congress in Yixing, Jiangsu, in May 1985. We are going to have branch organizations in seventeen provinces including municipalities and autonomous regions where bamboo production constitutes a part of forestry economics. Three branch associations have already been established in Chejiang, Jiangsu and Sichuang recently. More lower branches can be expected in bamboo counties or districts. Membership of the Chinese Bamboo Association is now over four thousand and increasing rapidly. The Forestry Ministry has recently decided to expand its Bamboo Research Laboratories into the Bamboo Research Institute attached to Nanjing Forestry University which is the first institute of this kind in China. An official announcement will be made next week in Nanjing. The Chinese Bamboo Association and the Bamboo Research Institute, Nanjing Forestry University will work together to organize national bamboo refresher course classes for bamboo workers, national coordination of bamboo research activities and international symposia on bamboo research. In addition, two periodicals, "Bamboo Research" and "Bamboo Information" are published by a joint editorial board of these two organizations for bamboo workers in China and abroad. Articles and information concerning bamboo research and production are always welcome, from all bamboo scientists.

According to the national economic development designed by the Central Government, the Chinese Bamboo Association will encourage its members to make great efforts to reach the goal of doubling the area of bamboo land and increasing the present bamboo production by four times. We have proposed to the government to exploit bamboo resource for timber wood substitution and for paper making material. We also encourage farmers to establish and develop different bamboo plantations to meet the increasing needs such as timber bamboos, shoot production, ornamental bamboos, soil conservation bamboos, etc. On the other hand, multiple utilization of bamboo materials should be greatly emphasized. We did some work on bamboo properties, bamboo mechanical processing, bamboo plywoods, bamboo particle boards and bamboo sheets which can be used for building floors, walls, ceilings, interior decoration, furniture and so on. Bamboo woven articles are Chinese traditional products which win high reputation all over the world. All of these mentioned above need more research and improvement technically. We face the great challenge of our modernization so far as bamboo development is concerned.

In order to promote the scientific and technical level of bamboo production and utilization the Chinese Bamboo Association through its appropriate channels plans to do some work for technical training and consultation, research cooperation and coordination, information communication and marketing on a national scale. At the same time the Chinese Bamboo Association will keep contacts with bamboo workers and bamboo organizations all over the world. We will follow the open policy of our government and welcome international cooperation, information exchange and friendship development on the basis of mutual benefits.

We have a long historical background and a glorious civilization that our ancestors have created for us. We will follow and regenerate this great traditional spirit to develop our bamboo science, production and utilization. Similarly we welcome all foreign colleagues to jpin us in our common goal, development of bamboo production and utilization. Cooperation is force. Cooperation means progress. Let us work together for future prosperity of bamboo business.

Bamboo Researchin India

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Abstract

Bamboos are the tallest and largest ofthe grasses distributed both in the hills and plains* of *Zndia. There are* four *exotic genera in addition to the twenty three indigenous ones. The flowering in bamboos* range *from constant flowering to regular sterility. Propagation is done mostly vegetatiuely using various techniques. Bamboo resources in lndia are abundant but they are not fully utilised. Oaft 100 native species only ten are commercially exploited.* In *the absence* of *reproductive structures bamboos can be identified at generic and specifidevel only on the basisof the morphology* of *culm sheath andjuuenile shoots, microscopicand ultramicroscopicfeatures* of *epidermal peels* of *culms and leaues* and other fine structures. The *distribution* is *briefly discussed. Growth* of *naturally regenerated bamboo, yield, source* of *supply, cytology, traditional and other uses are briefly reviewed. Further research on physiology* of *flowering, cytology and tissue culture techniques needto be intensified.

Habit and Distribution

The bamboos are widely distributed in India and abundantly occur in Andhra Pradesh, Arunachal Pradesh, Assam, Manipur, Meghalaya, N . E . Misoram, Nagaland, Sikkim, Tripura, Orissa, West Bengal and Madhya Pradesh States. A few species are also found scattered in other parts of the country both in the hills and the plains. The bamboos may occur as either an under storey or in pure form in all other parts except the Kashmir Valley. Their natural distribution is governed by rainfall, temperature (8^0C to 36^OC), altitude and soil. A minimum of 100 cm annual rainfall and a high atmospheric humidity promote luxuriant growth. In well drained parts of tropical and sub-tropical habitats going up to 3700 m of altitude in the Himalayas, these often form rich belts of vegetation. The main genera in India are: *Arundinaria, Bambusa, Cephalostachyum, Chimonobambusa, Dendrocalamus, Dinochloa, Gigantochloa, lndocalamus, Melocanna, Naohouseaua, Ochlandia,* Oxytenanthera, *Plaioblastus, Phyllostachys, Pseudostachyum, Schizostachyum, Semiarundinaria, Sinobambusa, Teinostachyum,* and *Thamnocalamus.* The exotic genera *Guadua, Pseudosasa* and *Thyrsostachys* are also in cultivation.

in general the genera Bambusa and *Dendrocalamus* occur under the tropical conditions, while *Arundinaria* occurs in the temperate region. The most important bamboo of the semi-evergreen forests of the Andamans is *Oxytananthera nigrociliata.* In the eastern region comprising of Assam, West Bengal, and North-East Himalayas, the commercially important bamboos are *Bambusa tulda, Den-*drocalamus hamiltonii and Melocanna *baccifera.* Recently two new species of bamboos viz. *Dendrocalamus sahnii* Naithani & Bahadur and *Pleoblastus simonii* (carr .) Nakai have been discovered from Arunachal Pradesh; these two are rare species.

Phenology

Bamboos have characteristic flowering and fruiting cycles. These range from constant flowering to constant sterlity as represented by Bambusa atra and B. *vulgaris* respectively. The majority of bamboos falls between these two extremes and the flowering cycle ranges from a few to 120 years. On the basis of their flowering behaviour, bamboos can be classified into those that flower annually or so but nongregariously, those that flower periodically but gregariously and those that flower sporadically or irregularly. In most cases the culms of bamboos die after flowering, but the flowering culms of a few species like *Bambusa* atra do not die and remain healthy and green even after flowering. In species with long flowering intervals, the culm reaches a maximum age of 15 years and then dies, but the whole bamboo clump is a continuous colony that dates back to the original seed. It is well known that populations of a given bamboo species belonging to the same provenance would flower simultaneously irrespective of their planting locations. A few recorded examples are cited here. Seeds of Thyrsostachys oliveri that flowered in Burma in 1891, were planted in Calcutta and at Dehra Dun which are 1500 km apart and the clumps at both places flowered synchronously in 1940. The synchronised flowering of Melo*canna beccifera* was observed in Garo Hills (Assam) and Dehra Dun. Bambusa **arun**-*cfinacea* flowered almost throughout India in 1970-71 after a lapse of 45 years. Thus the period between two gregarious flowering of a species over the same area seems to be constant and cyclic. *Dendrocalamus strictus* was introduced in Cuba, probably in 1912 from seeds from Garhwal (India} and it flowered in Cuba in 1956 after 44 years, (Clement 1956). Wang and Chen (1971) reported that a plantation of D. strictus raised in 1912 in Taiwan from the material sent from Bihar province, (India) flowered in 1969 – a cycle of 47 years.

From the published records the flowering cycle of some of the bamboo species found either wild or cultivated in India are given below:

Bamboo species	Flowering cycle
1. ***Bambusa atra***	Annual
2. *Ochlandra acriptoria (0. rheedii)*	Annual
3. *Bambusa* arundinacea	30 – 45 Years
4. *B. copalandii*	48 Years
5. *B. polymorpha*	35 – 60 Years
6. ***B. tulda***	30 – 60 Years
7. ***Chimonobambusa falcata***	*28 – 30 Years*
8, ***C. launsaransia***	45 55 Years
9. **Dendrocalamus *hamiltonii***	*30 – 40 Years*
10, **D. strictus**	20 – 60 Years
11. **Melocanna baccifara**	30 – 45 Years
12. ***Ochlandra travancorica***	7 Years
13. ***Oxytenanthera abyssinica***	30 Years
14. ***Phyllostachys bambusoides***	*60 Years*
15. ***Tbamnocalamus falcoreri***	*23 – 30 Years*
16. ***T. spathiflorus***	16 – 17 Years
17. ***Thyrsostachys olioeri***	48 – 50 Years
18. ***Bambusa vulgaris***	*So far flowering* not recorded.

In 1983 a clump of *Bambusa spinosa* flowered in New Forest Estate. There are no earlier records of its flowering. In addition, the species which flowered this year in Meghalya are Bambusa *nutans, Chimonobambusa khasiana, Dendrocalamus hamiltonii* and D. *hookeri.*

Propagation

Propagation of bamboos is done by seeds or vegetatively. The seeds and the seedlings are reared and transplanted in the field; but as seeding years are scarce and unpredictable and having short viability, vegetative propagation is the common practice. The seeds *of Dendrocalamus* strictus normally retain their viability for a period of *one year*. Storage of seeds of D. strictus over silica gel. or anhydrous calcium chloride or at low temperatures (3 – 5^0C) after reducing the moisture . content of the seeds to 8% increased the period of viability and after 34 months, the recorded germination percentage was 51, 54 and 59 respectively, (Gupta and Sood 1978).

Vegetative Propagation: The vegetative propagation is generally done by rhizomes or offset planting just before the onset of rainy season. One year old culm with its rhizome and roots is dug up and the culm is cut to about a meter high and the whole thing is planted in summer months and during the period of physiological inactivity. During rainy season these establish successfully. Other propagation techniques followed in bamboo planting are layering, nodal cutting, mar-totting. and culm cutting. Hormonal treatment promotes rooting. Bambusa balcooa when treated with Coumarin, NAA or a mixture of Coumarin and IAA gave the highest percentage of rooting and survival after transplanting in the field (Seetha Lakshmi et al. 1983).

Growth and Yield

Age of Culm: The age of the culms of ***Dendrocalamus*** strictus recorded from 1932 to 1950, in Balaghat Forest Division, Madhya Pradesh has been presented in Tables 1 & 2. Maximum number of culms died between the age of 9 — 12 years (Sharma & Tomar *1963).*

Growth of naturally regenerated bamboo: After gregarious flowering, the seedlings develop singly, and it takes about 6 years to form small clumps, each having 5 — 6 culms with an average height of 7 m and average culm girth of 7.5 cm which are' scattered irregularly 2 — 3 m apart. In 10 years, the best clump had culms of 12 m and a girth of 10 cm at breast height. The clump had sufficient number of normal commercial sized culms only after 12 years, (Pande & Lohani 1962).

The bamboo areas could roughly be classified into the following 4 categories according to the stocking.

1.Dense areas having more than 125 mature and well developed clumps per hectare (250 — 300. clumps/hectare, (Kondas 1982)). 2. Predominant areas having 50 — 125 mature clumps per hectare. 3. Sparse areas having 25 — 50 clumps per hectare, and 4. Poor or Scattered area having less than 25 clumps per hectare. India has abundant bamboo resources, which are not being utilised to the maximum. Out of 100 native bamboos only about 10 species are commercially exploited. The total bamboo area in the country is about 9.57 million ha and its annual potential yield is about 4.5 million tonnes (Tiwari, 1981). The statewise bamboo area and the annual potential availability of bamboo are given in Table No. 1.

Biological Research

It has been established that for specific end-uses, correct identification of bamboos is essential, as the physical and other properties differ from species to species. However, absence of flowers during collection poses an intractable problem in establishing the correct identity. Recently it has been observed that certain vegetative structures such as cull-sheaths and young cone like shoots can be successfully used in the identification of different species of bamboos. Keys for field identification of important Indian bamboos using these characters have already been published (Bahadur, 1979; Varmah and Bahadur, 1980). In the absence of culm-sheaths, external morphology of the young culm shoots is highly useful. So far this study has been completed for 39 species which are growing in New Forest Estate, Dehra Dun and Indian Botanic Garden, Calcutta. A bamboo guide atlas based on vegetative characters is under print and is likely to be released in early 1986. The diagnostic characters for 25 species *were* described by Varmah and Bahadur (1980).

Anatomy and Cytology

Based on anatomical structure of epidermal peels of the culms and ultra structure of epidermal peels and leaves, bamboos can be separated at both generic'and specific level (Ghosh and Negi 1960, Pattanath and Rao 1969). Scanning electron microscopical studies of the following 21 species *1. Arundinaria mailing, 2. A. racemosa, 3. A. pantlingii, 4. Bambusa* balcooa, 5, B. *burmanica, 6. B. coplandii, 7. B.* nana, *8. B. nutans, 9. B. oliveriana,* 10. *B. pallida,* 11. *B. tulda,* 12. B. ven-*tricosa, 15. B vulgaris, 14. Dendrocalamus brandisi, 15. D. calostachys, 16. D. giganteus, 17. D. hamiltonii, 18. D. longispathus, 19. D. membranaceus, 20. D. strictus, 21. Melocanna baccifera,* show that stomatal morphology and pattern of shoot cells and silica, besides three types of pubescence viz. i) unicellular long, ii) bicellular having equal and unequal length of apical and basal cells; iii) shape of trichomes and spines, could form the basis for the identification of different species of bamboos (Bisen 1985 Personal communication).

The cytology of most Indian bamboos is not adequately known, but chromosomes of species so far studied are tetraploids. Dendrocalamus and asiatic species of Bambusa are hexaploids. Amongst bamboos X = 12 is considered as the basic chromosome number and species with 48, 54, 70 and 72 somatic chromosomes have been recorded. B-chromosome has also been detected in certain species. However meiotic studies on bamboos has not been done in India and this is essential for understanding of seed fertility. Karyotype of 25 Indian bamboos both wild and cultivated have been investigated (Varmah and Bahadur 1980).

Rare/Endangered Bamboos Degree of Abundance

Another important activity relates to the conservation of rare/endangered Indian bamboos (Bahadur and Jain, 1981). They have mentioned that about 25 per cent of bamboo taxa in the country are rare. Twenty eight species have been classified in the, following three categories:

I. Those restricted to a very few localities or single locality but found in fairly large numbers, II. those found in small number, but occurring in several areas; III. those occurring as very few individuals over a small geographic area.

Bamboos under Category-1 – 1) Arundinaria manni Gamble: This is a slender, graceful, tufted climbing bamboo. It is known only from its type locality, Amkasur from Jaintia hills, Meghalaya. 2) Arundinaria rolloana Gamble: This is a shrubby bamboo with distant culms and with very broad leaves. It is known only from the type locality, Jullah Valley in Nagaland. 3) Bambusa atra Lindl. : Unlike most other bamboos it is a constant flowering species and the flowering culms do not die. This rare bamboo is found only in marshy areas of Rutland Island of the Andamans. Although it has been planted in Calcutta and at Dehra Dun, it is growing successfully in Calcutta only. 4) *Dinochloa* maclellandii (Munro) Kurz: It is an erect zigzag bamboo growing at the Indian Botanic Garden. Howrah, from where it has recently been introduced at F.R.l., Dehra Dun. Enquiries made recently from Bangla Desh and Burma (probable native homes) have revealed that this taxon has not been observed there in recent years. 5) lndocalamus *walkerianus* (Munro) Nakai: This frequently flowering shrubby bamboo looks very beautiful because of its purple panicles and large, thick leaves. It is found in Pulney Hills in South India, localised only at one place. 6) Ochlandra beddomii Gamble: It is known by a few collections from Wynaad, South India and from western slopes of the Nilgiris below Sispara between 1200 and 1350 m. 7) Ochlandra abracteata Raizada & Chatterjee: This shrubby reed-like bamboo is confined to the hilly districts of Kerala occurring along streams and in the valleys. It is good raw material for paper. It is becoming uncommon on account of over exploitation. 8) Ochlandra satigara Gamble: This is a small erect or straggling reed-like bamboo found on the western slopes of the Niligiri Hills in ravines above Gudalur at a height of 900 m. It appears that it has been collected only once since Gamble's time (ca 1896) and therefore it is certainly rare. 9) Ochlandra siuagiriana Camus: This shrubby bamboo is found in Sivagiri and Pulney Hills between 1200 — 2400 m. It has been collected only two or three times and considered as a rare Indian bamboo. 10) Ochlandra talbotii Brandis: This graceful, reed-!ike bamboo grows in dense clumps in North Canara along the banks of rivers. Due to large scale extraction for different uses, it has become rather uncommon in the area of its occurrence. 11) Phyllostachya assamica Gamble ex Brandis: This is a caespitose, graceful, thin yellow bamboo, which was earlier confused with the Chinese/Japanese *P. bambusoides* Sieb. & Zucc. It is found in patches in Arunachal Pradesh at about 2400 m, collected recently after a lapse of more than 50 years and appears to be rare.

Category – II – 1) ***Arundinariahirsuta*** Munro: Rare bamboo, found in Meghalaya only. 2) Bambusa arundinacea Rets. var. *gigantea* Bahadur: This is a thorny bamboo of India, which is one of the commonest bamboo in the plains. It is a complex species with lot of variations. One of its element is the tall, beautiful, large culmed variety frequently found in patches in the valleys in South India. It differs from the typical species both in height and girth. This has been planted at New Forest Estate., Dehra Dun. 3) *Chimonobambusa* densifolia (Munro) Nakai: This is the smallest bamboo (15 – 90 x 0.5 – 0.8 cm) which is occassionally found in patches in South India (rare) and Sri Lanka. 4) *Chimonobambusa iaunsarensis* (Gamble) Bahadur & Naithani: This graceful, reed-like bamboo is found sporadically in North West and Central Himalaya between 1800 3300 m. This species which is becoming scarce gradually, needs to be reared in Botanical Garden in temperate areas. 5) *Chimonobambusa khasiana* (Munro) Nakai: A stiffer and stronger bamboo found in Meghalaya. 6) *Dendrocalumus strictus* (Roxb.) Nees var. *argentea* Mcclure ex Bahadur. This is silvery white in colour and is found intermixed with the typical D. strictus in plantations. 7) *Oxytenanthera bourdillonii* Gamble: This is a moderate sized, straggling bamboo with long internodes forming open clumps. It grows on steep precipitous places and wet rocks between 900 and 1550 m in the Ghat region of Kerala only. 8) Phyllostachya mannii Gamble: This is a very pretty caespitose shrub with yellow culms. In wild, it is confined to Naga Hills, but is cultivated in Khasi Hills around 1500 m. *9) Semiarundinaria* pantlingii Gamble: This is an erect shrub with thin, hairy or spinous culms (at the nodes). It was collected from Sikkim and Arunachal Pradesh. Very few collections of this bamboo have been made and it appears that this is rare. *10) Sinobambusa elegans* (Kurz) Nakai: This is a slender, shrubby bamboo chiefly occurring in the Hills of Eastern Burma and extending northwards into the Naga Hills where it is localised and is used for making huts.

Category – III – 1) *Bambusa mastersii* Munro: This is a reed-like, climbing bamboo. It has been collected only once by Masters from Dibrugarh, Assam and hence is very rare. *2) G*ephalostachyum *canitatum* Munro var. *decomposita* Gamble: This semi-scandent bamboo with yellow culms has been collected only twice from Sikkim. It differs from typical *C. canitatum* which is characterised by having capitate flowers and is common in the hills of North-East India in possessing paniculate flowers. 3) *Dendrocalamus hookeri* Munro var. *parishii* (Munro) Blatter: This is an imperfectly known bamboo which has been collected only once by Lt. Parish from Himachal Pradesh, curiously the flower and fruits of this bamboo have been well described, but not the culms, cuim-sheaths and leaves. It is extremely rare. *4) Dendroculamus sahnii* Naithani & Bahadur: This bamboo with pale green culms has been described recently' from Subansiri district of Arunachal Pradesh. This new species is localised at one place and in all probability endemic to the area. 5) *Gigantochloa takseruh* Camus: Large evergreen bamboo with broad culm-sheaths and membranous blades. It is confined to Garo Hills from where it was collected by Gustav Mann in 1889. It is known only by its type collection. 6) *Ploblastus simonii* (Carr.) Nakai: Monopodial hollow green glabrous bamboo, found in Tale Valley 3000 m, Subansiri district, Arunachal Pradesh. This species is also known from China and Japan. It is necessary that these rare taxa are protected by means of in situ and exsitu conservation. In order to achieve this objective, the Forest Research Institute has developed a live bamboo collection of nearly 40 species in arboreta and Botanical Garden. *Bambusa khasiana, Cephalostachyum canitatum. Dendrocalamus sikkimensis, Phyllostachys nigra* and *Teinostachyum friffithii* will be introduced for enriching the germ-plasm in Forest Research Institute, Dehra Dun.

Utilisation

Due to its fast growth, easy propagation, soil binding properties, and short rotation, bamboo is an ideal plant for use in aff orestation, soil conservation and social forestry programme. Various aspects of research on utilisation carried out on bamboos in India have been summarised by Varmah and Bahadur 1980, The traditional and other uses in India are summarised below:

Traditional Uses: The strength of bamboo culms, their straightness, lightness, combined with hardness, range in sizes, hollowness, long fibre and easy working qualities, make them suitable for a variety of purposes In the humid tropics houses are built entirely of bamboo without using a single iron nail. Large suspension bridges are made solely of canes/bamboos by the tribals. Among the sophisticated uses, the manufacture of variety of writing and other paper, charcoal for electric batteries, liquid diesal fuel obtained by distillation, enzymes and media from shoot extracts used for culturing pathogenic bacteria are important. The white powder produced on the outer surface of young culms for the isolation of a crystalline compound is medicinally useful. Tabasheer or Banslochan, is a popular medicine which is a silicious secretion found in the culms of some species. It occurs in either fragments or in masses (2 cm thick) chalky, translucent or transparent and tasteless and is used as a cooling tonic and aphrodisiac and in asthama, cough and other debilitating diseases (Raizada et al, 1936).

Bamboos are also commonly used as agricultural implements for afforestation of river banks, anchors, arrows, boats, bows, broom, brushes, chairs, chicks, containers, cooking utensils, cordages, dustbins, fishing rods, flutes, flower pots, fuel, furniture, fish traps, hedges, hats, kit frames, ladders, lamps, mallets, musical instruments, paper, pens, poles, pulp rafts, rayons, roofing, ropes, scaffolding, tobacco pipes, toys, tool handles, table mats, tubs, umbrella handles, walking sticks, water pipes and wrappers.

Notwithstanding the status report mentioned above, certain areas like cytology, physiology of flowering, tissue culture and revision of their taxonomic position etc., need accelerated research in India.

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Table 1

Statewise bamboo bearing area and potential annual yield

(after Tiwari 1981)

Serial number	Name of State	Bamboo area (Sq. Km.)	Potential annual availability (Million tonnes)
1.	Andhra Pradesh	19,790	0.255
2.	Arunachal Pradesh	7,779	0.200
3.	Assam	10,000	1,210
4.	Bihar	5,296	0.200
5.	Gujarat	1,936	0.046
6.	Himachal Pradesh	104	0.003
7.	Jammu & Kashmir	negligible	-
8.	Karnataka	5,000	0.475
9.	Kerala	631	0.108
10.	Madhya Pradesh	14,864	0.800
11.	Maharastra	8,500	0.300
12.	Manipur	2,500	0.200
13.	Orissa	10,500	0.489
14.	Punjab	negligible	0.009
15.	Tamil Nadu	5,368	-
16.	Tripura	2,849	0.215
17.	Uttar Pradesh	4,000	0.041
18.	West Bengal	164	0.008
Total		1,00299	4.559

However, the annual yield per hectare is the maximum in Assam i.e. the 3.12 and 4.0 tonnes (dry)/ha of *Bambusa tulda* and Melocanna *baccifera respectively.*

Bamboo Research In Indonesia

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Abstract

Bamboo is found in natural forests, plantation forests and *in* unique types of agroforests *called* pekarangan in *many villages of* Indonesia. There are 35 *species* belonging to 11 genera, but only 13 *species are economically* valuable. *Some of these species have been cultivated by people for hundreds of years while the forest services started the cultivation in 1903 to meet the demand for specific purposes.* Bamboo is *mostly used for construction in Java and Bali. The bulk of supplies comes from millions of small pekarangans.* The annual consumption estimated for *the* farmers' *sector* is about 29-146 *million culms, and for paper miils* 3.5 *million* culms. *Bamboo is produced in approximately 50,000 ha* of *forests and in more than 30.616 ha of pekarangan* areas.

Introduction

There is ample evidence that bamboo plays an important role in Indonesia especially in village life, It is one of the three multipurpose plants cultivated in thousands of large and small villages; the other two being banana and coconut (the so-called BBC group). The importance of bamboo in Indonesia is similar to that of Indochina, China and Japan.

Bamboos are planted on the edges of home gardens called pekarangan and intermixed with other wood-producing and food-producing plants. Besides people use it as village boundary and to control erosion along the banks of rivers.

Though many species are grown in the country only a few are cultivated by people living in the villages of Java (99.2 million population), Bali (2.7 million population), Sumatra (31.3 million) and South Sulawesi (7.4 million). Most of the bamboo is converted into finished products by mechanical or manual means for such purposes as construction, household articles, furniture and other products. A certain quantity is processed chemically to produce paper. Other industrial products, though relatively very small in quantity, are laminated bamboo articles like plates, trays etc. Practically all products manufactured are consumed domestically. However, substitutes like plastics, are slowly taking over the functions of bamboo. Therefore, though some research has been carried out, further efforts are needed to give bamboo a better position in terms of its resource potential and utilization possibilities for the benefit of people who will be living in the twenty-first century.

Extent of Bamboo Resources

Most of the native bamboo species growing in Indonesia are sympodial which multiply mostly through rhizomes and very rarely by seeds. The shoots of some species emerge in the beginning of the wet season, others during the season and still other species at the end of it (Heyne, 1950). The size of the stem varies considerably ranging from 12 mm *in Bambusa muitiplex* to *200* mm in Dendrocalamus *asper.* The nodes and the internodes vary from 12-16 cm in *Phyllostachys aurea* to 70-120 cm in *Schizostachyum blumei.* The wall thickness at internodes ranges from 3-6 mm in Bambusa atra, *Bambusa* multiplex and *Gigantocholoa nigrociliata,* 25-41 mm in *Dendrocalamus asper.* The colors of fresh stems vary from dark green, greyish green, plain yellow with green stripes, green with yellow stripes or dark purple. It changes into shades of straw yellowish nuances which sometimes have brown spots while others have plain purple marks. There are 11 genera and 35 species (Table 1) (Heyne, 1950; Reilingh, 1921; Sastrapradja, 1977; Karsono, 1981). These species are distributed almost in every island of the archipelago depending on its soil conditions, climate and geographical aspects.

Phytogeography and extent of bamboo resource: The species which are known growing on many islands of Indonesia is shown in Table 1 (Reilingh, 1921; Heyne, 1950; Sastrapradja, 1977; Karsono, 1981).

It is clear that bamboo is practically found almost throughout the country. However, natural stands of bamboo species grow in different habitats. A total of 26,000 ha of bamboo forest is found in Banyuwangi, East Java, of which only 7,700 ha is reported economically productive to supply a paper mill (Soenjoto, 1970). A second bamboo forest complex located in Gowa, South Sulawesi, also managed by a state paper mill over an area of 24,000 ha (Hindrarto, 1985). A total of 15 species are found; however, their composition varies in different forest complexes. For example a stand in Wonosari complex consists of 20% broad leaved trees, 1% *Dendrocalamus flagellifer,* 3% *Oxytenanthera nigrociliaiu,* 6% surat bambu (similar to *Oxytenanthera),* 20% *Gigantochloa atter,* 30% *Gigantochloa apus,* 10% *Melocanna humiiis,* 2% *Schizostachyum brachycladum,* and 8% *Bambusa vulgaris.* In contrast only one species is recorded in Gayam-Manggar-Petut complex, namely *Bambusa spinosa* amidst

Table 1. Bamboo species growing in Indonesia.

No. Latin name	Local name	Island
1. Arundinaria *japonica* Sieb. & Zucc. ex steud.	–	Java
2. *Bambusa* atra Lindl.	buluh luleba, ute aul	Maluku, Sulawesi
3. *Bambusa* arundinacea (Retz) Wild.	bambu duri, ori	Java
4. *Bambusa* balcoa Roxb.	–	Java
5. Bambusa bambos Becker	trieng meduroi, aor duri, pring ori	Java
6. Bambusa *blumeana* Bl. ex Schult. f.	bambu duri	Java
7. *Bambusa gluucescens* (Willd.) Sieb. ex Munro	barn bu pagar	Java
8. Bambusa horsfieldii Munro	bambu embong	Java
9. *Bambusa multiplex* Raeusch	pring cendani, awi krisik	Java
10. *Bambusa polymorpha* Munro	–	Java
11. *Bambuso spinosa* Bl.	bambu duri kecil, pring	Java
12. *Bambusa tulda* Munro	–	Java
13. *Bambusa vulgaris* Schrad	trieng gading, pring ampel, tiing ampel, tahaki, bambu tutul	Java, Bali, Sumatra, Sulawesi. Maluku

No. Latin name	Local name	Island
14. Dendrocalamus asper Backer	oloh otong, betong, pring petung, tiing petung	Sumatra, Kalimantan, Java, Bali, Sulawesi
15. Dendrocalamus giganteus Munro	Bambu sembilang	Java
16. Dendrocalamus *strictus* (Roxb.) Nees	bambu batu, pring peting	Java
17. Dinochloa scandens O.K.	pring kadalan, cangkoreh	Java
18. Gigantochioa apus Kurz	awi tali, pring apus, tiing tali	Java, Bali
19. Gigantochloa atter (Hassk .) Kurz ex Munro	bambu ater, bambu hitam, pring wulung	Java
20. Gigantochloa hasskariiana Backer	awi lengka tali	Java
21. Gigantochloa kurzii Gambel	bambu ulet	Java
22. Gigantochloa nigrociliata Kurz	awi lengka	Java
23. Gigantochloa vertcillata Munro	awi andong, .pring surat	Java
24. Melocanna humulis Kurz.	bambu wulu, bulu	Java
25. Melocanna baccifera '(Roxb.) Kurz	–	Java
26. Nastus elegantissimus (Hassk.) Holtt.	bambu eul-eul	Java
27. Oxytenanthera nigrociliata Munro	bambu watu, benel	Java
28. Phyllostachys aurea A: & C. Riviera	bambu uncue	Java
29. Schizostachyum blumei Nees	bulu tamiang, awi bunar, pring wuluh, hamia, ute lauit	Sumatra, Java, Kalimantan, West Nusa Tenggara, Sulawesi, Maluku
30. *Schizostachyum brachycladum* Kurz	buluh nehe, awi buluh, ute wanat, tomula	Sumatra, Java, Maluku, Sulawesi
31. *Schizostachyum caudatum* Backer	buluh bungkok	Sumatra
32. Schizostachyum lima (Bianco) Merr .	bambu toi	Sulawesi, Maluku, Irian
33. Schizostachyum longispiculatum Kurz	bambu jalur	Java, Sumatra; Kalimantan
34. Schizostachyum zollingeri Kurz	buluh jalar, awi cakeutreuk	Sumatra, Java
35. -Thyrsostachys siamensis Gamble		Java

Note: Species no. 2, 5, 12, 17, 26, 34, 29, 30, 31, 32, 33 are indigenous.

broad leaved trees. The species found are Gigantochloa *apus,* Bambusa blumeana, Bambusa spinosa, *Schizostachyum brachycladum, Gigantochloa atter, Bambusa* vulgaris, *Oxytenanthera nigrociliata Melocanna humilis, Gigantochloa Kurzii, Bambusa* affinis, Dendrocalamus *flagellifer, Dendrocalamus strictus,* Bambu rampai, bambu surat, and bambu serit bupat. These are found up to 1,500 m above sea level on tertiary and secondary soil formations. The stand density varies from sparsely distributed suppresed individuals among other trees to dense forest complexes exclusively of bamboo. Drees (1938) mentioned about a bamboo forest in Tanah Bumbu South Kaiimantan but no data on this is known. Another location of *Dendrocalamus asper* forests is on the banks of Amandit river, Huiu Stingai Seiatan, South Kaiimantan (Kartasirang, 1985). About 30 km along the river sides, from the city of Kandangan to Lok Sado, this bamboo species is growing vigorously. This stretch of bamboo grove, approximately 120 ha, is said to be planted by a local tribe of Dayaks hundreds of years ago. Bamboo grew naturally in the forests of Sumatra as reported by Rappard (1937) who observed secondary growth of bamboo species in the northern part of Bengkuiu province. Also patches of bamboo are found around Ongkak Doemoega, Boiaang Mongondow in the province of North Suiawesi as reported by Verhoef (1929).

Besides the naturally occurring forests, people in Java, Sumatra, Bali and South Suiawesi seem to have planted it on their lands. Different species are cultivated by them depending on soil and climatic conditions of the different places. In relatively dry areas *Bambusa bamboo* and *Bambusa arundinacea* are the main species planted while in wetter conditions *Gigantochloa apus* or *Dendrocalamus asper* are preferred. The total area of patches of bamboo grooves on the pekarangans have never been enumerated; however, an illustration of the huge bamboo resource in the villages in Java, Sumatra, Bali and South Sulawesi can be estimated by the number of farmer households which depend on agricultural activities in general. According to the national population census in 1980 there were 14,665,656 household of farmers and the like in the four regions mentioned (Anonymous, 1981). Households in other regions are not included since no data are available whether they cultivate bamboo in their pekarangans or not.

Results of surveys on pekarangans carried out in the province of Yogyakarta showed that 83.5% of 840 samples in 7 1 villages were planted with bamboo intermixed with other plants like coconut, banana etc. Besides 95.7% of them planted coconut and 85.7% planted banana inside their small holdings (Harsono *et al.,* 1980a, 1979a; Hartono et al., 1979b, 1980b; Nasruiiah *et al.,* 1980, 1981; Siswandono *et al.*, 1979, 1981; Soenoeadji *et al.,* 1980; Wiryono *et al.,* 1980). The number of bamboo cuims in 159 pekarangans and enumerated in 15 villages was 114.9 cuims per pekarangan, 22.0 coconut tress and 22.8 banana clumps per pekarangan.

The size of pekarangan is on the average about 0.36 ha. Though relatively small, its function is significant and can be measured from the definition of pekarangan as follows (Anonymous, 1978) :

> A piece of land with certain boundaries where there is a dwelling place on it and has a functional relation with the dweller either economically, biophysicaily, or socio-culturally.

The figures presented earlier are used to estimate the extent of pekarangans with bamboos, throughout the four regions indicated as bamboo centres. 115 culms per pekarangan cover 5 x 5 meters because their diameters range from 2.5 – 20 cm. There are 17,468,560 households of farmers in the country (Anonymous, 1981) and in the 4 regions, the total farmers' households are around 14,665,656. Further more than 83.5% of them, (as indicated by a survey in the special province of Yogyakarta) plant bamboo in their pekarangans; the total is 12,246,582 pekarangans. Accordingly the area grown by bamboo is approximately 5 x 5 x 12,246,582 m2 or equal to 30,616 ha. But this does not mean that bamboo is confined to these because other agricultural lands are also planted with it. Unfortunately local governments of many villages in Java have instructed people to remove the bamboo plants especially from places nearby main roads. Their intentions are to make room for electric line poles to be erected which is outlined in the Indonesian village modernization programs. In addition it is also intended to plant more food crops intead in the pekarangans.

Nevertheless, the figures presented showed the significance of BBC-plants (Banana, Bamboo, Coconut) in rural villages. Accordingly it can be understood that these plants have some socio-cultural and socio-economic roles to play in the daily life of the people.

Socio-economic Aspects

Some economic species, trade names and grades: Of the 35 species only a few are of economic significance mainly because of their properties. In Java, *Gigantochloa apus*, *Dendrocalamus asper*, and *Bambusa arundinaceae* are mostly sold in trading places. Other species like *Gigantochloa atter, Bambusa vulgaris* and a few others form the second group in trade. Native names of bamboo vary from one place to another though they are botanically of the same species. *Gigantochloa apus* is known as bambu apus, pring tali (Java), pereng tali (Madura) and tiing tlantan (Bali). Another example is *Dendrocalamus asper* which. is known as trieng betong (Aceh), oloh otong (Gayo), bambu batueng (Minangkabau), bulo lotung (South East Kalimantan), Awi bitung (Sunda), pring petung (Java), bulo patong (Makasar) and tabadiko jawa (Ternate).

The culms of these economic species are purchased based on more or less clearly defined grades. The tobacco state corporations, which need fairly large quantity of bamboo for the construction of drying sheds, differentiate 4 grades of *Dendrocalamus asper* (grades A, I, II, III) and Gigantochloa *apus* (grades A, 1, 2, 3). The grades are baded on length of culm, diameter and age. On the other hand no clearly defined grades are available for bamboo intended for basketry manufacture, though some species are cultivated for it

Cultivation: Usually bamboo is planted by means of rhizome cuttings in Indonesia. Rhizome cuttings grow better (59.1%) when compared with stem cuttings (40.0%) (Verhoef, 1929) and culms should at least be l-year old (Sindoesoewarno, 1963). The period of planting is the begining of the wet season and spacings in forest plantations vary from 3 x 2 m, 3 x 3 m and for large species 4 x 4 m. Holes are first prepared 0.5 **x** 0.5 x 0.3 m in size for the cuttings to be planted straight or leaning with an angle of 45°. After four to six weeks shoots come up and in three or four years some culms can be harvested. However, after six or seven years the culms reach their normal size. A historical account on the cultivation of bamboo in forest areas was reported by Reilingh (1921) who stated that in 1903 the forest district of Besuki planted 10 ha of bamboo at Sumberkeneh. Further activities reported were the total of plantation made up until 1916 which reached an area of 165.5 ha. On the other hand farmers living in rural areas have planted bamboo for hundreds of years.

Supplies and utilization: A scheme of bamboo utilization can be outlined as follows:

1. Based on form of bamboo used as material: a. Round bamboo: village houses, tobacco drying sheds, musical instruments etc. b. Split bamboo: walls, mats, basketry, household utensils, screens, musical instruments, bird cages. c. Round & split bamboo: furniture, ladders etc. d. Defiberized bamboo: pulp, paper.

2. Based on end use: a. Constructions: village houses, tobacco drying sheds, bridges. b. Non constructions: Furniture: chairs, tables, racks, partitions. Non furniture: Containers: baskets, bags, tobacco boxes, water containers, food containers, Agricultural implements: tool handles, carrying rods, fences etc. Hunting & fishing tools: fishing rods, fish traps, blowpipes, arrows etc. Household & kitchen utensils: frying scoops, trays, bamboo screens, hand-fans, birds' cages. Food: snacks (lumpia), dinner dish (Lodeh), pickles. Fodder: cow fodder. Musical instruments: flutes, xylophones, angklungs. Miscellaneous: ornaments, special knives, medicine etc. Paper: writing paper, printing paper and Fuel.

It is easy to split bamboo radially, lengthwise or tangentially using machettes or knives. Its strength in round form is adequate for construction purposes. In split form bamboo can be woven easily into different commodities depending on its thickness and width. It has a relatively low specific gravity and therefore finished products are easy to be handled. Woven articles are adequately sturdy for several kitchen utensils or household stationaries. Accordingly rural population in many regions use bamboo quite intensively and therefore the amount of supplies runs to millions of culms.

Amount of supplies: The bulk of supplies of bamboo comes from pekarangans in the villages and also from some forest areas. Two groups of consumers utilize them, namely private individuals and various industrial agencies. It is difficult to estimate the consumption of millions of urban and rural farmers accurately. A very rough estimate may fall around 29 to 146 million culms in the four regions mentioned with the assumption that 2-10 culms/family/year are used to make fences, remove rafters etc. These figures are based on the fact that in 1980 there were about 14.6 million farmer house holds in the four regions,

The paper industry, tabacco estates and the handicraft small indusries use fairly large quantities of bamboo. The first consumes approximately 3.5 miilion cuims per year (Hindrarto, 1985; Soenjoto, 1970). However, the supply is ever decreasing because many bamboo forests have been converted into other types of forests, as state corporations in charge of reforestation consider these more economical to manage. The tobacco estates are mostly located in Besuki and Bojonegoro in East Java, and in Kiaten, Central Java. Yearly, the consumption of bamboo for them is estimated to be about 10 million culms in Besuki (Reiiingh, 1921), 2.32 million culms in Bojonegoro and 0.54 millions in Klaten. The cottage industry produces baskets, containers, bamboo trays, hats and other items. These are strewn throughout many counties and villages in the country and their number is not known accurately.

Some data on the supply of bamboo from the forests were collected from records of the former Besuki forest district. It revealed that during the period of 1907-1920 around 2,840,872 culms were cut (Reilingh, 1921) annually. This decreased to 1,593,500 cuims yearly during 1933-1936 (Fluyt, 1937). More recent statistical data indicates that the production of bamboo during the years of 1969-1975 was on average 135,975 smb annually (4,18 smb = 1 ton) and further during the period of 1981-1983 the average figure was 14,384 smb (Suwongso, 1985). These amounts of culms were collected and harvested by specific methods.

Collection and harvesting: To use bamboo for construction farmers cut the culms at predetermined times. Traditionally villagers in Central Java harvest during the 1 lth month of the Javanese calender. They believe, by experience, that even the most durable bamboo species will be susceptible to borer attack if it is not cut in the proper month. Some observations by Suithoni (1984) showed that at that particular time the starch content in bamboo is minimal. Logically they will be relatively resistant to borer attack since insects do not bore culms that have no food and therefore harvesting in that particular month is recommended.

They harvest bamboo selectively, choosing cuims of 3-4 years old in the central parts of the groove. Relatively young culms are left to grow further and for new shoots to come up. Results of some experiments suggest that 3-4 years old cuims are ready for harvest. (Sindoesoewarno, 1963). In the first year felling of 5 culms/clump is recommended but with the increase in age, 10 to 20 culms/clump/year can be harvested. In many cases, people prefer to cut in every 3 years rather than annually.

Conversion and manufacture: There are several methods to process bamboo from its original form and condition into finished products. However, in general there are two main types of processing namely mechanical and chemical processing. Besides, the methods also depend on the type of finished products. For construction purposes and the like, bamboo is mostly used in whole or round form. For basketry, woven handicraft, cuims of bamboo will be split into several assortments depending on the quality of the final product to be made. Similar ways of handling is applied in the production of plybamboo to manufacture plates and the like with additional gluing. However, to prepare bamboo for paper production, whole bamboo cuims are chipped into small parts and treated chemically.

House and building construction components: Green bamboo culms are air-dried for three months by end-stacking them in open air. In several cases villagers soak culms in running or stagnant water for a certain period as a simple preservative treatment prior to air-drying. They cut them into appropriate sizes before or after air-drying, Kiln drying is not applicable for bamboos used for construction. Knives or saws are used to cut the round bamboo culms. Gigantochloa apus, *Dendrocalamus* asper and sometimes also Gigantochloa utter, Bambusa *bambos* or Bambusa *arundinacea* are used. An example is the standard tobacco drying shed, 20 m x – 100 m in size. It needs 412 culms of Dendrocalamus asper and 5,415 culms of Gigantochloa apus and 22,000 culms of small diametered bamboo (Sudarsono, 1985).

A survey of wood consumption in Bali, East and Central Java indicate that 28.3% of 11.5 million houses are of bamboo, 32,2% of teak, 5.0% of Kalimantan wood, 26.5% of other broad leaved trees, 7.8 % of coconut wood and the remainder are of other materials (Anonymous, 1978).

Furniture: Air-dry bamboo is mostly used for furniture. Some parts consist of round bamboo, especially the frame of chairs, tables and other furniture, while the other parts are of split bamboo with the bark still on.

Basketry, mats and other woven articles: To manufacture woven articles bamboo is split into thick and thin split material, debarked or with bark on, wide and narrow material, artificially or naturally colored. Normally people split bamboo tangentially and rarely in radial directions. Later they weave them according to traditional designs and may consist of only de-barked or not-debarked split material, or a combination of both. For particufar products like traditional farmers' field hats, two layers of thin bamboo woven sheets are assembled.

Plybamboo: pulp and paper. The plate and trays of woven bamboo are produced in factories. Three layers of airdry woven bamboo sheets are glued together by the use of a hot press to allow urea-formaldehyde adhesives to cure. Unfortunately the domestic market for this type of product is low. There are two papermills using bamboo as raw materiaf; one is in Gowa, South Sufawesi with a capacity of 30-40 tons of pulp/day and another located in Banyuwangi, East Java. The Gowa paper mill owns a relatively large bamboo forest, 50% of which is economically exploitable (Hindrarto. 1985) and the main species is *Bambusa arundinacea.* Kraft process' using NaOH and Na_2S as chemicals is allowed for the cooking liquor with 19%--20% of active alkaline and a 19% sulfidicity . One ton pulp needs approximately 378 bamboo culms, each of 5 meter length. For making pulp. 55% bamboo and 45% wood materials are used.

To harvest bamboo people use ladders to cut the dense thorned branches from the upper part to the bottom first and then the culm itself. The daily production is about 3,600 culms which are transported by trucks to the bamboo yard.

The mill in Banyuwangi, East Java, has a capacity of 30 tons of pulp/day and bamboo is supplied from West Banyuwangi forest district. Some of it are harvested from natural forests while others are cut from plantations. The fatter has been cultivated since 1903 and up to 1927 there were 391 ha planted with two species. Several species are available as discussed earlier and all are used as raw material for pulp. In 1969 the raw material was 100% bamboo (Tjahjaputra, 1970) but in 1974 it consisted of 70% bamboo and 30% *Sesbania grandijjora* (Wijono, 1974), however, fater in 1975 the proportion was 60% bamboo, 30% *Sesbania gradiflora, and 10% Pinus merkusii.* In 1985 the bamboo proportion is decreased down to 20% -25% (Hindrarto, 1985). To produce 1 ton of paper an amount of 1,943 kg of bone dry chips are needed.

Musical instruments: Many traditional musical instruments are made of air dried bamboo. Widjaja (1980) divided them into three groups based on the way the sounds were produced namely idiophones which were grating or percussion instruments (angklung, cafung, gambang etc.), aerophones or aero instruments (suling, hatong, taleot etc.), and chordophones or string instruments (cefempung). *Gigantochloa utter* and sometimes *Gigantochloa apus* are used. for angklung or gambang manufacture while *Schizostachyum blumei* is used for flutes or sufing.

Bamboo is sold either in round form or in processed products. The second category may have the form of split material of various sizes to be manufactured into other products, and also completely finished products is included in this category.

The supply of bamboo to meet people's demand in Jakarta is done by floating bamboo rafts from Bogor to the capital along the river of Ciliwung (Saputro, 1985). Everyday 8-10 collones of rafts pass the river carrying 3,200 culms – 4,000 culms of bamboo. One raft consists of 50 culms and one collone contains 8 rafts tied to each other. Therefore it can be estimated that Jakarta consumes at least 1 ,000,000 culms transported through the Ciliwung river worth around Rp. 250,000,000 – (1 US$ = Rp. 1.120).

Socio-cultural practices use the bamboos for many purposes. In the past, midwives severed umbilical cords of newborns using the sharp edge of a freshly split bamboo (Widjaja, 1980) called "welat" by the Javanese.

The term "sedular nunggal welat",means "kin of the same bamboo umbilical knife" when someone was born brother or sister the same bamboo knife was used again to cut the umbilical cord.

Bamboo is referred as a symbol of unity. "Nasi 'ko'pau, A 'bulo sipappa, A 'lemo sibatu" meaning "It is agreed (to have one aim), to be like one bamboo culm (though it has many internodes, nonetheless, it is one), {United) like one orange (though it has many seeds inside, nonetheless, it is one)" (Usop, 1978). Another evidence comes from the famous Mahabarata epic in which a place called Pringgendani, presumably called after the local name of Bambusa multiplex, is the residence of prince Gatotkaca, son of prince Werkudara. a gallant knight, who fights for the glory of the Pandawas until his death.

A cultural tradition still exists in Buluspesan – tren, Kebumen, Central Java. When someone is going to have a wedding party, circumcision ceremony or to build a house, he invites his relatives or close acquaintances for a "ngepring" – day. Then everyone gives him one or two bamboo culms as a gift on that particular day. In return they get snacks and specially made rice called "tumpeng" to bring back home (Abdulroch – man, 1985). In the island of thousand temples of Bali, where tradition and modern living are intermixed, where magic and fight for daily survival exist side by side, the yellow bamboo, Bambusa vulgaris, plays a special role. Planted as an ornamental feature, a piece of the stem mixed with animal bones and accompanied with certain "mantra" or prayers, is said to be a tool in the practice of black magic to harm somebody (Tantra, 1985). A saying originated from Sumatra tells about "Her voice is so charming like the sound of a bamboo flute longing for a lover"

Bamboo Research

Some researches have been made on bamboo utilization and cultivation.

Cultivation research: Hasanbahri (1984) has studied the growth and morphological change of stem cuttings of some bamboo species in WANAGAMA I. He concluded that the parent plant age has an influence on the average bud growth of Dendrocalamus asper and on the number of shoots growing on *Gigantochloa atter* but not on *Gigantochloa apus.* Application of IAA promotes (4000 ppm) rhizome shoot growth of *Dendrocalamus asper* but not in the other two species. Location of stem cuttings on the bamboo stem has no effect on the three species investigated, The technique of planting {straight or leaning) affected the number of rhizomes growing in stem cuttings of *Dendrocalamus asper* and has no effect on the other two species. Sindoesoewarno (1963) cultivated several bamboo species by using rhizome cuttings. On an average one cutting of Bambusa vulgaris produces 10 living culms, 51 living shoots in 3 years. During the same period Gigantochloa *verticillata* produced 6 living culms, 3 dead culms, 3 dead shoots. Gigantochloa *apus* produced 42 living culms and 66 living shoots. *Dendro*calamus *asper* produced 9 living culms, 1 dead culm, 5 living shoots and 10 dead shoots.

Utilization research: Bamboo with starch is susceptible to borer attack. Soenardi et al. (1979) found the average starch content in *Dendrocalamus asper* about 1.4% of its kiln dry weight. Starch leaching was highest when samples were soaked in stagnant water.

Average starch contents vary in bamboo species after kiln treatment: *Gigantochloa apus* 0.287%, *Bambusa* vulgar-is 2.159%, *Dendrocalamus asper* 1.564% and *Gigantochloa atter* 0.273% (Sarwono, 1983) He also found on an average per unit area 9.2 borer holes on samples of *Bambusa vulgaris, 7.8* holes on *Dendrocalamus asper,* 1.9 holes on *Gigantochloa apus* and 1.4 holes on *Gigantochloa atter.*

The absorption and retention of preservatives vary depending on the treatment and concentrations used. Higher concentration resulted in less absorption. Both copper sulphate and Wolmanit CB were used in case of B. vulgaris and D. asper. The latter was more toxic to Dinoderus beetle. The rate of penetration was variable with other bamboo species (Abdurrachim, 1982; Widoyoko, 1983).

Salt was not a good preservative against *Dinoderus minutus* since an average *un*-preserved Bambusa vulgaris had 9.2 holes on sample surfaces compared with 6.9 holes in salt preserved samples. (Sunaryo, 1983).

Wuryanto (1982) observed that the green moisture content of Gigantochloa *apus, Gigantochloa uerticilata,* and Dendrocalamus *asper* increased from the bottom of the culm to the top. The hot-and-cold bath method increased penetration though the hot bath was only for four hours and the cold bath was for three days.

Measurements on mechanical properties of *Dendrocahmus asper* and *Gigantochloa apus* compression strength parallel to grain was 602 kg/cm^2, and 419 kg/cm^2 respectively (Wardoyo, 1983). Values of their bending strength were 2655 kg/cm2, and 2003 kg/cm2 These values were obtained from tests using split bamboo, 10 x 2.5 x 0.4 cm for the first property and 30 x 2.5 x 0.4 cm samples for the second property. Moisture content affected these properties: the higher the moisture content the lower the strength properties.

Kasmudjo (1981, 1982) measured the bonding strength of strips of *Gigantochloa apus* and *Gigantochloa utter* glued with caesin. It decreased from the bottom to the top of the culm of G. ***apus*** while the average was 9.1 kg/cm^2. It increased in G. *utter* and its average was 28.7 kg/cm^2. When the strips, of bamboo were treated with borax, all the bonding strength decreased; the higher the concentration of borax solution the lower the strength. Average bonding strengths of G. *apus* which has been treated with a 1%, 3% and 5% borax solution was 8.6 kg/cm^2, 7.4 kg/cm^2, and 6.5 kg/cm^2 respectively. In case of G. atter the bonding strengths decreased to 15.6 kg/cm^2 and 9.9 kg/cm^2 after being treated with a 5% and 10% borax solution.

Ongoing and Future Research

Some research is currently being undertaken by the Faculty of Forestry, Gadjah Mada University on mechanical properties of several bamboo species, preservation characteristics, bacterial degradation of starch in bamboo, and resistance of treated bamboo against pests. Funds are being provided by IDRC, *Canada and the government of Indonesia. Other agencies like Regional Housing Center in Bandung, Forest Research and Development Center and Forest Products Research and Development Center are also interested in Bamboo research.

Some aspects of bamboo to be investigated in future are 1) inventory of stocking potential in village plantations of Java, Sumatra, Bali, South Sulawesi and South Kalimantan. 2) economic significance to rural farmers and manufacture. 3) Bamboo cultivation in newly opened transmigration areas may be of primary priority. 4) Properties and possible application of preservatives and preservation methods on bamboo may be carried out besides looking for new technologies for construction purposes.

Another worthwhile investigation is in relation with bamboo cultivation knowhow for large scale application in new opened transmigration areas scatterred throughout the country. In 1979- 1983 approximately 500.00 families have been transmigrated and in 1984-1988 another 750.000 families will be transmigrated. They get 2 ha of land each and accordingly a total of 2.5 million ha of forests will be cleared for them. If popular cultivation techniques are practised, with 100 square meters per family, an addition of 12.500 ha of bamboo plantation can result. This is very attractive as these transmigrants are familiar with bamboo usage. In three to seven years between 2,000 – 10,000 culms/ ha/pa can be produced by these people. However, problems of seedling preparation, transportation etc. has to be solved. To enable better utilization basic properties of different species of bamboo are going to be investigated.

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The Bamboo Resource in Malaysia: Strategies for Development

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Abstract

The bamboo resources in Malaysia *are discussed. So jar Bamboos have not been used as an* industrial resource on *a commercial scale. The strategies for further development* of *bamboos are examined and certain suggestions are offered.*

Introduction

As is the case with many Southeast Asian countries, Malaysia has a long tradition in the use of bamboo. However, this use has not reached the level of sophistication like other agricultural resources. Whilst many interesting traditional uses of bamboo have been documented {viz., Burton 1979; Wong 1982, there is no quantitative assessment of the extent of utilisation of bamboos in the rural communities, including uses like fences for rice-fields, housing construction and baskets. Bamboos play an important part in rural Malaysian life-style and many sayings in the Malay language reflect this affinity. For example, with reference to the upbringing of children, their early stage of development, which is the formative period of character development, is likened to the bamboo shoot stage, which is an amendable to moulding. Similarly, there is wisdom in an old Malay saying that recognizes the interdependence between two close allies, in the expression “like bamboo clumps and a river-bank.”

Forest management in Malaysia has for a long time not given due emphasis to bamboo as a resource to be exploited more systematically. Traditionally, bamboo has been considered as a weed in forestry practice (Watson & Wyatt-Smith 1961; Chin 1979), in which attempts are made to prevent or control its growth.

In the few instances where bamboo has been considered as a resource, licences or permits are issued for their extraction, in which case a nominal amount of royalty is collected. Similar to other so-called minor forest produce, bamboo received comparatively little attention from foresters in Malaysia until recently, when the Forest Research Institute embarked upon a concerted effort at revising and documenting the taxonomy and biology of Malaysian bamboos and initiating research into various aspects of their utilization and silviculture.

The bamboo resources of Malaysia

There has never been an attempt to completely inventorise bamboo resources in this country as a whole. Nevertheless, during forest inventories, the occurrence of bamboo has been routinely noted but not quantified. It has not been possible, therefore, to analyse the abundance of bamboo as recorded in these inventories. Despite this, information from past forest inventories for the country may be reviewed to provide more definite conclusions regarding the presence and distribution of bamboo.

An attempt was made in 1981 at quantifying the stocking of bamboo and rattan in the northwestern Peninsular Malaysian state of Kedah in conjunction with further development of the rural industries there (Anon. 1982). In the inventory for Kedah, the same clusters of randomly distributed plots used for the routine National Forestry Inventory (emphasizing trees) were used for sampling the abundance and sizes of clumps of rattan and bamboo. Nineteen clusters, each of 12 plots, were inventorised for Kedah, covering areas that have been logged over, as well as those that have not been disturbed. The 'main species of bamboo identified included the Buluh Betong group (Gigantochloa spp.), which represented the most common useful species found there as determined by earlier ground-checks (Wong & Abdul Rauf 1981), and species other than the Betong group. A total of 512 clumps were recorded during this inventory. Estimating that the average culm density was 20 per clump and that culms had average harvestable lengths of 6m, the inventory indicated that for the state of Kedah, a resource abundance in the region of 27 million pieces of Buluh Betong, each of b-meter length, could be expected. This, translated into air-dried tonnage (at a conversion of ,150 pieces equivalent to 1 tonne), would amount to over 179,000 metric tons of air-dried bamboo. In the case of species other than those of the Betong group, the estimated average culm density was 40 per clump with an average harvestable lengths of 3m, giving an estimate of 152 million pieces equivalent to a total of over 185,000 metric tons (at a conversion of 820 pieces per tonne) of air-dried bamboo. The inventory in Kedah confirmed earlier notions that bamboo occurred signifi-Candy more within logged-over areas than within undisturbed forests. Table 1. compares the .resource abundance within undisturbed and logged-over areas as estimated through this inventory; the resource represented at the time of inventory was about 16 times and about 47 times more, in the case of Betong-type (Gigantochloa) bamboo and non-Betong bamboo respectively, in logged-over areas than undisturbed areas.

This fact is a reflection of bamboo developing profusely in logged forests which become more open. Whilst some bamboo growth does exist within natural forests, it can be assumed that logging creates a more light-abundant environment conducive to the plants' rigorous growth.

We do not have similar data for the other 12 states. However, bamboos are substantially common in habitats such as the foothills of the Peninsula's Main Range, forest fringes and along some river courses, They dominate the landscape in logged-over areas and on waste land (Holttum 1958; Wong 1985 a). Whilst no specific figures can be quoted, the abundance of the bamboo resource must be considered in the context of its intended manner of exploitation. Although McGrath (1970) came to the conclusion that the 50,000 acres (20,250 hectares) of land in Peninsular Malaysia that he estimated to hold varying densities of bamboo was insufficient to serve as a sole source of fibre for a pulp mill of minimum economic size, they seem abundant enough to support several cottage and factory-line industries (Wong 1982). Studies are now under way to revise the identification and classification of these bamboos and to provide a comprehensive field key to their identification. It is now known that 45 species of various sizes and growth habits, of bamboo are found in Peninsular Malaysia, including 25 that are indigenous (Wong 1985 b).

In terms of everyday rural life, cultivated bamboos are of considerable significance as well, although there are no plantations in

Table 1. The abundance of bamboos in undisturbed and logged-over forest areas in the state of Kedah (source: Anon1982)

		Betong-type bamboo (Gigantochloa spp.)		Bamboo of other species	
Forest Type	Area (ha)	No. of 6-m lengths harvestable	Dry weight (tonne)	No. of 3-m lengths harvestable	Dry weight (tonne)
Undisturbed	126,829	1,585,000	10,500	3,171,000	3,900
Logged-over	173,776	25,371,000	169,100	148,752,000	181,400
Total	300,605	26,956,000	179,600	151,923,000	185,300

Malaysia as yet, to supply raw material for mechanised industries. In the agricultural areas, along the rice-fields and in villages, cultivated bamboos are easily observable along streams as well as in clusters planted around country homes. This cultivated resource, albeit on an uncoordinated scale, is important in sustaining the traditional life-styles within village communities.

Bamboo as an industrial resource: now and the future

Malaysia has not had a significant tradition in the use of bamboo as an industrial resource on a commercial scale. This is reflected in popular reference to resources such as bamboo and rattan as minor forest produce. Although this has been true in the past, the potential role of rattan and bamboo within the framework of economic development of the country has not been realised. Fresh considerations should be given to these resources by building and managing on a scale large enough to support feasible industries in areas that are ecologically suitable. Commensurate with the government's interest in raising further, the standards of living of the rural population, it becomes imperative that all resources currently or potentially available in the rural environment are assessed with the view to managing them for exploitation to maximum effect. Bamboo, therefore, comes to the forefront as one of the more easily available resources within rural communities. It is a proven case in several Southeast Asian and East Asian countries that the value-added potential of bamboo products is extremely high if the proper techniques are developed for the processing and manufacturing stages.

Already, several cottage industries in the country are adequately sustained by the bamboo resource, as revealed by surveys carried out by the Forest Research Institute (Wong & Abdul Rauf 1981; Wong 1982). On an organized scale, these industries include the cottage industries making vegetable baskets (in the state of Perak), poultry cages (Kedah state) and incense sticks (Selangor state), which draw mainly on supplies of Giganto-CMOU scortechnii that occur abundantly at several localities in these states. In the northernmost peninsular state of Perks, culms are harvested from natural populations of Schizostachyum zollingeri for manufacturing baskets and plaiting wall-panels for houses. Apart from these established industries, there is a factory in Kedah manufacturing bamboo blinds on a limited scale, employing the use of electrically operated looms that thread thin strips of bamboo together; this industry also uses G. scortechinjj bamboo as its main raw material and occasionally also G. wrayi, a closely related species. Likewise, there is also a strong tradition of using bamboos of the genera *Gigantochloa* and *Schizostachyum* in the East Malaysian states of Sabah and Sarawak.

It is also pertinent to note that the Malaysian handicraft industry, essentially rural-based and cottage-scale and perhaps best developed in the states of Kelantan, Kedah, Perak (in Peninsular Malaysia) and Sarawak (in East Malaysia), is increasingly developing more effective uses of raw plant materials such as cane and bamboo. Again, the bamboo that features prominently is G. scortechinii collected from the wild, as well as some cultivated G. *wrayi* and *Bambusa vulgaris.* The handicraft industry is reconciled to the manufacture of a variety of items made from different raw materials and by its nature cannot consider the solitary advantage of being sited at large bamboo supply areas; it would be relevant, however, to provide more systematic management of existing stands near to the utilisation centres in order that yield and quality is more efficiently maintained.

The Forest Research Institute and the Malaysian Handicraft Development Corporation are now exploring ways in which bamboo may be used as a complementary material in furniture making, in combination with wood, rattan or other natural materials that. are aesthetically and functionally compatible. Another exciting potential may come from adapting from the traditional art of plaiting bamboo strips into wall-panels incorporating elaborate designs; such plaited panels can be innovatively used in constructing modern interior screens and panels, and incorporated into artcraft furniture (Wong 1985b).

