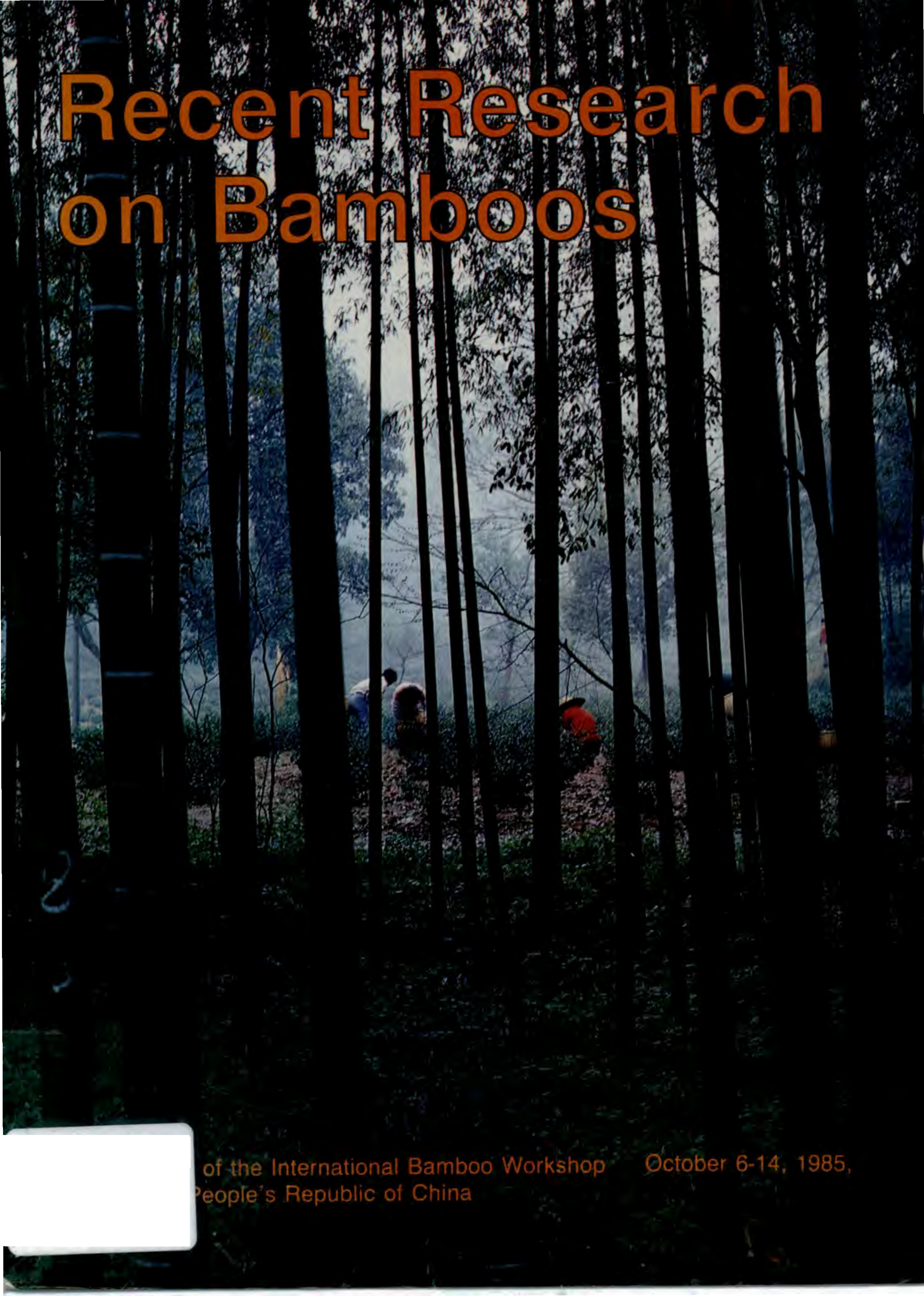
Recent Research on Bamboos



of the International Bamboo Workshop October 6-14, 1985,
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中国林业科学研究院

The Chinese Academy of Forestry was established in 1958. It is an agency of the Ministry of Forestry, People's Republic of China. The Academy now comprises of eight research institutes, namely, the Research Institutes of Forestry, Subtropical Forestry, Tropical Forestry, Lac, Wood Industry, Chemical Processing and Utilization of Forest Products, Forest Economics, and Scientific and Technical Information on Forestry. In addition to these facilities the Academy also maintains a library and three forestry experimental stations (the Deng Kou Experimental Bureau, Da Gang Shan Experimental Bureau and Da Qing Shan Experimental Bureau). All of these are located in Beijing, Nanjing, Zhejiang, Yunnan, Guangdong Provinces as well as Guangxi Zhuang and the Inner Mongolia Autonomous Regions.

CANADA

The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activities are concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional Offices are located in Africa, Asia, Latin America, and the Middle East.

Recent Research on Bamboos

Proceedings of the International Bamboo Workshop
October 6-14, 1985
Hangzhou, People's Republic of China

Organised jointly by:
Ministry of Forestry, People's Republic of China
International Development Research Centre, Canada
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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.cradIe 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 Phyllostachys 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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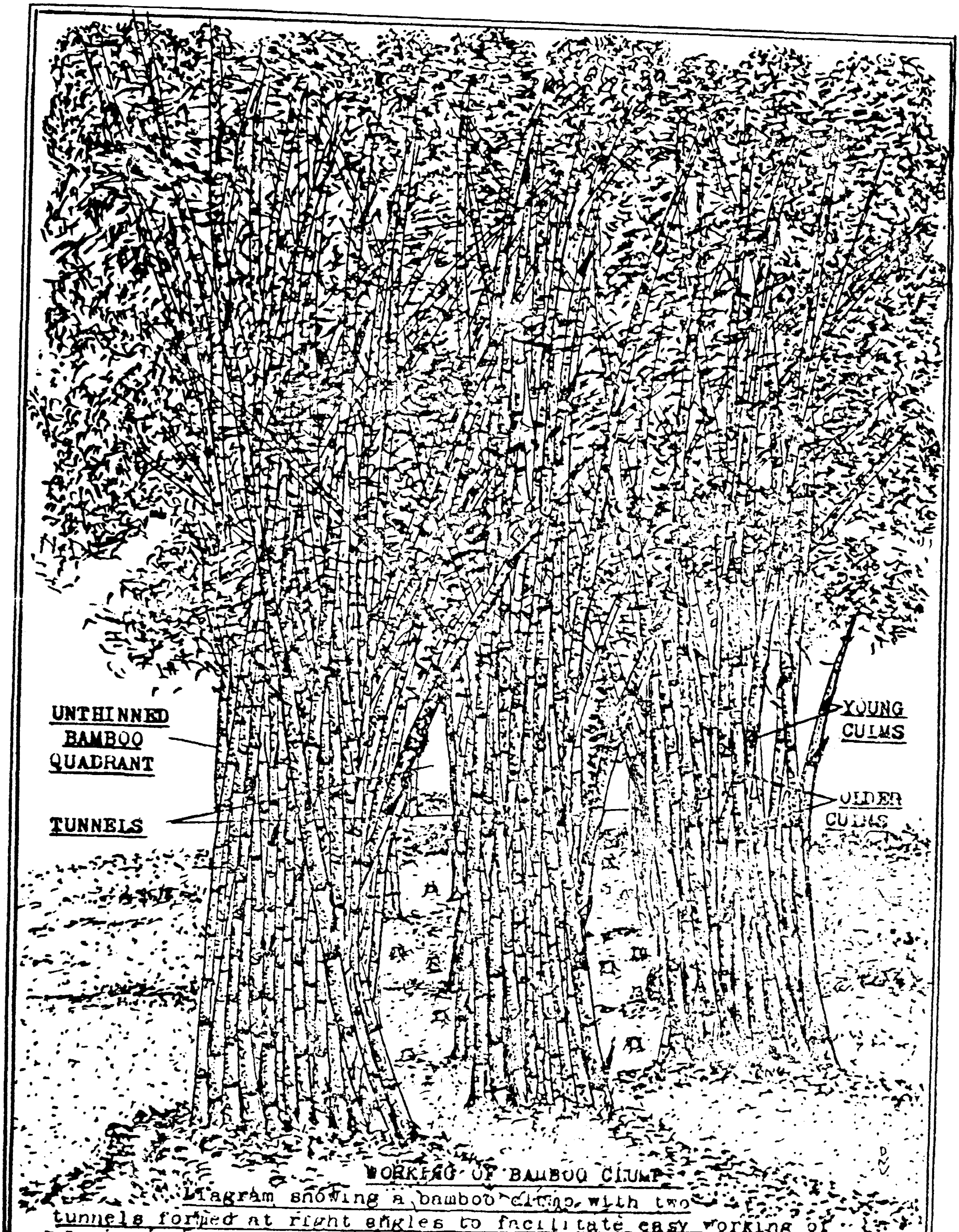
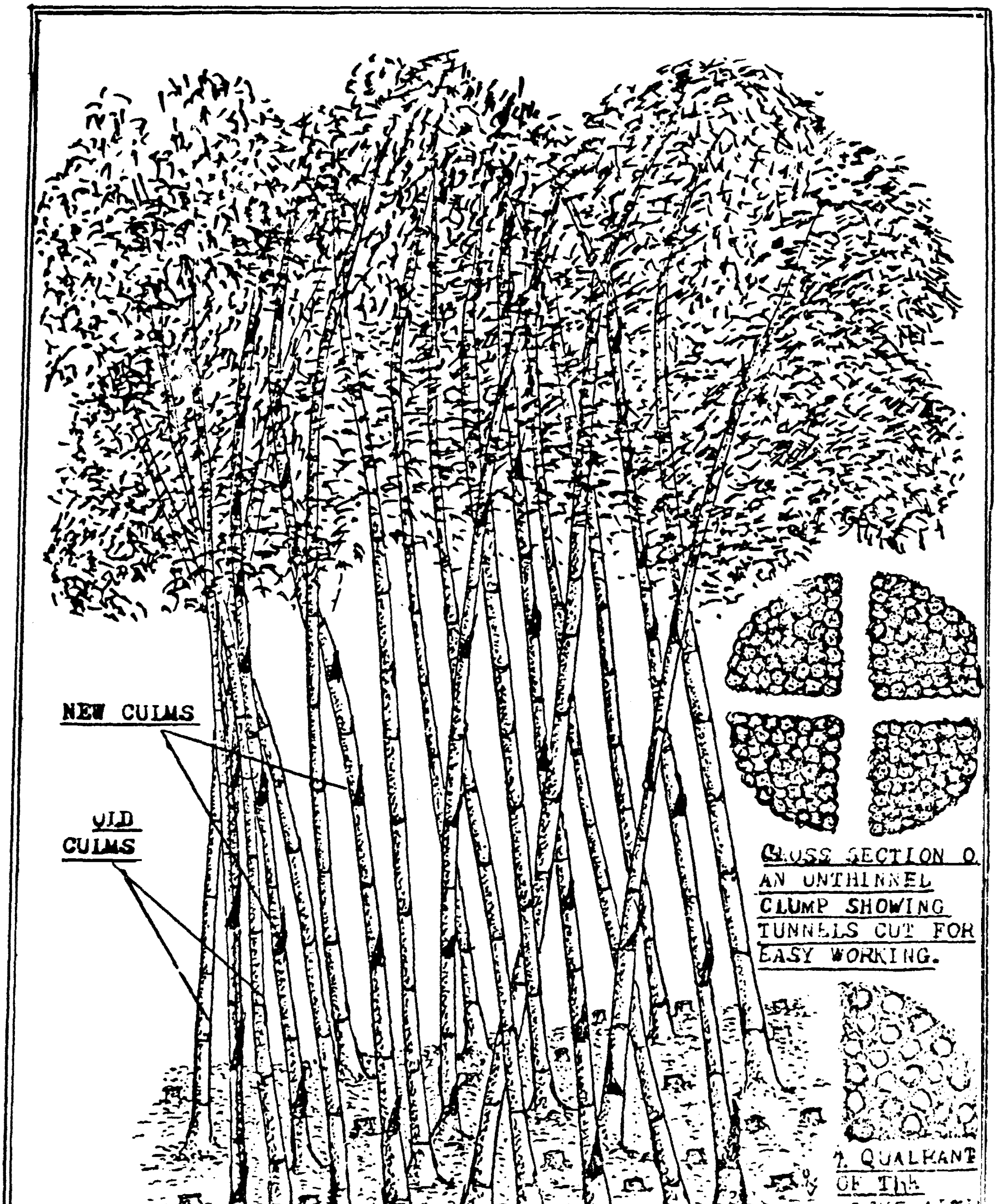


WORKING OF BAMBOO CLUMP

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.

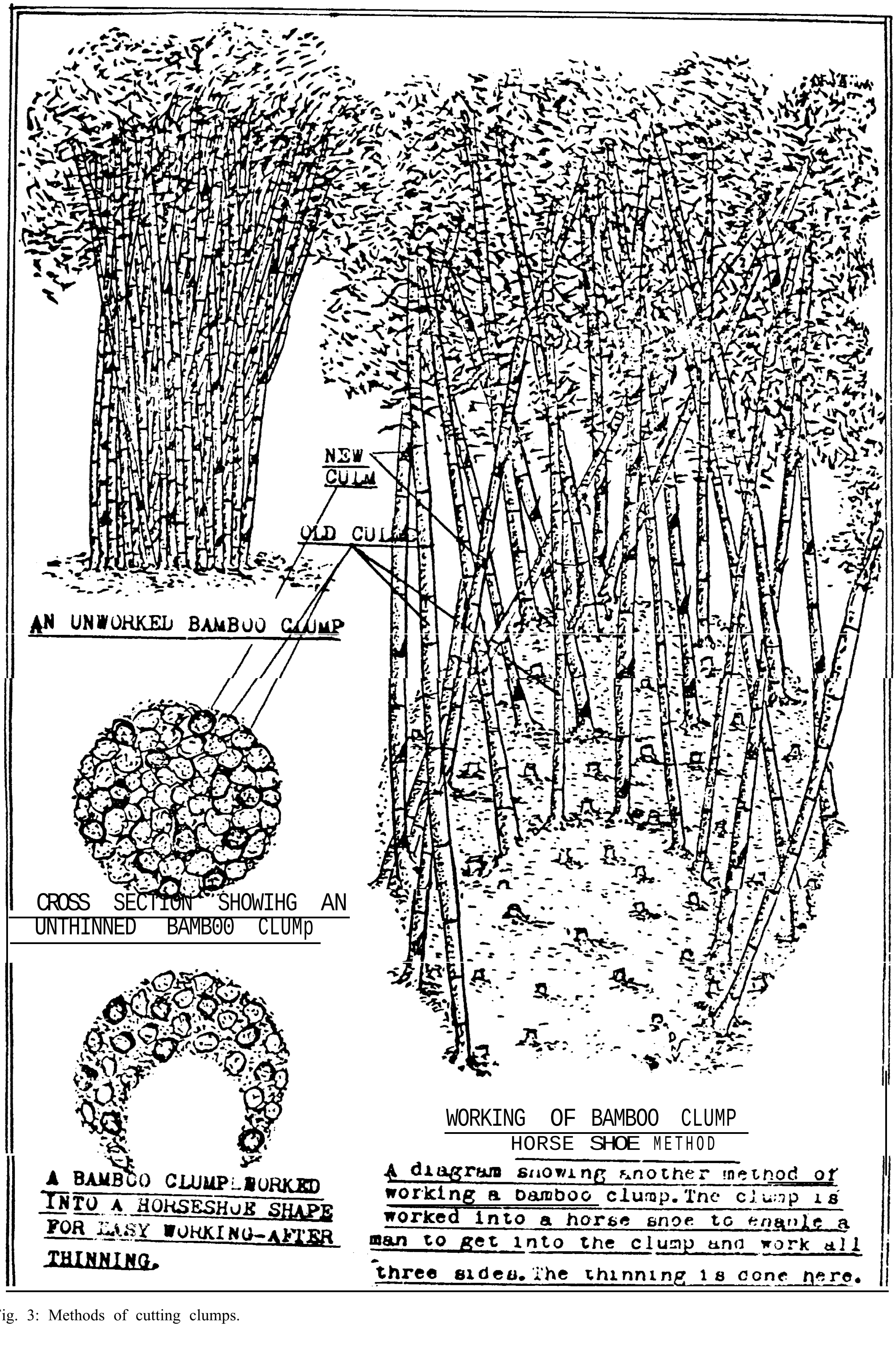
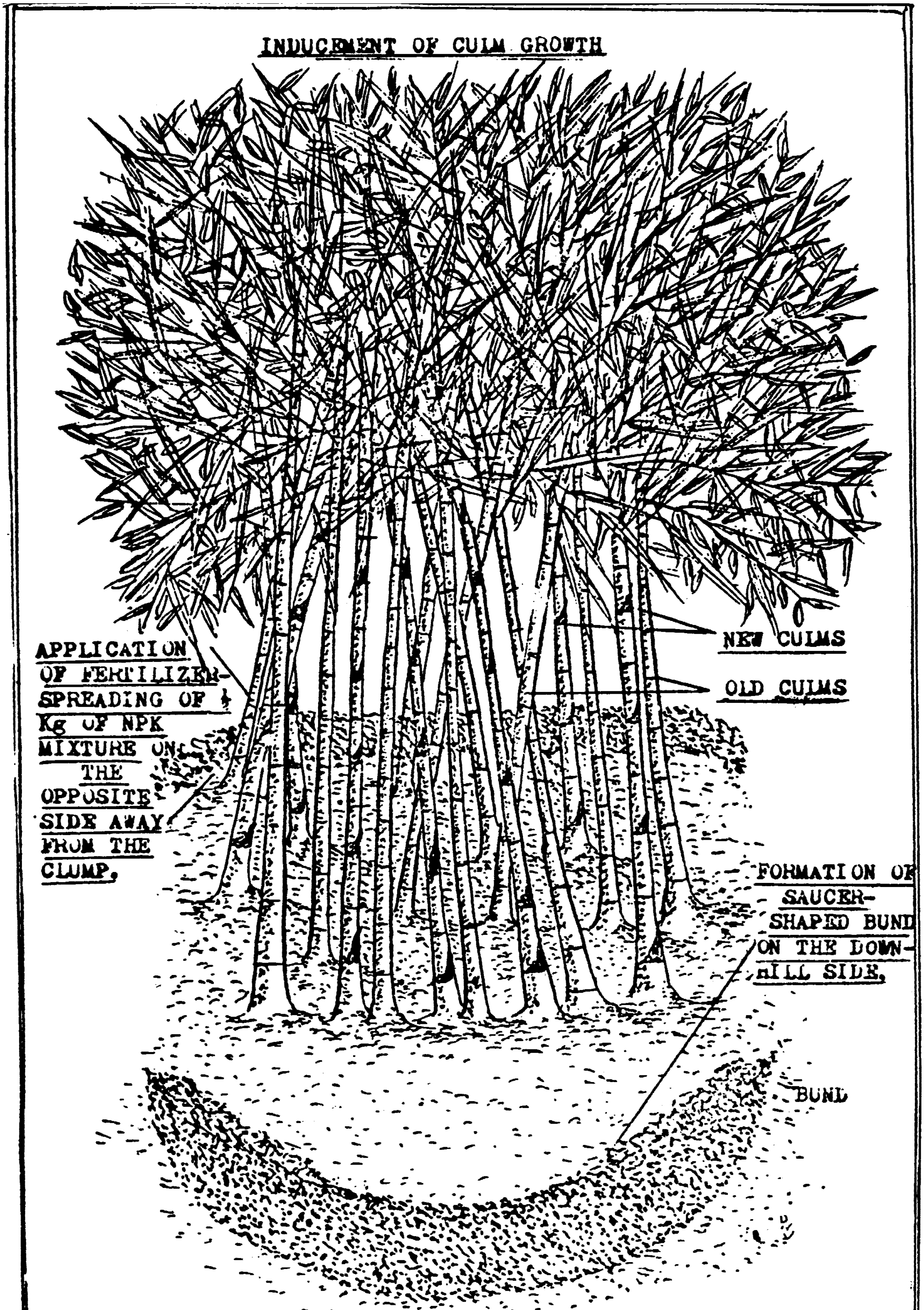


Fig. 3: Methods of cutting clumps.



Fig, 4: Spacing of Bamboo clumps.

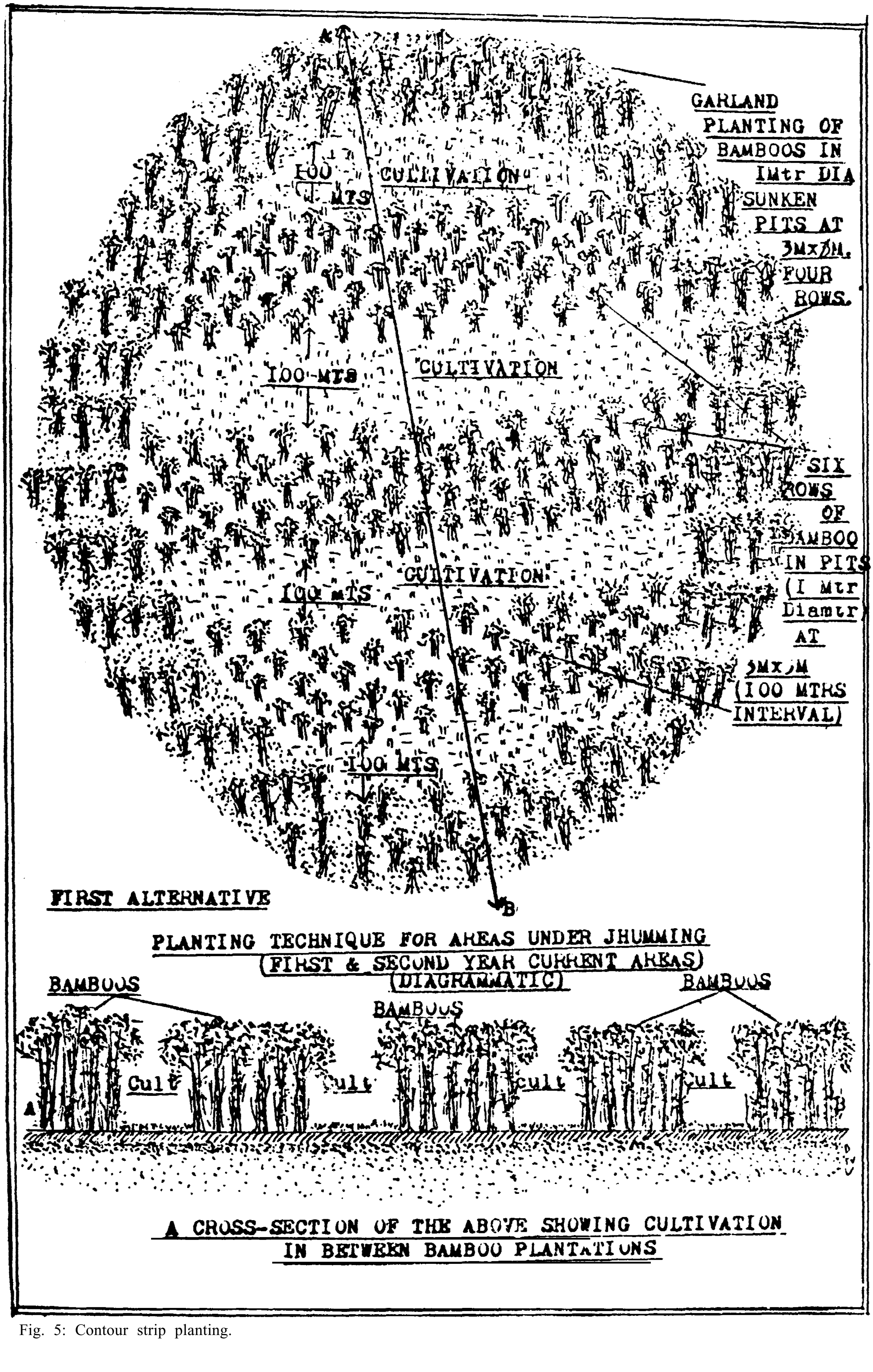


Fig. 5: Contour strip planting.

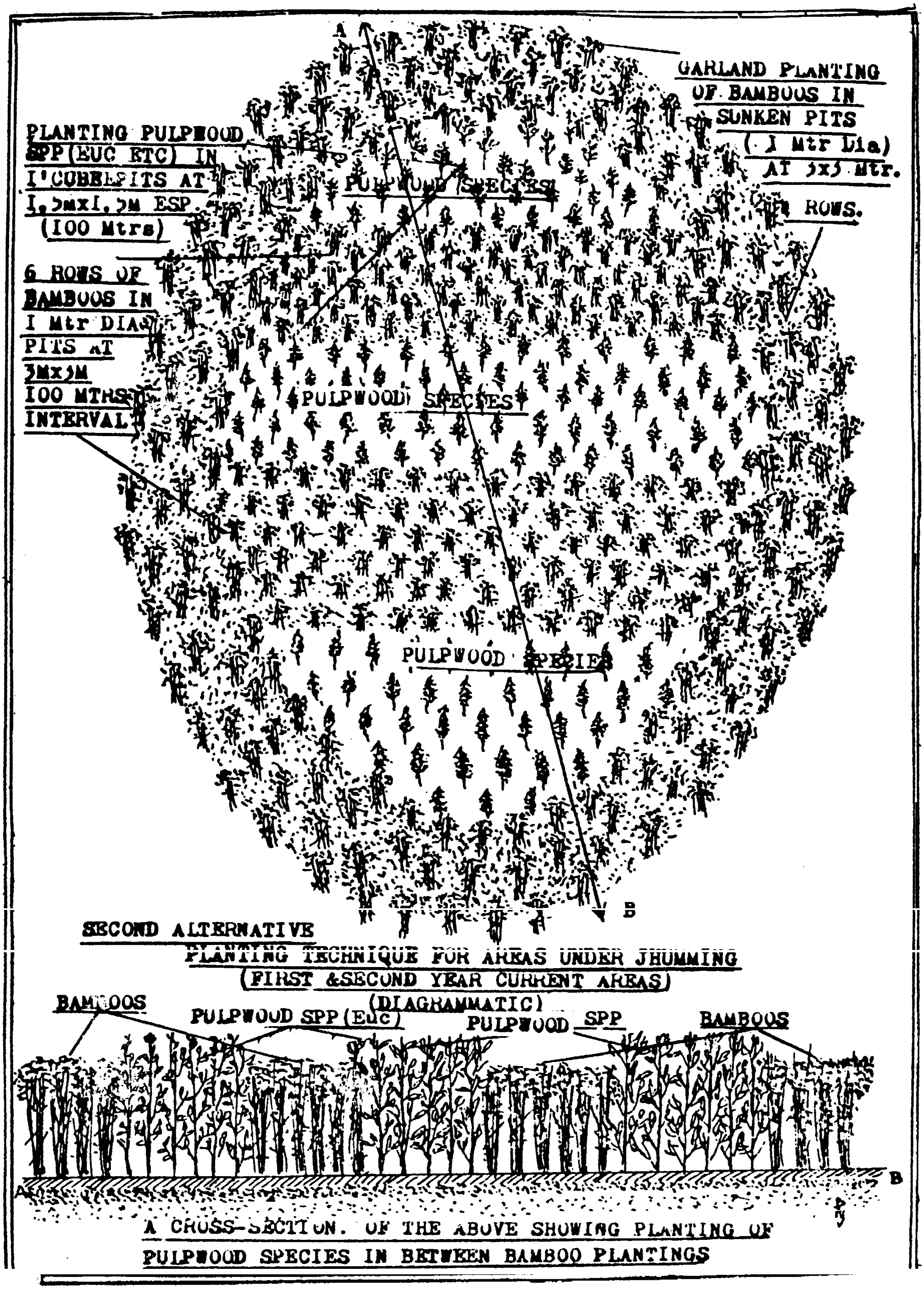


Fig. 6: Contour strip planting.

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 1 3 3 . 3 3			
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 southeast 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

Zhu difan

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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. Out of 100 native species only ten are commercially exploited.* In *the absence* of *reproductive structures bamboos can be identified at generic and specific level only on the basis of the morphology* of *culm sheath and juuenile shoots, microscopic and ultramicroscopic features* 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 need to 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 36^0C), 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, Dendrocalamus* 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^{0}C) 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 Na2S 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 I 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 rain-fall. (Bicol, Visayas, Tagalog provinces, and Mindanao (Davao Norte plantation).
5. Giant Bamboo (Gigantochloa aspera)	Moist soil occuring profusely in areas with well distri-buted rainfall throughout the year. (Mt. Makiling, Agusan del 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 fireplace 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. Distri-*bution:* 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 Km²	Northeastern Km²	Eastern Km²	Central Western Km²	Southern Km²	Total Km²
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 microrelief, 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.

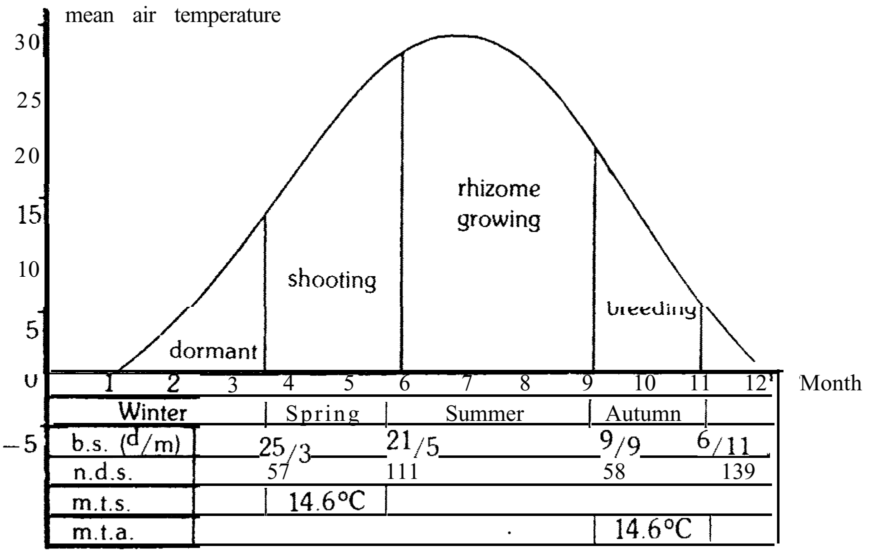

Fig. 1 Periodic growth of bamboo in a year in Zhengzhou. Henan versus air temperature.
b.s. (d/m) beginning of the season (day/month).
n.d.s. number of days in the season.
m.t.s. — mean air temperature in spring.
m.t.a. — mean air temperature in autumn

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.

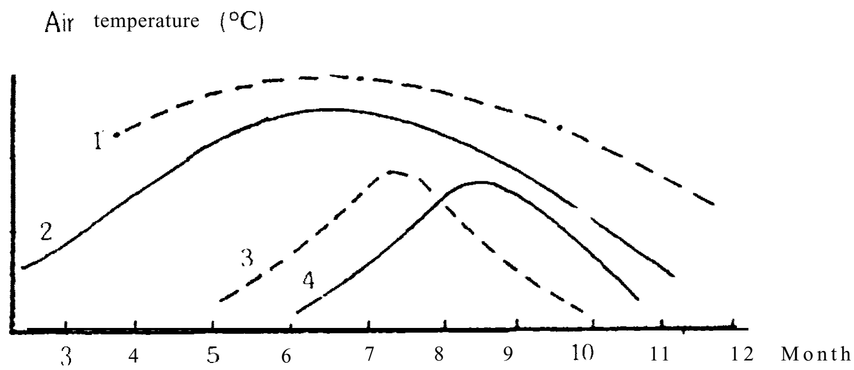

Fig 2 Comparison of reqularity of growth of Bambusa textilis in its native place and where it has been transplanted (1) Air temperature In Nanning. with observed values in dots (2) Air temperature in Xuchang. Henan (3) Growing period in Guangxt (4) Growing period in Xuchang

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 transplanting.

Management and operation of bamboo groves

An approp iate management and ooeration 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 luxuriantly 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 maintenance 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 consecutive 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 negligence 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 comprehensive way. The degree of management and output 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 production 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 rewarding.

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 harvesting 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 (McCI.) 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 diameterclass 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: $Y = a(X^2H)^b$, 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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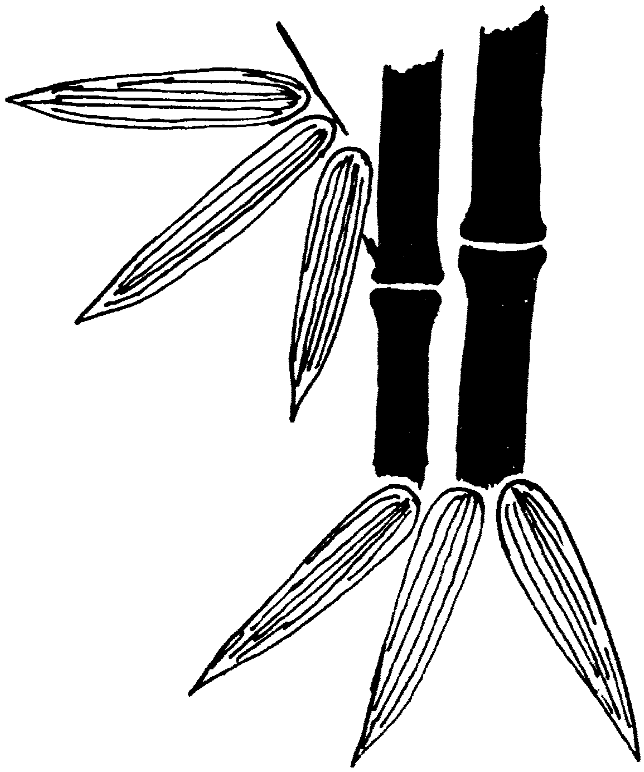

Study on the Application of Chemical Fertilizer to the Timber and Paper-pulp Stands of Phyllostachys pubescens

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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

				Total		Quick-acting	
Sites	Soil type	PH	Organic matter %	N%	P_2O_5%	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-l 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* Ievis (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.

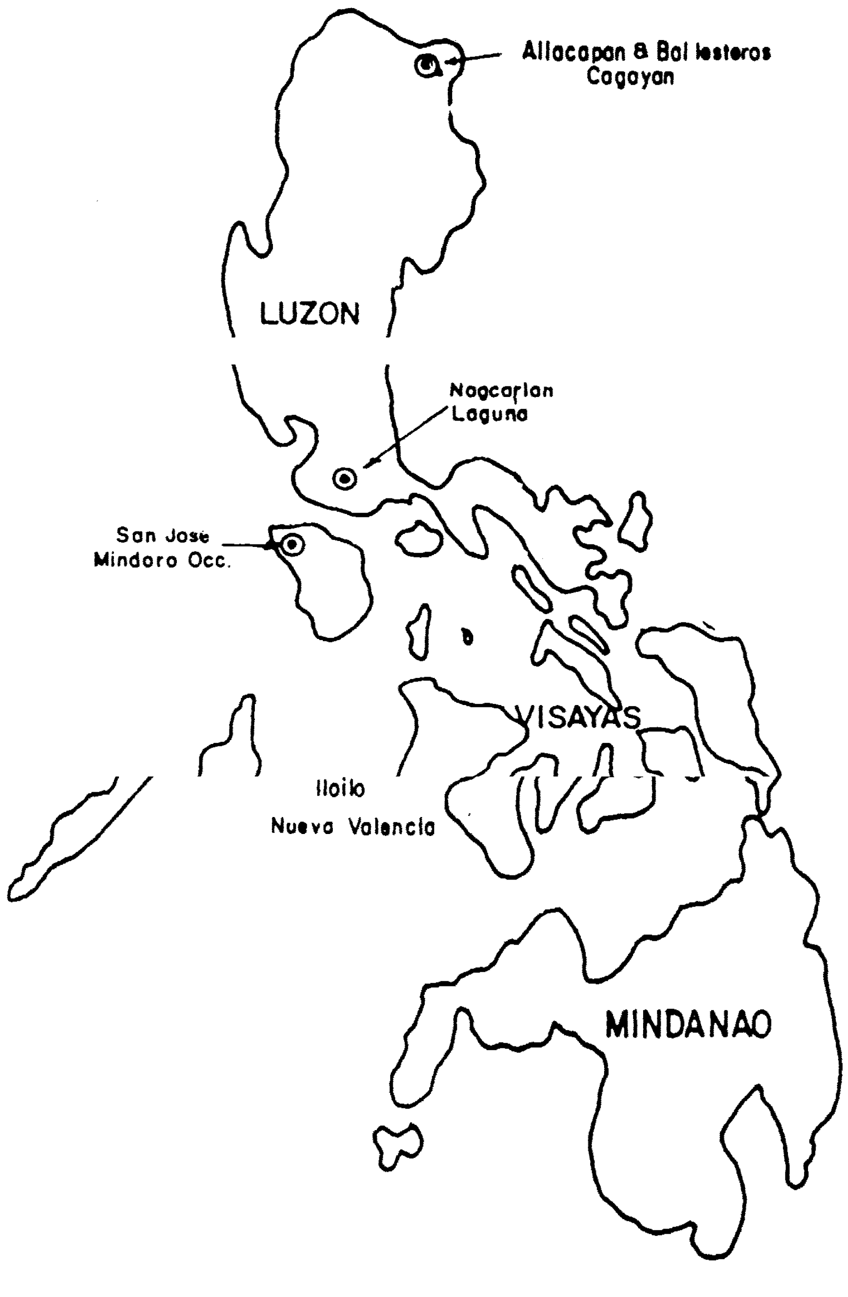


Fig. 1. Map of the Philippines showing locationof the study sites.

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***		***Bambusa vulgaris***		***Dendrocalamus* merrillianus**		***Gigantochloa* levis**		***Schizostachyum lumampao***	
	Mean'	SD* •	Mean	SD	Mean	SD	Mean	SD	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

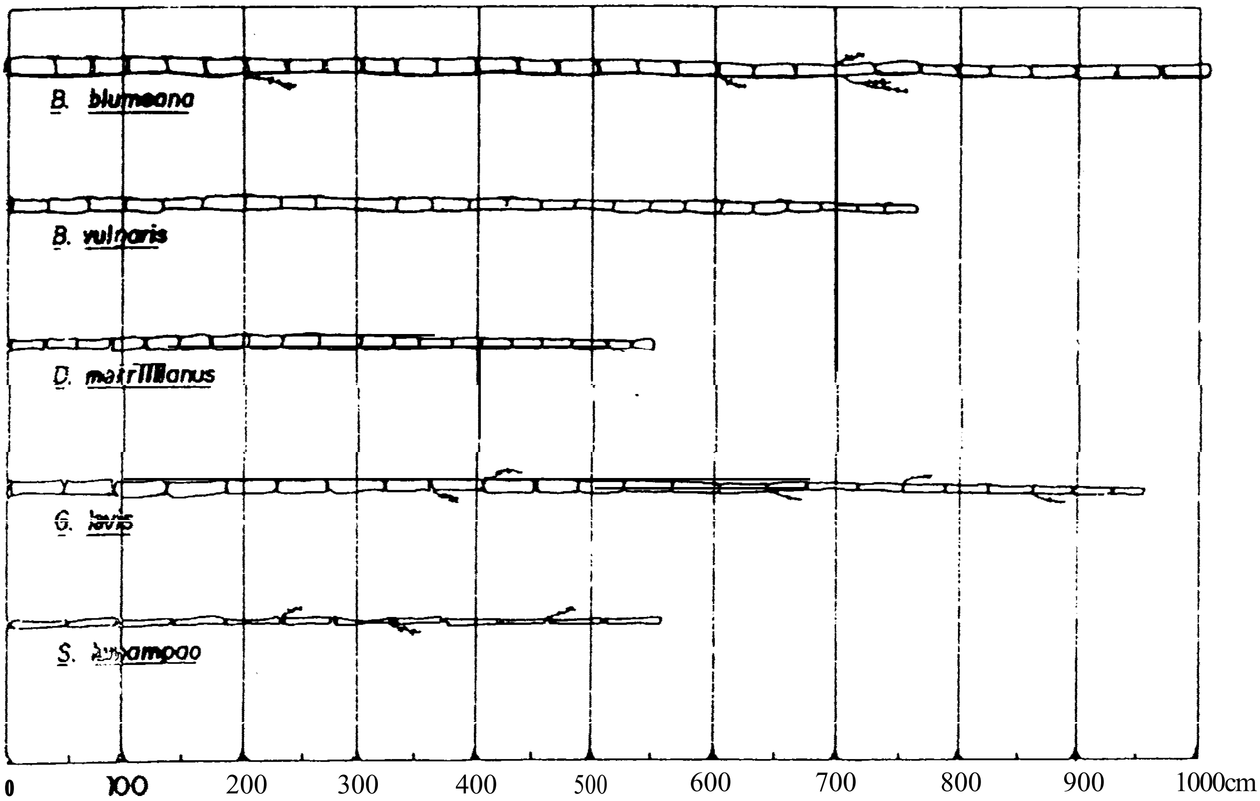


Fig. 2. Camparative length ad number of internodes per culm of the five bamboo species.

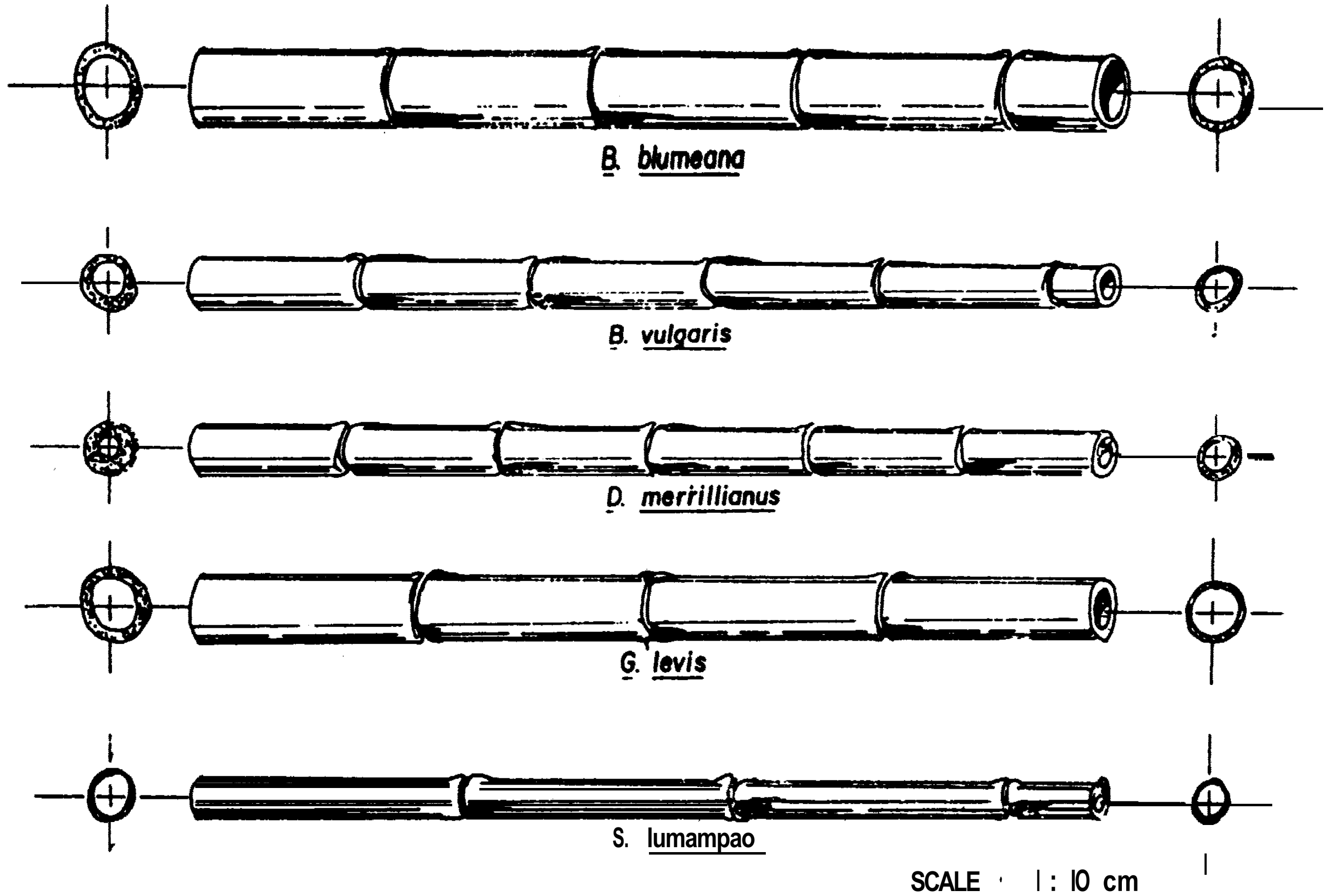


Fig. 3. Comparative culm-wall thickness, diameter and internode length of the five bamboo species.