Taking the utilization of bamboo from the beginning, the first potential, of course, is in the development of an industry based on bamboo shoots. In traditional Malay cuisine, bamboo shoots are also featured in various dishes. There is, however, little attempt at growing bamboo for shoots on a scale larger than the village grove. The opportunity to promote the cultivation of bamboo shoots on a large scale for an export-oriented industry thus exists. The locally cultivated and wild species of bamboo which are preferred as sources of edible shoots are mainly *Gigantochloa levis* (cultivated), *G. ligulata* (wild in widespread stands in the northern states) and *Dendrocalumus asper* (cultivated), and occasionally cultivated *Bambusa vulgaris*, *B. blumeana* and *Schizostachyum brachycladum* (Wong 1984). It is also likely, from preliminary tests carried out, that these favoured species will perform well as canned foodstuff, although bamboo shoots cannot form the sole raw material for a canning industry as they are affected in production by seasonality. In any case, the feasibility of canning bamboo shoots as an industry and of cultivating the preferred species as a source of raw material for this purpose will have to be assessed against the estimated production/yield as well as the proposed scale of operation. At present, the silvics of managing cultivated stands, influenced by such factors as mortality of shoots and stems, phenology of shoot production, fertilisation regimes, planting design and harvesting intensities, is not known and will only be forthcoming through trials that are now being planned. As species have different attributes, there is wisdom in using available experiences from other countries only as guidelines and on a comparative basis.

Development strategies

In the government's policy of promoting rurally centred industries, the Forest Research Institute has been identified as a back-stop agency for developing the technology for small-scale industries based on rattan, bamboo and wood. Although among the three resources, bamboo is presently the least important in economic terms, it nevertheless has tremendous potential as an industrial resource.

The main emphasis must be divided into two areas. Firstly, it must be ensured that the technology exists in this country for the development of the bamboo-based, rurally centred, small-scale industries. In this respect, the role and participation of regional development authorities is critical to ensure the translation of the relevant technology into viable and economic ventures for rural development. As an example, the Kedah Development Authority has been the prime mover for the development of a bamboo-based industry in the state. This attests to the pertinence of adapting the available technology and resources into appropriate industries. It is anticipated that such technology exists for the development of similar industries in other parts of the country. To this end, an important component of the process is a concerted public relation and promotion exercise necessary to catalyse the development of such industries. It is anticipated that small-scale industrial projects, with the assistance of the World Bank, will benefit from this approach in the near future. This project has the complementary and supplementary participation of various other agenices that will provide financial, management and administrative support to promote full development of such industries.

The second critical area to bear in mind involves harnessing and managing the raw material resource to best advantage. Cultivation on a plantation scale must be viewed in perspective to other categories of land-use, such as for plantation agriculture of economically more valuable crops, e.g. oil palm, rubber and rice. It is, however, feasible to consider exploiting marginal land and small areas in the vicinity of cottage industries for cultivating bamboos. But cultivation is not all. The substantial areas of bamboo-rich vegetation may be improved and sustained through the imposition of silvicultural management for the increased output of bamboo. Enrichment planting, optimal harvesting intensities and regeneration and growth rates are all key aspects that need consideration. Only when these areas are better understood can it be practical to regulate them in such a way that harvesting is both centraiised and rotatable among designated regions. These are problems that must be addressed by research and trial.

Crossroads

The development of the bamboo resource in Malaysia is at the threshold of a more organized exploitation | that can materialize only with logical, planned strategies based on both scientific' and technological *grounds. Thus, although the exploitation of bamboo is currently at a lower intensity than in other countries where bamboo-based industries have been more established, the scope of development can optimistically centre around several areas; these include further development of techniques required for a more organized and innovative handicraft industry, for the food and consumer industries using bamboo ranging from barbeque skewers and umbrella handles to blinds and artcraft furniture. Finally, the systematic improvement of the bamboo raw material resource of the country must progress along scientific lines.

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Bamboo Research in Philippines

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Abstract

The highlights of some important research findings on the production, properties and utilization of Philippine bamboos are presented in the paper. A discussion of current research undertakings, problems of bamboo-based industries and suggestions for further research are made. The need to develop a vigorous and systematic dissemination of information on bamboo research for the benefit of end users is emphasised.

Introduction

Bamboo is commonly referred to as "poor man's timber" in the Philippines. Most parts of the house of poor families, including floorings, sidings, roof framing, furniture and windows are made of bamboos. Bamboo is also extensively utilized in the country for the construction of fish traps known locally as "baklad" and of fishpens which have gained popularity in recent years for the production of certain species of fish like tilapia and milkfish in both fresh and salt water. Bamboo has become a popular material for these and other purposes not only because it is available and easy to handle but also because of its relative durability and low cost. The banana industry uses bamboos as props to support the plants at the fruiting stage. The handicraft and furniture industry, utilizes bamboos for the manufacture of baskets, lamp shades, fans, hampers, hats, household utensils, fancy furniture and a lot of decorative items.

Bamboo has also been used in the making of musical instruments like, the world famous bamboo organ of Las Pinas Church in Metro Manila. A musical band known as "Pangkat Kawayan" has become famous internaionally because all the instruments they use are made entirely of bamboo. In Davao del Norte in the island of Mindanao, a commercial bamboo shoot farm was established in 1971. The species being used in the farm is Dendrocalamus latiflorus which was introduced from Taiwan. In many areas of the country,. however, Bambusa blumeana is the most common species from which edible shoots are derived.

Eleven genera and thirty nine species (including two varieties) of bamboo are found in the Philippines and twenty eight of these are erect while the rest are climbing. The climbing species are not important from the economic standpoint and will not be dealt with in this paper. A list of the erect species is provided in Table 1. Because of the high demand for bamboo as a material for various purposes, the country's bamboo stock has dwindled considerably especially since plantation establishment is done on a very limited scale. According to a report made by the Bureau of Forest Development in 1979, only about 1.7 million culms or roughly 80,000 clumps remain in the country. Obviously, there is a need to widen the raw material base for bamboo to meet the local as well as foreign demand.

The purpose of this paper is to present a summary of the more important findings and current research efforts on bamboos in the Philippines.

Bamboo Production

Natural Habitat: Bamboos, according to Uchimura (1978)) can grow on areas from sea level to as high as 2,800 – 3,200 meters elevation, depending upon the species. In the Philippines, species of Bambusa, Dendroculamus and Schizostachyum are found in the lowlands while Yushania niitakayamensis

Table 1. List of erect specks of bamboos in the Philippines.

Scientific Name	Common Name
1. *Bambusa arundinacea Willd.*	India bamboo
2. *B. blumeana Schultes f.*	Kauayan tinik
3. B. *cornuta* Munro	Lopa
4. B. merrillii Gamble	Merrill bamboo
5. *B. nana* Roxb.	
6. *B. tulda* Roxb.	Spineless India bamboo
7. B. vuigaris Schrad. ex. Wendl. var. striata (Lodd .) Gamble	Kauayan kiling Striated bamboo
8. B. *ventricosa* McClure	
9. B. *multiplex* (Lour.) Raeusch	Kauayan China
10. *Dendrocalamus merrillianus* (Elm)	Bayog
11. D. curranii Gamble	Curran bamboo
12. D. *latiflorus* Munro	Botong
13. G. aspera Kunz	Giant bamboo
14. G. levis (Blanco) Merr.	Bolo
15. *Guadua philippinensis*	Guadua
16. *Leleba floribunda* Nakai	
17. Phyllostachys nigra Munro var. henonis (Mitf.) Stapf. ex. Wendle	Polevault bamboo
18. B. bam*busoides* var. *aurea* Makino	
19. P. pubescens Mazel ex. H. Lehaie	
20. *P. aurea* Carr.	
21. P. edulis Makino	
22. Schizostachyum lima (Blanco) Men.	Anos
23. *S. brachycladum* Kurz.	
24. *S. lumampao* (Blanco) Men.	Buho
25. S. textorium (Blanco) Men.	Kalbang
26. *S. zollingerii*	Yellow bu ho
27. Thyrsostachys siamensis Gamble	
28. *Yushania niitakayamensis* (Hayata) Keng. f.	Utod

thrives naturally at altitudes ranging from 2,100 to 2,600 meters. Some species of Phyllostachys have been observed to grow well at 1,500 meters altitude. Most of the commercially important species of bamboo in the Philippines thrive in a wide range of soil types. It has been observed that they grow best in well-drained sandy loam to clay loam soil derived from river alluvium or underlying rocks particularly where soil pH is 5 to 6.5 (Uchimura, 1978). Soil suitable for bamboo growing vary in color from yellow, reddish yellow to brown yellow. However, although growth is vigorous and luxuriant in most soils, some species thrive in drier sites or are drought resistant. The specific site locations of the Philippine commercial species of bamboos are shown in Table 2.

Propagation and Plantation Establishment: While bamboo can be propagated by seeds as shown by Caleda (1964) in his study on S. lumampao, asexual reproduction is the more common method since the various species do not flower regularly and even if they do, a high percentage of the fruits are sterile. In employing the asexual method, rhizomes, stumps, and culm cuttings are traditionally used. However, these materials are bulky, expensive and difficult to transport and handle.

A promising vegetative method was recently reported and the method involves the use of branch cuttings. Palijon (1983) obtained a rooting percentage of 83 to 90% using branch cuttings of B. blumeana. The same study revealed that

Table 2. Site requirements and distribution of commercially important bamboos in the Philippines.

Species	Site Requirements and Distribution
1. Kawayan tinik (Bambusa blemeana)	Moist soil, found throughout settled areas in the Phil. at low and medium altitude. Luxuriantly growing at river banks, creeks, farmhouses, backyards, (Rizal, Camarines Sur and Norte, Cavite, Batangas, Laguna, Pangasinan, La Union, Abra, Ilocos Sur, Ilocos Norte, Davao Sur and North Cotabato) .
2. Kawayan kiling *(Bambusa vulgaris*	Moist soil, found in backyards, periphery of cultivated lands, creeks, and at the foot of the hills. (Mt. Makiling and other parts of the province) few in Northern Luzon .
3. Bayog (Dendrocalamus)	in relatively drier sites at low and medium elevation. Widely distributed in the Philippines (Rizal, Central and North-eastern Luzon, Pangasinan, La Union, Ilocos Norte and Sur, Tarlac) .
4. Botong (Dendrocalamus latifiorus)	Moist soil, occuring particularly in areas with high rainfall. (Bicol, Visayas, Tagalog provinces, and Mindanao (Davao Norte plantation).
5. Giant Bamboo (Gigantochloa aspera)	Moist soil occuring profusely in areas with well distributed rainfall throughout the year. (Mt. Makiling, Agusan de1 Sur, Bukidnon) .
6. Bolo *(Gigantochloa leuis)*	Moist soil, abounds in and around towns in the settled areas in the country and also in the forest. Found in settled areas of the Philippines (Aklan, Capiz Antique, La Union).
7. Anos (Schitostachyum lima)	Relatively moist soil, found along creeks, forest fringes. Widely distributed in the Philippines (Zambales, Bataan, Abra, Cavite, Tarlac, Laguna, Quezon, Batangas and other provinces).
8. Buho (Schizostachyum lumampao)	Relatively moist soil, found in forest hills. Widely distri buted in the Philippines (Zambales, Bataan, Caliraya, Laguna, Tanay, Rizal) .

Table 3. Techniques of propagating Philippine bamboos.

Propagules	Species	Techniques
Seeds	Bambusa vulgoris	One to two year-old seedlings either-grown in pots or in transplant beds are used for outplanting.
	Schizostachyum lima S. lumampao	S-month old seedlings raised in pots and also wildings collected from natural stand conditioned in the nursery for 3 months are used for outplanting.
	Bambusa arundinacea	Seeds from Thailand brought to the Philippines for trial planting. One year old seedlings raised in pots are used for field planting.

Rhizome	Schizostachyum lima *S. lumampao and* other species	Rhizomes are severed from the mother plant and immediately planted in the field to avoid 'drying. Can also be started in the nursery and allowed to develop for6 months to a year before outplanting. This can also be applied in other species, however, the material is too bulky and only very few can be collected from a clump.
Stump	Bambusa blumeana other species	Three-node stump is dug up at the early rainy season and directly. planted in the field.
Culm cuttings	Bambusa blumeana	One to two year-old culms, taken from middle portion of the culm, large size with a length of at least one node and two halves internodes. Rooting can be enhanced by treating 600 ppm NAA and IBA. Can be directly planted in the field or be raised in nursery for 6 months to 1 year before outplanting.
	Bambusa vulgaris	Six month old culm, taken from butt portion of the culm, a length of one node with two halves internode, collected early and late rainy season, and should be growing in the nursery first before outplanting.
Culm cuttings	Gigantochloa levis G. uspera	Two-year old culm, taken from top and middle portion of the calm, a length of one node and two halves internodes, can be directly planted in the field or raised in the nursery during early rainy season.
	Bambusa arundinacea	One to two year old culms, taken from middle portion of the culm, a length of one node and two halves internodes, can be planted directly in the field or be raised in the nursery.
	Dendrocalamus	Three-year old culms, butt portion, two node cuttings. Can be planted directly in the field but better performance can be attained if raised first in the nursery.
Branch cuttings	Bambusa blumeana	Branches from 1 to 2 year old culms, 1.2 to 1.5 cms. diameter, with 3 nodal length, collected during early rainy season are good materials. Can be treated with 100 ppm IAA then propaged in sand bed. Rooted cuttings can be potted twenty days after. Two to three-months old seedlings can already be outplanted in the field.
	Bambusa vulgaris Dendrocalamus merrillianus	Can also be propagated by branch cuttings from one to two-year old culms. Should be rooted in the propagation bed and raised in pots and/or nursery bed for six-months before planting in the field.
Marcotting	*Bambusa blumeana*	Two-year old culms, should be topped down from the mother clump. Support these with strong props. Place ordinary garden soil and leaf with molds around the node then wrap with coconut husk fibers and tie with fine wire at both ends of the marcotted portion.
Layering	*Bambusa blumeana*	Partly two-year old culms and lay them in ground so that they produce roots and shoots at nodes. When the shoots have appeared, the internodes are cut and the layers planted separately.

hormone treatment, particularly IAA at 100 ppm, .can improve the quality of the planting stocks (branch cuttings) by enhancing root and sprout development. According to Palijon (1983) such improvement results in higher shoot production, better height and diameter growth and higher biomass in the field although survival may not be different from stocks that are not subjected to hormone treatment. He concluded, however, that hormone-treated and untreated nursery grown stocks (potted and transplanted) are desirable planting materials than freshly treated or untreated branch cuttings. A summary of the various techniques used in propagating important erect species of bamboos in the Philippines is shown in Table 3.

Insofar as plantation establishment is concerned, not much research has been undertaken in the Philippines. In practice, however, the planting site is prepared by clearing strips or sports of the areas where the propagules are to be *planted. The spots are usually 50 cms in diameter and the strips 50 cms in width The Holes are about 30 cms in diameter and deep enough to contain the potted or rooted stocks without their roots being curled upward when planted. After planting, grass mulch and other forms of litter are placed around the plants to reduce water loss. Planting is usually carried out at the besinninq of the rainv season and the distance of planting is usually 8 to 10 meters. Weeding or brushing around the plants is carried out whenever necessary and watering is done when signs of wilting show up after planting. Fertilizing bamboo plantations is not a widespread practice in the Philippines. According to a study made by Robillos (1984), the removal of spiny branches in and around the lower portion of clumps of *B. blumeana* and decongestion of the clumps by removing high stumps from previous. harvesting and cutting of deformed and overmature culms resulted in higher culm production. Treated clumps produced an average of eight culms while untreated clumps produced only five culms per growing season.

Pests and Diseases: According to PCARRD (1984)) the pests of bamboo in the Philippines include termites (Macrotermes *gilvus* and *Hospitalitermas huzonensis),* the cottony cushion mealybug *(Planococcus lilacinus)* , the bamboo scale *(Asterolecanium bumbusae)* , oriental migratory locust *(Locusta* migratoria *manillensis)* , leaf roller *(Pelopidas maths),* tussock moth *(Lymuntria ,lurata),* aphids *(Astegopteyx* bambusae) and mites *(Aponychus corpuzae) A . vannus* and *Schizotetranychus floresi).* Bamboo diseases, on the other hand include physiological disease and fungal disease (Loculistroma *bumbusae)* . None of these pests and diseases, however, have been reported as serious problems in nurseries, plantations and natural stands.

Structure and Properties

Structural Features: Studies on the structural features of Philippine bamboos have dealt mainly with anatomical features that are of value in identification and with fiber dimensions. Grosser and Zamuco (1971) and Zamuco and Tongacan (1973) have shown that various species of bamboos occuring in the Philippines can be delimited on the basis of anatomical characteristics. Insofar as fiber dimensions are concerned, Tamofang et al (1955) found that fiber length and other fiber dimensions, as well as indicators of pulp quality based on fiber dimensions, such as the slenderness ratio flexibility ratio and the Runkel ratio are highly variable with respect to species (Table 4). In the study conducted by Tamolang et al (1957) fiber length ranged from 1.36 mm to 3.78 mm with most of the species having fibers that are longer than 1.6 mm, which means that they can be classified as long-fibered following the definition of terms of the International Association of Wood Anatomists.

It has also been reported that fiber length in bamboos. tends to vary along the culm length. Espiloy (1982)) for instance, showed that fiber length in *B. blumeuna* increases from internode number 2 from the butt to internode number 18 after which it decreases. With increasing distances from the butt, the mean fiber diameter and mean cell wall thickness in *B. blumeana* are slightly higher in the lower internodes than in the upper.

Chemical Properties: Semana, Escolano and Monsalud (1967) studied the chemical composition of some Philippine bamboos and their results are summarized in

Table 4. Fiber dimensions of some Philippine bamboos.

Common Name	Fiber Length (L)	Dimensions Width (D)	Lumen Width (l)	Cell Wall Thickness (W)	Slenderness Ratio (L/D)	Flexibility Ratio L/D x 100	Runkel Ratio 2 w/I
	mm	mm	mm	mm			
1. Anos	1.67	0.022	0.004	0.009	76	18	4.50
2. Bayog	2.16	0.014	0.006	0.004	154	43	1.33
3. Bikal	2.00	0.021	0.007	0.007	95	33	2.00
4. Bolo	1.80	0.022	0.006	0.008	82	27	2.67
5. Buho	2.42	0.014	0.006	0.004	173	43	1.33
6. Giant bamboo	3.78	0.019	0.007	0.006	199	37	1.71
7, India bamboo	1.73	0.022	0.006	0.008	79	27	2.67
8. Kauayan-china	1.36	0.018	0.002	0.008	76	11	8.00
9. Kauayan-kiiing	2.33	0.017	0.004	0.007	137	23	3.50
10. Kauayan-tinik	1.95	0.018	0.004	0.007	108	22	3.50
11. P.ole-vault bamboo	1.86	0.019	0.006	0.0065	95	32	2.17
12. Spineless India bamboo	1.45	0.20	0.005	0.0075	73	25	3.00
13. Yellow bamboo	1.66	0.021	0.005	0.008	73	24	3.20

Source: Tamolang, F. N. et al. 1957. Fiber dimensions of certain Philippine broadleaved woods and bamboos. TAPPI 40: 671-676.

Table 5. Chemical composition of some Philippine bamboos

Species	Holocellulose %	Pentosans %	Lignin %	Sotubilities In: Alcohol Benzene %	Hot Water %	1% NaOH %	ASH %	Silica %
Bolo	62.9	18.8	24.2	3.2	4.4	28.3	5.3	2.8
Buho	60.6	20.6	20.4	5.0	4.3	31.4	9.7	6.4
Giant bamboo	61.3	19.6	22.5	5.4	3.8	22.3	4.1	2.4
Kuayan-kiiing	66.5	21.1	26.9	4.1	5.1	27.9	2.4	1.5
Kauayan-tinik	67.4	19.0	20.4	3.1	4.3	39.5	4.8	3.4
Yellow bamboo	63.6	21.5	25.9	3.7	3.9	24.7	3.0	1.3
Range of values for 10 Indian bamboo species		18.1-21.5	22.0-32.2	0.2-3.2	3.4-6.9	1510-21.8	1.7-3.2	0.44-2.11
Range of values for 10 Japanese, Burmese and Indonesian bamboo species	61.9-70.4	17.5-22.7	19.8-26.6	0.9-10.8	5.3-11.8	22.3-29.8	0.8-3.8	0.1-1.78

• Moisture- free basis

Source: Semana, J.A., J.O. Escolano and M.R. Monsalud, 1967. The kraft pulping qualities of some Philippine bamboos. TAPPI 50(8): 416-419.

Table 5, the alcohol-benzene, hot solubles, lignin, holocellulose, and pentosan contents of Philippine bamboos are similar to those of those Asian bamboos, but values for I% NaOH solubility, ash and silica content were higher. Content increases in a linear fashion from internode number 2 from the butt (1.60%) to internode number 30 (9.89%) in B. blumeana. (Espiloy, 1982).

Physical and Mechanical Properties: The variability of specific gravity among clumps, among culms and along the culm length has been examined by Espiloy (1982) in *B. blumeana***.** Variations among culms within clumps and internode were found to be highly significant. Differences among culms accounted for 61% of the total variation while internode number accounted for 19%. Specific gravity increased from internode no. 2 to 14 and then remained more or less constant up to internode no. 30.

The mechanicai properties of only three species B. vulgaris, G. ***aspera*** and S. lumampao have been examined so far. Results of these studies (Espiloy and Sasondoncillo, 1976a; Espiloy and Sasondoncillo, 1976b; Espiloy, Valmonte and Tongacan, 1979) showed that strength properties either increased or decreased along the length of the culm from the butt to the top, although a general increase in strength was more evident at the top and middle portions. In terms of shrinkage, the butt portion of the culm in G. aspera and S. ***lumampao*** gave higher values for thickness and width than the middle and top portions. In B. vulgaris, the middle portion of the culms gave the highest shrinkage values.

Utilization

Natural Durability: As reported by Tamolang et al (1980), the natural service life of untreated bamboo is from 1 to 3 years when used in contact with the soil and from 4 to 7 years when used indoors. They also mentioned that "materials used in kitchens in rural homes where they are exposed to fumes of- burning fuel, have service life extending from 10 to 15 years". Under marine water conditions, bamboo life expectancy is only 6 months.

Bamboos, are very susceptible to the attack of decay fungi and powder post beetles, particularly Dinoderus minutus. Tamolang et al (1980). According to Liese (1970) who studied the natural decay resistance of four species of bamboos, a soft rot fungus, Chaetomium globosum causes the most severe deterioration while a brown-rot fungus, Ceniophora putaena, and a white-rot fungus, Schizophyllum commune causes only a moderate decay.

De Guzman (1978) classified the resistance of some Philippine bamboos to fungal attack on the basis of weight loss after four months of exposure, *Perishable* – Dencfrocalamus merrillianus *Moderately* resistant – B. blumeana, B. vulgaris, G. aspera, G. levis, S. lumampao; Resistant – S. *lima; Very* resistant – S. zollingetii.

Preservation: The traditional non-chemical methods of improving the service life of bamboos in the Philippines are soaking, curing, smoking and white-washing. Soaking involves the cut culms to be under running or brackish water for about 60 days then allowed to dry, when their starch content is depleted (PCARRD, 1984). Curing involves cutting the bamboos and leaving them on the spot for sometime with their branches and leaves intact. Apparently,. the tissue respiration and the transpiration of water through the leaves reduce the amount of starch in the culm (PCARRD, 1984).

The amount of starch in the culms is also affected according to PCARRD (1984) by smoking which involves cutting the culms into desired lengths and storing them above a fire-place until they turn black due to smoke. Bamboos cured with smoke have been reported to last from 10 to 15 years (PCARRD, 1984). The method of white washing involves painting round of split bamboo culms with soaked lime which prevents the entry of moisture into the culm, keeping decay and stain fungi away. It was found that split and round bamboo pieces immersed in salt water for eight weeks helped prevent insect and decay fungi (Laxamana, 1966). The same study also revealed the following: a) Immersion of bamboo pieces, split or unsplit, in 20% boric acid-borax solution prevented beetle infestation. b) Spray treatment of split or round pieces of bamboo with either 5% DDT or BHC in kerosene is effective in preventing powder post beetles attack; only a few months. c) cold soaking in copper napthanate solution for 24 hours and preservative treatment with pentachlorophenol or Wolman salts are promising. d) Complete preservative penetration is possible in some bamboos after several days of cold soaking in water soluble preservations. e) Tanalith U (Wolman) treated specimens were the least infested, followed by those treated with Boliden S-25 and Boliden K-33. f) Effective protection against fungi, termites and borers may be achieved using the Boucherie process which involves the freshly cut bamboos standing in a container of preservative solution. The preservative is drawn upward due to leaf transpiration.

Seasoning: Casin and Mosteiro (1970) reported the bamboo culms may be thoroughly dried in a dry and well-ventilated shed. In this method, the culms are horizontally laid on a rack with the supports of the culms set at intervals to minimize bending. It takes two to four months before the culms become thoroughly dry with this method. They also have observed that immature culms lose moisture more rapidly than mature culms; thus the immature culms usually develop cracks and collapse during drying. Moisture content is 50% or more higher at the lower portion of the culm, than at the upper portion. Kiln drying of bamboo according to PCARRD (1984) has also been tried. With this method, drying takes about nine days.

Bamboo as a Concrete Reinforcement: Purugganan et al (1959) conducted a study on the suitability of bamboo as a concrete reinforcement. Their major findings are as follows: a) Bamboo reinforcement in concrete beams increased the load carrying capacity of members considerably above that to be expected from members of the same dimensions without reinforcement. b) Concrete member reinforced with well-seasoned bamboo splints and treated with .a dip coat of asphalt emulsion withstood loads greater than members with untreated splints. Further the excessive treatment will materially reduces the bond between concrete and bamboo. c) The use of seasoned and untreated bamboo splints greater than 1.9 centimeters as longitudinal reinforcement in beams result in the development of horizontal cracks, especially when the percentage of reinforcement is high. The cracking of the concrete is probably due to the swelling action of the bamboo. d) The load carrying capacity of beams reinforced with bamboo is increased by the addition of bamboo splints as diagonal tension reinforcement of sections where the vertical shear is high. e) The additional compressive area of flanges in tee sections is not effective in bamboo reinforced concrete members. f) A safe design stress of 218 to 290 kgs/sq. cm. may be used with building concrete reinforced with bamboo.

Bamboo Parquet: Bamboo parquets have been successfully developed by the Forest Products Research and Development Institute (FPRDI) (Tamolang et *al, 1980).* The parquets which are 38 mm x 57 mm in dimension are suitable as a flooring material. D. merrillianus, B. blumeana and G. aspera have been found suitable for the manufacture of this product (Tamolang et *al, 1980).* The procedure and machinery for their manufacture are known. That warping, shrinkage and swelling, easy wear, buckling, checking, etc. do not pose a problem to end-users because the construction is well-balanced and the slats are mounted on stable base and securely glued.

Laminated Bamboo: FPRDI has developed laminated bamboo sheets, panels, bonds, flitches, and other forms of construction materials for structural and decorative parts of houses, boats and furniture. Tamolang et *al* (1980). The procedure involves cracking the materials, spreading them out and flattening them into sheets with suitable binding and filling materials after which the sheets are treated, combined, lapped, arranged, glued, treated, and pressed to the desired form.

Bamboo strips for aircraft: In 1956, Leon experimented on the use of bamboo mats glued to wood or laminated to another bamboo mat as astress-skin covering for light aircraft. The resulting material was found to be relatively strong and its fatigue strength under bending stress was much higher than that of wood.

Pulp and Paper: A number of studies have been conducted on the suitability of various species of Philippine bamboos for pulp and paper. Escolano et al (1964), Escolano and Semana (1970), Escolano et *al* (1972)) Monsalud et al (1965), Nicolas and Navarro (1964), Semana (1959), Semana *(1965),* and Semana, Escolano and

Monsalud (1967). The more important findings obtained from these studies were summarized by Tamolang *et al* (1980).

Current Research Undertakings

The Philippine Council for Agriculture and Resources Research and Development (PCARRD) which sets the national research priorities in the Philippines on various commodities in forestry, agriculture, fisheries, and mining classifies bamboo as a top priority research commodity. This has provided an incentive for many researchers to submit research proposals on various aspects of bamboo production and utilization. To date there are a total of 15 ongoing research projects, seven of which deal with bamboo production, one which concerns structure and properties and seven which involve bamboo utilization (Table 6). The different researches are being carried out by researchers of the Forest Research Institute (FORI), the

Table 6. List of on-going research on Philippine bamboos (as of July 31, 1985)

Title	Implementing Agency
Bamboo Production	
1. Development of pilot scale plantations of selected bamboo species in Rizal and Quezon provinces for cottage industries.	FORI
2. Rhizome and clump development and yield of selected bamboo species in plantation _	FORI
3. Rhizome development and production of planting stock from rhizomes and branches of selected bamboo species.	FORI
4. Establishment of a bambusitum at the FORI Experimental Station in Mt. Makiling.	FORI
5. Trial planting of various bamboo species at different elevations in Benguet.	FORI
6. Determination of the optimum cutting cycle and cutting age of some erect bamboo species.	FORI
7. Bamboo propagation techniques.	UPLBCF/TARC
Structure and Properties	
1. Physico-mechanical properties and anatomical structure relationships of Philippine bamboos.	FPRDI
Bamboo Utilization	
1. Preservation of round bamboos for fishpen.	FPRDI
2. Design and development of bamboo roof trusses.	FPRDI
3. Construction and evaluation of bamboo houses for demonstration purposes.	UPLBCF
4. Design and development of bamboo walls and floor systems.	FPRDI
5. Development of machining and jointing techniques for bamboo furniture.	FPRDI
6. Development of steaming and bending equipment for round bamboos.	FPRDI
7. Study on the relative susceptability of different species of bamboos to power post beetles.	FPRDI

Notes: FORI – Forest Research Institute
FPRDI Forest Products Research and Development Institute
UPLBCF – UPLB College of Forestry
TARC – Tropical Agriculture Research Center, Japan

Forest Products Research and Development Institute (FPRDI) and the UPLS College of Forestry. A project on bamboo propagation techniques is being undertaken jointly by the College of Forestry and the Tropical Agriculture Research Center of Japan. Most of these will be completed in two to three year's time and they are expected to provide valuable information on various aspects of bamboo production, properties and utilization.

Suggested Future Research Thrusts

Bamboo-based industries in the Philippines are beset with a number of problems, the most serious of which are the following; Insufficiency of raw materials. As stated earlier, the estimated total number of standing culms in the Philippines is 1.7 million while the estimated annual demand is 31.27 million (Tesoro, 1983). Bamboo in the country is continuously getting scarce because there is usually no deliberate effort to replenish the resource after cutting. Also, cutting is usually indiscriminate, giving little regard to the growth of new culms. Likewise, there is no existing set of weil-defined policies regarding the management and exploitation of bamboos. Mass-producing planting stocks for large-scale plantation development is another difficulty. This problem has probably contributed to the non-existence of a plantation development program in the country.

Underutilization or non-economic use of some bamboo species arise because of insufficient knowledge of the variability of the properties and uses of different species.

Marketing and distribution is also a problem because bamboos from high production areas generally do not find their way to where the demand is high due to technical problems in the transporting. There is variability in the quality of many bamboo products.

Considering the above problems, it is not difficult to see that future research on bamboo in the Philippines should aim to: a) promote self sufficiency in raw materials; b) improve the utilization of the different species through the development of improved processing techniques, development of new products and increasing the service life of the products themselves; c) determine suitable uses for species that are presently not being utilized commercially, and d) increase the income of bamboo entrepreneurs so that their quality of life may be improved.

To meet these objectives, it is recommended that future research should place high priority on the following areas: a) Development of a cheap and reliable method of mass producing planting materials. b) Studies on species/site compatibility. c) Development of a harvesting system that will ensure sustained yield. d) Development of an effective technique for inducing flowering and fruiting. e) Site preparation techniques. f) Cultural requirements. g) Variability of structure and properties with position along the culm length and with culm age. h) Seasoning and preservation. i) Product development and quality control. j) Socio-economics of production and utilization, and k) Marketing and distribution.

Apart from undertaking research, it seems that there is also a need in the country for a vigorous and systematic dissemination of information to transfer the products of research to the end-users. This may be achieved by establishing a computer-based information and retrieval system on bamboos, the launching of an information program using the print and the broadcast media, and the establishment of bamboo production and utilization of demonstration centers. It should be borne in mind that research is useless unless its products are put to a good use by the intended users.

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Bamboo Research in Sri Lanka

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Abstract

As in other tropical Asian Countries Bam*boos are used* in *Sri Lanka for various* pur*poses. Besides taxonomic research, new cultivation methods are practised* for large *scale introduction and production.*

introduction

About eight decades ago Pou-Sou-Tung, a famous Chinese poet wrote "A meal should have meat, but a house must have a bamboo. Without meat we become thin; without bamboo we lose serenity and culture in itself". Bamboo is one of the four noblest plants in China, the others being the orchid, the plum tree and the chrysanthemum.

Bamboo, in classical forestry, has been referred to as a "minor forest produce", but during recent times the status of bamboo has changed considerably and it is emerging as an important source in many forestry programmes. Whatever it's status. there is no doubt that bamboo deserves much attention in Asia because of its traditional multi-faceted use and phenomenal growth rates. It has been cultivated for centuries in 'a number of Asian countries, and during the past few decades, many of them have embarked on large scale cultivation of economicalIy important species. R & D efforts have also been intensified in a number of countries, mainly through support lent by IDRC (International Development Research Centre). At the IUFRO (International Union of Forestry Research Organizations) International Workshop on Multi-Purpose Tree Species (MPTS) held in Kandy, Sri Lanka in July 1983, bamboo emerged as one of the ten most popular species selected for Research networking in Asia with Bangladesh as the Leader and China together with Thailand as Co-leaders. Sri Lanka, with its keen interest on Bamboo research is one of the participating countries in the network. This paper gives an update of the Bamboos in Sri Lanka and the status of research done under the auspices of the IDRC .

Bamboos in Sri Lanka

Bamboos occur mostly in natural vegetation of tropical, sub-tropical and temperate regions. They are, however, found in great abundance in tropical Asia. There are 45 genera and 750 species recorded (Dransfield 1980). In Sri Lanka 14 species belonging to 7 genera have been reported and detailed (Senaratne 1956). Keys for the identification are given in Appendix, 1. Of the 14 species found in Sri Lanka 5 species out of 214 are endemic (Senaratne, 1956). Trimen (1893-1900) in his "The Flora of Ceylon" includes only 7 species. Other species have also been introduced into Sri Lanka and some are found in the Botanic Gardens at Peradeniya and also cultivated in forest areas or grown in home gardens. There have been no proper documentation of these species. The Forest Department with IDRC support is now in the process of preparing a monograph of all the Bamboos both endemic and introduced.

During a recent survey of species in Botanic Gardens at Peradeniya the following seven species which were not recorded by Senaratne (1956) were identified. 1, *Bambusa* atra – this species is from eastern part of indonesia. *2. Bambusa polymorpha* – this resembles D. giganteus except that the lower internodes of young culms are covered with golden brown hair. This species is reputed for its quality shoots which is ranked as one of the best in the world. 3. *Dendrocalamus* mem-

branaceus 4. *Dendrocalamus sikkimensis* 5. Giganrochloa utter – It is from Java and was until now being erroneously labelled as *Bambusa nigra* (syn. *Phyllostachys nigra)* . *6. Tbyrsostachys siamensis* (syn. *Bambusa* nigra) – this is a native of Thailand. A brief botanical description of the 14 species already recorded by Senaratne (1956) are given, which together with the key given in Appendix 1 will help in the identification of the species.

Description of Bamboos

1. *Bambusa* orientalis *(Bambusa arundinacea)*
   Common name: Spiny Bamboo; Local name: Katu Una. *Culms* many, tufted on a stout rootstock, branching from the base, 25 to 35m high, 15 to 17.5 cm in diameter, graceful, curving. *Culm* sheaths coriaceous, variable in shape, up to 30 to 37.5 cm long 22.5 to 30 cm. *Nodes* prominent, lowest rooting, lower emitting horizontal, almost naked shoots armed at the nodes with 2 to 3 stout recurved spines sometimes 2.5 cm and more long. *Internodes* up to 45 cm long, walls up to 2.5 to 5 cm thick. *Distribution:* At low and mid-country elevations: Ambagamuva, Alut Oya, Central Province; rather common on river banks; flowers at about 30 years of age; one of the most useful of bamboos for construction purposes.
2. Bambusa vulgaris
   Common name: Bamboo; Local name: Una. *Culms* rather distant, 7 to 16 m high, 5 to 10 cm in diameter, polished, green, early branching. *Culm sheaths* 15 to 25 cm long, 17 to 22 cm wide, top rounded, retuse, thickly appressed-hairy, margins ciliate, blades 5 to 15 cm long, 7 to 10 cm wide. *Nodes* hardly raised, girt with a ring of hairs. Internodes 25 to 45 cm long. walls rather thin. *Distribution:* At low and mid-country elevations often cultivated; recorded from the earliest historic times; the culms are extensively used for construction purposes; this is the most widely cultivated bamboo in Sri Lanka.
3. *Bambusa vulgaris var. vittata*
   Common name: Golden Ba; Local name: Rana Una. *Culms* smaller, golden yellow with green bands along the length of the internode alternating at each node. The green stripes disappear on drying. Distribution and uses similar to B. vulgaris.
4. *Bambusa multiplex*
   Common name: Chinese Bamboo; Local name: China Una. *Culms* tufted 2 to 3 m high, 1.2 to 2.5 cm in diameter, much branched from the base, smooth green, at length yellow. *Culm sheaths* 10 to 15 cm long, 5 to 7.5 cm wide. *Internodes 20* to 37 cm long. *Nodes* thickened. *Distribution:* At low and mid-country elevations; cultivated for close fences and naturalized in places.
5. *Oxytenanthera monadelpha*
   Culms gregarious subscandent; 3 to 4 m high, about 2.5 cm in diameter, with whip-like curved tips bearing whorls of small-leaved branchlets, smooth. *Culm-sheaths* about 12 cm long, 7 to 10 cm wide, of old stems covered with appressed light brown hairs, of young thinner, glabrous, shining, base leaving a coriaceous ring on the nodes, mouth truncate, margins ciliate; ligule of old sheaths very long, fimbriate of younger narrow, erose; blades to 7.5 to 12.5 cm long, ovate acuminate, base rounded and decurrent on the top of the sheath and ending in large rounded auricles with bristly tips, bristle very long and flexuous on the leaf of young shoots. *Nodes* prominent. *Internodes 30* to 45 cm long, rough, young hirsute, walls 2.5 to 5 mm thick.
6. *Indocalamus walkerianus*
   Culms tufted, thickly covered above with bladeless leaf-sheaths. *Culm-sheaths* papery. *Distribution:* In the montane zone up to the highest elevations.
7. *Indocalamus wightianus*
   Culms gregarious, 2 to 3 m or more high, slender, dark green, at length yellowish brown. *Culm-sheaths* 10 to 20 cm-long, 2.5 to 7.5 cm wide, narrowed slightly upwards, straw coloured, thickly clothed with stiff, golden, tubercle-based hairs.
8. *Indocalamus floribundus*
   Culm .6 to 1.6 m high, erect. *Distribu-*

tion: In the montane zone.

9. *Indocalamus debilis*
Culms elongated, much branched. *Nodes* rather enlarged. *Distribution:* In the upper montane zone.

10. *Chimonobambusa* densifolia Stolons giving off stout, strong, densely leafy culms, 15 to 100 cm high, with fastigiate, short branches. *Culm-sheaths 2.5* cm or more long, striate, hirsute, tip rather narrowed, truncate, minutely 2-auricled. Internodes 3.8 to 7.5 cm long, 8 mm in diameter, rather thick-walled. *Nodes* not prominent. Distribution: In the upmost montane zone, in swamps.

11. *Teinostachyum attenuatum*
Culms tufted, 4 to 9 m high, 1.2 to 2.5 cm in diameter; tips very slender. *Culm-sheaths* pale, appressed- hairy. *Nodes* with many whorled leafy branches. *Distribution:* In the upper montane zone.

12. *Dendrocalamus giganteus*
Common name: Giant Bamboo; Local name: Yodha Una. *Culms* up to 35 m high, 15 to 25 cm in diameter, densely tufted, naked in the lower part. Culm-sheaths 25 to 35 cm long, glabrous, pale within, hairy outside, later glabrous but scaberulous. Distribution: Often cultivated in the mid-country and in the montane zone.

13. Ochlandra stridula
Culms crowded, 2 to 6 m high, 6 to 18 mm in diameter, pale green. Geniculate *nodes. Internodes 30* to 50 cm long, scabrous. *Culm-sheaths* glabrous, top rounded, auricles falcate, bristly. Distribution: In the low-country wet zone; covering hundreds of square miles.

14. *Ochlandra stridula* var. maculata
Stem greyish-green, banded and blotched dark purple. Loses its purple colour under cultivation *Distribution:* At low and mid-country elevations in the wet zone, extending to the montane zone.

Past Experiences with Bamboo

Although Bamboo has been used in Sri Lanka from the times of the ancient kings and recorded as a valuable commodity in old manuscripts there is hardly any evidence of large scale systematic planting of the species. Species such as *B. vulgaris* and B. *orientalis* have been used for construction of dwellings, scaffoldings and the making of handicrafts, while other smaller culm species have been used in cottage industry for the making of baskets and a number of household items which are commonly used by rural people. Cottage industry based on Bamboo has provided employment to rural folks and this, through the years, had led to its over-exploitation and thereby created a situation where the resource has been diminished to a critical level and can collapse if remedial measures are not taken. It is fortunate, however, that many villagers have realized this and have made attempts to propogate popular species like *B. vulgaris* in their homesteads or farms to meet their requirements.

It was only in the mid 1960's large scale planting of Bamboo was attempted by the Sri Lanka Forest Department. The species used was *Dendrocalamus strictus* and this was planted close to the Paper Mill in Valaichenai in the dry zone. A comprehensive account of this is given by Vivekanandan (1980). The iarge scale planting of *D, strictus* was suspended *in* 1975 and since then there has been no attempts to revive the planting of this species. To date there are 1150 hectares of plantations of *D. strictus* in the dry zone ready for exploitation,

Current Research on Bamboo

In 1980, the IDRC organized a Workshop in Singapore to review the status of Bamboo Research in Asia and Sri Lanka was represented. The Workshop provided a forum for exchange of ideas and to identify the gaps in our existing knowledge, At this Workshop Sri Lanka presented a proposal for undertaking research on Bamboo and Rattan and this was accepted in principle. The project came into operation in late 1984 with IDRC providing financial support to the amount of CAD 77,370 for a period of 3 years. The current status of the research done under this project is reviewed here.

Review of Research Under IDRC

During the first phase of the Project a preliminary survey of the Bamboo species was done through technical assistance provided by IDRC. The survey revealed that there were a number of species hitherto not recorded, found in the Botanic Gardens at Peradeniya. These species are mentioned. The overall assessment of the species revealed that the following local species, which have acclimatized to our climate, have good potential for large scale planting. a) *Bambusa vulgaris* b) Bambusa orientalis c) *Dendrocahmus giganteus* d) *Dendrocalamus strictus* and *e) Ochlandra stridula.*

The main objective of research was to mass produce propagules for large scale cultivation. With this in view the following investigations were undertaken at the IDRC Bamboo Nursery at Peradeniya. 1. Effect of age on rooting; 2. Effect of position of nodes on rooting; 3. Effect of rooting media; 4. Effect of hormones and fertilizers; 5. Comparison of split and entire culms on rooting and 6. Comparison of container vs bare rooted. These experiments have been laid out according to standard designs and are still in progress.

In addition it was also felt that introduction of species from overseas could broad-base our species composition. The following were identified for further research: a) *Dendrocalamus asper* b) *Thyrsostachys* siamensis *c) Gingantochloa species.* In view of the importance of *Bambusa vulgaris,* which is very commonly used in Sri Lanka, the first part of the research was undertaken with this species.

The preliminary results so far available are summarized here: a) *Rooting of culms – Positions.* Culms were selected from healthy clumps and were cut into sections so that each section contained 2 nodes. These were laid out vertically, horizontally and obliquely in nursery beds. All 3 positions proved to be satisfactory and because of ease of setting the cuttings in subsequent experiments, they were planted vertically burying the 2 internodes. In subsequent experiments using standard potting mixture (top soil and sand) it was found that rooting occurs after 2 months from the time of setting. b) Splitand *entire nodes.* This was done, in identical way as above in that culms were planted vertically, horizontally and obliquely and was found that the entire culms had high survival rate than split culms. This may be attributed to rapid desiccation of split culms. *c) Humidity.* One important observation which emerged from the preliminary experiments were that high humidity is vital for rooting. This was achieved through using improvised mist tents made of wooden frames and clear polythene sheets. In the earlier experiments where the culms which were set in nursery beds or planted in polythene bags (18 x 12 ") and not covered with polythene tents, the mortality rate was high. The introduction of polythene tents have kept up the survival rates and is being used in all the experiments in progress. It is an important observation for furture work. d) *Rooting of Side Branches.* Hitherto our studies have been concentrating on the main culm. In a programme designed to mass propagate a species the availability of clonal material is critical. As culms may not be available in sufficient quantity, studies were directed to investigate the possibility of rooting side shoots. Here too studies are underway to examine various factors which influence the rooting of culm cuttings. So far the indications are that this will prove to be successful, and full assessment will be done once the experiments are completed.

Future Programme

The work started with B. *vulgar-is is* being extended to *D. giganteus* and will eventually cover all major species of economic importance. The future programme envisaged under the project are: a) Establishment of Germplasm collection; b) Establishment of trial plantations especially in the Mahaweli river basin area; c) Mass production of propagules for sale to public for planting in homesteads. In addition, interest has also been expressed to explore the possibility of developing the Bamboo shoot industry and also develop local technology for increasing the service life of large culm Bamboos which are used as scaffoldings and for house construction,

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Appendix 1

KEY TO THE GENERA OF THE BAMBUSEAE

Stamens 6 to 30:

Stamens numerous, up to 30; paleas without keels; spikelets with 1 floret; pericarp fleshy, free (Subtr. 1. Melocanninae) — 1. Ochlandra

Stamens 6; paleas 2 keeled at least in the lower florets:

Pericarp crustaceous, detachable; spikelets with few to many florets; tress or shrubs (Subtr. 2 Dendrocalaminae):

Ovary glabrous; keels of palea ciliate — 2. Teinostachyum

Ovary pilose at apex; keels of palea glabrous — 3 . Dendrocalamus

Pericarp membranous, adnate to the grain (Subtr. 3 Bambusinae)

Filaments free: spikelets with 1 to many florets; lodicules 2 to 3; palea 2-keeled: trees or shrubs — 4. Bambusa

Filaments connate; spikelets longconical. with 1 to 3 florets; lodicules wanting; palea keeled or rounded; scandent shrub — 5. Ocytenanthera

Stamens 3: palea 2-keeled; pericarp thin; adnate to the seed (Subtr. 4. Arundinariinae):

Spikelets panicled, buds solitary at nodes of culm; leaf-sheaths persistent; bristles scabrid or setulose — 6. Indocalamus

Spikelets racemose; buds numerous at nodes of culm; leaf-sheaths deciduous; bristles not scabrid — 7. Chimonobambusa

KEY TO THE SPECIES AND VARIETIES OF THE BAMBUSEAE

Trees: culm erect, 7-25m high, over 5cm in diameter:

Culms spiny — *Bambusa orientalis (B. arundinacea)*

Culms not spiny:

Culms 7-16m high, 5-10cm in diameter: Culms green — *Bambusa vu!garis*

Culms yellow with vertical bands of green — *Bambusa vulgaris* var *vittata*

Culms l0-25m high, 12-25cm in diameter — *Dendrocalams giganteus*

Shrubs:

Culms erect:

Culms 15-160cm high:

Culms 15-100cm high, 8mm in diameter. with fastigiate short branches — *Chimonobambusa densifolia*

Culms 60-160cm high without fastigiate short branches:	
Leaf blades thick, 12-28cm long, 2-5cm wide, with cartilaginous margins	***Indocalamus*** walkerianus
Leaf blades thin. with membranous margins:	
Leaf blades 3.7-7.5cm long, 5-8mm wide	***Indocalamus debillis***
Leaf blades 12.5-20cm long, 12-18mm wide	***Indocalamus floribundus***
Culms 2-6m high:	
Leaf blades 20-30cm long, 3.7-6.2cm wide; culms 2-6m high, 6-18mm in diameter:	
Culms pale green, not banded and blotched	***Ochlandra stridula***
Culms greyish green, banded and blotched with dark purple	***Ochlandra stridula*** var ***maculata***
eaf blades 3-10cm long, 8-25mm wide:	
Culms 2-3m high about 36mm in diameter: Culm-sheathes with ligule short, truncate, fimbriate; their blades 2.5-3.8cm long, subulate	***Indocalamus wightianus***
Culms 2-3m high, 12-25mm in diameter; culm-sheathes with ligule narrow, entire; their blades 5-8cm long, linear-acuminate, with decurrent base	***Bambusa multiplex***
Culms not erect:	
Culms 4-9m high, 12-25mm in diameter, dropping from an erect base, with very slender tips	***Teinostachyum attenuatum***
Culms 3-4m high, 25mm in diameter, with whip-like curved tips	***Oxytenanthera monadelpha***

Bamboo Research in Thailand

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Abstract

A general account on the occurrence, utilisation, commercial potential of bamboos in Thailand is given. The various species and their uses are listed and the need for further research is emphasised.

General Information

Location	: Latitude 97 °E- 106°E, Longitude 5°N-21 °N, Southeast Asian Region		
Area	: 513,115 sq.km.		
Population	: 50,396,000 inhabitants		(1984)
Population Desity	98.2 persons/sq.km.		
Growth Rate	: 1.7%		(1984)
G.N.P. (billions US $)	: 39.2		(1983)
G.D.P. (billions US $)	: 40.4		(1983)
Per Capita income (US $)	: 815.5		(1983)
Forest Areas	: 156,600	sq.km.	(1982)
Forest Plantations	: 4,519.9	sq.km.	(1983)

Climatic Conditions and Forest Types

Climatic Conditions: Thailand is located in the Southeast Asian region. The climate in this region is greatly influenced by the Southeast and Northeast moonsoons, resulting in a marked wet and dry seasons and the vegetation are of two major types, i.e. tropical rain forest and the tropical savannah type. The climate is characterized by uniformly high temperatures and heavy rainfall and by the absence of a distinct dry season. The tropical Savannah climate has less rainfall and comprises three seasons, i.e. cool dry, hot dry and rainy season. The cool dry season extends from November to February, the hot dry season through March – April and the rainy season covers the longer period from May to October.

Forest Area and Forest Types: The total forest area in Thailand, as monitored and estimated by using the LANSAT system in 1982, was 156,600 sq.km. approximately 30.5% of the total area of the country. The forests in Thailand can be broadly divided into two major types, i.e. "Evergreen" and "Deciduous" forest and both these are further subdivided into several types according to their dominant and pre-dominant species as follows: - a) Evergreen Forests, Tropical Evergreen Forest, Pine Forest and/or Pine/ Dipterocarp Forest, and Mangrove Forest. b) Deciduous Forests, Mixed Deciduous Forest, Dry Dipterocarp Forest, Scrub Fore&- The areas of these six forest types in 5 regions of the country are presented (Table 1).

Bamboo and Its Economic Importance

In Thailand, bamboo is one of the most socio-economically important plant species. The species are used for many purposes such as food, household construction, supporting poles, basket and other handicraft making, fire wood and pulping. Bamboo occurs naturally throughout the country. The species are mainly found in the Mixed Deciduous and Tropical Evergreen forests and

Table 1. Forest Types and Forest Area in Thailand 1982.

Forest Types	Northern Km^2	Northeastern Km^2	Eastern Km^2	Central Western Km^2	Southern Km^2	Total Km^2
1 Evergreen	25,568	9,305	6,216	12,449	14,323	67,861
2 Mixed deciduous	35,006	2,618	1,113	5,192	–	33,929
3 Dry Dipterocarp	34,318	13,819	253	540	–	48,930
4 Mangrove	–	–	418	335	2,119	2,872
5 Pine/Dipterocarp	2,018	144	–	–	–	2,162
6 Scrub	846	–	–	–		846
7 Rubber Plantations			(650)	(15,220)		(15,850)
Total	87,756	25,886	8,000	18,516	16,442	156,600

– Figures in brackets are not included in total forest area.
– Source: Royal Forest Department, Bangkok, Thailand.

partly found in the dry Dipterocarp forest (Table I). Apart from natural Forests, the bamboo plantations and/or the bamboo farms have been widely established for shoots and stem production throughout the country.

There are 12 genera and 41 species of bamboo recorded in Thailand and the major type of bamboos found throughout the country is the "Sympodial" type. The important genera and species of bamboo in Thailand can be grouped as follows according to the utilization purposes: - 1) Bamboo for shoot production (for food), (Pai Tong) *Dendrocalamus asper,* (Pai Seesuk) *Bambusa blumeana,* (Pai Ruak) * *Thyrsostachys* siamensis, (Pai Ruakdam) *Thyrsostachys* oliverii, (Pai Bong) *Dendrocalamus brandisii,* (Pai Sang doi) *Dendrocalamus strictus* and (Pai Rai) *Gigantochloa albociliata,* 2) Bamboo for stem production (Construction and supporting pole) (Pai Paa) *Bambusa arundinaceae,* (Pai Seesuk) Bambusa *blumeana,* (Pai Tong) *Dendrocalamus asper,* (Pai Ruakdam) *Thyrsostachys oliverii,* (Pai Sang doi) *Dendrocalamus strictus,* (Pai Saang *nuan) Dendrocalamus membranaceus,* (Pai Liang) Bambusa *nana* and (Pai Phaak) *Gigantochloa hasskeriana,* 3) Bamboo for stem production (basketing and handicraft), (Pak Ruak) *Thyrsostachys siamensis,* (Pai Ruakdam) *Thyrsostachys oliuerii,* (Pai Seesuk) *Bambusa blumeana,* (Pai Liang) *Bambusa nana,* (Pai Phaak) *Gigantochloa hasskeriana,* (Pak Griab) *Schizostachyum humilis* and (Pai Hiae) *Cephalostachyum uirgatum.* The total production of bamboo as recorded in 1984 by the Royal Forest Department was 48,929,933 stems (culms).

Apart from local consumption, Thailand exports bamboo and its products to several countries in various parts of the world. The export-income of bamboo Thailand is shown (Table 2).

Bamboo Research

As mentioned earlier, bamboo is one of the most valuable forest species in Thailand. Due to pressure from a large population, both forest tree species (including bamboo) and the forest areas, especially the Mixed Deciduous forest types, have been heavily exploited for wood utilization and cleared for land need, Without exception, bamboo resources are decreasing rapidly both quantitatively and qualitatively. To increase the production of bamboo for both local consumption and export, a good production and management proaramme for bamboo in both natural forests

Table 2. Export value of Bamboos in Thailand,

YEAR	1983		1984		1985 (Jan – April)	
TYPES	Quant. Tons	Price us $	Quant Tons	Price us $	Quant . Tons	Price us $
1 Bamboo culms	18.9	24,885	22.2	16,798	22.1	2,573
2 Bamboo Handicraft	149.0	212,423,	79.2	290,188	25.8	83,890
3 Bamboo Shoot (Fresh chilled)	288.8	222,821	338.9	382,062	238.5	165,873
4 Bamboo shoot Dry)	29.7	129,182	15.2	48,332	–	–
Total	486.4	589,311	456.2	737.380	286.4	252,336

Source: Department of Business Economics Ministry of Commerce: Bangkok, Thailand.

and plantations is required.

A co-operative bamboo research programme in Thailand was initiated in 1965 between the United Nation Development Programme and the Royal Forest Department of Thailand. The major objective of this programme was to estimate the annual production of bamboo from natural forests, particularly in the Western part of Thailand, for pulp and paper industries. A research centre was set up in Kanchanaburi province where bamboo is the dominant forest species. In this research programme, a series of studies on ecological aspects and the management of bamboo forests, vegetative and the generative propagation of bamboo, other techniques of bamboo plantation establishment, etc. were intensively conducted. In 1972, the joint UNDP/RFD bamboo research project was terminated and bamboo research activities since then have been operated solely by the Royal Forest Department.

Since 1983, the RFD bamboo research programme has received support from the International Development Research Centre (IDRC) of Canada. The major objective of this programme is to introduce and establish a bamboo living collection as a source for bamboo plantation establishment. The bamboo living collection has been established in 3 localities and model bamboo plantations (or bamboo farms) have been established in 4 localities throughout the country. Apart from the establishment of the bamboo living collections and bamboo plantations (farm} a number of studies on eco-physiological aspects, utilization and preservation of bamboo wood etc. are also being conducted.

Cultivation and Production

Improved Cultivation Techniques of Bamboos in NorthChina

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Abstract

The growth habit, distribution and *cultivation methods of bamboos in North China* are discussed. *The periodic growth* pattern is *accounted.*

Introduction

China is rich in bamboo resources, having one fourth of the total world flora. *Phyllostachys* is the main genus and it grows luxuriantly in the north notwithstanding unevenly distributed sparse rainfall, remedied mostly through intensive cultivation and irrigation. Cultivation of bamboo in North China enjoys a long history dating back to 1 B.C. when the famous historian Sima Qian wrote in his "Historical Records" that a thousand mu of bamboo was worth the wealth of a marquis granted 1,000 households to labour on his territory. From the third century A. D., administrations were mostly established in the northern provinces by order of the court for proper management of bamboo groves, and the officials therein were also responsible to collect taxes. The technique of bamboo cultivation in North China is traditional, largely based on past practices.

Particular Features of Bamboo Groves in North China

Species of bamboo in North China: There are ten genera, 29 species and ten varieties naturally spread in North China, of which 16 species, and nine varieties belong to *Phyllostachys.* The distribution of bamboo groves in North China is apparently regional, the climate playing significant part in affecting the zoning. In the plains, bamboo-growing areas may be divided into three zones as a result of natural distribution: (1) On the upper reaches of Huaihe and Hanshui River in the northern subtropic zone subject to humid climate. (2) On the middle and lower reaches of the Huanghe River (Yellow River) in the temperate zone subject to semi-humid climate. (3) In the Shanxi-Gansu-Ningxia area, of temperate zone subject to semi-arid climate. Species of bamboo in each zone may be further classified into three groups: (1) widely distributed and frequently occurring. (2) Moderately distributed and occurring quite often. (3) Sparsely distributed and occurring rarely. The distribution of different species of bamboo in different zones is shown in Table 1, from which the following generalisations are made.

1. The widely distributed and frequently occurring species or those fit for cold climate or high altitude in the north, are mainly cultivated.

2. Those sparsely distributed and occurring rarely have more number of genera and species. This shows that in the north the environment is suited for the growth of many different species. Hence the species of bamboo which are not quite widely distributed may possibly be cultivated over a more extensive area.

3. *Phyllostuchys* glauca McClure and *Yushania Confusa* (McCl.) Wang et Ye grows in semi-humid as well as in semi-arid climate, which shows that these species are most suitable for development in the northern area.

Characteristics of distribution of bamboo groves in North China: The distribution of bamboo groves in North China is governed by the amount of rainfall and temperature available for plant growth, of which the precipitation plays the dominant role. Places favourable to the distribution of bamboo groves are as follows: a) Plots in areas adjacent to hills and rivers,

b) mountainous areas exhibiting discontinuous patches in landscape. Bamboos cultivated ,in hills or plains are mostly found along river banks or where water is available through irrigation. Bamboo-producing areas are often concentrated on the middle and lower reaches of rivers. Further the northwestern part of North China is mostly of arid and cold climate and the southeastern warm and wet. Hence the growth of the following species diminishes towards north: *Sinocalamus ajjinis, Barnbusa multiplex, Phyllostachys pubescens, Ph. heterocycla, Ph. propinqua, Ph.* bambusoides, *Ph. nigra* var. *henonis* etc, whereas species such *as Phyllostachys glauca, Ph. bambusoides lacrina-deae* Keng et Wen *Ph. glauca* f. yunzhu, *Ph. jlexuosa* increase in the direction towards north. Secondly, the land in North China gains in elevation towards west, in the direction of which species such as *Yushania conjusa, Fargesia spathacea, Bashania jargesii, Pleioblastus amarus* grow more luxuriantly. The species growing well jn flat country gradually vanish in the westward direction.

The topography is very complicated in North China, and the growth of bamboo is affected by topography. There are certain places favourable for the growth of bamboo with bamboos growing well *e.g. Phyllostachys propinqua,* which grows almost everywhere on rolling or flat country to the south of the Huaihe River, was cultivated in the area between the Huaihe and Huanghe River and transplanted in areas as far north as Beijing satisfactorily. Mixed planting of bamboos with other plants show that, with favourable micro-relief, bamboos which grow well in southern area may also be cultivated in the north, thus shifting southern species towards north. Through the efforts of the author, *Phyllostachys pubescens* has been transplanted in Henan province during the past ten years or more over a total area of 90,000 odd mu, or 6,000 ha.

Regularity of growth in North China: The growth of bamboo in North China is obviously consistent with the climatic cycle in a year. The four seasons of a year are very distinct in North China, and the growth of bamboo in the north is such that, in spring the bamboos shoot, in summer rhizomes grow, in autumn new shoots are developed, and in winter the plant becomes dormant, following the climatic cycle. Fig. 1 represents the growth data of over 20 species of bamboo studied in the experimental bamboo plots in Zheng Zhou. It can be seen that: (1) Seasonal changes influence the growth and phenological phases of bamboo. (2) Similar temperatures are required for the sprouting and growth of bamboo shoots, in spring and in autumn alike, with a seasonal mean air temperature of 14°C.

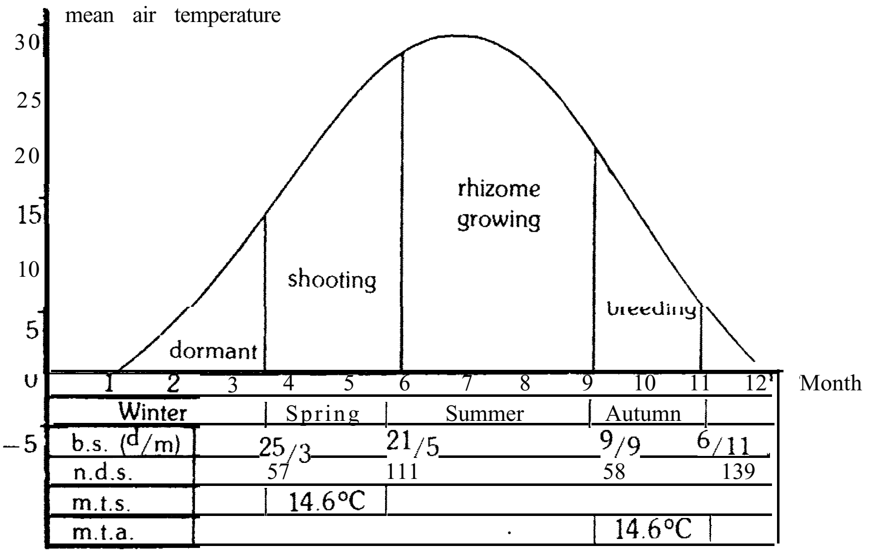

Fig. 1 Periodic growth of bamboo in a year in Zhengzhou. Henan versus air temperature.
b.s. (d/m) beginning of the season (day/month).
n.d.s. number of days in the season.
m.t.s. — mean air temperature in spring.
m.t.a. — mean air temperature in autumn

Bambusa textilis McClure was introduced into Henan province from South China for trial cultivation. The regularity of growth of this species of bamboo is such that by the turn of the season from summer to autumn, it shoots, ready to elongate and bear leaves next spring after passing the cold winter. But then during the, cold climate the tender shoots perish. A comparison of the relationship between the growth of the aforesaid species of bamboo versus air temperature in Nanning (22°50' N) and Xuchang (34° N or so) is shown in Fig. 2, from which it was seen that owing to lower air temperature in Xuchang, the growing period there is delayed by one month or so.

Technique of Cultivating Bamboo in North China for Bumper Harvest

1. Particular features of cultivating bamboo in North China include the following environmental conditions – Cold Winter and Wind. It is desirable to choose plots shelttered against the wind. Inter-montane basins or foot of hill slope are preferable if water supply is available.

Plains to the south of mountain ranges are usually fit for growth of bamboo over large area. Bamboo groves with history of over 1000 years, such as those in Boai and Qinyan in Henan and at Zhuganchuen in the suburbs of Zhengzhou are all adapted to the existing micro-climates. Measures for sheltering should be taken for planting bamboo on vast plains, either by means of building walls or locating the groves in villages, the buildings giving shelter to the groves.

2. Bumper harvest of bamboo is possible only through irrigation or by watering since rainfall is sparse and unevenly distributed. The dry season in spring is not favourable to the growth of bamboo with high demand for water. The bamboo shoots grow vigorously after rains. Engineer Liang Tairan of the Ministry of Forestry of China classified bamboo groves into those subject to irrigation and those that are not, as seen in North and South of China. The boundary between the two zones is essentially along the Qinling-Huaihe line, the natural line of division between north and south China. In the southern region which abounds in rainfall, the bamboo cultivation differs from that in the north where additional water is to be applied through irrigation. In shooting period, the soil moisture should be kept at 20% level or so for survival rate of 50%, whereas with moisture of 15% or so, only 30% of the bamboo may survive. It may thus be seen that irrigation plays an important role in cultivation of bamboo for bumper harvest in North China.

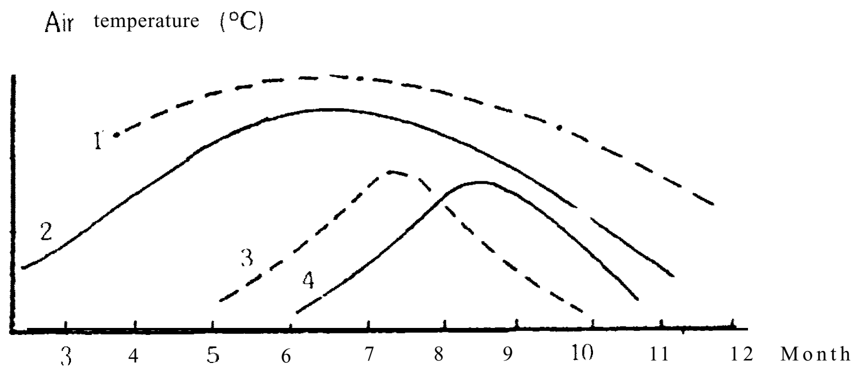

Fig 2 Comparison of reqularity of growth of Bambusa textilis in its native place and where it has been transplanted (1) Air temperature In Nanning. with observed values in dots (2) Air temperature in Xuchang. Henan (3) Growing period in Guangxt (4) Growing period in Xuchang

3. The bamboo groves should be well managed in the north where intensive cultivation is practised with irrigated land well trimmed and levelled, actually forming.a kind of garden. Irrigation is required and additional soil should be added regularly to raise the soil level so that the young rhizomes are kept close to the soil surface.

Other methods followed for cultivation include choosing, digging, conveying, transplanting and managing. "Choosing" is selection of good young bamboos.. Bamboos should be free from plant diseases and insect pests, being of 1 – 2 years of growth and not too tall. Of the three requirements, the age is the important factor, because bamboos growing for more than 2 years show ageing of the rhizomes with many sprouts and when transplanting, the sprouts may be destroyed and no bamboo will grow any more. In ancient books of farming, it is said that "in the presence of water, all seasons are appropriate for transplanting of bamboo", stress being laid on moisture. For rapid growth of bamboo groves, the season of spring is best chosen. According to tests made by the author, bamboos cultivated in spring will bring returns in the very year of transplanting. Bamboos cultivated in summer or autumn do not yield even the following year. Leaves drop off from bamboos transplanted in winter and do not develop further. Sunny and sheltered spots should be chosen and thick layer of soil is desired.

"Digging" of young bamboo should be carried out appropriately. Formerly, stress was laid on finding the rhizomes, a section of 30 cm of approaching rhizome and 60 cm of outgrowing rhizome being desired, together with 15 – 20 kg of soil. Such method is unfavourable for the following reasons: (1) The groves were damaged to a considerable extent. (2) During transport, all the exposed sprouts were ruined. (3) Packaging and moving were inconvenient. (4) The bamboos planted did not survive well. In view of the aforesaid, the author made attempts to dispense the carrying of both rhizomes. The improved technique is characterized by: (1) Each tuft of young bamboo dug should comprise at least 2 saplings. (2) Soil dug around the saplings should be cylindrical in shape. (3) No less than 50 kg of earth should be carried with each cluster.. (4) The diameter of the cylinder of soil should not be less than 30 cm. (5) The earth around the saplings should not be loosened when dug. The survival rate of 100% may be attained by this method and the bamboo shoots grow to desired size in the same year to form small groves. While transporting over long distances the earth should not be lost and proper packaging with cattail bags tied tightly with straw ropes is necessary. It has been recorded that on some occasions, in spite of the loading and unloading four times over a period of 15 days no moisture was lost and soil was intact.

In the past, while "transplanting" open pockets underneath the tuft of bamboo roots were left due to unsatisfactory refilling of earth, leading up to perishing of the transplanted saplings. The author has devoted a new three-step method of transplanting. The three steps are backfilling, covering and watering, each being manipulated in two operations, mainly as follows: Backfilling for the first time – In the pit made for transplantation a hemispherical mound of earth is formed, the tip of which is at a distance from ground surface equal to the depth of penetration of the bamboo into the earth prior to being dug. The sapling is placed upright on top of the mound, in close contact with the earth at the bottom. In the second step well crushed soil of fine texture is then backfilled until the pit is half full and the stems may stand upright. In the third step the partly refilled pit is filled with water to let the sapling absorb sufficient amount of moisture and the infiltration of water downward brings about compaction of earth. The fourth step includes the covering with earth for the second time. After all the water has infiltrated, appropriate amount of organic manure is to be applied and the pit refilled with the same kind of earth flush to ground surface. A ring shaped bund is to be made around the pit to prepare for the second application of water. The fifth step is watering for the second time. Water is applied to provide the sapling with more moisture and to let the soil become compact through infiltration. The sixth step includes the addition of more earth to form a conical mound around the stem after levelling off the ridge subsequent to complete infiltration of the water, which is functional in keeping the moisture and protect the sapling from wind damages. In employing the above method, no trampling and stamping is involved and open pockets will not be left undernearth the young plant. The rate of survival is higher than if planting is effected by means of "slurry method", so far known as the best, by which 86.6% of the saplings survive, according to reports made by Zhumadian prefecture, against 92.7 % throush the adoption of the above-mentioned method.

The principal measures for proper cultivation are application of water, use of fertilizer or manure, weeding and rational felling of unwanted stems as well as intercropping with melons, vegetables and beans. As the bamboos grow, crowding is inevitable and the younger bamboos are suppressed in growth. These should be removed so that more space will be available for others to grow well. Intercropping is effective in preventing growth of weeds. Vegetables may be introduced appropriately in the first year of bamboo cultivation, and melons the second year, after which no more intercropping is to be exercised.

Breeding technique: The agronomic methods practised in North China include: (1) Rational felling of unwanted ones. (2) Applying manure and earth and digging tufts at the proper time. (3) Tilling in hot summer days and suppressing green crops to serve as manure, as well as laying straw to preserve moisture. (4) Proper irrigation or watening methods. (5) Closing the area to grazing and collecting of fuel and protecting the bamboos from plant diseases and insect pests. (6) Renewing the grove in belt form and causing the rhizomes to develop along the periphery. By taking the aforementioned measures in a comprehensive way, the useful life of bamboo grove may be prolonged. Some of these are briefly elaborated.

(I) Rational felling and timely breedihg: Bamboo is a perennial plant, with woody fibres formed only in a number of years. Hence, bamboos may be felled only in a selective way. The purpose of felling is on one hand to obtain the stems as material for economic gains. Less crowding would improve the quality of the bamboo grove. Small, old, crooked and crowded ones as well as those infected with plant diseases and insect pests should be removed. One of the particular features of bamboo groves is that the plants should neither be too crowded nor too sparse. Grove of satisfactory quality should be such that it possesses adequate density and canopy density, with even distribution of bamboo, and distance between canopies not exceeding 60 cm.

(2) Applying manure and earth and digging tufts at the proper time are important to improve the underground growth including the twisting and gnarling of rhizomes, to prevent rhizomes from growing outside the soil and to avoid damages by frost and to prevent premature blooming. In North China, earth and manure are applied in ridges and subsequently flattened out, or by forming grooves through digging out and afterwards backfilled, or by laying earth. There is another way, called ridging, through which the grove is turned into ridges and ditches, each 50 cm wide and of V and inverted-V shape. Bamboos are cultivated on the ridges, and the ditches are left for watering, facilitating both irrigation and drainage.

(3) Applying water to meet the demands: Watering at appropriate periods would regulate the growth of bamboos – shooting in spring, rhizomes growing in summer, breeding shoots in autumn and being dormant in winter, in yearly cycles. In early spring, water is applied to promote shooting When the bamboo shoots grow above ground and rapidly gain in height: water is needed for jointing. In summer the growth of rhizomes is expedited through application of moisture in adequate quantities. In autumn, the growth of young sprouts is also effected through irrigation. In winter when the soil freezes at night and thaws in daytime, moisture is also applied, so that the plant may stand the cold climate safely. Application of water in the 5 aforesaid instances is a part of suitable cultivation technique for bamboo groves in North China. The number of times of application is governed by the actual precipitation occurring. The basic principle is that the first application should begin early, the last should be of sufficient quantity to saturate the soil and to meet future needs, whereas the intermediate one should be exercised fittingly.

(4) Rhizome development along the periphery: Good rhizome growth depends on fertile and loose soil and deep-plowing of earth along the periphery of the grove every year in summer. Rhizomes increase by 5-8 m in length in the same year. The grove expands 5-8 m in radius every year. In the first year, the extended area may be intercropped. Measures as such taken around groves totall-inq 3000 mu in area in Henan during the period 1974 – 1979 successfully resulted in an increase of 1176 mu of groves within 6 years, at an average rate of 1.5% per annum. Subsequently, the newly emerged bamboos are generally tall and thick, exhibiting the advantages of speedy grown, early returns and saving in investments as compared with bamboo groves newly formed through trans-planting.

Management and operation of bamboo groves

An approp iate management and ooera-tion system is th e guarantee for high yield and fine quality of bamboo. The task is to deal properly with the relationship regarding the cycle of growth within a year, the periodic growth of woody tissue and the life cycle of bamboo, so that the plant will grow lux-uriantly in an unfailing way. In spring, the shoots should be protected. In summer, tilling is a must and the rhizomes should be well groomed. In autumn, triming of shoots and preservation of moisture is to be effected. and in winter felling in a rational way should be exercised. The above-mentioned methods are the basic tasks in the inanagement and operation system which have a bearing on yield. Operation based on the formation of woody tissues is such that bamboos under 3 years are retained and those over 4 years felled, except for those necessary for the main-tenance of the required density of canopy. The maximum age should not exceed 7 years. The period may be determined on the basis of the relationship between specific gravity of the bamboo and the age, or the relationship between index of foliage area and age of bamboo. The period between conse-cutive blooming, which is generally several decades, be possibly prolonged if operation based on the former two cycles is rigorously enforced. It is known that long-lasting droughts and lack of soil fertility will lead to twisting and gnarling of the old rhizomes and improper management practice such as negli-gence of application of earth and manure. By experimenting, it was found that the blooming period may be delayed ten years or so if suitable measures are taken to improve the environment of bamboo growth two or three years prior to the expected blooming.

Economic returns from Bamboo Groves Cultivated in North China

The stress of the present operation system is on the provision of moisture and carrying out all-embracing management in a comprehen-sive way. The degree of management and out-put have much improved when compared to those prior to 1949. Groves well managed, implementing the aforesaid 7 measures of cultivation technique for high yield, promise yearly produce of over 6000 jin per mu, whereas at places where the measures were partially enforced, 3000 jin of bamboo or so were achieved each year. Where practice as such was intermittently carried out, the yield fluctuated over wide ranges. All in all, groves of the same category and same bamboo species may show difference in yield. Table 2 provides production details from 1949 through 1982. Generally speaking, yield from 6067 mu of bamboo groves doubled within the given period, as a result of taking suitable measures of cultivation for bumper harvest, in terms of economic returns.

Table 2 also shows indices of average yield of 6067 mu of bamboo groves, essentially representing the medium level of produc-tion of bamboo groves in North China, and comparable to certain, extent the average indices of produce in the entire land, It may be seen that bamboos cultivated in groves in North China show higher yield than the nationwide average, proving that growing bamboo in North China is markedly reward-ing.

Bamboo groves in irrigated areas in North China have long been regarded as a source of wealth, one mu of bamboo grove giving ten times as much economic returns as the mu of cropland – concretely illustrated by facts in Boai county in Henan province. Numerous groves are concentrated in the area, now known as the largest bamboo-producing area in North China. Recently, new policy of "earn iny more money rather "than merely har-vesting crops" has been adopted by the county administration, encouraging people to plant more bamboos in place of farming, to improve the economic conditions of farmers.

Table 1. General features of distribution of bamboo groves in North China.

Zone	Number of genera and species	Group i	Group 2	Group 3
1 (Subtropic, humid)	10 genera, 25 species {including mutantsand variaties)	4 genera, 6 species 1. ***Pttyllostachys*** *bambusoides* Sieb & zucc. 2. ***Ph. propinqua*** McClure 3. ***Ph. nigra var.*** *henonis (Mitf.)* stapf ex Rendle ***4. Bashania*** fargesii Keng f. et Yi 5. lndocalamus ***latifolius*** (Xeng) McClure ***6. Yushania confusa*** (McCI.) Wang et Ye	3 genera, 5 species ***I. Phyllostachys*** *pubescens* Maze1 exH. deLeh ***2. Ph. purpurata*** McClure cv. straightstem McClure ***3. Ph. hetercycla*** diver. 4. Neosinocalamus affinis (Rendle) Keng f 5 Fargesia ***spathacea*** Franchet	7 genera, 14 species ***1. Phyllostachys*** decora McClure ***2. Ph nuda*** McClure ***3. Ph. nigra*** (Lold.) McClure ***4. Ph. nidularia*** Munro ***5. Ph. aurea*** A. et C Riv. 6. ***Chrmonobambusa*** *guadragularia* (Fenzi) Mankino ***7. Pleioblastus*** *amarus (Keng)* Keng f. ***8. PI.*** simoni (Carr.) Nakai 9. ***Indocalamus migoi*** (Nakai) Xeng f. 10. ***I. longiauricus*** Hand-Mazz. 11. ***Bambusa*** *multiplex (Lour)* Raeusch 12. ***B multiplex*** var *nana (Roxb.)* Keng f 13. ***Yushania chungrr*** (Keng) Wang et Ye 14. Gelidocalamus ***fangianus*** (A Camus) Keng f et Wen
2 (Temperate. semi-humid)	8 genera. 23 species	2 genera. 3 species ***1. Phyllostachys*** glauca McClure 2. ***Ph. flexuosa*** (Can A. et C. Riv. ***3. Yushania*** confusa (McCI.) Wang et Ye	4 genera. 8 species 1. ***Ph. bambusoides*** lacrimadeae Keng f. et Wen 2. ***Ph. vivax*** McClure 3. ***Ph.*** viridis (Young) McClure ***4. Ph. propinqua*** McClure ***5. Ph. glauca*** McCI. f. yunzhu f. nov. Lu	5 genera, 12 species 1 Ph. aureosulcala McClure 2 ***Ph.*** aur McCl f spectabilis (Chu Chao) Lu ***3. Ph. aur.*** McCI. *pekinensis J. L.* Lu f. nov. 4. ***Ph*** vivax McCI f. huangwenzhu Lu f. nov. 5. ***Ph.*** vrridis (Young) McCl CV, R. Young McCl

Zone	Number of genera and species	Group 1	Group 2	Group 3
			6. Bashania fargesli Keng f et YI 7. In. latifolius MC. 8. Farg. spath. Fran	6. Ph viridis McClure CV Houzeau 7. Ph meyen McClure 8 Ph angusta McClure 9 Chimonobambusa quadragularis Makino 10 Pleioblastus amarus (Keng) Keng f 11 Yushanra chungii (A. Camus) Keng 12 Gelidocalamus fangianus (A. Camus) Keng f. et Wen
3 (Temperate, semi-arid)	5 genera, 6 species	1 genus, 1 species 1. Yushania confusa (McCl.) Wang et Ye	2 genera, 2 species 1 Bashania fargesii Kengf et Yi 2 Fargesra spathacea Franch.	3 genera. 3 species 1 Ph y llostachys glauca McClure 2 Yushania chungii (Keng) Wang et Ye 3. Gelidocalamus fangianus (A Camus) Keng f et Wen

Table 2. Changes in output from 6067 mu of bamboo groves through 33 years.

Item	Stock of bamboo, mean value		Bamboos felled each year, average quantity	
	jin/mu	kg/ha	jin/mu	kg/ha
1949	6250	46875	700	5250
1960	8773	65797	1282	9615
1982	10850	81375	1425	10688
Mean value for for China	2745	20588	177	1324

Notes: Mean values for the entire country were quoted from Jan 30th issue of “Economic References” in 1984.

Biomass Structure of Phyllostachys heteroclada

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Abstract

The biomass structure of different stands of Phyllostachys heteroclada Oliv. was studied **by *the*** allometric method. 18,808 ***bamboo culms, 47 rhizome quadrats and 38 bamboo samples 1-6 years old with diameter classes (0.5 –*** 3.0) ***from 39 sample plots were examined. The biomass of*** culm, ***branches, leaves*** and ***rhizomes in relation to diameter breast height was worked out. The results obtained show that the total biomass increases with diameter classes. The total above ground biomass*** **decreases with the increasing age.**

Introduction

Phyllostachys heterooluda provides the well known weave-craft material "Long Shu tribute Mat" bamboo. In order to solve the problem of shortage of this bamboo material, the Bureau of Forest Service of Shucheng Country of Anhui Province began to introduce and plant "water bamboos" on large scale since 1964. Now it is grown extensively. Present yields are quite sufficient to meet the market demands. This paper summarises the result of preliminary research on biomass structure and the cultivation of *Phyllostachys heteroclada at* five regions of Shucheng and Shucheng forest nursery between 1983-84.

The Environment and the Characteristics ofthe Bamboo Community

Shucheng County is situated at longitude 116°15' to 117°15', north latitude 31°1' to 31 °34 '. It lies in the north-eastern part of Daibei mountain. The river Han bu goes across this county. The climate is warm and humid. Annual mean temperature is 12 .9°C, annual precipitation is 1,319 mm. Annual evaporation is 1,398 mm and annual relative humidity 82%, providing a favourable standing for cultivating the bamboos.

Bamboo grows well in sandy soils having loam and clay in smaller proportions. An analysis of bamboo soils in the province showed that it contained below 0.0034-0.0086% of nitrogen, 4.9-33.3 ppm of quick phosphurus, 14-43 ppm of quick potash and 0.28-0.46% of other organic matter.

The Shucheng County is in the subtropical zone, with deciduous broad-leaved forest. The soil conditions are poor. The vegetation is in degenerated succession and is replaced by Kilimes sp. ,Polygonum sp., *Erigerom sp.* etc. The following are the chief communities investigated: *1) Kilimes indica Polygonum hydropipe* community: Average height of *Kilimes indica is 40* cm. It will accompany Hepaticeae, Musci and Medicago etc. Bamboos can grow well. Average diameter at breast height 2.5-3.0 cm, 3,500 per mu for culm, culm production 6,000- 7,000 jin/mu. Stand form is uniform. The distribution by diameter classes is even. It is called a high production stand in the community of Phyllostachys *heteroclada* of plantation. 2) *Erigerom canadensis – Ducheknea indica* community: Average height of *Erigerom canczdensis* is 50 cm, the soil is not very fertile. Bamboo growth is not superior. Average diameter at breast height is 2.01-2.5 cm. 2,500-3,000 per mu for culms. The average yield is 4,000-5,000 jin/mu. 3) Robinia pseudoacacia — Rrubus parvifolius community: Average height of Robinia pseu- is 50-70 cm. The growth is inferior, diameter classes poor. Numbers per unit area are higher, culm production is high. (Xu Munong, 1983).

The Method

Based on the condition of bamboo growth the diameter at breast height, full height, clear height, clear nodes are measured. 47 rhizome quadrats were established in 39 sample plots involving a total of 18,808 culms of different ages 1-6 years. The diameter classes were established. The culm was cut and divided into ten equal units. They were weighed before chopping.

The number of branches was calculated. 50 leaves were removed from the four parts of the crown with reference to East, West, North and South. Leaf area and weight were determined for 3,240 leaves.

Based on 47 sample quadrats of rhizomes the underground biomass was determined. The rhizome weight, length and diameter of rhizome nodes, rootlet weight and stump root weight were determined by ages. The values per unit areas were calculated (Sun T&iron, 1975).

Taking 9,280 test samples in different height culm and different height and direction of crown, wet and dry weight of culm branch, leaves and rhizomes were determined. The determinate value of samples times the numbers per unit area will give the biomass values. Details are shown in Table 1. The relationship between vegetative organs (Y) and diameter breast height (X) is significant. (Satoo. T.. 1974).

The Analysis of the Result

The above ground biomass of Phyllostachys heteroclada and their distribution:

1) The weight distribution of different age stages, the bamboo weight distribution by the different ages is closely related to cutting intensity, reserved stand numbers and reserved stand ages.

Denominator is the relative value in Table 2. It expresses the ratio of the total above ground weight to culm weight, leaf weight and branch weight respectively. The ratio of culm weight to the total above ground weight is

Table 1. Regression equations of the weights (Y) and diameter breast heights (X) in *Phyllostachys* heterocloda.

Weight constitution (jin)	Type of regression equations	Parameter a	Parameter b	Correlation coefficient	Relative error (%)
Culm weight	$Y = aX^b$	0.3809	1.8948	0.9693	4.6
	$Y = b(X^2H)^b$	0.1556	0.7110	0.9774	3.4
Branch leaves weight	$Y = aX^b$	0.2692	0.8308	0.7943	6.4
	$Y = ae^{\frac{b}{X}}$	0.1954	0.4415	0.8153	6.2
The total above ground weight	$Y = aX^b$	0.6439	1.5373	0.9057	6.5
	$Y = a(X^2H)^b$	0.3008	0.5908	0.8995	4.0
Rhizome weight	$Y = aX^b$	0.3404	1.1899	0.9732	9.66
	$Y = a(X^2H)^b$	0.3372	0.4179	0.9709	9.91
Rootlet weight	$Y = aX^b$	0.3087	1.2892	0.7983	10.12
	$Y = a(X^2H)^b$	0.2031	0.4851	0.7223	10.35
The total weight of the plant	$Y = aX^b$	0.7683	1.4117	0.9011	6.02
	$Y = a(X^2H)^b$	0.7820	1.3257	0.8753	7.01

Note: 1 jin = 1/2 kg (Chinese measure of weight).
1 mu = 666.7 M^2

Table 2. The weights of the different age stands and their constitution ratios.

Age (Yr)	Average diameter breast height (cm)	Number W/mu)	The weight constitution of stand (jin/mu)				
			Culm weight	Branch weight	Leaf weight	The total above ground weight	Percentage (%)
1	2.06	933	1397.6 72.6	288.0 15.0	239.1 12.4	1924.7	31.7
2	2.08	639	974.9 76.9	132.1 10.4	161.3 12.7	1268.3	22.0
3	1.88	628	736.2 73.1	136.4 13.5	134.1 13.4	1006.7	17.5
4.	1.69	611	629.0 71.4	133.3 15.1	119.1 13.5	881.4	15.3
5	1.71	163	426.7 79.4	45.1 8.4	65.4 12.2	537.2	4.2
6	2.28	235	171.6 71.7	35.3 14.8	32.3 13.5	239.2	9.3

effected by the reserved numbers, and the change is 70-80%. The ratio of age to the total above ground biomass is as follows: 1st year, 31%. 2nd year, 22%, 3rd year, 17.5%, 4-6 years or above 28.8% (about one-third of the total stand weight). It shows that quantity decreases with age. The cutting of the old bamboos should be increased. This way, the productivity of the bamboo stands can be increased.

2) The weight distribution of the different diameter classes: 18,808 bamboo culms were grouped by diameter classes. The average culm weight, branch weight, leaf weight and the total above ground weight of the different diameter classes per unit area are shown in Table 3.

Table 3. The weight structure of the different diameter class in Phyllstachys heteroclada.

Diameter class (cm)	Number (N/mu)	The average weight of single bamboo (iin)			Total above ground weight (jin/mu)	The proportion of the different diameter classes (%)
		Culm weight	Branch-leaf weight	Total		
0.5	36	0.10	0.24	0.34	12.24	0.2
1.0	451	0.38	0.30	0.63	306.68	5.3
1.5	1003	0.82	0.38	1.20	1203.60	20.9
2.0	935	1.41	0.47	1.88	1757.80	30.5
2.5	547	2.16	0.59	2.75	1504.25	26.1
3.0	190	3.05	0.73	3.78	718.20	12.5
3‘5	45	4.08	0.92	5.00	225.00	3.9
4.0	6	5.27	1.14	6 .41	38.46	0.7
Totaf	3213				5766.23	100.0

As indicated in Table 3, average production per mu is 5,768 jin. The distribution of weights by diameter classes are as follows: 16% for 1.5 cm diameter classes, 30.5% for 2 cm, 26.1% for 2.5 cm, 16.0% for 3 cm respectively. It should be noted that ratio of small diameter classes is higher. The structure of such stands is not desirable.

The site factor is used to recognise the well developed and the less developed stands, as shown in Table 4.

As. indicated in Table 4, the weight of culm and leaves affect the diameter breast height in the same factor. Culm weight increases with the bamboo stand numbers. When the density of the stand is high, the diameter breast height decreases. The larger diameter and higher weight of culms are present in 2,500 culms/mu of well developed stand. As for the less developed stand. the larger diameter class is 3,500 culms/mu.

The under ground biomass distribution: The under ground portion of water bamboo consists of three parts,stump root, rhizome and rootlet. The function of each part in the production of bamboo stand is different. Based on 47 rhizome quadrats for rhizomes of different ages (l-6 years) the density stand and the weight of rhizome vary. The rhizome ages and the ratios of young and old rhizomes to the total rhizome weights are shown in Table 5.

Table 4. The bamboo biomass of the different stands.

Stand type	Stand density (N/mu)	Average diameter breast height (cm)	Culm weight (jin/mu)	Leaf weight (jin/mu)	Branch weight (jin/mu)
Well developed stand	2000	2.46	4223.3	740.2	241.0
	2500	2.65	7166.0	754.5	760.3
	3000	2.02	4999.2	858.8	619.6
	3500	1.93	5556.6	404.5	767.3
Less well developed stand	2500	1.58	2389.9	472.5	379.1
	3000	1.59	2709.9	593.3	753.7
	3500	1.35	2337.1	511.4	572.4
	4000	1.32	2541.4	387.3	1186.0

Table 5. The biomass production of the rhizomes of varying ages.

Total rhizome weight (jin/mu)	The biomass constitution of the rhizomes of different ages (%)			Culm weight fjin/mu)	Culm-rhizome ratio
	The young rhizome (1-2 yrs)	The vigorous rhizome (3-4 yrs)	The old rhizome (5 yrs and above)		
8000	6.3	43.7	50.0	1319.7	1:6.1
5893	24.4	53.4	22.0	2541.4	1:2.3
3973	20.8	63.0	15.4	5556.6	1:0.7
2573	8.4	68.3	23.3	6515.6	1:0.4
4160	25.6	42.3	32.1	7166.0	1:0.6

The weight of rhizomes of different ages are shown in Table 5. Culm weight increases up to an extent and then along with rhizome weight, decreases with increase in ratio of the old rhizome. When rhizome weights are 2,000-4,000 jin/mu, 5060% are vigorous rhizomes and 15-30% old rhizomes. Culm production can yield 5,000-7,000 jin/mu.

The capacity structure of rhizome and the distribution of culm production: The rhizome capacity is expressed by thousand counts based on rhizome volume in the sample plot. The underground biomass is analysed in terms of rhizome, rootlet and bamboo stumps. The values are correlated with culm production. The numbers of underground stump roots influence the development of bamboo and the increment of culm production .

As shown in Table 6, when the rhizome capacity makes 20-25%, rhizome weighs 30.7%) stump root weighs 20% and the culm production is 5,000-7,000 jin/mu. If rhizome capacity is below 20%) rhizome weighs 37.3% and the culm production is only 2337.1 jin/mu.

The relationship between the biomass of the above ground and underground of Phyllostachys heteroclada stand: Ail parts function and effect the values of both above ground and the underground parts. The residual quantity of stump root and the old rhizome in water bamboo stand in long He Kou vary very much, Hard soil prohibits the growth of the rhizome, effecting the culm production, as shown in Table 7.

Table 6. The capacity structures of rhizomes and culm yields.

Rhizome capacity (%)	The biomass constitution of underground parts (%)			The total weight of underground parts (jin/mu)	Culm production (jin/mu)
	Rhizome	Rootlet	Bamboo stump		
15	37.5	39.7	22.8	7786.6	2337.1
20	30.7	48.9	20.4	8613.3	5513.0
25	50.0	29.6	20.4	12053.3	6335.6
30	44.8	24.4	30.8	9280.0	7211.0
35	41.0	48.2	10.8	9680.3	5446.6

Table 7. Correlations of the biomasses of above ground and underground parts in *Phyllostachys heteroclada.*

Average diameter at breast height (cm)	Culm production (jin/mu)	Ratio of single rhizome weight to single culm weight	Ratio of the total above ground weight to the total under ground weight
2.02	4999.2	0.84	1.1
2.46	4223.3	0.89	1.4
2.04	6053.3	1.08	1.5
1.98	5556.6	0.72	1.4
1.98	3677.4	1.87	2.1
1.32	2541.4	2.30	2.5
1.81	3286.7	1.60	3.4
1.51	2709.9	3.20	4.7

In a given site the total above ground and underground biomass seemed to have fixed ratios. When the ratio of the total weights are 1.0-1.5 and culm production is 4,000-6,000 jin/mu it signifies high production. When the ratio of the total above ground weight is 2.5-4.7, culm production is 2,000-3,000 jin/mu. The old rhizome is very vigorous and the capacity of rhizomes is above 30%.

The relationship *between the leaf area index and diameter at* breast height *and the biomass:* The biomass increase is related to the leaf area. The suitable leaf area promotes full utilization of solar energy.

According to the curve correlation of the leaf area, the stand density and diameter at breast height have been worked out according to the following regression equation:

$$S = 48.5288\, N^{-0.5719}\, D^{1.2025}$$

Plural correlation coefficient r = 0.8711, partial correlation coefficient of N and S, $r_{01.2} = 0.4455$, partial coefficient of S and D, $r_{02.1} = 0.8362$, reliability at the 95% level, precision 94.1% .

To derive the curve equation, the leaf area of individual culm of the different diameter classes and the different densities are used, as shown in Table 8. As seen in the equation, leaf area increases with the increase of diameter. When the stand densities increase to a given range, bamboo crown changes very little, the quantity of leaves decreases, the leaf area correspondingly decreases too. According to the data and the different growth conditions, the correlation curve equation of leaf area index (LAI), diameter breast height (D) and stand density (N) can be worked out.

$$LAI = 0.0113\, D^{1.1314}\, N^{0.6620}$$

Plural correlation coefficient of LAI and N, $r_{01.2} = 0.8071$, partial correlation coefficient of LAI and D, r = 0.7925, partial correlation coefficient of LAI and N, $r_{02.1} = 0.6276$, reliability at the 96% level, precision 77.4%.

The above formulae may be transformed to the following form:

$$N = 873.0113\, D^{1.7091}\, LAI^{1.5106}$$

According to the equations, we can prepare the table per unit area of the different leaf area index and diameter height of water bamboos. Discussion of the optimal leaf area index of *Phyllostachys heteroclada* stand: Leaf area index indicates the capability of making use of the solar energy within the bamboo community. The leaf area index increases with increasing stand density in the bamboo forest at the same site. The stand density increases to an optimum level owing to decrease of above ground and underground nutritional space and the efficiency of the solar energy utilization. Although the leaf area index of individual bamboo is high, the culm no longer increases as shown in Table 10.

Table 8. The leaf areas of the different diameter classes and the stand densities in *Phyllostachys heteroclada*

Stand density (N/mu)	Diameter classes (cm)				
	1.2	1.6	2.0	2.4	2.8
2000	0.7408	1.0469	1.3692	1.7048	2.0520
2500	0.6733	0.9515	1.2444	1.5495	1.8650
3000	0.6204	0.8768	1.1466	1.4277	1.7185
3500	0.5775	0.8162	1.0674	1.3291	1.5996
4000	0.5419	0.7659	1.0016	1.2472	1.5012
4500	0.4858	0.6866	0.9459	1.1181	1.3458
5000	0.4632	0.6547	0.8561	1.0660	1.2831

Table 9. The number of the different diameter classes and leaf area index in *Phyllostachys heterocloda*

Average diameter breast. height (cm)	Leaf area index				
	3	4	5	6	7
1.2	3361	5190	7270	9576	12087
1.4	2582	3988	5587	7358	9287
1.6	2055	3174	4446	5856	7392
1.8	1681	2595	3636	4789	6044
2.0	1404	2168	3037	3999	5048
2.2	1193	1842	2580	3398	4289
2.4	1028	1587	2224	2929	3697
2.6	8 %	1384	1939	2554	3224

Table 10. The culm productions of the different leaf area indices of *Phyllostachys heteroclada* stands in Long He Kou.

No.	Leaf area index	Average diameter breast height (cm)	Culm production (jin/mu)	No.	Leaf area index	Average diameter breast height (cm)	Cutm production (jin/mu)
1	2.59	1.11	1319.7	7	5.45	2.65	7166.0
2	3.01	1.58	2389.9	8	5.70	2.04	6515.6
3	3.61	1.51	2709.9	9	6.52	1.74	4229.6
4	3.88	1.66	3334.9	10	6.57	2.21	3669.6
5	3.65	2.26	4552.9	11	7.10	2.22	4890.0
6	4.03	1.70	5030.4	12	7.39	1.60	3767.2

Conclusion

1. The D.B.H. (X) of water bamboo is closely related to the weight of several organs (Y). The formulae so far obtained are: culm weight: $Y = a(X^2 H)^b$, branch and leaf weight $Y = ae^{bx}$, the total above ground weight: $Y = a(XH)^b$, the error is below 6%.
2. The ratios of culm weight of water bamboo stand to the total above ground weight are 70-80%. The weight distribution in terms is as follows: 31.7% for 1st year bamboo, 22% for 2nd year bamboo, 17.5% for 3rd year bamboo, 28.8% for 4th year or above. Bamboos of 4 years should be cut down in order to adjust the stand age and the structure and rational number of bamboos that we should keep. The weight distribution by diameter classes is as follows: 30.5% for the weight of two diameter classes to the total stand weight, 26.1% for 2.5 classes, 15% for 3 classes, 26% for 1.5 classes. In order to maintain continued production good management is necessary.
3. A bambod stand is defined as a high production stand, in which the categories are: vigorous rhizome 50-60%, rhizome capacity 20-25%) the ratio of the total

above ground weight to the total under ground weight 1.0-1.5, the stand yield production about 4,000-7,000 jin/mu.

4. If leaf area index is around four to six, the stand is highly productive, and if the index is above seven, the stand yield production decreases.

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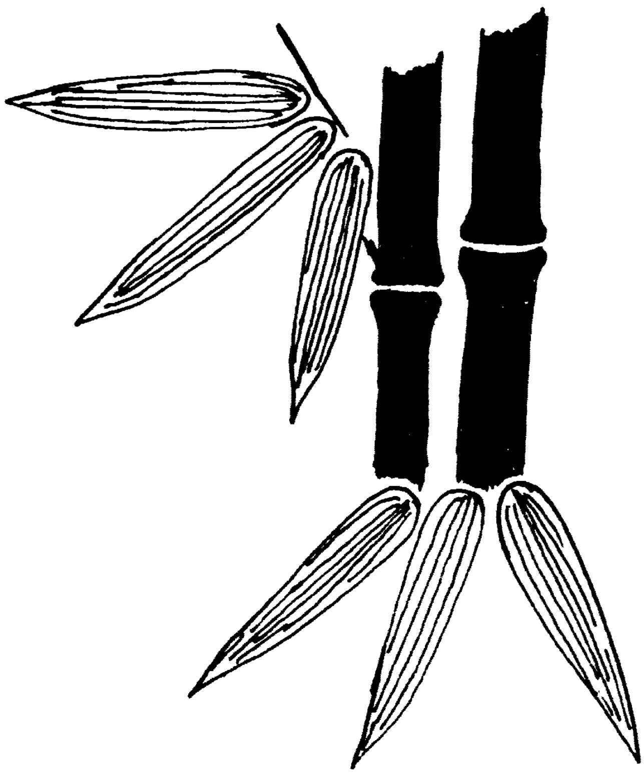

Study on the Application of Chemical Fertilizer to the Timber and Paper-pulp Stands of Phyllostachys pubescens

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Abstract

Fertilizer application in quantity and quality is very important to improve the growth and yield of Phyliostachys bamboos growing in Anji county, China. Absorption rate of NPK is correlated with the amount of dry matter produced.

Introduction

Phyllostachys pubescens is the main bamboo species for timber and paper-making in China. An intensively managed bamboo stand, with loosening of soil and application of organic fertilizer can produce 20-30 tons of wood per year per ha., but the application of organic fertilizer is expensive and laborious. The area of such bamboo stands is only 1% of total area of Ph. pubescens stands in China. Two thirds of bamboo stands are of lower yielding and produce wood about 7 tons per year per ha.

Since 1960, a series of experiments in applying ammonium sulfate, urea and compound fertilizer N,P,K were carried out and with the support from IDRC, experiments with chemical fertilizer have been continuing since 1982. The results show that with 150 kg/ha urea can increase yield of bamboo wood by 9% and 17% in Yuhang and Anji Couunties respectively. The net increase in inecome in the two sites is about 9%. In Fuyang County, the paper-pulp stands applied with urea 225 kg/ha increased production by 72% and the income by 70%. In all experiments N or N + P or N + P + K were applied. Among them, a plot applied N 225 kg + P 230 kg + K 64 kg (N:P:K = 3: 1: 1) per ha. could increase yield by 74 %.

Experimental Design and Site

The Experiments were carried out on two sites separately. One was in Anji County (30°39'N, 119°41'E) in 1982-1983, other was in Yuhang County in 1983-1984.

Experimental design: A split-plot design was used, and the plots were divided according to the density of grown plants (dense stand with 4500 per ha., mid-dense stand with 3750 per ha., sparse stand with 3000 per ha.). There were three sub-plots in each plot. They were treated by fertilizing N (urea 150 kg/ha), N + P (urea 150 kg/ha + $Ca_3(PO_4)_2$ CaO.MgO. SiO_2 150 kg/ha) and one with nothing served as control. All plots and sub-plots were arranged at random, with 6 replications. The ditches of 0.5 m wide and 0.4 m deep were laid between every two sub-plots to cut off rhizotaxis. In Anji experiment site a protection band of 5 m wide around each sub-plot was made. The area of each sub-plot was 667 m^2. The treatment of replication site is shown in Figure 1.

We enumerated the numbers and culm circumference at eye level at about 1.6 m above ground of bamboo plants from Oct. to Nov. of the year before applying fertilizers, identifying the number of plants following the design and determined the nutrients present in soil. Micro-meteorological observatory stations were separately built inside and outside the stand to record air and soil temperature, humdity and rainfall. Before and after treatment, we monitored the growth condition of the rhizomes, and determined the chlorophyll content of bamboo leaves. The fertilizer was applied from 25-30 August. The Winter and spring shoots were tended by full-time workers. The beginning of experiment was on 25 March. Every shoot produced was

Table 1. The climate of experimental sites

Sites	Average air temperature Year (°C)	July (°C)	Jan (°C)	High temperature (°C)	low temperature (°C)	Annual rainfall (mm)
Anji	14.5	31.5	8.2	39.2	-8.8	1875.7
Yuhang	15.7	27.0	8.2	39.1	- 7.9	1805.1

Table 2. The soil conditions of experimental sites

Sites	Soil type	PH	Organic matter %	Total N%	P_2O_5%	Quick-acting P (ppm)	K (ppm)
Anji	red loam	5.58	4.64	0.228	0.056	2.8	123.2
Yu hang	red loam	5.54	0.159	0.046	1.39	8.87	

Table 3. The climate of experimental sites

Site	Average air temperature year (°C)	July (°C)	Jan (°C)	Extreme high temperature (°C)	Extreme low temperature (°C)	Annual rainfall (mm)
Fuyang	16.1	20.7	11.5	37.8	-8.4	1700

removed and weighed once in five days. In June, the circumference at eye level of newly-grown plants, was measured and the data was tested by the 'q' test and variance analysis.

a. **Experiment in paper-pulp bamboo stand&** Experimental site was in Fuyang County (30°03'N, 119°57'E) and the work before fertilizing was completed in 1982. 60% of the above-mentioned fertilizer was applied on 25-30 August, 1983 and the remainder in February 1984. The yield of newly-grown bamboo plants was recorded in 1984.

The main objective was to supply tender bamboo plants as raw material for paper-pulp. The tender plants were cut down in June and lodging was common. So the application of a large quantity of fertilizer was needed. The yield of such bamboo stands was much lower; they only produced about 7-10 tons fresh bamboo wood per year/per ha.

b. **Fertilizers:** The types of fertilizer: Urea, Ca3 $(P04)_2.CaO.MgO.SiO_2$ and K-fertilizer.

The rate of compound fertilizer: 1. N; 2. $N:P_2O_5$ = 3:1:3. N:P:K = 3:1:1.

Urea was applied according to five dose grades: 225 kg/ha., 375 kg/ha., 675 kg/ha. and 825 kg/ha. Other fertilizers were also calculated and applied on the above-mentioned composition rate of fertilizer. The controls were not applied with any fertilizer. The fertilizer was applied into ditches which were digged at interval of 1.5 m.

Randomized block design: with 4 replications, plot area was 500 m^2. A protective ditch of 40 cm deep and 50 cm wide was dug around each plot. The density of bamboo plants in experimental area was 1800-2200 per ha., averaged 120-150 per plot.

Results

1. The details of climate and the soil conditions of experimental sites are given (Tables 1,2).

A. The experimental data tested by q value show that there was very significant difference in the yield of newly-grown plants between the treated and the control stands. The treated plots produced 4155 kg bamboo wood per ha. (i.e. increased 17%); Income from shoots also increased to 333 Yuan/ha. This was a net gain of 166 Yuan beside the cost of fertilizer and the wage of workers (See Table 5). (The net-income is 300 Yuan according to the price of 1985).

B. The stands applied N +P were compared with control, and there was no significant difference in income between both, and there was no difference in interaction between bamboo density and the type of fertilizer. (See table 6, 7, 8).

C. Chlorophyll content of bamboo leaves with N application (4.8598-5.1623%) was higher than that of the control (3.9631-4.7399%) and chlorophyll content of bamboo leaves applied N +P (4.569-5.002%) was still higher. In fertilized stands the leaves grow well and were dark green. The difference in leaf area index was not significant. But the number of newly-grown rhizomes increased obviously after fertilizing (See Table 9).

This experiment was repeated in Yuhang County in 1984. The results are as follows.

(1) The yield of newly-grown bamboo plants of the stand applied with urea was 150 kg/ha and yield 16925 kg per ha. Increase in bamboo wood was 1483 kg per ha. when compared with the control (15442 kg per ha) an increase of 9%. Dead shoots and newly-grown plants increased by 8%.

Table 4. The soil condition of experimental sites

Sitss	Soil type	P H	Organic matter %	Total N%	Total P_2O_5%	Quick-acting P (ppm)	Quick-acting K (ppm)
I	Red loam	5.73	2.76	0.1491	0.095	0.4	6.49
II	Red loam	5.49	3.70	0.1744	0.067	0.62	7.31
III	Red loam	5.66	4.47	0.2214	0.091	1.53	6.97
IV	Red loam	5.61	3.36	0.1653	0.091	0.95	7.01

Table 9. Results of newly-grown rhizomes before and after fertilizing.

Time of investigation infant rhizome (%)			Increased rate (%)
number of rhizomes	before	6.9	13.8
	after	20.7	
fresh weight	before	5.4	15.2
	after	20.6	
dry weight	before	3.7	10.5
	after	14.2	

(2) In the stands applied with N 150 kg/ha + P 150 kg/ha, bamboo wood increased to 1663 kg per ha. The income by plants increased by 11% , but a net-income, besides the cost of fertilizer and the wages of workers, had not obviously increased. Therefore the effect of applying N +P varied with the difference of soil condition. An optimum fertilizer depends on the optimum rate of compound fertilizer applied (N:P:K).

2. The results of application of fertilizer to paper-pulp bamboo stands.

(1) The stand applied with urea 225 kg per ha. with 4 replications gave an average yield of 18221 kg per ha., increased 73% compared with the control (10556 kg per ha.}, with increase in bamboo wood by 17-128% compared with the average yield of all contracts (8056- 15532- 12356- 10890- 14400 kg). The income rose 9-1 10%. An average income per ha. was 538 Yuan and after deducting the fertilizer and wage of workers (177 Yuan) from it there was a net-income of 361 Yuan. (See Table 11, 12, 13).

(2) The stand applied with N 225 kg + P 230 kg + K 64 kg per ha., an average yield was 18214 kg per ha., increased 73% compared with the control (10556 kg per ha.). The income increased 325 Yuan.

(3) The stand applied with N 675 kg + P 690 kg per ha. an average yield of 4 replication was 27744 kg (31215-25794-31365-22605 kg) per ha., increased by 16854 kg per ha. compared with that (10890 kg) of control: (10965-8955- 12426- 11220 kg), i.e. increase of 155%. A net-income increased 671 Yuan per ha.

Other stands applied with N 825 kg or N 825 + P 844 kg per ha. could also increase yield. but could not get any economic efficiency because of the high cost of chemical fertilizer.

Discussion and Suggestions

1. According to the present study for each 1000 kg of vegetable matter (including the roots. branches, leaves and culms), it needs to expend nutrition by as much as N 2.7 kg, K 3.6 kg, P 0.36 kg in soil. In Anji County, soil does not lack P. Although plenty of K is expended, which can be supplied from decomposed leaves, Ph. pubescens stand changes its leaves once every two years. But the effects of applying N or N + P was not suitable in some stands where the site condition was different. In Fuyang County, the stands applied with N 225 kg + P 230 kg + K 64 kg per ha. could increase the yield by 74%. So it is a better utilisation of compound fertilizer (i.e. N:P:K: = 3:1:1) for such paper-pulp bamboo stand and can be used widely. We suggest that applying N.P.K. to bamboo stands should depend on the soil nutrition condition in different areas.

2. Applying urea 150-225 kg per ha. to timber stands and low yield paper-pulp stands of Ph. *pubescens* in Anji, Yuhang and Fuyang counties increased the yield and income. (For example by investing 177 Yuan from the net income of more than 600 Yuan according to the 1985 prices). These measures can be widely popularised in bamboo production regions similar to Anji and Fuyang. With an increase of 10%, the yield of bamboo can be improved to 800-1500 thousand tons per year/per hectare. About 2.4 million ha. are properly fertilised.

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Mensurational Attributes of Five Philippine Erect Bamboos

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Abstract

Some mensurational *attributes, uiz. average* internode *length, cuim-wail thickness,* culm size, pole *length,* number of internodes per *pole* and taper of five *erect* bamboo species *from different localities in the Philippines* were determined. Data were gathered *on* 494 mature *cutms harvested from four* provinces in *Luzon and the Visayas.*

Significant linear relationship between *green weight and solid volume of the bamboo poles were observed for all the species studied. Their corresponding regression* equations *were* also determined.

Introduction

Bamboos are perennial true grasses which are widely distributed not only in the Philip. pines but also in many parts of the tropical. sub-tropical and mild temperate regions of the world. They are represented by 47 genera and 1250 known species, most of which are relatively unimportant from the commercial point of view.

Of the commercially utilized ones, those that are erect are more beneficial. In tropical countries, most erect bamboos are characteristically clump-forming. About 36 species of these erect clump-forming bamboos have been recorded in the Philippines. Only 8, however, are extensively studied and commercially utilized for construction and industrial purposes.

Regarded as a poor man's lumber, barnboos in the Philippines are important construction material especially in the rural areas. Low cost houses made of bamboos account for 25.89 percent of housing units in the country (Philippines Yearbook, 1975). However, bamboos have other uses, such as in the manufacture of handicrafts, furniture and for food. As an industrial material, they are used as a source of raw materials for pulp and paper making. Their fibers, being considerably long, add strength to any paper product.

Researches conducted on bamboos dealt mainly with their properties and characteristics, propagation and utilization, management and plantation establishment. However, no specific study has been done so far on their mensurational attributes based on actual samples gathered.

The study is the first local attempt to give comprehensive information on the different mensurational attributes of 5 commercially important erect bamboos in the Philippines namely: Bombusa blumeana Schultes f. (Kauayantinik) , *Bambusa vulgaris* Schrad. ex Wendl. (Kauayan-kiling) , *Dendrocalamus merrilliunus (Elm) Elm (Bayog), Gigantochloa* levis (Blanco) Merr. (Bolo) and *Schizostachyum lumampao* (Blanco) Merr. (Buho). In addition, the weight-volume relationship and regression equations for the different species were determined.

Knowledge of these information is important in the .yield determination and utilization of the five erect bamboos.

Methods

The study was conducted on different localities (Fig. 1) where there were sufficient stands of the 5 selected erect bamboo species (Table 1).

Data were gathered on freshly harvested* mature culms as follows:

1. For each whole culm, the circumferences of the node and the internode were measured from the base upward at an jnterval

of 5 internodes. The corresponding diameters of the node and internode were then calculated.

2. The length of each internode was also measured from the base upward.

3. The culm-wall thicknesses of the base and that of the apex were measured with vernier caliper to the nearest tenth of a centimeter.

4. Five to **15** samples per species were cut into four equal parts, i.e. 0-25%, 25-50%, 50-75%) and 75-100% of the whole culm. From each section, the culm-wall thickness, fresh weight and solid volume were determined.

The solid volume of each section was computed using the following formula:

. **This means that the top-most part of a culm which is too slender for use, about 2 meters was cut-off leaving only the merchantable pole.**

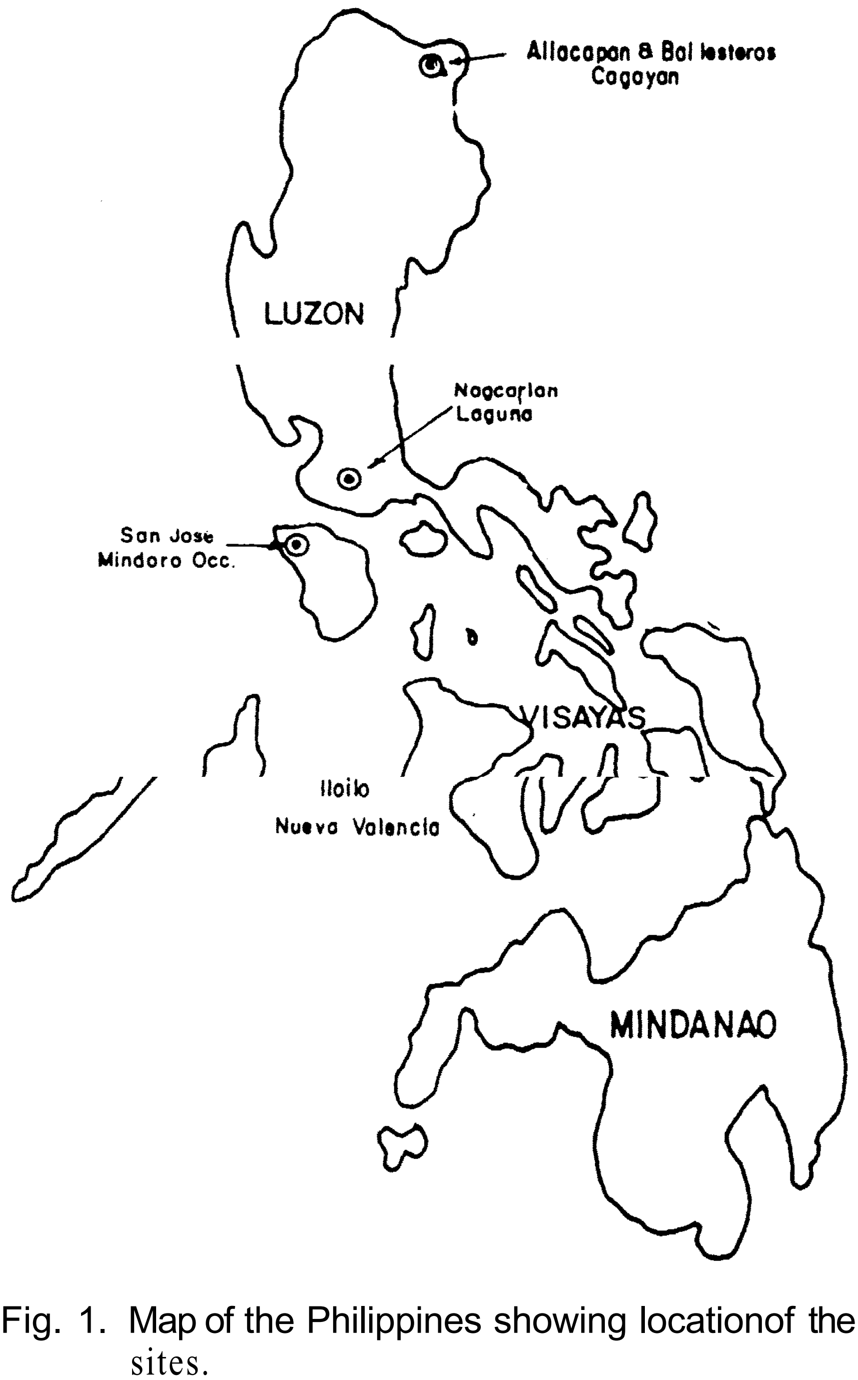


Fig. 1. Map of the Philippines showing locationof the study sites.

Table 1. Number of samples taken for each bamboo species and places of collection.

Species	Place	Number of Samples
Bambusa blumeana (Kauayan-tinik)	San Jose, Mindoro Oct. Nueva Valencia, Iloilo	113
Bambusa *vulgaris* (Kauayan-kiling)	Ballesteros, Cagayan	100
Dendrocalamus merrillianus (Bayog)	Nueva Valencia, Iloilo	54
Gigantochloa levis (Bolo)	Nagcarlan, Laguna	106
Schizostachyum lumampao (Buho)	Allacapan, Cagayan	121

$$V = \frac{(B_a - B_h) + (b_s - b_h)}{2} L$$

where:

V = solid volume in cubic centimeter of the section

B_a = area in square centimeter at the large end of the section

B_h = area in square centimeter at the large end of the hollow portion

b_s = area in square centimeter at the small end of the section

b_h = area in square centimeter at the small end of the hollow portion

L = length in centimeter of the section

Total green weights in kilograms were derived by summing up the values obtained for each section.

5. The culms of all the bamboos studied slightly tapered from the base to the top. This taper was calculated as the ratio of the solid volume (including the hollow portion, in this case) to the volume of a cylinder, with diameter equal to diameter at the base and length equal to total height.

Analysis of the data was facilitated by the IBM 370 computer system. The mensurationai attributes determined in the study are summarized in Table 2. Comparative sizes of the 5 species are shown in Figures 2 and 3.

Results and Discussion

Mensurational Attributes

(1) *Bambusa* blumeana Schultes f.

The 113 sample cuims of B. blumeana gathered for the study ranged from 6.7 to 15.6 m in merchantable length and from 6.6 to 12.3 cm in diameter at the base. Of the 5 species, this bamboo was observed to have the biggest diameter and the longest culms. The average internode length was 34.34 cm, shortest at both ends (apex and base) and longest about the middle. A typicalculm of B. blumeana has relatively thick wails ail throughout becoming gradually thinner towards the top. The thickest portion was found at the base ranging from 0.78 to 3.85 cm while the top had a thickness averaging 0.58 cm. It is large at the base and gradually tapers towards the top.

B. blumeana can be easily distinguished from other Philippine erect bamboo species by its large clumps of up to 10 or 40 culms per clump with densely interlaced thickets of very spiny branches at the base, 2 to 3 m high. This thicket actually protects the delicate young shoots from being eaten by herbivores, helps keep the tall culms erect and makes access to the culms exceedingly difficult.

B. blumeana is the most commercially known species in the Philippines being utilized for various purposes such as house construction, furniture, handicrafts, food, pulp and paper. At present, the cost per culm ranges from 20-50 depending upon the proximity of the stand to the road system and location.

(2) Bambusa *vulgaris* Schrad. ex. Wendl.

The 100 culms for the study ranged from 5.8 to 13.7 m in length and from 4.3 to 10.2 cm in diameter at the base. The internodes of each culm had an average length of 29.02 cm. At the base of the culm the wall thickness ranged from 1.08 to 2.58 cm while at the top, 0.34 to 0.82 cm.

Its culm also grows in clumps which are more or less open or loose. A typical culm of

-Table 2. Mensurational attributes of the five erect bamboo species.

Attributes	*Bambusa blumeana* Mean'	SD*	*Bambusa vulgaris* Mean	SD	*Dendrocalamus* merrillianus Mean	SD	*Gigantochloa* levis Mean	SD	*Schizostachyum lumampao* Mean	SD
Number of internodes	30.5	5.3	26.3	6.5	20.7	3.8	24.2	5.9	12.4	2.5
Merchantable length of the culm (cm)	1047.4	150.8	763.2	187.9	555.2	112.9	957.3	246.4	561.1	115.9
Diameter of the internode at the base (cm)	9.18	1.37	6.73	1.06	5.99	1.05	8.61	1.72	4.96	1.04
Node size (diameter) at base (cm)	10.0	1.3	7.2	1.2	7.1	1.3	9.0	1.7	5.1	1.0
Culm-wall thickness at base (cm)	1.42	0.39	1.69	0.36	2.54	0.40	1.78	0.51	0.63	0.18
Culm-wall thickness at apex (cm)	0.58	0.11	0.59	0.10	1.08	0.16	0.50	0.12	0.29	0.08
Average internode length (cm)	34.34	29.02	29.02		26.82		39.56		45.25	
Taper	0.76		0.84		0.69		0.69		0.72	

. average of sample culms per species
. standard deviation

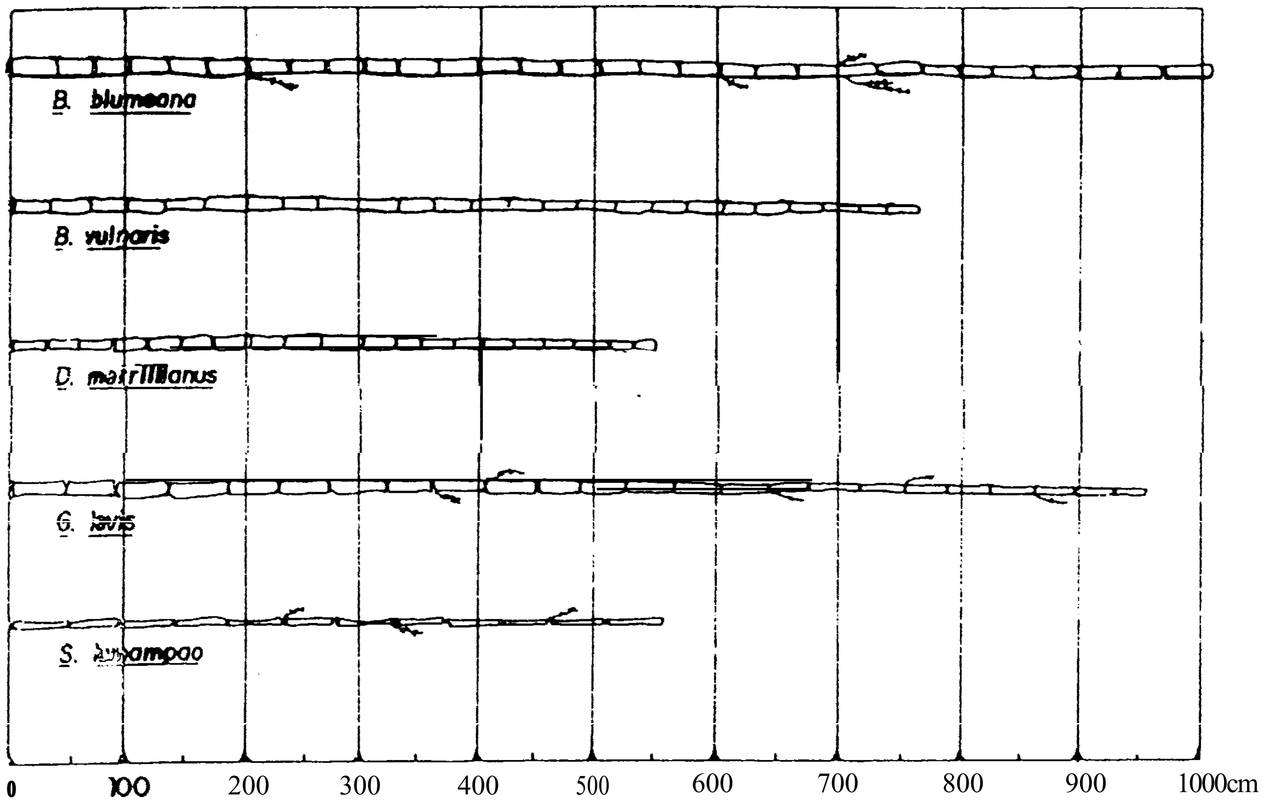


Fig. 2. Camparative length ad number of internodes per culm of the five bamboo species.