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.

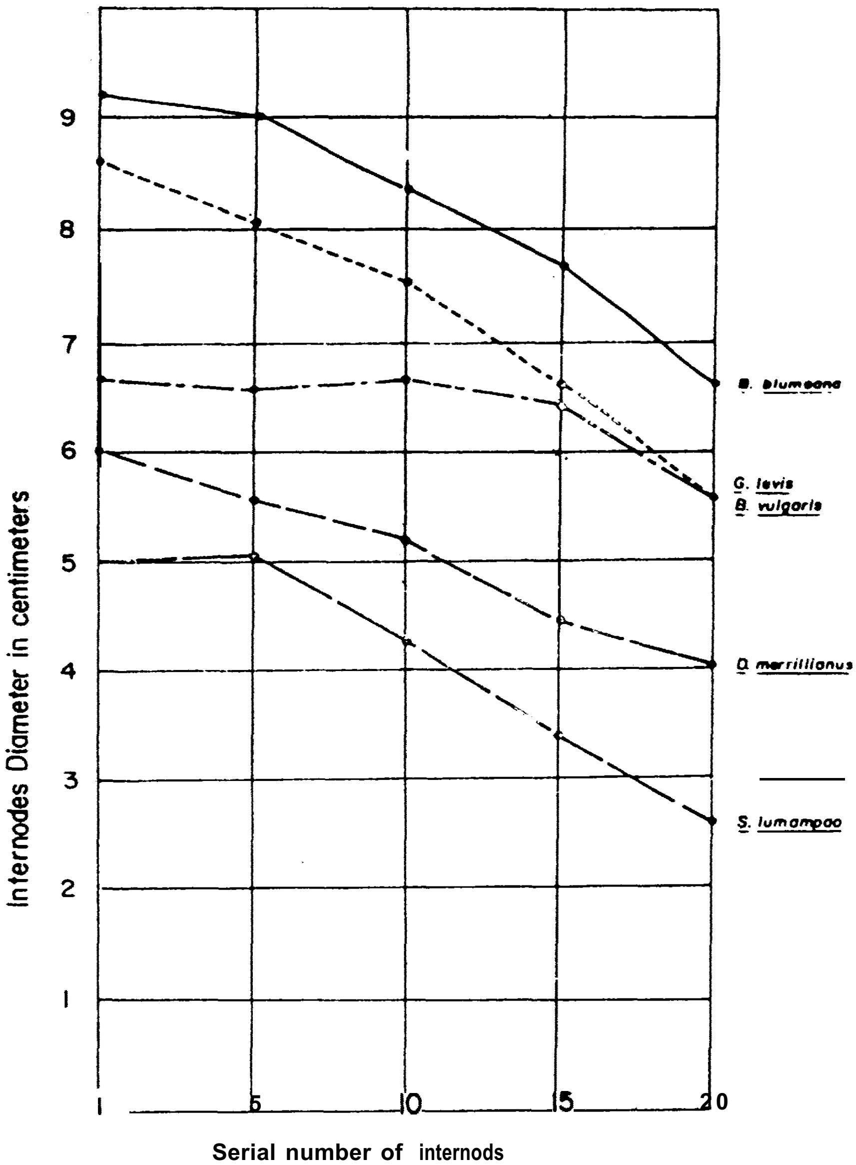
As in B. vulgaris, its culms also form into large clump that is open or loosely tufted. Sometimes, the culms can be seen bending over due to the weight of the upper portion which in this study was found to have an average wall thickness of 1.08 cm, the highest among the species.

(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 Iumampao (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 Iongest 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

Table 5. Average number of bamboo poles and the equivalent solid volume permetric 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

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 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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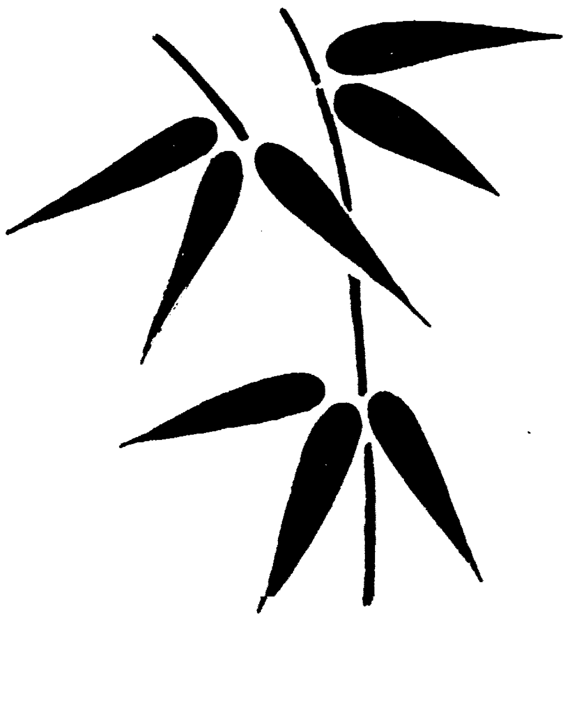

A Study on the Mineral Nutrition of Phyllostachys pubescens

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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 (1- 11% of the dry matter) next come Ca, Mg and P (0. 1- 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).

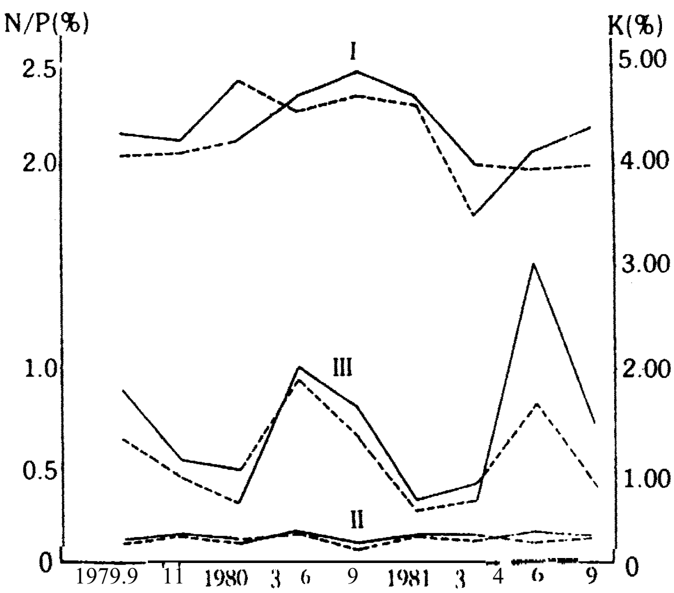
(3) Graph 4 shows that the contents of Zn, Na, Fe and other four mineral elements in the leaves of the on-year bamboo are less than those in the leaves of the off-year bamboo. These elements form their own peak before the leaf change in April and $enerally fall to the lowest point in June when new leaves 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

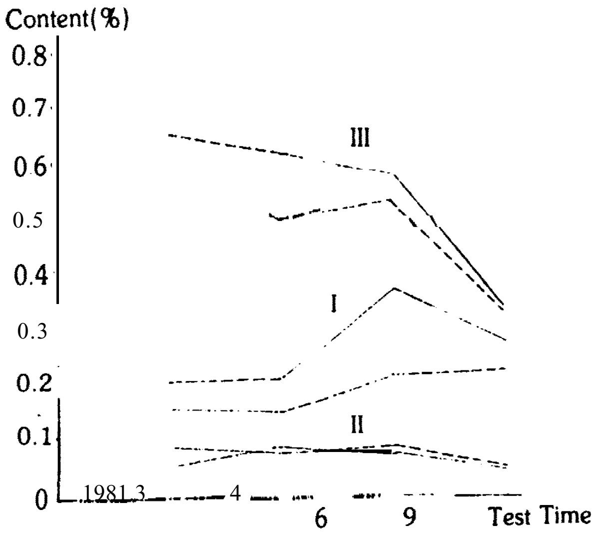
Element	Zn											
Month	3			4			6			9		
Part / On-or-Off Year	L	c	R	L	c	R	L	C	R	L	c	R
Off Year	0.00358	0.00063	0.00256	0.00401	0.00239	0.00192						
On Year	0.00347	0.00086	0.00313	0.00367	0.00261	0.00236						
On Year							0.00302	0.00109	0.00228	0.00360	0.00143	0.00266
Off Year							0.00445	0.00137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



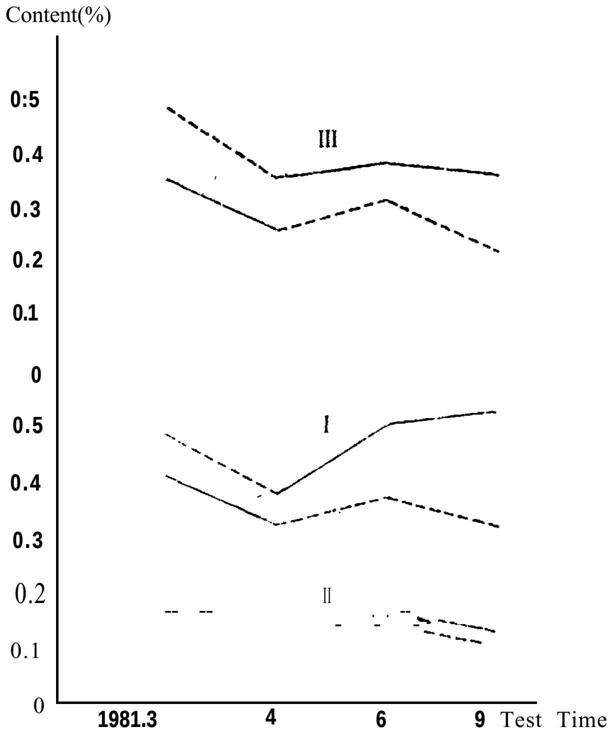
Graph One: The Dynamic Changes of the Elements; of Minerel Nutrition in the Leaves.

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.

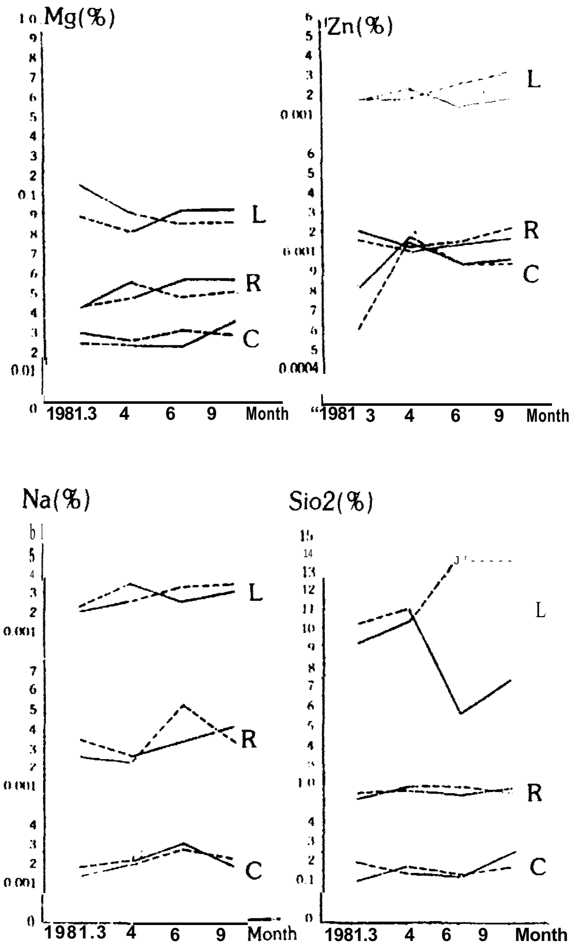
Curve I — N. Curve II — P. Curve III — K.



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.

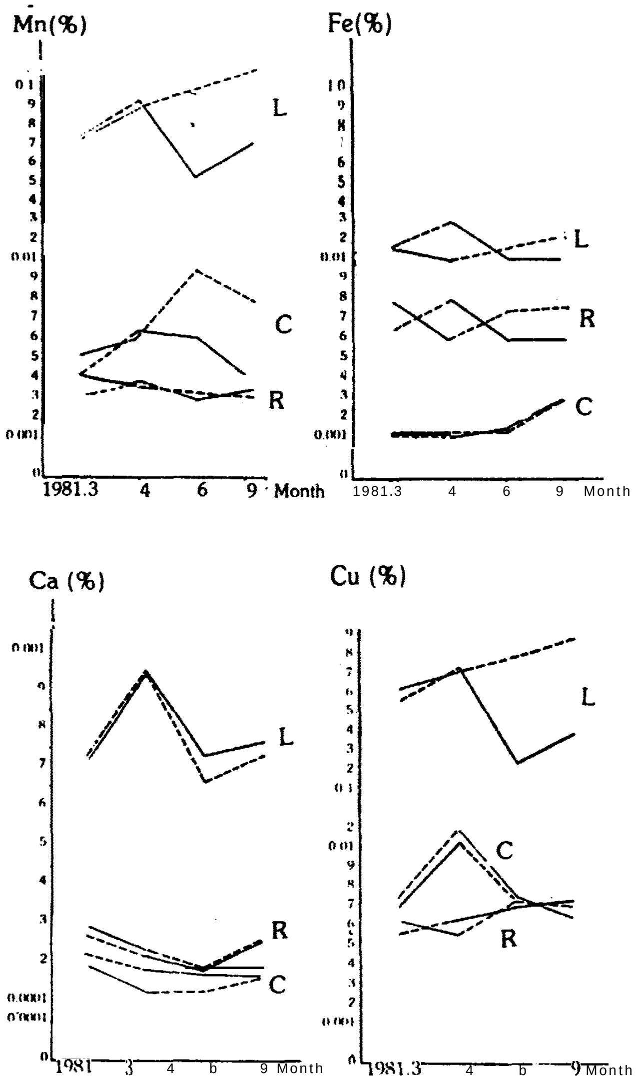
As to the off-to-on-year bamboo, its physiologica activities are strong after the leaf change. N, P, and K in the leaves accumulate gradually. As the development of vegetative organs is not synchronous with that of reproductive organs bamboo's needs for N, P and K are different. Consequently the time 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

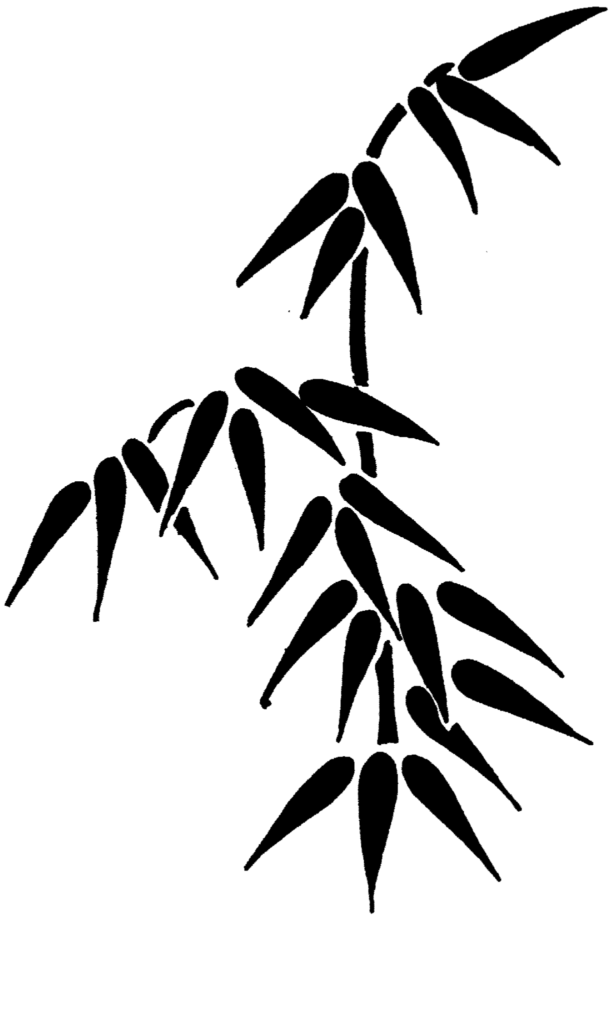
The dynamic study of mineral elements in the plant body provides a theoretical basis for researches on nutrient physiology of Phyllostachys pubescens.

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 (%)	Caustic Soda (1%) solubles (%)	Alcobol benzene solubles (%)	Lingnin (%)	Pento- (%)	Holo-cellulose (%)	a-cellu-lose (%)
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 detailed 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 Phyllostachys pubescens is discussed with reference to methods of application, kinds and dosages of fertilisers, time or period of application and the benefits derived therefrom.

Introduction

Mao Zhu *(Phyllostachys 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^{-1} 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^{-1} yr^{-1}. At present the maximum yield (^{W}f) from small area of bamboo wood stand is about 30 tons ha^{-1} yr^{-1} and the yield of bamboo shoots (^{W}f) from shoot stand about 20 tons ha^{-1} 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).

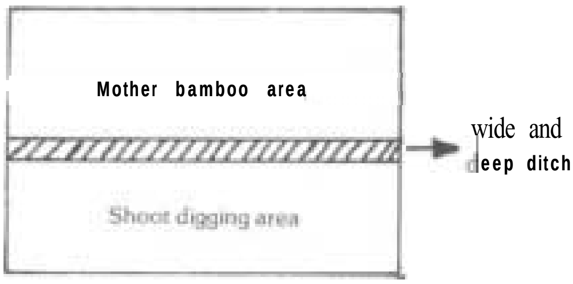


Fig 1 Fertilizing in a wide and deep ditch. which is 50 cm in width and 70 cm in depth

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).

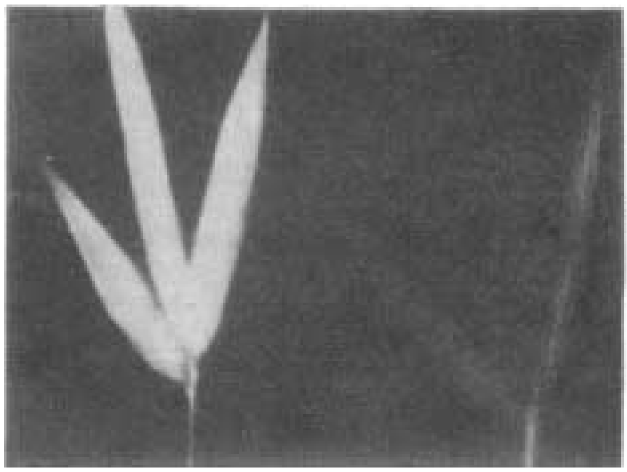


Fig. 2. Absorption of P^{32} — $(NH_4)_3PO_4$ by Ph. pubescens.

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		New culms		Increace proportion %	
		Number	A' (cm)	Number	A' (cm)	number	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 %				Proportion			
	N	P_2O_5	K_2O	Sio2	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.

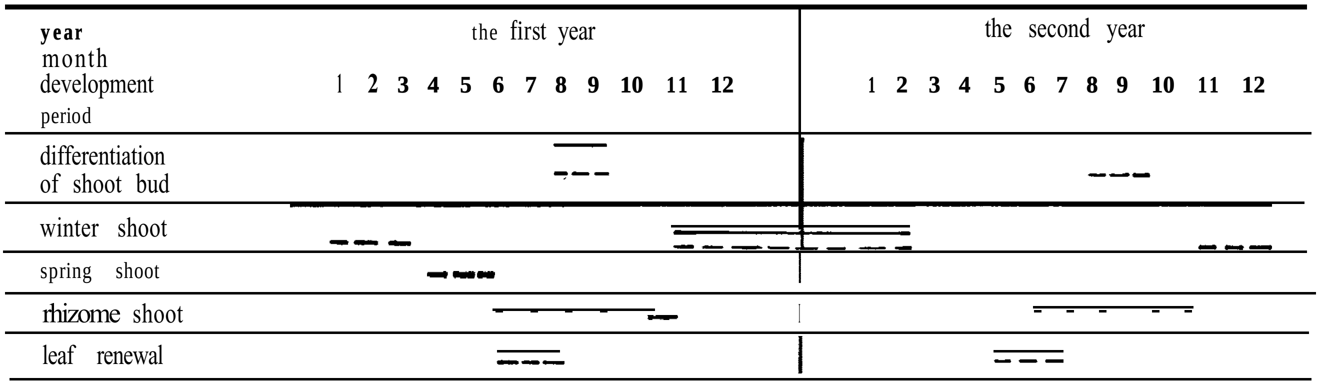
There are four growth periods in the growth of Mao Zhu stands. a) winter-shoot renewal period, b) spring-shoot growth period, c) leaf growth period, and d) rhizome growth period.

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

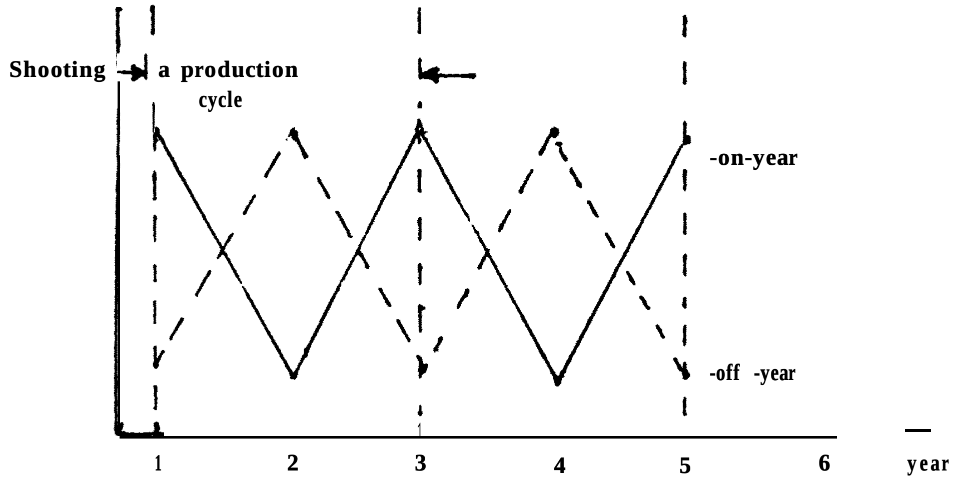


Fig. 3b. Growth patterns of on-year and off-year stand.

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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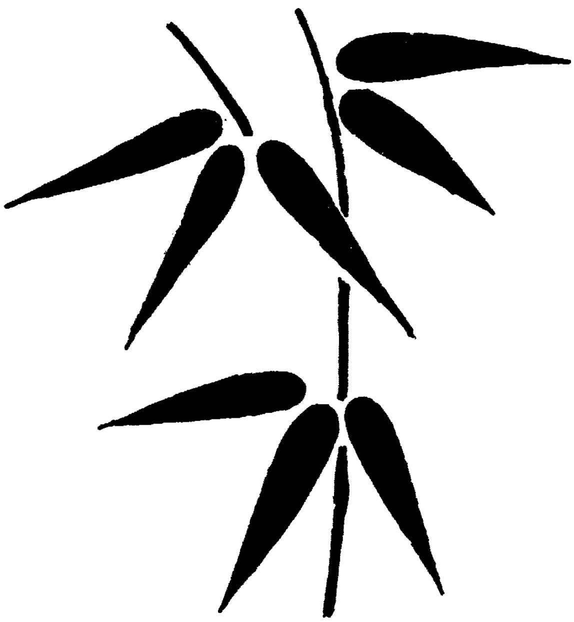

Effects of Photoperiod and Temperature on the Growth of Mosochiku Phyllostachys pubescens seedlings

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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
KC1	K_2O	30.0
$CaC1_2.2H_2O$	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

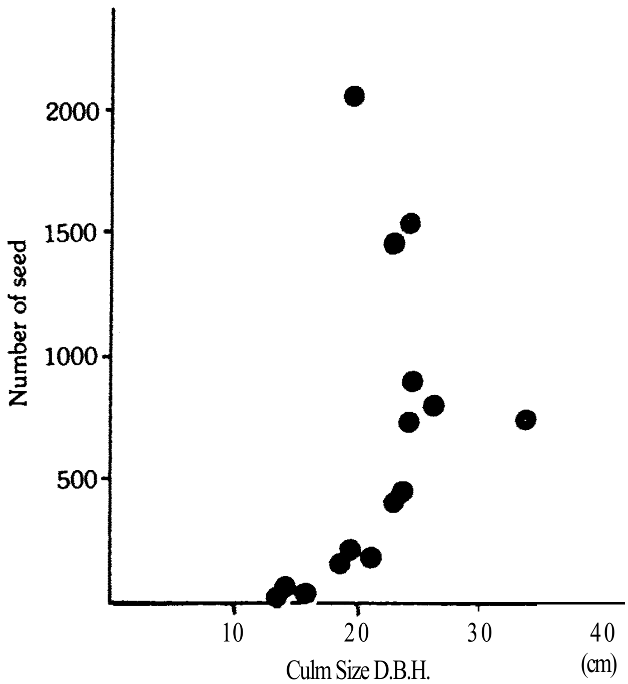

Fig. 1. Number of seed setting/culm,

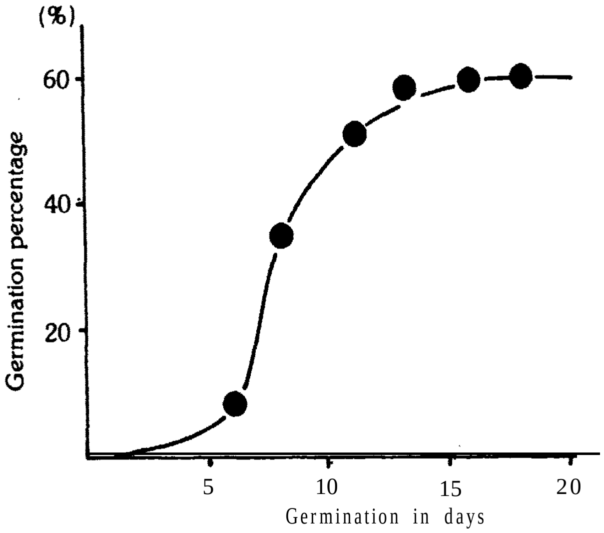

Fig. 2. Relationship between germination period and total germination percentage of P. pubescens seeds.

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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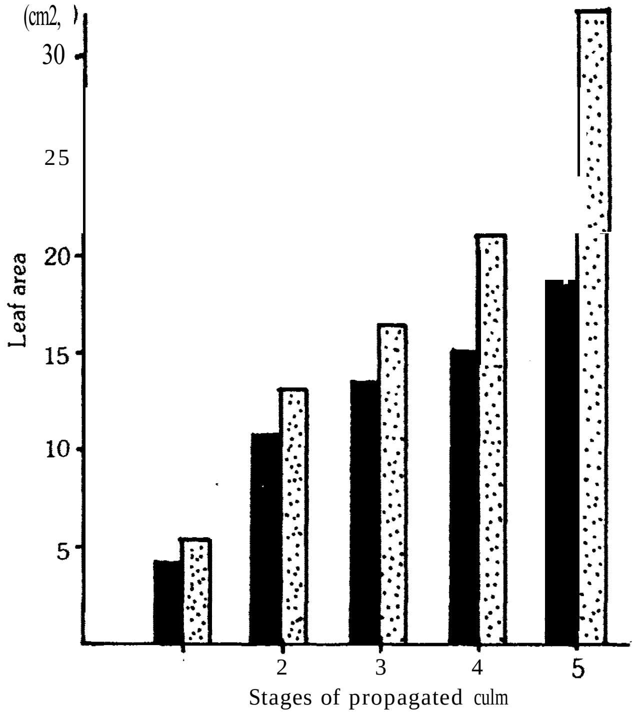


Fig. 3 Leaf area classified by every stage of propagated culm

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

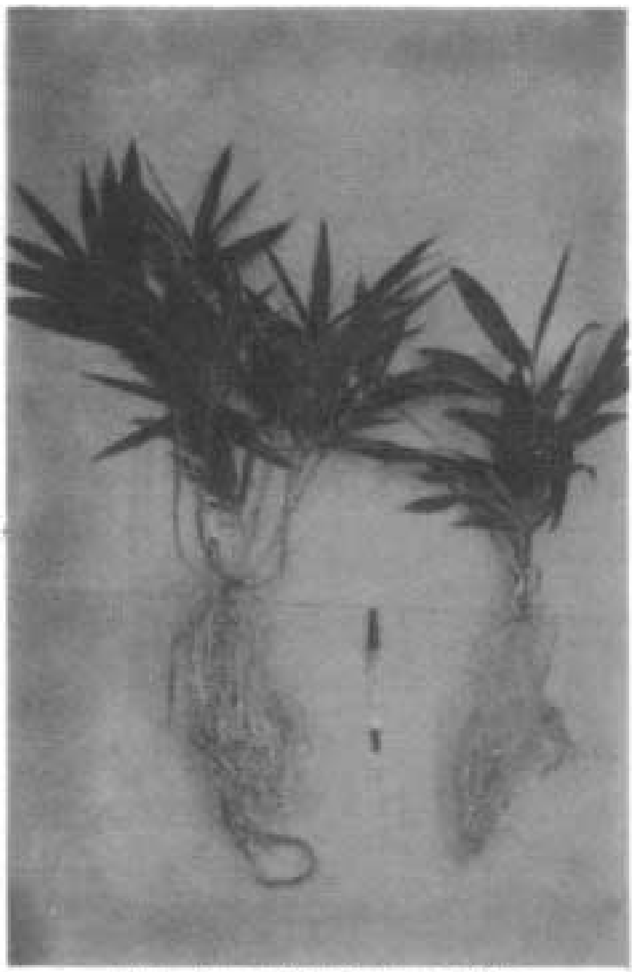
Table 3. Leaf area classified by stage ofulm growth.

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

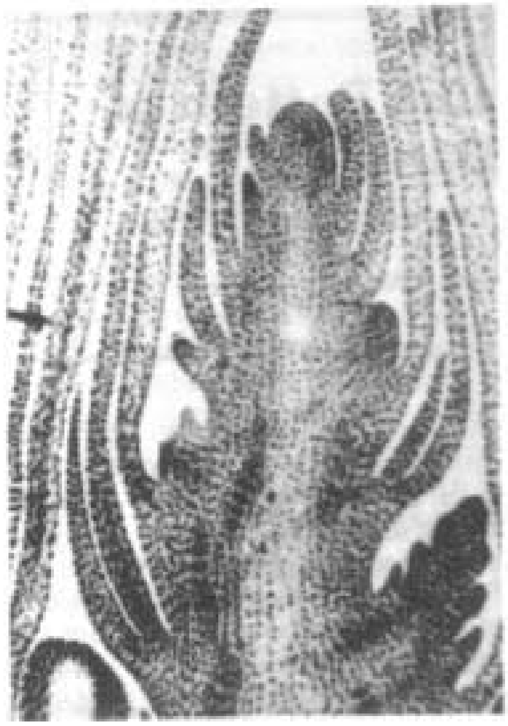


Fig. 1. Shoot tip of Phyllostachys pubescens showing apical meristem with leaf (sheath) primordia, young sheaths and their axillary buds which develop into primary branches. Fig, 2, Growth tip of rhizome shoot of Phyllostachys pubescens showing apical meristem with leaf (sheath) primordia, young sheaths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

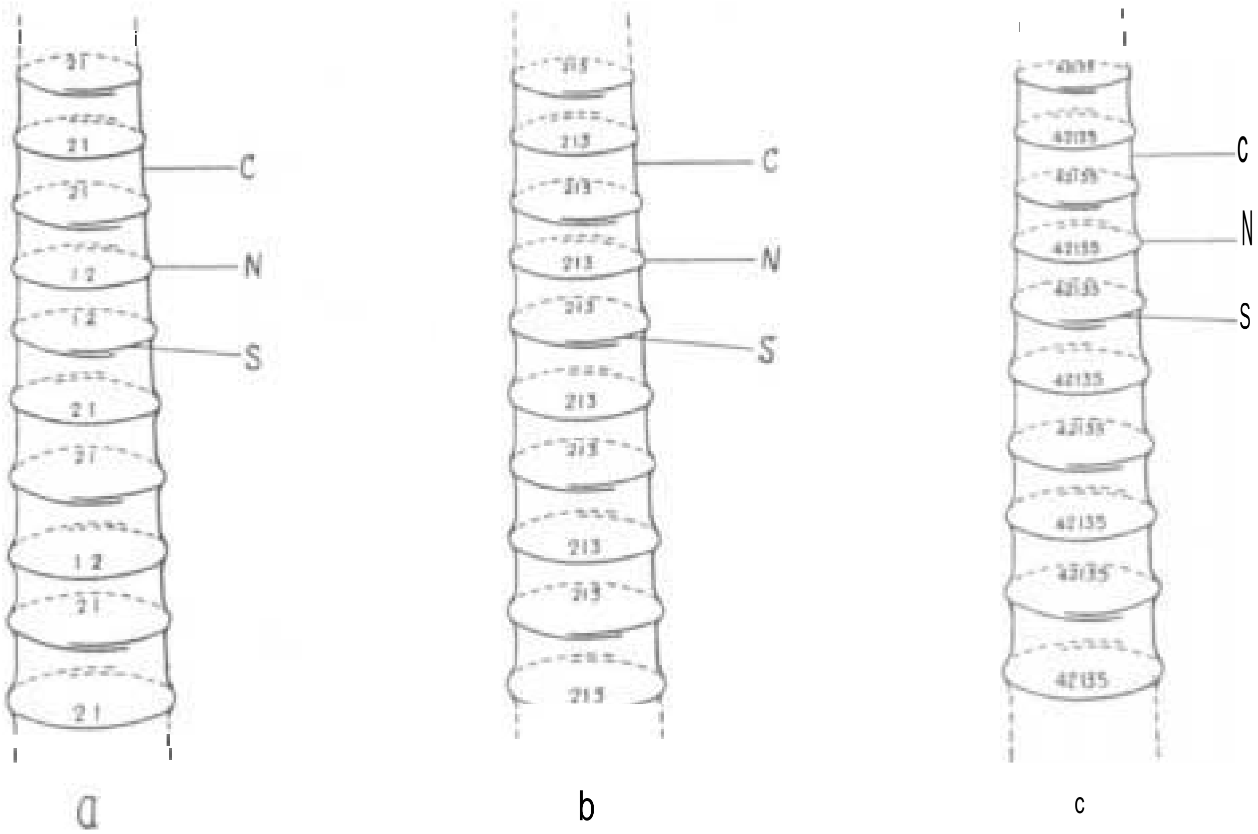


Fig 3, "Mirror image symmetry" overlapptng pattern of sheaths (S) showing the Iloc of primary bud : 1) and proliferating order of secondary branch buds (2 3, 4, 5) on nodes (N) of culms (C) a Double branching (Phyllostachys); b Triple branching (Slnobarnbusa). c Multiple branching *(Arundinaria.* Chimonobambusa,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

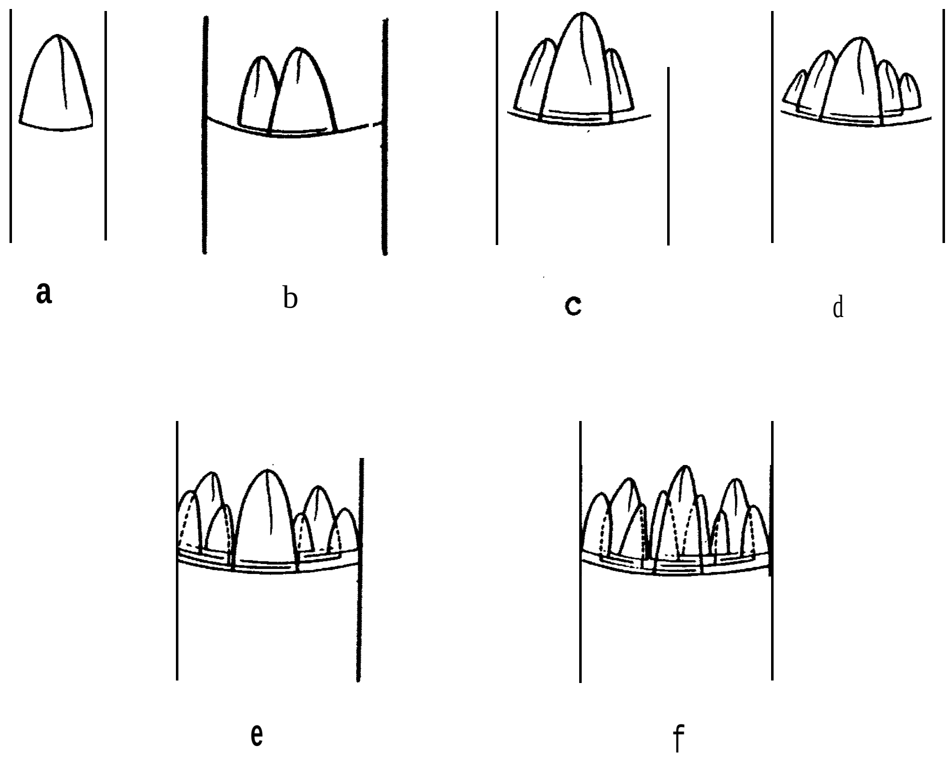


Fig. 4. Loci of primary branch buds and their ramificating order of secondary branch buds. Note the sheath and prophyll scars. a. Single branching bud *(Indocalamus);* b. Double branching bud *(Phyllostachys);* c. Triple branching bud *(Sinobambusa);* d-f. Multiple branching bud *(Arundinaria, Chimonobambusa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

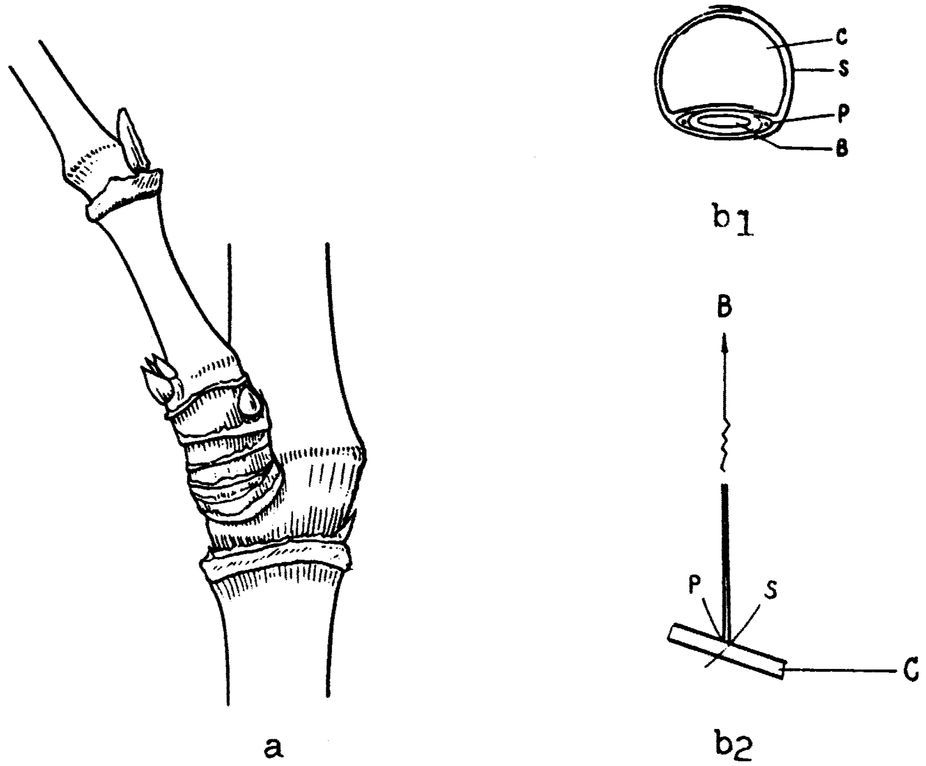


Fig. 5. Single branching pattern a. Solitary branch with constricted budless basal nodes; bl. Cross view of singie branching pattern; b2. Whole view of single branching pattern: C — culm, S — sheath, P — prophyll, B — branch.

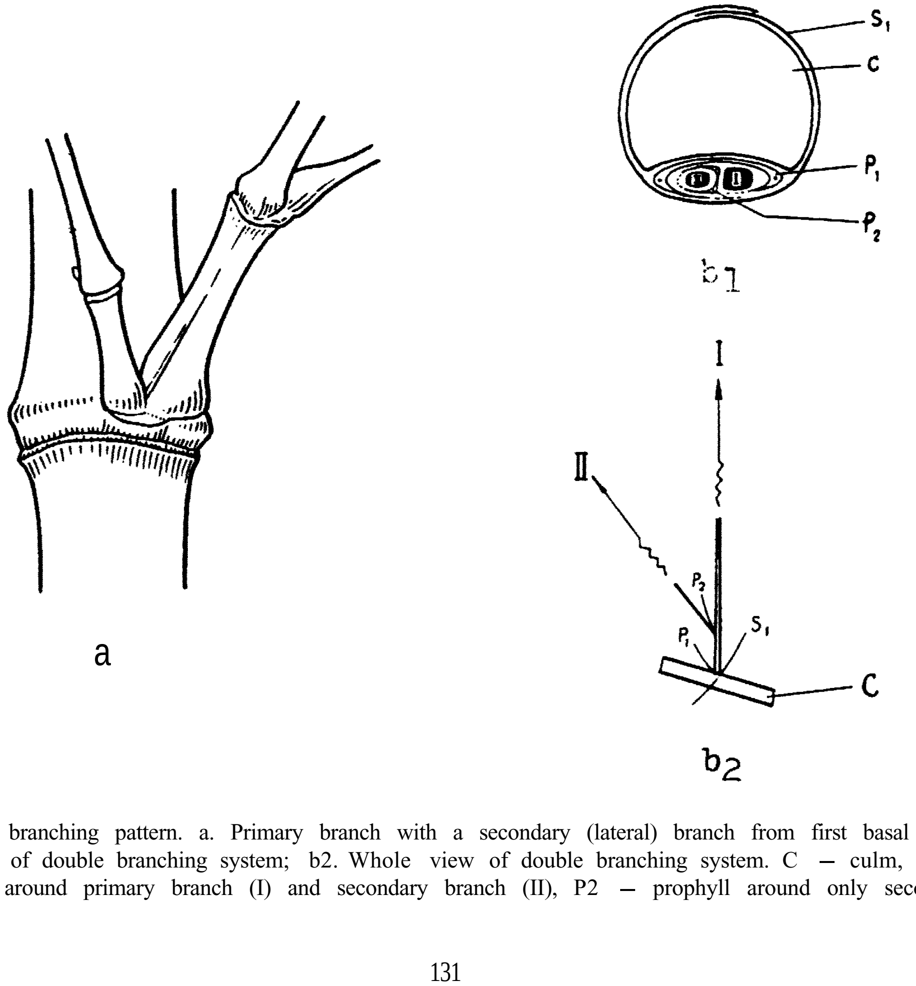


Fig. 6. Double branching pattern. a. Primary branch with a secondary (lateral) branch from first basal node; bl. Cross view of double branching system; b2. Whole view of double branching system. C — culm, Sl — sheath, Pl — prophyll around primary branch (I) and secondary branch (II), P2 — prophyll around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

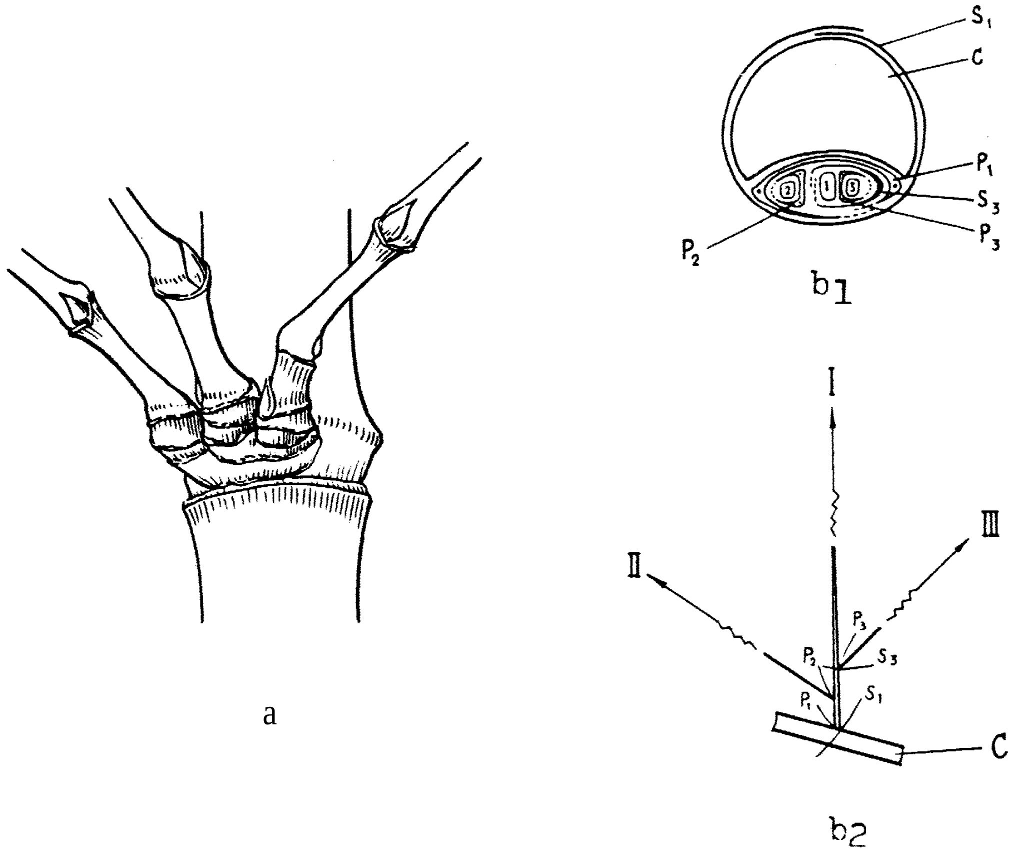


Fig. 7. Triple branching pattern. a. A dominant primary branch with two secondary (lateral) branches on its constricted basal nodes. Note their joined base at an almost same level; bl. Cross view of triple branching system; b2. Whole view of triple branching system. C — culm, Sl — sheath around culm 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

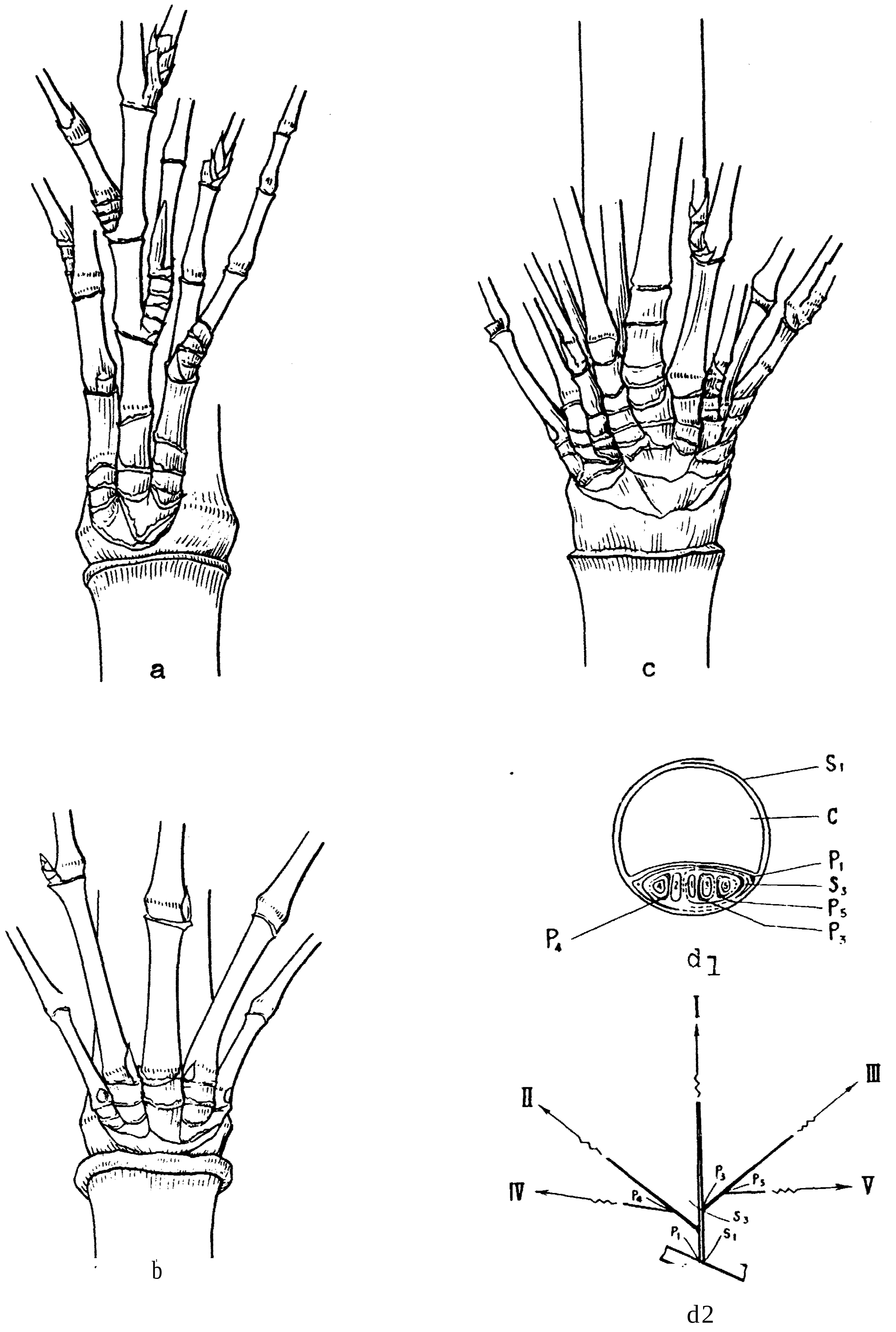
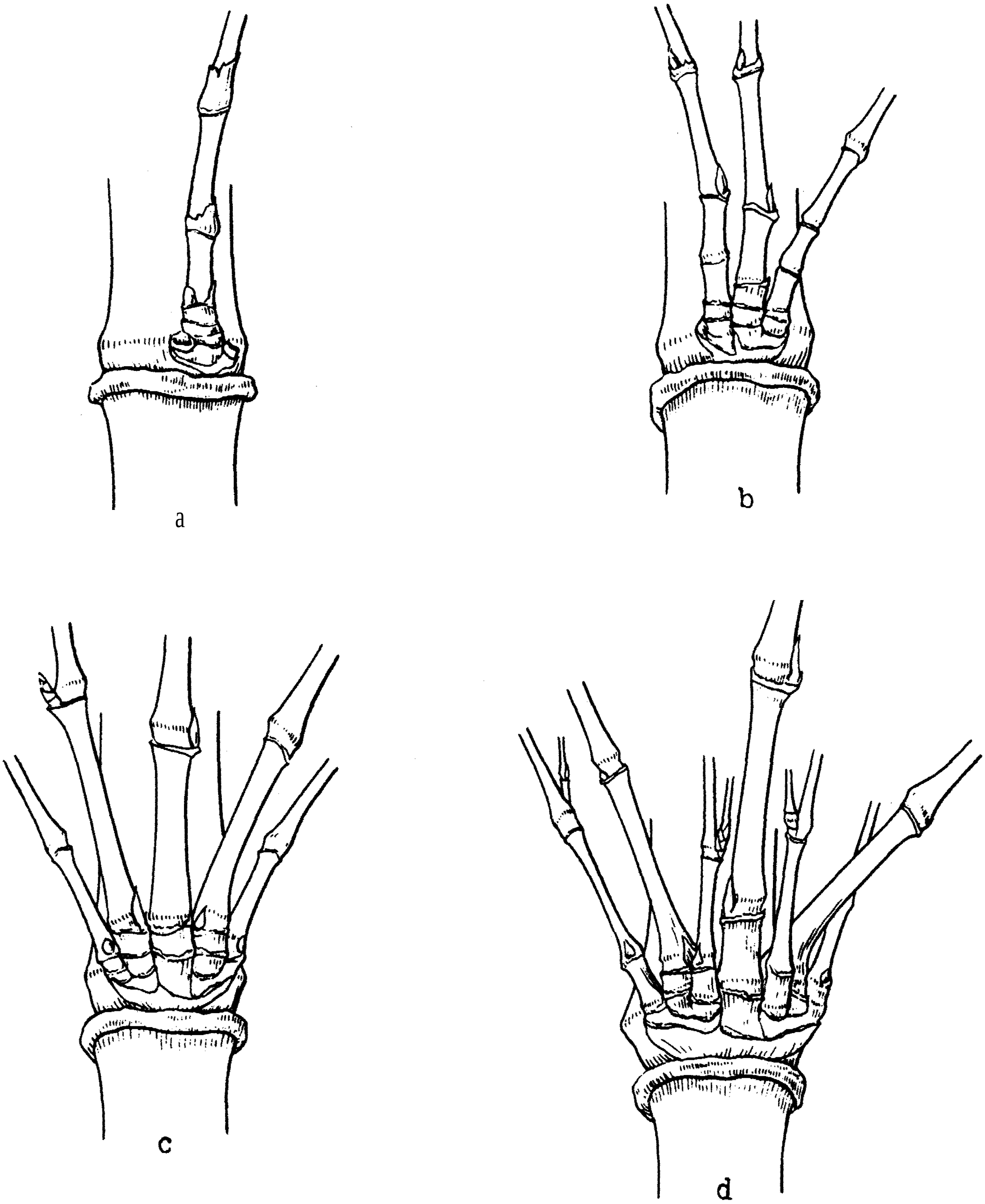


Fig. 8. Multiple branching pattern. a, b, c. Three different types of primary branches with multiple secondary (lateral) branches; dl. Cross view of multiple branching system; d2. Whole view of multiple branching system. C — culm, Sl — sheath around culm and primary branch, PI — prophyll around primary 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.

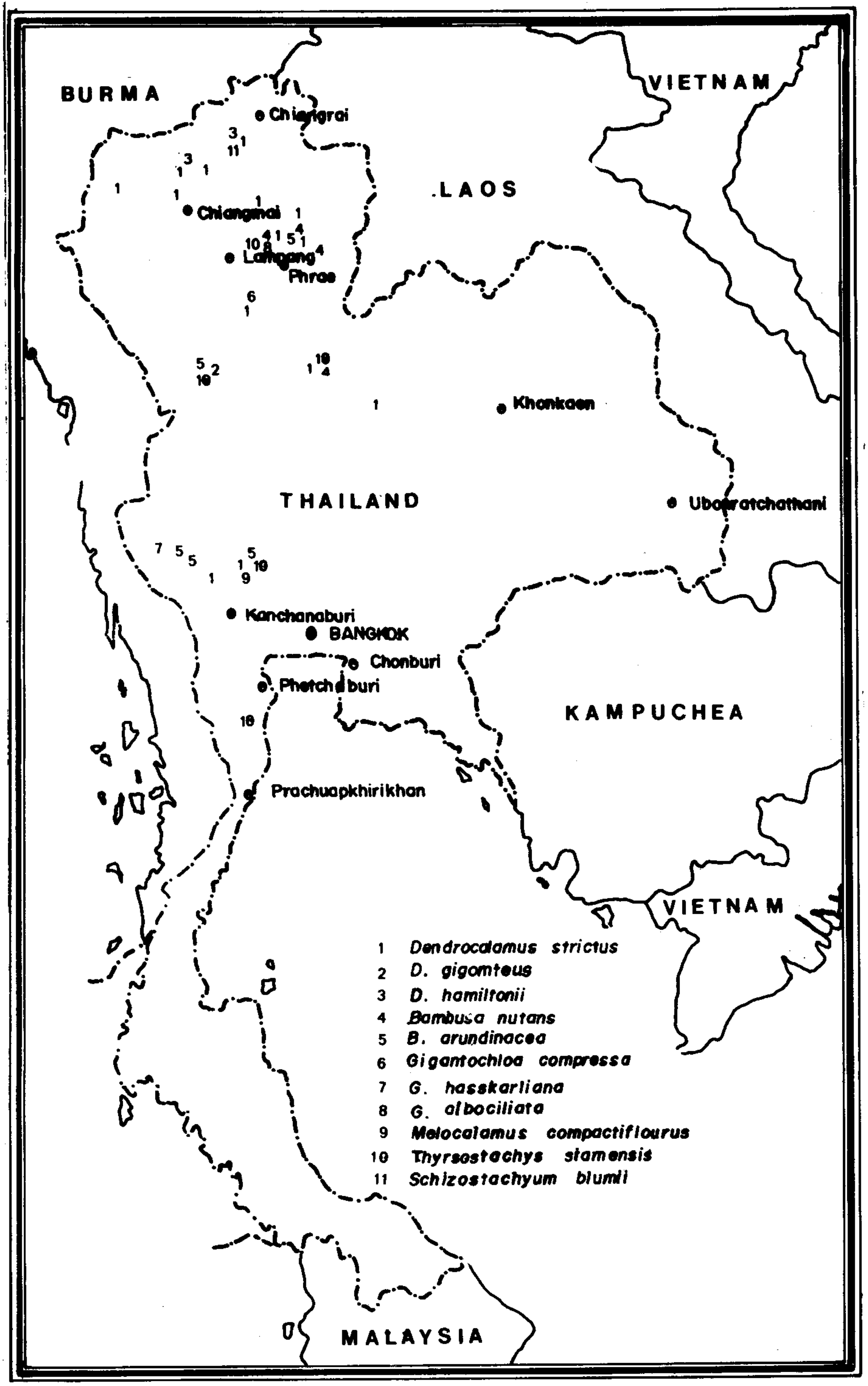

Fig. 1. Locations of bamboo seed collection.

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	Srisatchanalai: Sukhothai	–

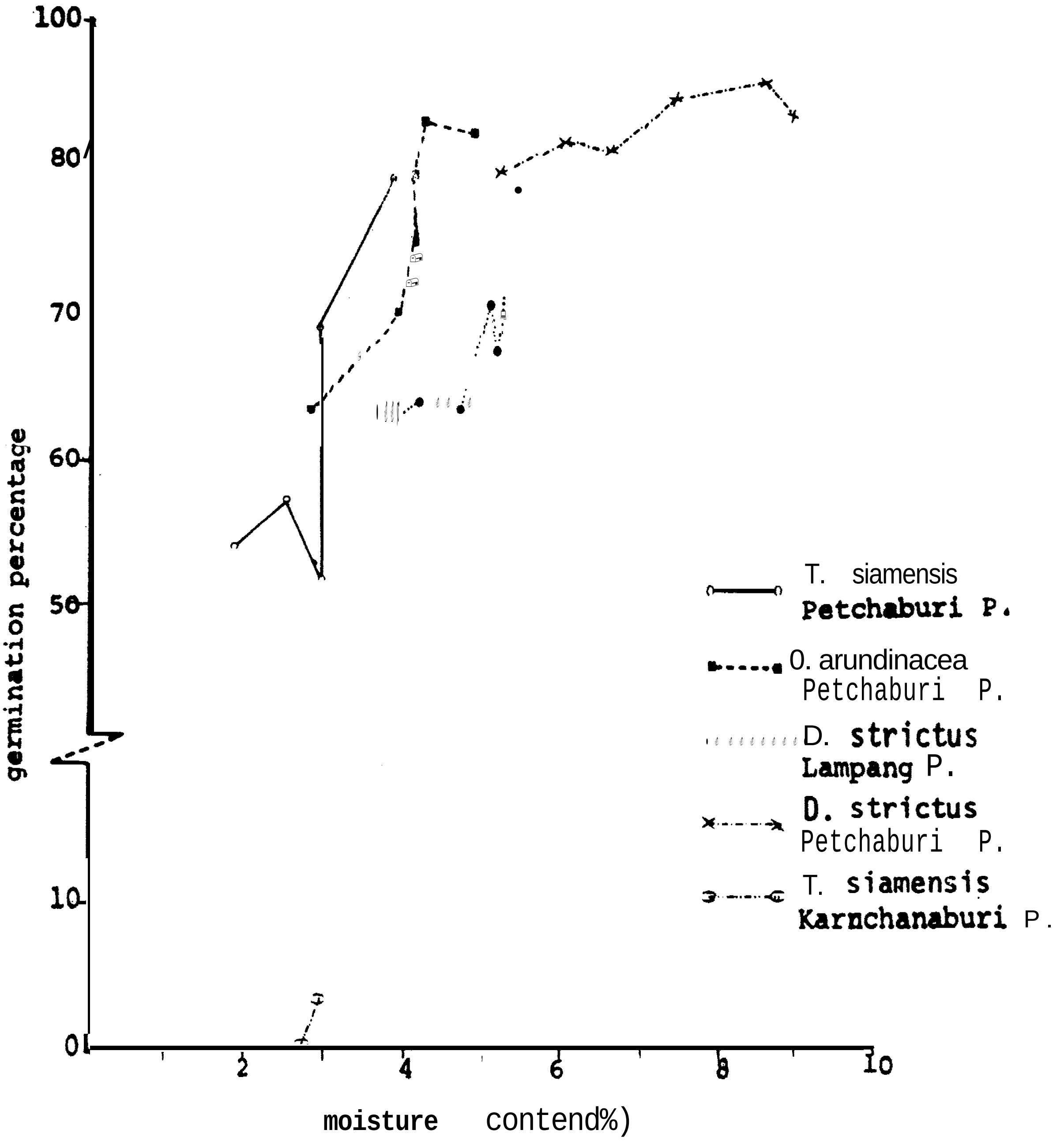

Fig. 2. The correlation between germination percentage and moisture content of some bamboo species in Thailand.

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.

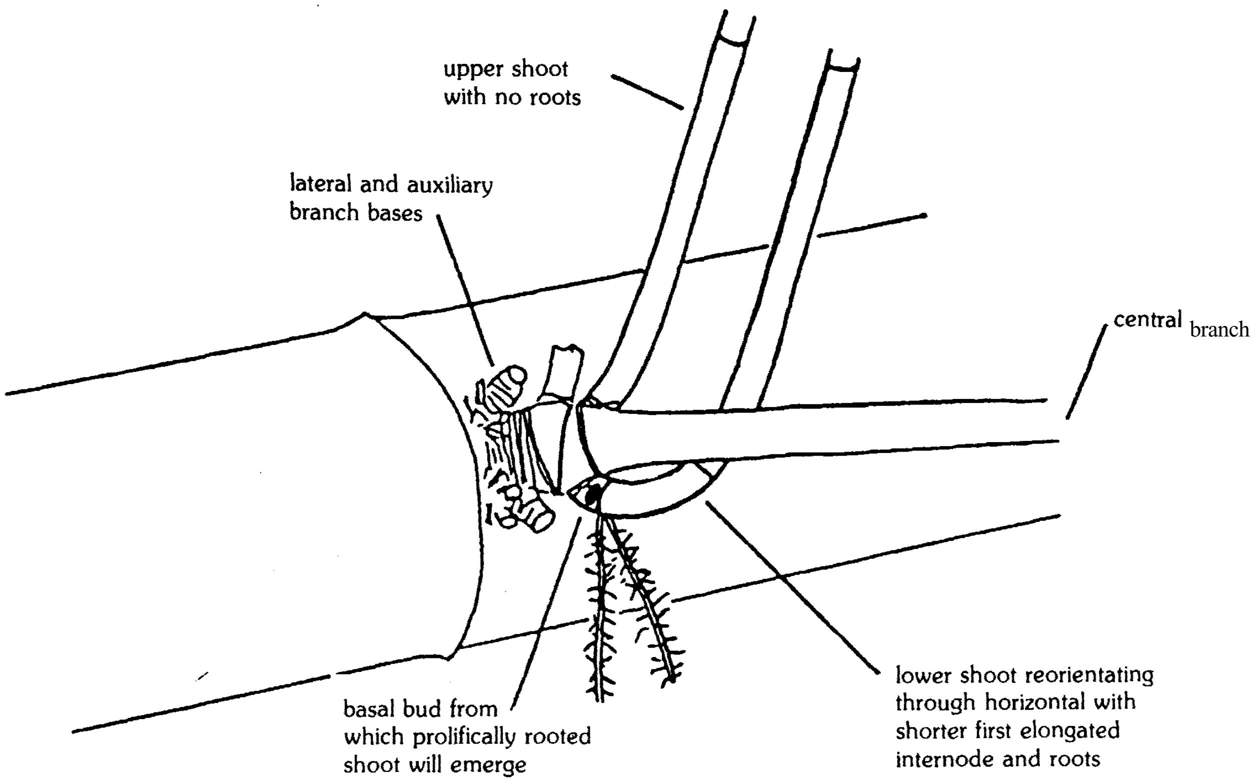


Fig. 1. Reorientating and rooting lower shoot and non-reorientating non-rooting upper shoot from central branch base in Bambusa nutans,

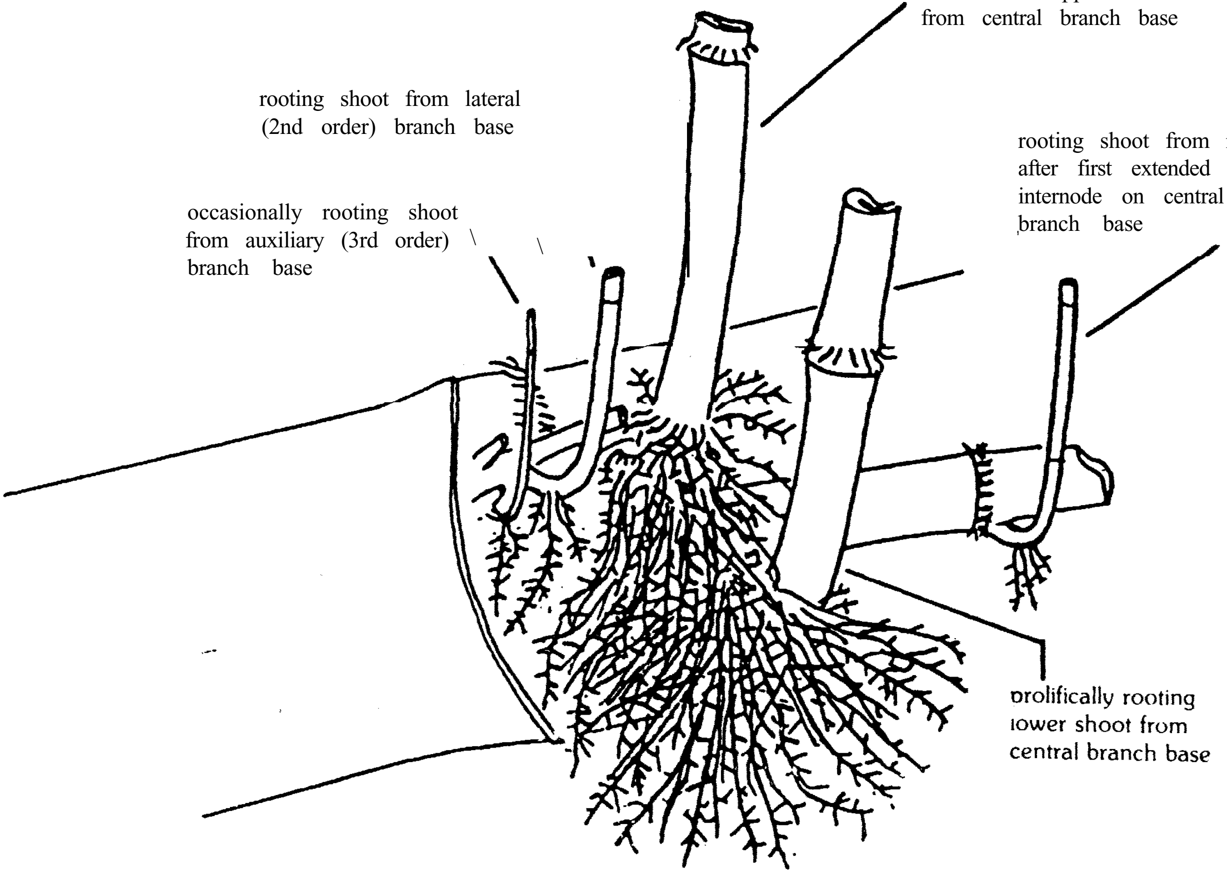
In addition, there were rooted shoots from several categories of branching which did not produce rooted shoots in B. nutans, and the overall rooting was much more prolific with many nodes producing more than one rooted shoot and several separate rooted plants (fig. 2). Under the arduous conditions development 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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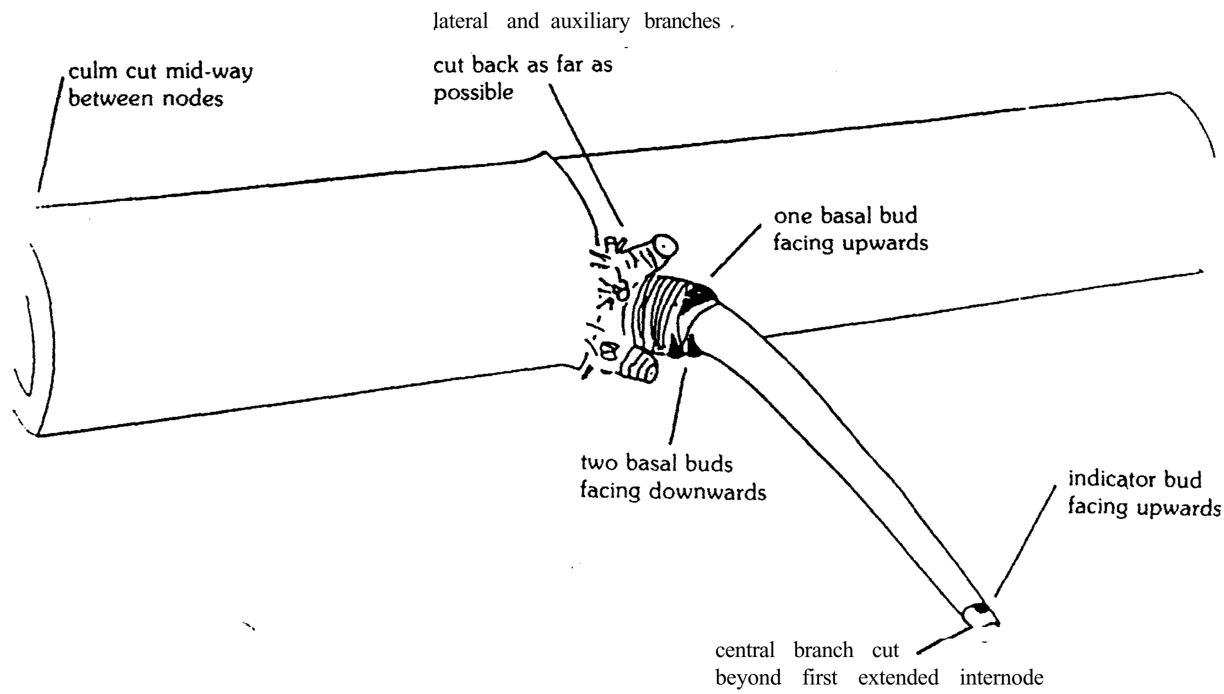
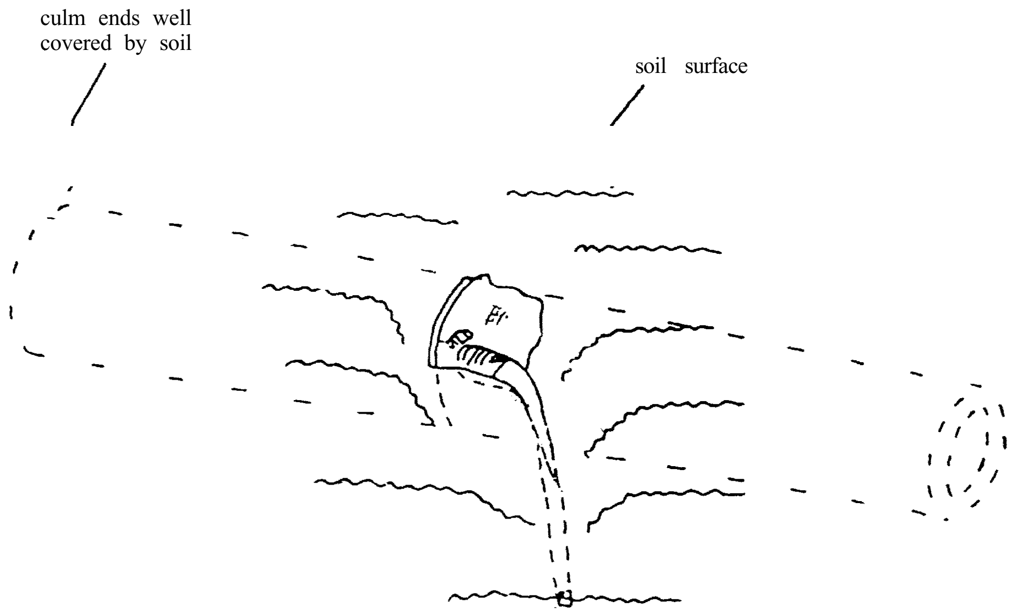


Fig. 3. a) Prepared single-node cutting of Bambusa species



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

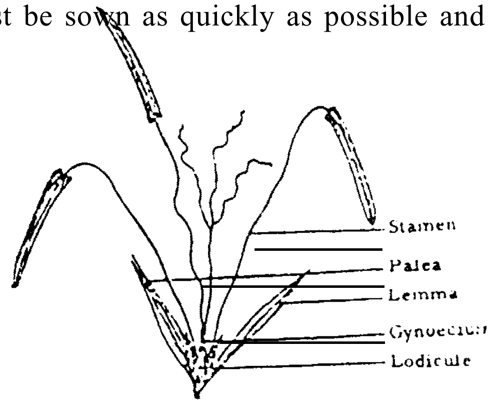


Fig. 1. Flower of P. *pubescens*

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° 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.

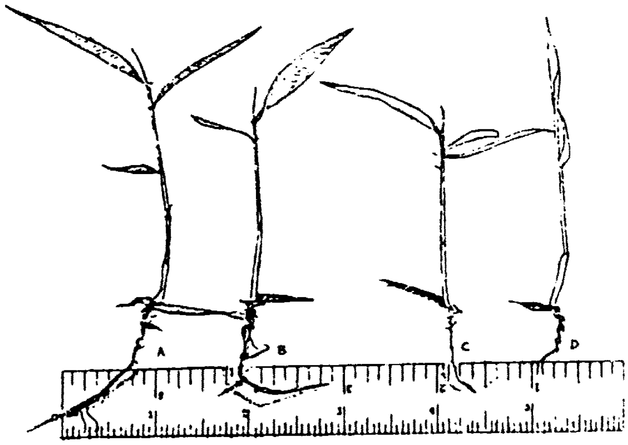


Fig. 2. Three leaf period seedlings. A&B. Healthy & normal. C&D. YUellowed. sickly & stunted.

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

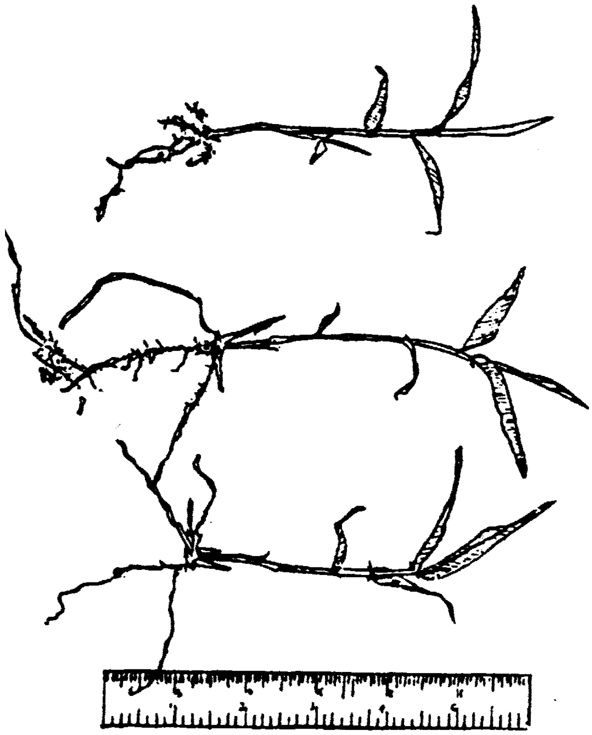


Fig. 3. Illustrating shoot development. A. Too deep-underdeveloped new shoot, mock shoot at node. B. Normal with one new shoot. C. Advanced with two new shoots.

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.

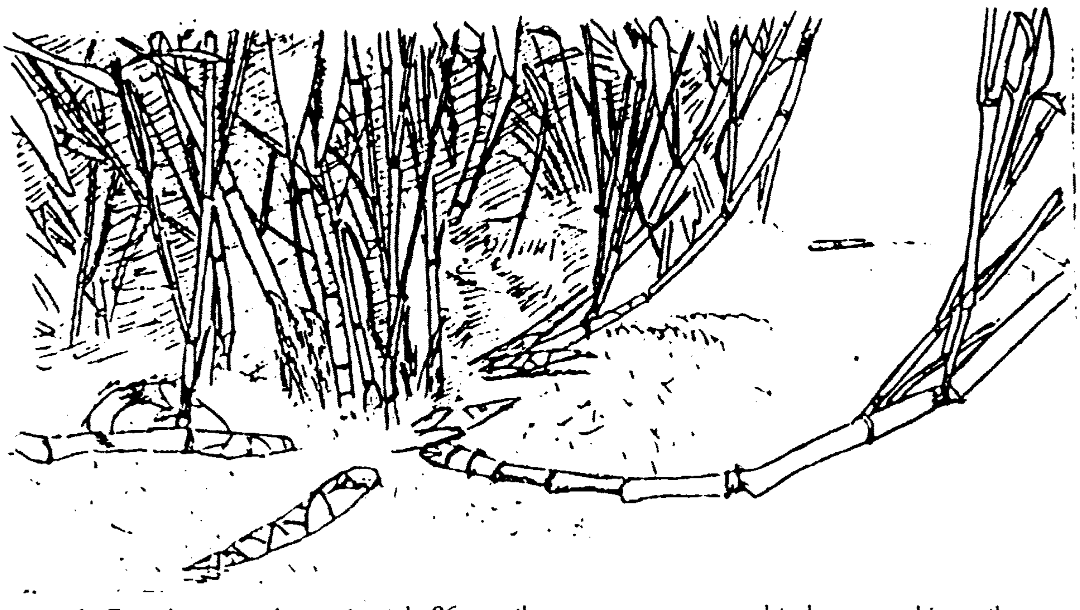


Fig. 6. First rhizomes. Approximately 36 months, some curve upward to become whips, others arch downward into the soil.

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

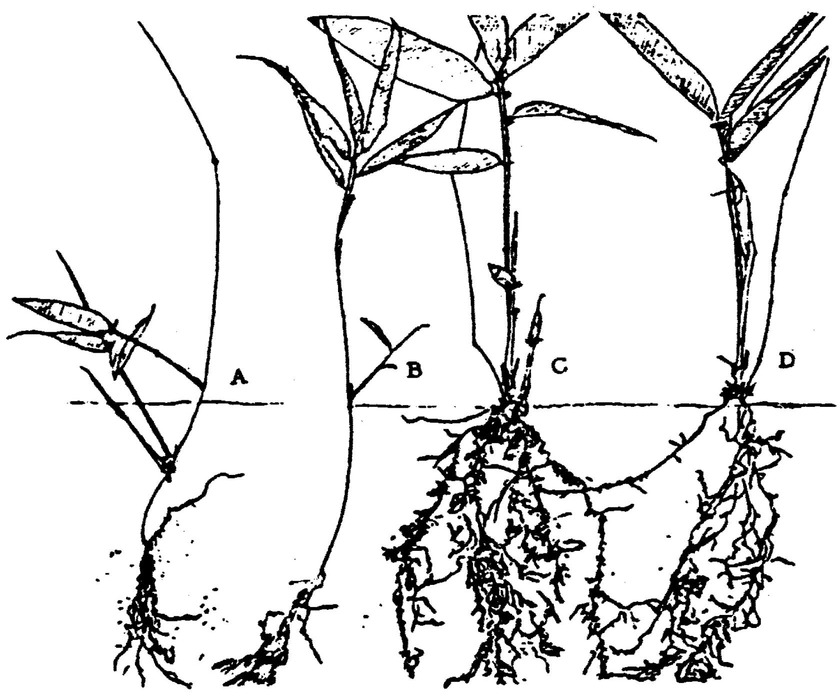


Fig. 8. Illustrating proper soil level. Ail seedfmgs 6 months.
A. Three mock shoots. B. Too deep, mock shoot at node.
C. Proper depth. D. Above soil, new shoots and roots exposed to weather.

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.

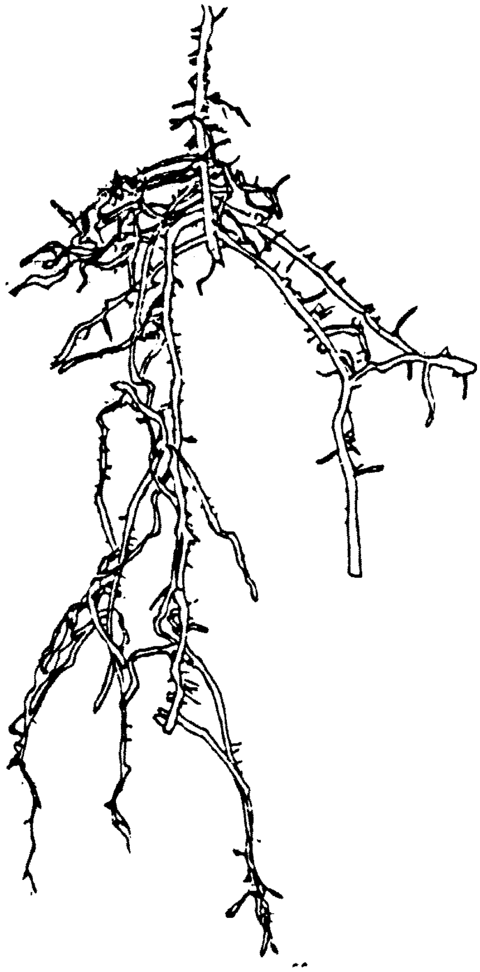
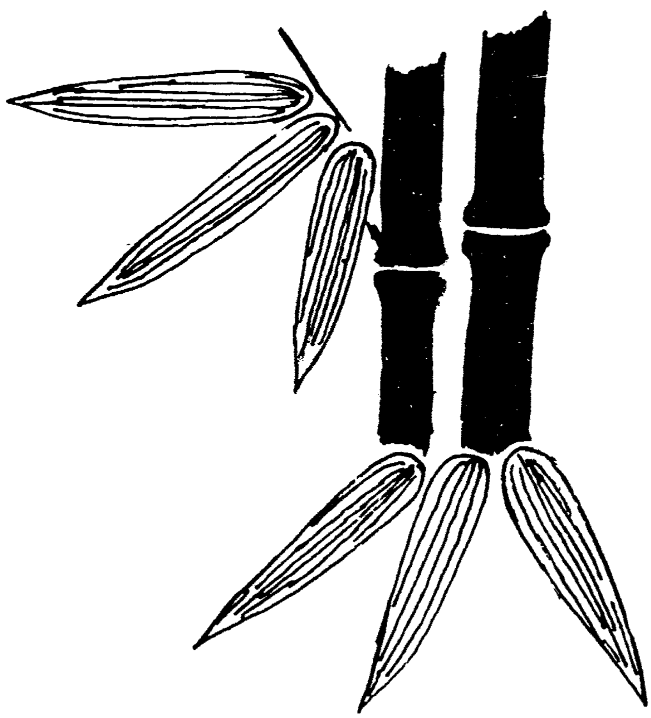


Fig. 9. Illustrating effect of cultivation on lateral root growth.



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 canbe*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. longis*piculata* 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	Year	Flowering nature	Seed Yield Yes	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. longispiculata	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.