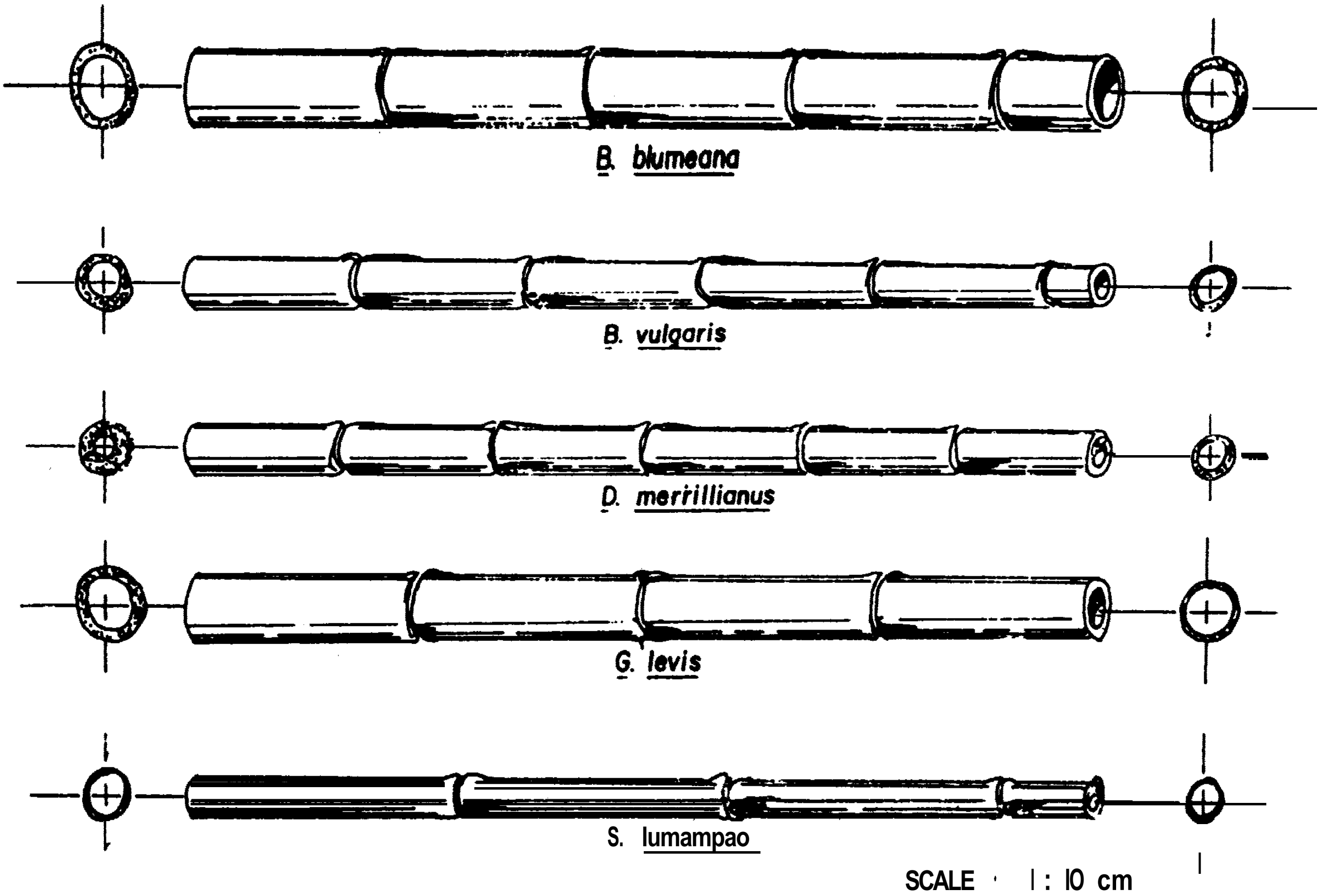


Fig. 3. Comparative culm-wall thickness, diameter and internode length of the five bamboo species.

B. vulgaris is smooth, spineless, usually yellowish or yellowish green. Though as versatile as B. blumeana, it is not as commonly used because of its susceptibility to insect attack.

(3) Dendrocalamus merdlianus (Elm.) Elm.

The 54 sample culms ranged from 4.1 to 8.0 cm in diameter at the base and from 4.4 to 7.8 m in length. D. merrillianus had the smallest average internode compared with the other species studied, averaging 26.82 cm in length while its nodes were very prominent ranging from 4.7 to 10.3 cm. Each culm had very thick walls at the base, ranging from 1.74 to 3.6 cm which sometimes become almost solid. Owing to its thick walls, it is considered one of the strongest and certainly the toughest of the erect varieties. That is why this' bamboo is chiefly utilized for purposes requiring strength and durability such as posts, beams, rafters, bridges and vehicle shafts.

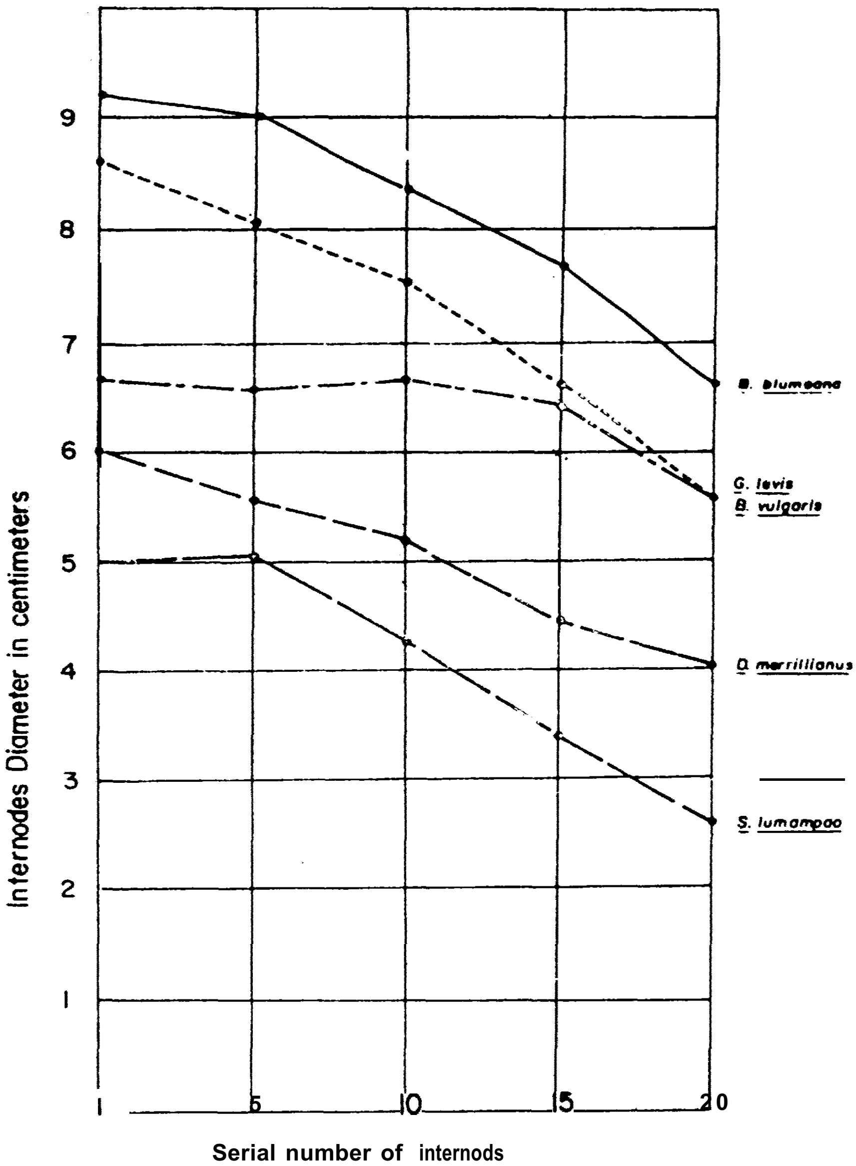
As in B. vulgaris, its culms also form into large clump that is open or loosely tufted. Sometimes, the culms can be seen bending over due to the weight of the upper portion which in this study was found to have an average wall thickness of 1.08 cm, the highest among the species.

(4) Gigantochloa levis (Blanco) Merr.

It is considered as one of the largest bamboos in the Philippines. In this study, the 106 sample culms ranged from 5.2 to 13.4 cm in diameter at the base and from 6.4 to 16.2 m in length. The average internode length was found to be 39.56 cm while the nodes were relatively inconspicuous. At the base of the culm, the wall had an average thickness of 1.78 cm and at the top, 0.50 cm.

Its culm is smooth, dull green and has a siliceous and pubescent outer surface. Its clump is relatively clean with culms numbering from 20 to 40.

G. levis is usually utilized for furniture and



Fig, 4. Diameters of the internodes at different portions in the culms of the five bamboos.

handicrafts but are rarely used for house construction because it is not especially durable. Its stems are long and straight. Hence, they are sometimes used as pipes for temporary water supplies.

(5) Schizostachyum lumampao (Blanco) Merr.

The 121 culms ranged from 3.5 to 10.3 m in merchantable length and-from 3.4 to 8.2 cm in diameter at the base. Of the 5 species studied, S. *lumampao* had the longest internode averaging 45.25 cm. The nodes were inconspicuous and ranged from 3.3 to 8.3 cm in diameter at the base. Owing to the non-prominence of the nodes, the culm appears straight or nearly so. It has thin walls having an average of only 0.63 cm at the base and 0.29 cm at the top. Being thin-walled, it is usually split and woven into a coarse matting (sawali) useful for houses in the rural areas as floors and walls.

S. lumampao is endemic in the Philippines. It grows in much denser clumps, sometimes with 100 or more culms in each clump.

It has no spiny growth at the bottom of the clump as those in B. blumeana.

In general, the culms of erect bamboos taper from the base to the top. However, of the 5 species studied, it was found that S. *lumampao* and B. *vulgaris* had culms that increased in diameter from the base up to a certain point then decreased gradually up to the top (Fig. 4). In the case of B. *vulgaris,* the largest diameter was almost at the middle of the culm about 3 meters from the base while in S. lumampao, the largest was near the fifth internode, about 2.5 m above the ground. According to the findings of Uchimura (1977), maximum diameters of some erect bamboos he studied, including these two species, B. *vulgar-is* and S. lumampao, were not at ground level but along the length of the culms. The same observation holds true for the internodes, i.e. they were found increasing in length from the base up to a certain point along the culm and then gradually decrease until the top.

Table 3. Average green weight and solid volume of the different species per merchantable pole based on the sample culms.

Species	Weight (kg)	Volume (cu cm)
B. blumeana	26.46	25718.34
B. vulgaris	22.83	17887.17
D. merrillianus	9.54	7589.71
G. levis	22.38	23250.73
S. lumampao	4.91	4344.80

Weight-volume Equations

The relationship between green weight and solid volume of the different species (Table 3) was also determined in this study. It was found that the average number of bamboos per 1,000 kg (1 ton) in fresh weight and the equivalent solid volume of the 5 species varied. Based on the regression equations (Table 4) generated from sample culm data, it was noted that the highest total solid volume (Table 5) was given by B. blumeana followed by D. mertillianus, S. lumampao, B. vulgaris and.G. levis, in that order, when culms of equal weight are considered.

The importance of this information lies more in determining the pulp yield of bamboos for paper manufacture. Bamboo has already gained acceptance as a source of raw materials for pulp and paper manufacture not only in the Philippines but also in other countries. According to Chandra (1975), most of the paper mills in Central India are now using 100% bamboos as raw material for pulp and paper manufacture. About 400,000 tons of their bamboos are being utilized for this industry. Bangladesh, Thailand, Japan, Taiwan and Burma are also using bamboos for the same purpose.

Likewise in the Philippines, it is now being considered as an alternate source of softwoods and hardwoods as principal raw material for paper making, Some sparse data is reported by Chinte (1965). According to him. a ton of 3 to 4 year old bamboo (G. aspera Kurz. and B. vulgaris Schrad. var. *striata)* contain 86 to *190* green culms or 217 to 337 air-dry culms, respectively. Some 543

Table 5. Average number of bamboo poles and the equivalent solid volume per metric ton (fresh weight) of the five species.

Species	Number/ 100 kg Range	Mean	Equivalent Solid Volume (cu. m)
B. blumeana	30-62	38	1.4099
B. vulgaris	**37-69**	**44**	**0.6721**
D. merrillianus	74-160	105	0.9526
G. levis	24-90	45	0.5380
S. lumampao	145-439	256	0.7397

Table 4. Regression equations to estimate the total volume per culm of each bamboo species.

Species	Equations*
B. blumeana	Y = – 17399.5447 + 1427.2800 x r = 0.9502'
B. vulgaris	Y = 2590.4400 + 669.4938 x r = 0.9510"
D . merrillianus	Y = – 1502.8436 + 954.1491 X f = 0.9771' .
levis	Y = 7975.0000 + 529.9745 x r = 0.9698'
S. lumampao	Y = 735.6779 + 738.9830 x r = 0.9267' .

*where : Y = volume in cu cm
X = weight in kg
r = correlation coefficient

. significant at 5% level
. ' highly significant at 1% level

to 842 air-dried cuims would produce one ton of pulp at 40% mill recovery. Beside the two species mentioned, G. levis is also suitable for kraft pulps, B. vulgaris for wrapping paper and boxes and B. blumeana for quality bond, onion skin and bag papers (Tamolang, et al., 1980).

Conclusions

1. Of the 5 erect bamboo species studied, B. blumeana was observed to have the biggest diameter and the longest culms.
2. D. *merrillianus* had the smallest average internode but the thickest walls.
3. G. levis was found to be second only to B. *blumeana* with regard to culm size and merchantable length.
4. S. *lumampao* though the smallest in terms of culm size, had the longest internodes but with the thinnest walls.
5. B. *vulgaris* had the largest diameter not at the base but along the length of the culm almost at the middle.
6. Significant linear relationships between green weight and solid volume of the sample poles were observed for all the species studied. Their corresponding regression equations were determined.
7. Knowledge of the given mensurational attributes and weight-volume relationship for the 5 species studied is important in their yield determination and utilization.

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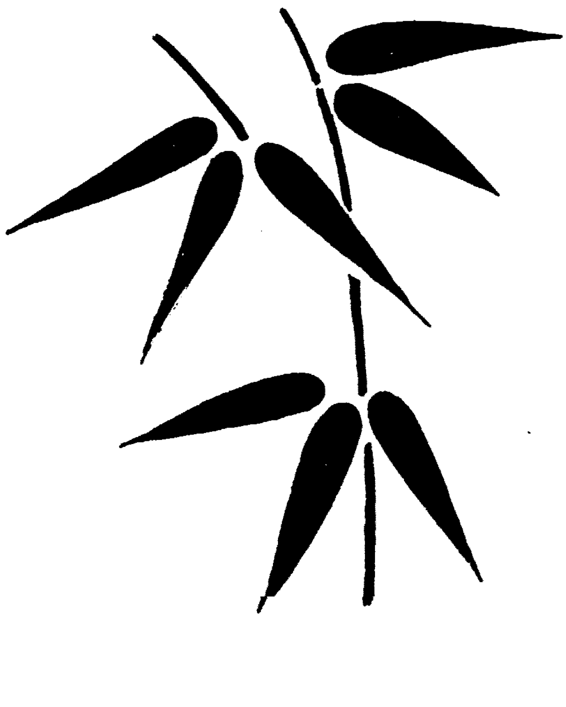

A Study on the Mineral Nutrition of Phyllostachys pubescens

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Abstract

The present paper discusses the mineral analysis of Phyllostchys pubescens. The dynamics of mineral nutrition in differenr parts of the plant body and variations between them are discussed.

Introduction

The dry matter in the plant body of Phyllostachys *pubescens* contains not only such elements as Ca, H, 0 but other mineral elements. Cct, H and 0, are taken from CO_2 in the air and water. These elements play an important role in the growth of Ph. *pubescens.* The present paper discusses the changing pattern of the different elements — N.P., K, Mg, Ca, Fe, Cu, Mn, Zn, Na and Sio.

Materials and Methods

The materials were collected from the forest of Ph. pubescens in Xunhuan Brigade, Lanxi County, Zhejiang Province, in March (i.e. the preshooting phase), April (the shooting phase), June (the phase of vegetative growth)‘and September (the phase of budding and rhizome running).

Healthy plants *of Ph. pubescens were selected from the same site conditions. The ‘plants of two different age groups were cut and leaves, culms and rhizomes were separated. The leaves were picked from different parts of the crown, the specimen culms were 20 cm in length, cut from plants at points of 1.5 m and 4 m above the ground. Young and old rhizomes were selected from the felled plants. Except for those for N.P.K. analyses, all other specimens ‘for the analyses of different elements were washed with distilled water in order to achieve the accuracy of the test results. In analysing elements of mineral nutrition, different methods were adopted: expansion for total N, yellow vitriol chromatography for total P; atomatic absorption and division spectrometry for total K; emission spectrophotometer method for total Na; gravimetric analysis for SiO_2; and atomic absorption spectrometry for such elements as Fe, Cu, Mg, Mn , Zn and Ca .

Test Result and Analysis

A. The dynamics of mineral nutrition in different parts of the plant body and relations between them:

The quantity of the mineral elements accumulated in the body of *Ph. pubescens* varies from one growth phase to another. (Table 5). As indicated in Table 1 the accumulations of N .P.K. and Mg are greater in March and June than in April. In an analysis made in March 1976 N.P.K. and Mg contents in the leaves were 2.47, 0.196, 0.98 and 0.1109 respectively. But values obtained for leaves picked in April 1984 were 1.55,0. 153. 0.69 and 0.889 respectively. Compared with elements contained in the leaves of March, they are reduced by 37%, 21%, 29.5% and 19.8%. The accumulations of N.P.K. and Mg in the leaves of June are 0.184, 0.16, 2.25 and 0.125 or 18.7%, 6.6%, 26% and 41% more than in the leaves of April. The accumulation of N. in the leaves of September surpasses that in the leaves of June by 12.546, while accumulations of P.K, and Mg fell by 31.25%, 49% and 11%. It is also clear from Table 1 that N.P.K. and Mg in the culms and rhizomes also undergo similar changes in content.

(2) The seasonal changes of the accumu-

Table 1. Dynamics of Elements of Mined Nutrition Unit (Percentase of the Dry Matter)

Element	Total N											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	c	R
1976	2.47	0.157	0.714	1.55	0.22	0.425	1.84	0.395	0.535	2.07	0.230	0.575
1977	2.58	0.185	0.488	1.91	0.131	0.194	1.91	0.200	0.470	1.605	0.160	0.460
1978	1.79	0.177	0.411	1.62	0.181	0.356	2.10	0.375	0 525	2.35	0.215	0.67
1979	2.16	0.134	0.334	2.12	0.177	0.297	1.91	0.230	0.275	1.97	0230	0.60
1980	2.06	0.282	0.33	2.18	0.227	0 382	2.26	0.34	0.455	2.16	0400	0.62
Average	2.212	0.187	0.454	1.876	0.187	0.330	2.004	0.308	0.367	2.031	0.247	0.582

Note: L = Leaf C = Culm R = Rhizome

Element	Total P											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	c	R	L	C	R	L	c	R
1976	0.196	0.026	0.149	0.153	0.1095	0 160	0.160	0.060	0 120	0.12	0.05	0.11
1977	0 197	0.103	0 132	0.160	0.070	0 126	0.145	0 092	0.140	0.13	0.04	0.11
1978	0.146	0 053	0.149	0.139	0.073	0.135	0 190	0.074	0.165	0.18	0 03	0.11
1979	0 146	0.080	0.153	0.178	0.105	0.190	0.140	0.100	0.135	0 16	0 055	0 11
1980	0.153	0.103	0.160	0.160	0.093	0.130	0.210	0 110	0 190	0 22	0.055	0.165
Average	0.167	0.073	0 149	0 158	0.090	0 148	0.169	0.0872	0 150	0.162	0.046	0.121

Element	Total K											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	c	R	L	C	R	L	C	R
1976	0 98	0.37	0.37	0 69	0.56	0.33	2.25	0.43	0 27	1.26	0 455	0 35
1977	0.77	0.54	0.25	0.885	0.28	0.18	1.71	0.46	0.29	0 73	0 325	0.230
1978	0 47	0 61	0.47	0.65	0.58	0.29	3.43	0.72	0.51	1.305	0.240	0.24
1979	0 64	0.61	0.45	0.83	0.72	0 35	1.65	0 60	0.335	0 995	0 350	0.220
1980	0 51	0 98	0.43	0.82	0.73	0 45	3 42	0.59	0 37	1.81	0 455	0 25
Average	0.67	0 62	0.39	0.77	0.57	0.32	2 492	0.56	0 35	1 22	0 365	0 258

lations of such elements as Ca. SiO_2. Mn and Cu in the body of Ph. *pubescens are* completely different from those of N.K. and Mg. The values are given in Table 1. The accumulations of Ca. SiO_2,, Mn in bamboos excised in March are smaller than those of April. The latter are greater than those harvested in June. In June the bamboo has lower accumulations of Ca. SiO_2, Mn and Cu. than in September. Against the accumulations of these elements in the *Ph. pubescens* of April, June witness a decrease of 31% for Ca, 28% of Sio2. 33% for Mn and 33.2% for Cu. But in September the bamboo obtains 30.5% more Ca, 18% more Sio2 and 31% more Mr than in June, although the amount of Cu remains the same as that in June.

(3) Our leaf analyses (Table 1) show that the accumulations of the four elements N.P.K. and Mg decrease in older leaves. In new leaves, they are the highest _Following the aging process of the leaves, Ca, SiO2, Mn and Cu steadily accumulate until they reach the highest amount in the old leaves. In new leaves, however, they are very low in content.

(4) The accumulations of elements of mineral nutrition in the plant body of Ph. *pubescens* vary from one organ to another.

Element	Fe											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	c	R
1976	0.01212	0.00124	0.00709	0.06420	0.00142	0.00745	0.01204	0.00133	0.00529	0.01123	0 0066	0 00556
1977	0.01408	0.00124	0.00943	0.01168	0.00151	0.00601	0.01906	000115	0.00790	0.01744	0 0043	0 00925
1978	0.2239	0.00124	0.00763	0.01573	0.00124	0.01213	0.01187	0.00160	0.00691	0.01033	000151	0 00745
1979	0.02271	0.00106	0.00709	0.01303	0 00124	0.00627	0.01716	0.00169	0.00727	0.01123	0 00205	0 00646
1980	0.02131	0.00142	0.00576	0.01402	0.00124	0.00484	0.01177	0.00196	0 00583	0.01042	0.00169	0.00621
Average	0.01852	0.00124	0.00738	0.02373	0.00134	0.00734	0.01402	0 00153	000664	0 01213	0 00313	0 00698

Element	Mg											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	C	R
1976	0.1109	0.0257	0.0398	0.0889	0.0255	0.0486	0.1251	0.0293	0.0527	0.1116	0.0309	0 0586
1977	0.1605	0.0401	0.0542	0.0905	0.0341	0.0704	0.0859	0.0359	0 0664	0.0844	0.0366	0 0531
1978	0.0852	0.0285	0.0567	0.0784	0.0267	0.0676	0 1033	0.0276	0.0605	0.1161	0.0314	0.0619
1979	0.0943	0.0227	0.0372	0.1100	0.0207	0.0505	0.1040	0.0292	0.0374	0.1455	0.0234	0.0569
1980	0.0950	0.0289	0.0434	0.0995	0.0222	0.0485	0.1145	0 0174	0.0697	0.1070	0 0153	0 0627
Average	0.0983	0.0281	0.0463	0.0935	0.0258	0 0571	0.1065	0.0278	0 0573	0 1192	0 0275	0 0546

Element	Zn											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	C	R
1976	0.00355	0.00081	0.00238	0.00390	0.00275	0.00175	0.00315	0.00106	0.00213	0.00435	0 00186	0 00234
1977	0.00355	0.00106	0.00392	0.00360	0.00292	0 00206	0.00465	0 00149	0.00376	0.00385	0.00116	0 00313
1978	0.00340	0.00063	0.00216	0.00375	0.00237	0.00207	0.00330	0.00095	0.00125	0.00410	0 00120	0 00246
1979	0.00340	0.00065	0.00313	0.00375	0.00231	0.00267	0.00425	0.00126	0.00199	0 0062	000124	000340
1980	0.00380	0.00044	0.00314	0.0044	0.00207	0.00195	0.00260	0 00128	0 00349	0 00235	0 00123	000199
Average	0 00354	0.00071	0.00294	0.00388	0.00248	0 00210	0.00359	0 00120	0.00251	0 00417	0 00133	0 00266

For example, in the rhizome they are higher than in the culm, but lower than in the leaves. The accumulations of K, Ca and Mn are, however, much greater in the culm than in the rhizome.

As we know, the dynamics of the accumulations of mineral elements in different parts of Ph. pubescens are decided by the participation of ions in the circulation within the plant body. N.P.K. and Mg are surely the elements which are capable of participating in the circulation within the plants. In the course of circulation, these elements are redistributed and utilized as bamboo leaves begin to wither. These mineral elements are gradually sent to various parts of the plant body. Hence there is quantitative variations between young and old leaves.

Elements of mineral nutrition such as Ca, SiO_2, Mn and Cu can seldom. if ever, be further utilized by the plant body of Ph. pubescens. In other words, they do not take part in the circulation within the plant body. So once accumulated in the leaves, these elements remam deposited. As a result, the older the leaves, the greater is the accumulations of these elements. Accumulations of elements vary in the plant body. N.P.K. and Mg are mostly found in the leaves where the process of metabolism is fast. This is also true of the rhizome which is the storehouse as well as the propagating organ. With the various

Table 1 cant

Element	Mn											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	c	R	L	C	R	L	C	R
1976	0089	0.0055	0.0031	0 119	0.0083	0.0035	0.080	00081	0.0028	0 105	00117	00035
1977	0.078	0.0076	0.0051	0 086	0.0079	0.0040	0.095	0.0096	00031	0 141	0 0096	00037
1978	0.081	0.0043	0 0047	0.107	0.0055	0.0054	0.040	0.0047	00024	0064	00077	0.0025
1979	0071	0.0031	00037	0.091	0.0045	0.0036	0.114	0.0096	0.0034	0.085	00065	00026
1980	0.055	0.0032	0.0053	0.056	0.0067	0.0031	0.044	0.0056	00039	0052	00026	0 0048
Average	0.075	0.0047	0.0043	00918	00065	0.0038	00746	00084	00031	00894	0.0076	00034

Element	Ca											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	C	R
1976	03396	0.00905	000657	06399	0.01575	000554	0.4415	000887	0.00801	05764	00090	000744
1977	0.5005	0.00696	000463	07205	001234	000617	08991	000755	000680	10099	000737	000606
1978	0 7105	0.00779	0.00311	0.9617	0.01166	0.00495	0.1090	0.00884	000684	0.2488	000510	0 00643
1979	0.7222	0.00686	0.00764	0.6667	0.01234	0.00502	0.6780	0.00737	0.00792	0.7356	000605	000784
1980	06059	000541	0.00761	0.5997	001012	0.00816	0.1483	000478	000602	03326	000530	000869
Average	0.5757	000721	0.00591	0 7176	0.01243	0.00591	0.455	0.00750	0.00713	0.580	000656	000729

Element	cu											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	C	R
1976	000081	000017	000031	000127	0.00019	0.00028	0.00085	000015	000023	0.00684	000017	000031
1977	000071	0.00022	000033	0.00099	000015	000023	000069	000017	000028	000061	000018	000026
1978	0 00065	0.00021	0.00028	0.00075	0.00027	0.00021	0.00069	000024	0 00021	0 00088	000015	0 00032
1979	0.00076	0.00026	0.00037	0.00111	0.00022	0.00034	000074	0.00018	000019	000094	000025	000035
1980	0.00089	000027	000036	000104	000025	0.00034	000080	000028	0.00024	0.00073	000027	000029
Average	0.00078	0.00022	0.00033	0.00103	0.00022	0.00028	0.00754	0.00020	000023	000080	000020	000030

Element	Na											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	c	R
1976	00043	0.00185	000377	0.00677	000306	000506	000315	000341	000312	0.00553	000164	000511
1977	0.00367	0.00230	0.00360	0.00674	000190	0.00298	0.00585	0.00303	0.00543	0.00406	0.00243	000367
1978	0.00315	0.00304	0.00476	0.00835	0.00253	0.00233	0.00829	0.00373	0.00411	000576	0.00267	0.00635
1979	0.00427	0.00127	0.00401	0.00219	0.00284	0.00377	0.00475	0.00308	000809	000664	000297	000528
1980	0.00466	0.00158	0.00535	000134	0.00234	000405	000285	000351	000629	000423	000234	000440
Average	0.00401	0.00200	0.00429	0.00507	000253	0.00363	0.00497	000335	000541	000524	000241	000496

Element	SiO_2											
Month	3			4			6			9		
Part / Year of Maturity	L	C	R	L	C	R	L	C	R	L	C	R
1976	10.215	0.287	1660	12.873	0 190	1380	9295	0150	1453	10980	0335	2 00
1977	10.275	0.137	1.155	12.325	0.145	1.783	15.75	0.195	1963	16 653	0 197	1345
1978	12.360	0.243	1.468	13460	0.185	2.033	3 727	0.155	1387	6.890	0330	1480
1979	9.915	0.150	1.178	.11.045	0.310	1.938	15.275	0 165	1.797	14.575	0 257	1.550
1980	11.040	0.290	1.495	11.265	0 192	1203	5.285	0 230	1538	6 135	0247	1.825
Average	10.761	0.221	1391	12194	0204	1667	9867	0179	1628	11050	0273	1640

metabolic processes, the accumulations of these elements are small. However, K, Ca and Mn which are plenty in young and tender tissues are accumulated more in the culm. In the rhizome, they are least accumulated. Table 1 shows that of ail accumulations of elements of 'mineral nutrition in the plant body of P. *pubescens,* N, SiO_2 and K are the greatest (l-11% of the dry matter) next come Ca, Mg and P (0. l- 0.5% of the dry matter). Micro-elements Fe, Mn, Cu, Na and Zn are not as high (0.08% ppm of the dry matter).

N.P. and K. play an important role in the growth of bamboos that they can affect the yield. In order to understand the relations between the three elements at different growth phases made relative analyses are made.

(1) N-P-K relations prior to the shoot production period:

Significance tests show that R(NP.K), R(KN.P) and R(PKN) are not appreciable or even do not exist; while R(N.K.), R(P.K.) and R(N.P.) as well as R(K.NP), R(P.KN) and R (N .PK) are distinctivery positive. This means that prior to the shooting season (i.e. March), each of the three elements, N, P and K not only plays a role by itself, but also is influenced by the other two elements. For this reason N, P and K should be applied at the same time in order to raise the yield.

(2) N-P-K relationship during the shooting season:

a. Relationship between two elements:

R(NP)=0.7638 R(NK)=0.5144 R(PK)=0.7611

b. Relationship between two elements and the other element:

R(NP.K)=0.4035 R(NK.P)=0.5144 R(PK.N) =0.3931

c. Relationships between one element and the other two elements:

R(N.KP)=0.8328 R(P.NK)=0.8846 R(K.NP)=0.8299

Significance tests have shown that R(NP.K), R(NK.P) and R(PK.N) are not distinctive, but N-P-type and N-KP-type relationships are rather distinctively positive. These elements have a great influence before the shooting period. Lack of any of these elements will affect the formation of the biomass of Ph. *pubescens.*

(3) N-P-K relations during the vegetative growth phase:

a. Relationship between two elements:

R(NP)=0.2388 R(NK) =0.9162 R(PK)=0.0684

b. Relationship between two elements and the other element:

R(NP.K)=0.4406 R(KN.P)=0.9289 R(PK.N)=0.3864

c. Relationship between one element and the other two elements:

R(N.PK)=0.9311 R(P.KN)=0.4486 R(K.NP)=0.9290

Significance tests have proved that R(KN.P) is neutrally positive while R(NP.K) and R(PK.N) do not exist, R(P.NK), R(K.NP) and R(N.PK) are all distinctively positive, although such positiveness does not exist in other relationships like R(PK) and R(N.PK) . This means that at the vegetative growth phase, N and K are closely related, and they have a greater influence on the bamboo than does P.

(4) N-P-K relationship at the budding and rhizome extending phase:

a. Relationship between two elements:

R(NP)=0.2015 R(NK)=0.7270 R(PK)=0.7749

b. Relationship between two elements and the other element:

R(NP.K)=0.8337 R(KN.P)=0.9220 R(KP.N)=0.9344

c. Relationship between the element and the other two elements:

R(P.NK)=0.9372 R(K.NP)=0.9696 R(N.PK)=0.9252

Significance tests have shown that at this phase of growth, P and K are more important than N.

To sum up, the accumulations of the ele ments in the plant body of P. **pubescens** differ from one growth phase to another and form seasonal change patterns.

B. Mineral elements and growth variations of bamboos over the years:

(1) The consumption of mineral elements by on-year and off-year bamboos in a forest under even-year working system is alternative (See Table 2). It is indicated in Graph 1 that after its shooting and cuim forming in Spring, 1981. the on-year bamboo becomes off-year. The accumulations of the three elements N, P and K in its leaves decrease gradually. But in the mean-time, the off-year bamboo, having changed its leaves in the same spring, assumes its on-year phase. And the accumu-

lations of the elements increase in the leaves. But in spite of the on-year and off-year difference, both P. and K. reach their own peak in June, N attains its peak in September in on-year bamboo. When the Spring of 1981 comes, the on-year bamboo starts its off-year period after shooting, and the off-year bamboo completes its leaf change and becomes on-year bamboo, This change of physiological patterns are correlated with the accumulations of mineral elements in the bamboo. Yet in spite of this on-to-off (or off-to-on) year change, the months in which P.K. and N. reach their highest points remain the same: June for P. and K. and September for N. After the peak, the quantity of each element decreases gradually, Graph 1 also indicates that N falls noticably around the shooting season. Besides, during the different growth phases of Ph. pubescens, the accumulation of N, P, K and Mg within the on-year bamboo is greater than that in the off-year bamboo. (Graphs 2 and 3)

Table 2. Dynamics of Elements of Mineral Nutrition Unit: (Percentase tlie Dry Matter)

Element	Total N											
Month	3			4			6			9		
On-or-Off Year	L	c	R	L	C	R	L	C	R	L	c	R
Off Year	2.10	0.205	0.485	1.780	0.209	0.387						
On Year	2.37	0.159	0.411	2 015	0 154	0.245						
On Year							2.067	0.370	0.505	2.190	0.282	0.621
Off Year							1.910	0.215	0.372	1.980	0.195	0.530
Element	Total P											
Month	3			4			6			9		
Part On-or-Off Year	L	C	R	L	c	R	L	C	R	L	C	R
Off Year	0.165	0.061	0.152	0.151	0.0918	0.141						
On Year	0.171	0.0915	0.142	0.169	0.0875	0.158						
On Year							0.186	0.0813	0 158	0.173	0.063	0.1280
Off Year							0.142	0.096	0.138	0.145	0.047	0.110
Element	Total K											
Month	3			4			6			9		
Part On-of-Off Year	L	C	R	L	C	R	L	c	R	L	C	R
Off Year	0.643	0.653	0.423	0.720	0.623	0.350						
On Year	0.705	0.575	0.350	0.857	0.500	0.265						
On Year							3.033	0.580	0383	1.458	0.348	0.280
Off Year							1.68	0.530	0.313	0.863	0.337	0.225
Element	Fe											
Month	3			4			6			9		
Part On-or-Off Year	L	C	R	L	C	R	L	C	R	L	C	R
Off Year	0.01861	0.00130	0.00679	0.03132	0.00130	0.00814						
On Year	0.0.1839	0.00125	0.00826	0.01235	0.00137	0.00614						
On Year							0.01187	0.00163	0.00601	0.01066	0.00310	0.00604
Off Year							0.01811	0.00142	0.00758	0.01433	0.00317	0.00785

Table 2 cont

Element	Ca											
Month	3			4			6			9		
Part On-or Off Year	L	C	R	L	C	R	L	c	R	L	c	R
Off Year	0 5520	0 00741	000576	0 7338	0 01876	0 00621						
On Year	06113	000691	000613	06940	001234	000559						
On Year							0.2329	000749	0 00695	0 3859	000646	000724
Off Year							0 7885	0 00746	0 00736	0 8727	0 00671	0 00695

Element	cu											
Month	3			4			6			9		
Part on-or-off Year	L	C	R	L	C	R	L	C	R	L	C	R
Off Year	000078	000027	000032	000102	000023	000027						
On Year	000077	000024	000035	000105	000018	000029						
On Year							000078	000022	000023	000082	000019	000031
Off Year							000071	000018	000024	0.00078	000022	000031

Element	N8											
Month	3			4			6			9		
Part On-or-Off Year	L	C	R	L	C	R	L	C	R	L	C	R
Off Year	000403	000215	000462	000548	000264	000381						
On Year	0.00397	0 00178	0.00380	000446	0.00237	0 00337						
On Year							000476	000355	000450	000517	000221	000528
Off Year							0 00530	0 00305	0 00676	0 00535	000270	0 00447

Element	smt											
Month	3			4			6			9		
Part On-or-Off Year	L	c	R	L	C	R	L	c	R	L	C	R
off Year	11205	0273	1541	12.532	0.189	1538						
On Year	10 095	0 143	1 166	11 685	0 227	1861						
On Year							6 102	0 178	1458	800	0304	1768
Off Year							15 513	0 180	1.880	15614	0 227	1 447

(2) Prior to the shooting season, the culm and its rhizome of the on-year bamboo contains less N, P and K than do the culm and rhizome of the off-year bamboo, but the situation is reversed after the shooting period. The seasonal changes of the accumulations of N, P and K in the rhizome synchronize with those in the leaves. These elements reach the highest point in June and September respectively. In the culm, the seasonal changes of elemental accumulations are not high (See Graphs 2 and 3).

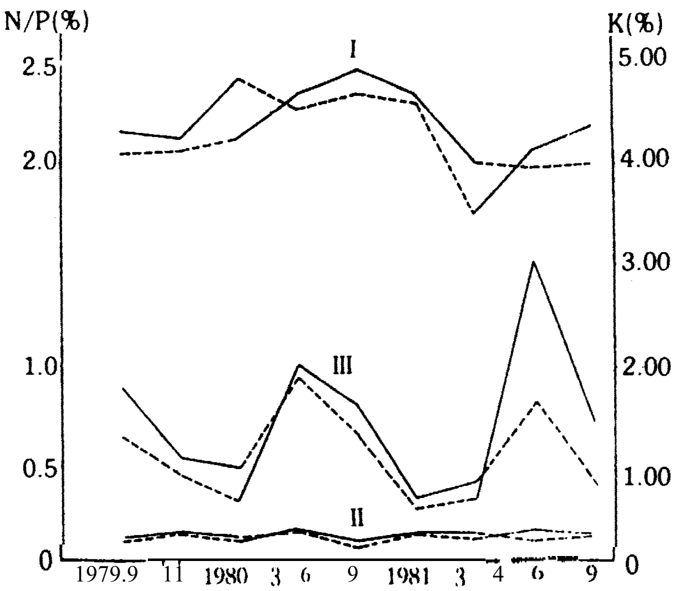
(3) Graph 4 shows that the contents of Zn, Na, Fe and other four mineral elements in the leaves of the on-year bamboo are less than those in the leaves of the off-year bamboo. These elements form their own peak before the leaf change in April and $enerally fall to the lowest point in June when new leaves begin to grow. The seasonal changes of these elements in the rhizome are similar to those in the leaves, but' in the culm, these changes are not apparent. In addition, in the rhizome Na, Zn, Ca, Fe and Mn slightly decrease after the shoot production. As changes of this kind take place regularly year after year, there arises the cyclical change of mineral elements in the plant body. This cyclical change is decided by the physiological heredity of Ph. pubescens, for in Ph. pubescens, the cycle of accumulation, composition and consumption and consumption of nutrition changes once in two years, the same length as the change cycle of the leaves – photosythetic organs. This two year cycle is also in harmony with the change of the seasons, although the beginning and duration of the growth phases of Ph. pubescens may vary from year to year. It is well known that the leaf changing coincides with on-and-off -year distinctiion. An even forest does not change its leaves until some plants have produced shoots and the leaves of other plants begin to fall. This means that the former have changed from on year to off year, while the latter have

Table 2 *cant*

Element	Mg											
Month	3			4			6			9		
Part / On-or-Off Year	L	c	R	L	c	R	L	c	R	L	C	R
Off Year	0.0970	0.0277	0.0466	0.0899	0.0248	0.0549						
On Year	0.1274	0.0314	0.0457	0.1003	0.0274	0.0604						
On Year							0.1143	0.0247	0.0609	0 1115	0 0388	00610
Off Year							0.0949	0.0325	0.0519	0.0957'	0.0300	0 0550

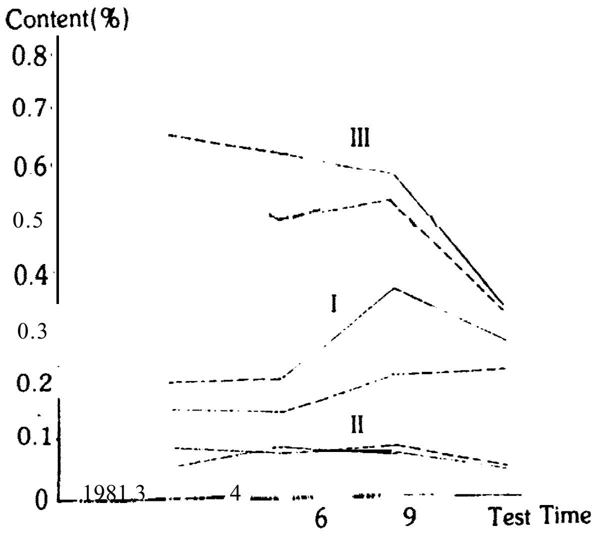
Element	Zn											
Month	3			4			6			9		
Part / On-or-Off Year	L	c	R	L	c	R	L	C	R	L	c	R
Off Year	0.00358	0.00063	0.00256	0.00401	0.00239	0.00192						
On Year	0.00347	0.00086	0.00313	0.00367	0.00261	0.00236						
On Year							0.00302	0.00109	0.00228	0.00360	0.00143	0.00266
Off Year							0.00445	0.00137	0.00287	0.00502	0.00120	000327

Element	Mn											
Month	3			4			6			9		
Part / On-of-Off Year	L	C	R	L	C	R	L	C	R	L	c	R
Off Year	0.075	0.0043	0.0035	0.094	0.0068	0.0039						
On Year	0.0745	0.0053	0.0044	0.088	0.0062	0.0038						
On Year							0.055	0.0061	0.0030	0.073	0.00382	000360
Off Year							0.1045	0.0096	0.0033	0.113	0.00805	0.00315



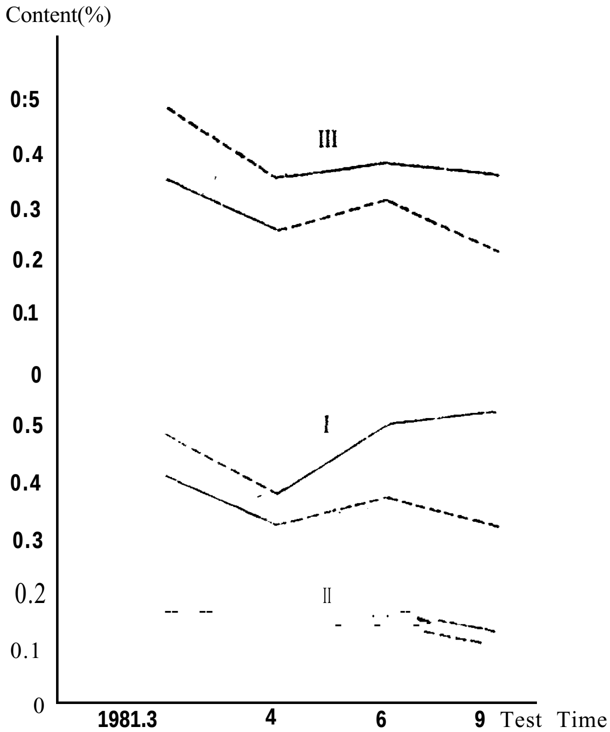
Graph One: The Dynamic Changes of the Elements; of Minerel Nutrition in the Leaves.

Note: Curve I — the change of the accumulation of N in the leaves of the on-to-off-year bamboo. Curve II — the change of the accumulation of P. Curve Ⅲ — the change of the accumulation of K in the leaves of the off-to-on-year bamboo.



Graph Two: The Dynamic changes of the Elements of Mineral Nutrition in the Culm.

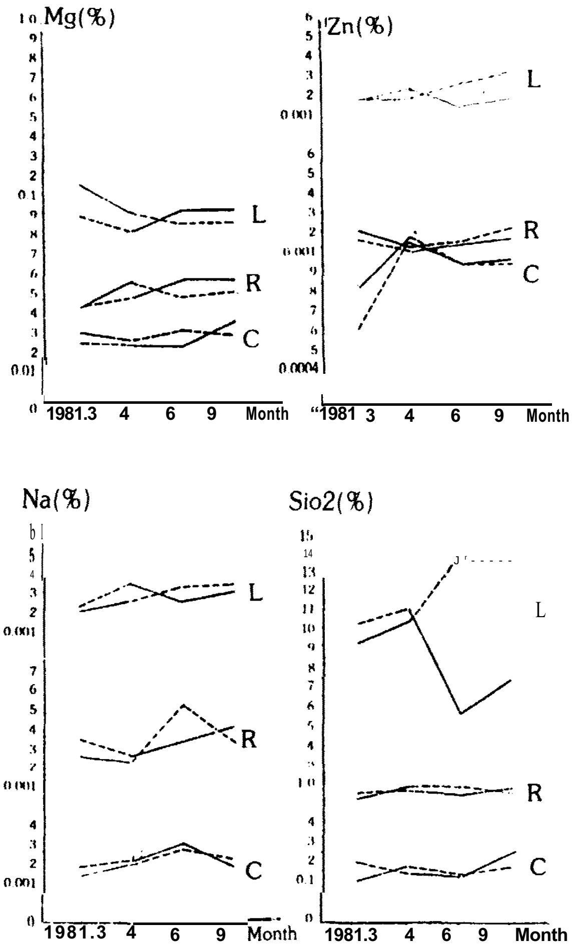
Curve I — N. Curve II — P. Curve III — K.



Graph Three: The Dynamic Changes of the Elements of Mineral Nutrition in the Rhizome.
Curve I N. Curve II P. Curve III — K.

changed from off year to on year. Bamboo which has changed from on year to off year now assumes the stage of -restoration after depression in vegetative growth and loss of nutrition in producing bamboo shoots. As more N is consumed in producing shoots than either P or K the rebuild-up of these elements does not take place at the same time. That is why with on-to-off-year the accumulations of P and K reach their own height in June while that of N reaches its height in September. Then the bamboo enters its physiological process of aging. The contents of N.P. and K. in the leaves begin to decline. But elements such as Cu, Fe and Na, as we have akeady mentioned before, increase in content as a result of the aging of the leaves. So the consumption of N and K is in the inverse ratio with the accumulation of such elements as CU.

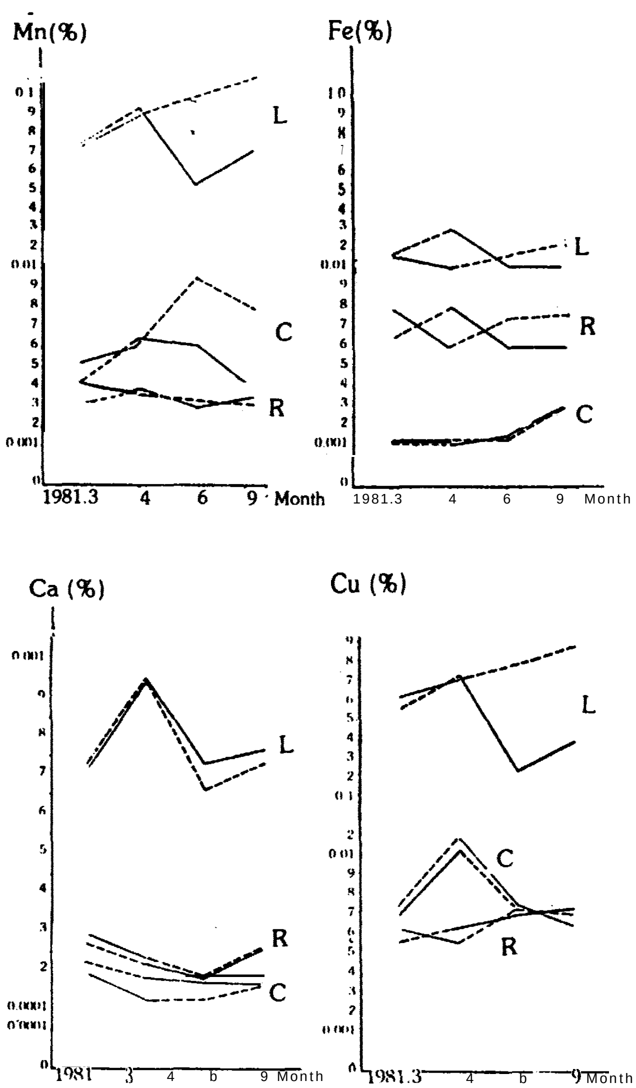
As to the off-to-on-year bamboo, its physiologica activities are strong after the leaf change. N, P, and K in the leaves accumulate gradually. As the development of vegetative organs is not synchronous with that of reproductive organs bamboo's needs for N, P and K are different. Consequently the time function which reflects the accumulations of N, P and K in the Ieaves are naturally different. So it is impossible for N, P and K to reach their own peak at the same time. It can be seen from Graph I that the peaks of P and K appear in June. Curve N ascends in September and descends after the shooting season. This indicates that bamboo consumes more N during the vegetative growth and shooting periods. But during the rhizome running and budding period, it needs more P and K than N. After September, with the fall of tempera-e ture, the growth tends to be slow. And the accumulations of N and K in the leaves reduce sharply. Besides, when off-year bamboo has completed its leaf change, it enters the phase of on-year growth. Its ability to photosynthesise improves and as a result, elements of mineral nutrition begin to accumulate. Unlike the off-year bamboo, the on-year bamboo begins to age after a heavy loss of



Graph Four: The Dynamic Changes of the Elements of Mineral Nutrition.

-... indicares the on-year bamboo which has become off year.

...- indicates the off-year bamboo which has become on year.



Graph Five: The Dynamic Changes of the Element of Mineral Nutrition.

— . . . indicates the on-year bamboo which has become off year.

. . . — indicates the off -year bamboo which has become on year.

nutrition in shoot-production. So in the even forest of Ph. *pubescens* the accumulations of N, P, K, Mg and the like elements are found to be greater in on-year plants than in off-year plants. The leaves of on-to-off-year bamboo, with the aging process advancing, particularly in the following March and April, wither to a further degree. The speed of photosynthesis slows down but the rate of decomposition speeds up. Much of the soluble material in the leaves is transferred to the other parts of the plant body. The mineral nutrients stored in the organ of reproduction — the rhizome — is used to produce new shoots and support their growth. The nutrition accumulated simultaneously in the leaves is shifted to shoots through the culm. Therefore in the culm and rhizome of the on-year bamboo the accumulations of N.P. and K. are lower than those in the culm and rhizome of the off-year bamboo.

From the above discussion, .we can see that the change of the elements of mineral nutrition in on and off year Ph. *pubescens* spend much mineral nutrition in producing shoots.

Conclusion

The dynamic study of mineral elements in the plant body provides a theoretical basis for researches on nutrient physiology of Phyllostachys pubescens.

1. The elements of mineral nutrition accumulated in different parts of the plant body of Ph. *pubescens* include not only N, P, and K, but also SiO_2, Ca and Mg. Of the latter three elements Sio2 is the most quantitive. Of the eleven elements of mineral nutrition analysed in this paper most decrease to varying degrees after shoot production, which means that the plant body also consumes a certain amount of trace elements. Therefore, in applying fertilizer, the mineral elements like Sio2, Mg and Ca should not be forgotten in order to achieve a higher biomass yield.'

2. Though N, P, and K are the three major mineral elements closely related to the growth of Ph. pubescens, the demand for them is not the same throughout different growth phases. During the shooting period and the vegetative growth period, the plant consumes more N than P or K. But during the period of shoot growth and rhizome-running, it needs more P and K than N. To raise biomass production, fertilizers rich in N or P and K should be applied as the occasion calls for. It is suggested that it the forest has an on-year-and-off -year distinctioin, fertilizer rich in N be applied one month before the shooting season around the leaf changing period, ie, from mid-April to the end of May. In June and July (the rhizome-running period), fertilizer rich in P and K should be applied. The organic manure should be applied in July and August of the off year and in the period from December to February the

following year. Grass and other green manure be spread in May and June. By doing so, elements like N, P and K will amply meet the needs-of different growing phases of Ph. *pubescens;*.

4. The even forest, with its seasonal change patterns of elements of mineral nutrition, produces a good effect on the circulation of mineral elements in the soil. It makes good use of soil fertility without exhausting it. The even forest is more economical and productive. If possible forests with on-and-off-year distinction be changed to even forests.

The Chemical Composition of Ten Bamboo Species

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Abstract

Details of chemical analysis of ten different bamboo species from Guangdong and Zbejiang provinces are reported. Ph. heteroclada, contains higher holocellulose and lower lignin, is good for chemical utilization Chemical compositions change with age of bamboos. When bamboos are older than one year, the contents of holocellulose and u -cellulose tend to decrease and lignin keeps unchanged or slightly increases. Therefore, when chemical use of bamboo is considered, prolonging the growth period of bamboo is not advisable.

Introduction

Bamboos, which belong to Bambusoideae of the grass family, are perennial plants. There are more than 30 genera and 300 species of bamboos in China (Hsiung, 1983). They grow mainly in the southern provinces of Guangdong, Guangxi, Fujian, Taiwan, Zhejiang, Jiangxi, Hunan, Sichuan, Guizhou and Yunnan. According to statistics, in 1980, China had about 3.4 million hectares of bamboo forest. At present, the total annual production of bamboos is estimated to be about at 70 million tons (Zhou, 1983). Bamboo is used to produce pulp and paper or charcoal and active carbon for special purposes. Since it is a plant with a high biomass (see Table 1), calorific value (about 4,600 Cal/g, wood 4,700-4,900 Cal/g), people have recently started to consider it as a source of bio-energy (Koichiro, 1981). In 'China, bamboo has been used for making pulp and paper for more than 1,700 years. Presently there are 74 mills producing 23 different kinds of papers. Chemical composition of bamboo will directly influence the quality of pulp and the resultant paper. It can also provide important information for taxonomical identification and seed selection.

Many papers dealing with the cell chemistry of bamboo including hemicellulose (Karnik, 1960; Maerawa, 1976; Negi et al.) 1970; Wilkie and Woo, 1976; 1977), lignin (Higuchi, 1958; Higuchi and Kaivamura, 1966; Nakatsubo et al., 1972; Pant et al.,

Table 1. Comparison of output of bamboo, wood and grass materials.

Kinds of raw material	Species	output (kg/ year mu)
Bamboo	*Phyllostachys pubescens*	600
	Sinocalumus affinis	830
	Ph. heteroclada	
	Ph. augusta	1,300
Wood	Poplar	670
	Picea asperata	150
	Reed.	530-670
Grasses	Rice straw	460
	Wheat straw	250

Table 2. Chemical components of ten species of bamboos (l-year old).

Species	Moisture (%)	Ash (%)	Cold water solubles (%)	Hot water solubles (%)	Caustic soda (1 %) solubles (%)	Alcohol benzene solubles (%)	Lignin (%)	Pento-san (%)	Holo-cellulose (%)	a -cellu-lose (%)
Bombusa textilts	10.58	2.08	6.30	7.55	30.57	3.72	19.39	20.83	79.39	50.40
B. peruariabilis	11.66	2.29	7.64	7.71	29.99	2.15	21.43	20.26	73.34	48 15
B. sinosptnosa	11.49	1.92	8.98	9.91	30.25	5.49	20.50	20.72	74.46	49.15
Llngnania *chungii*	10.33	2.10	8.07	9.46	29.97	4.35	21.41	18.72	73 72	47.76
Phyllostachys pubescens	9.79	1.13	8.13	6.34	29.34	3.67	24.77	22.97	75.07	59.82
Ph. heteroclada	8.38	1.24	13.57	9.60	30.89	5.83	22.42	20.43	71.98	58.15
Ph. nlgra	7.79	1.84	10.69	8.53	33.24	5.29	23.90	22.08	73.61	58.85
Ph. bambusoides	9.14	1.25	10.49	8.97	29.93	7.34	22.39	22.46	72.65	56 74
Ph. meyeri	8.29	1.29	10.79	8.91	34.28	7.04	23.62	22.35	72.84	57.88
Ph. praecox	8.19	1.96	11.21	7.68	32.84	3.80	24.68	22.24	73.31	56.13

1975; Shimada, 1972; Tanahashi et al., 1975) and others on cell wall (Fengel and Shao, 1984; Fengel and Shao Xiaoxun, 1984; Ku and Chion, 1972) have been published. Financially supported by the International Development Research Centre (IDRC) of Canada, a three-year bamboo research project is being carried out in China under the auspices of the Chinese Academy of Forestry. As a part of the work under this project, the chemical composition of bamboos of ten species was analysed and the results are reported here.

Result and Discussion

The investigation was carried out in the Subtropical Forestry Research Institute, Fuyang. The analytical results are listed in Table 2. The results show that holocellulose contents in bamboo culms are generally higher than 70%) which can compare with that of reed (75.4%), cotton shaft (75.1%) and bagasse (75.6%). The holocellulose contents of Ph. pubescens and B. textilis are even higher. The holocellulose content of a plant material is important to industries like pulp paper and wood hydrolysis because it is a key factor affecting the quality of these products. One-year old bamboo contains 2O-25% lignin, which is similar to deciduous woods and grasses (wheat straw is 20%) and slightly less than coniferous woods, Among the ten species of bamboos, lignin contents of Ph. praecox are higher and B. textilis is the lowest. When contents of both lignin and holocellulose are considered, B. textilis is superior for making paper than other bamboos. The pentosan content which is about 19-23%, is similar to broad-leaved woods and much higher than conifers (l0-15%;). Therefore, it is valuable for producing furfural in collaboration with making paper or other hydrolysis products. It also can be seen from Table 2 that bamboos with high holocellulose contents such as Ph. *pubescens* and B. textilis have less cold and hot water solubles. The details remain to be studied. The relationship between chemical composition and the age of bamboo (from 1/2 to 3 years old) has also been studied, The results (Table 3) show that with the increase in age, contents of holocellulose, -cellulose and ash slightly decrease while lignin and alcohol benzene solubles remain unchanged or rise slightly. The bamboos complete their growth within several months after sprouts emerge from the ground and lignification proceeds only slightly after their growth period. If it is used for chemical processing, the bamboo should not be more than 3 years old when the practices of cultivation and rotation are considered. This is in agreement with the conclusion reached (Omar Ali, 1981). In order to find out the reason for decrease of ash content with the growth of bamboo, the composition of ash was further analysed by atomic absorption spectrophotograph. The results are given in Table 4. It can be seen that the contents of nutrient elements such as copper, zinc, cobalt, phosphorus, iron

Table 3. The chemical composition with reference to the age of bamboos.

Species	Age (year old)	Moisture (%)	Ash (%)	Cold water solubles (%)	Hot water solubles (%l	Caustic 8oda (1%) solubles (%l	Alcobol benzene solubles (%l	Lingnin C%)	Pento- (%)	Holo-cellulose (%l	a _cellu-lose (%l
Ph. pubescens	1/2	9.00	1.77	5.41	3.26	27.34	1.60	26.36	22.19	76.62	61.97
	1/3	8.55	9.79	0.69	1.13	8.13	7.10	6.34	5.41	29.34	26.9
	7	8.51	0.52	7.14	5.47	26.83	4.78	26.75	22.04	74.98	59.09
B. textilis	1/2	9.09	2.39	6.64	8.03	32.27	4.59	18.67	22.22	77.71	51.96
	1	10.58	2.08	6.30	7.55	30.57	3.72	19.39	20.83	79.39	50.40
	3	10.33	1.58	6.84	8.75	28.01	5.43	23.81	18.87	73.37	45.50
L chungii	1/2	9.21	2.73	8.10	9.70	35.17	4.16	17.58	23.91	79.00	47.63
	'1	10.33	2.10	8.07	9.46	29.97	4.35	21.41	18.72	73.72	47.76
	3	10.26	1.50	6.34	9.24	30.57	3.98	22.70	18.88	71.70	43.65
B. pervariabilis	1/2	8.38	2.16	4.93	6.35	27.71	2.14	20.92	21.47	79.41	52.63
	1	11.66	2.29	7.64	7.71	29.99	2.15	21.43	20.26	73.34	48.15
	3	11.04	2.65	9.51	9.25	30.63	6.42	22.02	19.22	69.14	45.33
8. sinospinoxa		9.17	2.69	7.29	8.23	29.98	4.23	19.90	21.84	78.29	52.58
	1	11.49	1.92	8.98	9.91	30.25	5.49	20.54	20.72	74.46	49.15
	3	11.13	184	907	929	2692	588	2417	1927	7277	4710
Ph. heteroclada	1	838	124	1357	960	3089	538	2242	2043	7198	5815
	3	1087	127	968	1594	3484	911	2272	2183	5995	3896
Ph. nigra	1/2	1031	198	672	830	3183	412	2849	2224	7077	4538
	1	779	184	1069	853	3324	529	2399	2208	7361	5885
	3	11.61	1.71	650	836	3365	558	2500	2239	6864	4379
Ph. bambusoides	I/2	1069	222	462	593	2760	181	2451	2269	7641	4892
	1	914	125	1049	897	2993	734	2239	2246	7265	5674
	3	990	098	611	732	3133	586	2515	2265	6539	4292
Ph. meyeri	I/2	1070	168	369	515	2727	181	2358	2195	7847	4997
	1	829	129	1079	891	3428	704	2362	2235	7284	5788
	3	933	185	881	1271	3532	752	2335	2219	6240	3905
Ph. praecox	Y2	1064	324	672	857	3336	225	2674	2198	7283	4223
	1	819	196	1121	768	3284	380	2468	2224	7331	5613
	3	1129	228	718	909	3326	564	2565	2239	6577	4081

Table 4. Change of ash composition with age of Ph. *pubescens*

Sample Age	,Components of elements (ppb)								Components of elements (ppm)								
	Cu	Zn	Co	Ni	Pb	MO	cr	v	Ca	Al	P	Fe	Mn	Mg	Ti	K	Na
1-year	544	640	232	104	948	250	218	208	840	trace	30.4	2.12	0.74	16.1	0.26	317	2.72
7-year	324'	436	276	852	578	154	240	242	145	trace	128	100	290	346	0002	556	244

and potassium decrease and only a few elements like calcium increases with bamboo growth. It would seem that, when bamboo gets older, its ability of taking up nutrients from soil is less. Bamboos often die after flowering. Bamboo producers and researchers (Liao, 1983; Watanabe et al., 1981) are very much concerned about this phenomenon but no satisfactory explanation has been given so far. By comparing the compositions of vegetative and flowering tissues of Ph. heteroclada no significant difference can be found. (Table 5). This is a very interesting and important subject which deserves further investigation.

Analytical method: The Chinese National Standard Analytical Method for Material of Pulp and Paper is followed.

Acknowledgement

The authors wish to express their sincere thanks to Prof. Ho Chin-ko for direction and a detaiIed revision of this paper.

Table 5 (1). Chemical composition of vegetative and flowering bamboos.