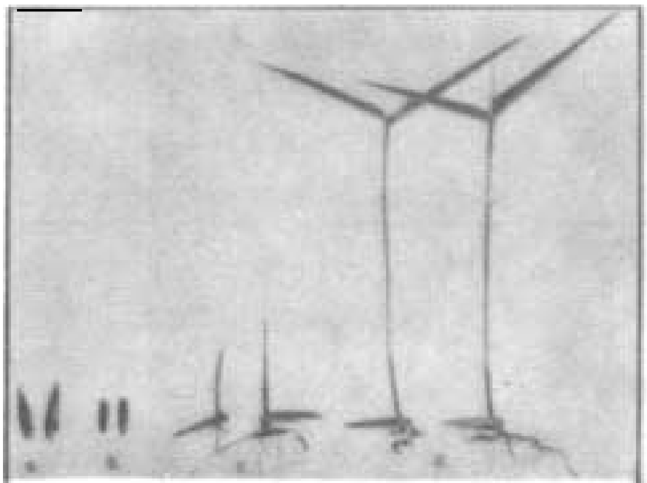
Species	Seeds/10 gm (Nos	Germination % (fresh seed)	Seed tongivety (days)	
			Room condition	Controlled condition
Bambusa arundinacea* var. *spinosa	1320 ± 7.0	52.3	65	–
B. glaucescens	151 ± 2.5	40.2	33	--
B. tulda	139 ± 1.1	48.0	35	540 (18 month)
Dendrocalmus longispathus	1351 ± 2.2	50.0	55	
D. strictus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

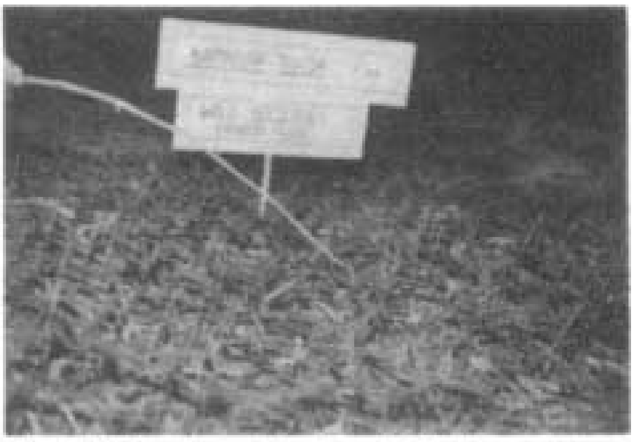


Plate 2. Wild seedlings of ***Bambusa tulda*** *Roxb. on the forest floor.*

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**

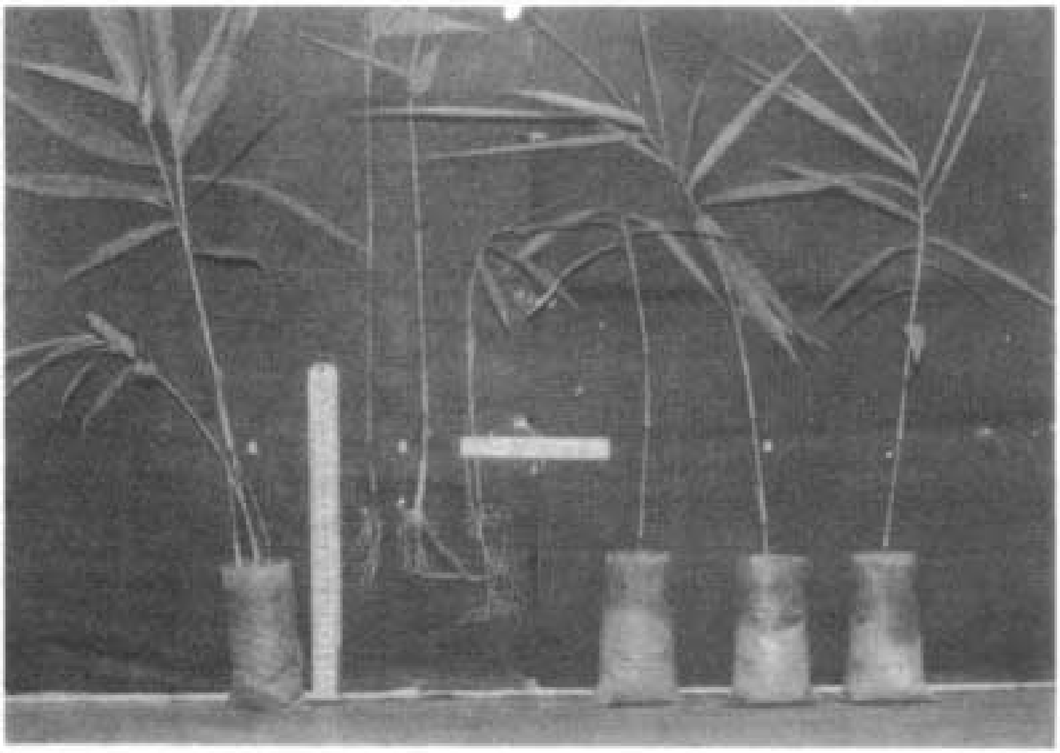


Plate 3. Seedling multiplication of **Bambusa tulda** *Roxb. Left to right: 9 months old seedling, culms are separated by rhizome division. 3 new seedlings developed*

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 cultivating 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. Culm 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). In 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 %	Rhizome formed %	Prerooted and prerhizomed branch cutting Rooting %	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

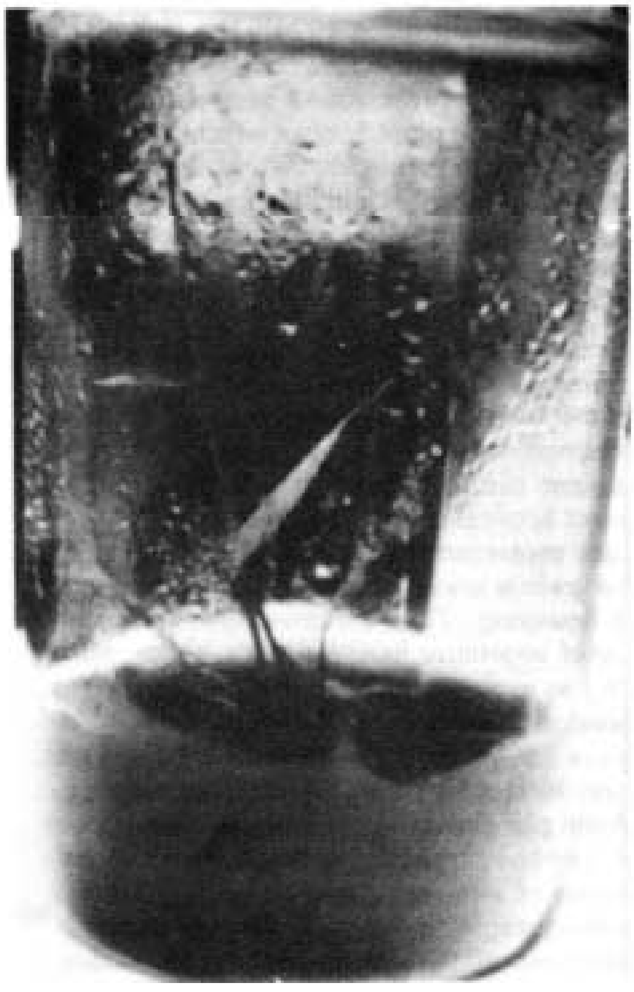


Plate 5 Tissue culture of Bambusa glaucescens Siebold: Shoot and root dvelopment *from* dormant *culm bud after* culturing 31/2 months *on* modified MS medium supplemented with BA (from 1.0 *mg to 7.0 mgl- ¹)* *and NAA (from 0.5 mg to 1.0* mgl-

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,

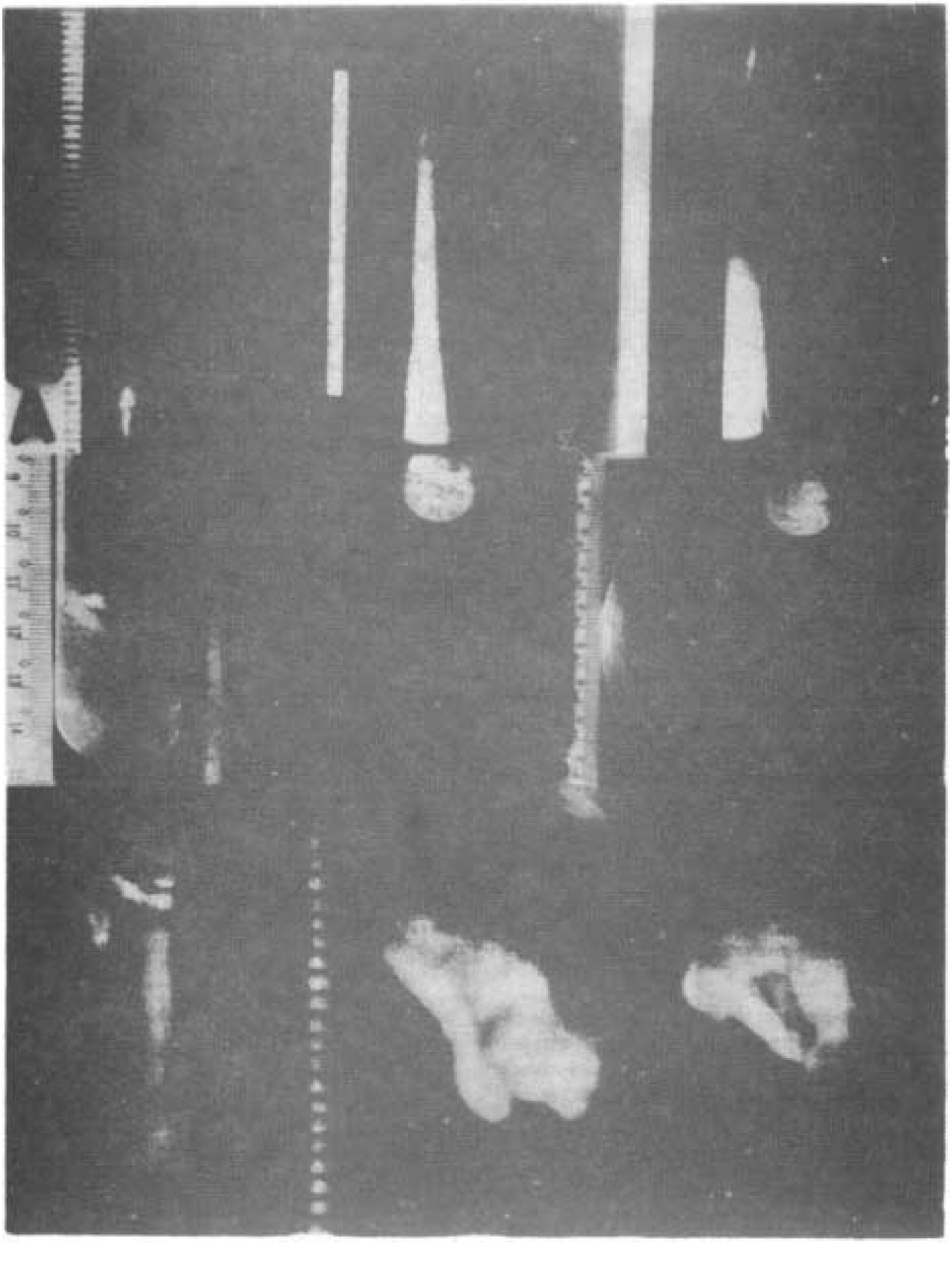

Fig. A, 1-9. Fig. 1. Excised young culm shoot of *Thyrsostachys siamensis*. Figs. 2-3. Culm shoots of *Schizostachyum brachicladum* with sheathing leaves peeled off showing nodes. Fig. 3. A single culm leaf excised with basal light coloured and upper dark coloured positions. Basal part used. Figs. 4-5. 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)

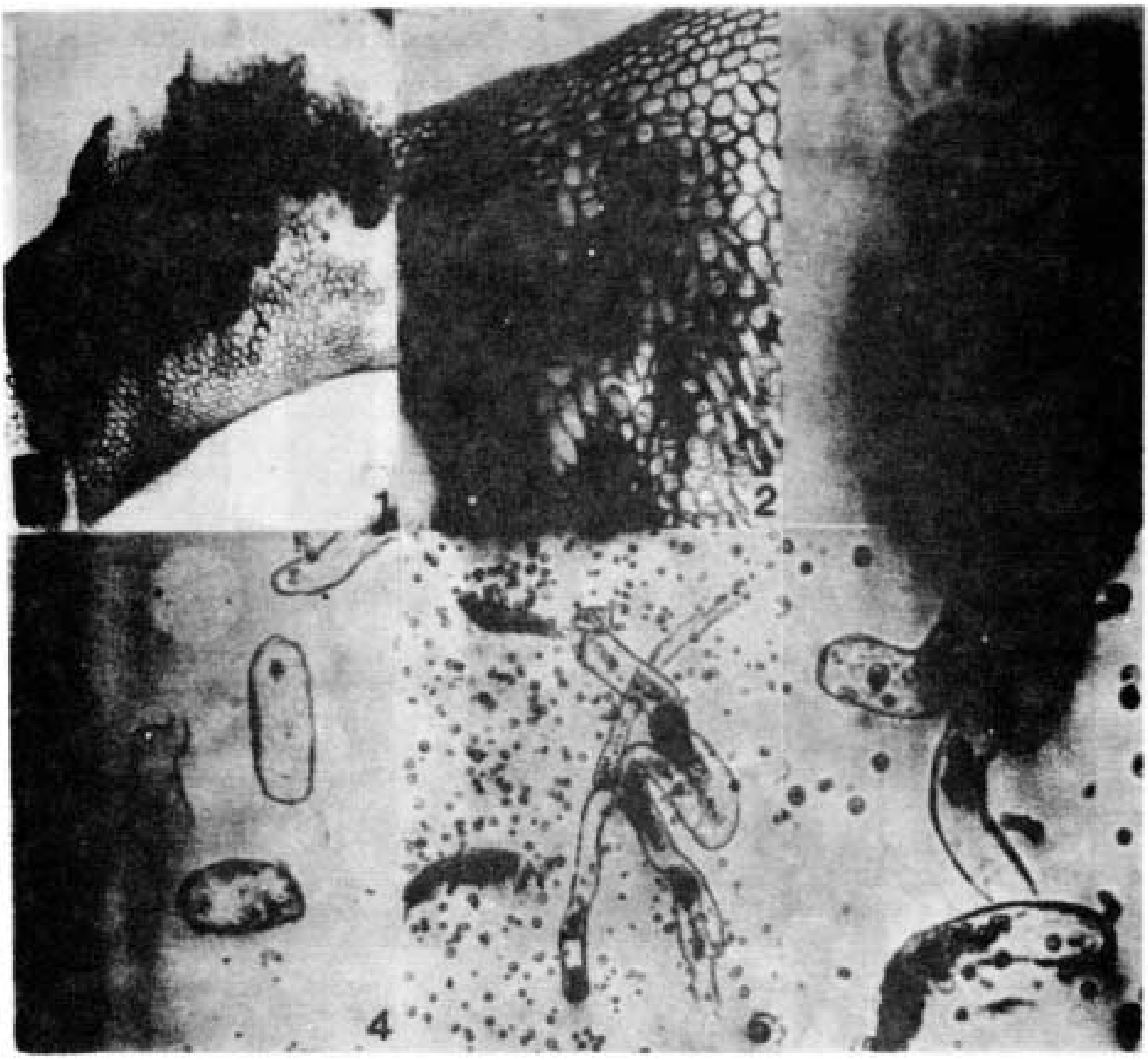

Fig. B, 1-6. Fig. 1. T.S. culm leaf showing epidermis and mesophyll outgrowth, Note the position of vascular bundles. Fig. 2. Lower epidermis and mesophyll enlarged showing active cell divisions, Note the pocket of collenchyma tissue. Figs. 3-6. Isolated or free cells obtained, enlarged to show the cell 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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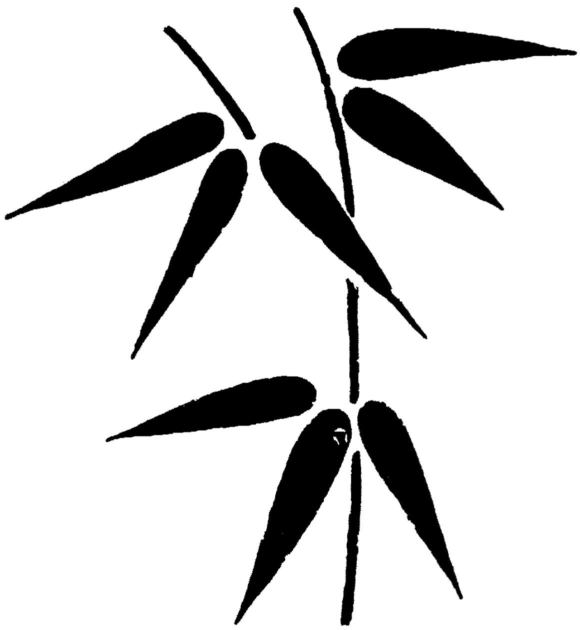

Studies on the Chromosome Number of Some Bamboo Species with Clump Rhizomes

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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 *Sinocalamus 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. textiiis 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 characters 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.

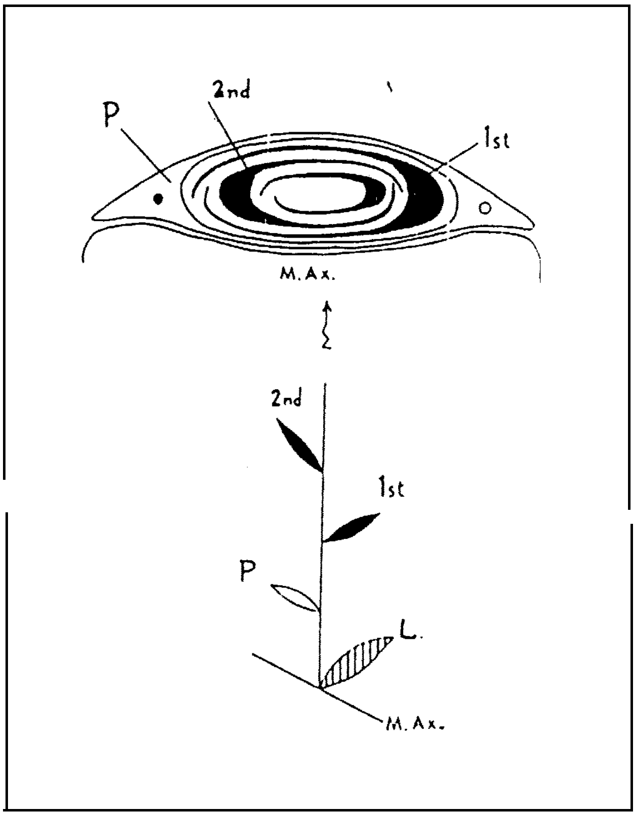


Fig: 1. Sasa type bud and branching. Abbreviations: P-prophyll: lst, the first foliage leaf: 2nd, the second foliage leaf: M.Ax., main axis: L, a leaf on the node of the main axis (= culm sheath). The black leaf represents a foliage leaf and the white one a prophyll.

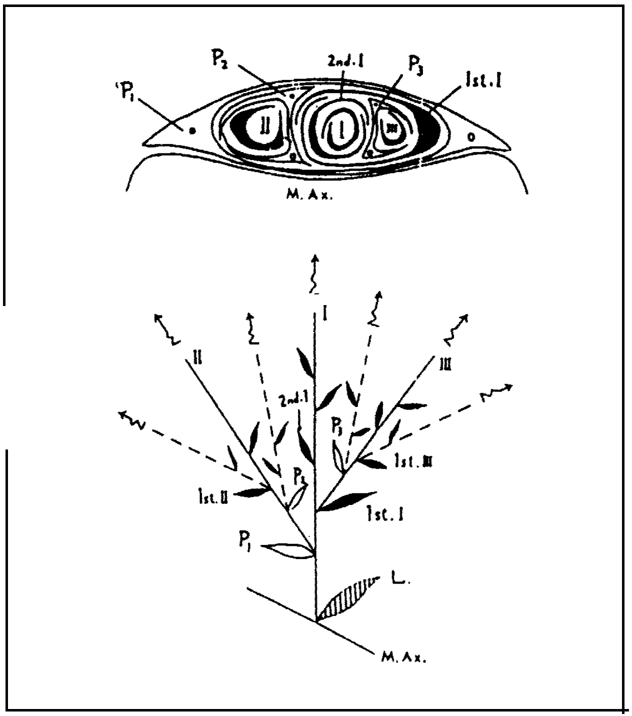


Fig. 2. Arundinaria type bud and branching. Abbreviations: PI, the outer prophyll: P2, the second prophyll in th axil of the p : P3, the third prophyll in the axil of the first foliage leaf: 1st. 1., the first foliage leaf of the first branch: 2nd. 1., the second foliage leaf of the first branch : M.Ax., main axis: L., a leaf on the node of main axis (= culm sheath).

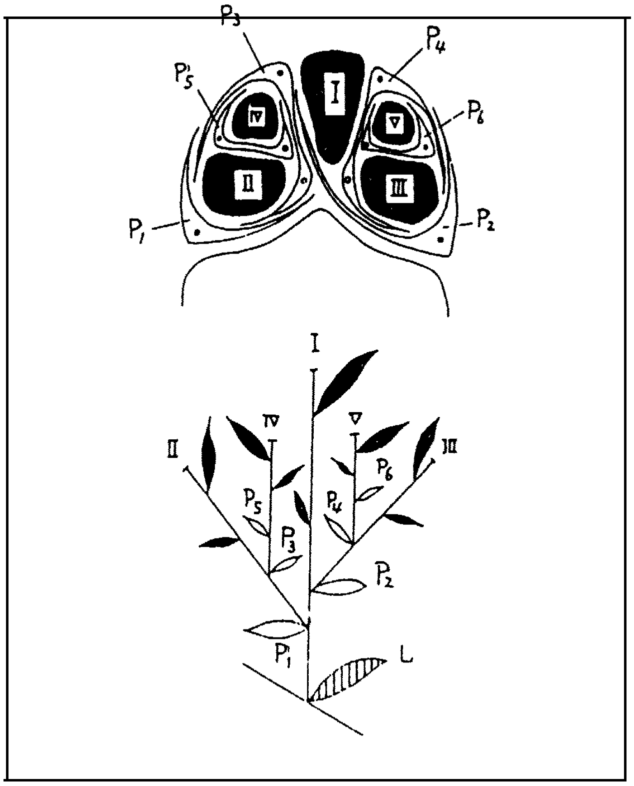


Fig. 3. Shibataea type bud and branching; note that the outermost prophylls are not the usual two-keeled form, but separated,

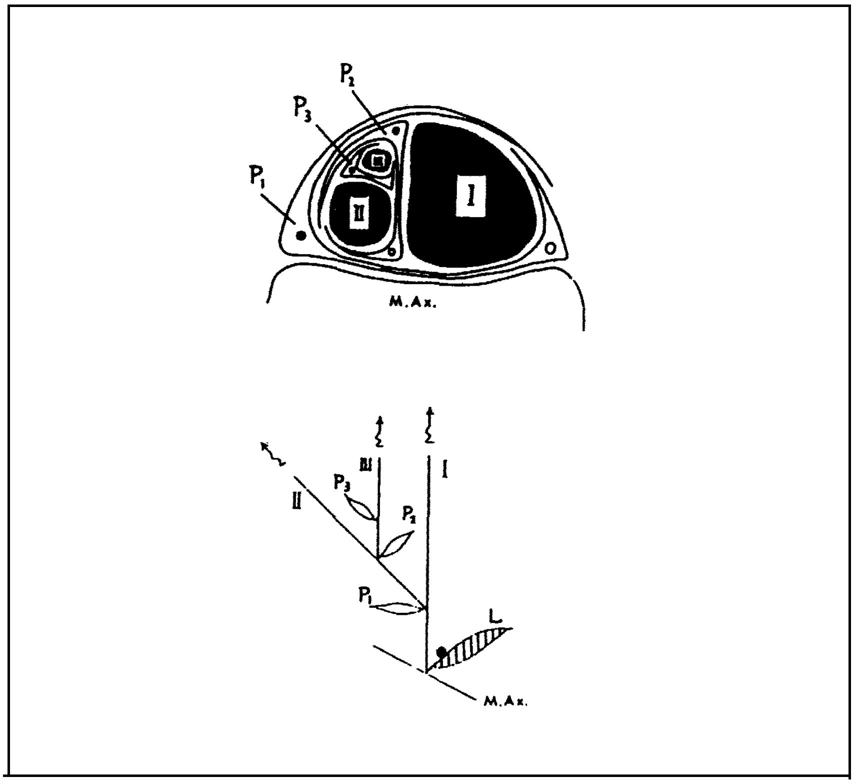


Fig. 4. Phyllostachys type bud and branching; note the peculiar branching.

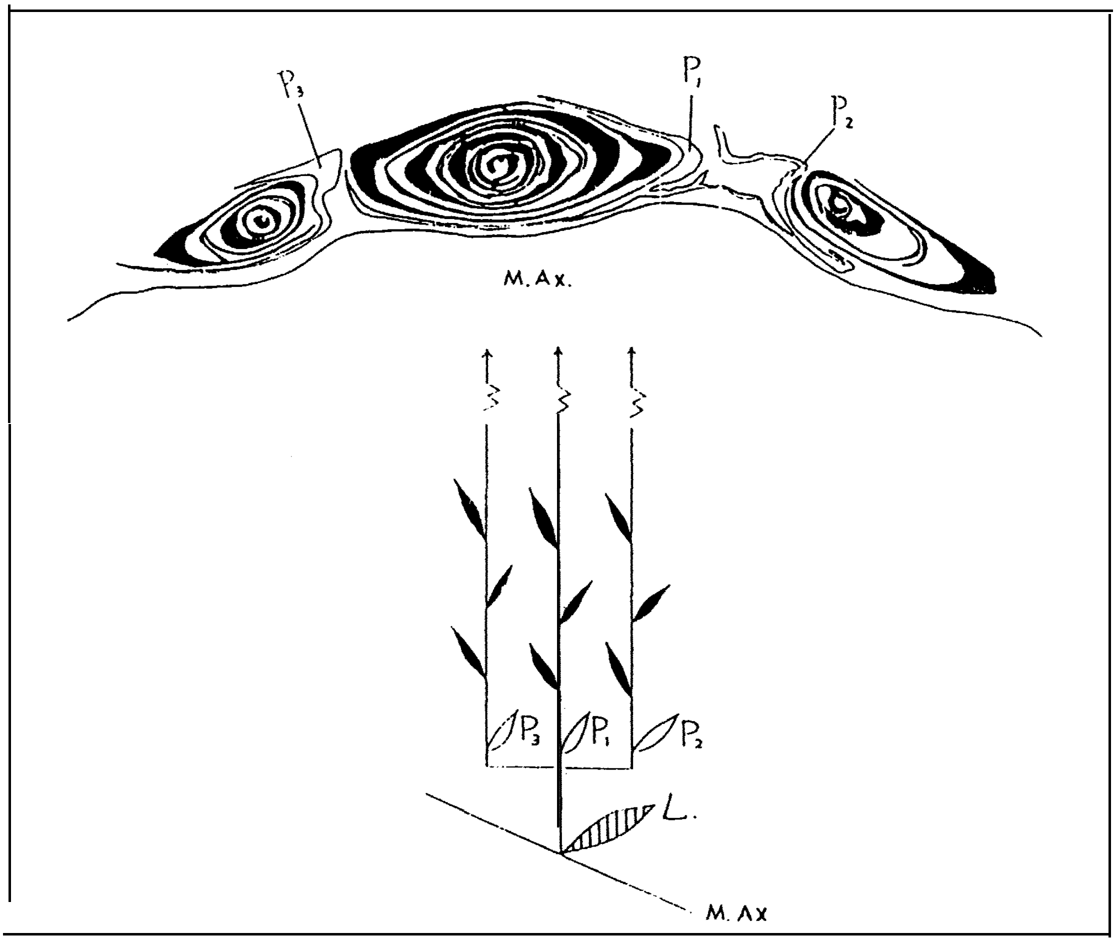


Fig. 5. *Chimonobambusa* type bud and branching diagram. Three branches and their prophylls are each separated.

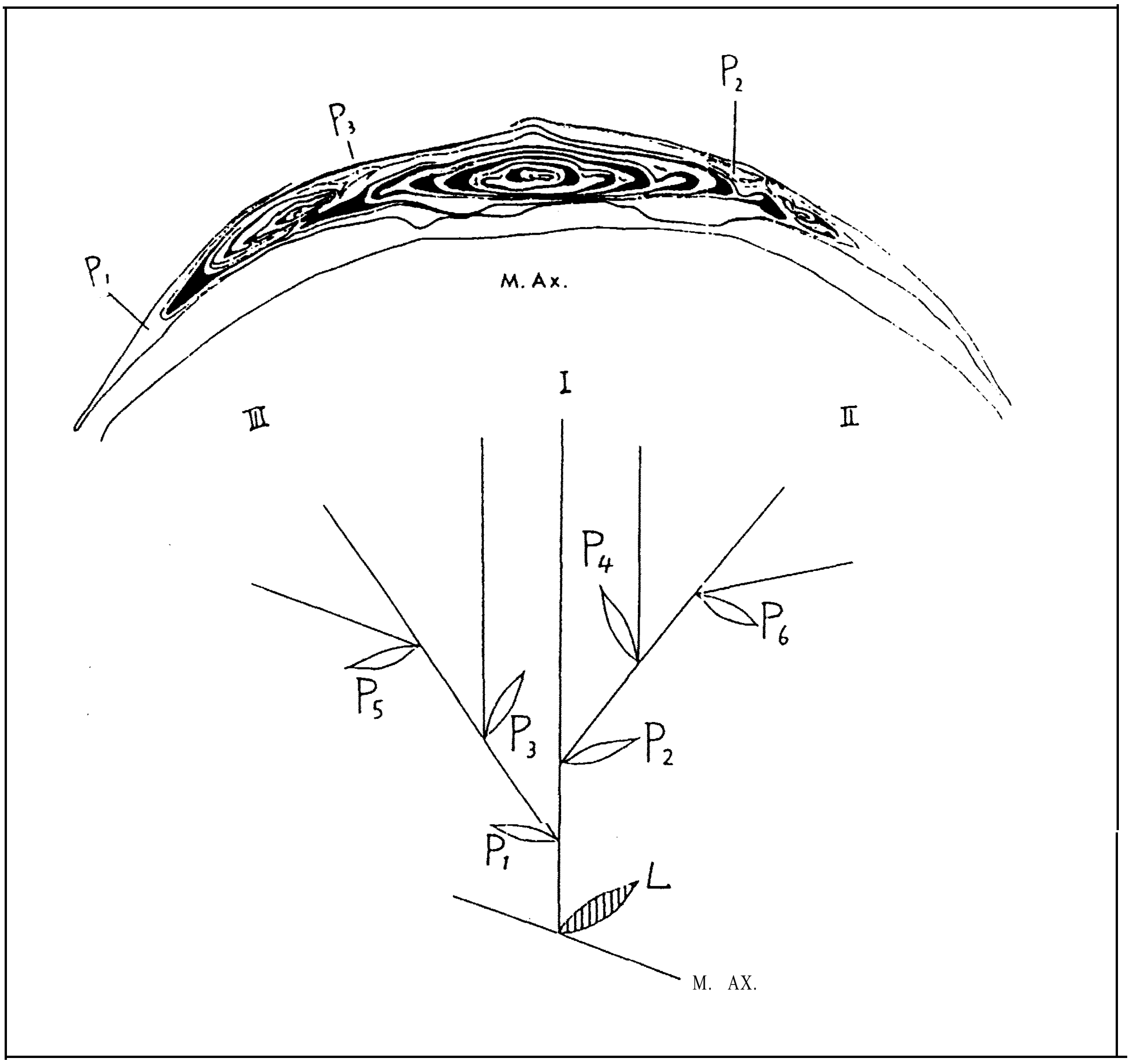


Fig. 6. Bambusa type bud and branching. Each prophyll shows a pointed tip.

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.

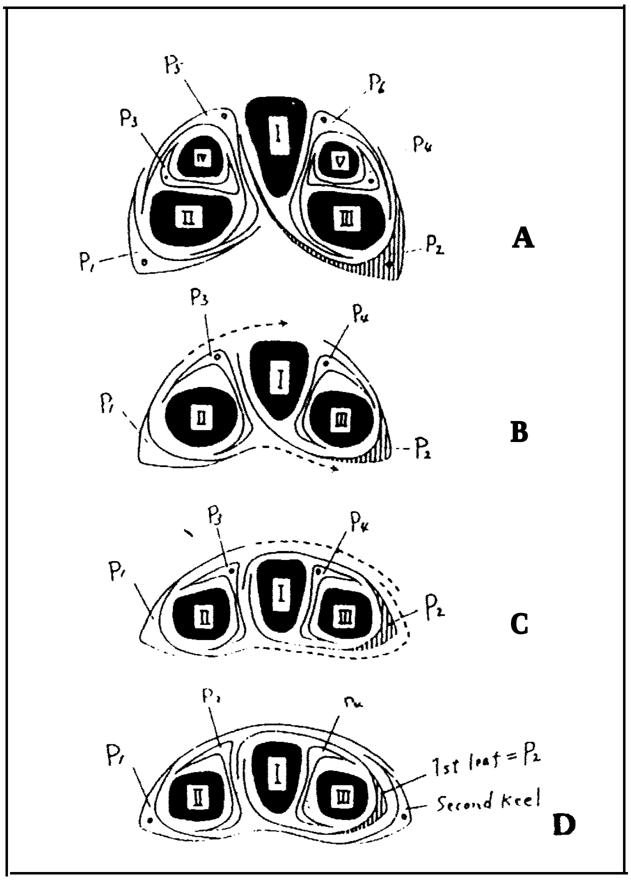
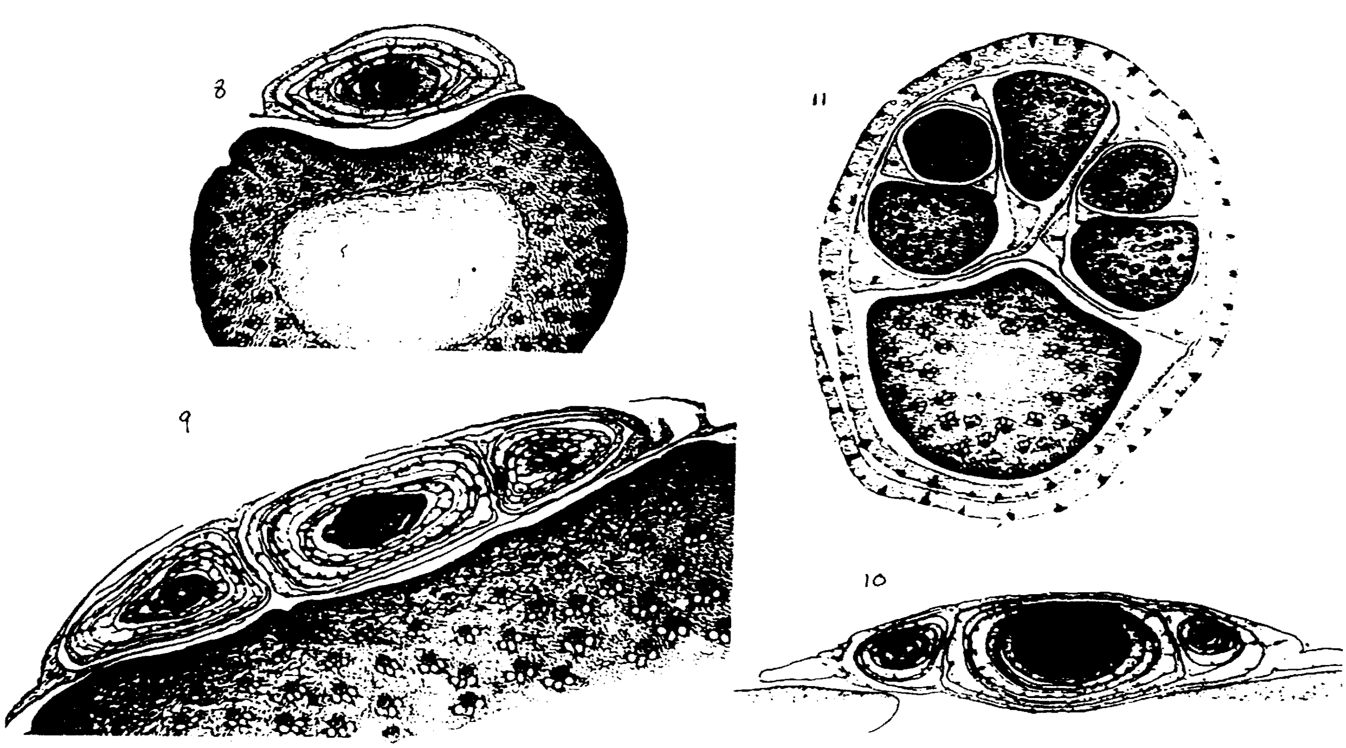
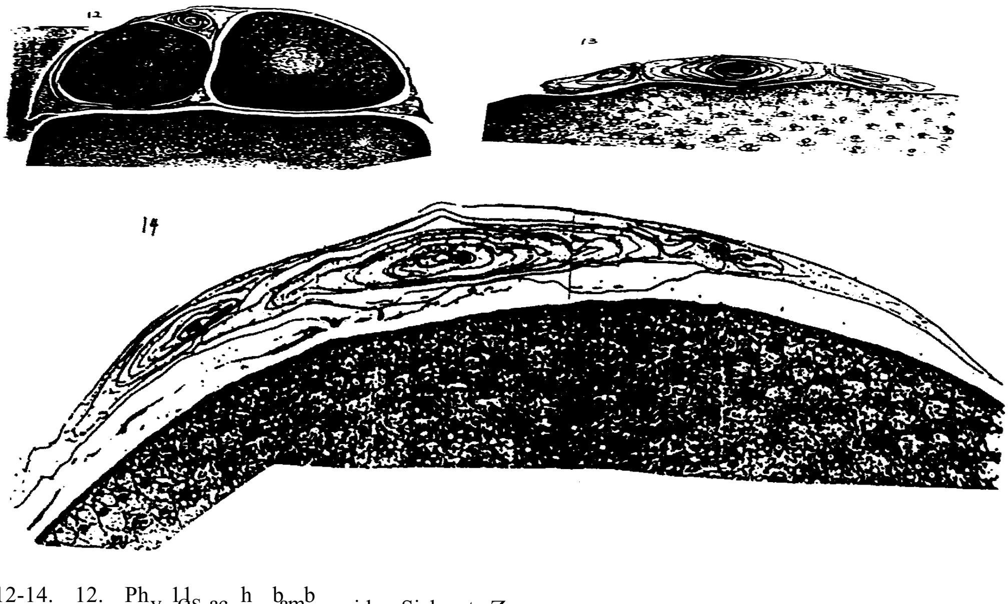


Fig. 7. Diagram showing the transformation from the Shibataea type to the Arundinaria type. Note the outerprophyll (P1) developing to envelope the inner leaf (the 1st foliage leaf) which subtended the first and third branches.



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. Phyllostachys 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

Anatomy and Properties of Bamboo

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Abstract

The numerous alternatives in the use of bamboo depend on the unique properties of its culm. In order to understand the anatomical and chemical make-up and its ensuing mechanical properties, an attempt has been made to summarize the accessible information.

Anatomy

Gross anatomy: The properties of the culm are determined by its anatomical structure. The culm consists of internodes and nodes. At the internodes, the cells are axially oriented, whereas at the nodes, cells provide the transverse interconnections. No radial cell elements, such as rays, exist in the internodes. Within the nodes an intensive branching of the vessels occurs. These also bend radially inward and provide transverse conduction through the nodal diaphragms, so that all parts of the culm are interwoven. The outer part of the culm is formed by two epidermal cell layers, the inner appearing thicker and highly lignified. The surface of outermost cells are covered by a cutinized layer with a wax coating. The inner parts of the culm consist of numerous sclerenchyma cells. Any lateral movement of liquids is therefore much hindered. Pathways for penetration are thus only the cross ends of the culm and to a much smaller extent the sheath scars around the nodes.

The gross anatomical structure of a transverse section of any culm internode is determined by the shape, size, arrangement and number of the vascular bundles. They are clearly contrasted by the darker colored sclerenchymatous tissue against the parenchymatous ground tissue. At the peripheral zone of the culm the vascular bundles are smaller and more numerous, in the inner parts larger and fewer (Figs. 1, 2). Within the culm wall the total number of vascular bundles decreases from bottom towards the top, while their density increases at the same time. The culm tissue is mostly parenchyma and the vascular bundles which are composed of vessels, sieve tubes with companion cells and fibres. The total culm comprises about 50% parenchyma, 40% fibre, and 10% conducting tissues (vessels and sieve tubes) with some variation according to species. The percentage distribution and orientation of cells show a definite pattern within the culm, both horizontally and vertically. Parenchyma and conducting cells are more frequent in the inner third of the wall, whereas in the outer third the percentage of fibers is distinctly higher. In the vertical direction the amount of fibres increases from bottom to top and that of parenchyma decreases (Fig. 3) The common practice of leaving the upper part of a cut culm unused in the forest is therefore a waste with regard to its higher fibre content.

Parenchyma: The ground tissue consists of parenchyma cells, which are mostly vertically elongated (100 x 20 urn) with short, cube-like ones interspersed in between. The former are characterized by thicker walls with a polylamellate structure (Fig. 4); they become Iignified in the early stages of shoot growth. The shorter cells have a denser cytoplasm, thinner walls and retain their cytoplasmic activity for a long time. The function of these two different types of parenchyma cells is still unknown.

Of interest in the structure of parenchyma walls is the occurrence of warts in many taxa

See also recent GTZ publication: Bamboos – Biology, Silvics, Properties, Utilization by Liese, 1985 – Ed,

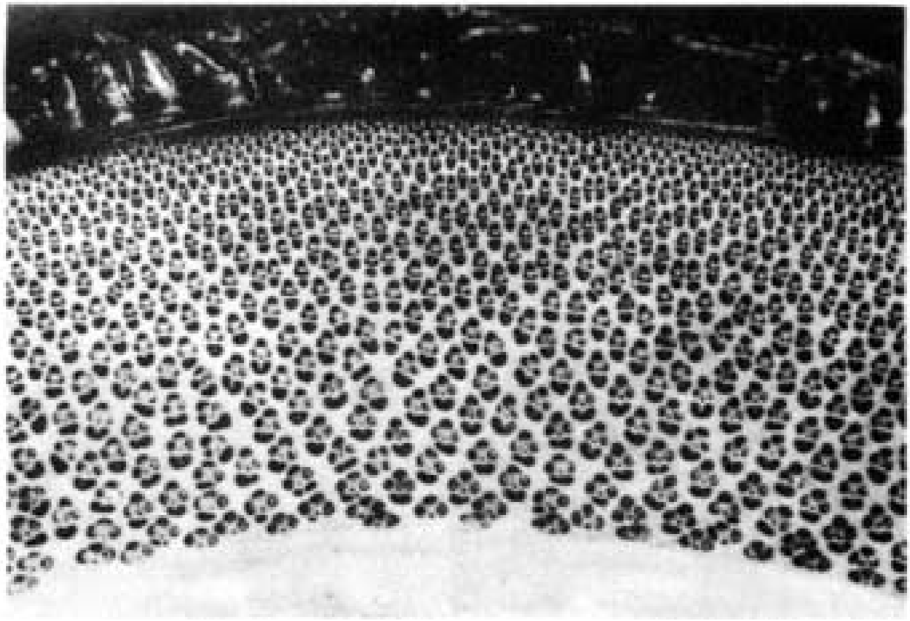

Figure 2. Overview of 6 culm section, Dendrocalamus giganteus.

Ftgure 2. Three-dlmenslonal view of culm tissue with vascular bundles.

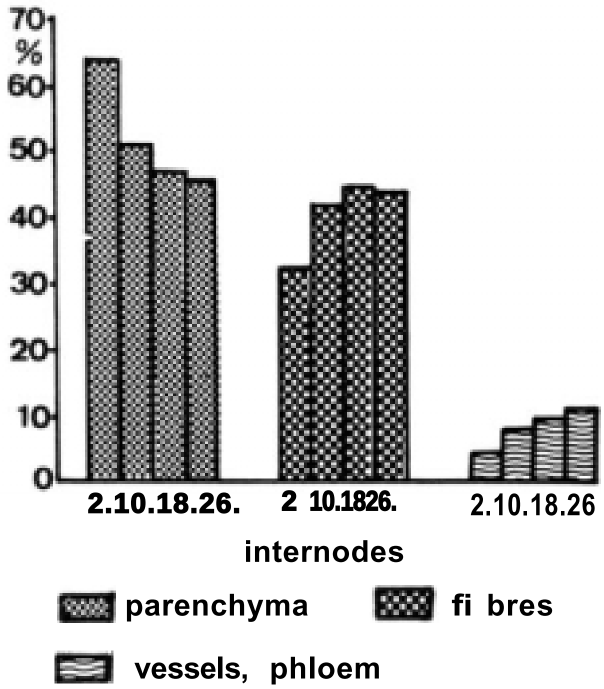

Figure 3. Percentage of cell type in the vertical direction of a culm;Cephalostachyum perqracile.

like Bombusa, *Cephalostachyum, Dendro-calamus, Oxytenanthera,* *Thyrostachys,* which have not been observed so far in the **parenchyma** of hardwoods. Genuine warts have to be carefully distinguished from cyto-**plasmic** debris, which are also frequent in parenchyma cells after the death of the proto-plast. Their distribution is variable from very dense to sparse. Among the species examined the parenchyma cells appear to possess a even higher number and density of warts than fibres and vessel members. Their size varies from 120 – 520 nm. The occurrence of warts in the lignified paren-chyma cells of bamboo is perhaps an expres-sion of the close association of lignin-like nature of warts, since warts have not been observed in non-lignified cells (Parameswaran and Liese, 1977).

Vascular bundles: The vascular bundle in the bamboo culm consists of the xylem with one or two smaller protoxylem elements and two large metaxylem vessels (40 – 120 urn)

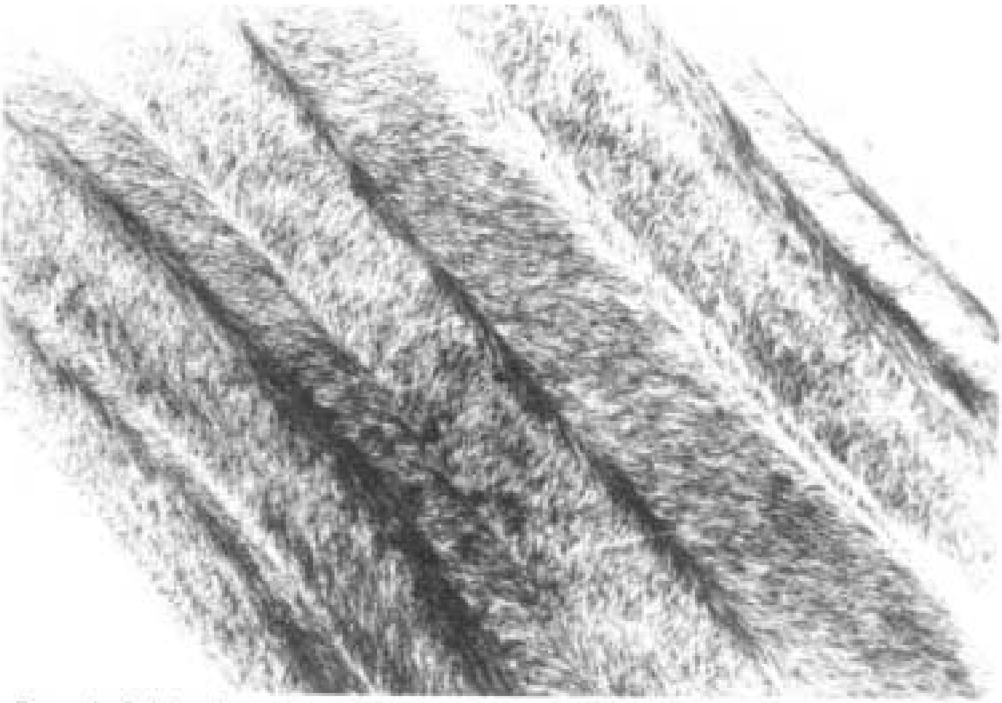

Figure 4. Polylamellate structure of a parenchyma cell wall. **Phyllostachys edulis**, 19.000 x.

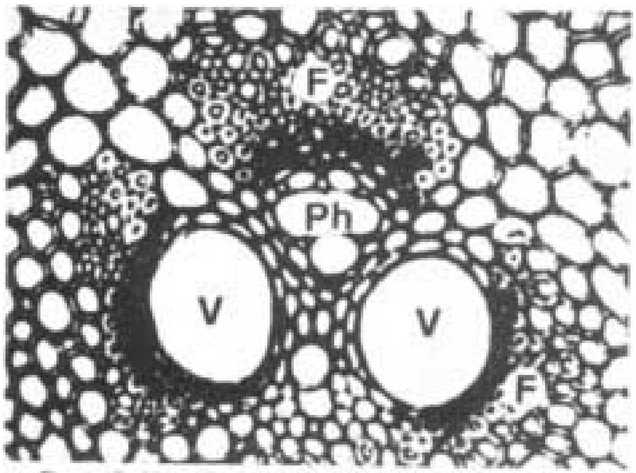

Figure 5. Vascular bundle with two large metaxylem vessels (V) and phloem (Ph) surrounded by fibres (F)

and the phloem with thinwalled, unlignified sieve tubes connected to companion cells (Fig. 5). The vessels possess large diameters in the inner parts of the culm wall and become small towards outside. These water conducting elements have to function throughout the lifetime of a culm without the formation of any new tissue, as in the case of hardwoods and softwoods with cambial activity. In older culms, vessels and sieve tubes can become partly impermeable due to depositions of gum-like substances, thus losing their conductivity which may cause death of the aged culms. The one or two tracheary elements of the protoxylem have mostly annular thickenings. They are **local** areas of stasis accumulating wall material, which are connected with each other by membranes in the early stages of development. During extension growth of the cell, they are disrupted.

The walls of metaxyiem vessels of bamboo are characterized by a middle lamella and a primary wall together with a well developed zonation of the secondary wall into Sl and S2. Whereas the Sl possesses a flat spiral arrangement of fibrils (90 – 95°) the S2 zone shows a slight deviation from the known fibril orientation in tracheids. The fibrils are arranged at an angle of 30 – 90° to the cell axis; also microlamellae are present with fibrils arranged in a fan-like fashion. This wall structure perhaps to be considered as "normal", is modified In some taxa like Oxytenatherd abysinica and Melocanna bambusoides to such an extent that a polylamellae construction results, resembling a parenchyma wall with the herringbone pattern of fibrillar arrangement whereby the number of layers are mostly restricted to two to four (Parameswaran and Liese. 1980). Warts have been observed in the metaxylem of vessels of *Oxytenanthera* nigrociliata, Melocanna bambusoides. Gigantochloa alter. f nigra. *Schizostachyum blumei.* and S brachycla dium. The pits of these vessels towards the surrounding parenchyma of adjacent vessel elements are slightly bordered. Their membrane consists of fibrils with a net-like texture, resembling hardwood pits,

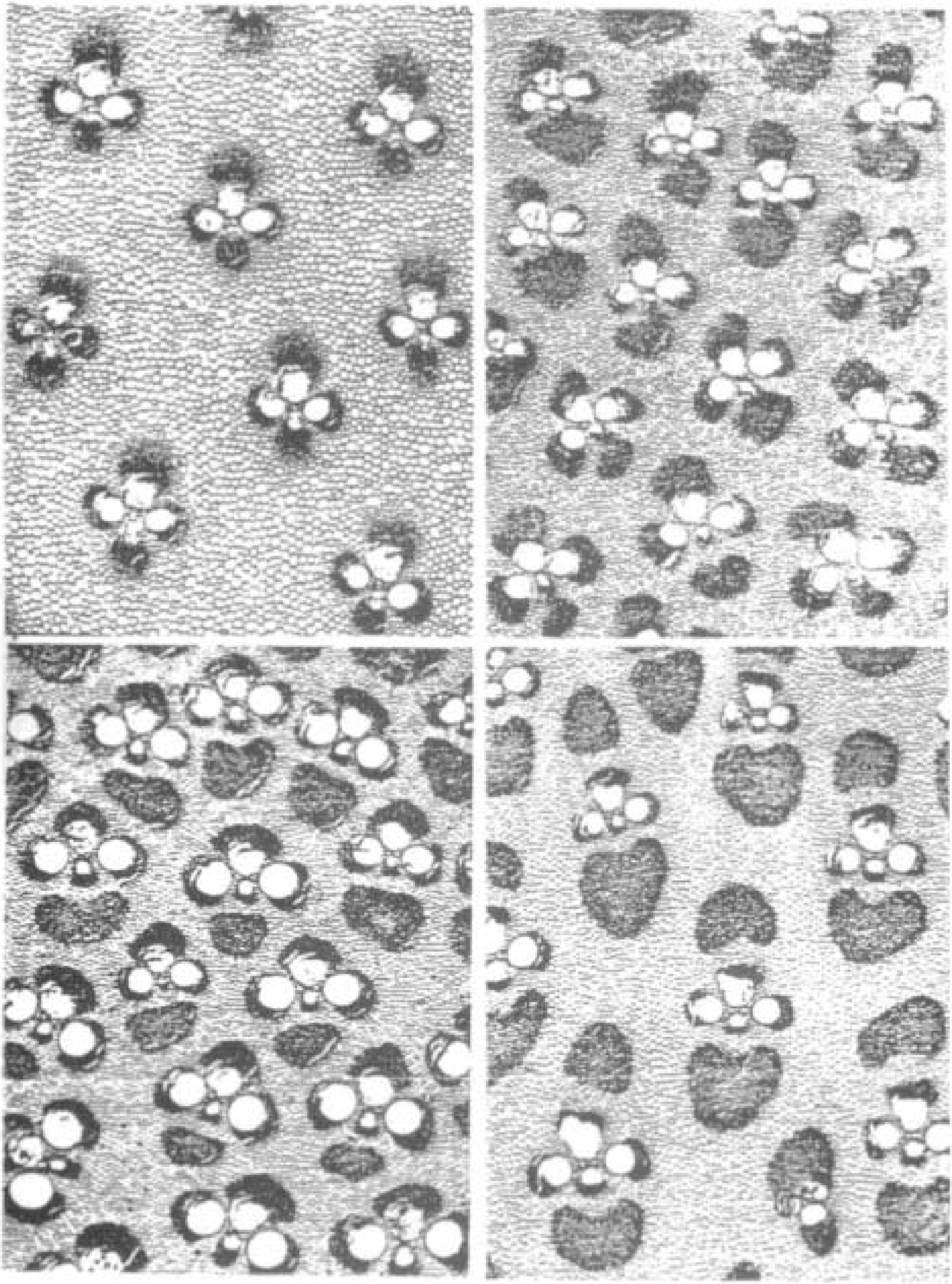

Figure 6. Different types of vascular bundles. I: Phyllostachys edulis. II Cephalostachyum pergracile. III Oxytonanthcra albociliata, IV: Thyrsostachys oliveri,

Of particular interest is also the presence of a protective layer in the parenchyma cells adjacent to metaxylem vessels; it consists of polysaccharides of the cellulose and hemicellulose type without lignification. This observation extends the presence of such a layer to monocots, besides dicots and softwoods.

Both the metaxylem vessels and the phloem tissue are surrounded by sclerenchyma sheaths. They differ considerably in size, shape and location according to their position in the culm and the bamboo species (Grosser and Liese, 1971; 1973; Wu and Wang, 1976; Jiang and Li, 1982).

Four to five major types of vascular bundles can be differentiated (cf. Fig. 6).

Type I : consisting ,of one central vascular strand; supporting tissue only as sclerenchyma sheaths;

Type II : consisting of one central vascular strand; supporting tissue only as sclerenchyma sheaths; sheath at the intercellular space (protoxylem) strikingly larger than the other three;

Type III : consisting-of two parts, the central vascular strand with sclerenchyma sheaths and one isolated fibre bundles;

Type IV : consisting of three parts, the central vascular strand with small sclerenchyma sheaths and two isolated fibre bundles outside and inside the central strand;

Type V : a semi-open type representing a further link in the evolution tendency _

The vascular bundle types and their distribution within the culm correlate with the taxonomic classification system of Holttum (1956) based on the ovary structure.

For example:

Type I alone : Arundinaria, *Phyllostachys, Fargeria, Sinanundinaria*

Type II alone : *Cephalostachyum, Pleioblastus*

Type II and III : Melocanna, *Schizostachyum*

Type III alone : *Oxytenanthera*

Type III and IV : *Bambusa, Dendrocalamus. Gigantochloa. Sinoclamus*

Leptomorph genera have only the vascular bundle type I, whereas pachymorph genera possess types II, III and IV. Size and shape of the vascular bundles vary across an internode but also with the height of a culm.

Fibres: The fibres constitute the sclerenchymatous tissue and occur in the internodes as caps of vascular bundles and in some species additionally as isolated strands. They contribute to 40 – 50% of the total culm tissue and 60 – 70% by weight. The fibres are long and tapered at their ends. The ratio of length to width varies between 150 : 1 and 250 : 1. The length shows considerable variation both between and within species.

Fibre measurements for 78 species were summarized by Liese and Grosser (1972). Generally, the fibers are much longer than those from hardwoods. Different values have been reported for one and the same species. The reason is mainly due to the considerable variation of fibre length within one culm. Across the culm wall the fibre length often increases from the periphery, reaches its maximum at about the middle and decreases towards the inner pan. However, few species show a general decrease from the outer part towards the center. The fibres in the inner part of the culm are always much shorter (20 – 40%).

An even greater variation of more than 100% exists longitudinally within one internode: the shortest fibres are always near to the nodes, the longest in the middle part (Fig. 7). With increasing height of the culm there

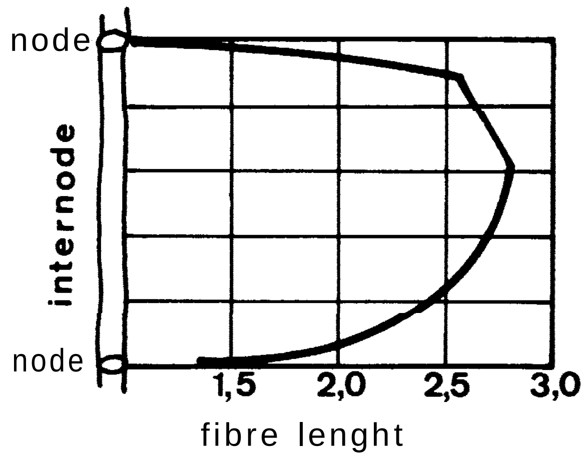

Figure 7. Variation of fibre length within *one, intemode.*

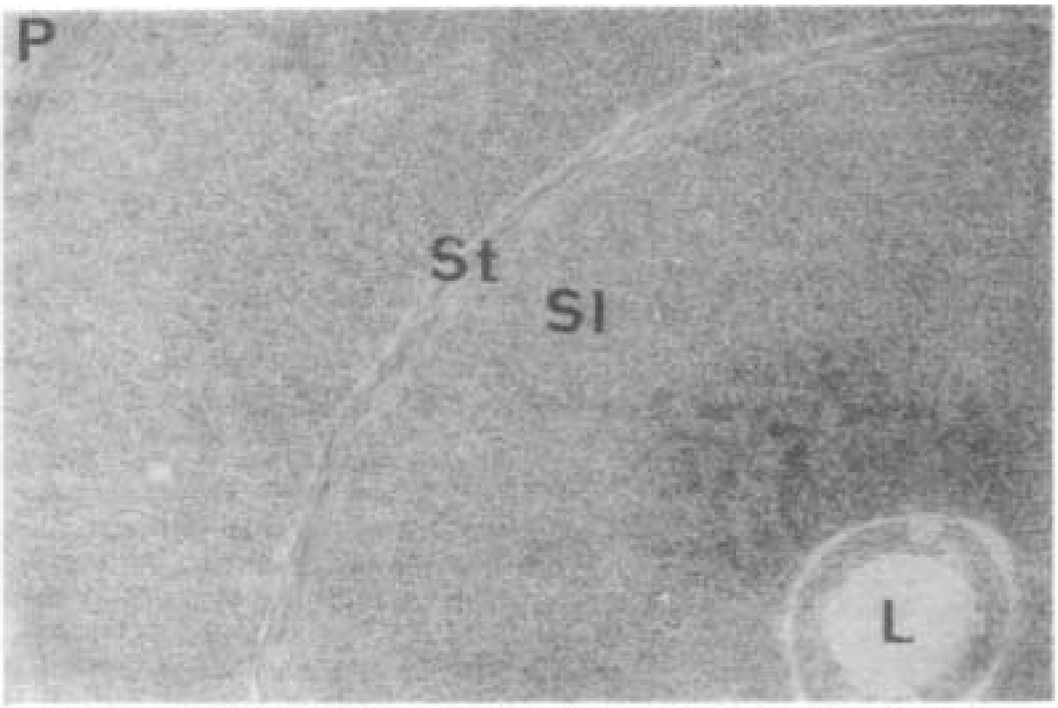

Figure 8. Crossection of delignified fibre wall with broad (s-1) and narrow (s-2) lamellae with different fibrillar orientation. P = Primary wall, L = Lumen, **Phyllostachys edulis**, *19 000 x.*

occurs only a slight reduction in fibre length. As the fibre length serves as an important criterion for pulping suitability, any measurement has to consider the distinct pattern of variation within the culm by taking representative samples.

The fibre length is positively and strongly correlated with fiber diameter, cell wall thickness and internode diameter, but not with lumen diameter and internode length. The fibre diameter varies between 11 and 19 urn, the lumen diameter between 2 – 4 um and the cell wall thickness between 4 -- 6 urn. The ultrastructure of most of the fibres is characterized by thick polylamellate secondary walls. This lamellation consists of alternating broad and narrow layers with differing fibrillar orientation (Fig. 8). In the broad lamellae the fibrils are oriented at a small angle to the fibre axis, whereas the narrow ones show mostly a transverse orientation 1 The narrow lamellae exhibit a higher lignin content than the broader ones. A typical tertiary wall is not present, but in some taxa (Oxytenanthera. *Bambusa, Ochlandra) w*arts cover the innermost layer (Parameswaran and Liese, 1976; 1981) The polylamellate wall structure of the fibres especially at the periphery of the culm leads to an extremely high tensile strength, as demonstrated in engineering constructions with bamboo culms. Fig. 9 demonstrates

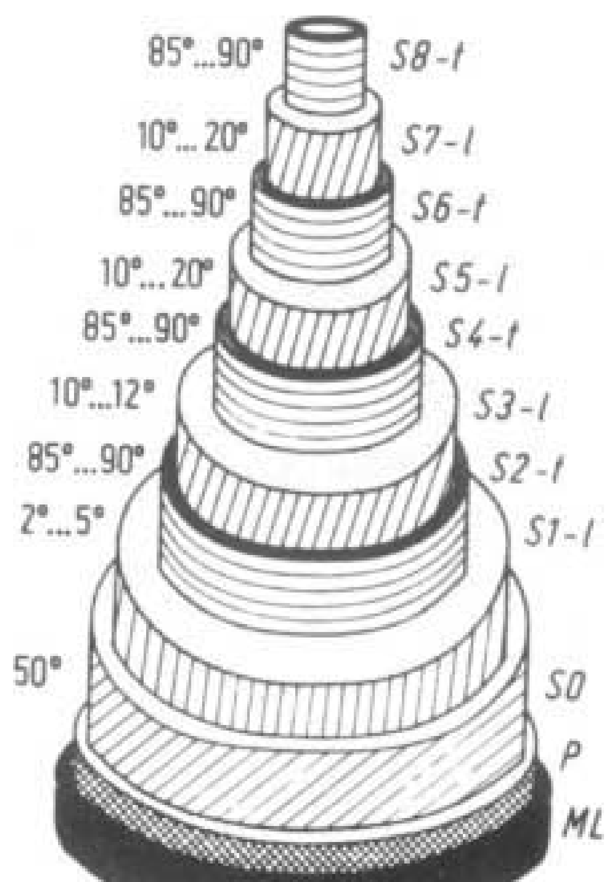

Figure 9. Model of thepolylamellate structure of a thick waled bamboo fibre

the finestructural make-up of a bamboo fibre. The polylamellate structure does not exist in the cell'walls of fibres or tracheids of normal wood.

In culms with curved internodes no reaction tissue comparable with the tension wood-fibres of hardwoods has been observed, Some of the fibres with secondary walls possess septa in their lumina as in the case of hardwoods. The obvious difference is the presence of secondary thickening of the otherwise normally formed septum with a middle lamella-like layer and a primary wall. In the polylamellate fibres it is surprising to find septa containing several secondary wall lamellae, which are continued into the longitudinal wall of the fibres. These septa are lignified, a phenomenon normally absent in hardwood fibres.

Phloem: The phloem consists of large thin-walled sieve tubes, among which smaller companion cells are distributed. The fine structural studies have revealed the presence of plastids in sieve tubes characterized by osmiophilic cuneate proteinaceous bodies and lattice-like crystalloids with parallel tubular units. The plastids in sieve elements are devoid of starch. This type of plastid (P IIb) is characteristic of the Poaceae. Thus Bambusaceae belonging to the Poaceae of the Order Poales constitute yet another group with a definite plastid type, implying its taxonomic significance, as has been suggested for other families.

The density of the cytoplasm is caused by the presence of numerous ribosomes. At the periphery there occurs a rough endoplasmic reticulum, which is extensively developed. Mitochondria with well defined cristae are also present. Distinct, P-protein-like filament have not been observed at any stage. Dictyosomes are few. Occasionally, microbodies-like structures have been noticed with filamentous contents. The peripherally located nucleus is elongated and lobed. With the aging of the sieve elements there originates a vacuole in the centre of the cell, restricting the cytoplasm to the periphery. The plastids still contain well-developed cuneate proteinaceous bodies in addition to paracrystalline structures as well as vesicular and tubular units. The sieve elements are connected with each other by sieve pores which are lined with small callose platelets.

The wall of the sieve element is characterized by microfibrils oriented parallel to each other in a concentric manner around the cell and perpendicular to cell axis, creating a strong birefringence in the polarizing microscope. The sieve element wall contains generally only cellin material without obvious signs of lignification even in mature stages. Due to the prolonged and continuous growth of bamboo culms over more than 30 years it is conceivable that the sieve elements and metaxylem, vessels remain active in their transport function over several decades. Distributed among the sieve elements are companion cells, which are characterized by dense cytoplasm and a large nucleus. Mitochondria are numerous and the endoplasmic reticulum is extensively ramified. Plastids are few, The companion cells are connected with the sieve elements by plasmodesmata, which are branched on the companion cell side with a weak callose development.

Chemical Properties

Chemical constitution: The main constituents of the bamboo culms are cellulose, hemicellulose and lignin; minor constituents consist of resins, tannins, waxes and inorganic salts. The composition varies according to species, the conditions of growth, the age of the bamboo and the part of the culm. Because the bamboo culm tissue matures within a year when the soft and fragile sprout becomes hard and strong, the proportion of lignin and carbohydrates is changed during this period. However, after the full maturation of the culm, the chemical composition tends to remain rather constant. Tables 1, 2 give approximate chemical analysis for some bamboo species. Small differences exist along a culm, as shown in Table 2. The nodes contain less water-soluble extractives, pentosans, ash, and lignin but more cellulose than the internodes. The season influences the amount of water-soluble materials, which are higher in the dry season than in the rainy season. The starch content reaches its maximum in the driest months before the rainy season and sprouting. The ash content (1 – 5%) is higher in the inner part than in the outer one. The silica content varies on an average from 0.5 to 4%. increasing from bottom to top. Most silica is deposited in the epidermis, the

Table 1. Chemical compoadtion of some bamboo0(Tamolang et al.1980)

Species	H&cellulose (%)	Pentosans (%)	Lignin (%)	Akoholbenzene (%)	Hot water (%)	1 % NaOH (%)	Ash (%)	Silica (%)
Gigantochlca levis	62.9	18.8	24.2	3.2	4.4	28.3	5.3	2.8
Gigantochloa aspera	61.3	19.6	25.5	5.4	3.8	22.3	41	2.4
Bambusa vulgaris	66.5	21.1	26.9	4.1	5.1	27.9	2.4	1.5
Range of values for 10 Indian bamboo species	- 21.5	15. 1 32.2	22.0- 3.2	0.2- 6.9	3.4- 21.8	15.0- 3.2	1.7- 2.1	0.44
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	22.2. 29.8	0 8- 3.8	0 l- 1.7

Table 2. Chemical coniposition of Phyllostachys pubescens at different heights (Li 1983)

	Holocellulose (%)	Pentosans (%)	Lignin (%)	Ash (%)	alcoholbenzene (%)	Hot water extracts (%)	1% NaOH (%)
upper culm	54.1	31.8	24.7	1.2	6.0	7.0	25.6
middle culm	53.6	30.8	24.5	1.2	7.6	8.5	27.6
lower culm	54.4	32.9	24.0	1.1	7.4	9.3	28.3

"skin zone", whereas the nodes contain little silica and the tissues of the internodes almost none. Silica content affects the pulping properties of bamboo.

Cellulose and hemicellulose: The cellulose in bamboo amounts – as holocellulose – to more than 50% of the chemical constituents. As in other plants it consists of linear chains of 1, 4 bonded hydroglucose units (C2H1206). The number of glucose units in one molecular chain is referred to as the degree of polymerization (DP). The DP for bamboo is considerably higher than for dicotyledoneous woods. Cellulose is difficult to isolate in pure form because it is closely associated with the hemicelluloses and the lignin.

More than 90% of the bamboo hemicelluloses consist of a xylan which seems to be a 1, 4-linked linear polymer forming a 4-0-methyl-D-glucuronic acid, L-arabinose, and D-xylose in a molar ratio of 1 .0 : 1.3 : 25 respectively. It is in the main chain linear, but appears to be different from the xylan found in the woods of gymnosperms with regard to the degree of branching and molecular properties. Furthermore, the bamboo xylan contains 6 – 7% of native acetyl groups, which is a feature shared by hardwoods. With regard to the presence of arabinose it is closer to softwoods. Thus, the bamboo xylan is intermediate between hardwood and softwood xylans. These results indicate that the bamboo xylan has the unique structure of Gramineae (Higuchi, 1980).

Lignin: After cellulose, lignin represents the second most abundant constituent in the bamboo and much interest has been focused on its chemical nature and structure. Bamboo lignin is a typical grass lignin, which is built up from the three phenyl-propane units p-coumaryl, coniferyl, and sinapyl alcohols interconnected through biosynthetic pathways.

Bamboo grows very rapidly and completes the height growth within a few months reaching the full size. The growing bamboo shows various lignification stages from the bottom to the top portions of the same culm (Itoh and Shimaji, 1981). The lignification within every internode proceeds downward from top to bottom, whereas transversely it proceeds from inside to outside. During the height growth lignification of epidermaf cells and fibres precede that of ground tissue parenchyma. Full lignification of bamboo culm is completed within one growing season, showing no further ageing effects. No difference has been detected in lignin composition between vascular bundles and parenchyma tissue (Higuchi et al., 1966). Bamboo has been chosen as one of the suitable plants to study the biosynthesis of lignin. lnitially, these investigations were almost exclusively based on feeding experiments with radioactive precursors and it has been known that lignin is synthesized' from glucose formed by photosynthesis via the "Shikimic acid pathway" (Higuchi, 1969). Several key enzymes involved in the synthesis of shikimic acid were isolated from bamboo shoots (Fengel and Shao, 1984; 1985).

Physical and Mechanical Properties

Moisture content: The moisture content varies within one culm and is influenced by its age, the season of felling and the species, In the green stage greater differences exist within one culm as well as in relation to age, season and species. Young, one-year old shoots have a high relative moisture content of about 120 – 130% both at bottom and top. The nodes, however, show lower values than the internodes. These differences can amount to 25% of the water content and are larger at the base than at the top. In culms of 3 – 4 years the base has a higher moisture content than the top, e.g. for *Dendrocalamus strictus* about 100% and 60% relative moisture content respectively. The moisture content across the culm wall is higher in the inner part than in the outer part.

The season has a great influence on the water content of the culm, with a minimum at the end of the dry period, followed by a maximum in the rainy season, During this period the stem can double its water content. The variation due to the season is higher than the differences between base and top as well as between species. Among species the water content varies even in the same locality. This is mainly due to the variation in the amount of parenchyma cells, which corresponds to water holding capacity (Liese and Grover, 1961). The considerable differences in the moisture content of freshly felled culms have to be considered when determining the yield of bamboo expressed by its fresh weight.

Fibre saturation point and shrinkage: The fibre saturation point is influenced by the composition of the tissue and the amount of hygroscopic extractives. Since fibres and parenchyma have apparently a different fibre saturation point, their varying amount within a culm leads to different values. The fibre saturation point consequently differs within one culm and between species. For *Dendrocalamus strictus* the mean value was determined to be about 20%, for *Phyllostachys pubescens* about 13% (Ota, 1955).

Unlike wood, bamboo begins to shrink right from the beginning of seasoning. The shrinkage affects both the thickness of the culm walls and the circumference. Seasoning of mature bamboo from green condition to about 20% moisture content leads to a shrinkage of 4 to 14% in the wall thickness and 3 to 12% in diameter. Bamboo tissue shrinks mainly in the radial direction, and the minimum deformation occurs in the axial direction. The tangential shrinkage is higher in the outer parts of the wall than in the inner parts. The shrinkage of the whole wall appears to be governed by the shrinkage of the outermost portion, which possesses also the highest specific gravity. Mature culms shrink less than immature ones.

Value of shrinkage from freshly felled to the oven-dry state were determined for *Phyllostachys pubescens* as follows: tangential: 8.2% for the outer part of the wall and 4.1% for the inner; radial: 6, 8% for the outer part and 7.2% for the inner; longitudinal: 0.17% for the outer part and 0.43% for the inner. Shrinkage starts simultaneously with the decrease of moisture content but does not continue regularly As water content diminishes from 70 to 40%, shrinkage stops; below this range it can again be initiated. Parenchyma tissue shrinks less in bamboo than in timber, while vascular fibres shrink as much as in timbers of the same specific gravity. When the moisture content is low, swelling due to absorption of water is almost equal to shrinkage. Moist heating leads to irreversible swelling in all directions. The percentage of swelling decreases with an increase of basic density (Kishen et al., 1958; Sekhar and Rawat, 1964).

Seasoning: The cut bamboo should first be dried for at least four weeks preferably standing upright. Lying horizontally almost doubles the drying time.

Air seasoning under cover is preferred, but seldom possible. Kiln seasoning under controlled conditions can be performed in about two to three weeks, but is considered to be uneconomical. The different seasoning behaviour of bamboo species is chiefly due to the different culm wall thickness which is the most important factor in controlling the rate of drying. The bottom part, therefore, takes much longer to season than the top portion. The rate of drying of immature cuims is generally faster than that of mature ones, but since the former have a higher moisture content they need longer. In the initial stages drying occurs quite rapidly, but slows down gradually as drying progresses.

Compared with timber of the same specific gravity, the drying period needed for air or kiln drying is longer due to the higher initial moisture content and the presence of water soluble extractives in the parenchyma cells. Their hygroscopicity in humid air is of about the same degree as invert sugar. The water absorption of dried bamboo therefore is quite rapid compared with that of timber. Bamboos, from which water-soluble extractives have been removed by soaking, dry faster and take up moisture slower than untreated ones.

Seasoning defects: Several defects can occur during seasoning. They may be due to the poor initial condition of the culm, due to excessive shrinkage during drying or both.

End splitting is not so common or severe as in timber. Surface cracking can occur during drying with all species. Cracks start at the nodes but their extent depends on the species and wall thickness. Thick-walled mature bamboo is especially liable to crack. A deformed surface of the round cross-section of immature bamboo is common. Thick-walled species evince an uneven outer surface, and cracks quite often develop on the inner side of the wall. Considerable shrinkage can take place in the middle part of the internodes, which become concave.

Collapse is a most serious seasoning defect. It occurs during artificial as well as natural drying processes and leads to cavities on the outer surface and to wide cracks on the inner part of the culm. Green bamboo is apt to collapse due to differential tension during drying. This shrinkage takes place in the early stages of seasoning. The outer fiber bundles are pressed together but the inner ones are stretched and this causes severe stresses. Immature bamboo is more liable to collapse than mature. Because of faster drying during the dry season, collapse occurs more often than during the rainy season. The lower portion with thicker walls is more liable to collapse than the upper portion. Slow drying bamboo species are apparently more liable to collapse than others.

To avoid seasoning defects, several methods of pretreatment have been tried. Soaking in water for two to six weeks did not improve the seasoning behaviour. Actually the devaluation due to checking, splitting and collapse was more severe in soaked pieces than in controls. Also water-soaked bamboo smells unpleasant, due to change of its organic constitutents. On the other hand, pieces which have been soaked are not liable to be attacked by powder post beetles during subsequent storage as the food material for the beetles leaches out during soaking.

Presteaming of green bamboo culms did not improve the seasoning as cracking and collapse still occur. Heat treatment over an open fire can be applied if the culms are half dry already, i.e. with not more than 50% moisture content.

Changes in colour can occur during seasoning. Fresh bamboo normally looks green or rather yellowish according to the stage of maturity, it changes during seasoning to a light green shade. Immature bamboos turn emerald green and mature ones pale yellow. Culms which are slowly air-dried develop a darker yellow colour than those which are dried rapidly in a kiln.

Specific gravity and mechanical properties: The specific gravity varies from about 0.5 to 0.8 (0.9) g/cm^3. The outer part of the culm has a far higher specific gravity than the inner part. The specific gravity increases along the culm from the bottom to the top. The mechanical properties are correlated with specific gravity. Bamboo possesses excellent mechanical properties. These depend mainly on the fiber content and therefore vary considerably within the culm and between species. At the base, for example, the bending strength of the outer part is 2 — 3 times that of the inner part. Such differences become smaller with increasing height of the culm. With the decreasing thickness of the culm wall there is an increase in specific gravity and mechanical strength of the inner parts which contain less parenchyma and more fibers, whereas these properties in the outer parts change only slightly. The variation of strength properties is much greater in the horizontal direction than in the vertical direction (Janssen, 1981),

A close correlation exists between specific gravity and maximum crushing strength. It seems that resistance to compression parallel to the grain is more or less uniform, hardly being affected by the height of the culm. For bending strength and modulus of elasticity, higher values were obtained from the upper part. Bamboo splints with the epidermis downwards have a higher fiber stress, bending strength and modulus of elasticity than those with the epidermis upwards. Splints without nodes have about one to two times the ultimate tensile strength of timbers such as spruce, pine, oak and beech.

The specific gravity of the nodes is generally higher .than that of the internodes due to less parenchyma, whereas bending strength, compression strength and shear strength are lower. This is due to the irregularity of the grain, caused by the arrangement of cells. The presence of nodes thus leads to a remarkable reduction in all strength properties.

Since there are still no standard methods of evaluating the strength properties of bamboo, as in the case of wood, the results are based on different methods of testing and on widely varying dimensions (Limaye, 1952; Sekhar and Bhartai, 1960).

The superior tensile strength of bamboo in relation to wood and steel is demonstrated by the following comparison: a steel bow of a certain quality (SA 37) of 1 cm^2 with 1 m length has a weight of 0.785 kg and a ultimate tensile force of ca. 40 kH; a stick from wood with the same length and weight would have a cross section of 13.5 cm^2 and a breaking point at 80 kN, but one from bamboo with 12 cm^2 would resist up to 240 kN; e.g. six times that of steel. The moisture content has a similar influence on the strength as it has in timber. Generally in the dry condition the strength is higher than in the green condition. This increase in strength with seasoning is more obvious for younger culms than for older ones. The differences between the air dry and green condition are sometimes relatively small, especially for bending and cleavage (cf. Table 3) (Ota, 1953).

Table 3. Mechanical properties of *Phyllostachys pubescens* in the water saturated, air dry and oven dry state (Suzuki 1950)

Property	Part		water saturated	air dry	oven dry
Bending strength N/mm^2	Outer		250	270	370
	inner		120	144	160
Cleavage strength N/mm^2	outer	6	7	8	
	inner	5	6	8	
	whole		6	7	8
Shear strength N/mm^2	whole		9	11	18
Janka-Hardness N/mm^2	outer	end	49	63	91
		side	22	25	37
	inner	end	27	32	66
		side	13	17	37

Influence Of Age

Age is an important factor for the development of strength properties. It is a general assumption that bamboos mature until about three years and have then reached their maximum strength. Investigations with Dendrocalamus strictus have shown that in the green condition older bamboo culms have higher strength properties than younger ones (the moisture content of the latter is much higher) In the dry condition, however, higher values were obtained at the age of one and two years than from older culms. Tests on splints from the central portion of the culm wall indicated better strength properties for one year old bamboo than for two years old ones, whereas those of culms of later years were slightly lower. Comprehensive tests by Zhou (1981) revealed a further increase of strength properties with age, viz for radial and tangential bending strength up to 8 years and for tensile strength and compression strength (parallel to the grain) up to 5 years. Older culms (10 years) showed a decrease in all strength properties.

Besides the above mentioned variations of properties within one culm, marked differences exist among individual culms from the same stand and even more among those from different localities. Needless to say. strength properties vary considerably between different species.

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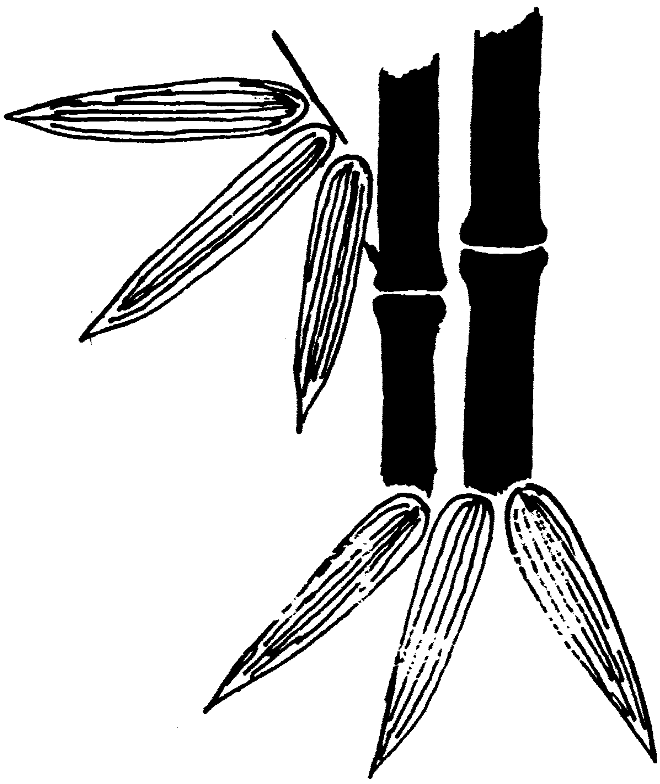

Anatomical Studies on Certain Bamboos Growing in Singapore

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Abstract

Bamboos are common useful plants in the Asian tropics mostly used by the rural people for food, housing and other utility purposes. Like other natural resources their production is decreasing and there is a renewed interest to promote their cultivation for economic benefits. The constraints are several including the basic information on plant growth, its structure and function. It is amazing to see so much paucity in our knowledge on bamboo anatomy. In this paper the anatomical details of the shoot apex, axillary buds, young and mature stems, culm and regular leaves and roots are presented. The need for further basic studies towards improving the plant growth and production is stressed.

Apart from individual scientific contributions, active teamwork is necessary to promote both research and manpower training in Asian countries. The latter is most important and urgent since there are very few in the field who are familiar with the taxonomy, growth and reproduction of bamboos. Multinational work programmes based on the model of certain on-going projects are suggested.

Introduction

The history of bamboos is inextricably interwoven with the history of man, especially in tropical countries. Most of the developing and poor countries are in the tropical zone and bamboo is a poor man's plant. The family Gramineae is one of the biggest among angiosperms with 450 genera and 4,500 species (Willis, 1951). Bamboos are classified into 21 genera and 170 species. In tropical Asia alone there are 14 genera and 120 species (Dransfield, 1980) Bamboos are the woody grasses that are comparatively less specialised than the herbaceous species in Gramineae. The taxonomy of Bambusoideae is based on spikelet structure (Gilliland, 1971) and among others, the limitations imposed by a) infrequent flowering of the various species, and b) lack of suitable fresh flowering materials for study are obvious. Hence, attempts are also made to use vegetative characters and here again the details are enumerated by very few observations on fresh materials and the emphasis is based on the morphology of culm leaves (Gilliland, 1971; Holttum, 1958). Although bamboos posses fairly conservative structures many variations are seen at subspecific or varietal levels. A detailed study especially in the field as well as on herbarium materials is necessary. For all practical purposes an illustrated simple guide to identify the useful bamboos would be of great practical value since biologists of various disciplines are interested in the propagation, genetic improvement and multiple use of bamboos.

The unique growth habit of bamboos and their fast growth rates provide an excellent opportunity to improve the biomass. This is very important to many of the poorer countries where forest resources are fast depleting and people are faced with many hardships caused by the lack of timber and fuel wood (Anon, 1980).

After the earlier work of Arber (1934), nothing much has been,done on the growth, structure, cytology and reproduction of bamboos. Nevertheless the general interest in bamboos continues among the biologists in general, and the foresters in particular. Their observations and reports are published from time to time (McClure, 1966). The first Symposium on Bamboos held in Singapore (sponsored by International Development Research Centre of Canada) and the publication of the proceedings therefrom is a significant contribution in this decade, updating the available information on bamboo research in Asia (Lessard and Chouinard, 1980). Most of the papers published are country or status reports emphasizing the need to increase bamboo production for economic gains. Some of the authors have clearly emphasized the urgent need for further basic research on bamboos that would help the conservation of genetic resources and the propagation of superior bamboos in great numbers employing both traditional and modern methods.

Due to a variety of reasons, the bamboos are difficult if not complex materials to work with and hence the paucity of knowledge on many basic aspects, including anatomy (Esau, 1965; 1977; Fahn,' 1967; Cutter, 1971). This paper is a brief report on certain anatomical characters of some wild and cultivated bamboo species present in Singapore.

Materials And Methods

Large mature clumps of bamboo species are growing wild in the nature reserves as well as the cultivated groups in Singapore Botanic Gardens. Certain species like Bambusa uerti-*cillate* and other grass bamboos are also cultivated in private gardens. About six genera and 23 species are locally present (Table 1). The following eight species are presently investigated: Bambusa pergracile, B. teres, B. tulda, B. vulgaris, Gigantochloa oerticillata, Schizostachyum brachycladum, S. jaculans and Thyrsostachys siamensis. The materials were collected, photographed and the required parts were fixed in FAA. ButyI alcohol series was used for dehydration. The embedding of tissues, microtoming and staining were carried out following the standard methods (Sass, 1951).

Table 1. Bamboos growing in Singapore Botanic Gardens with Acquisition Numbers.

1. Bambusa dolichoclada. W. 260B.
2. *B. glaucescens. W. 247.*
3. B. pergracile. W. 253.
4. B. teres' W. 252.
5. B. tulda' W. 233.
6. B. variegata. W. 271.
7. B. ventricosa. W. 232, W. 264A, W. 269, W. 275.
8. *B. vulgaris'* W. 243A, A. 260A, Y 95, Y 95A.
9. Dendrocalamus pendulus. W. 280.
10. Gigantochloa apus. W. 254, W 277A, W 302.
11. G. naname. W. 278.
12. G. verticillata' W. 256B.
13. Phyllostachys sp. W. 248, W. 249.
14. Schizostachys brachycladum' W. 231. W. 268, W. 277.
15. S. jaculans* W. 154, W. 243.
16. Thyrsostachys *siamensis'* W. 215, W. 222, W. 237, W. 262, W. 277.
17. Bambusa arundinacea.
18. B. heterostachya.
19. B. ridleyi.
20. B. oerticillata.
21. *Dendrocalamus strictus*
22. *Gigan* tochloa *levis*.
23. G. ridleyi.