Sample	Moisture (%)	Ash (%)	Cold water solubles (%)	Hot water solubles (%)	Caustic soda (1 %) solubles (%)	Alcohol benzene solubles (%)	Lignln (%)	Pento-San (%)	Holo-cellulose (%)	a -cellulose (%)
Vegetative	8.38	1.24	13.57	9.60	30.89	5.38	22.42	20.43	71.98	58.15
Flowering	8.30	1.28	14.58	9.39	32.81	5.31	22.48	19.90	73.1'1	56.22

(2) Composition of ash

Sample	Components of elements (ppb)								Components of elements (ppm)								
	Cu	Zn	Co	Ni	Pb	Mo	Cr	V	Ca	Al	P	Fe	Mn	Mg	Ti	K	Na
Vegetative	584	880	19.5	15.3	105	25.8	15.6	28.2	17.9	trace	63.0	1.50	2.10	32 0	0.008	275	5.20
Flowering	490	1254	2.04	25.2	106	20.8	11.5	26.6	31.2	trace	67.8	1.93	4.18	19.2	0.028	202	7.74

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Fertiliser Application and Growth of Phyllostachys pubescens

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Abstract

The fertiliser application and the growth of Phvllostachys pubescens is discussed with reference to methods of applic ation, kinds and dosages of fertilisers, time or period of app li- cation and the benefits derived therefrom.

Introduction

Mao Zhu *(Phy llosta chys heterocycla* var. pubescens (Mazal) Ohwi) is a fine bamboo species in China. It is distributed widely, gives the highest yield, and is very useful. It plays an important role in improving the forest economy and there exists a great potential to increase the production. The total area of Mao Zhu forest in China is more than two million hectares, where the Mao Zhu stands cover over 70% of the area. The yield of fresh culm wood from such stand is about 5 tons ha-' yr^{-1} which is very low when compared to the yield (^{W}f = fresh weight) from bamboo stands covering about 5% of the area, is more than 15 tons ha-' yr^{-1}. At present the maximum yield (^{W}f) from small area of bamboo wood stand is about 30 tons ha-' yr^{-1} and the yield of bamboo shoots (^{W}f) from shoot stand about 20 tons ha-' yr^{-1}. This shoot production drains the soil of a lot of nutrition from bamboo stands, According to recent analyses the production of 1,000 kg of bamboo culms need 1.5 kg of nitrogen, 0.5 kg of phosphorus and 3.8 kg of potassium, and each 1,000 kg of fresh bamboo shoots needs 7.0 kg N, 1.5 kg P and 2.5 kg K. Unless these nutritional elements are replaced the fertility of soil will decrease year by year, which in turn will lead to a decrease in **yield.** Almost all of the Mao Zhu stands in China face this serious problem currently (Anon, 1974).

Fertiliser trials in Mao Zhu stand with organic fertilisers were started in the late 1950s, and with commercial chemicals in the 1960s. but all of the studies covered only a small area and studies were not systematic. Real systematic studies over large area started only in the last few years. There are two reasons for this, the first one is that in the past, the chemical industry was not so developed that most of the commercial fertilisers had to be imported and the organic fertilisers were limited. The second one is that the prices for bamboo culm wood and by-products were on the low side, and commercial fertilisers were expensive. Compared with other crops, the economic benefits of fertilising bamboo is only 25-50%.

However, with the general improvement of the Chinese economy and rising standards of living of the people, there seems to be an increase in the demand for bamboo culms and products. This has consequently increased the price of the commodity. Increased prices make it economically attractive to'fertilise bamboo with commercial fertilisers which is also becoming easily and cheaply available in the country. This cycle of events has stimulated an increased use of fertilisers in bamboo stands in all the districts thereby making an in-depth study of fertiliser applications an urgent matter.

It is very useful that the application of orgnic fertilizer, which has been a traditional one in Chinese agriculture, can be used in the culture of Mao Zhu (Ph. pubescens) stand. Because the organic fertilizer contains all the nutrition needed by plant, i.e. it is a complete fertilizer, the application of which **can** increase a) the humus in the soil, b) improve its physico-chemical properties, c) increase the capacity in keeping it warm and preserving its

-moisture and fertility, The rhizomes can grow without any barrier, and it is easy for shoots to grow up through the soil. Several high yielding plantations bamboo, such as Shimen of Fong Hua county, Shifong, of Ninxian county, Dongmaoshan of Yuyao county, Gangkou of Anji county etc., are based mainly on using organic fertilizer accompanied with the application of commercial fertilizer. But the Mao Zhu (Ph. pubescens) stands are distributed so widely in China, and some are located in the remote mountain areas, where transportation is difficult, making it hard to apply organic fertilizer in such big areas.

The method for determining the size of Mao Zhu's culm in China is to measure the circumference at the eye-height (1.6 m). Sometimes the weight of culm is considered, but it is calculated from the circumference at eye-height. This method has encouraged the production departments to use nitrogen, and neglect the proper proportions of the different fertilizers. Nitrogen no doubt improves the vegetative growth of both height and thickness of the culms. The potassium will improve the hardiness and it will not increases the size of the culm. It has been proved from many trials that according to the method of current measurement nitrogen increases the yield when applied as urea at 300 kg ha-'. If it is the first application the bamboo culms wood increases by 30 – 50%. But the results from the application of phosphorus and patassium are not so good. As the processing and utilization of bamboo culm wood are increasing, there is a need to improve the quality of bamboo wood. In the case of bamboo shoots, the edible parts should be large as well as tender and of good taste. So people have paid more attention for the proper application of different fertilizers which contain different nutritients. Since 1982 the International Development Research Centre of Canada (IDRC) has given financial support to the study of bamboo fertilization in China, the purpose of which is to increase the yield of Mao Zhu (Ph. pubescens) stand. The fertilizer trials with different dosages and proportion of nitrogen and other fertilizers have been laid out to increase wood stands and pulp stands in Anji Uhang and Fuyang Counties of Zhejiang province. The preliminary results of the experiment, which are in progress at different sites have been obtained.

This paper summarizes the data so far obtained and general comment with the hope that,.it will be a suitable referance for the later bamboo fertilization practice.

Fertiliser Application

The common methods of application are broadcasting/spreading and putting it in furrows. Broadcasting means that the fertilizer should be evenly spread in the stand, then when loosening soil, it can be buried into the soil. This method has some advantages such as it is easy to operate, the fertilizer can be well-distributed and so on. But if the fertilizer can not be covered up with soil in time, it will leach, and volatilization will happen and ammonia (HN3) from $(NH_4)_2CO_3$, will damage the bamboo culm. Fertilising in furrow can be both in the whole stand or around the base of culm. If in the whole stand along the contour, a ditch should be dug at every meter 20 – 30 cm in depth and width. The fertilizer should be evenly applied and then covered up with soil. Though this method is a little complicated compared with the former, the volatilization and washing away of fertilizer can be avoided. Fertilizing around the'culm base means that around the culm base, a half circle ditch will be dug, after the fertilizer is put in, it is covered up with soil. Due to the close distribution of bamboo roots around the culm base, the fertilizer will be absorbed soon. This method is better than the two mentioned above. Recently, a study of new fertilization methods has been started in China, i.e. foliage dressing/spray, stump fertilization, and fertilizing in wide and deep furrow.

Fertilizing in wide and deep furrow: The whole stand or Mao Zhu (Ph. pubescens) will be divided into two parts, the mother bamboo area and the shoot digging area and after several years these two parts will be separated. One of the keys for this method is to dig a ditch at the common boundary area between the mother bamboo area and the shoot digging area, which is 70 cm in depth and 50 cm in width. The mixed fertilizer (organic and commercial one) will be placed in the ditch. The bamboo rhizome wifl be led into the deep soil and the shoots formed in the following year will be bigger and of good quality. After the rhizomes from shoot digging area grow into the mother bamboo area one after another. the ditch should be covered up with soil (see Fig. 1).

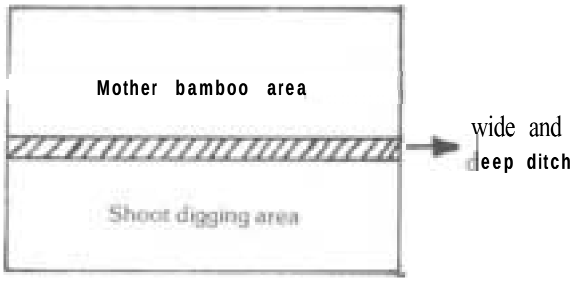


Fig 1 Fertilizing in a wide and deep ditch. which is 50 cm in width and 70 cm in depth

Foliage dressing: The fertilizer solution sprayed to the foliage, will be absorbed by leaves. An experiment with P^{32}-NaH_2PO_4 was laid out to determine that bamboo leaves can absorb phosphorus actively and then transport it to other organs. The result from 1977 trial with spraying the urea solution of 1% and 2% (once a week, total three times) to Ph. *iridenscens* before shooting period has shown that the treated bamboo leaves became greener than control. Earlier workers sprayed the 2% urea solution to Mao Zhu (Ph. pubescens) before shooting. The dosage was 75 kg ha- (once two weeks, total three times). The yields increased by 40.1% and 28.7% respectively. In 1985 they have attempted to spray fertilizers by aeroplane. If the bamboo stand is located in such places where the water resource is rich; transport is convenient, and topography is suitable, this method is worth adopting.

Stump fertilization: the solid commercial fertilizer will be placed in the hole made of bamboo stump, The authors studied the absorption capacity of the inner-wall of bamboo culm for pesticide by labelled compounds. The C_{14}-Bavistin ($C_9H_9O_2N_3$), was rapidly absorbed by bamboo inner-wall and the absorption rate was higher. Then an injection of phosphate solution was carried out. It was found that both NaH_2PO_4 solution and $(NH_4)_3PO_4$ solution could be absorbed in rather big amounts, But the absorbed quantity of NaH_2PO_4 was greater because of high solubility than $(NH_4)_3PO_4$ which has a low solubility, This confirms that nutrition elements can be absorbed by inner-wall of bamboo hole and transported to other organs soon, and that there is a certain relationship between the absorbed quantity and the physico-chemical properties of the solute. To test the absorption efficiency, fertilizing around the bamboo roots and injecting the bamboo culm-wall with P^{32}-$(NH_4)_3PO_4$ were adopted, It was found that the absorption efficiency of injection exceeded that of fertilizing around the roots very much. (see Fig. 2).

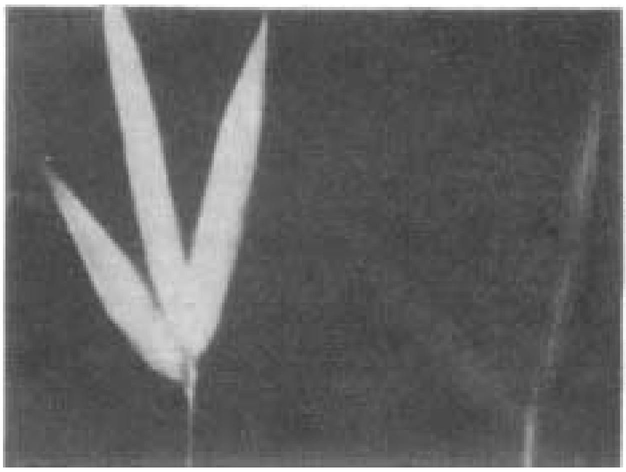


Fig. 2. Absorption of P^{32} — $(NH_4)_3PO_4$ by Ph. pubescens.

During the Mao Zhu (Ph Pubescens) shooting period of 1978. an experiment of injection with urea solution at culm base was carried out, Each culm in the treated plots was given 2 injections one per two weeks with urea solution of 20%, 30-50 ml. The control (untreated plot) was injected with water The results are shown in table I,

From Table 1, it is clear that increment of yield was higher, But it should be pointed that it is expensive to inject each culm and after injection the utilization value of culm will be reduced. It has also been proved that stumps have limited absorption capacity. A stump fertilization trial was laid out in Yongfu County, Jiangxi province, and almost at the same time a similar one was done by Shi Qiuantai in Anji County, Zhejiang province. Both of them gave some good results. Stump fertilization does not need soil preparation, Fertilizer will not volitilize and be washed away, and it can accelerate the decay of bamboo stump. so it is worth to popularise this technique.

Table 1. Fertilisation effect from the bamboo cavity-wail injection.

Treatment	Treated area (ha)	Original culms Number	Original culms A' (cm)	New culms Number	New culms A' (cm)	Increace proportion % number	Increace proportion % A'
Injection	0.067	284	29.4	40	35.7	18	6
Control	0.067	315	31.3	3433.7	—	—	

A . . Circumference at eye-height (1.6m)

Kinds and Dosages of Fertilizers

The distribution of Mao Zhu (Ph. *pubescens)* in China is very wide, the situation of sites varies much, and the soil fertility are very different. So the kinds and dosages of fertilizers should also be different at different places. Here the results obtained with Mao Zhu stands in north-west Zhejiang province, will be discussed.

The fertility of the soil in the Mao Zhu stands of north-west Zhejiang province is better; its mineral nutritive elements are rather rich, the nitrogen content is in the middle, but the phosphorus is low. Table 2 shows the analysis of the soil samples from Anji, Yuhang, Fuyang County in Zhejiang provience. (Qiou, 1979).

As mentioned earlier the minerals are absorbed during Mao Zhu growth and it should be supplemented by fertilization. It was reported that the application of urea, 225 kg ha-' can increase yield by 17% & 9% and product value of 19% & 8% in Anji County and Yuhang County respectively and that the high dosage (675 kg ha-') is better than the low one (225 kg ha-1), the increments of yield and product value are 17% and 147% respectively. The result from another trial, a comparison between N, P, K, Si mixed fertilizers, which have two types i.e. I & II, and urea (Ma Naixun & Wang Zhuyi et al., 1983), is that when the same dosage was applied the, increments of yield and product value from I and II are 13.7%, 14.8% and 16.8%, 12.5% respectively. The details of component and proportion for mixed fertilizers are shown in Table 3.

Hong Shungshan and Jiang Yigeng (1984) laid out a field trial with different dosages and proportions of N P K in 1984. They found that the importance of three *main elements in N K P. The finest prescription is urea 15 kg + $Ca(H_2PO_4)_2$ 20 kg + K_2SO_4 15 kg per mu (Chinese unit of measurement, it equals 667 M^2), the N P K proportion of which is 1: 0.4: 1.2 (N: P_2O_5: K_2O). Compared with control, the yield of bamboo wood increased 452 kg and the net income increased 59%. The finest prescription for shoot stand is urea 20 kg + $Ca(H_2SO_4)_2$ & $CaSO_4$ 20 kg + K_2SO_4 5 kg and its N P K proportion is 1: 0.3: 0.3 (N: P_2O_5 K_2O). All the results from the above trials have proved that a) N fertilizer is the more important for the yield of Mao Zhu stand, and the reasonable application of nitrogen will give obvious effects for its yield increment. b) P and K are necessary when a lot of N has been used. Especially for red soil, P is rather important. c) The kinds of fertilizer used, their proportion and dosage should be decided by the fertility of soil and the purpose of management. There has been few reports on the effects of the application of silicate fertilizer from abroad, and in China we have also done some experiments on it. But it is still a problem which we should study further.

Fertilization Time

According to the growth pattern and production cycle of Mao Zhu stand, another important problem exists, that is, to choose a reasonable time for fertilization. Not enough' attention and no systematic study has been done, in this area.

Most of the Mao Zhu stands in China can be divded into on-year stand and off-year stand, i.e. in a certain year some of them shoot a lot (on-year stand). the others shoot very few (off year stand). In the following year the-situation changes with each other. So a

Table 2. Determined nutrition value of soil in Anji Yuhang, Fuyang County in Zhejiang provience,

Site		Soil type	Organic matter %	Total N %	Total P_2O_5	Quickacting P PPM	Quickacting K PPM
	Guanshanwu	red soil	4.64	0.228	0.056	2.8	123.2
Anji	Xiaoxiwu	red soil	4.26	0.204	0.054	0.3	128.7
	Gangkou	red soil	4.70	0.209	0.115	0.2	100.4
	Yinjiangling	red soil	2.76	0.149	0.095	0.40	64.9
	Shanchawan	red soil	3.70	0.174	0.067	0.62	73.1
Fuyang	Chiaoxiwu	red soil	4.47	0.221	0.091	1.53	69.7
	Xiaqinwu	red soil	3.36	0.165	0.091	0.95	70.1
	Hen he	red soil	3.95	0.159	0.046	1.39	88.7
Yuhang							
	Jiudongling	red soil	3.59	0.184	0.071	2.19	120.9

Table 3. The nutrition component of proportion for special mixed fertilizers of Mao Zhu.

Name of fertilizer	nutrition containing % N	P_2O_5	K_2O	Sio2	Proportion N:	P:	K:	Si
Bamboo fertilizer I	16.42	8.23	8.46	12.85	2:	1:	1:	1.5
Bamboo fertilizer II	17.70	8.85	4.47	13.8	2:	1:	0.5	1.5

two year production cycle is formed, The growth patterns of on-year and off-year stands have been shown in Figure 3a &b.

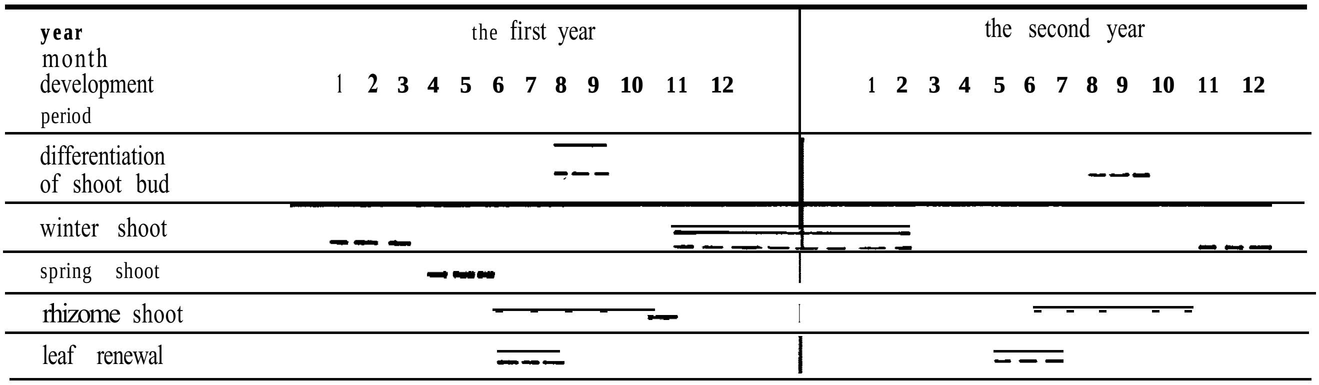
There are four growth periods in the growth of Mao Zhu stands. a) winter-shoot renewal period, b) spring-shoot growth period, c) leaf growth period, and d) rhizome growth period.

A trial with application of urea has been done in spring-shoot growth period by the authors and the results are shown in table 3.

We can see from Table 3 that one or two months before shooting, the application of urea has given some yield increments. At the mid-period of spring shoot growth there is no effect. The reason might be that approaching spring, bamboo is actively growing. This needs good mineral nutrition and at that time temperature and moisture are also suitable, thereby helping assimilation.

In practice the fertilizers are applied at the period of shoot bud differentiation. Its effects for yield increment is obvious, By fertilizing soil or poor soil with 15-20 kg urea per mu (667 m^2) the range of yield increases by 30-50%. even with poor soil it can still be 10-20%. Another suitable time to fertilize is the period of leaf renewal. The current culms of Mao Zhu change leaves once a year, but the older, once every two years. In the districts of north Zhejiang province. it is in April to May. If fertilizing is late, it will show up in leaf area and in the content of chlorophyll. Because of the lack of data, it is difficult to say that between this period and shoot bud differentiation period which one is better to fertilise. In the culture of shoot stand. it is common to fer-

Fig. 3a. The growth rhythm of Mao Zhu stand



Note: — on-year stand
--- **mixture-year** stand

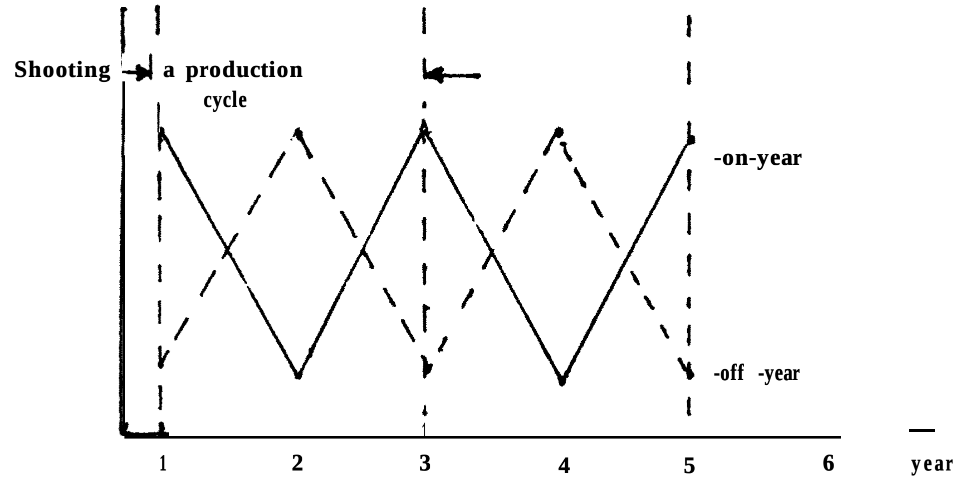


Fig. 3b. Growth patterns of on-year and off-year stand.

Table 3. The fertilization effects in and before spring-shoot growth period.

fertilizing time	treatment urea (kg/mu)	increment of new culm number	increment of new culm A' (cm)	percentage of yield increment % number	percentage of yield increment % A* /
28, February	25	16	-0.3	31	-0.8
16, March	25	16	0.6	31	1.8
12, April	25	5	-0.7	7	2.3

tilize at shoot digging period i.e. a) When digging spring-shoot to put fertilizer solution with low concentration into the cavity where the shoot was taken away. b) When digging winter-shoot to put solid fertilizer into the cavity. As discussed above there are no obvious benefits from fertilization at mid-shooting periods so application af winter-shoot digging time, will improve the spring-shoots both in quality and quantity.

Discussion

1. It is proposed that two methods — the stump fertilization and the furrow one around the culm base are adopted, for it is easy to apply and the efficiency of fertilizer appli-

cation is high. The organic fertilizers should be put into furrow or spread and then burried in soil.

2. Both- the organic fertilizer and the commercial fertilizers should be used widely. Among them N is the most 'important one followed by P and K.

3. As regards dosages, 50 kg ha-' is better for Nitrogen (net N). If the soil lacks P and K, the proportion N:P:K = 2:2:1 could be adopted or the N P K mixed fertilizer could be used.

4. The period of shoot bud differentiation and that of leaf renewal are suitable for fertilizing. As to the shoot stand, it could be fertilized when the shoots are dug out in winter: Fertilizer application is very important. The foresters are increasingly aware of the new fertilizing system. Further improvements are necessary.

a) An evaluation should be made on the fertility levels of soils for the present bamboo stands, i.e. a systematic investigation of the soils in bamboo stands should be made so that different soil types and their fertility can be divided.

b) The qualities of different nutrients which are needed by the present yield and the maximum yield should be calculated. This means that plant samples should be analysed.

c) It is also necessary to learn more of the nutrient cycle in Mao Zhu stand, i.e. how much is absorbed by the bamboo stand. In this case, the small water shed study may be useful.

d) To study the relationship between using fertilization and its effects, both in quality and quantity. The nutrients can be supplied at appropriate time according to the production needs, and the fertility of soil can be maintained or even be raised. Finaily it is necessary for scientists working on soil, with silvi culture ecology, and economics to cooperate with one another. Improved results will bring the abound benefits.

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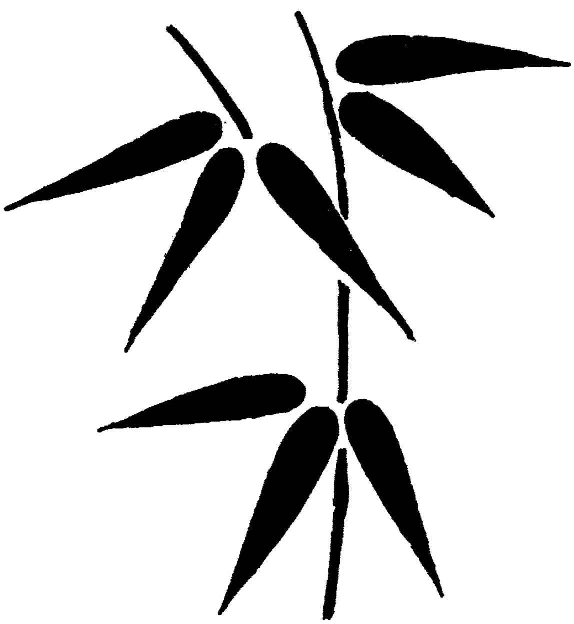

Effects of Photoperiod and Temperature on the Growth of Mosochiku Phyllostachys pubescens seedlings

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Abstract

Mosochiku (Phyllostachys pubescens), which is the most useful and popular bamboo species in Japan hardly flowers and euen if it flowers, it is very difficult to get fertile seeds. Effects of photdperiodism and temperature on the growth of Mosochiku seedlings are determined, Long term seed storage without treatment is difficult and percentage germination of seeds differ. Temperature higher than 30°C is not suitable for continuous growth of Mosochiku, but long day lighting is good for the growth.

Introduction

Mosochiku (Phyllostachys pubescens) , one of the typical useful Japanese bamboo species grows widely throughout the country except Hokkaido in northern Japan. Most of the bamboo forests in Japan are cultivated for edible sprouts or for the production of bamboo culms. Bamboo sprout and culm production, is increasing year after year keeping with the demand for culms which are used for construction. Mosochiku, Madake (Phyllostachys *reticulata)* and other useful bamboos, however, are indispensable and important needs for Japanese family life and culture. Bamboo species are widely distributed in the area from temperate region to tropical region with two different growth types of bamboo rhizome.

The first growth type is the non-clump , forming type which mainly is common in temperate and subtropical region, and the second type is the clump forming, which is common in the tropical region.[4] There are two methods of bamboo multiplication. One is the asexual propagation such as rhizome cutting (: offset planting), culm cutting and layering, and the other is the sexual propagation by seeds and seedlings. Mosochiku flowers rarely and therefore, the seeds are very precious[2]. For this reason, studies on bamboo seedling are very few. This paper describes the effects of photoperiodism and temperature on the growth of seedlings.

Materials and methods

Mosochiku seeds were collected from many forests in Japan during 1978 to 1979, and seed fertility was tested by X-Ray television which is commonly called Softex or Softex television. This is widely used in medical fields and industries. Softex model 25-l can be used to observe the internal structure of endosperm, embryo and so on. Twelve seeds were laid on a moderately wet filter paper within 12 cm petri dish in diameter, and kept at constant 25°C in fixed temperature box. These tests were repeated five times, and observed for three weeks.

Thermal effect of growth on bamboo seedling was tried in the Phytotron with fixed temperature at 20°C – 15°C (: Day time) and at 30°C – 25°C (night) in each chamber. Temperature at 20°C and 30°C of day time represent the natural temperature in North and South of Japan.

Ten days old seedlings were planted in the one ten thousandth Wagner's..pot hold

Table 1. Composition of the nutrient solution

Salts used'	Elements	Concentration (ppm)
NH_4NO_3	N	50.0
$NaH_2PO_4.2H_2O$	P_2O_5	25.0
KCl	K_2O	30.0
$CaCl_2.2H_2O$	CaO	20.0
$MgSO_4.7H_2O$	MgO	10.0
EDTA-Fe	Fe_2O_3	1.0
EDTA-Cu	cu	0.1
EDTA-Mn	M n	0.1
EDTA-Zn	Zn	0.1
H_3BO_3	B	0.1
$MoO_3.2H_2O$	M o	0.1

with vermiculite as medium of culture soil, and kept on the trolley. Trolleys have been devised for bamboo culturing and to circulate water between upper and lower tanks controlled by two timers. Composition of the culture solution is given in Table 1 and it was used 100 ppm, with initial pH 5.3. Relative humidity was fixed 75 ± 7% and with natural light intensity. Different light periods tor 6 hours, 12 and 24 hours per a/day was used in each chamber.

Results and Discussion

Number of seed setting per culm of Moso-chiku is shown in Fig. 1. There is no clear relationship between culm size diameter and seed setting, but in general, bigger culms have manv branches and leaves. Seed. production is high and they are viable. Seeds collected from different places such as Shizuoka, Tochigi, Kagoshima, Yokohama and others were compared for their germination percentage. There was 25% to 65% variation with minor differences for individual bamboo culm. Germination percentage was 34% for fresh seeds 27% after one month storage, and 7% after two months. This shows that germination percentage decreases rapidly. Nearly 40% seedlings die after three weeks of germination, Seedlings maintained at 30°C grew 4.6 cm in height with 5.8 leaves culm on an average of 29 pots. Other details are given in Table 2. Growth with Treatment I was better, but leat

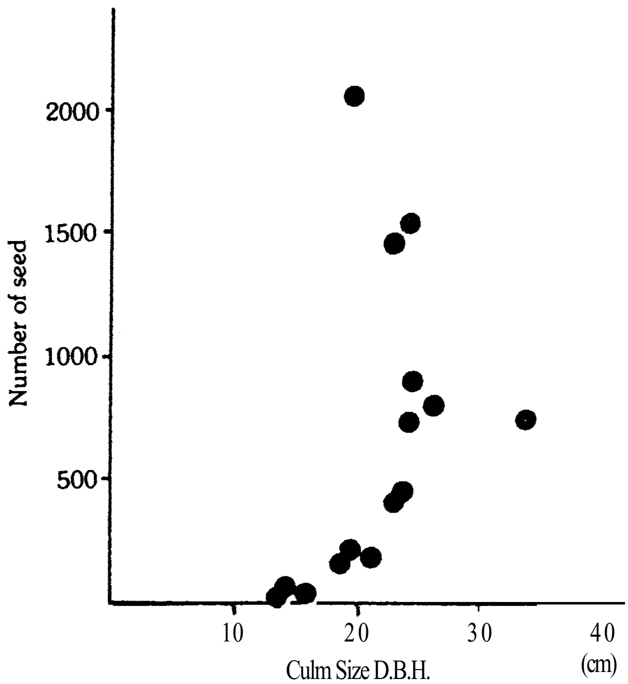

Fig. 1. Number of seed setting/culm,

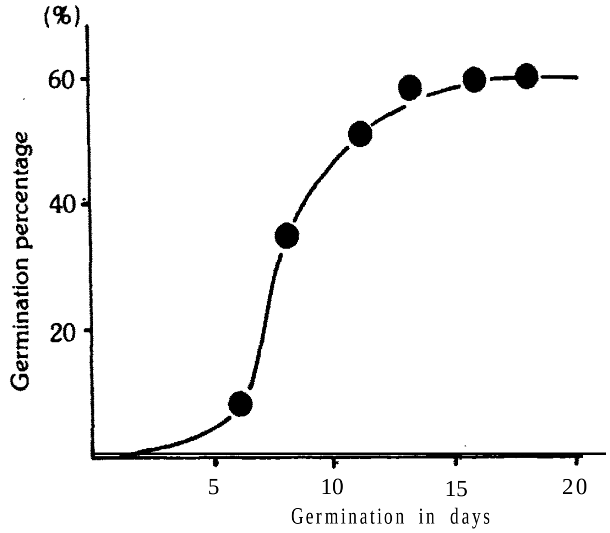

Fig. 2. Relationship between germination period and total germination percentage of P. pubescens seeds.

area increase was better in Treatment II (Table 3). The colour of oral setae' was normal brown in Treatment I and in Treatment II it was white. Some leaves suffered chlorosis and the seedlings died after the second month. This phenomenon was noticed in tropical plantations[3]. It seems that temperate bamboo species are not suitable for tropics. Colour in Treatment II was dark green and Treatment I, light green. Differences in growth and leaf areas are shown in Figs. 3,4 and Table 3.

Photoperiodism

The leaf area increase under long clay treatment (24 hours light in a day) was greater than under short day treatment (6 hours lighting in a day). The above results may prove helpful to raise bamboo seedlings of various species.

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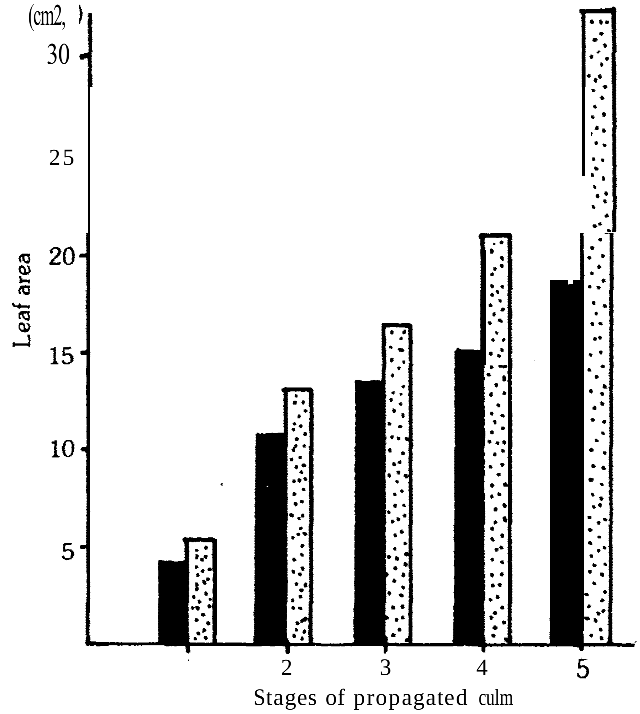


Fig. 3 Leaf area classified by every stage of propagated culm

Table 2. Treatment of temperature and growth of seedling.

Treatment	Items	Date of observation: July 19	Aug. 16	Sep. 20	Nov. 4
30°C	Stage of leaf – Number of leaf	l-5.8	l-8.3 2-4.1 3-1.0	l-10.3 2-7.3 3-4.1 4-3.3	l-11.0, Z-12.9 3-10.9, 4-9.5 5-6.2 6 to 9-15.5
	Culm length	1.4-6	l-6.0 2-7.9 3-2.5	l-7.1 2-12.6 3-13.5 4-10.2	l-7.8, Z-17.3 3-21.8, 4-22.3 5-21.4 6 to 9-21.2
20°C	Stage of leaf – Number of leaf	l-6.1	l-7.5 2-2.5	l-8.0 Z-5.1 3-2.9 4-2.5	l-6.1, 2-9.3 3-9.4, 4-8.7 5-4.2 6 to 8-11.1
	Culm length	l-4.3	l-5.3 2-3.6	l-7.0 2-9.8 3-6.0 4-5.0	l-8.0, 2-16.1 3-18.1, 4-17.1 5-13.2 6 to 8-9.0

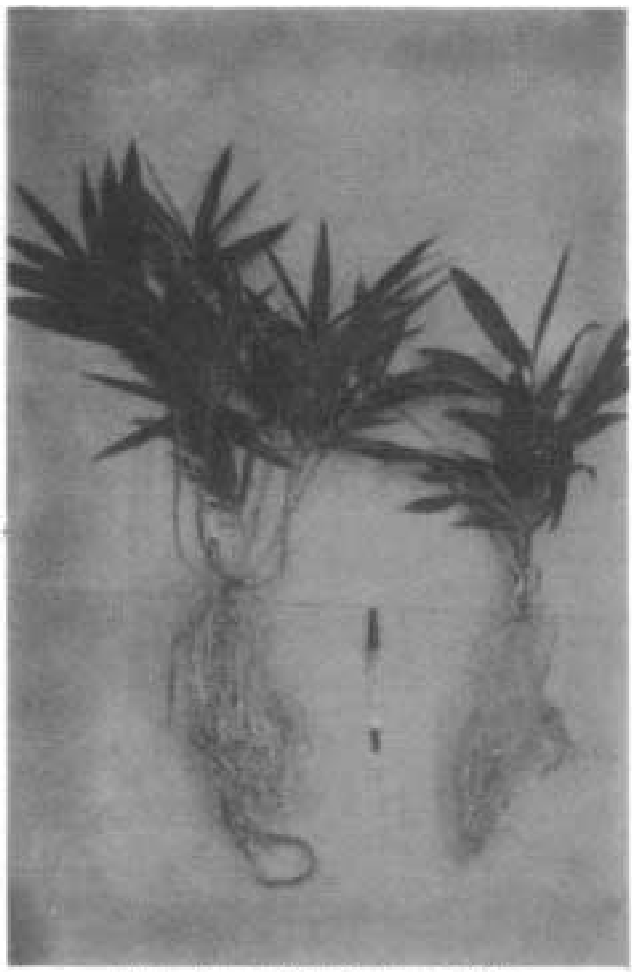
Table 3. Leaf area classified by stage ofulm growth.

Treatment	Items	Stage of culm growth: 1	2	3	4	5	6-9	Average/ Total
3o°C	Leaf area	4.7	10.9	14.7	15.2	18.7	20.0	14.0
	Total Leaf area	51.7	140.6	160.2	144.4	115.9	310.0	922.8
20°C	Leaf area	5.5	13.2	14.9	21.2	32.5	33.0	20.0
	Total Leaf area	44.0	212.5	269.7	362.5	429.0	894.3	2212.0

Growth of Mosochiku seedlings 150 days after planting.

(1) Treatment at 20°C

(2) Treatment at 30°C



(3) Left side: 30°C. Right side: 20°C.

(4) Left side: 30°C. Right side: 20°C.

Growth and Propagation

Studies on Branching Pattern of Monopodial Bamboos

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Abstract

The bud initiation, bud types and branching patterns are discussed in the species of Arundinaria, lndocalamus, Phyllostachys and *Sinobambusa.*

Introduction

Branching on nodes is a general characteristic of plants that affects stem form, crown form and foliage distribution. On the other hand, branching pattern is also determined by leaf order and bud structure. Bamboo plants are of alternate phyllotaxy with distichous branch order. In the case of individual nodes and axillary buds, however, their number, size, length and occurring sequence vary greatly with species. This paper mainly discusses the bud structure and branching pattern of monopodial bamboos.

Materials and Methods

In 1984 and 1985, some species of indocalamus, , Phyllostachys, Sinobambusa, Chimonobambusa and Arundinaria in the Bamboo Garden, Nanjing Forestry University were investigated. The sheath initiation, bud formation and structure, branching sequence and development were carefully examined and observed. Slides of shoot apices and branching nodes of young culms were prepared for comparative studies.

Bud Initiation and Structure

The apical meristem of a culm shoot consists of tunica and corpus. The tunica is a mantle of two to four layered cells which are relatively-uniform in size and dense in arrangement, while the corpus is an interior mass of unlayered cells. Between the tunica and corpus there is a layer of cells with outward walls uniform and inward walls distorted known as a transitional layer. Both the tunica and corpus are active in division as seen in Figs. 1 and 2 which show the apical structure of a culm shoot, a rhizomal shoot and differentiation respectively. (Hsu, 1944, Lee and Chin, 1960, 1962, Cutter, 1965, Clowes, 1961, Esau, 1965).

In the lower part of apical meristem a leaf (sheath) primordium is initiated from the tunica cells and becomes visible as a small protrusion. With further apical activity the primordium develops into a young sheath, another new leaf primordium occurs at the opposite position alternatively. The young sheath grows circumaxially by its apical, intercalary and marginal divisions and embraces the internode and node to which it is attached and overlaps 1/5 – 1/4 on the opposite side after its full development. At the same time, another young sheath develops from the other side of the upper node and develops in a reverse way. As a result, two adjdining sheaths are superposed in a symmetrical manner. Such a crossoverlapping continues until the shoot ceases to grow (Fig. 3). At the sheath axil a primary bud primordium is initiated from the peripheral meristem and appears as a protrusion which finally develops into a primary branch. It may be solitary or ramificate at its basal nodes depending on the species (Fig. 4). The lowest leaf primordium of the primary branch bud develops into a prophyll which encircles it entirely or partially, while the culm sheath embraces the axis and the bud. At the locus of a lateral bud procambia (provascular strands) are derived from the peripheral meristem and arranged in axial rows. Their cells are packed in bundles with large nuclei and active division and differentiation. Axial

Fig. 1. Shoot tip of Phyllostachys pubescens showing apical meristem with leaf (sheath) primordia, young sheaths and their axillary buds which develop into primary branches. Fig, 2, Growth tip of rhizome shoot of Phyllostachys pubescens showing apical meristem with leaf (sheath) primordia, young sheaths and their axillary buds which develop into new rhizomes or culm shoots.

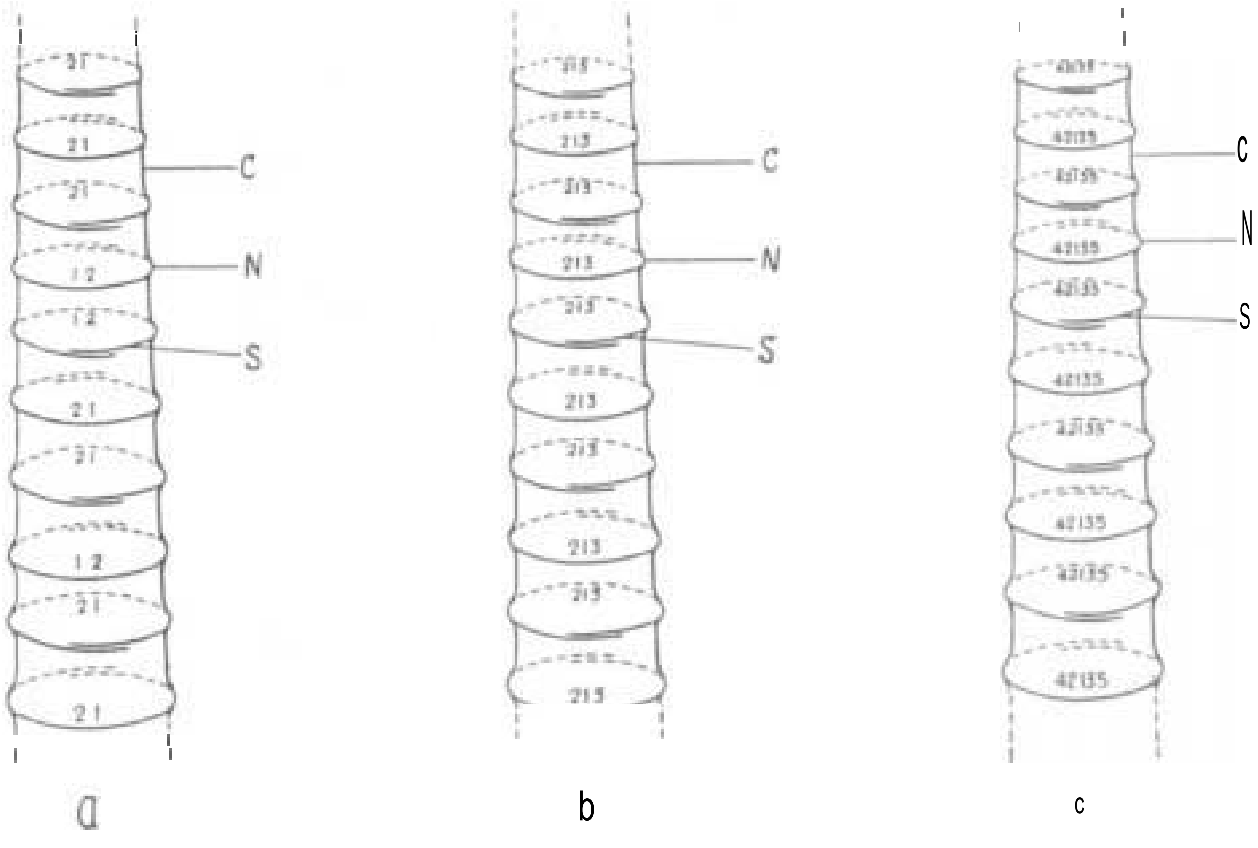


Fig 3, "Mirror image symmetry" overlapptng pattern of sheaths (S) showing the loc of primary bud (1) and proliferating order of secondary branch buds (2 3, 4, 5) on nodes (N) of culms (C) a Double branching (Phyllostachys); b Triple branching (Sinobambusa). c Multiple branching *(Arundinaria.* Chimonobambusa, Gelidocalamus~

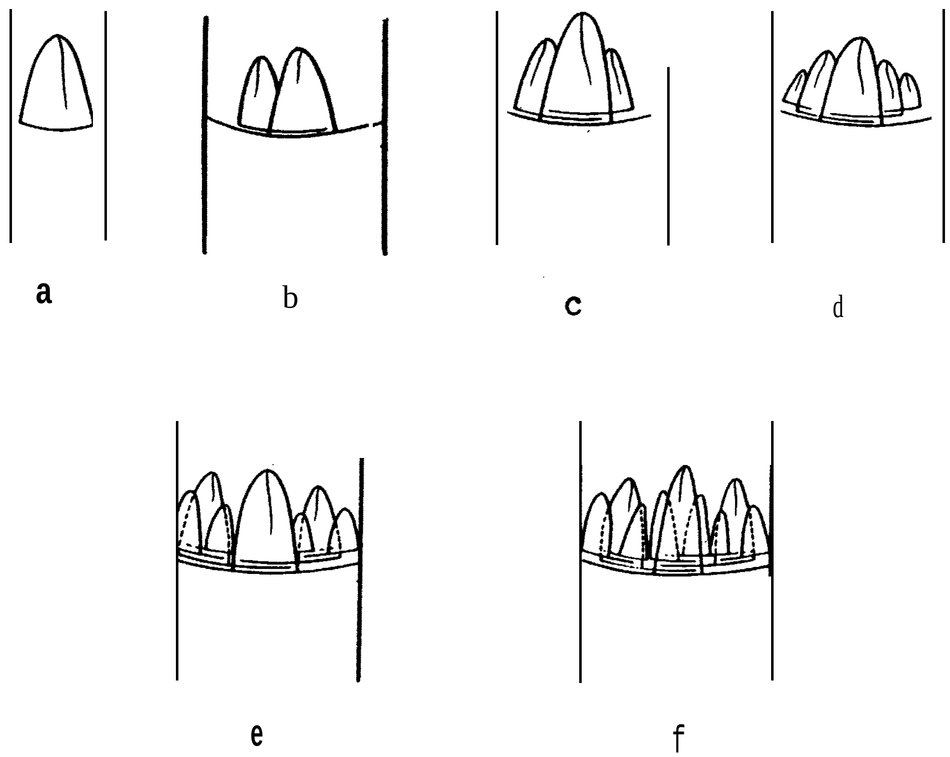


Fig. 4. Loci of primary branch buds and their ramificating order of secondary branch buds. Note the sheath and prophyll scars. a. Single branching bud *(Indocalamus);* b. Double branching bud *(Phyllostachys);* c. Triple branching bud *(Sinobambusa);* d-f. Multiple branching bud *(Arundinaria, Chimonobambusa and Gelidocalamus).*

division commonly occurs in provascular cells, but radial division is often seen, too, As culm growth progresses, provascular bundles increase gradually and become curved transversely at the position of young sheath where a new node is in the making. The newly formed node separates the meristematic tissue into two parts known as intercalary meristem. As a result of shoot growth a culm is divided into a number of nodes and internodes which are called “stem units”. (Grosser and Liese, 1971, Hsiung et al, 1980, 1980a, 1981, Usui, 1957, Ueda, 1960).

Bud Types and Branching Pattern

Branching pattern is determined by the primary buds of which the locus, number and size of buds and constriction of basal internodes vary greatly from species to species.

Single branching bud: Primary buds are solitary and elongate promptly to develop solitary branches, each with three to five con stricted budless nodes at its lower part. The branch size is somewhat smaller than the culm from which it protrudes. Its Jateral buds commonly occur at the higher nodes. Culm-branch angles are generally small, less than 20 0. Branches are nearly erect and close to the culm as seen in species of Indocalumus (Figs. 4a, 5).

Double branching bud: A primary bud bears a lateral bud at its first node which is so close to its base that seems paired buds from a common base (Fig. 4b). The primary bud and its lateral one elongate simultaneously to develop into two branches. The primary axis becomes dominant over the other. In most species of Phyllostachys 7080% of small branches are situated on the overlapping side, the rest on the overlapped side (Fig. 3a), but *Phyllostachys aureosulcata f sepectabilis* has all its small branches located or the overlapping side. Occasionally triple branching occurs in the double branching group by lateral bud initiated from the second basal node of the primary branch as seen on midculm nodes of *Phyllostachys pubescens.* Angles between culm and branches and between branches vary from 60° to 80° that results in a wide spread crown horizontally (Fig. 6).

Triple branching bud: A primary bud produces two lateral buds alternatively at its first and second basal nodes which are so close

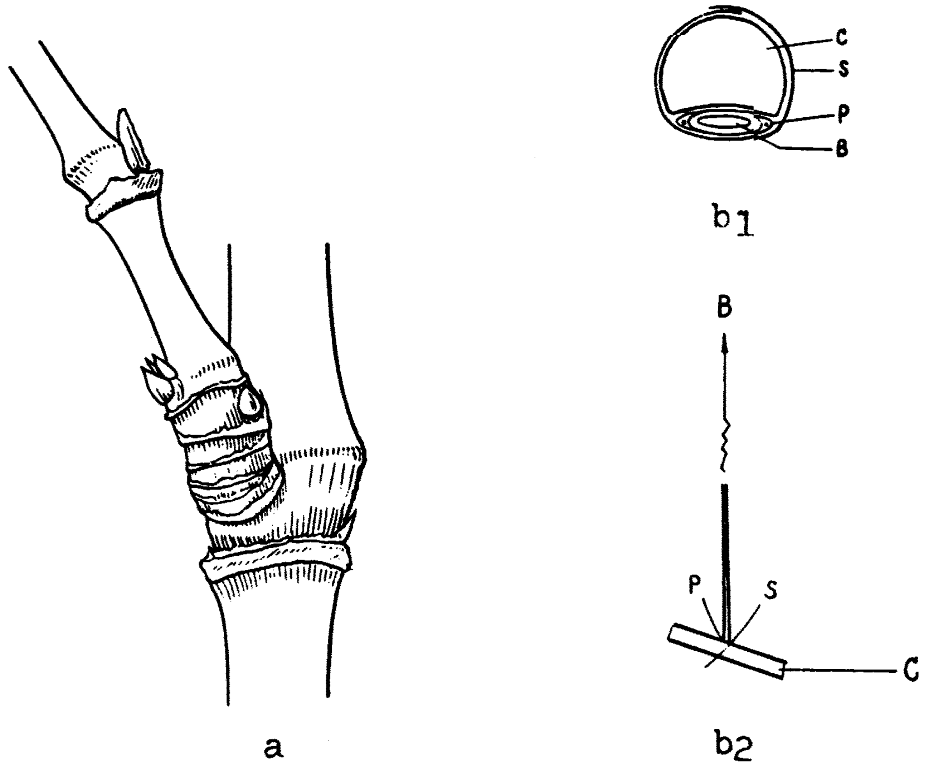


Fig. 5. Single branching pattern a. Solitary branch with constricted budless basal nodes; bl. Cross view of singie branching pattern; b2. Whole view of single branching pattern: C — culm, S — sheath, P — prophyll, B — branch.

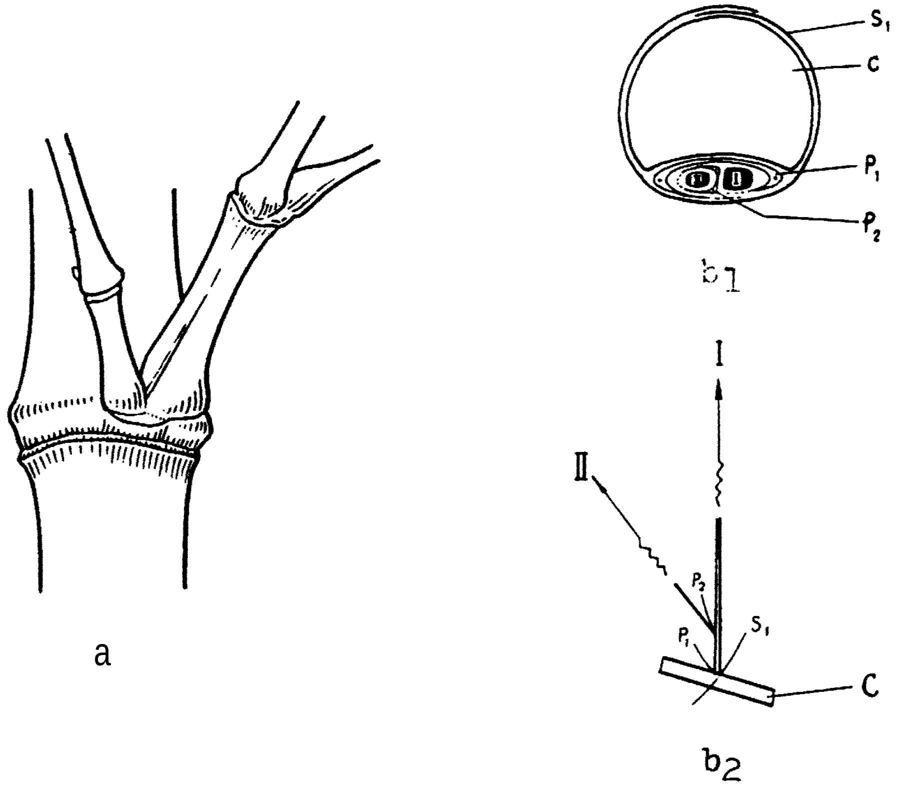


Fig. 6. Double branching pattern. a. Primary branch with a secondary (lateral) branch from first basal node; bl. Cross view of double branching system; b2. Whole view of double branching system. C — culm, Sl — sheath, Pl — prophyll around primary branch (I) and secondary branch (II), P2 — prophyll around only secondary branch.

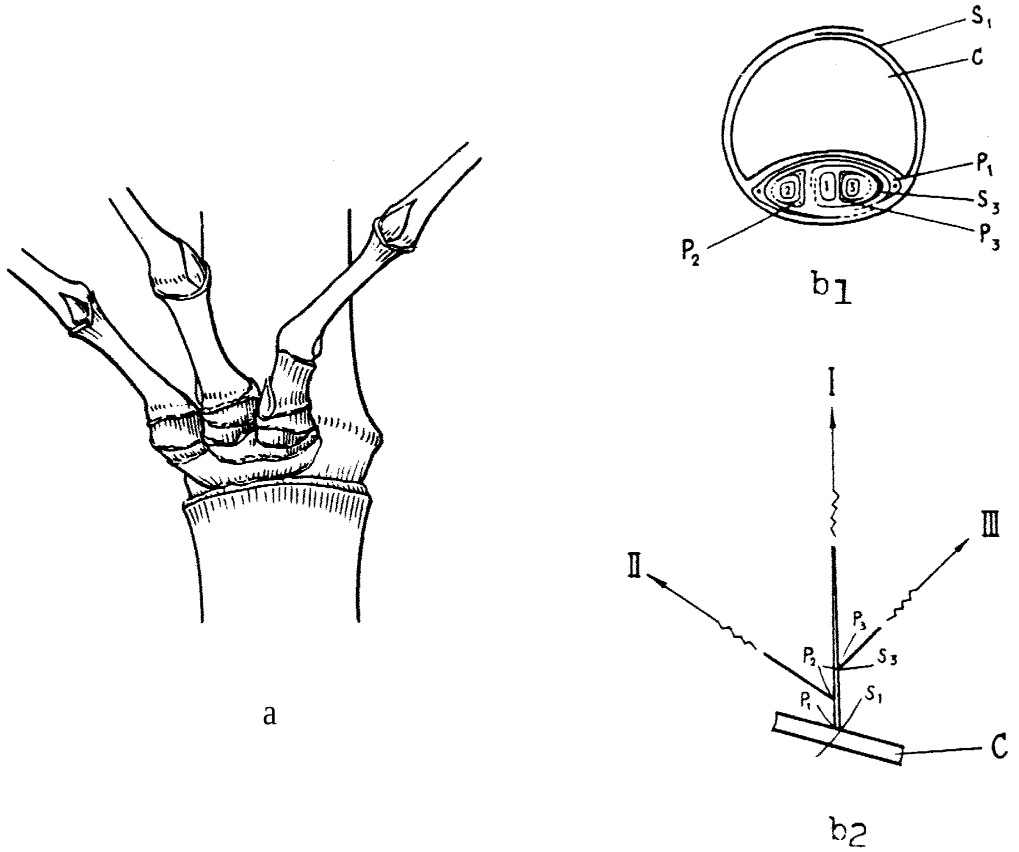


Fig. 7. Triple branching pattern. a. A dominant primary branch with two secondary (lateral) branches on its constricted basal nodes. Note their joined base at an almost same level; bl. Cross view of triple branching system; b2. Whole view of triple branching system. C — culm, Sl — sheath around culm and primary branch and its lateral ones, Pl — prophyll around primary branch (I) and its lateral ones, P2 — prophyll around first lateral branch (II), S3 — around primary branch (I) and second lateral branch (III), P3 — prophyll around only second lateral branch (III).

together as to be formed from a common base at the same level (Fig. 4c). Three buds elongate almost simultaneously into three branches. In the centre is the primary branch which develops from the primary bud and becomes dominant over the laterals on either side. Their loci are clearly fixed in an order according to an alternate reverse overlapping pattern of sheaths as indicated in Fig. 3b. Angles between culm and branches are about 40-50° and those between branches about 30-40°. Such a branching pattern is clearly seen in species of Sinobambusa and Indocalamus (Fig. 7).

Multiple branching bud: On the basis of triple branching, more proliferation occurs at the basal nodes of a primary bud (Fig. 4d, e, f): A branch complement at the midculm nodes comprises a primary branch dominant over the lateral ones. Their basal nodes are closely constricted in a packed order at approximately the same level (Fig. 8). Several metamorphic modes can be distinguished. (1) The joined basal stump of the primary bud and its two laterals is narrow and strongly adnate to the culm. Two or three budless nodes in their lower parts become fairly constricted. Branching occurs on their higher nodes with small culm-branch angles as seen in Arundinaria amabilis (Fig. 8a). (2) The joined basal stump of branches is relatively wide with larger culm-branch angles. Their lower internodes are closely constricted. From either side of their basal nodes branches proliferate more new branches that makes branch complements as illustrated in Arundinaria muculata and Gelidocalamus tessallatus (Fig. 8b, c, d). As this pattern becomes conspicuous, more branching can be expected in a single node particularly with increase in culm age. A similar trend can be visualized acropetally in a single culm (Fig. 9). In general, the more subsequent proliferation

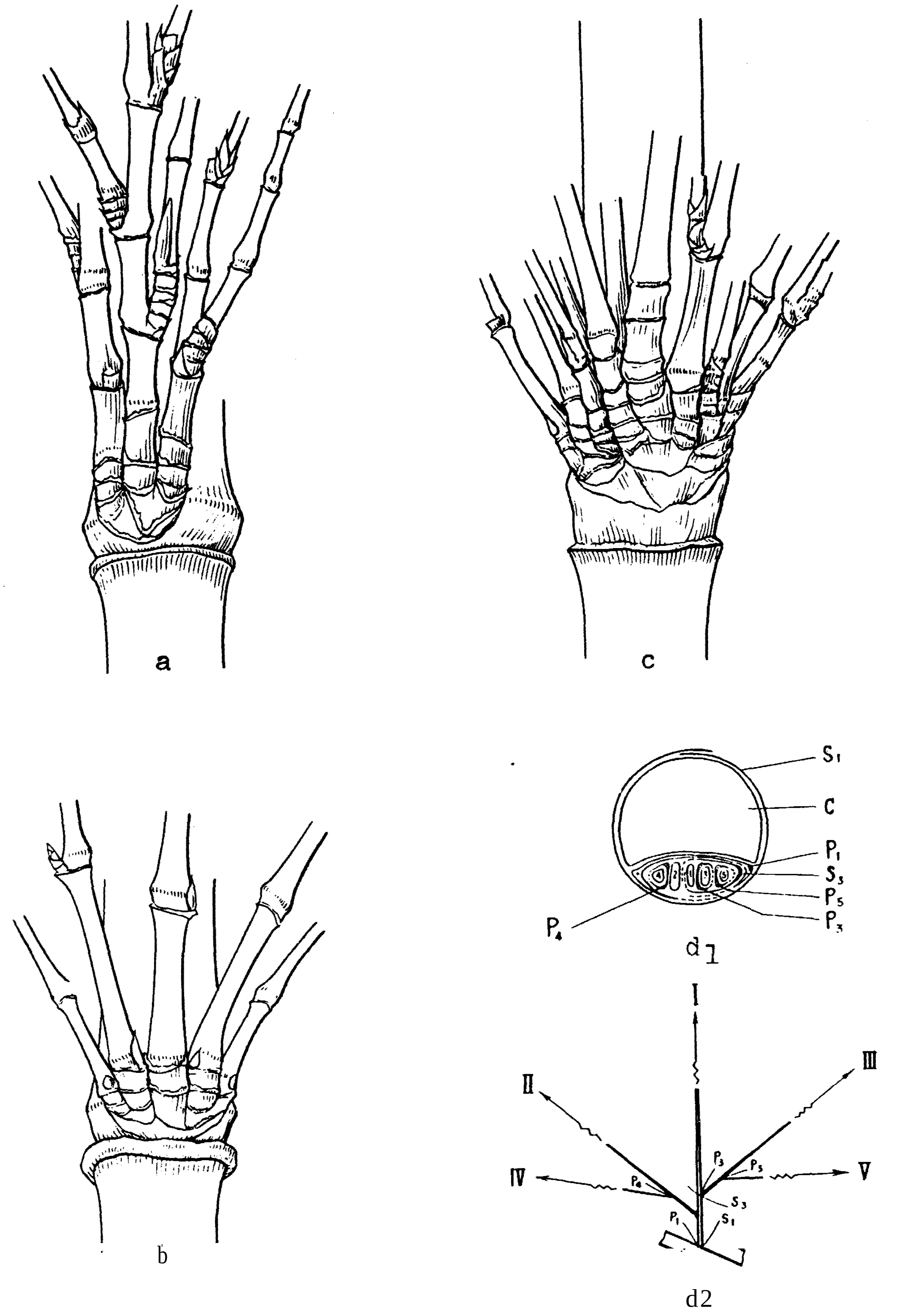
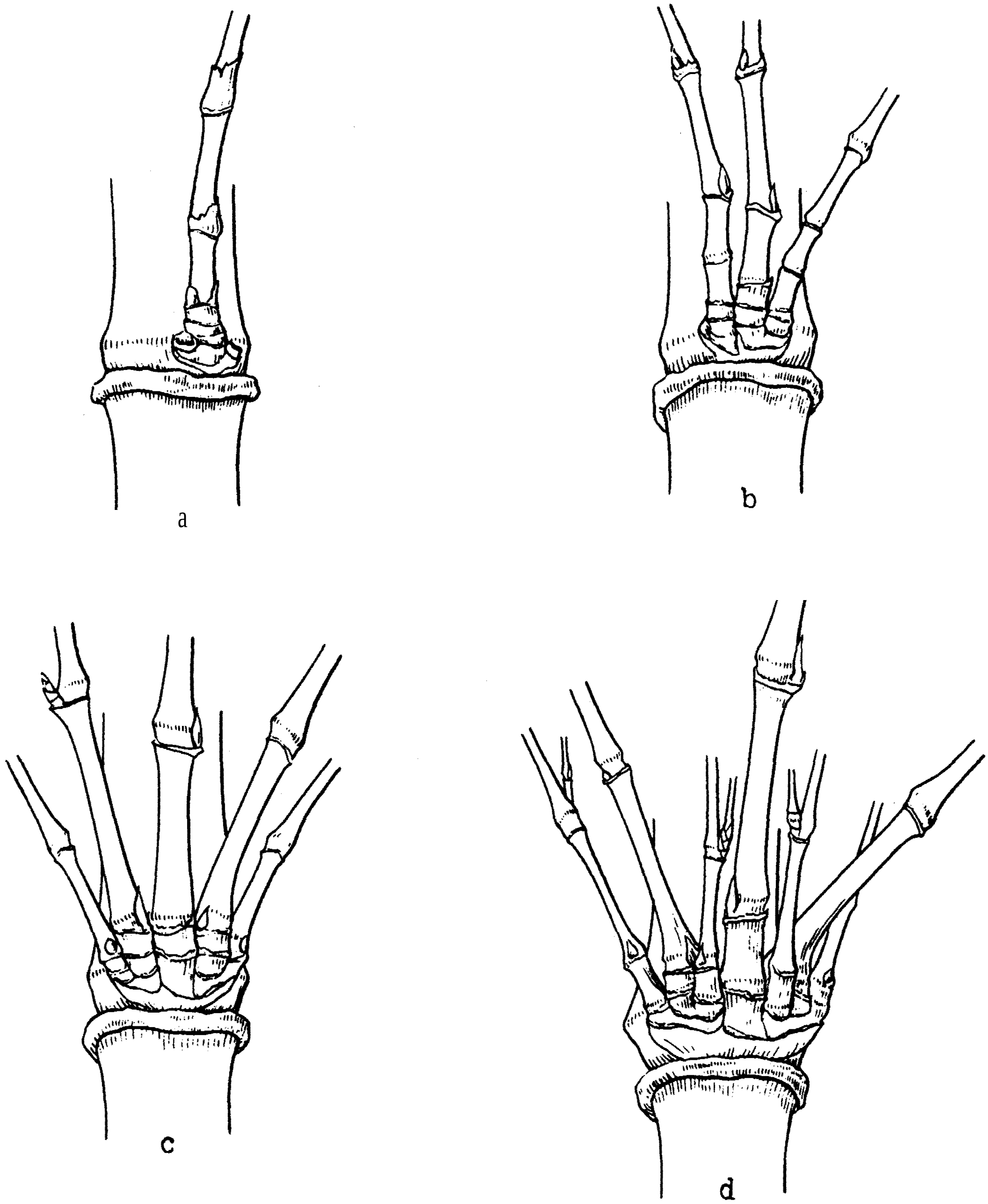


Fig. 8. Multiple branching pattern. a, b, c. Three different types of primary branches with multiple secondary (lateral) branches; dl. Cross view of multiple branching system; d2. Whole view of multiple branching system. C — culm, Sl — sheath around culm and primary branch, PI — prophyll around primary branch (I) and its lateral ones, S3 — sheath around primary branch (I) and its second lateral branch (III), P3 — prophyll around second lateral branch (III) only, P4 — prophyll around third branch (IV), P5 — prophyll around fourth lateral branch (V).