• Used in the present study; easily accessible and ideally situated for growth studies. 17-23. less commonly found due to urbanisation.

Observations

Morphological considerations: Both taxonomic and general descriptions are available for the species mentioned in Table 1, and many of them are commercially important species (Gilliland, 1971; Holttum, 1958) Hence, these details are not repeated again. The healthy mature clumps of bamboos grown in Singapore Botanic-Gardens are easily accessible to study the growth characteristics. Due to the humid tropical climate the growth, in general, is non-seasonal and new shoots are produced all the year round. In some species the growth is more profuse in the post monsoon period of February-April. The fresh bamboo shoots are of varied sizes and shapes, all covered with compactly arranged culm sheaths (Figs. l-8). The culm sheaths vary in size and shape depending on the species examined (Figs. 'A-C). The elongation of the axis or the culm commences when the shoots are approximately 2-3 feet long, and the cone-shaped structure becomes axial with distinct nodes and internodes. The culm sheaths are placed distant apart due to internodal elongation and they fall off after 120-160 days after the internode elongation begins. How long the bamboo shoots would take, in terms of days or weeks, to emerge out of the soil surface and grow further into culms is yet to be determined. The bamboo clumps studied presently are more than 30-50 years old according to the records maintained in the Gardens. Although most of the bamboo species grow in clumps there are certain variations among them. Some of the clumps are very dense due to heavy accumulation of debris, soil and rhizomes. Size, colour, length of internodes and formation of aerial branches are all variable. The basal part of the clump in certain species like B. pergracile, B. vulgaris is very woody, dense and form thick rhizome plexus which appears as a raised platform of 2-4 feet above ground and the dense culms emerge out of the thicket. In other species the beginning of each culm can be seen separately. The size, colour and the thickness of the growing axes vary among these different species (Figs. A, B, l-4). Some of the axillary buds at the mature nodes grow to form the lateral branches at the base of which many roots are formed. The number of young shoots formed from each bud is variable. Unlike the culm sheaths, which are variable in shape and size, the lamina of the regular leaves are less distinctive at the species level. They are all dorsiventral structures and their sizes vary in different species (Figs. l-8). Both axillary as well as accessory structures are common and the latter are more profuse at the lower nodes developing into roots. Some of the axillary buds at higher nodes develop into lateral branches.

Shoot apices: The origin and development of shoots in woody monocots is unique in many respects. The apices in most of them are conical (Fig. D, l-6). The apex of B. vulgaris is comparatively broader than others (Fig. D, 3). The developing leaf primordia are arranged more or less at the same transverse level, protecting the shoot apex and contributing to the formation of abroad massive structure (Fig. D, 3). In all of them the developing leaves grow vertically and parallel to the axis and cover the apex. The photographs in Fig. D, 1-6 are the general view of the apices taken at lower magnification showing apex, developing leaves and their arrangement as well as the gradual distinction seen in the formation of nodes and internodes. The closer view of the shoot apices are shown in Fig. E, l-8. The tissue organization in them conforms to the generalized angiosperm pattern with regular tunica, corpus, peripheral and rib meristems (Fig. E, 1, 3, 5, 7). The tunica consists of two well defined cell layers and they are distinctly seen in all the species investigated (Fig. E, 2, 4, 6, 8). The corpus zone is about six to ten layers deep below the inner layer of the tunica with many darkly stained, isodiametric cells. The nuclei are large compared to cell size and contents. The tissue below the corpus is highly meristematic. Active growth of this region results in the formation of more tissue towards the establishment of the stem axis (Fig. E, 2, 4, 6, 8). The corpus zone extends into the rib meristem below and laterally into the peripheral meristem, the tissues of which are actively dividing and densely stained (Fig. E, 1, 3, 5, 7). Very many prominent vascular strands are also present. The rib meristem basal to the corpus differentiates into a very distinct intercalary merisrem with many meristematic cell layers. The derivatives of these layers are added on basipetally which enlarge and in sections the central part of the apex appears lighter in colour (Fig. E, 1, 3, 5, 7).

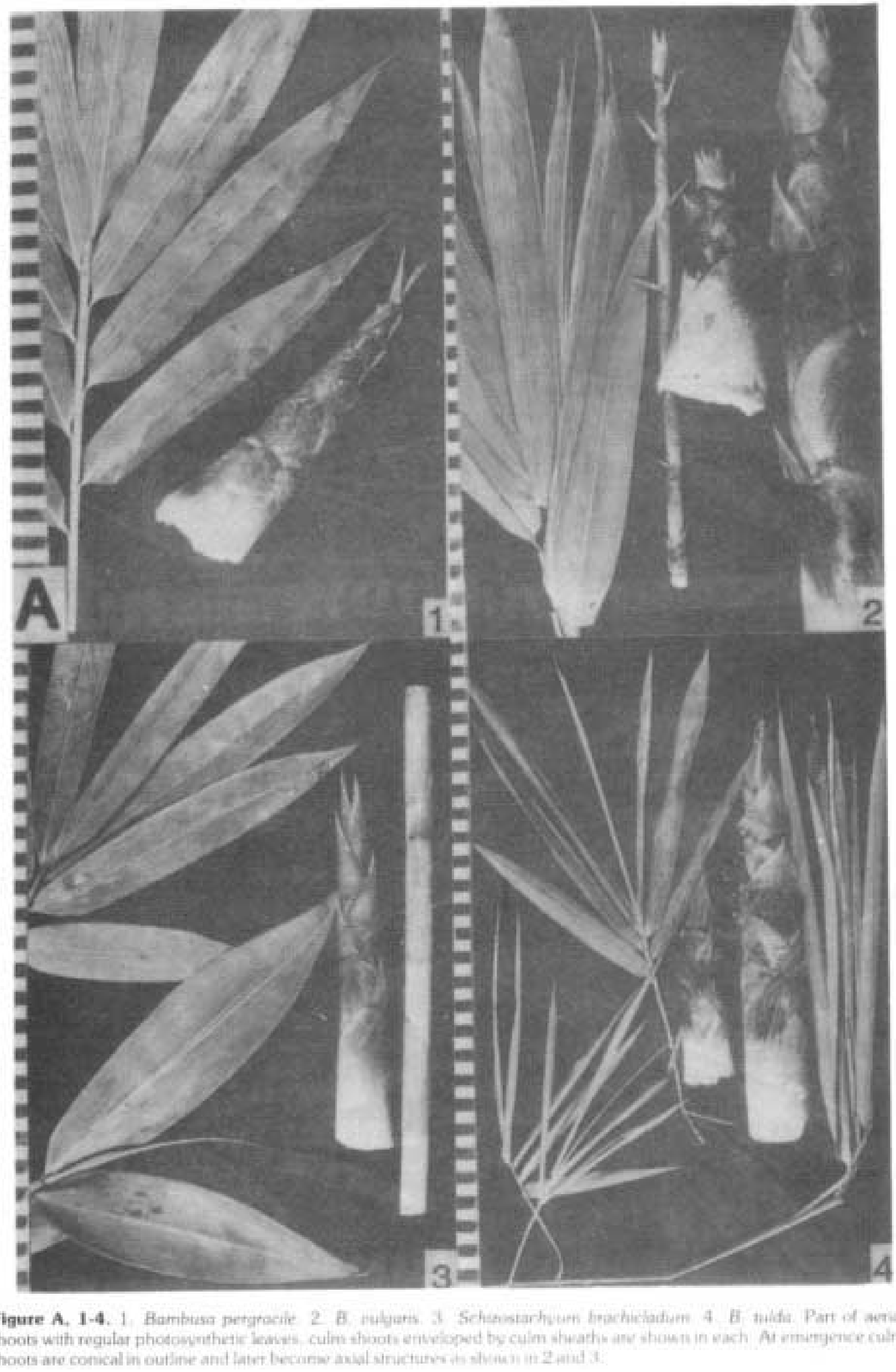


Figure A. 1-4. 1. *Bambusa pergracile.* 2. *B. vulgaris.* 3. *Schizostachyum brachicladum.* 4. *B. tulda.* Part of aerial shoots with regular photosynthetic leaves, culm shoots enveloped by culm sheaths are shown in each. At emergence culm shoots are conical in outline and later become axial structures as shown in 2 and 3.

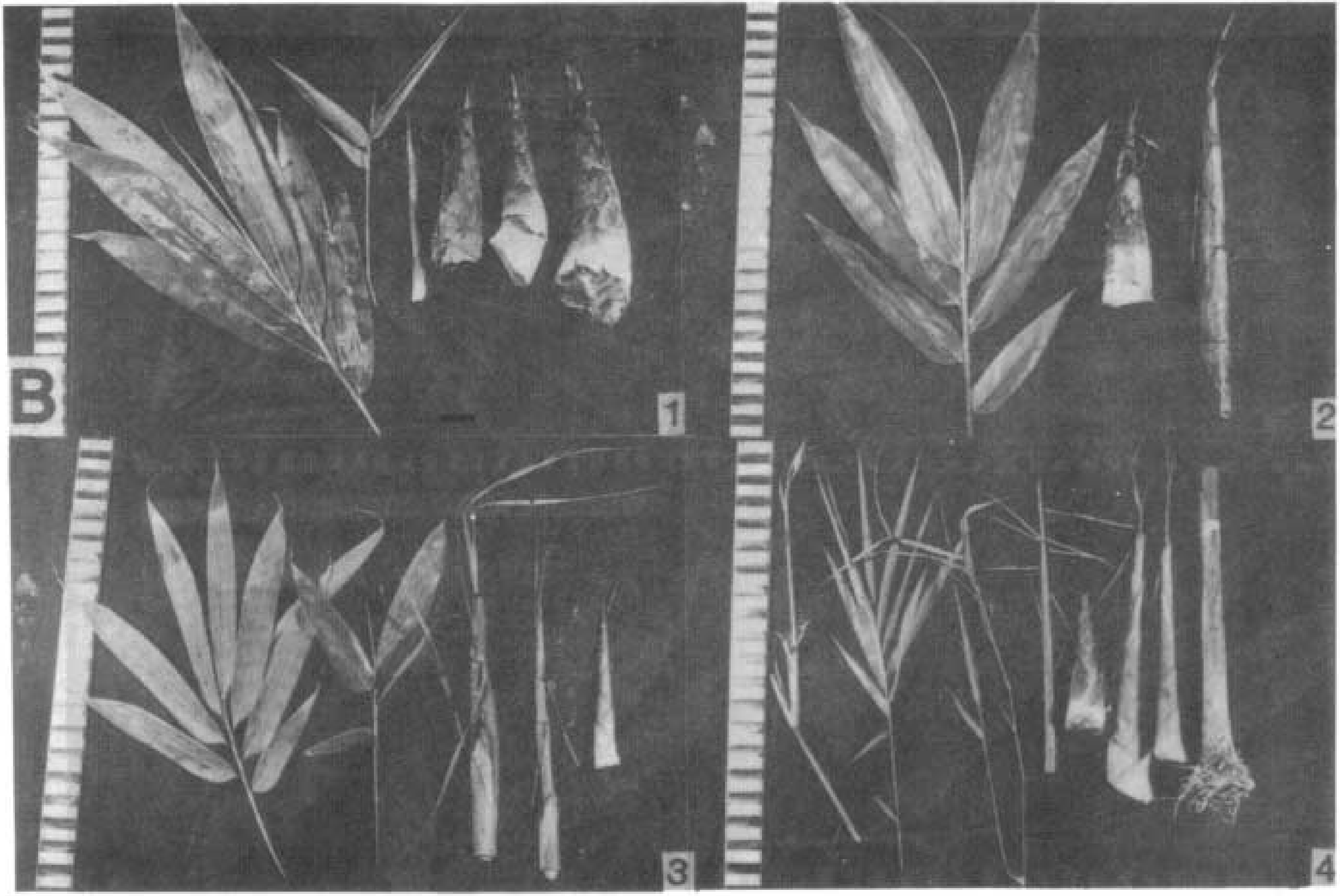
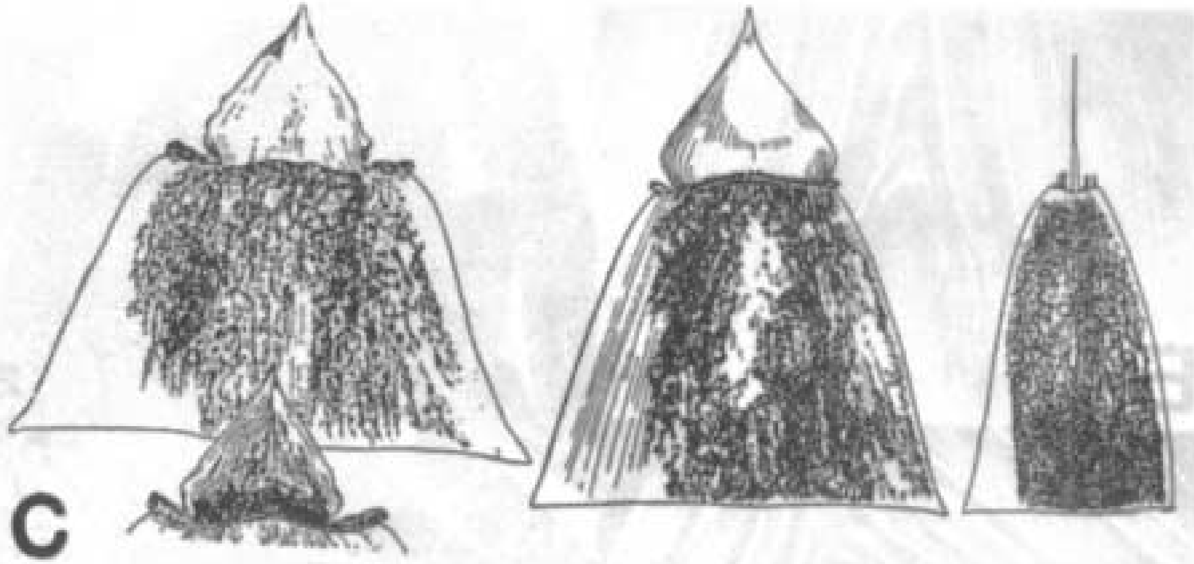


Figure B. 1-4. 1. *B. teres.* 2. *Gigantochloa verticillata.* 3. *Schizostachyum jaculans.* 4. *Thyrsostachys siamensis.* Descriptions are same as in Figure A.



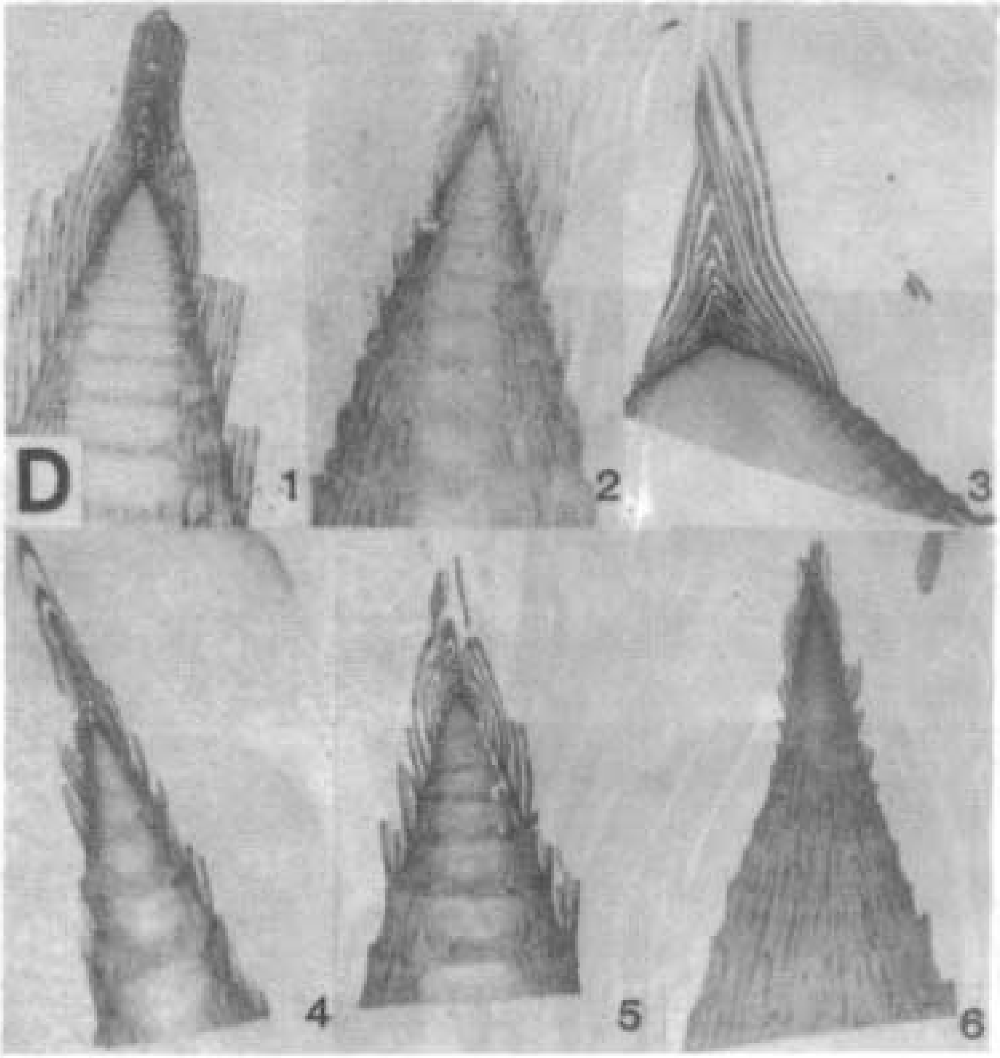


Figure C, 1-3. 1. *B. vulgaris.* 2. *Schizostachyum brachycladum.* 3. *S. jaculans.* Culm sheaths enlarged to show the broad base and upper triangular area. In 1, the tip of the next leaf is overlapping. In 3, the upper part is needle-like.

Figure D, 1-6. Enlarged view shoot apices as seen under dissecting microscope. 1. *B. pergracile.* 2. *B. teres.* 3. *B. vulgaris.* 4. *Gigantochloa verticillata.* 5. *Schizostachyum jaculans.* 6. *Thyrsostachys siamensis.* Note the broad apex in 3 and all the rest are typically conical. Nodal and internodal regions very distinct in 1, 2, 4, 5, slightly distinct in 3 and not very distinct in 6. Note the large number of procambial strands in 6.

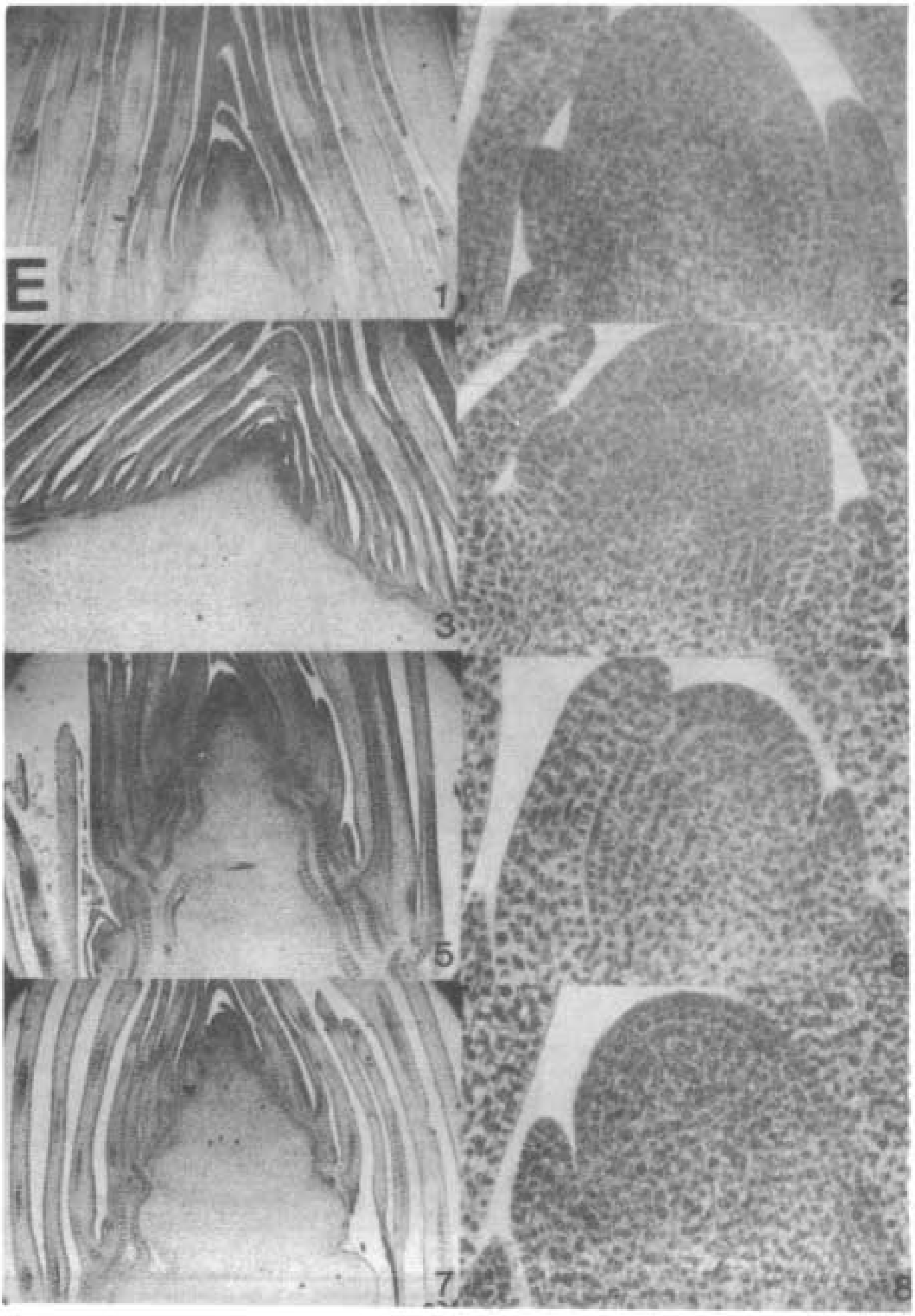


Figure E. 1-8. Photomicrographs of shoot apices. 1, 2. *B. teres*. 3, 4. *B. vulgaris*. 5, 6. *Gigantochloa verticillata*. 7, 8. *Schizostachyum jaculans*. The pictures on left show the whole apices with dome-shaped apex, several leaf primordia with or without axillary buds. The pictures on right are the enlargements of those on left showing two-layered tunica, corpus, rib meristem and the developing leaf primordia.

The leaf primordia develop at the flank of the shoot apex and most of them form the leaf sheaths (Fig. E, 1, 3, 5, 7). Many of them have a bigger or thicker base and the terminal part ends as an attenuated structure. Majority of the primordia have a knick or depression in the middle and others split in the middle or at the base (Fig. E, 1, 5, 7). The bamboo shoots are covered by a variety of sheath-like structures that encircle the stem. The various primordia develop into culm sheaths, sheath blades, ligules and other outgrowths on the iigules. Thus the apex as a whole is a centre of immense activity producing a large number of primordia that differentiate into many varied structures subsequently (Fig. E, 1,3,5,7).

From about the level of eighth to tenth node the demarcation between nodal and internodal regions becomes distinct. The nodal plates appear as dark cross bars separating the lightly colaured internodal regions (Figs. D, E). The intercalary meristem at two nodes are enlarged (Fig. G, 8, 9). In the former, the files of actively dividing cells are very clear and neatly arranged. In the latter, which is an older node the nodal plate has become thicker with vascular strands traversing in different directions. The intercaiary meristem is intact both below and above the nodal plates. The disintegration of cells making way for the hollow cavity is also in progress (Fig. G. 9).

Axillary buds: The bud primordia are distinct and they can be distinguished from the leaf primordia even during early stages of development. The latter develop as elongated, slender structures growing acropetally over-arching the main apex. in contrast the primordia of the axillary buds are asymmetrical in outline since the growth is more towards the leaf than on the stem side. Buds in different stages of development are shown in Fig. F, 1-6. Because of their sloping position the first prophyli formed towards the axis is shorter, somewhat triangular in outline and grows parallel to the stem axis and the second prophyll is longer, over-arches the apex and joins the triangular structure. Both of them cover the developing apex (Fig. F, 5, 6). The middle part of the bud enlarges and the subsequent leaf primordia originate as lateral structures. The apical region outgrows the primordia and develops into a broad dome shaped apex. The apex of the axillary bud also shows a two-layered tunica and a regular corpus region. The leaf primordia remain small and more than six to eight prophylis are present in certain buds. The first two prophylis formed would cover the bud for a long time and these are well vascularised (Fig. F, 6, 7). The subtending axial tissue below the bud undergoes a series of periclinal divisions and many curved layers of meristematic tissue are present organising the shell zone (Fig. F, 6). There is considerable variation in bud development among the different species studied. In B. teres and B. *vulgaris,* no bud initiation is seen even up to 10- 12 leaf stage. They seem to develop much later (Fig. F, 1, 2). In others, such as G. *verticillata,* *S. jaculans,* *T. siamensis* and B. teres the bud primordia develop much earlier (Fig. E, 1, 5, 7). More number of apices cut both transversely and longitudinally need to be examined to determine the early or late bud development and their relative positions to one another. This is very important to correlate the rate of shoot growth and the influence of bud dominance in branching.

Structure of bamboo shoots: The conical bamboo shoots were studied in detail (Figs. A, B, 1-4). The young axis is surrounded by a number of culm sheaths and when these are removed one by one the young stem is exposed. In B. pergracile, B. *vulgaris B. tulda* and B. teres the conical shoots are relatively massive when compared with other species (Figs. A, B, 1-4). The central cylindrical stem is relatively soft and easy to section. The various regions of the stem axis were studied a) from the periphery to the centre and b) from the tip to the base.

The cortical region shows a single layered epidermis and the surface is usually covered with many epidermal hairs (Fig. G, 1, 2, 4). About two to three subepidermal layers also consist of small cell layers followed by the ground tissue in which the numerous vascular bundles of different sizes showing varying stages of development are present (Fig. G, 2-5). In some, only groups of fiber cells are present with one, two or few vascular elements. Judged by the configuration and structure, it is clear that fiber cells develop early and there is no synchronisation in development either between the vascular and non-vascular elements or between the xylem and phloem tissues. Also the peripheral bundles of similar sizes show varied number or quantity of xylem and phloem tissues. In contrast, the

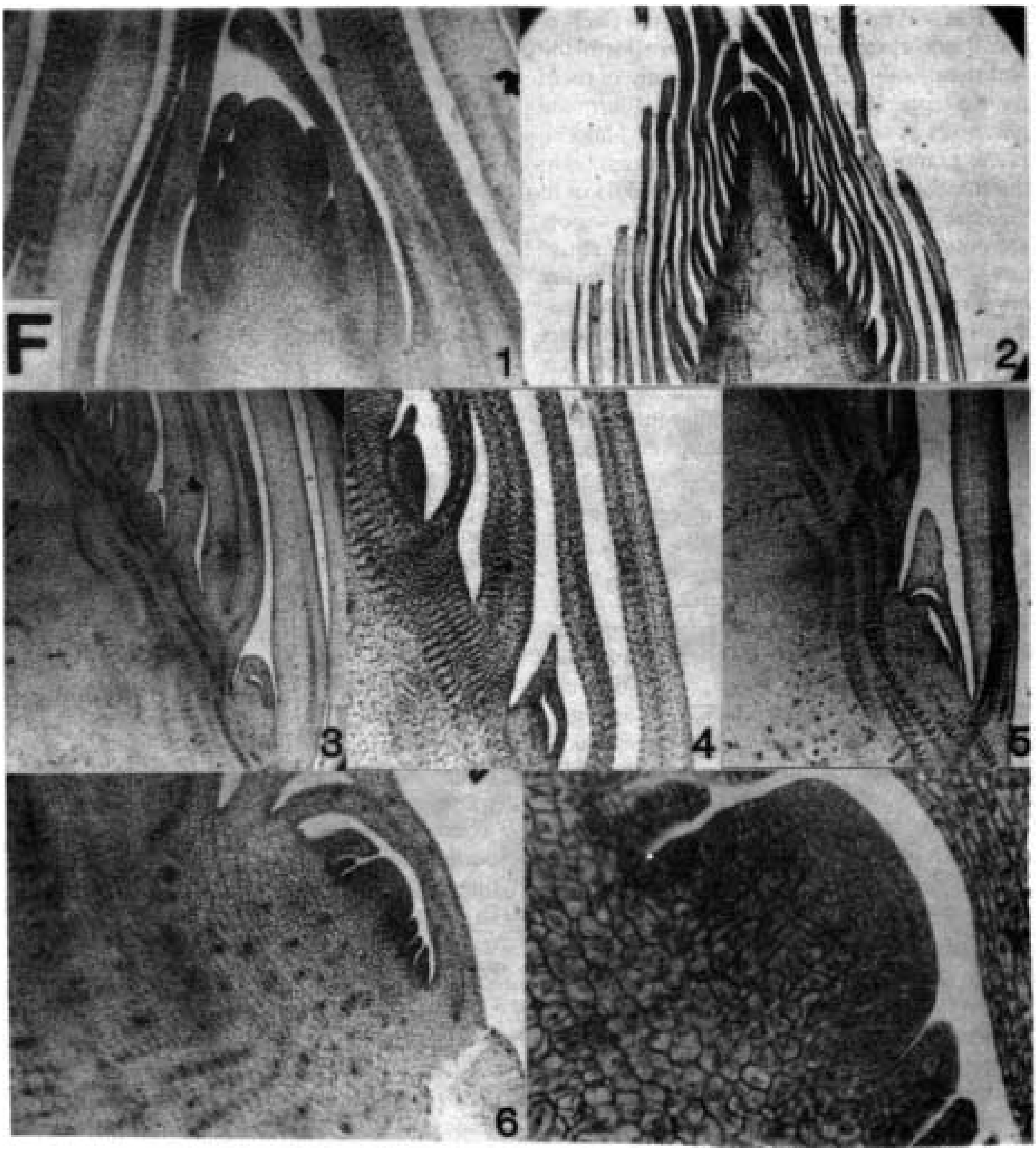


Figure F, 1-7. 1. **LS. shoot apex B, teres showing development of leaf primordia. 2. L.S. shoot spex Thyrsostachys siamensis. Note the elongated apex with many leaf primordia and a single axillary bud on right hand side of the axis. 3. 7. L.S. apex of B. teres showing the development of axillary buds. The early prophylls arch over the apex and central part of the bud enlarges. well protected. The central dome and prophylls are well developed as seen in 6 and 7. Two-layered tunica and corpus are very clear in 7.**

bundles in the centre are fairly uniform in size and contents (Fig. G, 6). Both proto and metaxylem as well as phloem can be easily distinguished. The sclerenchymatous caps seem to develop later. In general, it is clear that the vascular bundle development is centrifugal. In B. teres there are many radial vascular strands extending from the periphery to the cortex (Fig. 6). Since tissues for sectioning were taken at random from the different regions of the cone, no generalization can be made on the sequential development of vascular strands with regard to their relationship to the main apex or the nodes. It is possible to establish the relative degree of tissue maturity in the massive, conical bamboo

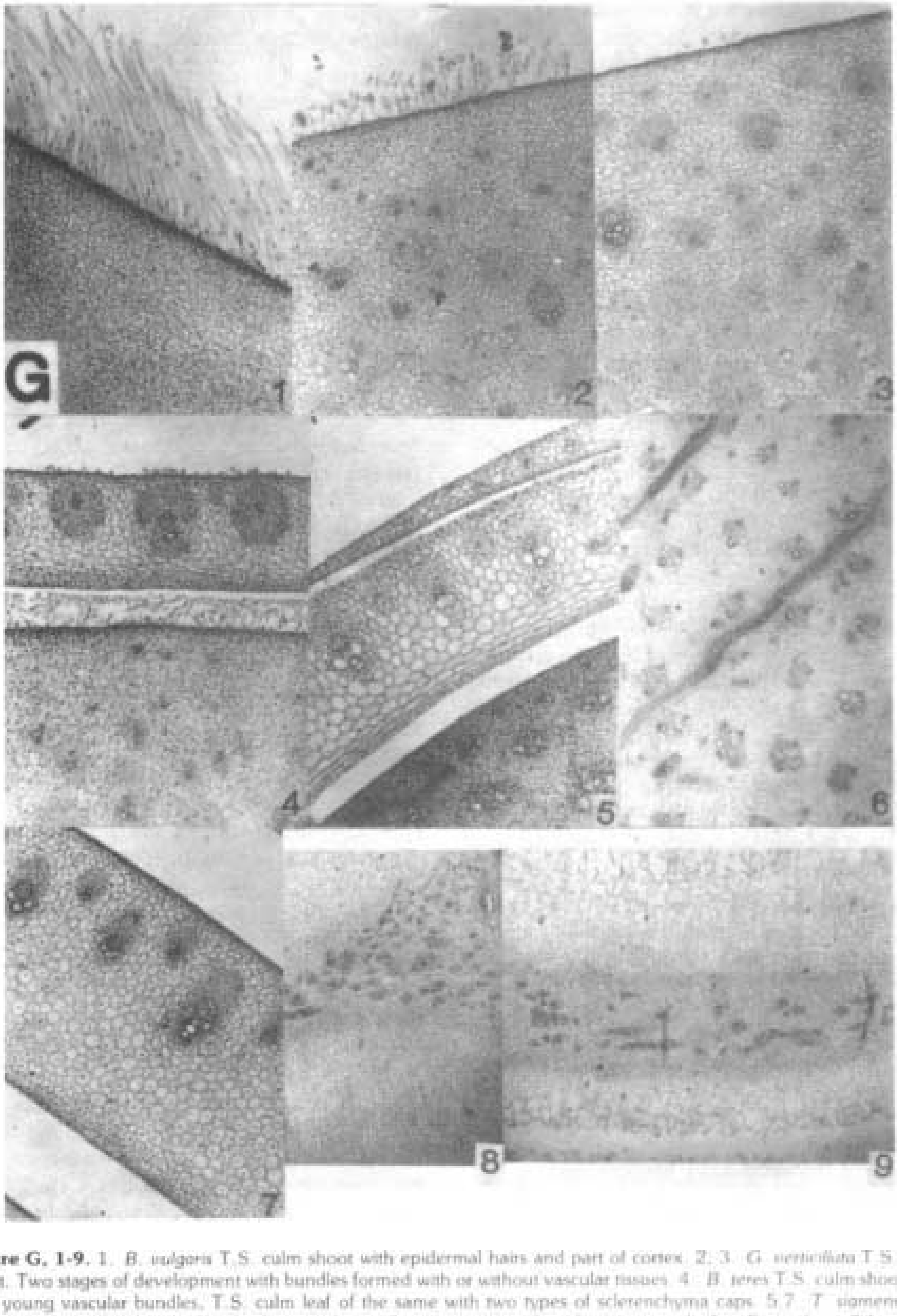


Figure G, 1-9. 1. *B. vulgaris* T.S. culm shoot with epidermal hairs and part of cortex. 2, 3. *G. verticillata* T.S. culm shoot. Two stages of development with bundles formed with or without vascular tissues. 4. *B. teres* T.S. culm shoot with very young vascular bundles, T.S. culm leaf of the same with two types of sclerenchyma caps. 5-7. *T. siamensis*. 5, 6. T.S. young culm shoot, peripheral part and central parts, respectively with many vascular bundles and parallel vascular strands extending radially. 7. T.S. culm leaf. Note the organisation of vascular bundles and mesophyll. Note the similarity in all of them with regard to undifferentiated mesophyll and vascular bundles towards the upper epidermis. The size and shape of sclerenchyma caps differ from one another. 8, 9. *S. jaculans*. Internodal portions enlarged to show the intercalary meristems. in 8 the meristem is intact and in 9, the cell layers above and below the nodal plate are degenerating making way for the pith cavity. The peripheral and central part of the nodal plates are enlarged respectively in these two figures.

shoots with reference to the enlargement of the axis and the nodal positions. Similarly, a correlation can also be established between the vascular bundles that are present in the outer and inner cortical regions.

Culm sheath: The bases of culm sheaths are cut along with the tender main axis (Fig. G, 4, 5, 7). The transections of these show distinct structural variations between their outer and inner surfaces. As in the stem the outer epidermis consists of a single layer of cells with or without epidermal outgrowths. One or two subepidermal layers differentiate into sclerenchyma. The rest of the mesophyll is undifferentiated and the cells increase in their size towards the inner epidermis. The vascular bundles are of different sizes and shapes either oval or round (Fig. G, 4, 5, 7) covered all round or partly by prominent sclerenchymatous bundle caps. In the early stages of development, the vascular bundles occupy almost or more than half of the cross sectional area of the sheath. With subsequent development of the mesophyll, more towards the inner epidermis, the vascular bundles are restricted more towards the outer epidermis (Fig. G, 5, 7). The inner epidermis is small, one-layered, distinctive with thickwalled cells. Facing the bigger bundles there is a group of smaller cells with characteristic thick walls resembling collenchyma. Many of the enlarged mesophyll cells in T. *siamensis* had two or more nuclei in them (Fig. G, 7).

Stem structure: The aerial stems of the different species studied show the monocot type of stem anatomy with a distinct epidermal layer, ground tissue and big vascular bundles (Figs. H, 2, 6, 8; I, 1, 3). In S. *jaculans* the epidermis is more prominent than in others- with enlarged cells, with three to four layers of smaller subepidermal cells that develop later into regular sclerenchyma (Fig. H, 8). in other species, the subepidermal scierenchyma is formed early (Figs. H. 2, 6; I, 3). The ground parenchyma is homogeneous in nature with cell size increasing centrifugally. Additional enlarged cell groups surrounding the vascular bundles are distinct in certain species like S. jaculans and *B. pergracile* (Fig. H, 1, 8, 9) These cell layers may develop into thick sclerenchyma at subsequent stages. The smaller bundles are arranged nearer the periphery and the larger bundles are towards the centre. The vascular bundles are collateral with sclerenchyma sheaths or caps present either in two or three groups.

In most of the cases, only young stems are used and obviously the distinct fiber strands or caps are yet to develop. The pith cavity formation is distinct in *B. vulgaris, S. jaculans* and T. siamensis (Figs. H, 6; I, 1, 2). The stem structure of B. teres is shown in detail with both the peripheral and central part of the axis with intact perenchyma (Fig. H, Z-5). Within the central part there are two distinct vascular bundles, slightly smaller in size than those present in the inner peripheral region. The arrangement of the vascular tissues in these two medullary bundles is similar to those in the peripheral region. The demarcation between the peripheral and central regions is also clear (Fig. H, 3). Another very interesting detail is that most of the enlarged pith cells have two or more nuclei in them (Fig: H, 4, 5). In B. *vulgaris* the innermost cell layers adjacent to pith are somewhat thick-walled and very distinct almost appearing as a border zone (Fig. H, 6).

Root structure: As seen in transverse sections, the young roots show a number of epidermal hairs, fairly straight and majority of them are uninucleate (Fig. 1, 5). Below the epidermis there are. three to four layers of sclerenchyma followed by a uniform region of parenchyma. The stelar structure is typically monocotyledonous with regular endodermis and distinct vascular groups of xylem and phloem. Many large air spaces are present both in cortex and the stelar regions which seem to be a common feature in many grasses. In the older roots the hairs are slightly thicker and many of them have small kinks and curved outlines. In a few cases even the branching of root hairs is seen (Fig. I, 6, 7).

Root hairs are simple epidermal outgrowths, commonly formed on young roots, showing very few or no abnormalities in their cell morphology. Very few cases are known where the root hairs are actually branched (Rao and Chin, 1972). Such details are discussed mostly in relation to certain dicots and this seems to be the first instance for monocots and especially the bamboos (Rao and Chin, 1972).

The structure of rhizome and root system is important since they are adaptable to a variety of soil conditions and prevent soil erosion. In many ways they are much more

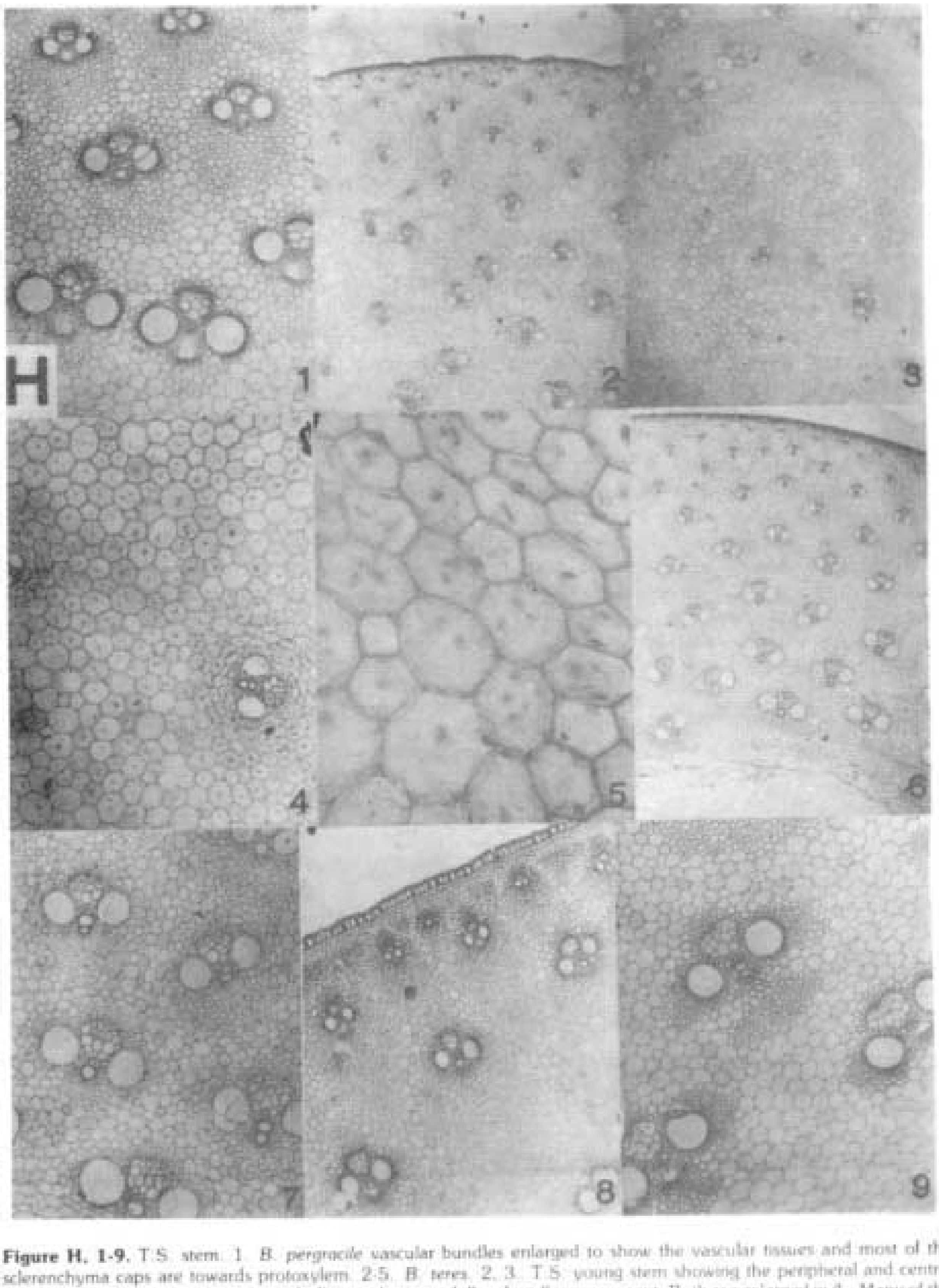


Figure H, 1-9. T.S. stem. 1. *B. pergracile* vascular bundles enlarged to show the vascular tissues and most of the sclerenchyma caps are towards protoxylem. 2-5. *B. teres*. 2, 3. T.S. young stem showing the peripheral and central parts. Note in 3 the central part is not hollow and two medullary bundles are present. Both are enlarged in 4. Many of the cells in the medullary part show two, three or more nuclei in them. 6, 7. *B. vulgaris* T.S. whole stem in 6 shows variations in size of the bundles from peripheral to central regions; note the increase in size of the bundles. Pith cavity in centre and adjacent to pith region there are three to four distinct cell layers. Bundles of the same enlarged. Vascular tissue well developed and sclerenchyma yet to be formed. 8, 9. *S. jaculans*. Part of stem showing epidermis and the adjacent regions with gradual increase in size of vascular bundles. Vascular bundles enlarged in 9, where the vascular tissues are clearly seen with three groups of sclerenchyma.