Fig, 9. Branching variations of a single culm **in** Arundinaria *muculata* **from lower nodes (a, b) to middle nodes (c) and upper nodes (d).**

results in the shorter secondary branches. Consequently the culm crown becomes more narrow and the nodal ridge becomes prominent. (McClure, 1967).

Conclusions

In bamboos, sheaths embrace the internodes circumaxially and overlap alternatively in a reverse way that shows a "mirror image symmetry" pattern along either side of the culm and indicates the arrangement of the branching order of individual nodes.

Branching system of monopodial bamboos is monophyletic. A primary bud develops into a primary branch. On its basal nodes lateral buds occur to develop secondary branches. The basal internodes are so closely constructed that they look paired or arising clumped axes at an approximately same level from a common base. The primary bud and its lateral ones elongate almost simultaneously, though their initiation differs in time sequence. Branching behaviour varies greatly even in a species. A typical branching always occurs at the midculm nodes of crown with more above and less below. Multiple branching with short internodes may increase foliage leaves that favour the physiological activity of bamboos.

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Flowering and Seed Characteristics of Bamboos in Thailand

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Abstract

Most commercial bamboo species in Thailand flower sporadically and the flowering occurs in small areas or in a few clumps. Every year, flowering is observed approximately over five months between October to April depending on the species. The existence of the geographic variation in flowering of some bamboo species is also observed. Seeds of bamboos are very different, especially in weight. Within species, there are also variations. Big seeds show higher percentage germination than small ones. Germination is highly correlated with moisture content of the seed. Seeds were infected by fungi which destroy the seeds during storage, as proper seed storage is very necessary to facilitate bamboo propagation by seeds.

Introduction

Bamboo is one of the most commercially important multipurpose plants in Thailand. The uses of bamboos, as food, versatile construction material, manufacture of farm implements, various household utensils and raw materials for the cottage industry are well known. The rural people of Thailand depend on bamboos in many facets of their daily lives. This heavy dependence has in recent years seen a drastic reduction of bamboos in the country except for a few restricted areas. People grow bamboo unmindful of any silvicultural, biological and ecological importance of the species. Selection and gropagation of good quality bamboos in the different parts of the country are made with inadequate information.

Bamboos can be propagated both vegetatively and by seeds. Rural people generally propaqate bamboos vegetatively by rhizomes and culm cuttings. However, for large scale plantation, these methods are not appropriate. Due to the scarcity of planting material and transport costs, it is also not economical. Success of propagation depends on age, season, nature and location of propagating material, and it can be poor (Guha et al, 1976; White, 1947, Ueda, 1960; Hasan, 1977; Cabanday, 1957). On the other hand, propagation through seeds is not always possible due to inadequate supply. Generally, bamboos have long intervals between flowering. Moreover, it is impossible to predict the exact year or age at which bamboos will produce seeds. However, studies have been done to determine the exact seedling cycle (from seed year to seed year) of some bamboo species (Blatter , 1929- 1930; Blatter and Parker, 1929; Bowden, 1950; Wang and Chen, 1971). The results of these studies indicate the diversity of the bamboo flowering and seeding cycles.

In Thailand, bamboos flower and seed every year involving different species and locations. In some locations, more than one species will flower and seed. Therefore, to establish bamboo plantations in future, propagation through seeds would be the most promising method. Further research into the flowering and seeding characteristics is essential. The study of flowering and seeding of bamboos in Thailand reported here was initiated in February, 1983 with financial support from IDRC.

In general, bamboos flower sporadically and gregariously. With the exception of *Gigantochloa hasskarliana* in Kanchanaburi

Province, where they flower every year in small areas or in a few clumps. G. hasskarliana sometimes flowers well in Kanchanaburi Province. The earliest flowering starts in October and ends in February when seeding begins. Seeds are transferred four months later. Bamboos flower over five months in Thailand regardless of locations. The species that flower every year are Arundinaria *pusilla, Bambusa arundinacea, B. nutans, B.* blumeana, *Cephalostachyum pergrade, C. virgatum, Gigantochloa albociliata, G. hasskarliana, G. apus, Thyrsostachys oliveri,* and *T. siamensis.* These are commercial species and, given this characteristic of annual seeding, possess the potential for propagation in large scale plantations.

Seed Characteristics Of Some Bamboo Species

The characteristics studied included seed weight, germination, and seed-borne pathogens. Seed samples were collected from 43 locations in nine provinces of the northern and central parts of Thailand (Table 1, Fig. 1), of which 11 were commercially important. All

Table 1. Bamboo seed collection in Thailand.

Seed number	Species	Location District, Province	Weight(gm)
1	*Dendrocalff mus strictus*	Mae Sarauy, Chiangrai	138.3
2	D. strictus	Mae Sarauy, Chiangrai	582.9
3	D. strictus	Mae Sarauy, Chiangrai	214.3
4	D. strictus	Muang, Maehongsorn	19.4
5	D. strictus	Muang, Maehongsorn	59.8
6	D. strictus	Muang, Maehongsorn	4.6
7	D. stricfus	Maerim, Chiangmai	25.3
8	D. strictus	Maerim, Chiangmai	125.3
9	*D. strictus*	Chiangdao, Chiangmai	3.4
10	D. strictus	Watbost, Pitsanuloke	348.3
11	D. *strictus*	Watbost, Pitsanuloke	15.2
12	D. strictus	Srisatchanalai, Sukothai	27.6
13	D. strictus	Boploy, Kanchanaburi	279.7
14	D. strictus	Boploy, Kanchanaburi	36.3
15	D. strictus	Ngao, Lampang	127.3
16	D. strictus	Ngao, Lampang	24.3
17	D. strictus	Ngao, Lampang	29.9
18	D. strictus	Jaehom, Lampang	208.0
19	D. gigan teus	Muang, Tak	90.2
20	D. hamiltonii	Mae Sarauy, Chiangrai	54.4
21	D. hamiltonii	Chiangdao, Chiangmai	12.5
22	Bambusa nutans	Ngaw , Lampang	60.1
23	B. nutans	Ngaw, Lampang	34.9
24	B. nutans	Ngaw , Lampang	1,625.8

Table 1. Bambao seed collection in Thailand. (cont'd)

Seed number	Species	Location District, Province	weight (gm)
25	B. arundinacea	Song, Prae	loo.4
26	B. arundinacea	Thongpapoom,Kanchanaburi	292.2
27	B. arundinacea	Thongpapoom, Kanchanaburi	139.6
28	B. arundinacea	Boploy, Karnchanaburi	118.1
29	B. arundinacea	Muang, Tak	27.9
30	*B. arundinacea*	Ngao, Lampang	11.0
31	Gigantochloa compressa	Srisatchanalai, Sukothai	12.2
32	G. hasskarliana	Thongpapoom, Kanchanaburi	532.7
33	G . albociliata	Maesarauy, Chiangrai	121.3
34	G. albociliata	Watbost, Pitsanuloke	137.7
35	G. albociliata	Watbost, Pitsanuloke	94.6
36	G . albociliata	Ngao, Lampang	28.1
37	*Melocalamus compactiforus*	Boploy, Kanchanaburi	15.3
38	*Thyrsostachys* siamensis	Boploy, Kanchanaburi	10.4
39	*T. siamensis*	Muang, Tak	14.5
40	*T. siamensis*	Ngao, Lampang	82.1
41	*T. siamensis*	Watbost, Pitsanuloke	2.0
42	*T. siamensis*	Cna-urn, Petchaburi	706.0
43	*Schizostachyum blumii*	Srisatchanalai, Sukothai	12.2

the seeds were separately cleaned and stored in the refrigerator at approximately 5°C prior to measurements.

Seed weight characteristic: In order to determine the variation in seed weight, five groups of'randomly selected seeds, 40 per group, were sampled (Table 2). The weights of bamboo seeds varied specifically. There were also variations in seed weight of D. strictus collected from different locations (Table 3). The results of the study can be used as the basic information for future seed collections. In general, big seeds produced larger seedling than small seeds. With this fact, seed weight may be used as the key in selection for predetermining the quality of the seedling.

The samples of 100 randomly selected seeds from each of the collected samples were used in determining percentages, All seed samples were separately sowed in the sterilized sand trays under open greenhouse condition. Germination percentages were determined by counting the total number of the germinated seeds. Of the 40 seed trials, seeds of 26 germinated (Table 4), whilst those of others did not germinate due to immaturity of the seeds. The % germination ranged from 86 to 1 percent and T. siamensis from Petchaburi Province had 86% germination. There were also geographic variations in seed germination.

Correlation was found between germination percentage and the moisture content of seeds. The species used and the places of collection are given (Table 5, Fig. 2). This information can be used in conducting the storage experiments for the specific bamboo seeds, in order to prolong the viability of the seed fqr the future uses.

Seed-borne pathogens of some bamboo species: Seed-borne pathogens of ***D. strictus, B. nutans, B. arundinacea, G. hasskarliana,*** **and** ***T. siamensis*** were studied.

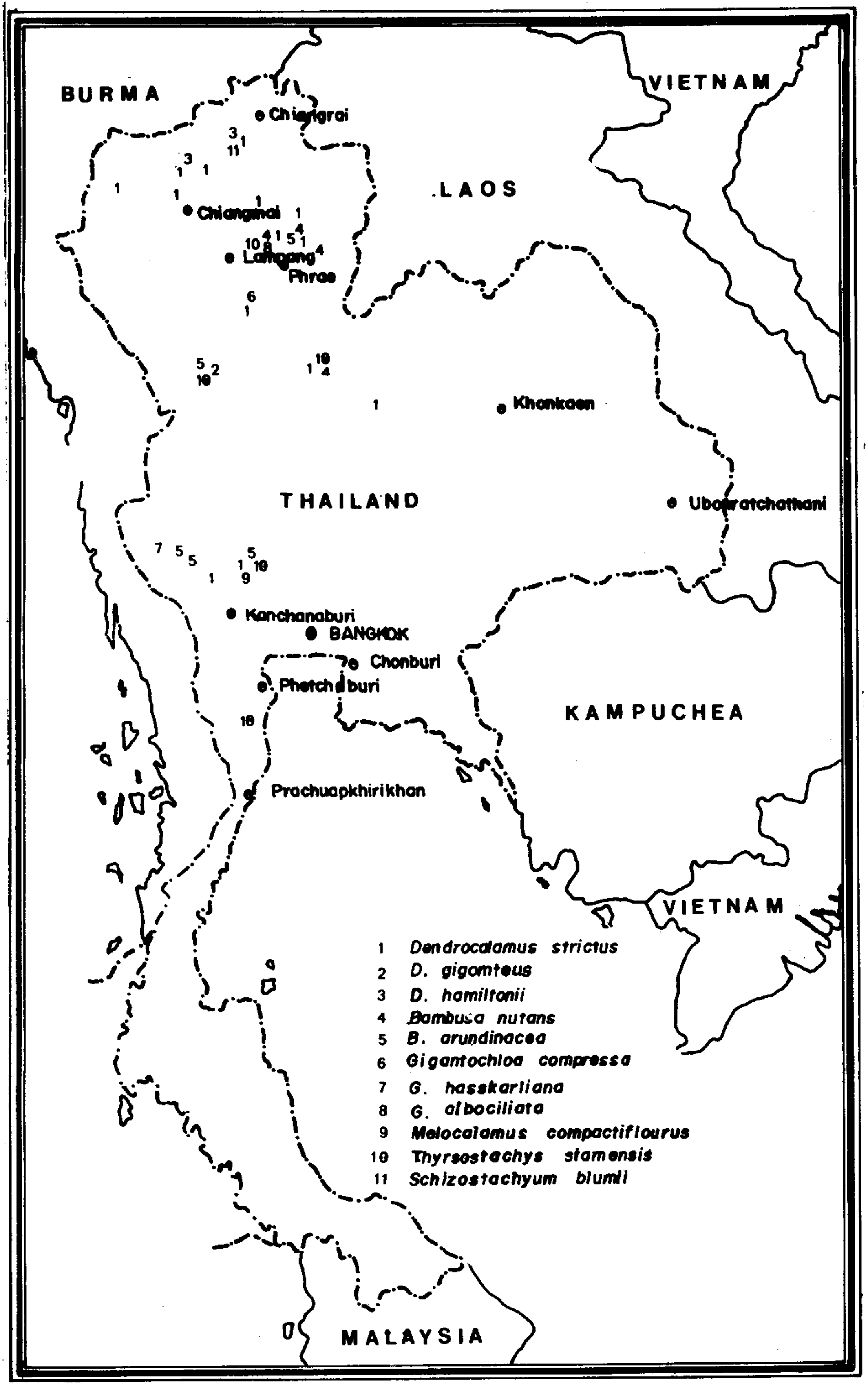

Fig. 1. Locations of bamboo seed collection.

Table 2. Variations in seed weight of some bamboos in Thailand.

Species	Location (Province)	Mean (g)	Standard Deviation	C.V.	Range
Dendrocalamus strictus	Kanchanaburi	0.4327	0.0352	8.139	.0241
D. strictus	Chiangrai	0.9450	0.0907	9.5955	.2494
D. strictus	Lampang	1.2120	0.0293	2.4194	.0901
D. strictus	Chiangrai	1.4180	0.1449	10.2221	.4754
D. strictus	Lampang	0.7360	0.0559	7.5925	.2002
Thyrsostachys siamensis	Petchaburi	0.6190	0.0141	2.2843	.0398
Bambusu nutans	Lampang	0.2750	0.0205	7.4615	.0601
B. nutans	Prae	0.4770	0.0161	3.3754	.0434
Gigantochloa hasskarliana	Kanchanaburi	0.3810	0.0230	6.0484	.0884
Bambusa arundinocea	Kanchanaburi	0.4160	0.0148	3.5641	.0471

Table 3. Geographic variation in seed weights of Dendrocalamus strictus in Thailand.

S.O.V.	df.	S.S.	M.S.	F
Locations	5	3.28292	0.65658	112.79644’ •
Errors	24	0.13970	0.00582	
Total	29	3.42262		

• *Significant at the 0.01 level of probability.

S.O.V. = source of variance
df. = degree of freedon
S.S. = sum of squares
M.S. = mean square
F = frequency

Table 4. Germination percentage of bamboo seeds.

Seed No.	Species Local Name: Scientific Name	Location District: Province	Germination %
1	Pai Pak: Gigantochloa hasskarliana	Thongpapoom: Kanchanaburi	3
2	Pai Rai: G. albociliata	Mae Sauy: Chiangrai	3
3	Pai Rai: G. albociliata	Ngao: Lampang	3
4	Pai Rai: G. albociliata	Wat Bost: Pitsanuloke	1
5	Pai Sangbom: *Dendrocalamus strictus*	Ngao: Lampang	70
6	Pai Sangbom: *D. strictus*	Mae Sauy: Chiangrai	4
7	Pai Sangbom: *D. strictus*	Jaehom: Lampang	83
8	Pai Sangbom: *D. strictus*	Ngao: Lampang	–
9	Pai Sangbom: *D.* strictus	Srisatchanalai: Sukhothai	–
10	Pai Sangbom: *D. strictus*	Muang: Maehongsorn	83
11	Pai Sang: D. *strictus*	Mae Sauy: Chiangrai	4
12	Pai Sang: D. *strictus*	Wat Bost: Pitsanuloke	1

Table 4. Germination percentage of bamboo seeds (cont'd)

Seed No.	Species Local Name: Scientific Name	Location District: Province	Germination %
13	Pai Sang: D. strictus	Thasanun: Kanchanaburi	9
14	Pai Sang: D. strictus	Mae Sauy: Chiangrai	4
15	Pai Sang: D. strictus	Maeteep: Lampang	2
16	Pai Sang: D. strictus	Ban Maeprao: Lampang	3
17	Pai Sang: D. strictus	Ngao: Lampang	6
18	Pai Sang: D. strictus	Boploy: Kanchanaburi	35
19	Pai Hokyai: D. hamiltonu	Chiangdao: Chiangmai	–
20	Pai Hokjae: D. *hamiltonu*	Chiangdao : C hiangmai	–
21	Pai Hok: D. hamiltonu	Mae Sauy: Chiangrai	–
22	Pai Wan: D. giganteus	Larnsang: Tak	3
23	Pai Sang: Kee: D. strictus	Muang: Petchaboon	79
24	Pai Ruak: Thyrsostachys siamensis	Larnsang: Tak	10
25	Pai Ruak: T. siamensis	Chaum: Petchaburi	86
26	Pai Ruak: T. siamensis	Ngao: Larnpang	7
27	Pai Bong: Bambusa *nutans*	Boploy: Kanchanaburi	1
28	Pai Bong: B. nutans	Song: Prae	–
29	Pai Bong: B. nutans	Ngao: Lampang	–
30	Pai Bong: B. nutans	Song: Lampang	–
31	Pai Bong: B. *nutans*	Song: Prae	–
32	Pai Bong: B. nutans	Ngao: Lampang	3
33	Pai Pa: B. arundinacea	Ngao: Lampang	–
34	Pai Pa: B. arundinacea	Thongpapoom: Kanchanaburi	3
35	Pai Pa: B. arundinacea	Boploy: Kanchanaburi	1
36	Pai Pa: B. arundinacea	Muang: Tak	10
37	Pai Pa: B. arundinacea	Ban Tungna: Kanchanaburi	–
38	Pai Hangchang: *Melocalamus* compactiflorous	Srisatchanalai: Sukhothai	–
39	Pai Kainai: –	Srisatchanalai: Sukhothai	–
40	Pai Hia: *Cephalostachyum* virgatum	SrisatchanaIai: Sukhothai	–

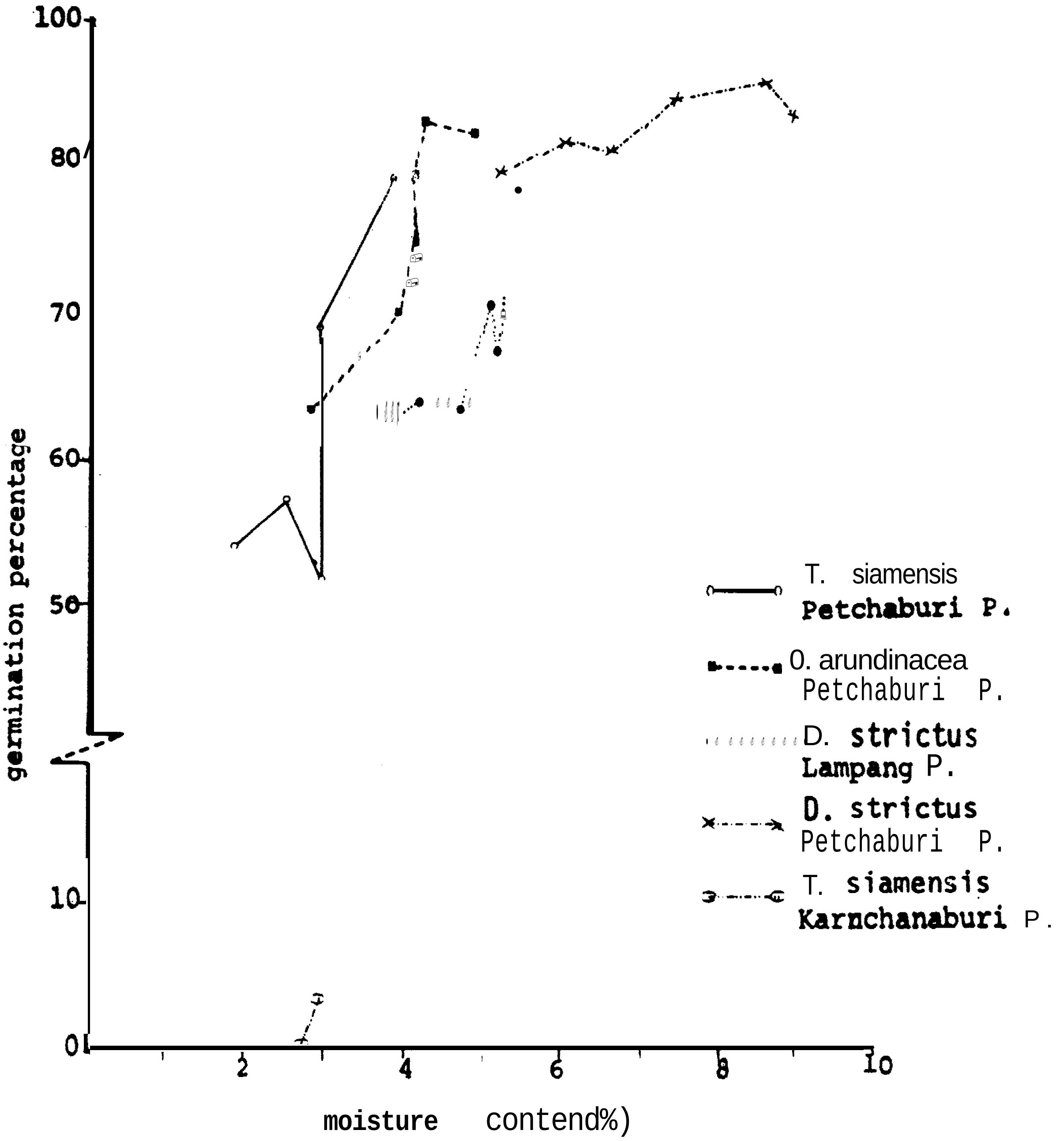

Fig. 2. The correlation between germination percentage and moisture content of some bamboo species in Thailand.

Table 5. The correlation between germination percentage and moisture content of some bamboo species in Thailand.

Species/location	Y = a + b X	R^2	r	S.D.
T. siamensis/Petchaburi Province	23.5 + 13.7X	0.724	0.851	6.6
T. siamensis, Kanchanaburi Province	– 1.4 + 1.02x	0.369	0.607	1.1
D. strictus/Lampang Province	35.5 + 6.8X	0.623	0.789	3.8
D. strictus/Petchaburi Province	72.4 + 1.3X	0.734	0.856	1.4
B. arundinacea/Petchaburi Province	33.8 + 10.3x	0.785	0.886	4.0

R* = coefficient of determination
r = coefficient of correlation
S.D. = standard error of estimate

The determination of seed-borne fungi was based on using the blotter method of the International Seed Testing Association (ETA). Four hundred seed samples were tested. For each species, 20 seeds were placed on moist filter paper in the petri-dish for a total of 20 replicates. Consequently, they were placed in the incubator that composed of the near ultraviolet lamps which automatically turned on and off every 12 hours. The temperature in the incubator was 30 ± 5OC. The seed samples were incubated for the total of five to seven days. After the incubation period, seed-borne fungi were identified. The results indicated that there were altogether 48 species of fungi obtained from seed samples, including 13 parasitic and saprophytic species (127.1%) and 35 others (72.9%). (Table 6).

Table 6. Seed-borne fungi of some bamboo species of Thailand.

Species number	Seed-borne fungi
1	Alternaria longissima .
2	*A. tennuis* .
3	*Arthrinium sp.*
4	*Ascochyts sp.*
5	*Ascomycetes*
6	*Aspergillus flavus*
7	*A. niger*
8	*A. wentii*
9	Beltrania sp.
10	*Chaetomium sp.*
11	*Cladosporium sp.*
12	*Curvularia borreriae*
13	*C. brachyspora*
14	*C. cragrostidis*
15	*C. geniculata*
16	*C. lunata*
17	*C. oyzae*
18	*C.* pallescens
19	*C. senegalensis*
20	*C. stapeliae*
21	*Dinemasporium sp.*
22	*Drechslera halodes*
23	*D. hawaiiensis*
24	*D. papendorjii*
25	*D. rostrata*
26	*D. tetramera*
27	*Epicoccum sp.*
28	*Fusarium equiseti*

Table 6. Seed-borne fungi of some bamboo species of Thailand (cont'd)

Species number	Seed-borne fungi
29	Fusurium *semitectum* .
30	*Fusarium sp.* .
31	*Graphium sp.* '
32	*Memnoniella sp.* .
33	Mucor sp.
34	*Myrothecium sp.* *
35	Nigrospora oryzae *
36	*Nodulosporium sp.*
37	*Penicillium sp.*
38	*Periconia sp.*
39	*Periconia tiratupatiensis*
40	*Phaeotrichoconis sp.*
41	*Phoma sp.* *
42	*Phomopsis sp.* .
43	*Pithomyces sp.*
44	Rhizopus *sp.*
45	Stachybotrys sp.
46	*Stemphylium sp.* .
47	Torula sp.
48	Trichoconis padwickii .

'parasitic *fungi*

Some fungi were common and others were seed specific. However, the parasitic fungi affecting seed and seedling quality are the most important ones we need to be concerned with. The parasitic fungi that were found on the seeds of the studied bamboos are shown separately in Table 7.

When compared with the other forest tree seeds, there were more fungi species on bamboo seeds. This indicated that time of seed collection, cleaning processes, storage conditions, and duration of bamboo seed storage were the major factors in developing bamboo plantation in the future.

The propagation of bamboos through seeds is one of the most promising methods in cultivation of bamboos in Thailand. Most valuable bamboo species flower sporadicaily, and seeds are available. Studies relating to seed, e.g., selection of desirable characteristic of bamboo for specific uses, genetics, variation pattern, determination of seedling establishment, seed dispersion, and natural regeneration, need to be investigated further.

Table 7. Percentage of the bamboo seeds and the parasitic fungi by using the blotter method.

Parasitic fungi	Percentage of bamboo seed				
	D. strictus	B. nutans	B. arundinacea	G. hasskarliana	T. siamensis
Alternaria longissima	1.25	–	0.25	–	–
A. tenuis	9.75	0.50	–	0.25	0.75
Ascochyts sp.	–	0.25	–	–	–
Curuularia lunata	11.00	2.25	1.25	4.25	5.50
Fusarium semitectum	13.50	1.25	0.25	89.00	0.25
Fusarium sp.	–	2.50	1.50	–	–
Graphium sp.	–	–	0.75	6.25	–
Myrothecium sp.	–	–	0.25	2.75	0.50
Nigrospora oryzae	61.50	1.50	–	0.50	–
Phoma sp.	2.75	0.25	–	0.75	–
Phomopsis sp.	0.25	–	–	–	–
Stemphylium sp.	0.25	–	–	–	–
Trichoconis padwickii	2.00	–	–	0.25	–

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Studies on Vegetative Propagation of Bambusa and Dendrocalamus Species by Culm Cuttings

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Abstract

Investigations have been undertaken to determine some of the factors that limit root production in *culm cuttings* of Bambusa *species. Whole culms* of Bambusa nutans gave *successfully rooted shoots in 8.8% of nodes and polythene tunnels did not improve the performance. The reasons for the high percentage of failure is explained. In comparison 70 – 84 % cuttings* of Dendrocalamus hamiltonii *and* D. hookeri *produced rooted shoots. The reorientation of noded cuttings in* Bambusa nutans gave *an overall success rate of 59.5%. Competition from strong non-rooting shoots was shown to reduce rooting and a further simple refinement of the planting technique was shown to allow more shoots to root and at the same time reduce competition, giving* a *75% success rate. Further improvements are* suggested.

Introduction

Large stature bamboos of the genera *Bambusa* and *Dendrocalamus* are very important in the rural economy of Nepal. Being multi-purpose species they provide constructional materials, animal fodder, fuelwood, food, and woven products for agricultural and domestic purposes, as well as baskets for transport of most commodities beyond the roadheads in the hills. Planting large bamboos has in the past been severely restricted by lack of seed and lack of knowledge concerning' improved vegetative propagation techniques, The traditional offset cutting has been used almost exclusively in Nepal until very recently.

Short culm cuttings offer many advantages over the traditional cutting. An average clump may provide only about five traditional cuttings each year without a severe reduction in clump vigour and productivity, while up to one or two hundred single-node culm cuttings can be taken without affecting clump productivity or disturbing the rhizome system. Traditional cuttings can weigh up to 40kg. each, making transport extremely difficult. Each culm cutting weighs about 1/2kg or less. Traditional cuttings retain certain advantages (Stapleton and Tamrakar, 1983). Nursery facilities are not required; survival is very good even under extremely arduous conditions; protection against grazing animals is much easier and establishment is quicker. The problems of communication and transport in the hills of Nepal and the simple nature of most forest nurseries impose severe restrictions upon propagation techniques.

Investigations as how to improve the success of culm cuttings in Nepalese *Bambusa* species which do not root readily have been undertaken for the past three' years. They have shown a few interesting factors which seem to restrict rooting and some methodsbf overcoming the limitations which they impose.

Literature review

It is known for a long time that bamboos vary greatly in their ability to root from culm cuttings and Troup (1921) recorded the relationship between rooting ability and the abundance of roots on the culm. McClure (1966) refined this method relating rooting ability to root abundance on central branch bases in the mid- culm region. Beyond these basic observations it would appear that very little is known as to why this is or how reluctant species can be persuaded to root. It has been pointed out (McClure, 1966; Soderstrom and Calderon, 1979; Xiong et al, 1980) that bamboos have received little attention in the more fundamental aspects of morphology, physiology , and propagation and consequently there does not appear to be a standard cutting, nor adequate guidance for selection of the best material for propagation. As far as simple vegetative propagation is concerned there is a substantial amount of information available, although it is widely dispersed in the literature and often a little contradictory.

Recently important advances have been made in the more sophisticated fields of propagation such as tissue culture and use of several growth-regulating substances (Huang and Murashige, 1983; Wang, 1981; Seethalakshmi et al, 1983) but such techniques are not necessarily relevant to the basic forest nurseries often encountered in the less developed countries,

For material selection both morphological and physiological characters have been discussed. Riviere and Riviere (1879) were among the first to appreciate the similarity between the swollen central branch base and the rhizome in many genera and its potential value in propagation. They found that inclusion of a pact of the culm was essential for the branch base to successfully produce rooted plants which was also supported by the findings of Prange (1974). Gupta and Pattanath (1976) showed that the physiological state of the culms was important for subsequent shoot production, although Azzini and Ciaramello (1978) could not improve rooting by supplying glucose solutions. McClure and Kennard (1955) showed how different species had different optimum ages for taking cuttings, and McClure (1966) suggested that this could be due to variations between bud development and the physiological materials and food reserves in supporting tissues. McClure (1973) and Hasan (1982) initiated studies into branch complement structure and development and further studies are needed for a good understanding of the correction factors.

Physiological conditions of plants are important to obtain cuttings. It is known from experience in other plants that the optimum time is often immediately prior to growth initiation in the plant's normal cycles. McClure (1966) described this as the end of the dry season for bamboos in his group I, although growth in branches usually commences several months earlier and experience has shown early spring to be best for these bamboos, (Gupta and Pattanath, 1976; Dai, 1981).

In order to make the best use of finite resources of cutting material it must be planted in a manner which will give the greatest number of plants. Cabanday (1957) undertook comparisons of whole cuims, two-node cuttings, and single-node cuttings. From his results it would appear that single-node cuttings gave the greatest number of rooted shoots per culm used, although the success rate was not the highest. Similarly Dai (1981) showed that whole culms. partially severed between the nodes were more productive than uncut culms, although his culms still had the rhizomes attached. Medina et al (1962) and others have reported that horizontal cuttings are more successful than vertical or oblique ones. Although it has been observed that the environment is not the limiting factor in many cases (Hasan., 1980), Abeels (1962) reported that waterlogged conditions were not successful, and Khan (1972) found clay soil to be better than silty sand. McClure (1966) attributed some of his failures to insufficient irrigation.

Comparison of different trials is often difficult as most authors have used different criteria. Some reports of success have been based upon shoot production alone without any evaluation of rooting. Others have considered both shoot and root production as important and successful, Some authors only consider propagation successful when a clump has been established under field conditions, which vary greatly, and this appears as a stringent criterion. McClure (1966) gave the required features of a truly successful cutting as one which carries a bud that developed into a rhizome from which new rooted shoots had arisen. He used the term rhizome in a'black and white' sense which may have obscured the potential transition between partially rhizomatous shoot bases and true rhizomes in his group I bamboos.

1983: Bambusa nutans trial

The method adopted in this first propagation attempt was the standard technique used by McClure and Kennard (1955) in Puerto Rico: shallowly burying entire two-year-old culms severed above the rhizome in March with branches trimmed back to 10cm. The environment was improved by shading and irrigating the loamy beds and by putting sealed polythene tunnels over two treatments with different irrigation regimes, Eighteen twelve-meter culms were planted with a total of 487 nodes, most of these bearing many branches with viable buds, giving several thousand shoots from several orders of branching arising in different orientations at different soil depths.

Evaluation after seven months showed an overall mean production of only 2.2 rooted plants per culm, with successful plants arising from only 8.8% of the nodes, and no significant differences between the treatments. McClure and Kennard (1955) had obtained between 9.4 and 28.7 plants from 12-meter lengths of four other Bambusa species, which suggests that Bambusa nutans is very reluctant to root indeed. This is backed up by its morphology. It is a bamboo of extremely fine form, with no trace of aerial root production or the nodal swelling associated with it.

Limitations to rooting did not appear to be environmental, as there were no significant differences between treatments with and without polythene tunnels to prevent desiccation. To look for other reasons why the shoots had not rooted, all nodes were excavated and carefully examined. This yielded more useful results than the quantitative evaluation of the treatments. Four factors which had limited the development of rooted plants were observed:

1. Firstly it was seen that at all except the very basal nodes, the only buds which gave rise to rooted shoots were on the base of the central branch. Buds from no other branches produced rooted plants, merely vigorous shoots.

2. Secondly it was observed that only when these shoots underwent a reorientation through the horizontal did they produce roots. In attaining the light and responding to gravitational stimuli they assumed a curving shape similar to the normal rhizome, and rooted from the curving basal portion which had a shorter first extended internode than found in shoots which went straight upwards and which never rooted (Fig. 1).

3. Thirdly, shoots which arose too deeply in the soil and could not quickly reach the light died before doing so.

4. Fourthly there were several shoots which had rooted, but died. There seemed little reason for this but it was also noted that the successfully rooted shoots had not initially grown as vigorously as others.

Thus it was seen that while B. nutans appeared to be a very reluctantly rooting species, there were several identifiable factors which limited rooting. It seemed there was potential for improving the performance by planting the material more suitably so that basal buds from the central branches faced in the correct direction at the correct soil depth at all nodes.

1984: Dendrocalamus hamiltonii and Dendrocalamus hookeri trials

To confirm and demonstrate the superior rooting of Dendrocalamus species with abundant aerial roots two culms of each species were planted with a further seven culms of Bambusa nutans for comparison. Conditions in the nursery were very arduous and only 5.5% of nodes of B. nutans produced rooted shoots. In contrast D. hamiltonii produced rooted shoots from 70% of nodes while D. hookeri produced them from 84% of the nodes. While branch development in Nepalese Bambusa species is very uniform along the culm it varies considerably in Dendrocalamus species. Three types of branch development were found. At the base of the culm the central branch was about the same size as in Bambusa species. Higher up the culm, it was either represented by a large bud or was well developed with a very large prolifically rooting base bearing large buds. Both Dendrocalamus species produced most abundant rooting from the central branch as it developed, it had a bud at planting, or from shoots from its basal buds if it had already been developed Shoots reorientated horizontally produced more roots than those which were vertical.

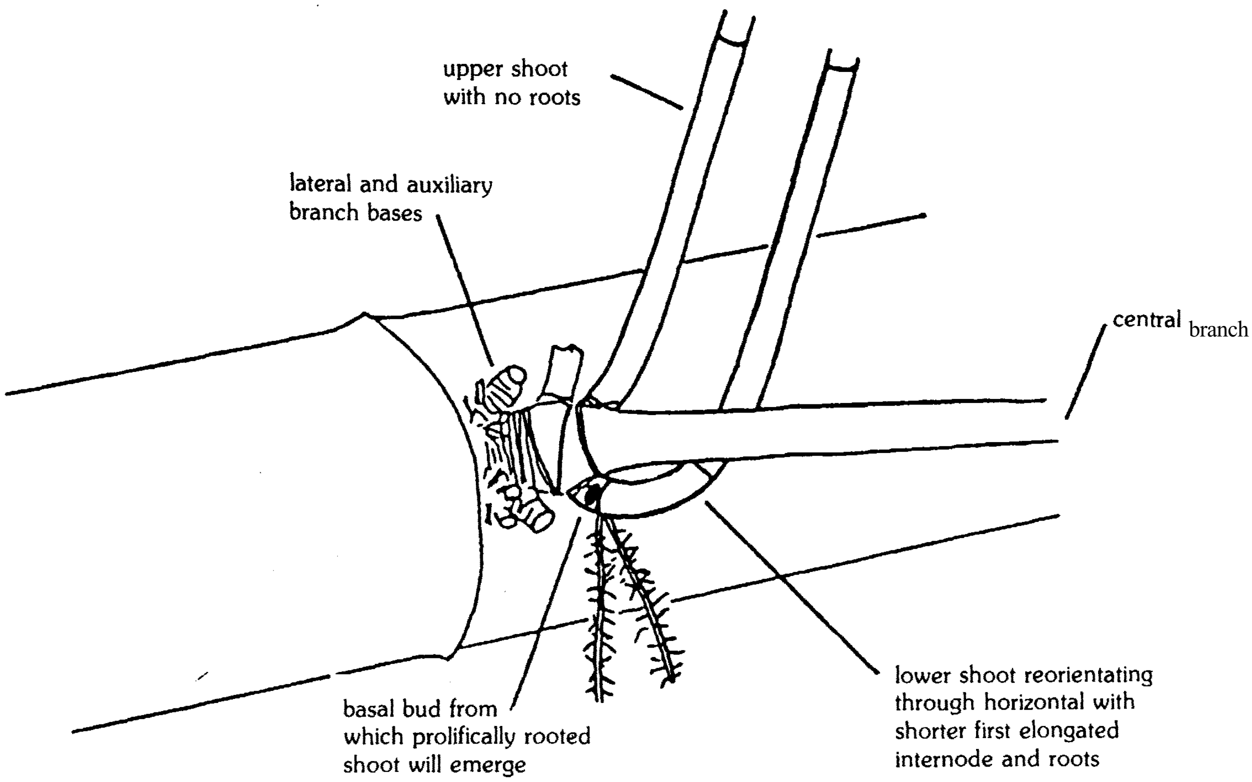


Fig. 1. Reorientating and rooting lower shoot and non-reorientating non-rooting upper shoot from central branch base in Bambusa nutans,

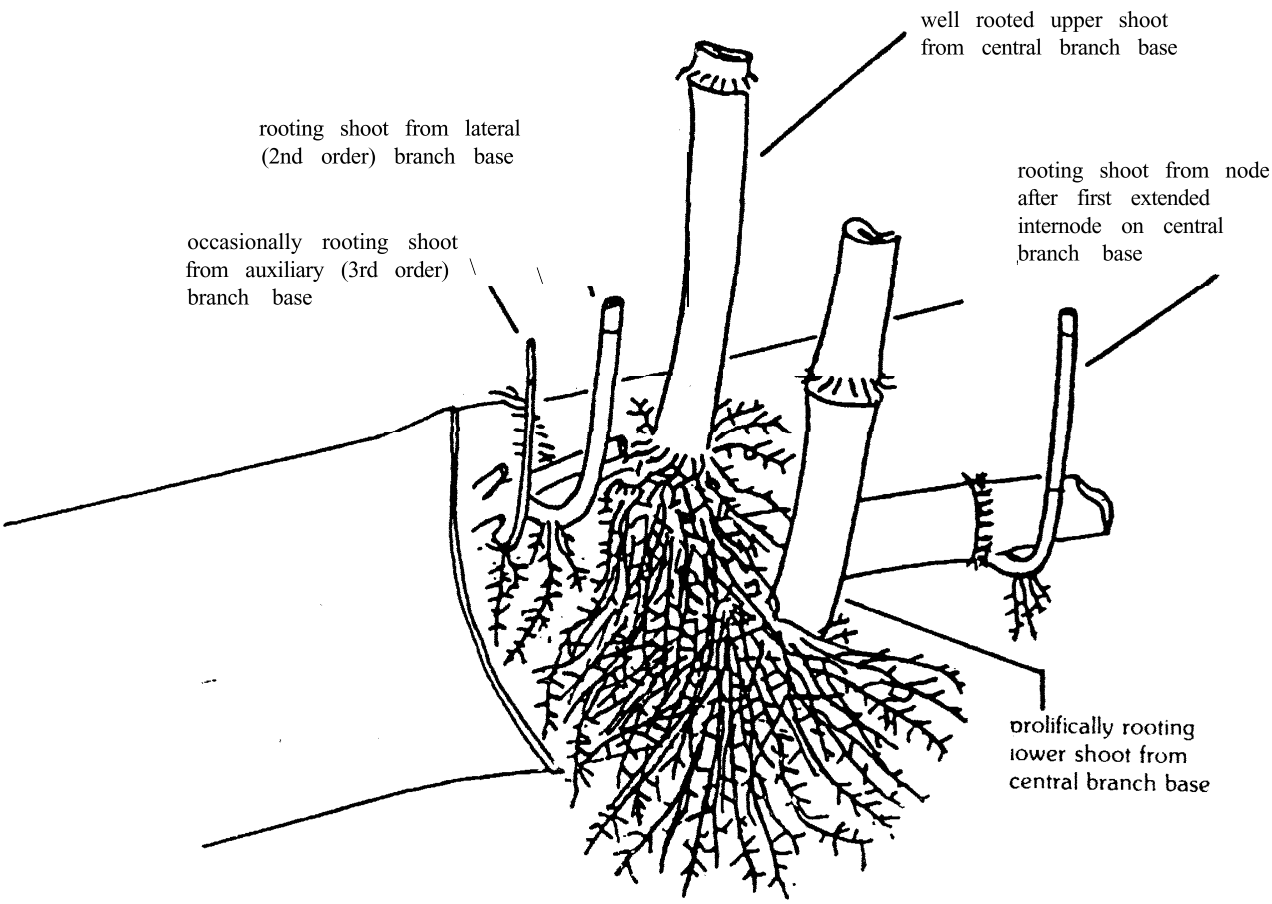
In addition, there were rooted shoots from several categories of branching which did not produce rooted shoots in B. nutans, and the overall rooting was much more prolific with many nodes producing more than one rooted shoot and several separate rooted plants (fig. 2). Under the arduous conditions development of the pre-existing roots was very limited and it was considered that the greater success in *Dendrocalamus species* was due to a greater overall inclination to production of roots rather than the support of pre-existing roots.

1984: Bambusa sp (tharu bans) trial of single-node cuttings

Bearing in mind the limitations to adequate rooting in Bambusa nutans seen in 1983 a new technique of planting was developed for Bambusa species. Two-year-old culms with a reasonably strong central branch were selected. The central branches were only cut beyond the first elongated internode, 15-25cm from the cuim, while other branches were cut at 2-4cm both to promote development shoots from the central branch and to simplify orientation of the cutting.

In order to allow optimum orientation of developing shoots at the correct depth the culms were cut into single-node units. It had been observed that the die-back from cut ends in 1983 was negligible. It was also realised that water required for the rapidly developing shoots had to enter the culm at the severed ends. Dividing it into fifteen or so cuttings and planted horizontally increased the surface area for water absorption by a factor of about fifteen, In this manner all the cuttings were planted in the same way as the nodes which had been successful in 1983, with certain small improvements in materiai selection (fig. 3). Cuttings were made from ten culms; planted under hessian shades in April and watered daily until evaluation in November.

The cuttings developed as expected, showing the close similarities between the two *Bambusa* species. Those cuttings which rooted produced about the same number of roots as *Bambusa nutans cuttings had pro-*



Fig, 2. Rooting shoots from several categories of branching in Dendrocalamus hookeri

duced. Although 64% of rooted cuttings produced less than three roots from any single rooting shoot, and this was sufficient for further new axes to develop from the basal buds of these shoots, with prolific rooting, successively larger dimensions, and a closer similarity to full-sized rhizomes.

The overall success rate was 59.5% with an average of 11.3 plants per culm. Excluding the cuttings which came from the upper regions of the culm where its diameter was less than 3.5cm the success rate was 64.5% with productivity of 10.7 rooting nodes per culm. Although a strict comparison with the Bambusa nutans trial of the previous year cannot be made as this is a different species planted in a different nursery, it certainly appeared that by reducing the effects of the factors seen to limit rooting in B. *nutans* and planting single-node cuttings in the correct orientation, a satisfactory response could be obtained in this very similar species which also has no aerial roots at all. The stimulation of production of only a very few roots on certain shoots allowed the development of strongly rooted shoots from the basal buds giving viable plants in a predictable and fairly uniform fashion.

1984 Bambusa sp (tharu bans) trial – details of development

While it had been observed 'in B. *nutans* trial that only certain shoots in a particular orientation could root, the detailed development of such shoots and the interactions between shoots had not been followed closely. With three similar strong shoots arising from the central branch it was realised that there was potential for more than one shoot to root, and also potential for relative competition between these shoots and with the smaller shoots from the lateral and auxiliary branches.

Further studies in the removal of small

shoots suggested that they had not been diverting resources excessively. There were no significant .differences in root production between those cuttings with shoots removed (mean 3.41 roots, standard error of the mean (s.e.m.) 0.62) and those with shoots left intact (mean 3.94. s.e.m. 0.61). Further there was interaction between the upper (from the top of the branch base) and lower shoots (from the bottom). Eighty-eight percent of cuttings had a total of three shoots arising from the central branch base, ten percent had four shoots, and two percent had only two shoots.

Those cuttings with two shoots developing downwards obviously had more potential for producing roots than those with only one, and produced a mean of 4.6 roots (s.e.m. 0.59) as opposed to only 2.1 (s.e.m. 0.33) roots per cutting. Therefore it is desirable to plant the cuttings so that two shoots will develop downwards, to maximise the total rooting and also the number of rooted plants obtainable. The mean number of roots per rooting lower shoot was significantly higher in those cuttings with only one upper shoot to compete with (2.52, s.e.m. 0.35) than in those cuttings with two (1.63, s.e.m. 0.27).

It was noted that the cuttings which have no upper shoots at all would produce even more roots, and this is presently under investigation. It is clear that by planting the cuttings the correct way up, root production can be enhanced greatly. In this trial, cuttings planted the correct way up, produced a mean of 5.3 roots (s.e.m. 0.74) while those planted the other way up produced a mean of only 2.5 roots (s.e.m. 0.43). Seventy five percent of the cuttings in the former category successfully produced rooted shoots from the central branch base. There was still some visible domination of lower shoots by single vigorous non-rooting upper shoots however. To eliminate this influence altogether the bud can be destroyed at planting or the shoot removed as it emerges.

It is quite difficult to see the buds at branch base at the time of planting as they are covered by overlapping sheaths. However, the bud after the first extended internode on the central branch is clearly visible, and because of the alternate arrangement the orientation of this bud can act as a simple indicator of which way up the cutting should be planted, (Fig. 3). If this bud faces upwards there will almost always be two buds facing downwards at the branch base.

The major remaining limitation to successful rooting was suspected to be connected with the considerable delay between shoot and root production, which usually was around ten to fifteen weeks. Some healthy shoots still had not produced roots after as much as twenty weeks and several were damaged or had dried out before they could root. Preliminary inspection of ongoing trials has indicated that altering planting depth may be an effective and convenient way of controlling the timing of loss of apical dominance.

Discussion

The superior rooting ability of shoots arising from the base of the central branch, is well known but appreciable rooting ability of shoots from other branches in the complement of readily rooting species such as many Dendrocalamus species does not appear-to be well known. This is important as it offers potential for producing more rooted plants from each node. The apparent effect of shoot orientation on root production is very interesting but needs further investigation. An experiment which aims to determine the effects of different environments on shoots reorientated in the same manner is underway. The development of a standard method of planting cuttings with a quantitative criterion of success offers scope for more accurate identification of limiting factors in producing rooting species and evaluation of techniques to overcome such poor responses.

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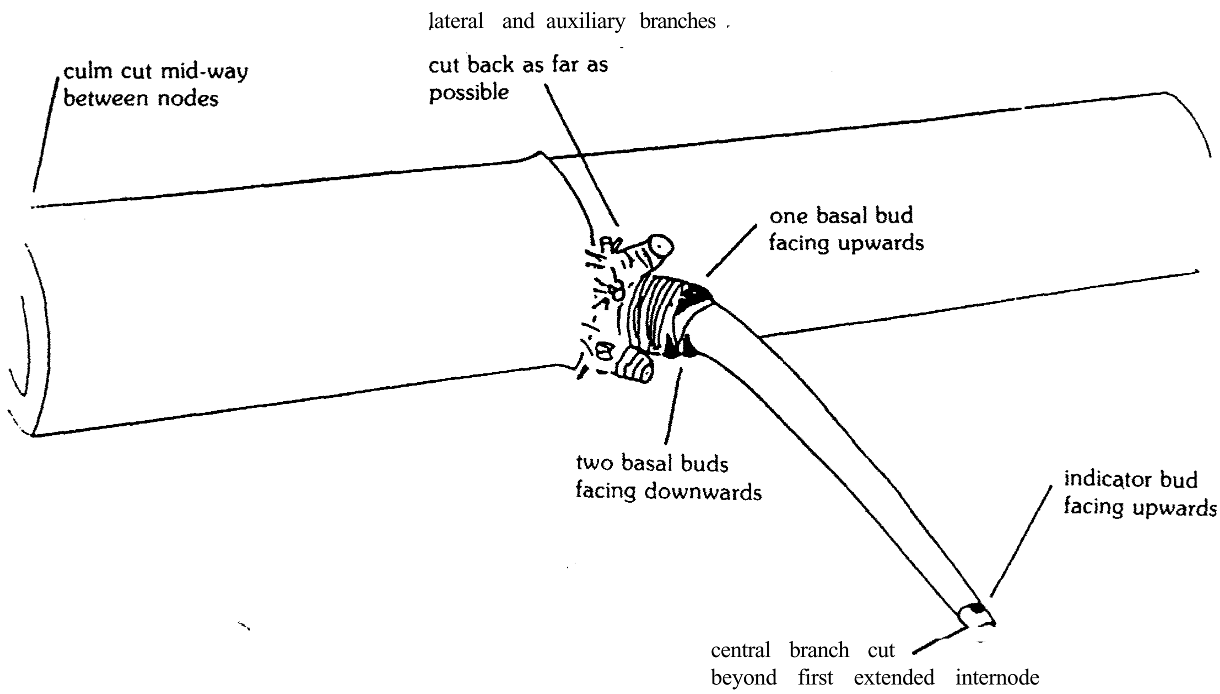
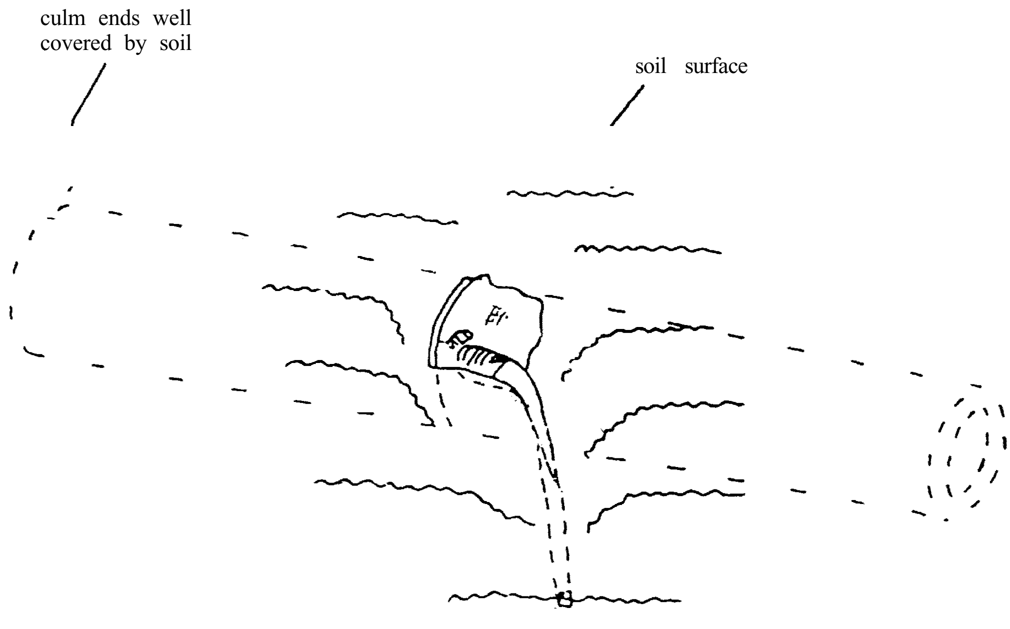


Fig. 3. a) Prepared single-node cutting of Bambusa species



b) Planting technique with culm and branch horizonral and only branch base not covered by soil.

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Research on the Raising of Phyllostachys pubescens Seedlings

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Abstract

Growth stages of juvenile plants, flowering and fruit bearing characteristics of Phyllostachys pubescens are described.

Introduction

In China the land area covered by bamboo forest exceeds 3,400,000 acres, comprising one-fifth of the world's bamboo forest area. Approximately 80% of the area is covered by *Phyllostachys pubescens.* Further *P. pubescens* is spread throughout every province south of the Chang Jiang River and Taiwan. The vast area covered by this bamboo means that it grows in a wide range of climates where rainfall, drought, variations in the quality of soils, overcrowding and thinning become important factors which influence the flowering cycle in a given place. Because of this, at any given time, *P. pubescens* is flowering somewhere, and it is possible to collect seeds, though language, transportation and government plant export restrictions hamper any effort.

Flowering and Fruit Bearing Characteristics;P. *pubescens* is a perennial plant, which in China, generally only flowers once every 50-60 years. In each of the provinces south of the Chang Jiang River, *P. pubescens* flowers generally from April to August and the seeds mature somewhere between June and October. After maturing, the seeds will fall or be naturally dispersed by the wind.

P. pubescens is an anemophilous (wind pollinated) plant. Each flower has three stamens. The filaments are long and slender, approximately 5 mm in length (Fig. 1) protruding from the flower. The ovary is conical or three-sided, about 3 mm in length. The stigma has three vents which look feathery. The pistil is generally wrapped in the flower or to a small extent protrudes outside the flower. This feature appears to be unconducive for P. *pubescens* pollination and hence only about 10% of the flowers are pollinated. Seeds have no dormancy period, and therefore the seeds must be sown as quickly as possible and the

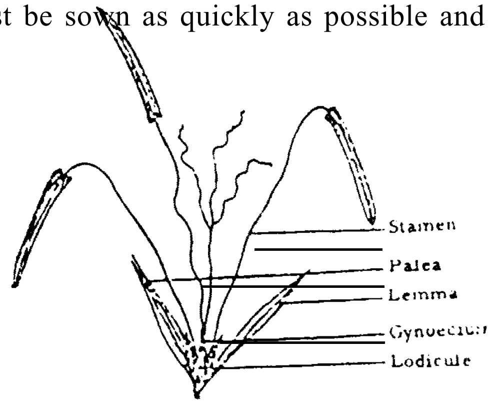


Fig. 1. Flower of P. *pubescens*

percentage germination is around 50%. Under room temperature conditions, the seeds remain viable for half a year, but *germination* percentage is reduced to 10-20%. After about eight months the percentage germination is almost zero. However, by keeping the seeds at 4-5^{o} centigrade below zero, higher % germination can be obtained up to one year. As seeds are scarce and have a low germination rate, it is recommended that the seeds be germinated and raised indoors. The seeds will germinate within seven days at 20-25°C. In the same group of seeds, germination can be as far apart as one month and this may be due to variations in seed maturity.

Before planting, it is best to soak the seeds in warm water (20-25°C) for 24 hours. The soil for planting the seeds should be loose and humus-rich, with a pH of roughly 5-7. A thousand husked P. *pubescens* seeds will weigh from 8-15 grams and when unhusked weigh approximately 15-25 grams. Taking several factors into consideration, the age, number, weight (husked or unhusked) of seeds, one can estimate potting soil, pots and space to set aside for a nursery. A long range projection can also be made about the land needed later for planting out larger areas permanently.

When the seeds germinate, the rate of growth of the tap root is one or two times greater than that of the seed leaf. The stem grows upward slowly, putting out new leaves to become the first generation of bamboo culmlets. If while seeds are in the process of germinating soil moisture content is insufficient, the tap root growth will be faster and the young stem's growth will be retarded. If the moisture level is excessive, the situation will be reversed – the growth rate of the stem will be faster and the growth of the tap root will be retarded. Such a seedling cannot be raised to be strong and healthy. Generally soil with a water- holding capacity of 70-80 % is best. The soil should not become soggy and water stagnant. It should be pointed out that the ability of bamboo rhizomes to endure being submerged in water (during flood experiments) is comparatively good. Two-year-old plants were used in these flooding tests in which the root systems of the plants were kept submerged in fresh standing water. Under these conditions, in which water was not over the tops of the plants, there were no visible manifestations of debilitating effects for half a month and the plants were still alive after two months, at which time the leaves began to yellow and stop growing.

Growth Stages in Juvenile Plants: After the seeds germinate and produce the first generation of culmlets, they will grow to their full height within one or two months. Their height is mainly under 15 cm and they will put out 10-18 leaves. There are no side branchlets.

About the time that the first generation culmlet is putting out its third leaf, the seedling growth has reached a key period. We call it the "three leaf period". During this time one will frequently find that a certain portion of the young seedlings deveiop yellowed leaves, stop growing, and gradually wither and die. Even though they may have had excellent care the above-mentioned phenomenon is unavoidable. From statistics gathered during the times we have raised seedlings, this sort of death eventually comes to about 25% of the total amount of seedlings originally germinated. From experienced observational research, we believe that since the nutrients needed for the growth of the young seedling during the initial stage comes from the seed itself, the fault lies in the seed's quality.

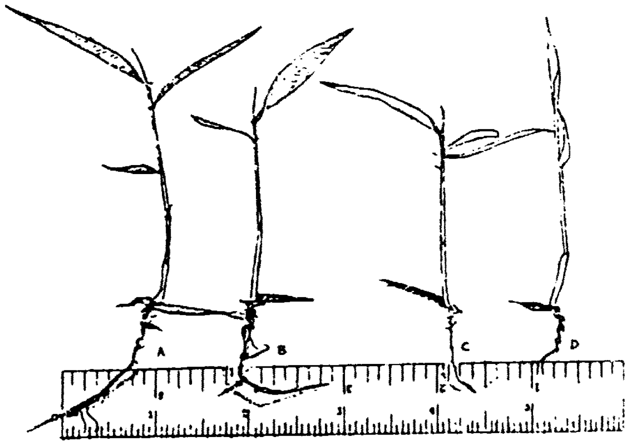


Fig. 2. Three leaf period seedlings. A&B. Healthy & normal. C&D. YUellowed. sickly & stunted.

With the subsequent growth of the young seedlings, the feeder root system is, little by little, taking in nutrients from the soil. Around the time the third leaf appears the nutrients in the seed have just been used up. The seedling then starts to depend completely upon the root system for its intake of nutrients and water. If the seed quality is not high (mainly depending on the difference in maturation within seeds of the same group), the 'root system is weak during the three leaf period (Fig., 2). The seed nutrients are exhausted. The underdeveloped root system cannot take over the responsibility and function of drawing up moisture and nutrients for an advanced culmlet which makes oversized demands. This appears to be the reason why the young seedlings die,

The dying off of a portion of the young seedlings is not necessarily a negative phenomenon. It serves the function of the natural selection process, weeding out the weak from the strong. Of course, if the quantity of seeds is really small and especially since seeds are hard to come by, extreme care can save some of these young seedlings.