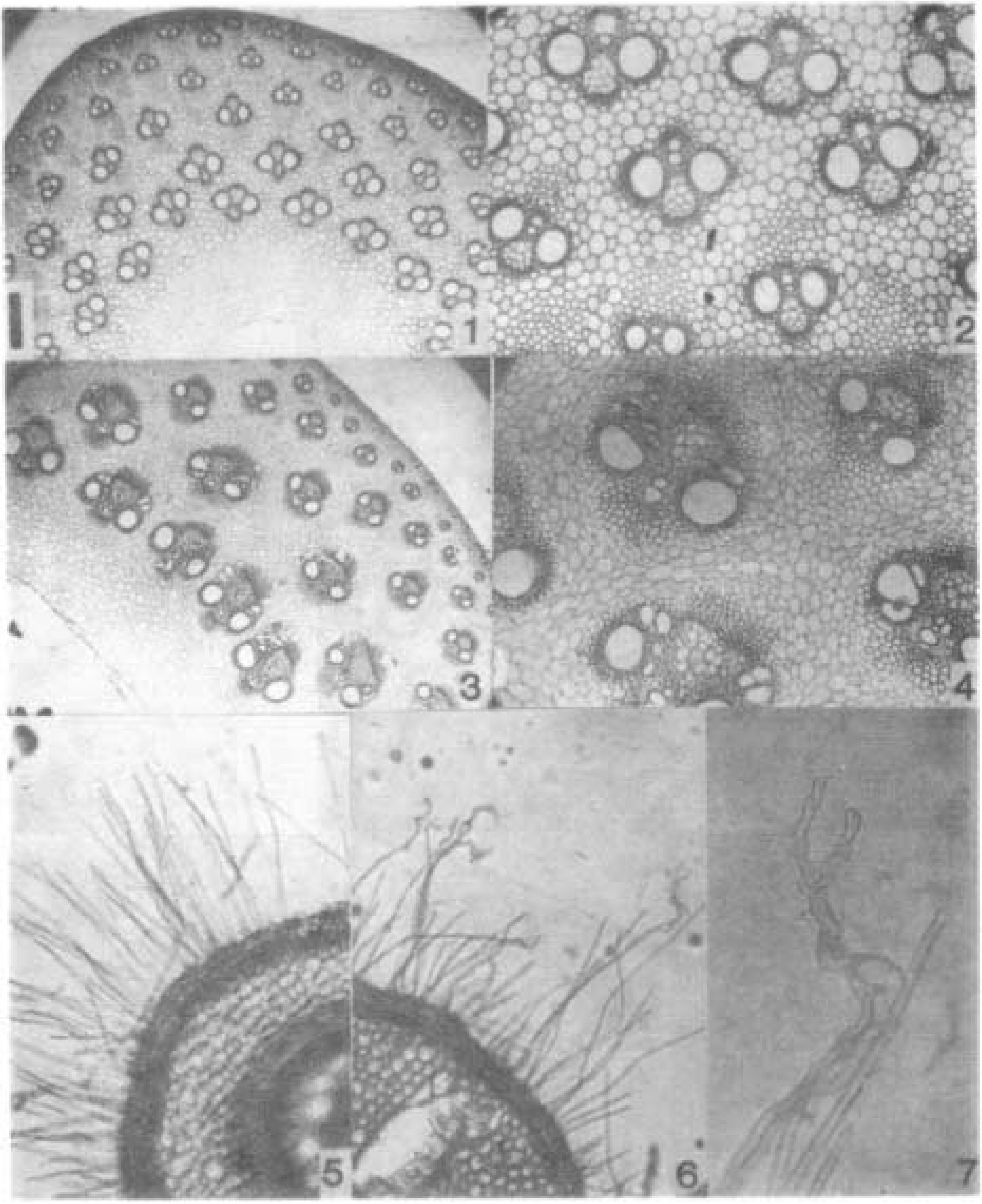


Figure I, 1-7. T.S. stems and roots. 1, 2. *B. tulda*. Bundles arranged in five or six rings. Sclerenchyma caps developed in some. 3, 4. *S. brachycladum*. Bundles in five rings. Sclerenchyma more well developed on phloem side than on xylem. 5, 6. *B. verticillata*. Root hairs on young and fairly old roots, straight on the former and somewhat crooked and twisted on the latter. 7. shows a branched root hair with many kinks.

efficient than the grasses which are the early colonisers of the cleared or open land.

Leaf structure: Leaves in the family Gramineae are specialised structures. Many of them are primarily the protective structures covering the growing parts of the rhizome, shoot apices and axillary buds. The rhizome sheaths are simple, triangular in outline with small pointed ends and near the apex the margin is sometimes serrated. The structure that covers the bamboo shoots and young stems are the culm sheaths which have smooth, adaxial and rough abaxial surfaces, the latter surface covered with many types of epidermal outgrowths including hairs (Fig. C, l-3). The culm sheath is also triangular in outline and the basal part is broad with a narrow terminal part (Fig. C, l-3). Distinct Iigule and auricles may be present at the point where the broad base slightly narrows down to form the triangular structure (Fig. G, 9-l 1). The third structure is the foliage leaf with the basal sheath or a petiole and a regular lamina.

The transections of the lamina in different species reveal an upper epidermis, two or three layers of mesophyll with or without a distinct palisade layer, fairly large air spaces, lower mesophyll and lower epidermis (Fig. J, 1-13). The upper epidermal layer is more distinctive than the lower with groups of bulliform cells which are bigger in certain species than in others (Fig. J, 4. 5, 8. 10. 12). The groups of bulliform cells alternate with air spaces. The cuticle is thick on both the layers and in many of them like B. *teres*, B. *tulda*, B. vulgaris and G. *verticillata* the cuticle on lower epidermis is papillate (Fig. J, 3, 5, 8). In S. *brachycladum* the palisade layer is much more prominent. The plicate or lobed condition is common in many of the outer mesophyll layers. At places where either air spaces or the bulliform cells are present the upper palisade is restricted to a single layer. The second layer is represented by a group of two or four cells that form a bridge interconnecting the upper mesophyll with the lower. The size and extent of air spaces are also variable (Fig. J. 1. 2. 4. 6, 7. 9, 11. 13). In B. tulda, G. verticillata and S. jaculans the prominent intercostal ridges are occasionally present and these form regular hump-like structures and each one of these consists well developed sclerenchymatbus tissue (Fig. J. 9. 11). Both the number and the size of bulliform cells increase between these groups of sclerenchymatous humps. The vascular bundles in the leaves show the regular monocotyledonous structure and a group of sclerenchymatous cells interconnect the vascular bundles with upper and lower epidermis (Fig. J, 3, 10, 12). Stomata are commonly present on the lower epidermis and in leaf transections the guard cells appear smaller than the epidermal cells and devoid of papillate outgrowths or thick cuticle (Fig. J, 3, 5, 12).

Discussion

The well known work on bamboos by McClure (1966) summarises the basic work done until 1960s. A critical survey of literature. however reveals the fact that by and large the basic botany of bamboos is yet to- be worked out and recorded in a proper manner. The literature available at present is fragmentary, scattered and inadequate and the reasons are not too difficult to understand. Like in other aspects of tropical plants. whether wild or cultivated, there is very little effort made to study them well by the local scientists. Lack of trained manpower is another problem. Only taxonomic studies are fairly complete and here again, there is no well illustrated simple guide, easy to use by the common man or others not familiar with technical terms.

More specifically, as it refers to the present study, it was very revealing to note that there is hardly any good paper describing the anatomy of bamboos. The list of references given by McClure (1966) and in the proceedings of the last workshop on bamboos in Asia would substantiate the above statement. Standard recent reference works on plant anatomy (Esau. 1977; Fahn. 1967; Cutter. 1971) or even some of the older works (Goebel. 1930; Eames and McDaniels. 1947; Eames. 1961) do not provide much information due to the lack of any anatomical research. The recent papers published by other Asian or German botanists are not easily available since they are in local journals. As stated before. bamboo anatomy is hard to work since most of the structures provide a good challenge to microtomy and the structures are relatively difficult to interpret. even though many other grasses including the various cereal crops are fairly well studied. Another reason for this inade-

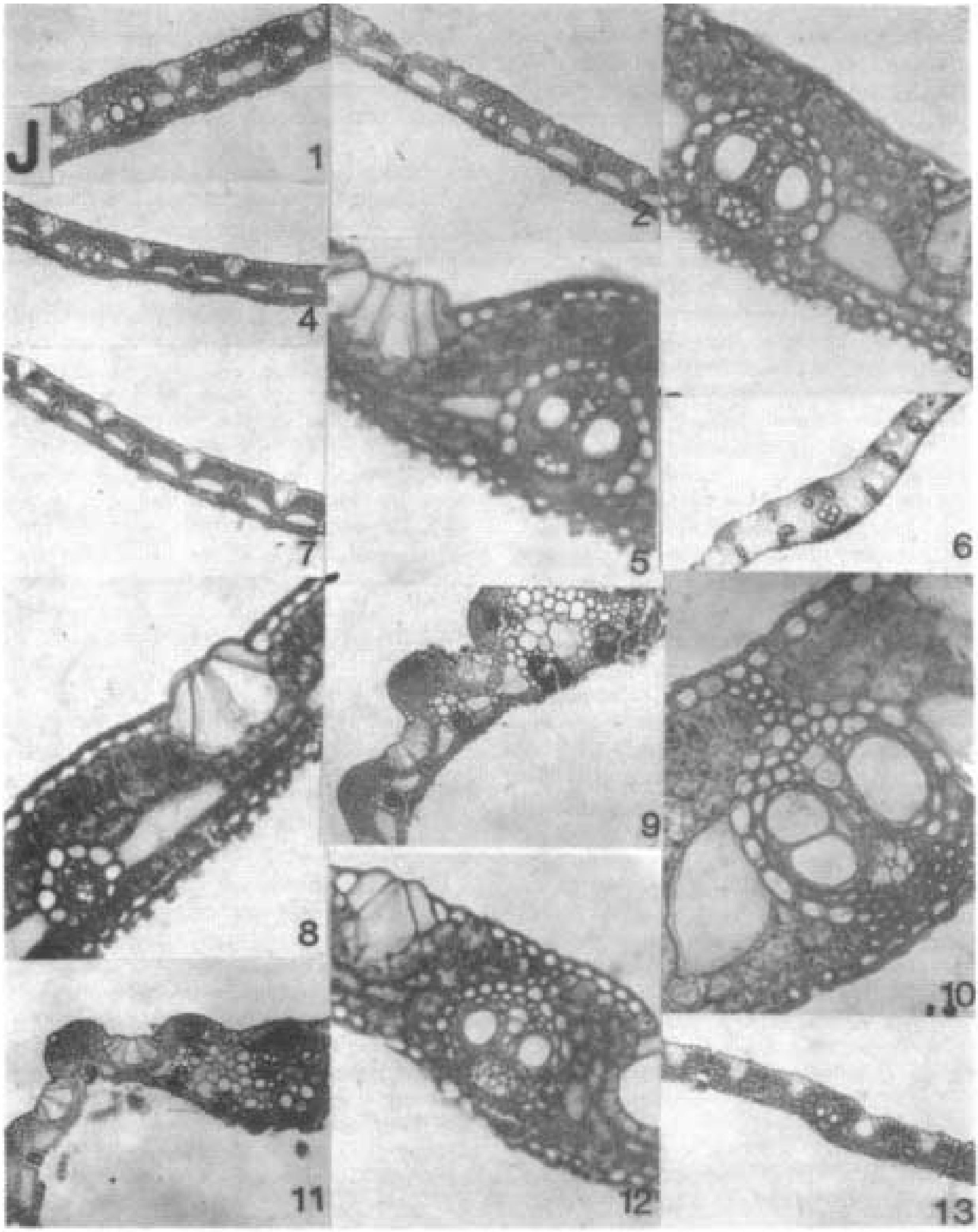


Figure J, X-13. Leaf transections as seen under low and high magnifications. 1. B pergracile. 2. 3 B teres 4, 5 B tulda 6, 10 S. brachycladum 7. 8, B vulgarls 9 G, uerticillata. 11 S. jaculans 12, 13. T siamensis the upper and lower epidermis are distinct in all with bulliform cells on the upper and stomata on the lower Sclerenchyma humps are formed in some as seen in 9 and 1 1 Bundles are connected with epidermis by sclerenchyma pegs quacy in our knowledge is the general assumption that all is well with bamboos and they grow well naturally or in plantation. Only recently when the natural supply is running short or inadequate to meet the needs of the increasing population there is a renewed interest in increasing bamboo production. For the same reason, two international workshops have been conducted within a period of five years.

Perhaps there are no other single group of plants that display so many variable vegetative characters as bamboos and our knowledge about the developmental aspects of these is very limited.

The general organisation of shoot apex conforms to the pattern well known in angiosperms and there is only one earlier study on *Sinocalamus (= Bambusa) beecheyana,* distributed in China (Hsu, 1944). This work is not quoted in other works or easily missed for reasons unknown. The axillary bud development takes place early in the second or third leaf axils which is different from the majority of the species studied presently.

The shoot apex in woody monocotyledons is very interesting as recorded in the case of palms (Ball, 1941; Tan and Rao, 1980). The primary thickening meristem characteristic of palms (Ball, 1941) is absent in bamboos. The prominent tissues of the flank region, commonly seen in palms is seen presently only in case of *Bambusa vulgaris.* The differentiation of many procambial strands and the prominent peripheral meristem are similarities noticed between palm and bamboo shoot apices. The plicate leaf condition seen in other monocots is absent in bamboos (Periasamy, 1980).

Some of the bamboo shoots are very massive structures and they are very richly vascularised as evidenced by the formation of vascular strands. A detailed anatomical study to show the differences between the hard mature culm and the soft tissues in the bamboo shoots would be interesting and so also the node and internode development between the young bamboo shoots emerging at the ground level and the aerial wood culms. The environmental conditions under which these two develop are totally different.

The morphogenesis of different kinds of axillary buds, single or multiple, or those that give rise to leptomorph or pachymorph rhizomes will not only be very interesting to understand the growth habits of bamboos but also would help to improve their propagation by vegetative cuttings,

The stem structure is relatively well studied and four types of vascular bundles are recognised which also lend support to the systematics of the group (Liese, 1980; Holttum, 1958). The materials studied at present came from young stems and the number of sclerenchymatous caps or groups could not be clearly determined for this reason.

The bamboo leaf structure is similar to those of other grasses with characteristic bulliform cells, presence of larger air spaces and big vascular bundles with characteristic bundle sheaths (Esau, 1977). Many of these details are also recorded presently. The structural variations noticed between regular leaves and culm sheaths are interesting especially the differences in mesophyll and the nature of vascular bundles. Whether these differences are present in all the bamboos is yet to be determined and different types of sheathing organs should be studied in detail. The morphogenesis of different types of leaves will be interesting both from the descriptive and experimental points of view. It closely resembles heterophyllous condition since the same axis from rhizome to fleshy shoots to strong aerial axes produce three different types of foliar structures. This is an interesting problem to work with.

As an outcome of the previous workshop meeting in Singapore several important research needs and priorities were identified and recommended. Very briefly these include the following: a) Studies on culm anatomy to determine or correlate the strength and structural properties. b) Detailed studies on bamboo fibres. c) Factors responsible for natural regeneration in bamboos. d) Identifying the easily recognisable vegetative characters. e) Propagation by tissue culture and shoot culture for mass production and germplasm exchange. f) To use the juvenile tissues on the culm for large scale propagation. following the experiences gained in sugarcane. g) To identify very easy methods for vegetative propagation so that the bamboo industry can be revolutionised. h) Increasing the quantity of propagules/hectare. i) More frequent use of bud material for in vitro studies and a few others. The papers presented in the second workshop have provided a few or some answers and indicators to solve some of the problems posed earlier.

With the number of papers presented in the form of valuable contributions towards improving the quality and quantity of bamboos in Asia and with different suggestions made, we are now in a better position to plan further activities to achieve the objectives laid down. Foremost is the need to improve the basic work on bamboos and here we have to use the existing expertise in different countries so that no time or money is unnecessarily wasted by repeating the same research in four or five countries simultaneously, unless the nature of the problem is such that it needs attention by different people in several laboratories. Several models are already available like Asian Mangrove project supported by UNDP and others. Under this project both training and research programmes are included with the main objectives of improving the trained manpower for specific researches. Wherever possible, the skills of the staff already working need to be improved. New staff should be technically trained to work on bamboos. Improvement of bamboos in Asia can be launched as an international project and the different activities can be coordinated by one or two persons. Any money, manpower and efforts spent in this direction will pay rich dividends in the near future.

For many of the big world organisations such a project may be a very insignificant one and they may not have the necessary manpower which means establishing a new section to manage the project. By launching a new medium-sized project for three or four years many of such cumbersome procedures can be avoided which would also bring the desired results within a shorter period of time. Hopefully the benefits derived can be shared by all and many of the needs of poor rural people can be easily met.

Acknowledgements

I am grateful to Dr C B Sastry , IDRC, Singapore for inviting me to participate in the workshop meeting; to my colleagues Mr Johnny Wee, Mr Ong Tang Kwee and Mdm Chan Siew Khim for their technical help and the National University of Singapore for the award of research grant FSOF 3/80 under which this work has been carried out.

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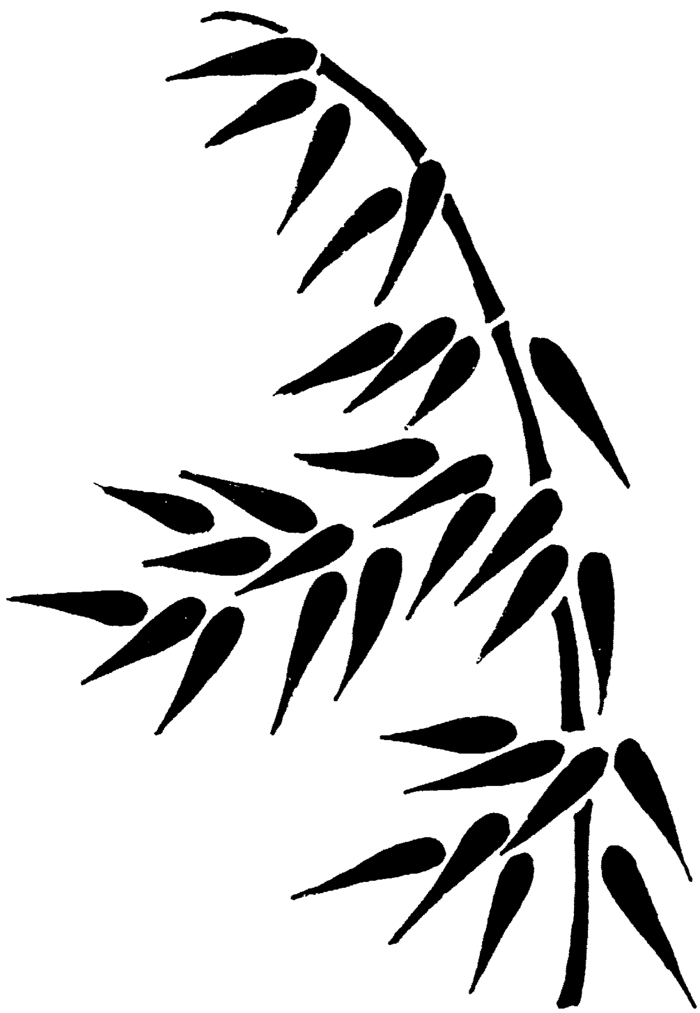

Observations on Vascular Bundles of Bamboos Native to China

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Abstract

The arrangement of vascular *bundles, presence or absence of cortical air spaces, the extent* of parenchyma between *the* bundles *are used as the important criteria in the* present study of bamboo *types.* About 45 species of 10 genera are classified under four major types.

Using vascular bundle arrangement as the criterion in leptomorph rhizomes* of bamboos, ten genera and 45 species of bamboos native to China can be classified into the following four major types:

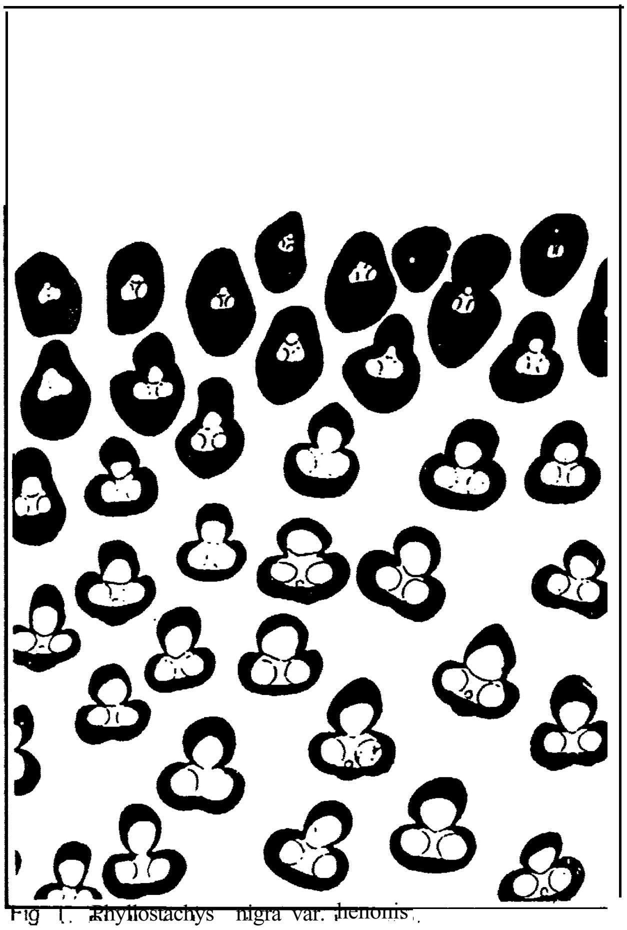


Fig. 1. Phyllostachys nigra var. henonis.

Type I Vascular bundles are separated by parenchyma.

(A) No air canals in cortex (Fig. 1). Bamboos of this type are the following:- *Phyllostachys arcana, Ph. aurea, Ph. aureosulcata, Ph. bambusoides, Ph. bambusoides var. tanakae, Ph. bambusoides var. castilloni, Ph. bambusoides var. castilloni-inverssa, Ph. besseti, Ph. decora, Ph. dulcis, Ph. flexsuosa, Ph. glauca, Ph. glauca f. yunzu, Ph. meyeri, Ph. nigra, Ph. nigra var. henonis, Ph. nuda, Ph. nuda f. localis, Ph. viridis, Ph. platyglossa, Ph. praecox, Ph. prapinqua* and *Ph. pubescens.*

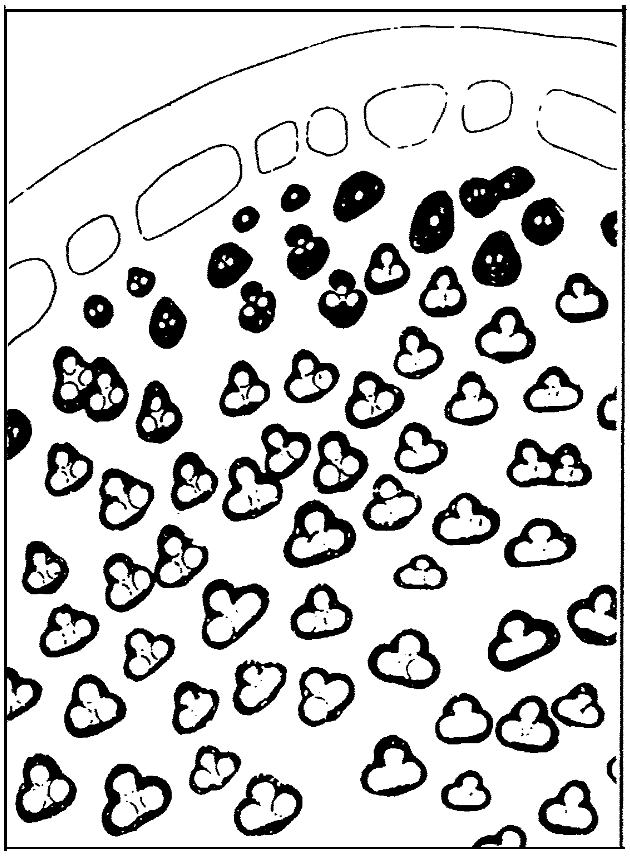


Fig. 2. Phyllostachys robvstiramea.

* Leptomorph rhizomes are the same as monoaxial and amphiaxial rhizomes. In China the bamboo rhizomes are divided into three kinds, moaoxial, amphiaxial and sympodial rhizomes

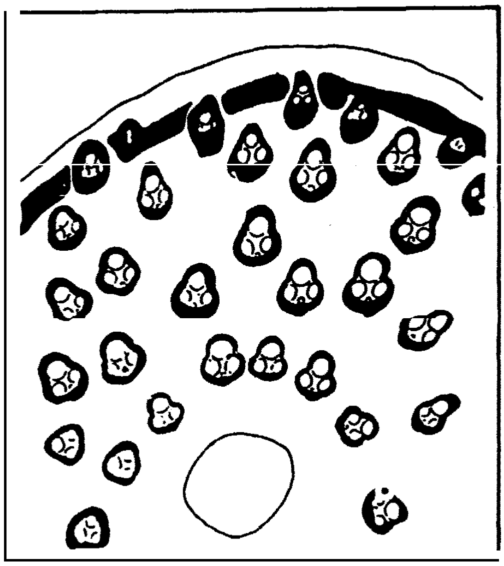


Fig. 3. Indocalamus victorialis,

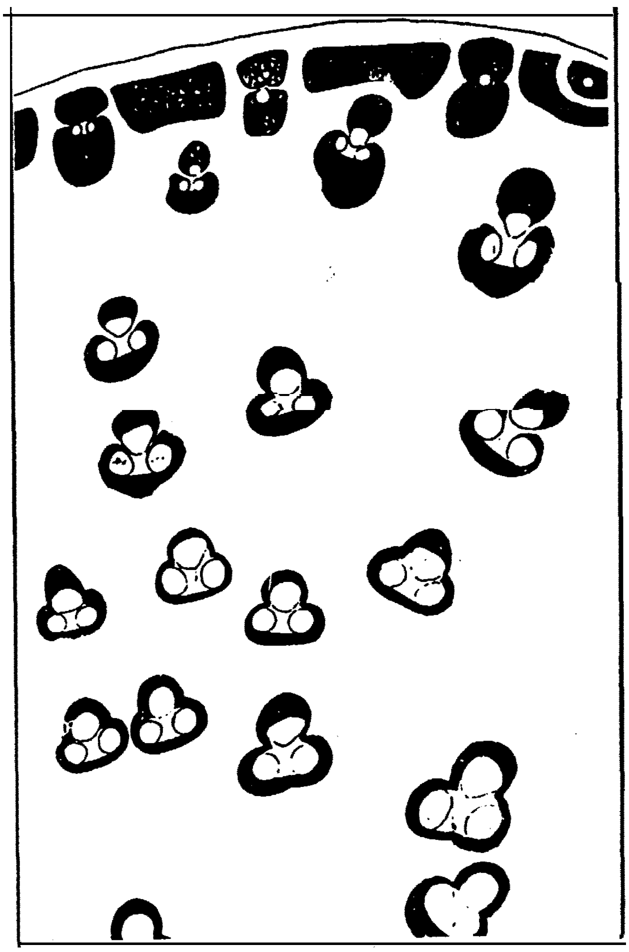


Fig. 4. Pleioblastus amarus.

Type II Vascular bundles are isolated. Between them, there are fibres — cell groups in rectangular, round, or variant forms, and they are never linked. These are mostly peripheral in position. No air canals in cortex (Figs. 3 and 4). Bamboos characteristic of this type are as follows: Indocalamus *longiauritus,* I, victorialis, *Pleioblastus* amarus, PI. gramineus, *PI. sp., PI. sp., Psudosasa* amabilis and *Sinobambusa tootsik.*

Type III Vascular bundles are linked, occasionally with very narrow gaps of parenchyma interrupting Air canals in cortex (Fig. 5). This type includes: *Phyllostachys heteroclada* and Ph. nidularia.

Type IV Vascular bundles are connected in the form of a ring enclosing stele.

(A) No air canals in cortex (Fig. 6). Bamboos of this type are as follows: *Arundinaria* fargesii, Chimonobambusa utilis, Ch. quadrangular&, Ch. *purpurea, Qionzbuea lumidinoda, Sasa unbigena* and Sinarundinaria *fangiana.*

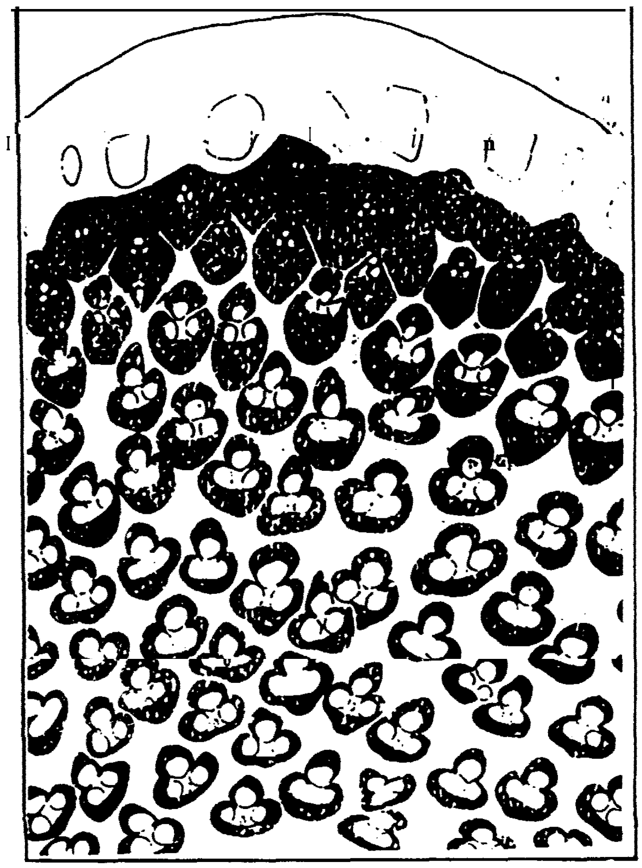


Fig. 5. Phyllostachys heteroclada.

(B) Air canals are present in cortex (Fig. 2). Bamboos of this type are listed as follows: PhyllostAchys robustiramea.

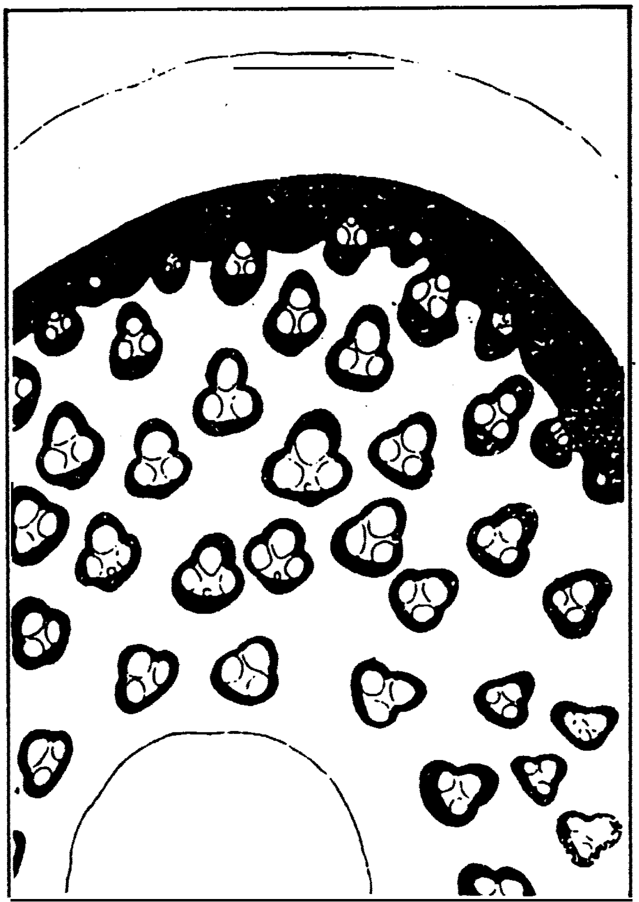


Fig. 6. Chimonobambusa utilis.

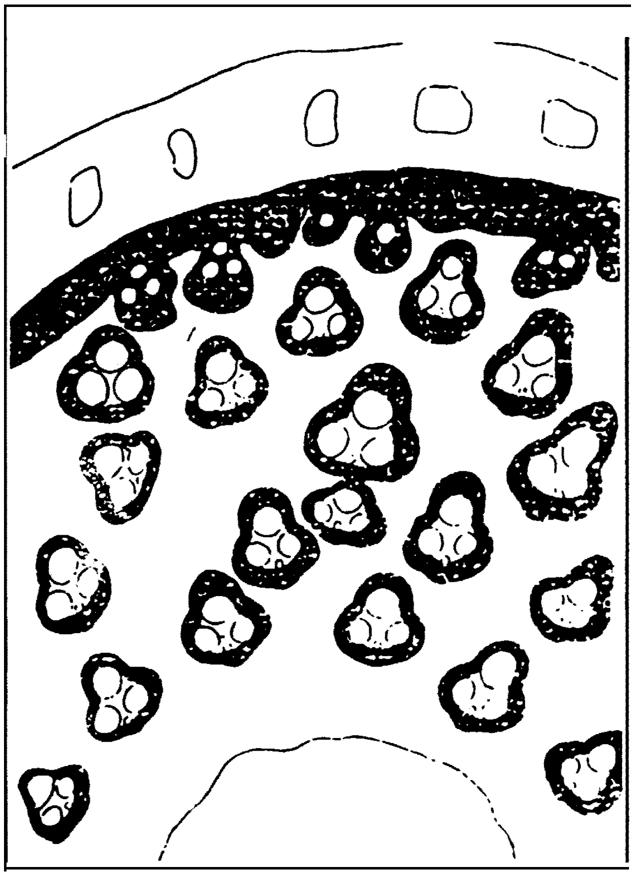
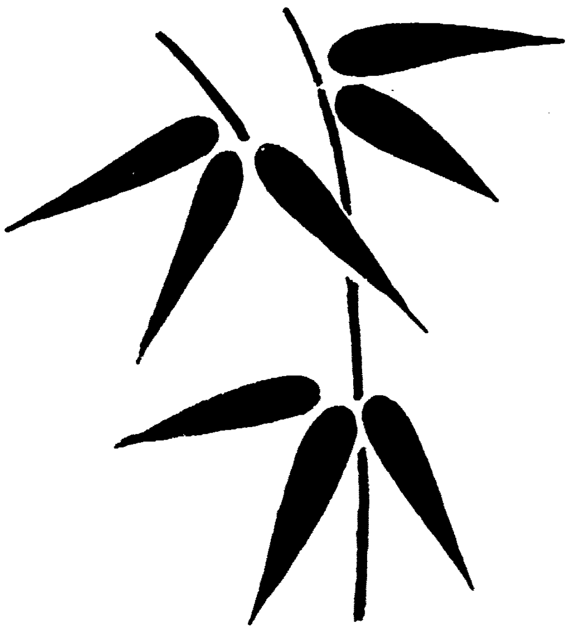


Fig. 7. Chimonobambusa szechuanensis.

(B) Air canals in cortex (Fig. 7). Bamboos of this type are: *Chimonobambusa szechuanensis* and *Qionzhuea opienensis*.

Observations have shown that there is correlation between vascular bundle arrangement mentioned above and with the other vegetative characters of a species. These are useful characters in classification and identification.



A Study on the Anatomy of the Vascular Bundles of Bamboos from China

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Abstract

This paper provides anatomical details of regular *vascular bundles of the culms of 28 bamboo genera with 100 species and five varieties from China, The characteristics of the vascular bundles from the outer wall to the inner wall are also illustrated for certain species and this data helps to show the* difference *between the* consanguinity of *the characteristics and morphology of the vascular bundles of bamboos of each genus. It also provides valuable reference for identifying bamboo material, articles made of bamboos, relics and fossils.*

The paper also describes a simple method ofpreparing and examining the cross sectional surface of bamboos. The method is convenientfor use infield examination.

The vascular bundles are categorized into five types, that is, the double broken type, broken type, slender-waist type, semi-open type and open type.

Variations in vascular bundles and their usefulness are mentioned.

The anatomical characteristics of the culm vascular bundles are an important supplement to the classification of bamboos and appropriale examples are given.

The variations in distribution and anatomical characters of Indocalamus and Sasa are discussed. *The vascular bundles of Sasa (inclusive of Sasamorpha) are all semi-open while those of Indocalamus are mostly open type. The arrangement of the vascular bundles of the genera is as follows: Indo*calamus: *undifferentiated –* semi-differ*entiated – semi-open – open. Sasa (including Sasamorpha): undifferentiated* – semi-differentiated – semi-open.

Introduction

Anatomy of the vascular bundles of bamboo culm is a useful guide for bamboo taxonomy. The details can be used when some bamboos cannot be identified with their flowers. It is also used in identifying some bamboos from ancient cultural relics. In addition, the anatomical details will help to determine the splitting property, strength and the ratio of fiber strands of bamboo culm used by modern papermaking industry, handicraft industry and other bamboo processing industries. This article introduces a simple method for examining culm vascular bundles by using only a saw, a knife and a magnifying glass. First cut a culm into three sections, the upper, the middle and the lower part, then smooth the cut with a sharp knife and smear it with water. This will make the vascular bundles visible, if seen through magnifying glass. Bamboos can be identified on the basis of characteristics and features, arrangements and types of the vascular bundles. If the cross-sectional area of vascular bundle sheaths and the fiber strands are larger, then the bamboo wood is strong and contain a high percentage of fiber. If the vascular bimdles are evenly distributed the bamboo wood has a good splitting property.

Materials and Methods

The plant materials used in this study included 99 species and 5 varieties belonging to 28 genera collected between 1976 and 1983 in Zhejiang, Fujian, Guangdong, Yuennan, Jiangxi, Shichuan provinces in China. *Each* bamboo culm was cut into three sections, the. upper, middle, and the lower part, about 0.2-0.3 mm thick taken from 5 cm beyond culm nodes with a sharp knife. After being wetted, the section was observed under a microscope, 8 x 15, with a tessellated scale in its eye piece, and the figure was drawn on tessellated paper to the scale. Other techniques like micrography and tracing were also used. Serial of the vascular bundles from the sections on the outer wall to the inner wall of 3 segments were drawn, so that it could be well seen from the drawing, size and arrangement of the vascular bundles.

Collection of plant materials.