Development of Shoot Types

When the first generation of culmlets have grown to their full height, basal shoots will start to grow. Generally one basal shoot will grow, but under rare circumstances they will send out two shoots at the same time (Fig. 3). With good care they will send out six to eight basal shoots in one year, each new shoot becoming larger and thicker than the last. In the second year it is possible to have a small clump of 40-50 culmlets. There are some

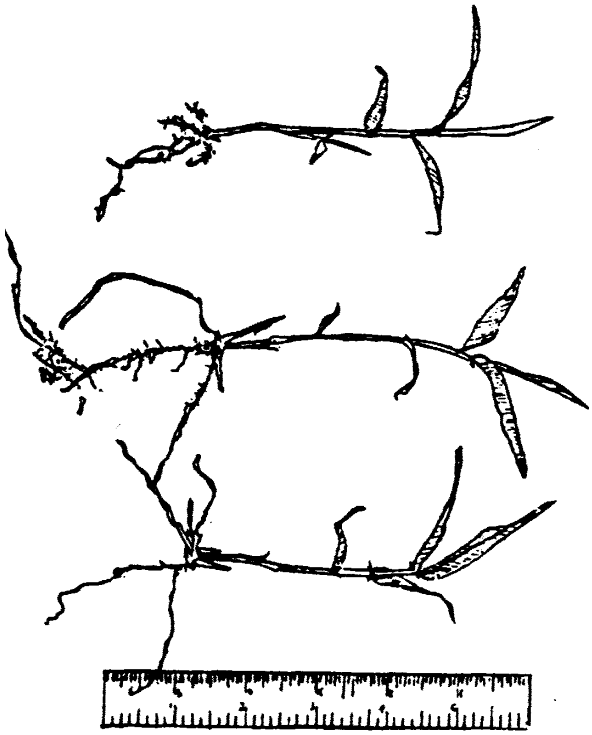


Fig. 3. Illustrating shoot development. A. Too deep-underdeveloped new shoot, mock shoot at node. B. Normal with one new shoot. C. Advanced with two new shoots.

slight differences between a seedling clump of P. pubescens and other bamboos. We divide the clumping stage into four categories.

Type A: Mainly the first generation of culmlets. Their special characteristic is that they will not have, or will have very few side branches. The culmlets will radiate outward in all directions.

Type B: When the second year basal shoots come forth, most will grow straight up. At the nodes, side branchlets will appear. At the lower nodes only one side branchlet will grow out. From the upper nodes two branchlets will grow next to each other. At this time, from outward appearances, the bamboo clump will clearly manifest its tiered quality (Fig. 4).

Type C: During the later part of the second year or beginning of the third year, shoots will start to grow from the base. Of these shoots some will grow straight upward to become Type B culmlets, but some, after growing outward horizontally 1-2 feet, will then curve upward to become culmlets (Figs. 5,6).

Type D: In the third to fourth year, real rhizomes will grow from the basal part and shoots, which will afterward become true culms, will grow out of the side rhizomal bud. In the fourth to fifth year new culms will resemble the mature plant (Fig. 7),

It could be that the above-mentioned

Fig. 4. Clump at approximately 12 months.

Fig. 5. Illustrating two-year-old plant. A. Lower portion showing first 12 months of growth. B. Upper portion showing second 12 months of growth.

Fig. 7. Fourth to fifth year culms.

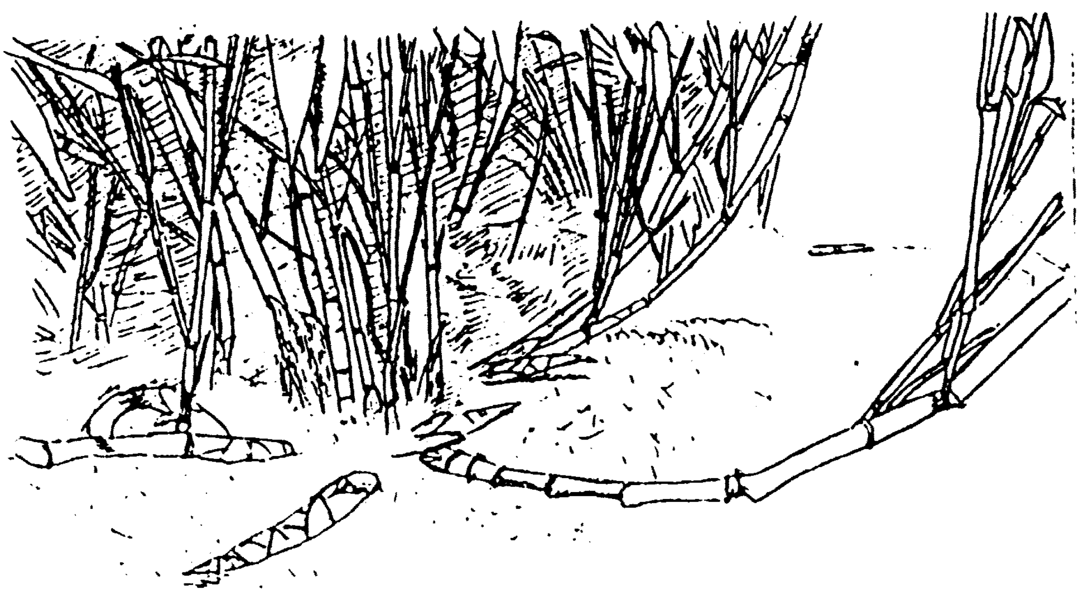


Fig. 6. First rhizomes. Approximately 36 months, some curve upward to become whips, others arch downward into the soil.

changes in the clump reflect a stage of development in the evolution of P. ***pubescens;*** from a clumping variety to a mixture of clumpers with runner characteristics and finally to a true runner. Because of this some people believe that Phyllostachys and other running bamboos in general are more advanced from the evolutionary standpoint than clumpers.

Care of the Young Seedlings

One of the basic rules of agricultural production is "30% planting and 70% care". The following few points are important for the care of young seedlings,

Protective shade: Bamboo seedlings need shade because of their large juvenile leaves and the excessive transpiration these cause, and also due to the fact that their root system dries out easily, The practice of supplying adequate shade protection can promote seedling growth, early secondary shoots, more secondary shooting and deep green healthy leaves. If shade is not provided the seedling will be stunted, the leaves will yellow and the secondary shoots will be affected. However, if there is excessive shade the culms will be long, slender and weak. There will also be an obvious decrease in the number of basal shoots. The degree of shade and penetrable light is optimal at 40-50%.

Shade protection is most important in the summer to avoid strong direct sunlight. But in autumn or winter the shade material should be slowly removed to let the seedlings harden their culms. Around this time permanent planting of the seedlings is possible.

Watering and fertilizing: The soil moisture should be maintained at sufficient levels. The soil moisture level of 70-80% mentioned above is best.

About a month after the seedlings have germinated, a 37% mixture of urine or another nitrogen fertilizer (ammonium sulphide at 57% strength) can be employed. Generally nitrogen is the most important, with demand for potassium second. Fertilizers should be given once every two or three weeks. As the plants grow, the concentration of the fertilizer can be appropriately increased.

Topping to promote secondary shooting: When the seedlings have produced shoots for the third time, reached their full height and stopped growing, cutting off the tops of the culmlets to just a couple of inches above the soil and increasing watering and fertilizing will greatly encourage otherwise latent buds to start shooting. This is one method of encouraging **30-70%** more shoot growth.

Transplanting seedlings: The question of how deep the seedlings should be planted is always ignored. Generally it is best to make sure the base of the plant is about 1 cm below the surface of the soil. If planted too shallow the basal shoots will often be affected by extreme changes of temperature, moisture and dryness. If planted too deeply, the shoots at the basal portion cannot grow. Instead, the node branchlet nearest the surface of the soil will grow a "mock" shoot; these mock shoots are extremely detrimental (Fig. 8). If this circumstance goes unnoticed for several

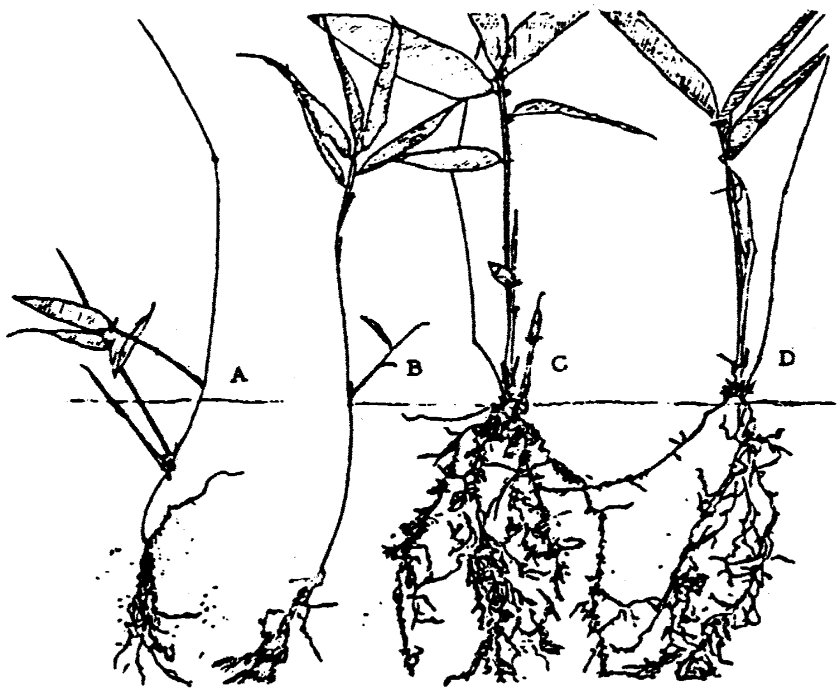


Fig. 8. Illustrating proper soil level. Ail seedfmgs 6 months.
A. Three mock shoots. B. Too deep, mock shoot at node.
C. Proper depth. D. Above soil, new shoots and roots exposed to weather.

months,, removing excess soil to the proper level will have no effect. The remedy in this case is to apply soil up to the level slightly covering the mock branchlet. After a time a new root system will start to grow and the seedling will begin shooting from the branchlet within two weeks to a month. However, these "node sprouters" will lag far behind properly planted seedlings in growth.

Weeding and loosening soil: In the young stage of the plant, seedling growth is gradual. Because of this, attention must be paid to getting rid of weeds, It should be especially pointed out that during the fall and winter period it is best to cultivate the soil once, to a depth of around 10 c-m. Cultivation promotes secondary root growth by cutting or breaking off the terminal portions of roots, thereby causing more lateral root growth and developing a more efficient root system (Fig. 9). Done occasionally, according to need of weather, cultivation not only takes care of weed problems but at the same time increases aeration of the soil.

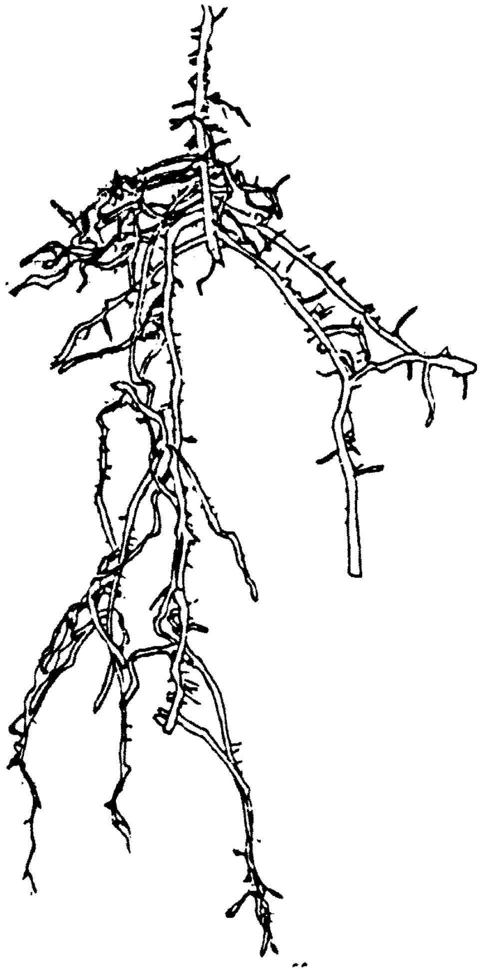
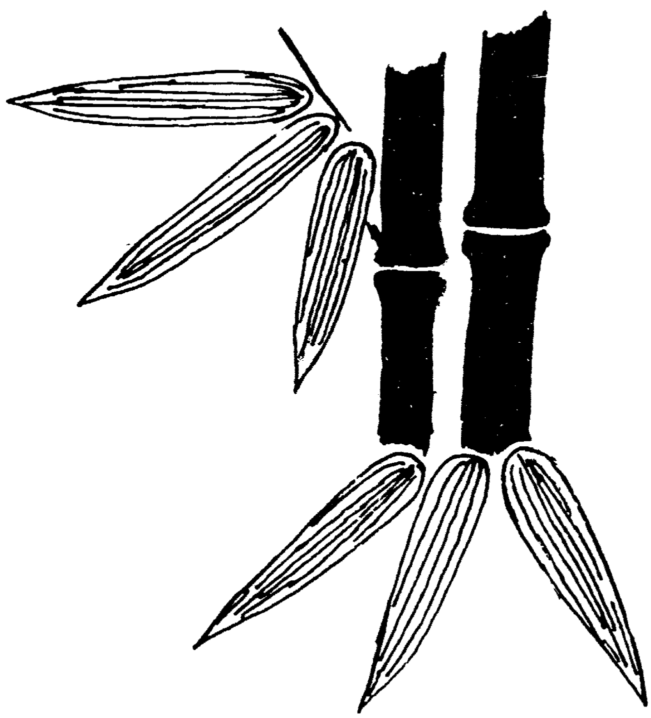


Fig. 9. Illustrating effect of cultivation on lateral root growth.



Techniques of Bamboo Propagation with Special Reference to Prerooted and Prerhizomed Branch Cuttings and Tissue Culture

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Abstract

Bamboo is an important multipurpose plant in Bangladesh.

The seeds are short lived and can be stored up to 18 months under c&trolled conditions. Seed longevity varies from species to species. After each gregarious flowering and fruiting wild seedlings carbe*collected from the forest floor and successfully utilized for bamboo plantation programs. A bamboo seedling may be multiplied 3 times by rhizome separation. The process would help in continuous annual supply of small size transportable propagating materials for a number of years. Thick-walled bamboo species may be successfully propagated through prerooted and prerhizomed branch cuttings. Vegetative propagation of thin-walled bamboo species is very difficult. Propagation of bamboo through tissue culture is possible. Inoculation of dormant culm bud tissue on modified MS medium amended with activated charcoal, benzyladenine and naphthalene acetic acid initiates shoot proliferation and root growth. Varietal and germ plasm collection and their regional exchange via in vitro techniques provides immense opportunities for the development of a regional gene bank for important bamboo species. Regional seed exchange should also be encouraged.

Introduction

Bamboo is a perennial giant woody grass belonging to the sub-family Bambusoidae. They are the fastest growing plant species so far known with a high cellulose content. It is estimated that six or seven times as much cellulosic material can be obtained per unit area from a bamboo forest as from a pine forest (Sineath and Daugherty 1954). It is common in tropical forests and widely cultivated in the villages throughout south and southeast Asia. In many countries of the tropics, bamboo plays an important role in the village economy. It is extensively used as a material for housing, fencing, food, fuel, novelties and agricultural implements.

In Bangladesh, bamboo is found naturally in the forests either in association with other species or in pure stands. Because pf its immense economic importance. it is widely cultivated in the villages and the major species in the forests of Bangladesh are *Melocanna baccifera* Trin., *Bambusa tulda* Roxb., *Dendrocalamus longispathus* Kurz, *Oxytenanthera nigrociliata* Munro, and *Neohouzeaua dullooa* Camus. These species are generally thin-walled (less than 1.0 cm) and 4.0 to 20.0 m tall with diameter of 2.0 to 8.0 cm, and mostly used for walling, partitions, ceilings by interweaving the splitted and flattened culms. The widely cultivated bamboo species in the villages of Bangladesh are Bambusa vulgaris Schrad. Bambusa *balcooa* Roxb., *Bambusa longispiculata* Gamble. ex Brandis, and *Bambusa nutans* Munro. Sometimes *Dendrocalamus giganteus* Munro, *Bambusa arundinacea* Wild, *Bambusa polymorpha* Munro, and *Dendrocalamus strictus* Nees are also cultivated sporadically in different villages. Cultivated species, mostly used in structural works, are taller (10.0 to 35.0 m), wider in diameter (6.0 to 20.0 cm at base) and thicker (1.16 to 1.63

cm wall thickness at mid culm) than the species growing in natural forests.

Research on the development of techniques for large scale bamboo propagation viz. seed propagation, vegetative propagation and tissue culture are being conducted in the Bangladesh Forest Research Institute (BFRI) at Chittagong for the last 10 years and the details are as follows:

Seed And Seedling Propogation

Flowering nature and seed yield: Like other grasses most of the bamboo species are monocarpic and the number of bamboo species which flowered in different parts of Bangladesh during the last 10 years are given (Table I). It has been observed that all the species start flowering between January and March. and continued till August. Flowering is. however, not continuous but occurs in three successive flushes with two dormant interval periods. Seeds from the first two flushes generally germinated better than those produced in third flush (Banik 1980). The interval between flowering is generally 1 to 3 years and varies from species to species (Table 1). Most of the plants (species) (except four clumps of B. longispiculata) died on completion of flowering. Four clumps of B. longispiculata in the central bambusetum of BFRI have been sporadically flowering and producing seeds every year since 1978. Selfing, achieved by bagging, generally resulted in less seeds per pseudospikelet. Four to five times more seeds were produced when cross pollination was done among the flowering clumps of D. longispathus. In fact, grasses are generally cross pollinated in nature (Arber 1934, Evans 1964).

Some bamboo species sometimes produce flowers and seeds in a few clumps in between its normal interseeding period. Seeds from these out-of-phase flowering 'varieties' may be utilized for bamboo plantation programs even in the absence of normal seeding year. Plants originating from out-of-phase seeds are expected to maintain the same period of cycle as the normal species

Table 1. Flowering of different bamboo species in Bangladesh during 1977-1985.

Species	Flowering duration: Date	Flowering duration: Year	Flowering nature	Seed Yield: Yes	Seed Yield: No
Bambusa arundinacea	1979	1	gregarious	•	[illegible]
B. balcooa	1983-84	2	sporadic	—	.
	1984-85	2	sporadic	[illegible]	•
B [illegible]	1977-78	2	sporadic	•	[illegible]
B. longispicu*lata*	1978-85	8 or more	sporadic	•	[illegible]
	1983-85	2	gregarious	•	[illegible]
B. nutuns	1978, 79	1	sporadic	.	
B. polymorpha	1981-82	2	gregarious	.	
B. tulda	1976-77	2	gregarious	[illegible]	—
	1978-79	2	gregarious	.	—
	1982-83	2	gregarious	.	—
	1983-84	2	gregarious	•	[illegible]
[illegible] vulgaris	1980-81	2	sporadic	[illegible]	•
	1983-84	2	sporadic	[illegible]	•
Dendrocalamus strictus	1983-84	2	gregarious	•	[illegible]
D. longispathus	1978	1	gregarious	•	[illegible]
	1978-79	2	gregarious	[illegible]	—
	1977-79	3	gregarious	[illegible]	—
Oxytenanthera nigrociliata	1978	1	gregarious	•	[illegible]

Table 2. Seed weight, germination and seed longivety in different bamboo species in Bangladesh. Seeds of B. *tulda* were only stored in desiccator over silicagel.

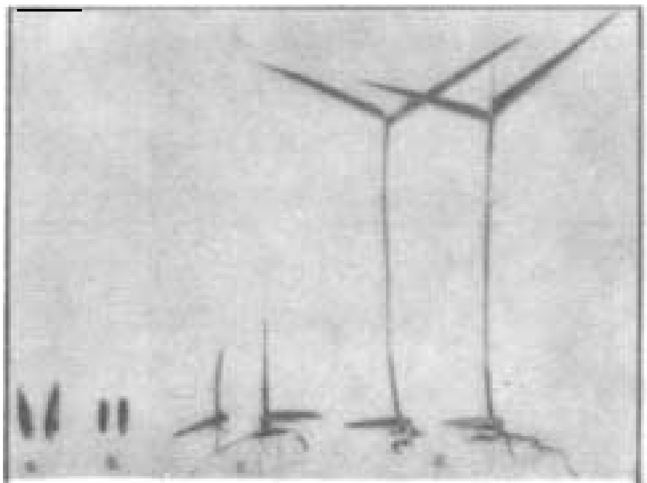
Species	Seeds/10 gm (Nos	Germination % (fresh seed)	Seed tongivety (days) Room condition	Controlled condition
Bambusa arundinacea var. *spinosa*	1320 ± 7.0	52.3	65	–
B. glaucescens	151 ± 2.5	40.2	33	--
B. tulda	139 ± 1.1	48.0	35	540 (18 month)
Dendrocalmus longispathus	1351 ± 2.2	50.0	55	
D. strictus	512 ± 3.6	42.0	–	
Oxytenanthem nigrociliata	265 ± 1.1	39.0	–	

but they flower at different times (Banik 1980, Hasan 1980), It will be interesting to maintain the record of flowering cycles of these out-of-phase 'varieties'. However, so far 31 out-of-phase 'varieties' of 10 bamboo species have been collected from different parts of Bangladesh and these have been centralized in the bambusetum of BFRI.

In 1977 B. tulda, flowered precociously though these plants are said to flower normally in a 25 years cycle (Banik 1980). Such early flowering (18 months) behaviour was transmitted in subsequent populations of F1, F2, F3, F4, and F5 generations and after flowering they died. Such flowering behaviour seems to be genetically controlled and the responsible gene(s) is segregated and expressed in each generation. The indications obtained from the above observations need further confirmation which may unveil some of the facts about flower induction in bamboos. These may help us to understand seed production and regeneration in bamboos.

Seed germination andlongevity: Generally the vegetative period in bamboo is very iong and irregular. Therefore, the scope of annual propagation of this plant by seeds is very limited. The bamboo species that have so far flowered in Bangladesh in the last 10 years have produced seeds, except B. *balcooa* (Banik and Aiam; in press) and B. vulgaris (Banik 1979). These two species are widely cultivated and flower gregariously produce seeds (Gamble 1896, McClure 1967). The species died after flowering. As the clumps of these two species die after flowering without leaving any offspring, the existence of their race is also in danger. It is interesting to note that one out of 6 clumps of B. vulgaris survived even after flowering though ail of them were growing in the same locality (Banik 1979). It is assumed that the genetic makeup of this clump might be different from the others and, therefore. this clump was centralized and preserved in the central bambusetum of BFRI for future cionai propagation. This clone of B. uulgar,is responds well to branch cutting propagation technique.

Sizes and shapes of seeds vary from species to species. *Bambusa* and Oxytenanthera spp. produce wheat shaped seeds but in *Derdrocalamus these are ovoid* arc ovoid. Seeds of B. tulda arc heavier than those of other *Bambusa* sp.. *Oxytenanthera* sp.. and *Dandrocalamus* sp. studied (Table 2). Bamboo seeds generally germinate within 5 to 10 days of sowing in the soil and seedlings attain l-leaf stage in 7 days (Plate 1). Percentage of germination is higher when seeds are sowed directly in polyethylene bags than in nursery beds. For example, direct sowing of seeds of B. *tulda* resulted in 24.78 germination against 5.5% in nursery beds (Banik 1980). Freshly collected bamboo seeds germinated better than those stored at room condition. The longevity of seeds varies from species to species and generally it is up to 1 to 2 months (Table 2) although the period can be increased under controlled storage condition. It has been observed that seeds of B. *tulda* stored in a desiccator over silica gel maintained their longevity even after 18 months.



Plore I **Seeds *and seedings*** of Bambusa tulda ***Roxb***

Wild bamboo seedlings: Profuse natural regeneration of several bamboo species by seeds usually appears on the forest floor after each gregarious flowering, Ripe seeds fall on the ground between May and August and a thick mat of seedlings may be seen on the forest floor if not disturbed otherwise (Plate 2). Suppression by weeds and interseedling competition usually affect the regeneration and establishment process. To minimize the competition, weeding should be regularly done and the seedlings from the regenerating areas should be thinned out. Wild seedlings of B. tulda and D, longispathus at 2-leaves stage were thinned out from the densely populated areas of the forest floor and brought to the nursery for potting. These seedlings survived well in the nursery and have been replanted after 6 months in the forest under half yearly weeding practice for 2 years (Table 3), Thus, thinning of wild bamboo seedlings from the densely regenerating areas of forest could be useful for natural regeneration as well as for any artificial plantation activities (Banik 1985).

Seedling **multiplication:** Several methods of vegetative propagation are common in grasses like using tillers, culms, rhizomes or stolons (Langer and Ryle 1958). Like many other grasses, bamboo has the inherent proliferating capacity and offset planting capability to reproduce itself probably due to its long interseeding period.

A bamboo seedling produces new culms at the age of 30 to 40 days and at this stage the rhizome development also starts. If seedlings are raised in polyethylene bags in July, they attain the 4 to 5-culm stage in the following April or 9 months later with well developed root and rhizome systems. Seedlings. at this stage, are ready for multiplication Soil from the roots should then be washed off with water, and the rhizomes separated and be planted in polyethylene bags. A seedling at 4 to 5 culm stage may be separated into 3 units in, such a way that each 'piece' has roots, old and young rhizome, shoots and rhizome buds (Plate 3). Seedlings are then kept in shade for 3 days and watered twice a day. After that. seedlings need to be brought into the nursery

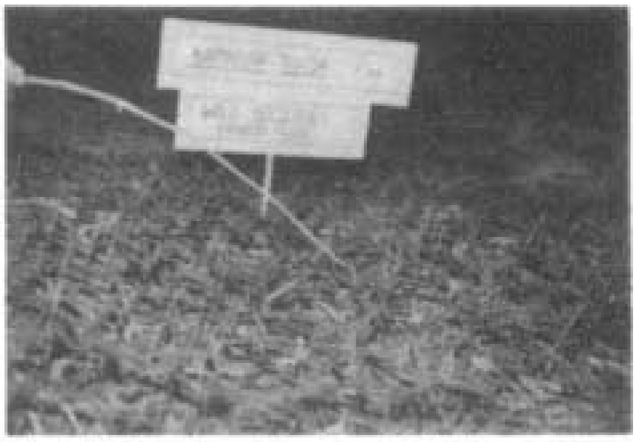


Plate 2. Wild seedlings of **Bambusa tulda** *Roxb. on the forest floor.*

Table 3, Survival percentages of the wild bamboo seedlings after potting in nursery and **then planted in the field.**

Species	Wild seedlings collected (Nos)	Nursery bed Survived (No)	%	Field (forest) Survivcld (%) 1st yr.	2nd yr	3rd yr
Bambusa tulda	**5000**	**4805**	96 1	88 3	**73 4**	**70 :3**
Dendrocalamus longispathus	**5000**	**4330**	**86 6**	**82 4**	**70 2**	**66 4**

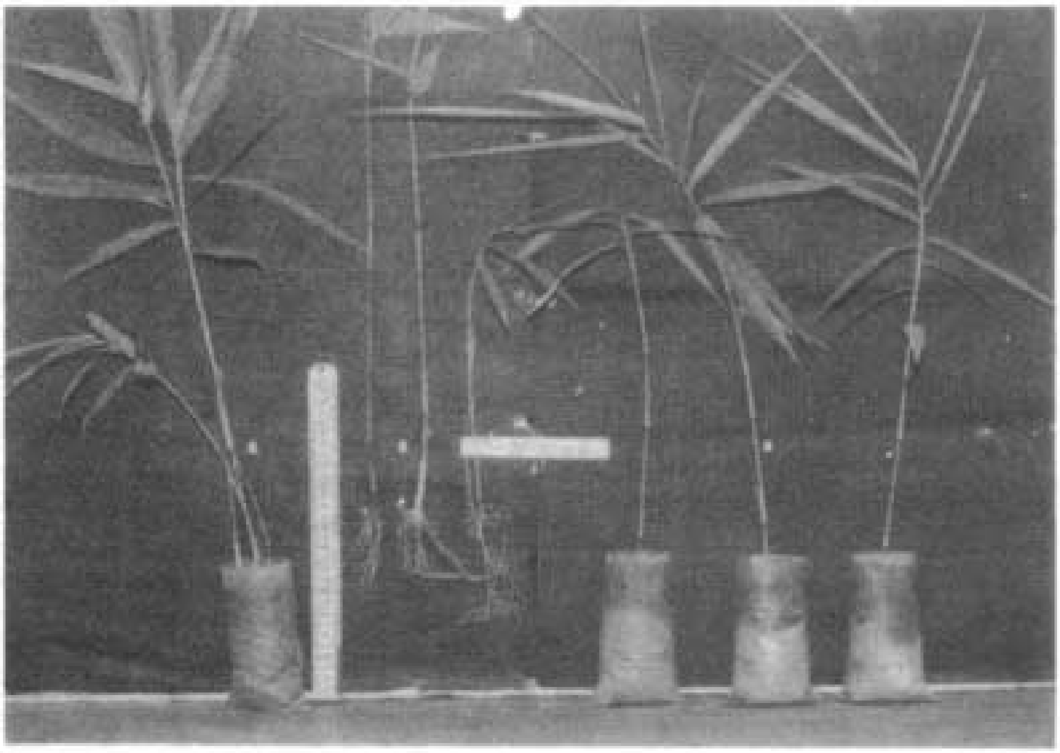


Plate 3. Seedling multiplication of **Bambusa tulda** *Roxb. Left to right: 9 months old seedling, culms are separated by rhizome division. 3 new seedlings developed*

bed under the sun. This practice in the nursery stage ensures little or no casualities. Every year the seedling gets multiplied 3 times (as in the case of B. tulda) of the intial stock. Out of this, two-third of the seedlings may be planted in the field. The rest can again be multiplied after nine months (April-May} and the process can be repeated every year for a period of time. As an extra advantage the proliferated seedlings remain small in size due to continuous rhizome separation. thereby making it easy to handle and transport them. However, the process of seedling multiplication should not be continued for a long time (e,g. not more than 10 years. in B. tulda) as the time gap between the last multiplication and flowering gets shorter, Multiplied seedlings are clones and become physiologically older as the time passes from the date of mother seedling germination, Under such condition, the last multiplied seedlings are likely to start flowering due to their physiological maturity before attaining the merchandable culm size. This method of seedling multiplication has been practiced for some years in B. tulda, a thin-walled bamboo species, in BFRI Chittagong. Detail scientific study is essential on such a macro-proliferation of bamboo seedling to develop a new dependable technique for bamboo propagation at least for a few years.

Vegetative Propogation

Offset and rhizome plantings are the most common methods of propagating bamboos in the villages of Bangladesh. Use of these propagules are practicable only in cultlvating a few clumps. particularly within a small accessible area. Their availability in huge numbers is very much limited and too expensive for any large scale bamboo plantation program (Banik 1980) However. a proper scientific know ~ how about this method is essential for obtaining better results in homestead bamboo cultivation. Generally offset from 1-2 years old culms give better results as the rhizome is young, vigorous and possess active culm buds. Culm buds on the rhizome of older offsets (4-7 years of age) are mostly dead and therefore they fail to produce any new culm. The success of this method depends on both vitality of the culm bud in the rhizome and the time of the year when the offset is planted, The months of March and April are the most favourable time for offset planting in Bangladesh as culm buds in the rhizome become active during that time due to an increase in temperature and humidity. The desirable length of the culm part of' an offset is 1 to 1.5 m with 3 to 4 nodes bearing viable branch buds. Success of offset planting in thin-walled bamboo species is relatively poor and vary greatly from species to species. Hasan (1977) reported that the ultimate establishment of offset was *5%* in M. *baccifera, 9%* in B. tulda, 33% in 0. *nigrociliata* and 40% in *D. longispathus.* The success is relatively better, reaching 100 percent, in some thick-walled (e.g. B. *vulgaris)* bamboo species.

Generally part-clump planting of M. *baccifera* shows better success (35%) as this type of planting material has more than one rhizome with many buds than offset having only one rhizome and limited number of buds. Buds on the rhizome start growing at the end of the winter, During the monsoon period in May and June, the apices (new culm) emerge above the soil at about 1.0 to 1 .5 meters away from the mother culm due to long rhizome neck (Banik 1983b). Collection of planting material is easy during this period.

Culm-cutting and layering: Culm segments 0.5 to 1 .0 m long are used for propagating bamboos. CuIm cuttings are generally placed slanting about 45°C, 7 to 15 cm deep in any rooting medium (preferably coarse sand). Rooting medium should be inert, pathogen free, well drained, moist and warm. Propagation structure like poly ethylene or fibre glass tent provides favourable environment for rooting by raising the media and air temperature 3 to 5°C and relative humidity 10 to 20% above the normal atmospheric condition. An experiment on this aspect showed that 45 to 56% cutting of different thick-walled bamboos such as B. vulgaris, B. polymorpha and D. giganteus and 38% of B. nutans gave successful propagules. Culm cuttings of thin-walled bamboo species like M. baccifera, B. tulda, D. *Iongispathus and 0. nigrociliata* failed to produce any propagules. Preparation of culm segments in the month of April-May from the mid-zone of a young culm is critical for obtaining successful results.

Success was achieved by both air and ground layering in bamboo mainly in the mid-culm zone but it varied from species to species. About 10% of the branches/nodes ouot of the total in a culm produce roloted propagules in B. *vulgaris* and D. *giganteus* (Banik 1984b, Serajuddoula 1985). M. *baccijera* did not respond to any of the layering methods. April and May are the best period of the year for such layering works.

Normal branch cutting versupre-rooted and pre-rhizomed branch cutting: Propagation of bamboo through branch cutting could be a useful approach due to availability and ease in their handling. Previous studies showed that the ultimate establishment (rhizome development) of normal branch cuttings in bamboo was poor even after abundant root production (60 to 75%) .by rooting hormone (White 1947, Abeels 1961, Hasan 1977). ln most cases bamboo cutting rooted well with hormonal application but majority of them did not produce any new culm mainly due to the failure of rhizome development (Hasan 1977, Banik 1980). For successful establishment -and growth, a bamboo propagule must possess all three structures — well developed root system, rhizomes, and shoots. Some researchers (Chaturvedi 1947, McClure 1967, Banik 1980) have stressed the importance of selecting the branch cuttings that have spontaneous in situ rooting and rhizome tips at their base. Studies on the artificial induction of such in situ rooting and rhizome formation at the branch base has also been suggested and such principles be termed as prerooted and prerhizomed branch cuttings (Banik 1980). Artificial induction is possible by chopping the culm tops and removal of newly emerging culms (Banik 1984a) Regular removal of emerging culms produced more (3.4 to 83.8%) prerooted and prerhizomed branches per bamboo clump than chopping the culm top (9.1 to 27.3%). Aerial roots and rhizomes, of such cuttings are not always fully active and therefore needs maxing them. Such cuttings perform better than normal branch cutting (Table 4) (Banik 1984). Normal branch cuttings require 6 to 12 month for rooting and 12 to 30 months for rhizome development (Hasan 1977).

Cuttings with profuse active roots and rhizomes are then transferred to the polyethylene bags and kept in the nursery till next monsoon before planting in the field (Plate 4). Survival of those cuttings in the field is high. almost 90 — 100%. They maintain good growth and health after quarter yearly weed-

Table 4. Percentage of successful propagules (active rooting and rhizome formation) prdduced by normal as well as prerooted and prerhizomed branch cuttings in different bamboo species of Bangladesh (Hasan 1977, Banik 1984).

Species	Normal branch cutting Rooting %	Normal branch cutting Rhizome formed %	Prerooted and prerhizomed branch cutting Rooting %	Prerooted and prerhizomed branch cutting Rhizomed formed %
Bambusa nutans	2.7	0.0	80.0	80.0
B. balcooa	18.5	0.0	60.0	60.0
B. polymorpha	61.2	7.4	93.3	90.0
B. vulgaris	40.0	34.2	96.7	93.3
Dendrocalamus giganteus	40.7	0.0	66.7	66.7
Melocanna baccifera	0.0	0.0	0.0	0.0

Plate 4. Successful prerooted and prerhizomed branch *cuttings* (6 months old) of Bambusa vulgaris. Placed *in nursery bed,*

ing in the first year and then half yearly weeding for the next 3 years. Like the layering and cutting techniques, the thin-walled bamboo species also did not show any promising results in branch cutting and it may be due to the presence of much less undifferentiated tissue at the branch base (Hasan 1980).

Propagation through tissue culture: Recent progress in the field of plant cell and tissue culture has reached a point where it can be considered applicable in solving economic problems. The advantages of cell cultures over the conventional agricultural or horticultural production of plant imaterials are numerous (Murashige 1974). The techniques of tissue culture have been successfully employed for year round propagation program of some plant species which are generally difficult to propagate by any conventional vegetative means. Until now most of the successful in vitro cultures of different grass species are either from tissues of immature inflorescences or caryopses (Conger 1981).

Complete plantlets of a bamboo species *(Bambusa arundinacea), in vitro,* from 'somatic embryos' (Usha et al, 1982), were obtained using bamboo grains (seed) as explant tissue. Use of grains restricted the direct application of their findings for *in vitro* mass propagation of species as availability of the grain is uncertain due to the long interval of flowering. Thus the investigation on the use of vegetative tissues (leaves, stems, buds etc.) as explants is of immense importance to develop an efficient mass propagation technique for bamboo plants through tissue culture. In fact Heinz et al (1977) were able to obtain plantlets in sugar cane, a close relative of bamboo, from roots, leaves and parenchyma of internodal tissue via tissue culture techniques. With this view, a series of exploratory experiments with young branch nodes, dormant culm buds, non-dormant culm buds, and emerging shoot (culm) tips has been undertaken using Bambusa *glaucescens,* a thin walled bamboo, (Banik

The dormant bud explants grew, while other explants did not develop. Key steps of the experiments included the dis-infestation of the tissue with 20 to 30% “Javex” (5 to 6%) sodium hypochlorite) ; MS medium modified to include 4% sucrose, 3g 1– ¹ activated charcoal; the use of dormant culm buds as explant with 1 mgl- ¹ benzyladenine (BA) for initiation under 14 hour photoperiod and a temperature of 28°C, followed by two successive transfers of explant on fresh modified MS medium supplemented with activated charcoal and 5 mgl- ¹ BA and 1 mgl-1 napthalene acetic acid (NAA) . The culture proliferated and produced 7 to 9 cm long shoots. Extensive root development was observed after 31/2 months (approximately 105 days) of culture and successive transfers on the same type of medium with progressively higher levels of BA (from 1 mg to 7 mg 1 -I) and NAA (from 0.5 mg to 1 mg 1 ¹) (Plate 5). The plantlets attained 12 cm height

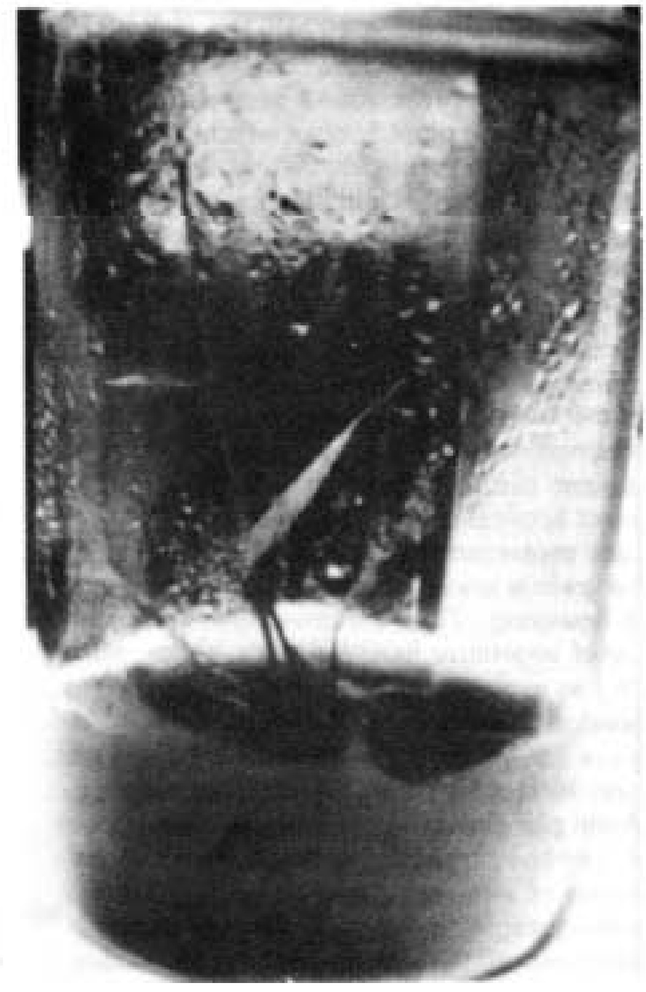


Plate 5 Tissue culture of Bambusa glaucescens Siebold: Shoot and root dvelopment *from* dormant *culm bud after* culturing 31/2 months *on* modified MS medium supplemented with BA (from 1.0 *mg to 7.0 mgl- ¹)* *and NAA (from 0.5 mg to 1.0* mgl-

Plate 6. *Tissue* culture of B. glaucescens Siebold: A healthy bamboo *planted with 48 cm long shoot ufter.5* months of transfer to the soil.

after 4 months (120 days) of tissue culture and these were successfully transferred to moist sterile soil in perforated transparent polyethylene cover After 5 months of transfer to the soil, the plants were 48 cm tall with more shoots (Plate 6). Therefore, it appears that the frequent transfer of tissues into fresh media supplemented with activated charcoal and BA is an important procedure for in vitro culture of bamboo. However, a detailed study on the physiological requirements for bamboo tissue culture is necessary to optimize the procedure Knowledge on tissue culture in B. *glaucescens* gives a definite hope for the mass propagation of thin -walled bamboo species of Bangladesh which are generally not amenable to any known vegetative methods.

Conclusions

The studies revealed that some of the widely cultivated thick-walled bamboo species *(e.g. Bambusa vulgaris, B. polymorpha, B. balcooa)* of Bangladesh may be successfully propagated through prerooted and prerhizomed branch cuttings. Almost all the forest species (thin-walled) of the country so far showed poor or no success in reproduction through any of the macropropagation techniques. Shoot proliferation and rooting of explant tissues of both thick and thin-walled bamboo in in vitro culture is possible. It is therefore worthwhile to study the techniques of tissue culture and bud culture in bamboos. The cloning of desired genotypes and the recovery of new variant types provide additional opportunities for improvement of bamboos which are difficult to manipulate with conventional genetic and breeding methods.

Acknowledgements

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In Vitro Callus in Bamboos Schizostachyum and Thyrsostachys Species

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Abstract

The scarcity of woody material either for timber or fuel is a serious problem facing mankind, at present. The usefulness of bamboos and the dependency of a large population of people in the developing countries on bamboo resources is well known. The traditional methods of propagation are said to be inadequate to increase the desired levels of production and tissue culture methods seem to offer great promise. In vitro callus induction in *two bamboo species of Schizostachyum and Thyrsostachys is briefly reported. The importance of selecting the suitable vegetative materials* for culture *work is stressed under discussion.*

Introduction

The shortage of forest products both at present and in the next two decades will be a serious problem unless the forest biomass production is urgently increased. The demand for timber and paper will increase by a factor of two to three. The world annual consumption of timber and fuel wood at present is 1,300 and 1,500 million cubic metres, respectively. It is estimated that in the northern half of the world the average paper consump&n at present is 150 kg/year/person while in the south it is 5 kg. Almost half of the human population of the developing world (2.7 billion) will face serious shortage of both timber and fuel wood by the year 2000. At present, bamboos are used for one of the above purposes in many countries. Due to a variety of reasons there is an urgent need to augment the bamboo cultivation in various developing countries of Asia. While traditional methods of using seeds or cuttings are largely applied for propagation, with good *or* partial success. an urgent appeal is also made for further experimental research to use the modern methods of plant tissue culture (Lessard and Chouinard, 1980).

The availability of seeds and their regular supply is very uncertain or almost impossible since bamboos are very irregular in their flowering habit, The alternative of using the vegetative materials has many limitations. Under these circumstances, tissue culture methods offer promise and *in vitro* culture work has started in some of the Asian countries like India, Malaysia. Japan, Thailand, Bangladesh and others. A few publications have resulted so far (Mehta *et al.,* 1982). The present paper is a preliminary report based on the *in vitro* culture work conducted on two local bamboos in our laboratories.

Materials And Methods

The species of bamboos growing in Singapore are listed in another paper published in this proceedings (See Rao. 1985). Young fast growing culm shoots of two species *Schizostachyum brachicladum* and *Thyrsostachys siamensis* are used for culturing. After surface sterilization with water and alcohol, the culm sheaths are removed one by one until the tender parts of the axis are exposed. The nodal regions, axillary buds and smooth basal parts of culm sheaths are clearly seen at this stage. The lower parts of the sheaths are cut into smaller pieces of about 1 cm long and half cm wide and used as inoculae.

N^6 medium is used supplemented with sucrose (3-5%), casein hydrolysate (0.1 g/l) and 2.4-D (0.5- 10 mg/l) _The cultures are maintained under 16 hrs daylight regime at 25 ± 2°C.

Observations And Results

In the two species selected for the present study Schizostachym brac~ic~a~um represents the thick and *Thyrsostachys* siamensis represents the thin types of bamboos. The bamboos grow all the year round due to the uniform humid climate in Singapore. This *also* facilitates ail the year round availability of suitable vegetative shoots. Like in other parts the flowering is very rare in locally grown bamboos and there is no hope of obtaining seed materials frequently. Therefore, suitable vegetative materials need to be used. The cuim shoots are the tender axial regions of the growing bamboos and at any one time different sized shoots can be collected which ensure a steady supply of materials for experimental work. (Also the advantages are many which shall be discussed later.)

The cuim sheaths are separated in basipetal order up to the point of obtaining the solid stem axis with regular nodes and axiliary buds (Fig. A, l-3). The nodes are condensed and closely arranged representing the pre-elongation phase of the internodes. The cuim sheaths are arranged spirally and closely packed over one another. Each sheath has a basal and an apical region. Nearly 60-70% of the sheath represents the basal part, which is smooth and cream coioured. The upper part is dark, somewhat triangular with epidermai outgrowths and these are rejected. Only the basal parts of culm sheath are suitable to be used as inocuium. The cut pieces are placed either horizontally or vertically on the medium (Fig. A, 4-6).

The initial swelling of the inocuium is observed in about l0-12 days and most of the units appear as fluffed structures with many ridges and grooves (Fig. A, 4-7). When removed from the container and examined under the binocular microscope, the uneven nature of tissue growth becomes clear in many cases with ruptured epidermis. The early growth is restricted to cut ends of the segment (Fig. A, 4, 7) which shows formation of smooth, homogeneous, white tissue (Fig. A, 7). Later the growth extends to other parts of the segment and nearly *20-30%* of the inoculae used would give massive, uniform callus (Fig. A, 5, 6, 8, 9) and others show limited growth. In the well grown mass, the growth is uniform, the surface directly in touch with the medium growing more vigorously and incurling over the surface exposed to the air. Small areas of original inocuium not so actively grown appear as leftover crevices or cavities, darker in colour than the well formed callus part (Fig. A, 8, 9). Small papillae are distinct on the growing callus, some are more emerging than others. Any part of the inocuium torn or segmented and in contact with the medium would also form the callus (Fig. A, 7, 9).

Sections of the developing callused segments reveal the origin of the callus from the leaf tissues. The cuim sheath in transection shows distinct upper and lower epidermis, the former with thicker cuticle (Fig. B, 1). The mesophyii tissue is undifferentiated and the vascular bundles are closer towards the upper epidermis. Fig. B, 1 is a cross-section of the two week old inoculum ‘showing ruptured upper epidermis with many enlarged or elongating cells emerging out of the surface. The mesophyii towards the lower epidermis remains intact and at this stage, many ceils show active cell divisions (Fig. B, 2). In the well formed old callus the tissue arrangement is loose and the individual ceils can be easily separated from one another either by squashing the tissues under the coverslip or applying pressure by thumb. The individual cells thus separated appear somewhat angular, oval, round or elongated (Fig. B, 3, 4). The elongated cells develop into ionq fiiamentous structures and many divide to form two or three celled filaments. The thickness of the wail is uneven. Each ceil has a prominent nucleus surrounded by a number of granular brown bodies and in squashed preparations they easily get dispersed into the mounting medium.

Further work is in progress.

Discussion

By comparison the in vitro culture studies on members of Gramineae is very recent (Vasii 1982). Sugar cane and rice tissues or embryos are grown under in vitro to improve the genetic varieties as part of the breeding programmes (Swaminathan, 1982; Sondahl et al. , 1983). Of late, the results of work on several other cereals are published (Vasii,

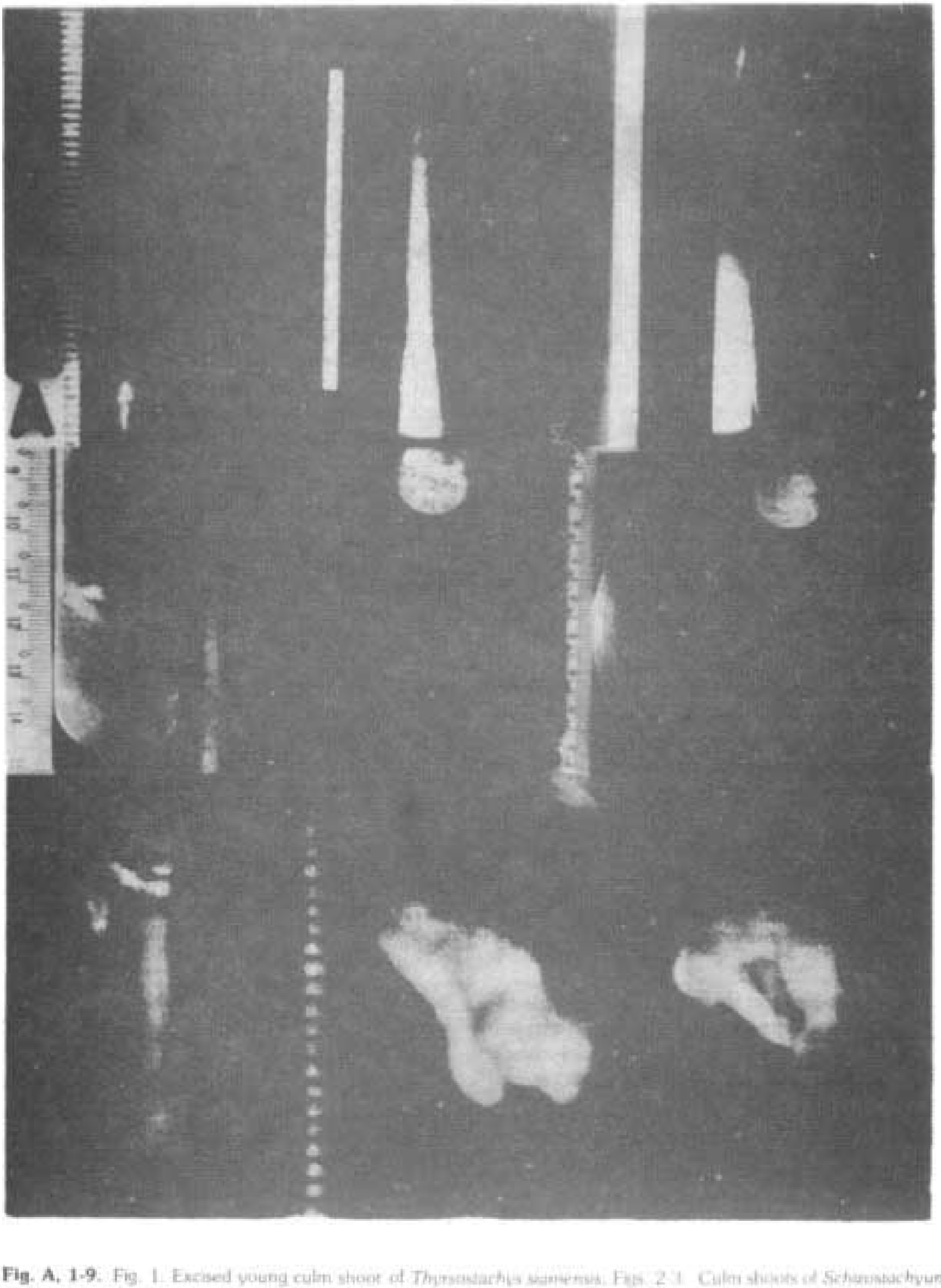

Fig. A, 1-9. Fig. 1. Excised young culm shoot of *Thyrsostachys siamensis*. Figs. 2-3. Culm shoots of *Schizostachyum brachicladum* with sheathing leaves peeled off showing nodes. Fig. 3. A single culm leaf excised with basal light coloured and upper dark coloured positions. Basal part used. Figs. 4-5. Culture of *S. brachicladum* with 2, 4-D 10 mg/l 7 weeks old. Fig. 6. Culture of *T. siamensis* with 2, 4-D 8 mg/l. Fig. 7. *T. siamensis* explant enlarged 2, 4-D 4 mg 12 weeks old. Figs. 8-9. *T. siamensis* enlarged from Fig. 6 showing the callus surface and mode of growth (mm scale)

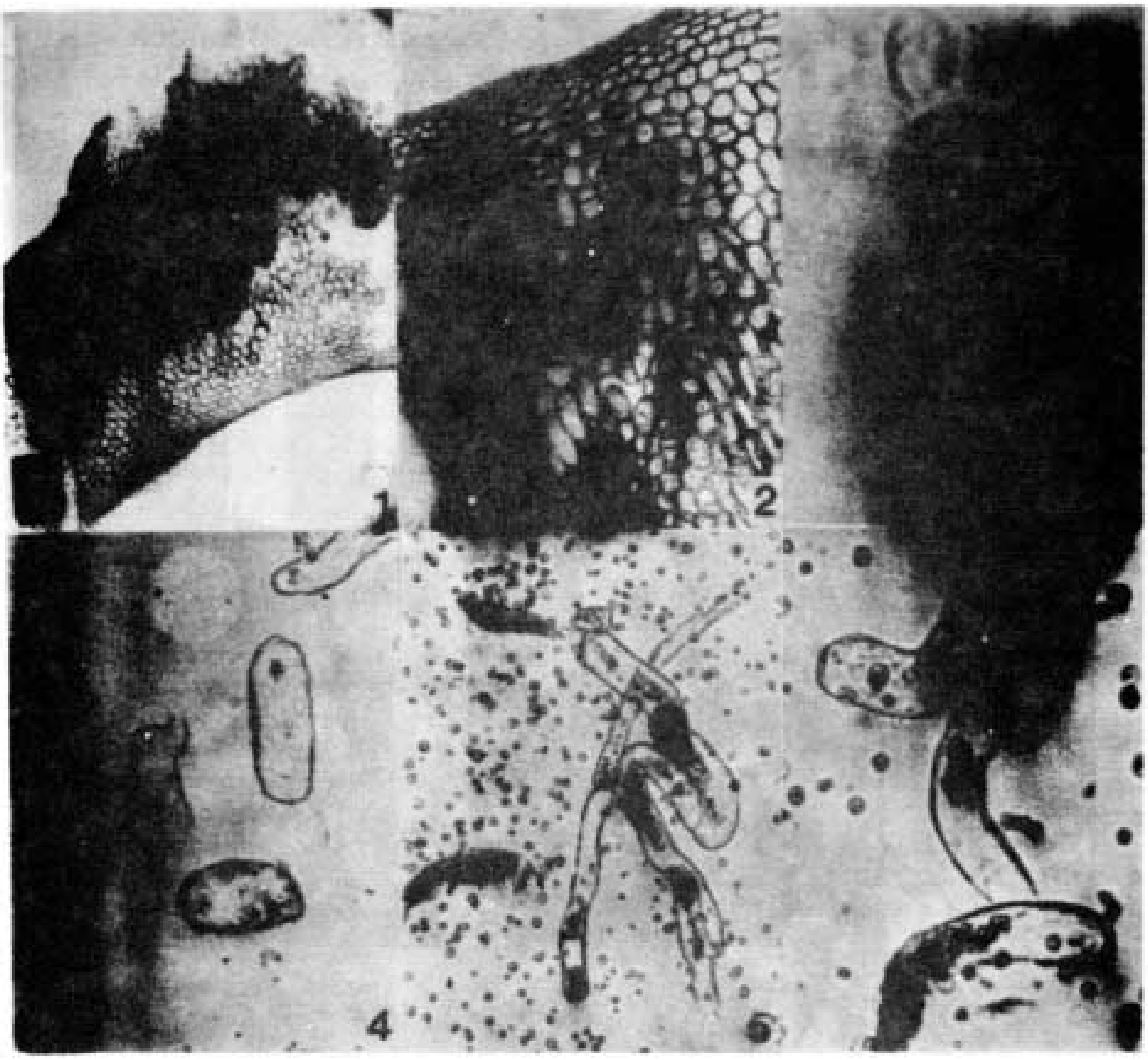

Fig. B, 1-6. Fig. 1. T.S. culm leaf showing epidermis and mesophyll outgrowth, Note the position of vascular bundles. Fig. 2. Lower epidermis and mesophyll enlarged showing active cell divisions, Note the pocket of collenchyma tissue. Figs. 3-6. Isolated or free cells obtained, enlarged to show the cell characteristics. Fig. 6 has a two-celled filament,

1982; Bhojwani and Razdan, 1983). Seeds of Bambusa arundinacea give callus tissues which differentiate into many embryoids. Also, individual embryos are obtained- from free cells which regenerate into plantlets, all under in vitro, This excellent work has laid the foundation to grow bamboo tissues in vitro (Mehta, 1982). The present studies indicate the possibility of using the vegetative or leaf tissues to obtain callus which serve as the most important source material that can be used for further organ differentiation to obtain regenerated plantlets or to obtain protoplasts for fusion.

The tissues of the two bamboo species used presently show uniform growth and hardly they can be differentiated from one another at callus level or by their cell characteristics. As far as the authors are aware, this is the first report where the in vitro growth of vegetative tissues of bamboos is reported. Using the vegetative materials, especially the leaf base, have many definite advantages over seeds or embryos, since bamboos are notorious as they rarely flower and produce any seeds. Further the seeds are of limited viability or recalcitrant and adequate supply of good seeds is scarce, Hence, seeds are not reliable as experimental materials to establish continuous cultures and for mass propagation. The axillary buds on mature shoots are available but they are not for these two reasons:

1) Bud scales are hard to remove and

obtaining clean material is a problem.

2) Many buds remain empty inside since the inner tissues are damaged either by rotting or insects or fungus, especially under humid conditions.

The technical problems for initiating or inducing callus are many and these have to be solved at each plant species or variety level. These problems are solved for the two species studied presently. The results obtained so far help to plan further work and pursue the same either at cellular or tissue level. Protoplasts are also obtained both from the fresh and in vitro grown tissues and these results will be reported in a subsequent paper.

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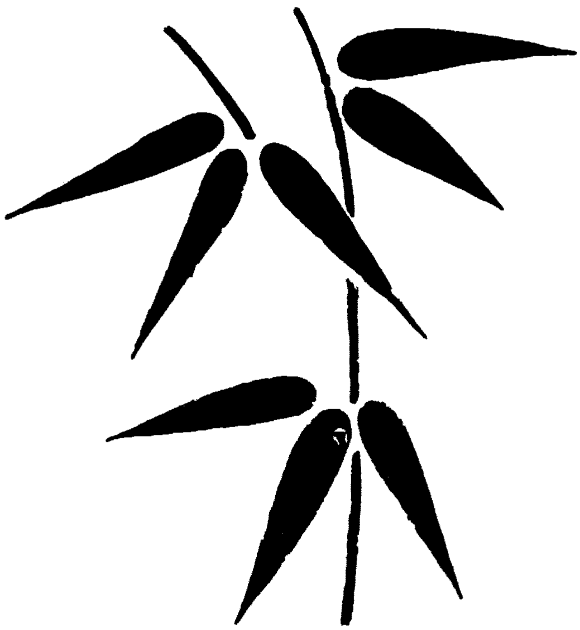

Studies on the Chromosome Number of Some Bamboo Species with Clump Rhizomes

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Abstract

The chromosome numbers of 16 bamboos species from South China are recorded. The material was collected from the bamboo garden in Forest Research Institute of Guangdong Province. Many bamboo species have somatic chromosome number of 2n = 64, and ccm be easily hybridized with strong affinity. From the study it is apparent that there are different basic chromosome numbers in various bamboos studied.

Introduction

Chromosome is the carrier of hereditary substance. By investigating the chromosome number of plants, one can understand the relationship between species and explain heredity phenomena. This report is on the chromosome number of 30 bamboo species with clump rhizomes. Studies on the chromosome number of bamboo have been reported earlier (1). It is generally agreed that the somatic chromosome number 2n = 72 and 2n = 48, in the tropical and subtropical bamboo. The basic number is x = 12 and tetraploids and hexaploids are formed.

Materials and Methods

Root tips of bamboo were obtained from fresh roots. One year old secondary branches of bamboo were wrapped in moist towel, then put in 25°C, and newly emerged fresh roots were used. Preparation of specimen was based on the low osmotic method removing cell wall (Chen and Sang, 1982). The procedures are as follows: 1. Immerse tender roots in 5/10000 Colchicine and 0.002M8-Hydroxyquinoline mixed solution for 3-5 hours. 2. Then immerse roots in 0.75M kcl solution for 15-20 minutes. 3. Immerse roots in 3% cellulase and pectinase mixture (1:1) for 3 hours. 4. Wash with distilled water, 1-2 times, immerse roots in distilled water, Let it stand for 2-4 minutes. 5. Drain off water, squash the root tips with dissecting needles. 6. Pour 3:1 methyl alcohol and glacial acetic acid mixture on it and fix for 20-30 minutes. 7. Drain off precipitates. Suck several drops of cell solution, drop it in prefrozen slides, and dry slides quickly in oven. 8. Immerse the slides in pH7.2 Giemsa solution, stain for 30 minutes. 9. Take the slide out, wash, let dry and observe under microcopic.

Dispersed chromosomes were selected, chromosomes counted and photographed. For each bamboo species, at least 60 cells were counted. Living plants of bamboo were kept in the garden, Forest Research Institute of Guangdong Province.

Results

In table 1, the chromosome numbers of bamboos not reported in China is listed. The results show that:

1. Many bamboo species have 2 or more chromosome numbers in their somatic cells. The chromosome number in Bambusa peruariabilis is 2n = 64, and 56, and occasionally 72. This phenomenon is quite often found in bamboo with clump rhizomes. The chromosome number of a certain bamboo species referred to is in fact the number found most commonly.

2. In addition to the chromosome numbers of 2n = 72 and 2n = 48, many bamboo species have 2n =64. Bambusa pervariabilis, B. textilis, B. lapida, B. dissemulater

var. albonodia, B. sinospinosa, B. sp. A species of bamboo in Guangxi has the same chromosome number of 2n =64. This indicates that 2n =64 is a common feature in some bamboo groups.

3. It is confirmed that hybrid No. 1, B. pervariabilis x (Dendrocalamus + B. textilis) and hybrid No. 14, B. textilis x (Dendrocalamus latiflorus + B. pervariabilis) are true hybrids. The two sets of mixed pollination show that only one of the pollen is effective in fertilization, the other one acts as a mentor. Because the chromosome number of their FI. is 68, this is equal to the sum of chromosome numbers in the gametes of B. pervariablis and D. latiflorus or in those of B. textilis and D. *Iatiflorus.* (The chromosome number in the gametes is half of that in the somatic cell).

4. The chromosome number of Sino*calamus stenoauritus* is 2n = 68. Probably, it is a natural hybrid. 2n = 96 of B. vari-striatus is the largest chromosome number hitherto reported,

5. Ir, Dendrocalamus Iatiflorus and D. minor 2n = 72, the same number reported in Dendrocalamus genus.

6. Lingnania chungii 2n = 72; Sinocalamus affinis 2n = 70.

Discussion

From the observations made, it is proposed, that Sinocalamus stenoauritus is a natural hybrid of *B. textilis x D. latiflorus. The* reasons are: *(1) S. stenoauritus* has thinner wall, smaller buds, a character of branching at higher level, small main branch; lateral branches with nearly same size, moderate sized leaves. All these morphological characters are very similiar to the artifically pollinated B. textilis x D. latiflorus hybrid No. 11. (2) It has a chromosome number 2n =68, that exactly equals the sum of the chromosome number in the gametes of the two parents added together. (3) Pollen of S. stenoauritus are highly sterile, and nearly no

Table 1. Chromosome numbers of some bamboo species with clump rhizomes in China

Scientific name	No. of chromosomes
Bambusa pervariabilis	64,56,72
Dendrocalamus latiflorus	72.64.48
Bambusa textilis	64,56,72
Cheng Ma Qing No. 1	68
Qing Ma Cheng No. 14	68
Sinocalamus stenoauritus	68
Bambusa lapida	64,52
Bambusa chungii (Lingnania chungii)	72,64
Bambsa emeiensis (Sinocalamus affinis)	70
Bambusa biciatricatus (Sinocalamus biciatricatus)	64,72
Dendrocaiamus minor	72
Bambusa vario-striates	96,84
Bambusa sp. Guabgxi	64
Bambusa dissemulater var. albonodia	64
Bambusa rutila	64
Bambusa sinospinosa	64

seed setting (Same results in Lin's paper (1980). This agrees with the fact that FI cross is sterile.

(2) Bambusa vario-striatus is a natural mutant, because it has a very large chromosome number of 2n = 96 (Table 1, 2). Furthermore, no crossing from of any two bamboo species has the number of 2n =96, so probably this is not a hybrid. Bamboos with 2n = 64, in abnormal reduction division, would produce gametes without reduction, then fuse with a normal gamete to form 3n (3n = 3 x 32 = 96). Though B. vario-striatus flowers easily, the percent of seed setting is very low. From this point of view, it may be an odd basic number of a poiypioid.

(3) In addition to the basic number of x= 12, other basic number also exists. Since the new finding of 2n =64, the only basic number 2 x 2/2 is questionable. If this is true then bamboo with 2n = 64, should be 2n=64=5x 12+4 an odd number aneupioid. From the genetic standpoint, fertility of ail odd number aneupioid is very low. Statistical data have shown that only 25% of tripioid's gametes with a basic number of 3 and 12.5% of its gametes with a basic number of 4 are alive. That means, the higher the basic number, lesser the number of living gametes. Triploid with a basic number of 6 or more will be completely sterile.

(4) Accordingly an aneupioid of 2n = 64 = 5 x 12 + 4, will be completely sterile too. But this is in contradiction to the present results. Both of B. textiiis and B. pervariabiiis have chromosome number of 64, and they are fertile, especially B. sinospinosa. The percent of seed setting is quite high. Our conclusion is that 2n = 64 should not be an odd number aneupioid and it must be considered as an even number eupioid. This shows that Bamboos have a basic number of x = 12 and other basic numbers as well.

Even though the chromosome number of ***B. pervariabilis, D. Iatiflorus*** and B. textilis is different from each other, they can be easily hybridized and have strong affinity to each other. The author proposes that, D. latifiorus 2n = 72, octopioid, a basic number of 9; B. pervariabiis and B. textiis 2n = 64, octopioid, a basic number of 8. The basic number of 8 is a derivation from x = 9, with one chromosome eieminated from the genome. Their chromosomes are homogeneous, therefore, bamboos with 2n = 72 and 2n =64 can be crossed with each other. This explains why 2x = 64 is fertile, because it is an octopioid with a basic of 8. Generally an even number eupioid is fertile.

(4) Chromosome numbers of bamboos adapt to variation of temperature zones. Previous research pointed out: clump bamboos in the tropical zone mostly have 2n = 72; dispersal bamboos in the warm temperate zone mostly have 2n =48. Our cytological study on bamboos in southern subtropical zone shows that they mostly have 2n = 64. The number is in the range between 72 and 48, the difference in chromosome number is affected by climatic condition, numbers decrease gradually from the tropical zone to the subtropical zone (72- 64- 48-). It is expected, if 2n is less than 48 woody bamboos will exist and they can only be found in the colder regions, viz. on high latitude or at high elevation.

China covers a large area with a wide ranging climatic condition, and has many bamboo species, Cytological studies in China will help to explain the origin, evolution and derivation of bamboos, and may solve many taxonomic probiems. To understand the relationship between bamboo species, chromosome study alone is not sufficient, and studies on karyotype analysis, together with compatibility experiment are needed. By comparing the results obtained, more correct conclusions can be drawn (Soderstrom, 1981; Lin, 1980; Roes and Jones, 1977; Anon 1976,1980).

Table 2. Chromosome numbers reported in previous work-outside China.

Species	No. of chromosome	Species	No. of chromosome
Arudinaria iwatekensis	48	Ph. bambusoides	48
A. gigantea	48	Ph. striata	48
A. simonii	48	Ph. marliacea	48,72?
Bambusa arundnacea	72	Ph. flexusa	54?
B. floribunda	72	Pleioblastus fortunei	48
B. multiplex	72	P. gramineus	48
B. polymorpha	72	P. hindsii	48
B. tulda	72	P. communis	48
Chimonobambusa marmorea	48	P. chino	48
C. falcata	48	P. simonii	48
Cephalostachyum pergraciie	72	P. pygmaeus	54?
Dendrocalamus brandisii	72+2B	Pseudosasa japonica	48
D. giganteus	72	Sasa kazsa	48
D. hamiltonii	72	S. kurilensis	48
D. logispathus	72	S. paniculata	48
D. strictus	72,70?	s. sp (3x)	36
Gigantochloa macrostachya	72	Sasamorpha purpurascens	48
Guadua capitaya	46	Semiarunfinaria yashadake	48
G. chacoensis	46	Se. pamtiingii	48
G . paraguayana	46	Sinobambusa tooksik	48
Indocalamus wightianus	48	Tetragonocalamus agulatus	48
Melocanna baccifera	72	Thamnocalamus aristatus	48
Phyllostachys aurea	48		

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Studies on Bamboo Hybridization

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Abstract

There are very few *papers* published on hybridisation *in* bamboos. *The biological characters* of flouters, *the pollen* viability, *the process* of hand *pollination, seed productivity and their germination are* discussed. *Many successfully* viable hybrids resulted from *the crosses made between Bambusa,* *Phyllostachys and* Dendrocalamus *species. The criteria for selecting the good hybrids are* discussed.

Introduction

Bamboo grows fast, producing useful timber. Once planted a bamboo stand can be cut repeatedly for a long period. So, developing bamboo production is of great significance not only to promote economical gains but also to help rural commodity economy and increasing farmer's income. Guangdong province in Southern China enjoys warm climate all year round and rainfall is abundant and suitable for bamboo growth. In order to cultivate the new type of bamboo that shows fast growth, provides quality timber, has wide adaptability and higher economic value the research on bamboo hybridisation has been undertaken.

Flowering and Formation of Caryopsis

Prior to flowering, the growth of the plant abates, the yield is reduced and the shoot emergence is earlier than usual with deformed branches and leaves. The wood becomes fragile. Bamboos can flower in all the four seasons, but the main period of regular flowering is from February to June. There is a long or short interval between the successive groups of plants. During early spring, the interval between plants is about one month or longer. As the weather gets warm, the interval shortens by 2 weeks from May to July,

The flower structure of bamboo is composed of lemma, palea, stamen, pistil and lodicule. When flowering, floral glumes open, stamens stretch out and the stigma separates in three directions. The flowers last for about 2 – 3 hours, and then close. When the weather is dry, they will close more quickly. In some species of *e.g. Dendrocalamus latiflorus,* the pistils first extend out of gfumes, followed by stamens few days later. In case the glumes do not open it is difficult to know when the bamboo flowers are suitable for pollination. Therefore the anthesis should be determined before pollination. Pollen scatters after the flowers have opened for about one hour and it will be earlier if the temperature is high and the humidity is low.

The Viability of Pollen and the Methods of its Preservation: Sucrose solution at 5 – 10% with 5 p.p.m. Borax were used to test pollen germination in several bamboo species (Table 1). Better percentage germination correlated with high seed selfing. In some the values are low.

Table 1. The percentage pollen germination in some species.

Bamboo species	Extent of pollen germination percentage (%)
Phyllostachys pubescens	26.5 – 64.1
Dendrocalamus latiflorus	5.4 – 40.4
Bambusa pervariabilis	2.9 – 14.8

Bambusa textilis	3.4 - 7.2
Bambusa sinospinosa	4.3 - 14.3

The bamboo pollen begins to germinate in about 15 - 20 minutes. The length of pollen tube exceeds the diameter of pollen grain in 20 - 30 minutes. The percentage germination stabilises in 30 — 60 minutes. The tips of some pollen tubes burst. The pollen swells by absorbing nutrients and when it is dry they shrink. The percentage of pollen germination declines. When it is dry the pollen would loose viability in about half an hour. Therefore for successful hybridization of bamboos the viability of pollen should be maintained, if the other species which are to be hybridized are not flowering at the same time. The pollen can be stored in refrigerater to preserve viability. For this the fresh anthers are placed in a finger like bottle about one-third of its capacity, and closed with a ball of wet cotton to maintain the moisture of anthers. The bottle is stored in the refrigerator under a temperature of 4°C. In this way the anthers do not dehisce and scatter pollen during the period of storage. By using this method, the pollen of Phyllostachys pubescens, can be stored. After five days of storage, the percentage of germination is reduced by 28.3% but stored pollens can still be used for pollination.

Seed Setting: The seeds of the sympodial bamboo ripen in about 15 to 30 days after pollination, but the monopodial type of bamboo, such as Phyllostachys pubescens takes a longer period of 50 to 70 days. The ripe seeds are easily released and drop off naturally. The percentage of natural seed setting under the condition of irregular flowering is usually very low. The reasons are as follows:

1. Both insufficient nutrition and low light intensity in bamboo stands affect the normal development of flower buds, very few pollen, so that the percent of fertility is considerably low.

2. The bamboo pollen easily lose their germinability under conditions such as severe sunlight, heavy rainfall and low humidity. In such conditions flowering may be high but percentage seed set is low.

5. Small sucking insects usually assemble on the stigma of flower, and lay eggs in the floscules. The larvae are hatched with the glumes and they bore into the ovary, causing severe damage of the whole inflorescence. Sometimes, 90% of the flowers are damaged.

Technique of Hybridization

Because of the low percentage of natural seed setting, more attention was paid to understand the biological characters of bamboo flowering. The following effective measures were taken to raise the percentage of seed setting.

1. Bamboo clumps were transplanted in special nusery or in a large pot. Fertilisers only with phosphporous and potassiam were applied. Light conditions were improved. The flower buds develop normally so as to promote seed setting. While transplanting the experimental material was cut into dwarf plants in order to pollinate the flowers conveniently.

2. During the period of February.of June, especially from May to June, bamboos flower in great quantity. Generally speaking, the earlier the flowering, the better the seed setting. Because the tempereture is low at that time and it results in a longer period of 'seed-ripening. The seeds grow large and give a high percentage of germination. A great quantity of seedling is produced. With the higher temperature the ripening period of seeds shortens gradually, which helps to reduce the low quality of seeds. Therefore, it is preferable to do the hybridization work in the early part of the season.

Some species of bamboo, such as Phyllostachys pubescens and Dendrocalamus *Iatiflorus,* produce a small quantity of flowers in November and' December. Although in this period the quantity of flowers is not as great as those formed in May and June, the percentage of caryopsis bearing is quite high.

3. During the season many flowers are tormed but all of these can't be pollinated so it is reasonable to remove some of them in order to reduce nutritive consumption, The flowers in the middle part of the spikelet develop much better than those at the top of the spikelet. More than 60% of seed is set in the middle part. Therefore it is better to select the flowers in the middle part

of inflorscence to pollinate for the purpose of getting larger percentage of seed setting in hybridization.

4. Bamboo flowers generally open from 5 a.m. to 9 a.m. and close at noon. It is necessary to pollinate in the early morning. because it is cooler, atmospheric humidity is higher, which is good for doing controlled pollination.

5. Bamboo pollen loses viability very quickly. In order to get the fresh pollen, bamboo plants need to be transported in separate batches preferably during September to November and February to May. By doing this the early and less flowering varieties may be made to overlap. In this way fresh pollen can be collected for the experiment almost every day.

6. Precautions should be taken against bad weather, which affect the germinating ability of pollen. During and soon after pollination the plant should be left out of sunshine and rainfall. The parent material should be grown in large pots, and they can be moved under the sun or shade as the case may be.

7. It is necessary to control pests during flowering. T.T.V. solution with a concentration of 0.1% was sprayed 2 or 3 times and this helped to control the pests effectively.

Seed Collection, Seedling Development

About 7 to 10 days after controlled pollination, the experimental plants should be checked for seed development. If the flowers are exposed to sunlight a green shadow the size of a rice grain may be visible. This is the ovary ready for seed development. A few days following this the mature flower should be enclosed in a transparent plastic bag to collect falling seeds.

The hybrid seed should be sown at once, in a nutritive container with burnt-soil mixed with 1-Z% of superphosphate. The seed should not be covered too thick with soil and it should be watered properly. In general, the condition should be suitable for seed germination. The soil should be wet but not water logged. The seed takes 5 or 10 days to germinate. When the height of the seedling is about 10 to 15 cm, it is necessary to transplant it into a larger pot for further growth. The seedling should be watered with a nutrient solution every 10 or 20 days. When the seedlings reach a height of a third of a meter it can be transplanted in the field.

Hybrid Combinations

Hybridization trial of 21 groups has been done including 4 genera and 7 species of bamboos. The relationships are as follows:-

1. The hybridizing affinity of the different bamboo species under the same genus is closer, For instance, the percentage of caryopsis bearing in the hybridized combination of Dendrocalamus minor X D. latiflorus is 22%; Bambusa textilis X B. pervariabilis is 13.6% ; and Bambusa textilis X B. sinospinosa is 10%.

2. The hybridizing affinity of the species under different genera but with similar ecological characteristics varies tremendously. For instance, the percentage of caryopsis in the hybridized combination of B. pervariabilis X D. latiflorus or B. textilis X D. latiflorus is 8.1 to 14.5%, but that of B. sinospinosa X D. latiflorus is only 0.6 to 1.6%.

3. The hybridizing affinity of the species in different genera and with various ecological characteristics is more distant. For example, the percentage of caryopsis bearing in the hybridized combination of B. pervariabilis X Phyllostachys pubescens is 1.3 to 3.8%; that of B. textilis X Ph. pubescens is 1.0 to 2.0%: and B. sinospinosa X Ph. pubescens is 0.47 to 1.56%.

4. The percent of caryopsis bearing in distant hybridization may be raised by mixed pollination of bamboos in different genera and with various ecological characteristics, For instance, the percent (8%) of caryopsis bearing in the hybridized combination of B. pervariabilis X (Ph. pubescens + D. latiflorus) is higher than that (1.3 to 3.8%) of B. pervariabilis X Ph. pubescens; similiarly that (3.7%) of B. sinospnosa x (Ph. pubescens + D. minor) is higher than that (0.47 to 1.5%) of B. sinospinosa x Ph.

pubescens.

It is important to study those species with close hybridising affinity. Stronger affinity indicates that the relationship is very close; weaker affinity indicates that the relationship is more distant with regard to breeding. When a bamboo species hybridizes with a closely related one, their offsprings (Fl) grow normally, from which hybrids with good char.- acters can easily be selected. On the contrary if a bamboo species hybridizes with a distantly related one, most of their offsprings (Fl) grow abnormalIy, from which a desirable hybrid can hardly be chosen. For instance, in the hybridized combination of B. pervariabilis X Ph. pubescens , 12,000 flowers were pollinated but only 34 seeedlings were obtained none of which is the ideal hybrid. Therefore, more attention must' be paid to the bamboo species with close affinity, for future hybridization trials.

Another significance of studying affinity between bamboo species is to provide experimental data that may help classification of bamboos. The affinity between B. pervariabilis x D. latiflorus is considerably close. But according to the present classification system, they are not only in the different genera but also in the different subtribes. It is suggested that the taxonomic position of these two species may **be** checked again.

Selection and Identification of Species for Hybridisation

Selection of species depends on the breeding objective. For instance, in order to get good timber for construction. the mechanical strength and durability of bamboo timber should be the major factors of selection. For papermaking, the morphological characters of fibers and the rate of fiber tissue formation should be important in selection. The steps of hybrid selection we have taken are as follows: (1) Observe the growth performance of hybrids, and select the superior hybrids with good growth. (2) Observe the anatomical characters of the bamboo timber of the selected hybrids, and then propagate them by means of vegetative propagation. The hybrids should be tested further for adaptatability, mechanical strength **and** durability. (3) Experiments need to be done to compare the productivity of hybrid clones and their parents which is commensurate to the intermediary experiment before popularization. Final selection is done according to the above procedure. And several selected hybrids with good characters are provided for popularization or for further experiments.

1. The hybrid of 'Bambusa pervariabilis x (B. textilis + D. latiflorus)' No. 1, has the following good characteristics. A) The culm is very high and wide in diameter (up to 13 — 15 M height 6 — 9 cm in diameter). The shoot grows rapidly and-develops into a mature culm in a short time (6 — 18 culms per clump each year). B The mechanical strength of its timber is similar to that of B. pervariabilis and better than that of D. latiflorus. It is not easily broken when used out doors. The timber is useful for scaffolding in construction and as support for banana plants. C) The shoot is a delicacy. There are apparent stripes of yellow alternating with green on the surface of its culm. It is a good ornamental plant in a garden. Besides its culm the big branches in the upper part of the culm can be used for propagation.

2. The hybrid of 'Bambusa pervariabilis x Dendrocalamus latiflorus' No. 25, is suitable to be used as papermaking material, because of long fibre (2332), great ratio of length/width (139), and high ratio of fibre tissue (47.1%) The properties of mechanical strength of unbleached pulp are as follows: Breaking Length 6830 7620 M, Burst 5.21 5.52 kg/cm^2, Folding Endurance 1464 - 1648 times, Tearing Strength 162 — 178 g. The pulp has great strength properties. At the age of 6, its culm develops into mature timber with a maximum diameter of 7.1 cm, height of 13 m, fresh weight of 8.5 kg per culm. On an average, there are 7 culms per clump each year and the yield of fresh weight is more than 2000 kg per m on moderate sites.

3. The hybrid of 'Bambusa textilis x Dendrocalamus clatiflorus' No. 4 and No. 11, have straight culms, with branches at high position, and good appearance. They are suitable for planting in gardens, the timber is also suitable for papermaking, because of the morphological characters of their fibres.

4. The hybrid of 'Dendrocalamus minor x D. latiflorus' No. 5, has a straight culm with

branches at high position. It would be the first grade timber for papermaking according to the morphological and anatomical characters of its fibres. The shoot is edible and delicious. It is a kind of bamboo with good comprehensive characters, suitable both for edible shoots and used for paper making.

In order to reduce the quantity of breeding work, the research in the early identification of timber quality of hybrids has been done so that good hybrids can remain and bad ones would be eliminated. Some of the forest management work would be in vain because the time required from propagating to cutting is about 7 – 8 years. The result of character correlation analysis shows that two characters, namely density of vascular bundles and ratio of fibre tissues may be used for predicting the timber quality of hybrids.

According to the anatomical data, we make the following standards: A) The bamboo timber with large density of vascular bundles and high ratio of fibre tissues may be considered as the hybrid of good quality. B) The bamboo timber with large density of vascular bundles and low ratio of fibre tissues or small density of vascular bundles and high ratio of fibre tissues may be considered as the hybrid of moderate quality. C) The bamboo timber with small density of vascular bundles and low ratio of fibre tissues may be considered as the hybrid of poor quality. Based on the above standards, and the evaluation made for 9 samples the results are almost same as the result of tests on mechanical strength. Significant tests of the correlation coefficients between the data obtained for anatomical characters and the data from the mechanical strength experiment (a = 0.1; p = 1 – a = 90%) show that it is possible to predict the bamboo timber quality at the early stage. The anatomical work on hybrids may usually be done on one year old bamboos. However, the mechanical strength experiment of hybrids can only be done on bamboo 6 – 7 years old. The evaluation of hybrids by anatomical data can be made 4 – 6 years ahead, so that the good hybrids can remain and bad hybrids can be eliminated, which would save a lot of breeding work and wastage of time and labour.

Cytological Observations of Hybrids and Their Parents

In order to establish the relationship of affinity between bamboo species the cytological observations have to be done. The results obtained on somatic cells of 30 bamboo species show that the basic chromosome number of many bamboo species in South China is 64 and 72, as against 48 reported from other studies done aboard. The new chromosome number (64) negates the conclusion that there is only one cardinal number (x = 12) of chromosome in Bambusoideae. For D. latiflorus (2n = 72) can hybridize with B. pervariabilis (2n = 64) and B. textilis (2n = 64), the authors think that the bamboo species with the chromosome number (2n = 64) is an octoploid with the chromosome cardinal number (x = 8), which is derived from x = 9, with one chromosome eliminated from the genome. The affinity relationship is very close, so that compatibility in hybridization is higher. Such results also suggest that Hybrid 'B. pervariabilis x (D. latiflorus + B. textilis)' No. 1, has the qualities of 'B. pervariabilis x D. latiflorus'. The chromosome number is 68, the sum (32 + 36 = 68) of the gamete chromosome number of B. *pervariobilis* (2n = 64) plus that of D. *Iatiflorus* (2n = 72). The pollen of B. textilis only acts as a mentor which does not take part in the insemination. Besides, Bambusa vario-striatus the chromosome number 2n = 96 has the highest chromosome number ever reported so far. It probably is a natural mutant, and also a triploid (n = 32).

Dominating Characters in Hybrids

In the studies made the following genetic characters of hybrids are apparent:

1. The morphological and anatomical characteristics such as the size of leaves, the width of culms, the symmetry of sheaths, the hairy trait of culms, the size, shape of distribution of vascular bundles, etc. are distinct in hybrids. A hybrid usually is the intermediate type between its parents.

2. Some new characters appear in a few hybrids including those from parents. For instance, the fibre length of hybrid 'B. pervariabilis x D. latiflorus', No. 25, is 2332u . However, the fibre length of its parents, B. pervariabilis 1778 ,U and D. latiflorus 1530 u respectively. Hence this character of the hybrid surpasses that of its parents. Further-

more, there are no stripes on the culms of D. Iatiflorus and D. minor, but some stripes of yellow alternating with green on the culm base of their hybrid 'D. minor x D. Iatiflorus' No. 4. Besides, there is a thicker layer of wax on the culm surface of some hybrids. The specific gravity of bamboo timber of some hybrids is larger than that of others. These specific variations would probably be valuable in selection.

3. The suitability of hybrids for vegetative propagation is usually higher and the survival rate of their seedling is also higher. In addition to genetical factors, there is greater vitality in hybrids.

Bamboo plants can easily be grown by way of vegetative propagation. A good hybrid created in hybridization can be propagated into many plants infinitely. The advantage of vegetative propagation is that the good characters of hybrid can last for a long time without character divergence. In South China, the isolated flowering phenomenon of bamboo plants is not rare. In order to improve the traits of bamboo species and create some new cultivation types it is of great significance to do some hybridization experiments at the time when bamboo plants are flowering sporadically. Furthermore, it can provide some experimental data to clear up the present misunderstanding in bamboo taxonomy. The flowering frequency of bamboo plants is rather long which delimits bamboo hybridization. The parents for hybridization work can not be freely selected. However, it is forecasted that with better understanding of flowering physiology of bamboo, it is likely that bamboo flowering can be controlled and regulated. More and more researchers may become interested in bamboo hybridization and utilization of good quality hybrids.

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Morphological studies on the Prophylls and their Systematic Significance

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Abstract

Japanese bamboos are classified into six genera according to the arrangement of prophylls in the bud and these are: Sasa 2. Arundinaria, 3. Shibataea, 4. Phyllostachys, 5. Chimonobambusa and 6. Bambusa. The bud morphology in **Shibataea** ***and number of stamens in*** **Bambusa** ***and*** **Sasa** ***are helpful in identifying the genera.***

Introduction

In 1957, the author reported "Morphological studies on the prophyll of Japanese Bamboos" in the Bot. Mag. Tokyo. The report dealt with four different genera classified according to the arrangement of prophylls in their buds. The present paper is a revision.

The branching of bamboos is regulated by the arrangement of prophylls in a bud. This is an important characteristic of the genus.

Materials and Method

The bamboos studied are: 1. Sasa nipponica Makino (Miyakozasa), 2. Sasa paniculata Makino (Chimakizasa), 3. Sasa kurilensis makino et Shibata (Chishimazasa), 4. Sasa ramosa Makino (Azumazasa), 5. Sasa borealis (Hack.) Makino (Suzutake), 6. Sasa veitchii (Carr,) Rehd. (Kumazasa), 7. Arundinaria hindsii Munro (Kanzanchiku) , 8. Arundinaria graminea (Bean) Makino (Taiminchiku), 9. Arundinaria simonii (Carr.) Riviere (Medake) , 10. Arundinaria chino (Fr. et Sav.) Makino (Azumanezasa), 11. Shibataea kumasaca (Zollinger) Makino (Okamezasa), 12. Phyllostachys heterocycla (Car-r.) Mitf. var. pubescens (Mazel) Ohwi (Mousou chiku), 13. Phyllostachys heterocycra var. heterocycla (Mazel) Ohwi (Kikkouchiku), 14. Phyllostachys nigra (Lodigges) Munro var. henonis (Bean) Stapf. (Hachiku), 15. Phyllostachys nigra var. nigra Munro (Kurochiku) , 16. Phyllostachys bambusoides sieb. et Zucc. (Madake), 17. Phyllostachys bambusoides var. aurea (Sieb.) Makino (Hoteichiku), 18. Chimonobambusa marmorea (Mitf.) Makino, 19. Chimonobambusa quadrangularis (Fenzi) Makino, 20. Semiarundinaria fastuosa (Mitf.) Makino (Narihiradake), 2 1. Bambusa multiplex (Lour .) Raeuschel (Houraichiku), 22. Bambusa multiplex f. Alphonso-Karri (Satow) Nakai (suhouchiku) 23. Bambusa multiplex f. .variegata (Camus) Hatsushima (Houshochiku)

The buds of new shoots were fixed in Bouins fluid. The samples were embedded in paraffin wax (m.p. 56-58C) and 10 nm thick section were obtained and stained with tannic acid ferric chloride and Haidenhains iron haematoxylin.

Results

1. Sasa type: The prophyll is of a two-keeled form and the species produces only one branch. (Fig. 1)
2, Arundinaria type: This type has at least three two-keeled prophylls and produces at least three branches. There are species having seven to nine branches at a node, but these develop from secondary buds. (Figs. 2, 7)
3. Shibataea type: The two outermost prophylls are not of the usual two-keeled form. Two are separated, while the others P3, P4, P5, P6 are two-keeled. Shibataea produces five branches. (Fig. 3)

4. Phyllostachys type: The cross section of this type is the same as the right half of the Shibataea type. This type usually produces two branches or often three. (Fig. 4)
5. Chimonobambusa type: This type produces three branches. These are characterized. by three separate prophylls and the three branches are independent up to the base. (Fig. 5)
6. Bambusa type: This type produces numerous branches at a node. The outermost prophyll shows the usual two-keeled form, but others do not. There are several leaf groups in a bud, and their prophylls have pointed tips. (Fig. 6). Further details are given in Figs. 8-14.

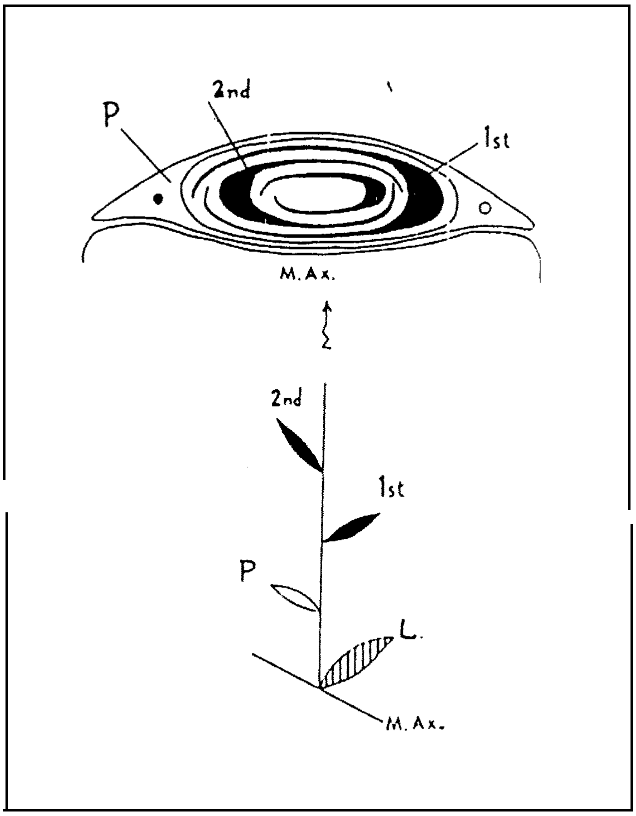


Fig: 1. Sasa type bud and branching. Abbreviations: P-prophyll: lst, the first foliage leaf: 2nd, the second foliage leaf: M.Ax., main axis: L, a leaf on the node of the main axis (= culm sheath). The black leaf represents a foliage leaf and the white one a prophyll.

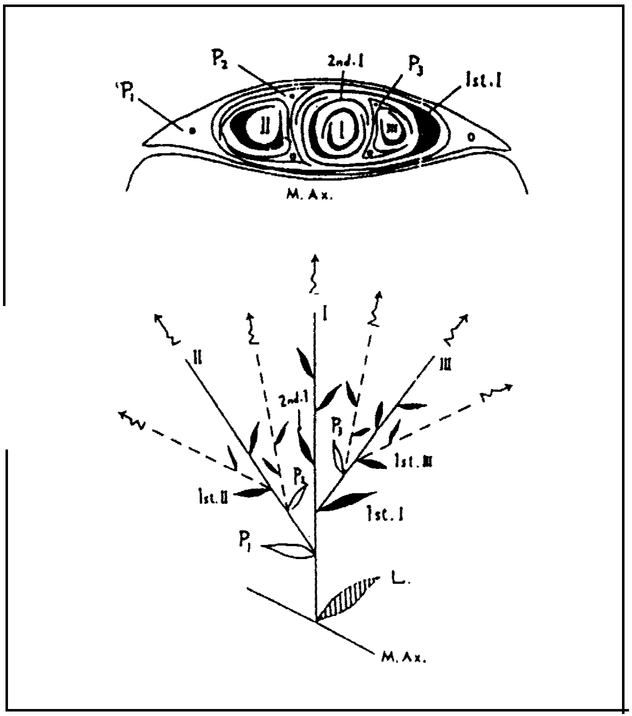


Fig. 2. Arundinaria type bud and branching. Abbreviations: PI, the outer prophyll: P2, the second prophyll in th axil of the p : P3, the third prophyll in the axil of the first foliage leaf: 1st. 1., the first foliage leaf of the first branch: 2nd. 1., the second foliage leaf of the first branch : M.Ax., main axis: L., a leaf on the node of main axis (= culm sheath).

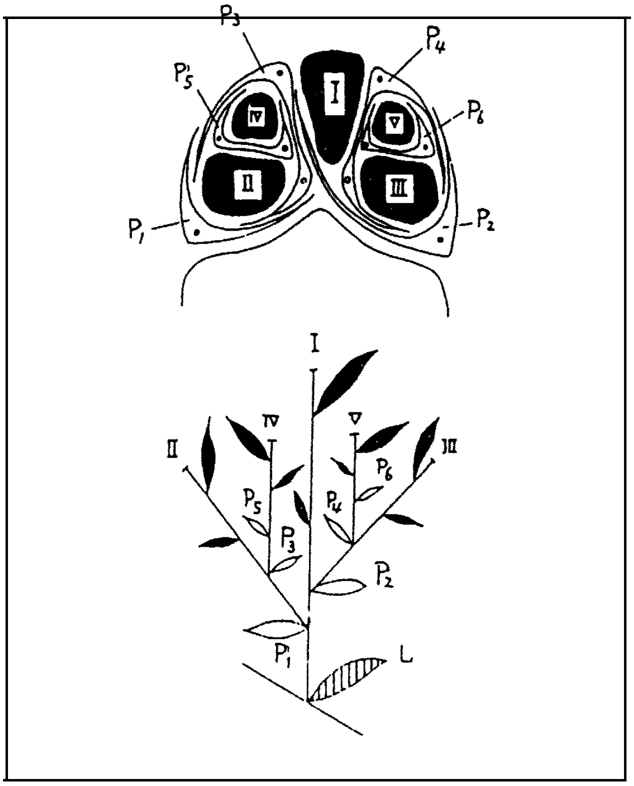


Fig. 3. Shibataea type bud and branching; note that the outermost prophylls are not the usual two-keeled form, but separated,

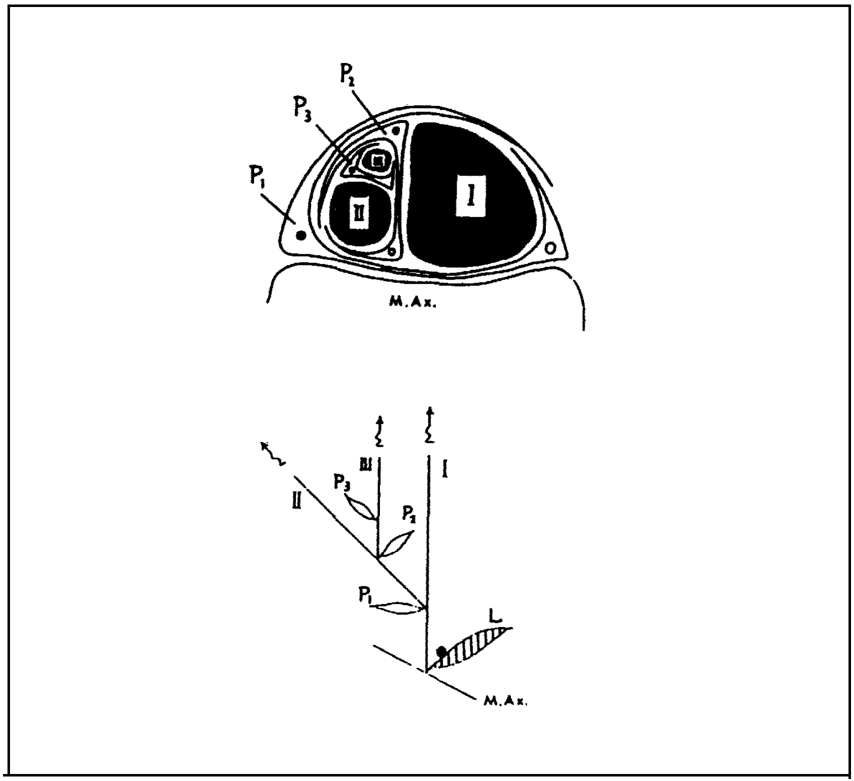


Fig. 4. Phyllostachys type bud and branching; note the peculiar branching.

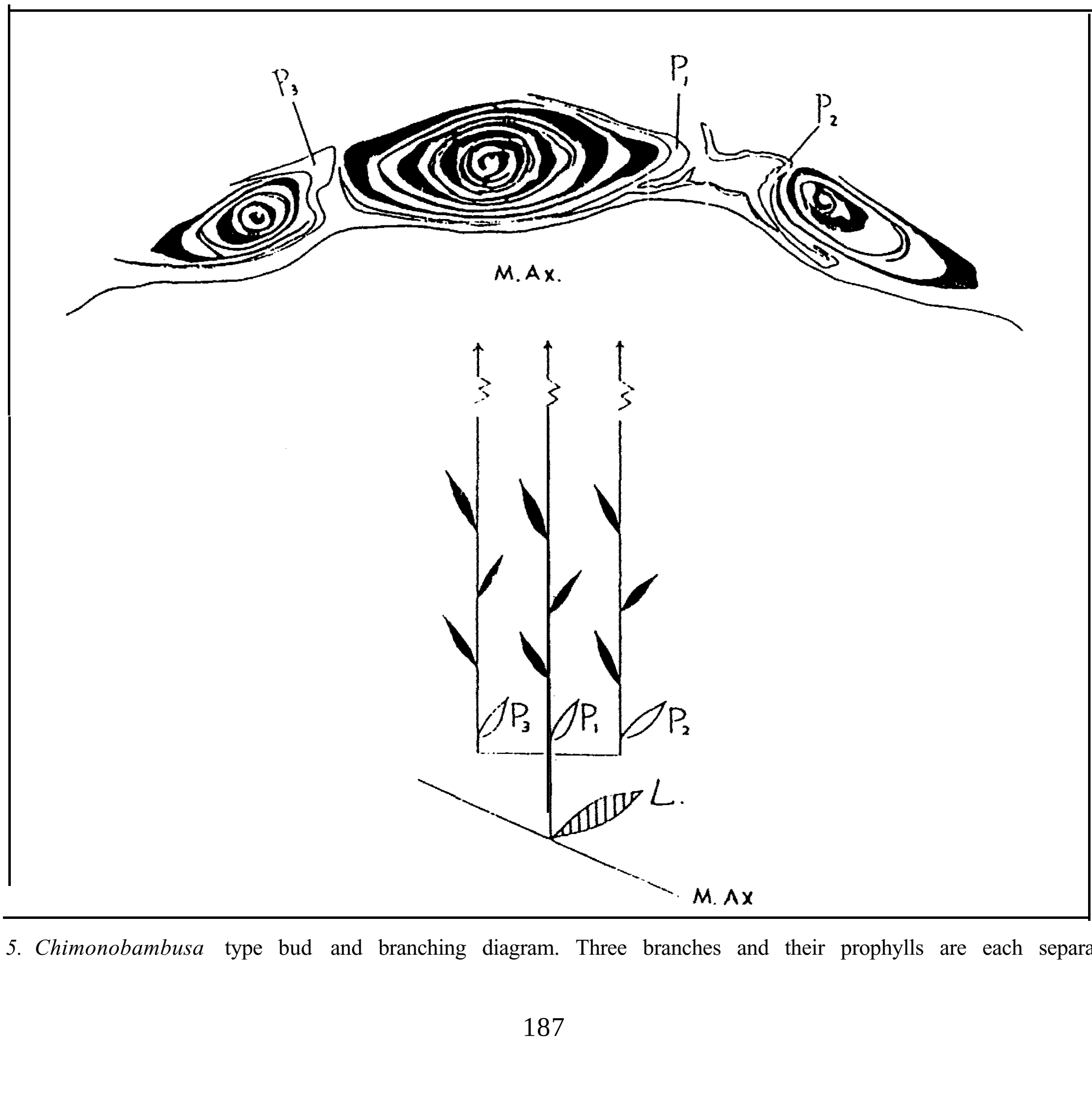


Fig. 5. *Chimonobambusa* type bud and branching diagram. Three branches and their prophylls are each separated.

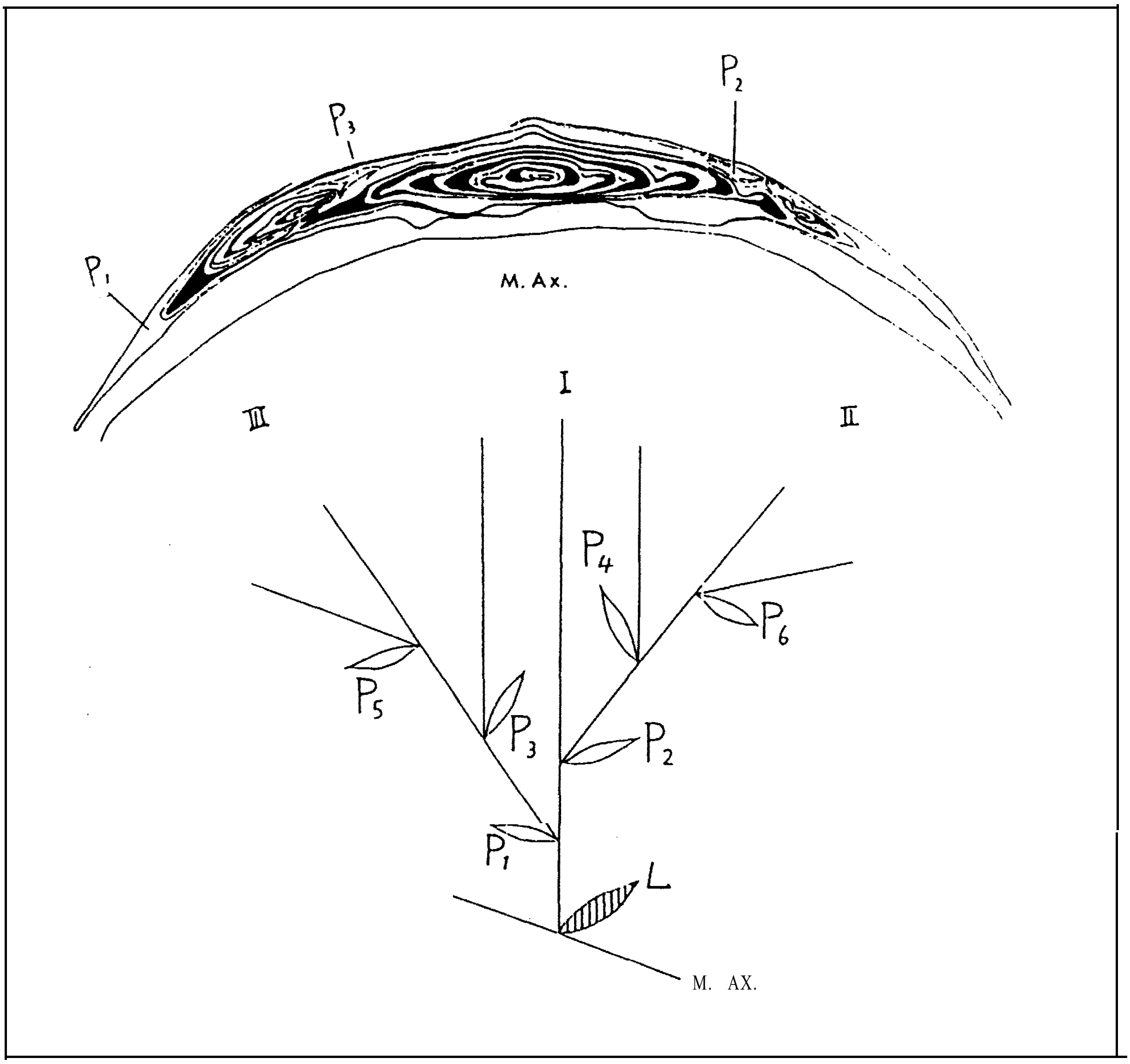


Fig. 6. Bambusa type bud and branching. Each prophyll shows a pointed tip.

Discussion

1, True nature of prophylls

The true nature of prophylls has been the topic of numerous discussions from the 19th century. The usual two-keeled prophyll is thought to be of "double origin". That is, two separate prophylls are fused together on the adaxial side. In another interpretation, the prophyll is an adaxial organ, and the bundles found on the keels are not the main bundle, but side ones. The main bundle disappeared during evolution. The cross section of the Shibataea type revealed that the outermost prophylls (PI, P2) are separated and not fused. If the prophyll of P1 elongates further and covers P2 (Fig. 7) it becomes the same as the Arundinaria type. That is, the prophyll is a lateral organ, and one of the keels has a main bundle.

This interpretation agrees with those of Arber (1925), Bugnon (1924) and Guilland (1924) and the opinion of Blaser (1944); the prophylls and the foliage leaves are not distinguishable and both are merely leaves.

2. Pieioblastus or Aundinaria

In 1966, Dr McClure of Smithsonian Institution, quoted the authors 1957 report in "The Bamboos" and pointed out that Pleioblastus is the same as Arundinaria, and described Arndinaria amabilis in detail. The bud of A. amabilis has been explained and its cross section very closely resembles Arun-

dinaria simonii found in Japan. T. Nakai who did much early work on bamboos was perplexed about Pleioblastus and later proposed the new genus Nipponocalamus. Several ***Pleioblastus*** species belong to Arundinaria as described by T. Makino.

3. Phylogenic considerations

The transformation from the Shibataea to the Arundinaria type is shown in Fig. 7. Section A shows a cross section of the Shibataea type; B, the initial stage of Shibataea when branch IV and V are not yet developed; C, prophyll (P1) which covers branch II extend to the right and cover the prophyll (P2) which covers branch I and III; D, the opposite side of P1 produces a second keel, assuming the same features as of the Arundinaria type. (Fig. 7). The right half of the Shibataea type (branch I and III covered by P2) is the same as the Phyllostachys type. The peculiar Shibataea features reported in 1957 indicated that they led to the Arundinaria and Phylostachys types.

Japanese bamboos can be divided into two groups those having six stamens and those having three. The former are Bambusa and ***Sasa,*** and the latter are Phyllostachys, Arundinaria, Semiarundinaria, Sinobambusa, Shibataea and Pseudosasa. The Sasa species seem to have been derived from southern Bambusa or Dendrocalamus acquiring the characteristic of underground propagation by rhizome. These considerations can be summarized as follows:

Bambusa or ——— Protosasa -Sass
Dendrocalamus

Shibataea ⟨ Arundinaria —— Pseudosasa
Phyllostachys

4. Significance of genus type

Makino, the first to study the taxonomy of Japanese bamboos, established the following new genera in different years: 1901: Sasa; 1912: Shibataea; 1914: Chimonobambusa; 1918: Semiarundinaria; 1918: Sinobambusa; 1920: Pseudosasa; 1929: Sasaella; After 1925, Nakai continued this work: 1925: Pleioblastus; 1930: Sasamorpha; 1933: Tetragonocalamus; 1944: Nipponocalamus; (Makino 1912 – 1925, Nakai 1925 – 1933).

The relationships between these genera are as follows: 1. Sasa type: Pseudosasa, *Sasamorpha and Sasaella* are of this type. Only pseudosasa have three stamens and the other two genera are less important. 2. Arundinaria type: This type includes Semiarundinaria, Sinobambusa, Pleioblastus, and Nipponocalamus. The Iast two should belong to Arundinaria, as explained above. Semiarundinaria is distinguished by a long bract covered with spikelets. Sinobambusa is a distinct genus. 3. Shibataea type and 4. Phyllostachys type are easy to distinguish. 5. C himonobambusa type Tetragonocalamus *was* once classified as Chimonobambusa. Tetragonocalamus is not considered to be an important type. 6. Bambusa type is very distinct.

From the above standpoint, *Sinobambusa, Pleioblastus, Nipponocalamus,* Sasaella, Sasamorpha and Tetragonocalamus are considered to be of little importance. The classification depends on the flower characteristics, and in the bamboo tribe, the genus type should be considered.

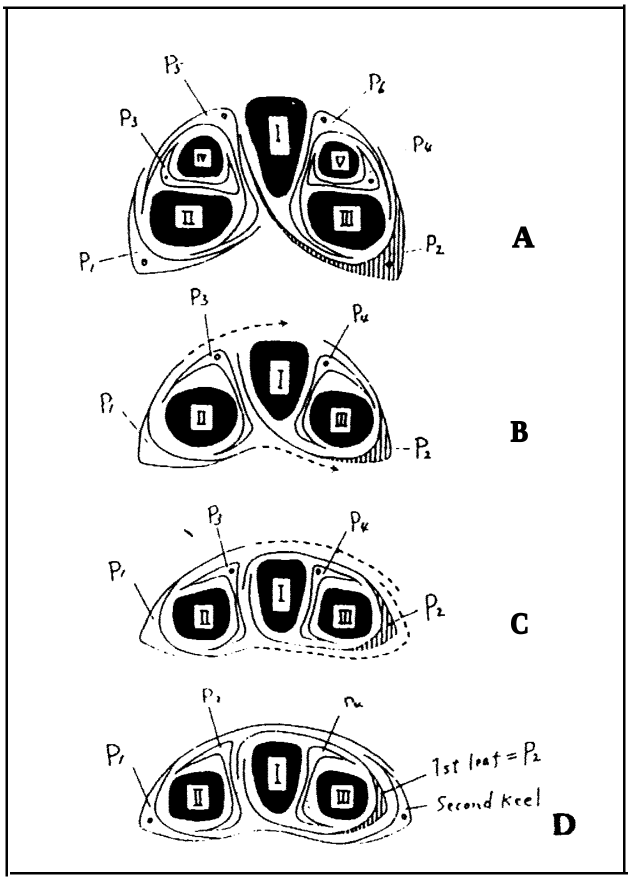
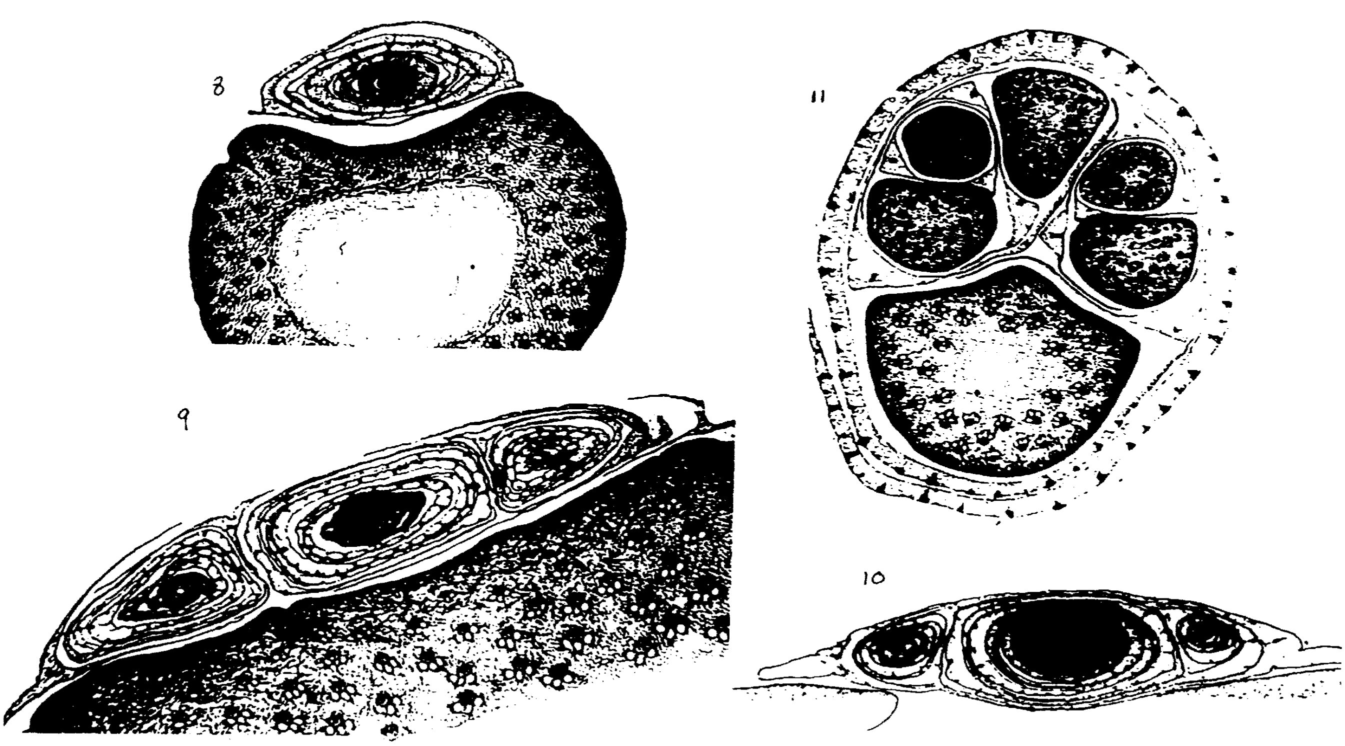
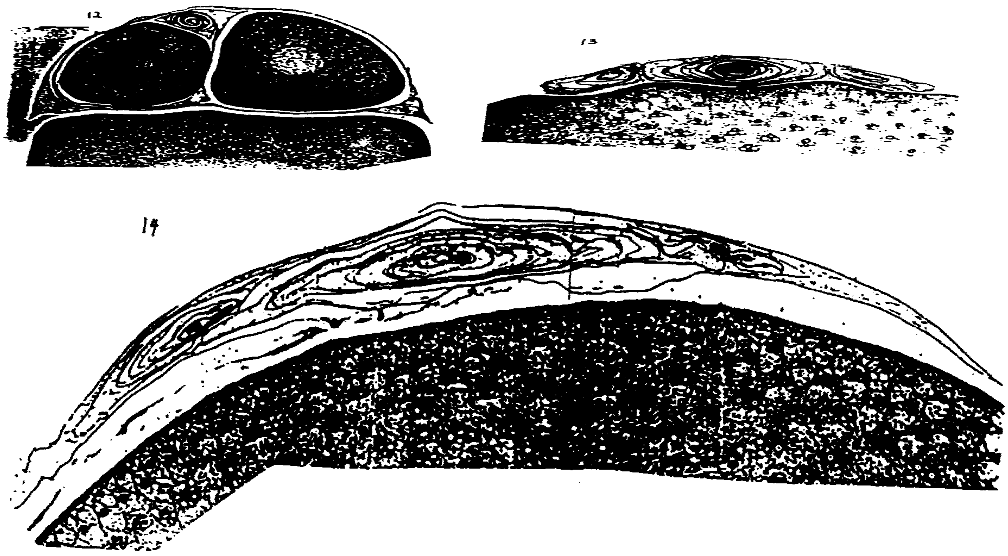


Fig. 7. Diagram showing the transformation from the Shibataea type to the Arundinaria type. Note the outerprophyll (P1) developing to envelope the inner leaf (the 1st foliage leaf) which subtended the first and third branches.



Figs. 8-14 8. Sasa paniculata Makino 9. Arundinaria amabilis McClure 10 Arundinaria simonii (Carr.) Riviere 11. Shibataea kumasaca (Zollinger) Makino.



Figs. 12-14. 12. Phyllosac h bambusoides Sieb. et Zucc 13. Chimonobambusa matmorea (Mitford) Makino 14. Bambusa multiplex (Loureiro) Raeuschel.

Acknowledgement

The author is grateful to His Majesty the Emperor of Japan and the staff of Imperial Household Agency for granting permission to collect bamboo samples and for sending the author new shoots of bamboos. The author wishes to acknowledge the kind suggestions of the late Professor Fumio Maekawa of the University of Tokyo during the author's studies in 1955.

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Three Genera of Bambusoideae from China

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Abstract

The taxonomy of bamboos is well studied in China and in the last 10 years 190 new species have been discovered, Three of the genera Gelidocalamus, Clavinodum and Ampelocalamus are briefly discussed here.

Introduction

China is a big country with about 3.4 million ha. of bamboo forest, widely distributed in 22 provinces, and with about 400 species, of 38 genera. They extend up to a.s.l.3700 m at Xicang. In the last 10 years, 190 new species have been discovered.

Three new genera

Gelidocalamus, Clavinodum, Ampelocalamus have been named by the present author together with others. They are:

1) **Gelidocalamus Wen,** Journ. Bamb. Res. 1(1):20-21. 1982. (Fig. 1).

This genus is a natural group, because of its speciefic characteristics. It differs from other genera of Bambusoideae in very

Fig 1. Gelidocalamus **stellatus Wen**
1. flowering branch; 2. branch and leaf; 3. rhizome; 4. outside of culm-sheath. 5 inside of culm-sheath: 6 lemma; 7. palea: 8. lodicules; 9, stamens: 10. gynoecium

short branches which do not rebranch in the same year; large grass-like panicle and quite small spikelets. Gelidocalamus Wen is shrubby, with amphipodial rhizomes; its internodes cylindrical. unfurrowed, with 7-12 branches at a node; the branches are short and slender, simple, having 2-3 nodes, usually with one leaf on it, and the branch sheath is longer than the internode. The bamboo shoots swell in winter, sheath persistent, sheath-auricles rudimentary or lacking, and sheath-ligule extremely short, curve or wedge shaped; leaf-blades lanceolate to broadly lanceolate, acute at the apex and decurrented; transverse veinlets obvious on both side. lnflorescence piniculate, spikelet very small, with 3-5 florets; the floret has 2 glumes, lemma with keels acuminated and is shorter than palea; lodicules 3; stamen 3; style 2. The type species is Gelidocalamus stellatus Wen, distributed in Jiangxi and Hunan provinces. The type specimen was collected in Jinggang Mountain, Jiangxi province. This genus is distributed in Jiangxi, Hunan, Guizhou, Guangxi, and Zhjiang provinces.

Gelidocalamus stellatus Wen, Journ. Bamb. Res. l(1): 22-23. f. 1. 1982. Dis. Jiangxi Hunan

Gelidocalamus tessellatus Wen, Journ. Bamb. Res. l(1): 24. f. 2. 1982. Dis. Guizhou , Guangxi.

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Gelidocalamus solidus C.D. Chu et C.S. Chao, Journ. Nanjing For. Ins. 2:75. f. 2. 1984. Dis. Guangxi.

Gelidocalamus ***latiflolius*** Q .H. Dai et T. Chen, Journ. Bamb. Res. 4(l): 53-54. f. 1. 1985.

Gelidocalamus kunishii (Hayata) Keng f. et Wen, Journ. Bamb. Res. 2(l): 20. 1983.

2) Clavinodum Wen, Journ. Bamb. Res. 3(2): 23-25. 1984. Tribus Arundinarieae Steudel.

Typus generis: Clavinodum oedogonatum (Z.P. Wang et G.H. Ye) Wen (Fig, 2).

This genus was newly established by the author also, in the Journal Bamboo Research, at 1984. Shrubby or subarborescent,; amphipodial rhizomes; internodes cylindical, nodes rigid irregular; culm-sheaths persistent or late dropping, much shorter than internode; sheath-auricles well developed or wanting, sheath-blades subulate and recurved; branches 3-5 at a node, slender. Determinate inflorescence racemose, lateral, 3 spikelets; spikelet with 2-7 florets, cum usually only one floret can be seen on a spikelet. because the rachilla caducous; spike petiolule slender, zigzag; paleas tips bilobed; lodiculous 2, sometimes 3, stamens 3-4, filament free. styles 2, sometimes 3.

Fig. 2. Clavinodum oedogonatum (Z.P. Wang et G.H. Ye) Wen
1. culm and branch; 2. branch and leaf; 3. bamboo shoot; 4. outside of culm-sheath; 5. inside of culm-sheath; 6. apex of leaf-sheath: 7. inflorescence and piniculate; 8. lemma; 9. palea; 10. lodicules; 11. stamen; 12. gynoecium

Clavinodum oedogonatum (Z.P. Wang et G.H. Ye) Wen type species, in Journ. Bamb. Res. Vol. 3. No. 2. 1984. Found in Jiangxi, Fujian and Zhejiang provinces, the type specimen was collected in the Wuyi Mountain, Fujan province.

Claoinodum globinodum (C . H . Hu)

Keng f. et Wen, in Journ, Bamb, Res. Vol. 3. No. 2. Found in Guangdong province, Hainan.

3) Ampelocaiamus S.L. Chen Wen et C.Y. Sheng, Act. Phytotax. Sin 19(3): 332-334. 1981. (Fig. 3).

This genus is a rather perculiar one. It differs from other genera of Bambusoideae by the following characters: sympodial rhizome; culms slender climbing, branches fine numerous, culm-sheaths much shorter than internode, both sheath-auricles and leaf-auricles well developed numerous long setose radiative at margin, sheath-ligules long ciliates at the apex; leaf-blades setose; determinated infloresence racemus; spikelet petioled, with 5-7 florets; stamen 3; styles 2.

Owing to a lack of knowledge about the features of its rhizomes and culms for a long time, the genus was kept under genera Pleioblastus, Arundinaria and Indocalamus for a time, in 1978, I collected an intact specimen in Hainan island, Guangdong province, thereby clarifying the form of its rhizomes and culms. So wepublished this new genus.

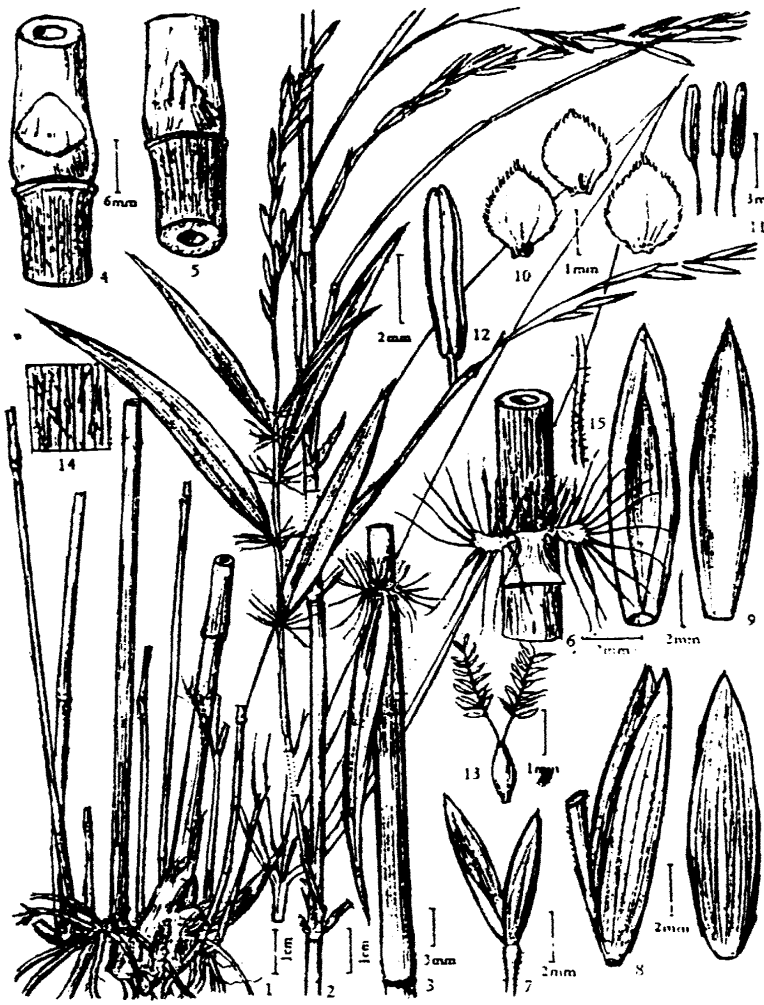

Fig. 3 Ampelocaiamus actinotrichus (Merr. & Chun) S.L. Chen, Wen et G.Y'. Sheng.
1. rhizome and culm. 2. flowering branch; 3. culm-sheath; 4-5. nodeculm; 6. apex of culm-sheath; 7. glumes and pedicel; 8. floret; 9. palea; 10. lodicules; 11 stamen; 12. anther: 13 gynoecium; 14. a part of leaf; 15. a seta of auricule-leaf.

Structure and Properties