Test No.	Scientific Name	Place of Collection
2-1. 1.	Thyrsostachys siamensis Gamble	Yunnan Xishuangbanna
2-1 2.	Oxytenanthera *nigrocilliata* Munro	Yunnan Xishuangbanna
2-1. 3.	Gigantochloa ligulata Gamble	Yunnan Xishuangbanna
3-1. 4.	Dendrocalamus brandissi Kurz	Yunnan Tengchong
3-1. 2.	D. giganteus Munro	Yunnan Xishuangbanna
3-1. 3.	D. patellanis Gamble	Yunnan Mangshi
2-2. 4.	D. strictus *Nees*	Yunnan Xishuangbanna
2-2. 5,	D. *latiflorus* Munro	Fujian Futing
2-2. 6.	Neosinocalamus affinis (Munro) Keng f.	Zhejiang dinghai
3-1. 5.	N. distegius (Keng & Keng f.) Keng f. & Wen, ined.	Yunnan Kunming
3-1. 7.	N. beecheyanus (munro) Keng f. & Wen, ined.	Fujian Xiamen
2-3. 7.	Lingnania chungii McClure	Zhejiang Dinghai
3-l. 9.	L. wenchouensis Wen.	Fujian Futing
3-1. 10.	Bambusa basihirsuta McClure	Zhejiang Dinghai
3-1. 11.	B. breviflora Munro	Zhejiang Dinghai
3-1. 12.	B. dolichomerithalla Hayata	Zhejiang Dinghai
3-1. 13.	B. eutudoides McClure	Zhejiang Dinghai
3-1. 14.	B. gibbodes Lin	Zhejiang Dinghai
3-1. 15.	Bambusa glaucescens (Will) Sieb.	Zhejiang Xunan
3-1. 16.	B. glaucescens var. shimadia (Hayata) Chia ex But	Zhejiang Linhai
3-1. 17.	B. nana Roxb	Zhejiang Pujiang
2-3. 8.	B. pervariabilis McClure	Zhejiang Dinghai
3-1. 19.	B. textilis McClure	Zhejiang Wenling
3-1. 20.	B. textilis var. albo-stricta McClure	Zhejiang Xiamen
3-1. 21.	B. textilis var. glabra McClure	Zhejiang Dinghai
3-1. 22.	B. pachinensis var. hirsutissima (Odash.) Lin	Zhejiang Dinghai
3-1. 23.	B. tuldoides Munro	Fujian
3-1. 24.	B. vulgris Schrad	Yunnan Kunming
3-2. 25.	B. subtrimcata Chia ex Fung	Zhejiang Dinghai
3-2. 26.	B. lapidea McClure	Zhejiang Dinghai
3-2. 28.	B. oldhami Munro	Zhejiang Dinghai
3-2. 27.	B. prasina Wen	Zhejiang Fingyang
2-3. 9.	Dinochloa utilis McClure	Guangdon Hainan
3-2. 29.	D. orenuda McClure	Guangdon Hainan
3-2. 32	Cephalostachyum fuchsianum Gamble	Yunnan Mangshi
2-4. 10.	C. pergracile Munro	Yunnan Xishuangbanna
2-4. 11.	Melocanna humils Kurz	Fujian Xiamen
2-4. 12.	Schizostachyum pseudolima McClure	Yunnan Luxi
3-2. 35.	S. funghomii McClure	Yunnan Xishuangbanna
3-2. 33.	S. xinwuensis Wen	Jiangxi Xunwu
3-2. 34.	S. hainanensis Merr.	Jiangxi Xunwu
2-4. 13.	Ampelocalamus actinotrichus (Merr. & Chun) Chen. Wen ex Sheng	Guangdon Hainan
2-5. 14.	Chimonocalamus pa/lens Hseuh ex Yi	Yunnan Jinping

Test No.	Scientific Name	Place of Collection
3-2. 27.	*C. fimbriatus* Hseuh ex Yi	Yunnan Luxi
4-3. 31.	Ferrocalamus strictus Hseuh ex Yi	Yunnan Jinping
2-5. 15.	Fargesia farcta Yi	Yunnan Luxi
3-2. 39.	Fargesia ampullaris Yi	Yunnan Luxi
3-2. 40.	F. chungii (Keng) Wang ex Yi	Yunnan Mongshi
3-2. 41,	*F. grossa* Yi	Yunnan Lijiang
3-2. 42.	*F. setosa* Yi	Yunnan Zhongdian
3-2. 44.	*F. edulis* Yi	Yunnan Kunming
2-5. 16.	Yushania niitakayamensis (Hayata) Keng f.	Zhejiang Linan
3-2. 46.	Y. hirticaulis Wang ex Ye	Jiangxi
3-2. 45.	Y. wixiensis Yi	Yunnan
3-2. 47.	Y. hasihirsuta (McClure) Wang & Ye	Fujian Chongan
3-2. 48.	Y. confusa (McClure) Wang & Ye	Jiangxi Huangan
5-2. 81.	Chimonobambusa quadragularis Makino	Fujian Sanmin
4-2. 23.	C. setiformis Wen	Fujian Wuyishan
5-2. 83.	*C. conoolta* Dai ex Tao	Yunnan Luxi
5-2. 80.	C. armata (Gamble) Hsueh ex Yi	Guangxi Luye
4-1. 17.	*Indosasa crassiflora* McClure	Guangxi Nanning
5-l. 50.	*I. sinica* Chu & Chao	Yunnan Hekou
5-l. 51.	*I. shibataeaoides* McClure	Guangxi Guilin
5-l. 63.	*I. glabrata* Chu ex Chao	Fujian Wuyi
5-l. 60.	*Sinobambusa intermedia* McClure	Sichunan Changning
5-l. 54.	*Sinobambusa rubroligula* McClure	Guangzhou
5-1. 52.	*S. edulis* Wen	Yunnan Malipo
5-l. 57.	S. glabrecens Wen	Zhejiang Qinguan
5-1. 55.	*S. nephroaurita* Chu ex Chao	Guangxi quangzhou
5-l. 56.	*S. tootsik* var. *Ieata* (McClure) Wen	Fujian anxi
4-l. 18.	*S. tootsik* Makino	Fujian anxi
5-1. 58.	*S. anaurita* Wen	Jiangxi Jingangshan
5-l. 62	*S. giganteus* Wen	Zhejiang Longquen
4-1. 19.	*Semiarundinaria lubrica* Wen	Zhejiang Longquen
4-2. 20.	*Brachystachyum* densiflorum Keng	Zhejiang Jinghua
5-2. 71.	*Phyllostachys uiridis* (Young) McClure	Zhejiang Lin hai
4-2. 21.	*P.* heterocycla (Carr.) Matsum	Hangzhou
5-2, 70.	*Phyllostachys praecox* Chu ex Chao	Zhejiang Linhai
5-2. 72.	P. stimilosa Zhou et Lin	Zhejiang Linhai
5-1. 66.	*P.* heteroclada Oliv.	Zhejiang Linhai
5-l. 67.	*P. rubromarginata* McClure	Zhejiang Luoqing
4-2. 22.	*Pseudosasa amabilis* (McClure) Keng g.	Jiangxi
5-2. 74.	*P. longiligula* Wen	Guangxi Quanzhou
5-2. 75.	*P. contori* (Munro) Keng f.	Guangzhou
5-2. 76.	*P. orthotropa* Chen ex Wen	Zhejiang Taishun
5-2. 77.	*P. notata* Wang ex Ye	Fujian
4-2. 25.	*Pleioblastus amarus* (Keng) Keng f.	Fujian Jianyang
5-2. 86.	*Pl. chino* Makino	Fujian Xiamen
5-2. 87.	*PI.* ovatoauritus Wen, ined	Zhejiang Luoqing
5-2. 88.	*PI. hisiaenchuensis* Wen	Zhejiang Qingyuan
5-2. 89	*PI. kwangsiensis* Hsiung	Zhejiang Yongjia
5-2. 90.	*PI. matsunoi* (Makino) Nakai	Fujian Shanghang
4-3. 26.	*PI.* gramineus (Bean) Nakai	Guangzhou
5-2. 92.	*PI. oleosus* Wen	Jiangxi Fongxing
5-2. 93.	*PI. maculatus* (McClure) Chu ex Chao	Fujian Jiang ou
4-3. 27.	*Clauinodum bedogonatum* (Wang et Ye) Wen	Jiangxi Wuyishan

Test No.	Scientific Name	Place of Collection
4-2. 24.	*Oligostachyum sulcatum* Wang ex Ye	Fujiang Mingqing
4-3. 28.	Indocalamus tessellatus (Munro) Keng f.	Zhejiang qingtin
5-2. 98.	*I. Iongiauritus* Handel-Mazz	Jiangxi Daiyu
5-2. 97.	*I. Iatifolius* McClure	Jiangxi Xunwu
5-2. 96.	I. *mogoi* (Nakai) Keng f.	Fujian Wuyishan
4-3. 29.	*Gelidocalamus stellatus* Wen	Jiangxi Daiyu
5-1. 64.	*Sasa qingyuanensis* Hu	Zhejiang Qingyuan
4-3. 30.	*S. sinica* Keng	Zhejiang Linan

Variations in the Vascular Bundles

The vascular bundle includes both the conducting tissue and the mechanical tissue. Joining up the plant parts, the underground rhizomes and the upper leaves, as a whole, the vascular bundles transport nutrient solution by vessels and sieve tubes. Because of the large size of the bamboo plant the conducting tissue is reinforced by an outside mechanical tissue which may facilitate circulation.

Some species even have one or two fiber strands. The sectional area of these fiber strands is usually greater than that of the central vascular bundle. The parenchyma in the vascular bundles serves as a buffer zone contributing to the elasticity of the culms, without which the culms would be inflexible and brittle. Near the epidermis, there are generally one or two layers of fiber bundles, closely arranged giving mechanical strength. These are followed by one to three layers of semi-differentiated vascular bundles with incipient conducting tissue. Further inside are regular vascular bundles, generally in the central part of the culm section, two to ten in number.-The shape and arrangement of the vascular bundles near the inner wall are irregular, and the position of sclerenchyma bundle sheath varies from sideward to outward or inward.

Although the morphology of the vascular bundle varies a lot, it remains relatively stable within a given internode of a species.

The Evolution of the Vascular Bundle in Sympodial Bamboos

Sympodial bamboos are said to be comparatively primitive with wide range of differentiation. Based on vegetative characters the sympodials are divided into two groups, sympodial rhizomes with short necks (clump) and long necks (spreading). The former include genera *Thyrsostachys, Dendrocalamus,* Lingnania, *Bambusa, Ampelocalamus* and *Schizostachyum,* and the latter *Chimonocalamus, Fargesia, Yushania. Melocanna, Pseudostachyum etc.* The inflorescences are indeterminate as in *Bambusa, Dendrocalamus, Lingnania, Thyrsostachys* and determinate in *Ampelocalamus, Chimonocalamus, Fargesia, Yushania* etc. The anatomical details of the vascular bundles reflect the main evolutionary trends.

The sympodial genera that possess the double-broken and broken types of vascular bundle are *Thyrsostachys, Dendrocalamus,* Lingnania, Bambusa, Schizostachyum, *Gigantochloa, Oxytenanthera,* Neosino-*calamus* etc.

Schizostachyum, Cephalostachyum, Melocanna are sympodial but taxonomists usually do not treat them as the same, but group them separatly as a tribe named Melocanneae or Schizostachyeae. This classification of a sub-tribe can be justified since all these genera have the bundles which are not the broken type but slender waist type. The sympodials with long necks like Fargesia and Yushania are distributed at high elevation with advanced indeterminate inflorescense which is considered more advanced than the sympodial with short neck type, also they have their representive vascular bundles as open or semi-open type and not slender waist type.

The Character of Vascular Bundles of Running Type Bamboos

The monopodial and amphipodial type of bamboos have long been classified into two major categories. The anatomical details of the vascular bundles are not distinct in these two categories. They both have open and semi-open type of vascular bundles, (except in few species of *Chimonobambusa).* Although *Phyllostachys* is a monopodial genus, sometimes we can also find species that have amphipodial rhizomes, such as P. heteroclada, P. bombusoides and P. makinoi. The anatomy of the vascular bundles of running type of bamboos is different from that of clump type. Besides, the form and structure of the vascular bundles are different from one another.

1) The typical semi-open type of vascular bundles are found in *Sass, Gelidocalamus, Semiarundinariu, Clavinodum,* Oligo-stuchyum, and the Subgen. *Pleioblastus, Pleioblustus gramineus, P. matsunoi* etc. Of these, Sass and *Semiarundinaria* consist of vascular bundles which are somewhat typical. In Sasa the upper, middle, or the lower part have about six bundles but in *Semiarun-*dinaria there are four vascular bundles in the upper part, five in the middle and eight in the lower part. The typical vascular bundles of *Gelidocalamus* are of semi-open type except those near the inner wall of the upper part of the culm which are of open type. The vascular bundles of Subgen. *Pleioblastus* are all of semi-open type.

2) The genera that have all or nearly all open -type vascular bundles are *Ferrocalamus, lndocalamus* and *Pseudosasa. Ferrocalamus* has clump type, but its rhizomes are amphipodial and the vascular bundle of the culms are of open type. The undifferentiated vascular bundles on the outer wall of the culms of *Ferrocalamus* are exceptionally big; therefore, the tissue in the wall is well developed and forms a strong and hard outer wall. Almost all the vascular bundles of *Pseudosasa* and *Chimonobambusa are* of open type. The regular vascular bundles of other genera are mainly open type.. In the process of changing from undifferentiated vascular bundles to regular ones, the semi-' open type gradually changes into open type. In this changing process Indocalamus usually shows semi-open type before the regular open type appears.

3) Open and semi-open type vascular bundles exist at the same time and sometimes they are of equal number, for example, *Phyllostachys, Brachystachyum* and species of Subgen. *Pleioblastus, as Pleioblastus amarus,* Pleioblustus hsienchuensis, Pleioblastue oleosus and Pleioblustus maculatus. Phyllostachys is intermediate among the running type, that is to say, the typical open type vascular bundles of *Phyllostachys* are nearly as many as the semi-open ones. The regular vascular bundles of *Brachystachyum* are mainly of open type, while those of Subgen. *Pleioblastus* are mainly semi-open type.

4) Regular vascular bundles are mainly of open type, but sometimes near the inner wall and outer wall of the culms semi-open type vascular bundles are found, and among the groups of vascular bundles there are layers of parenchyma. These can *also* be found in both *Indosasa* and *Sinobambusa,* which show that the two genera not only look alike in their appearances but also have similar vascular bundle features.

A Generic Key to the Vascular Bundles of Bamboos

1. The culm vascular bundles is broken once or twice in the middle and the lower or upper parts of the central vascular bundle has a proliferation of fibre strands,

2. Co-existance of the broken type and double broken type of vascular bundles.

3. The lower part of the culm with the double broken type vascular bundles, the middle and upper parts with the broken type vascular bundles.

4. The vascular bundles of the lower part of the culm are mostly double broken type.

5. The lower part of the culm with a considerable number of vascular bundles, the upper and middle parts with a sudden reduction of vascular bundles, the lower part with vascular bundles over twice as many as those in the. upper and middle parts . *Thyrsostachys*

5. The lower part of the culm with many vascular bundles, but gradually reducing from

the middle part upwards . . . . . . Gigantochloa

4. The lower part of the culm with few double broken type vascular bundles.

5, The lower part with outer vascular bundle sheath developed particularly well and its section area is larger than the sum total of other vascular bundle sheaths , ... * . . . . Dendrocalamus

5. The lower part of the culm with outer bundle sheath particularly well-developed and its section area is as large as that of the left and right side vascular bundle sheath or smaller . . . . *Oxytenanthera*

3. The lower and middle parts or only the middle part of the culm with the double broken type vascular bundles.

2. The culm with the broken type and without the double broken type vascular bundles.

3. In the middle of the cross section surface of the upper, middle and lower parts of the culm or near the inner wall, scalariform vessels are specially big . . . . *Lingnania*

3. Scalariform vessels of the vascular bundles of the culm are of the common size.

4, One open type vascular bundle near the inner wall . . . . , . . . , . . . *Neosinocalamus*

4. Two open type vascular bundles near the inner wall are changeable (a few species with the double broken type vascular bundles). . . . .*.......*.....*.... *Bambusa*

1. Vascular bundles of the culm do not break, fibre strands do not proliferate at the upper and lower parts of the central vascular bundle.

2. With the slender-waist type vascular bundles.

3. The lower part of the culm with a row of over ten vascular bundles, the upper and middle parts with a sharp reduction . . . .*....*...*....*. Cephalostachyum

3. The lower part of the culm with relatively fewer vascular bundles, the vascular bundles in the upper, middle and lower parts are almost equal in number.

4. Culms slender but with fairly big vascular bundles, the inner sheaths of vascular bundles near the inner wall are normal , ... - . . . . I . . . . ' . . . . . . Melocanna

4. Culms thick but with. comparatively small vascular bundles, the inner sheaths of vascular bundles near the inner wall are undeveloped . . . . *Schizostachyum*

2. With the open type and semi-open type vascular bundles.

3. With the open type regular vascular bundles.

4. The undifferentiated and semi-differentiated vascular bundles are especially well-developed, the sectional area of sclerenchyma is one to three times the size of the regular vascular bundles . , ... *Ferrocalamus*

4. The undifferentiated and semi-differentiated vascular bundles are a little bigger than regular vascular bundles.

5. The outer vascular bundle sheath of the semi-differentiated vascular bundle is especially well-developed. and is one to three times as big as other vascular bundle sheaths . . . . *Pseudosasa*

5. The outer vascular bundle sheath of the semi-differentiated vascular bundle is almost as big as or a little bigger than other vascular bundle sheaths . . . . *Chimonobambusa*

3. All the vascular bundles are semi-open.

4. The semi-differentiated vascu tar bundles are two times bigger than regular bundles . . . . , , . . *Gelidocalamus*

4. The semi-differentiated vascular bundles and regular vascular bundles are almost equal in number.

5. A row of about three to four vascular bundles, amphipodial rhizomes . , , . Subgen. *Pleioblastus*

5. A row of more than five vascular bundles.

6. The lower part of the culm with a row of five to six vascular bundles.

7. Semi-differentiated vascular bundles, and the inner vascular bundle sheath is almost rectangular.. . . . . , ... *Yushania*

7. Semi-differentiated vascular bundles, and the inner vascular bundle sheath is triangular . . . . Sasa

6. The lower part of the culm with a row of seven to eight vascular bundles, the inner sheath of the semi-differentiated vascular bundle is triangular, the outer sheath is oval . . . . *Semiarudinaria*

3. The open type and the semi-open type vascular bundles coexist.

4. Mainly with the semi-open type vascular bundles.

5. The vascular bundles in the lower part of the culm are all semi-open, near the inner wall of the upper and middle parts are two or three open type vascular bundles . . . Fargesiu

5. Near the inner wall of the upper, middle or lower part are one to two open type vascular bundles.

6. The inner vascular bundle sheath of the semi-open type vascular bundle in the three parts of the culm is triangular. . . . , . . Subgen. *Amarus*

6. The characteristics and morphology of the inner vascular bundle sheath of the semi-open type vascular bundles are irregular . . . . *. . . . . *Clavinodum*

4. Mainly with the open type vascular bundles.

5. The semi-differentiated vascular bundles and the regular vascular bundles are almost equal in size . . . . . , ... *Phyllostachys*

5. The semi-differentiated vascular bundles are bigger .than regular vascular bundles.

6. The outer sheath of the semi-differentiated vascular bundle is almost as big as the outer sheath of the regular vascular bundle . . . . *Zndocalamus*

6. The outer sheath of the semi-differentiated vascular bundle is quite well-developed, and far bigger than the outer sheath of the regular vascular bundle . . . *Brachystachyum*

4. The open type and the semi-open type vascular bundles coexist; sometimes there are parenchyma cell rings among groups of vascular bundles or the open type vascular bundles among the semi-open type vascular bundles.

5. The vascular bundles in the upper middle and lower parts of the culm are in a ratio of 4:5:9. shaped like an upside-down pagoda . . . . *lndosasa*

5. The vascular bundles in the upper, middle and lower parts of the culm are in a ratio of 6:8:8. almost equal in number . . . . _ . . . . * . . . . *Sinobambusa*

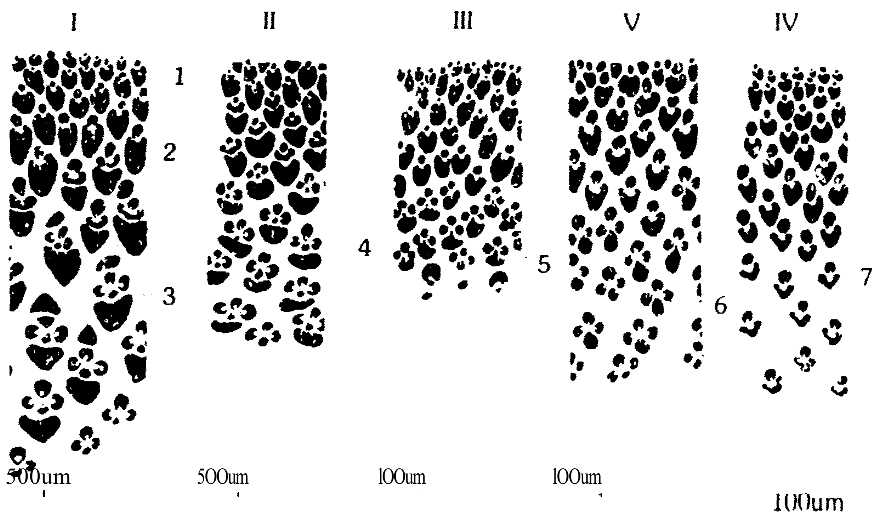
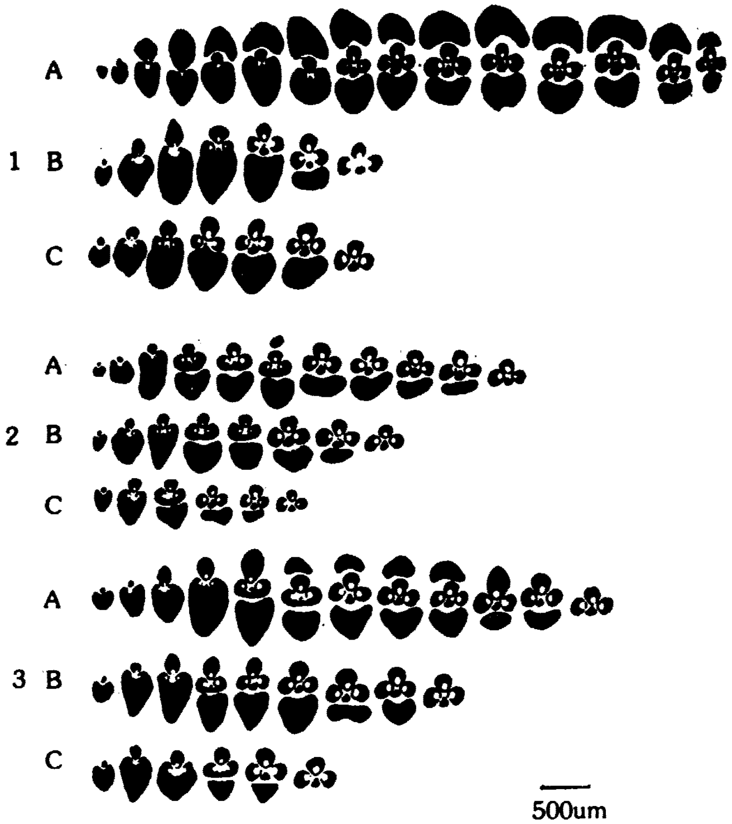


Fig. 1. Morphology of vascular bundles of bamboo. I. Dendrocalamus strictus Nees. II. Bambusa peruariabilis McClure. III. Melocanna *humilis* Kurt. IV. *Phyllostachys oiridis* (Young) McClure. V. Fargesia farcta Yi.
1. non-differentiated vascular bundles; 2. semi-differentiated vascular bundles; 3. double-broken vascular bundles; 4. broken vascular bundles; 5. slender waist vascular bundles: 6. open vascular bundles; 7. semi-open vascular bundles.



Fii. 2-1. sections of the upper, middle and lower of bamboo culm from left to right is outside to inner wall. 1. Thyrsostachys siamensis Gamble; 2. Oxytenanthera nigrocilliata Munro; 3. Gigantochloa *ligudata* Gamble. A. lower of culm; B. middle of culm; C. upper of culm.

Fii. 2-2. 4. Dendrocalamus atrictus Nees; 5. Dendrocalamus latiflotus Munro; 6. Neosinocalamus affinis (Mumro) Keng f .

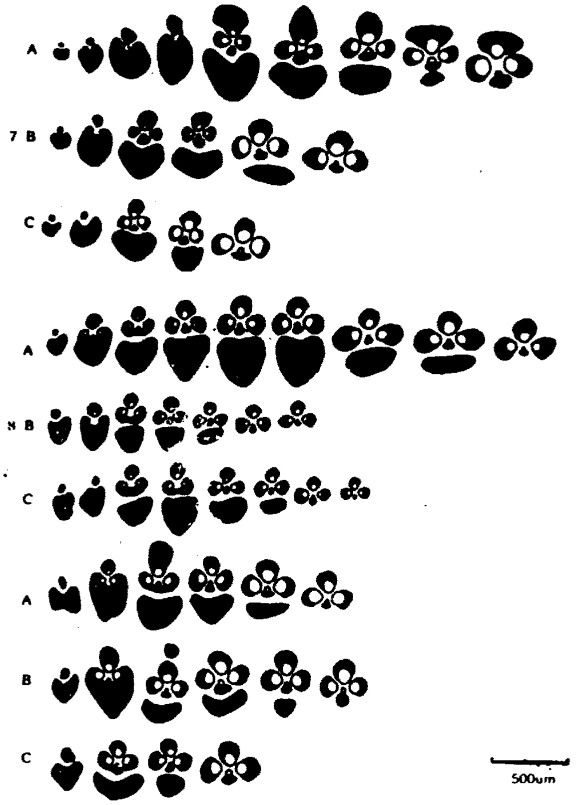


Fig. 2-3. 7. *Lingnania chungii* McClure; 8. *Bambusa pervariabilis* McClure; 9. *Dinochloa utilis* McClure

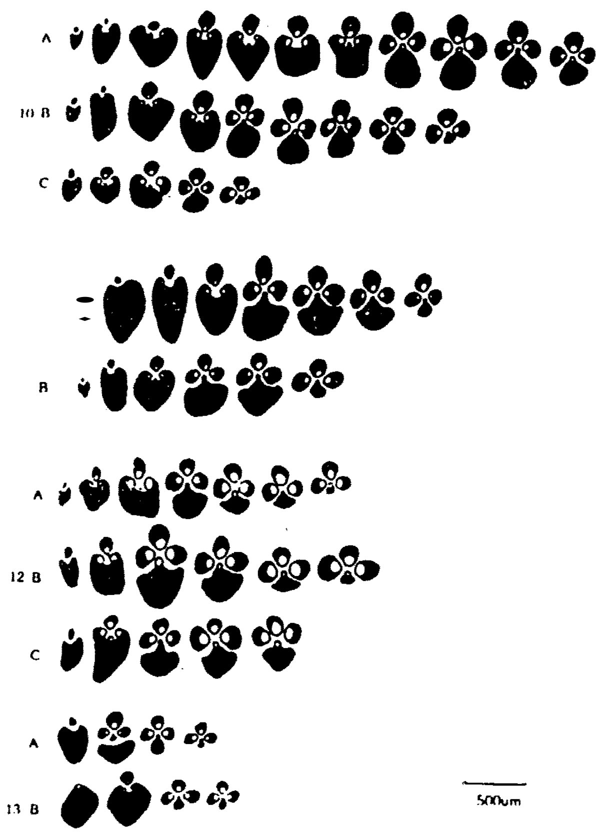


Fig. 2-4. 10. *Cephalostachyum pergracile* Munro; 11. *Melocanna humilis* Kurz; *ta*
McClure; 13. *Ampelocalamus actinotrichus* Chen, Wen et Sheng.

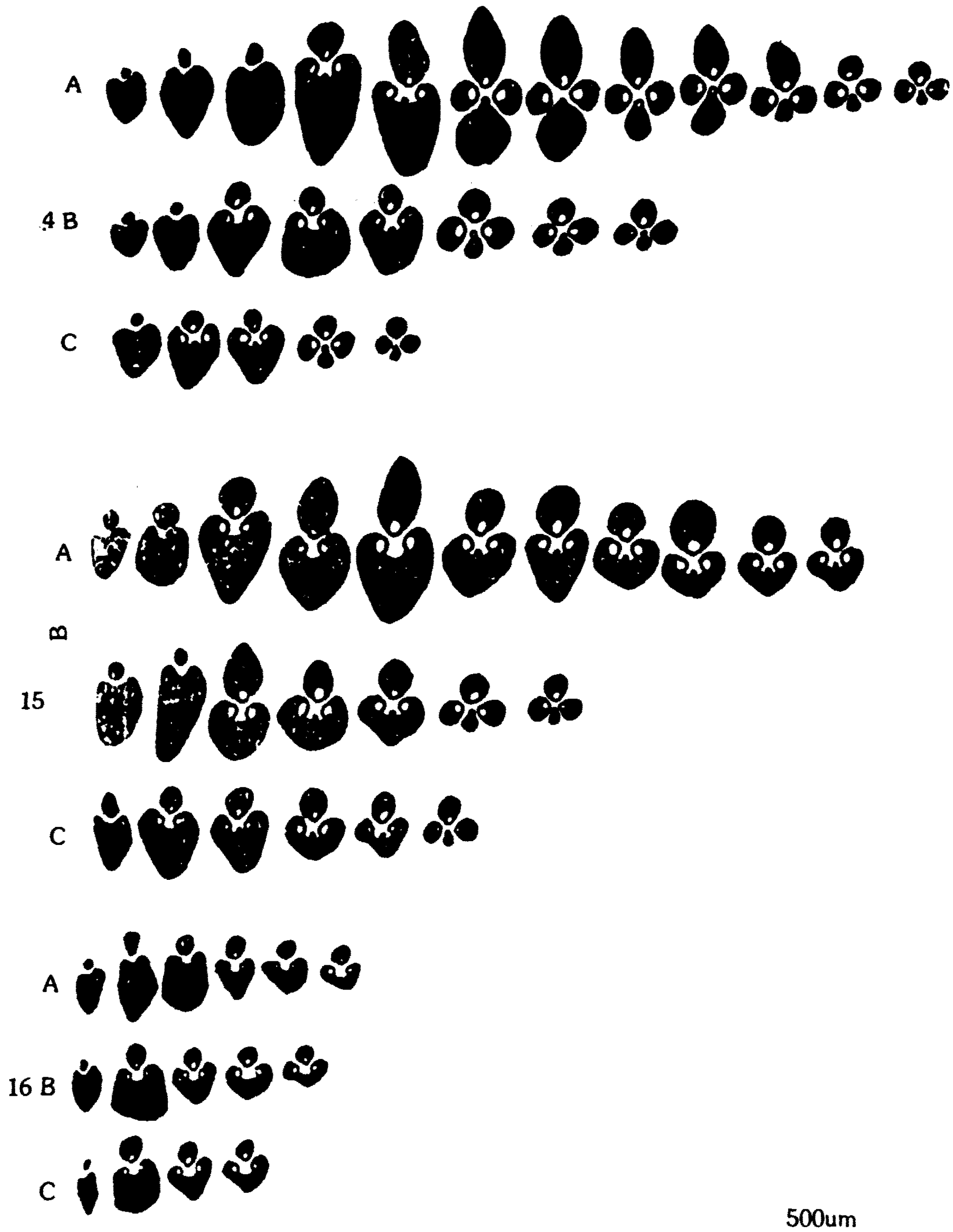


Fig. 2-5. 14. Chimonocalamus pal/ens Hseuh et Yi; 15. Fargesia farcta Yi; 16. Yushania niitakayamensis (Hayata) Keng f.

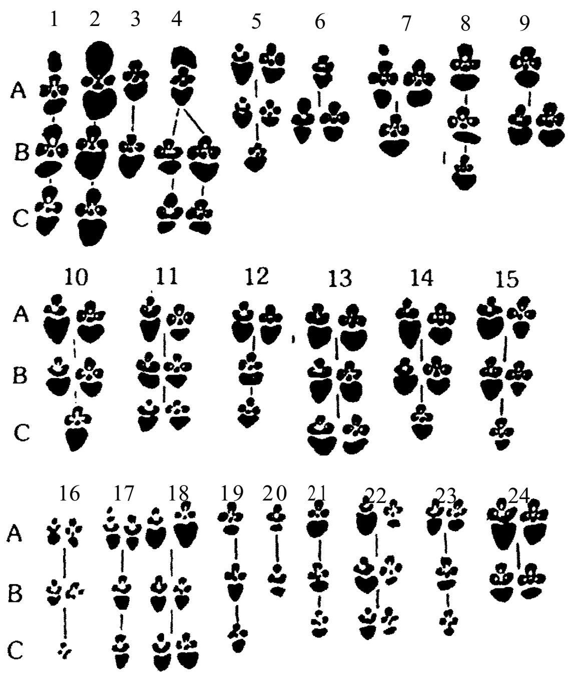


Fig. 3-1. The morphology of vascular bundles of bamboos. ali the test No. 1-24, see the table. A. lower of culm; B middle of culm: C. upper of culm

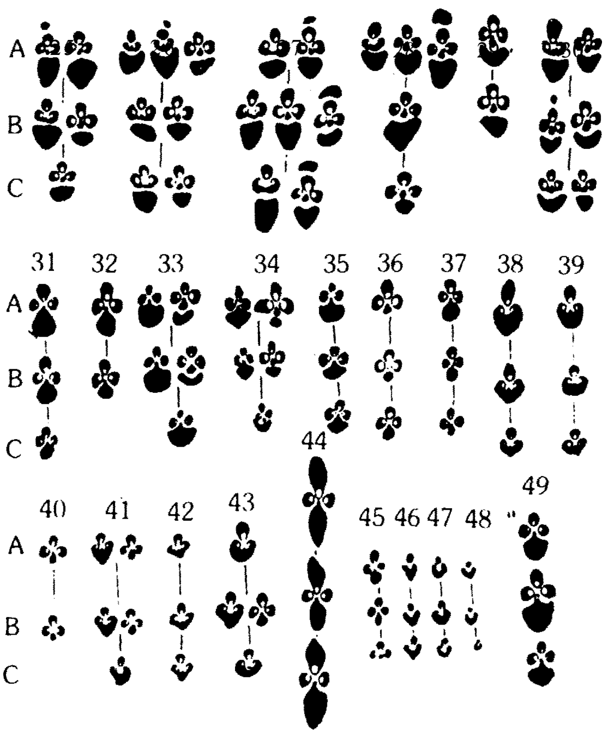


Fig 3-2 The morphology of vascular bundle of bamboos. all the test No 25-48, see the table, A lower of culm. B middle of culm. C lower of culm

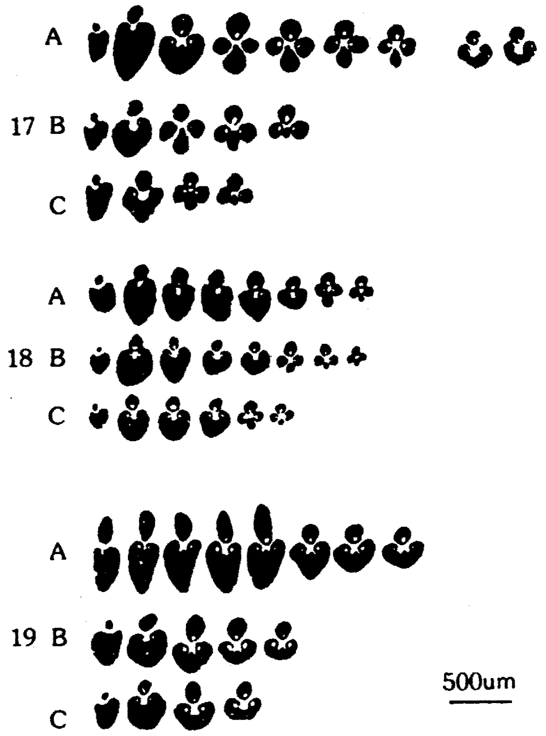


Fig. 4-l. Sections of the upper, middle and lower of bamboo culm, from left to right is outside to inner wall. A. lower of culm; B. middle of eulm; C. upper of culm. 17. Indosasa crassifllora McClure; 18. *Sinobambusa tootsik* Makino; 19. Semiarundinaria lubrica Wen.

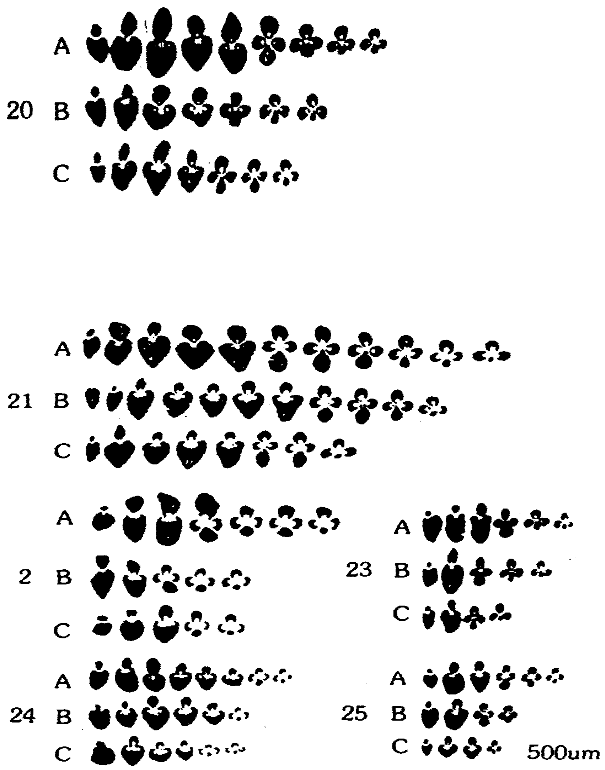


Fig. 4-2. 20. Brachystachyum densijjorum Keng; 21. *Phyllostachys heterocycla (Carr.)* Matsum; 22. Pseudosasa amabilis (McClure) Keng f.; 23. Chimonobambusa *marmorea* Makino; *24. OIigostochyum sulcatum C.P.* Wang et *Ye; 25. Pleioblastus amarus* (Keng) Keng f.

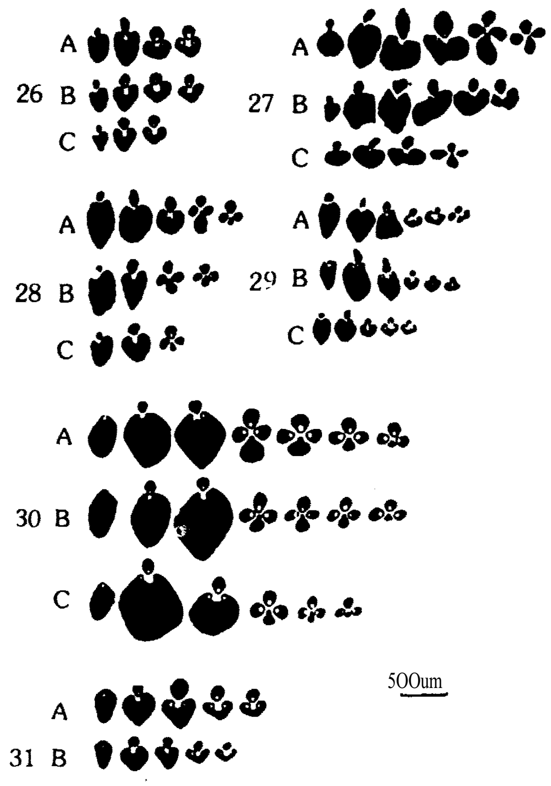


Fig. 4-3. 26. Pleioblastus gramineus (Bean) Nakai; 27 Clauinodum oedogonotum (C.P. Wang et Ye) Wen; *28. Indocalamus tessellatus* (Munro) Keng f.; 29. Gelidocalomus stellatus Wen; 30. Sasa sinica Keng; 31. Ferrocalamus strictus Hsueh et Kens. f.

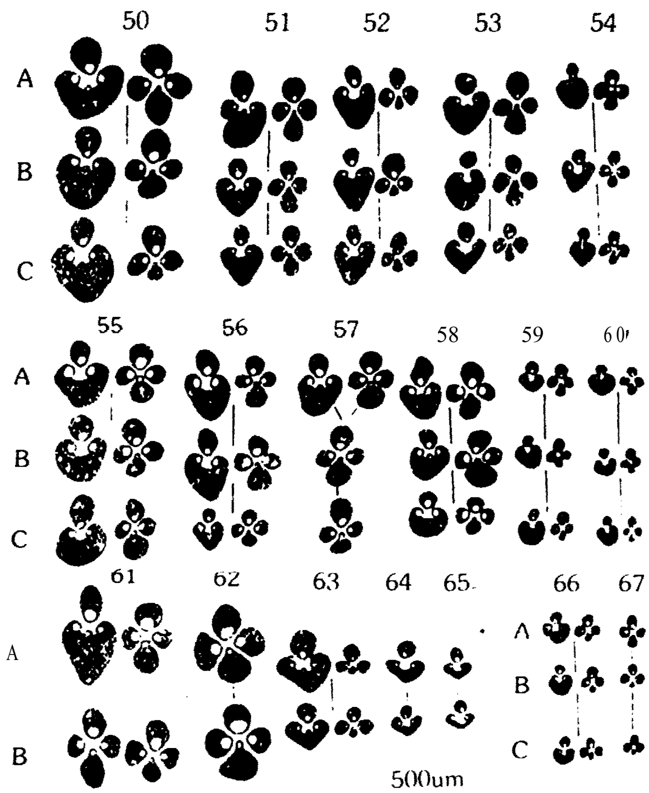


Fig. 5-l. The morphology of vascular bundle of bamboos, all the test No. 50-67. see the tables
A lower of culm; B. middle'of culm; C. upper of culm

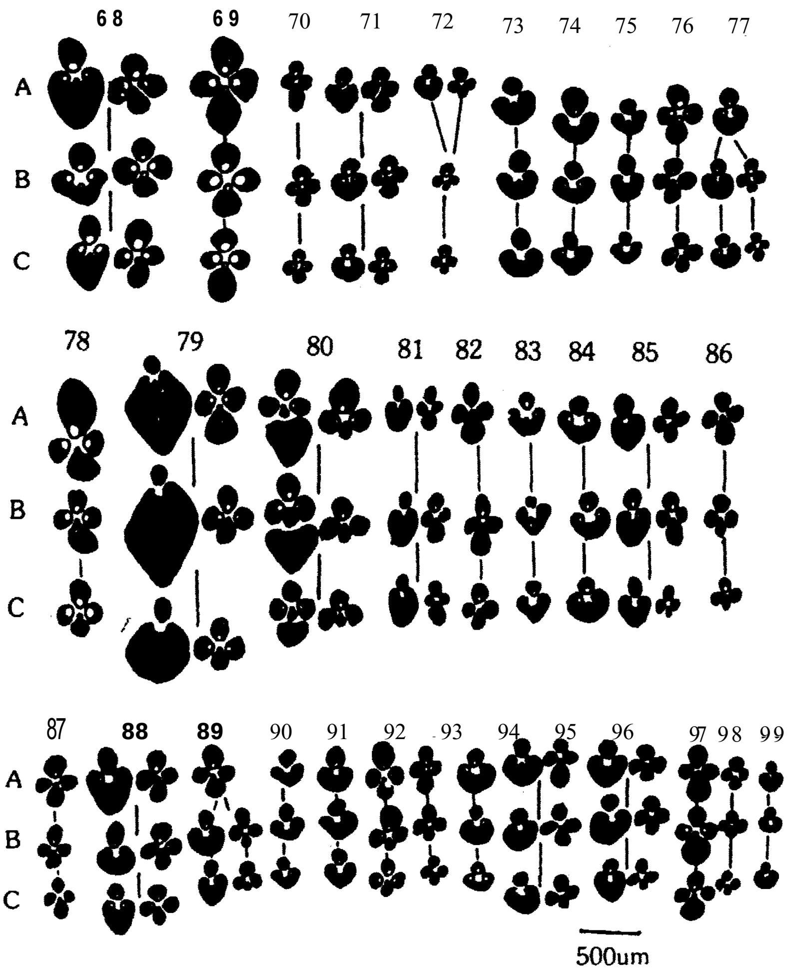


Fig. 5-2. The morphology of vascular bundle of bamboos. all the test No. 68-99. see the tables. A. lower of culm; B. middle of culm; C. upper of culm. (The construction of the key is left in its original form but this can be further simplified References, other detaib and explanations connected with this paper can be obtained from the authors – Eds).

Anatomical Properties of Some Bamboos Utilized. in Indonesia

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Abstract

Four species of bamboo (i.e. Dendrocalamus giganteus, Dendrocalamus asper Gigantochloa robusta, Bambusa vulgaris, oat. *striata)* utilised in Indonesia are studied anatomically and the results are correlated to their mechanical properties. There is a correlation between fiber length, modulus os elasticity and compression strength.

Introduction

Among the sixteen species of bamboo utilized in Indonesia (Widjaja, 1980), ten of them (i.e. *Gigantochloa apus* (Schult. & Schult.) Kurz, . *Gigantochloa verticillata* (Munro*), *Gigantochloa robusta* Kurz, *Gigantochloa atter* (Hassk.) Kurz, *Dendrocalamus asper* (Schult.) Backer *ex* Heyne, *Bambusa* arundinacea (Retz.) Willd., Bambusa vulgaris Schrad. var. *striata, Bambusa blumeana* Schult., *Gigantochloa aff. atter** and *Bambusa polymorpha* Munro) are useful in the building construction, (• hereafter referred to as *Gigantochloa pseudoarundinacea* (Steud.) Widjaja and *Gigantochloa* atroviolacea Widjaja respectively). Their mechanical properties, however, have yet to be determined. Grosser & Liese (1974) concluded that the percentage of sclerenchyma fibres increases from the bottom to the top of the culm, accompanied by compression strength. Janssen (1981) pointed out that the bending stress decreases with the height of the culm but the modulus of elasticity increases with the latter. Kawase (1981) reported that the fiber size in the middle part of culm is greater than in the bottom and the top, and that the outer part of the culm has longer fibers than the inner part.

In this paper, the correlation between the fibre length and the mechanical properties (including compression strength, tensile strength, static bending strength and stiffness) of *Dendrocakamus asper, Gigantochloa robusta, Bambusa vulgaris* var. *striata* and *Dendrocalamus giganteus,* is studied. Although *D. giganteus* is not cultivated outside the botanical gardens in Indonesia, it is included in this study because of its potential value for building purposes.

Materials and Methods

This study was based on 4 species of bamboos grown in the Bogor Botanical Gardens.

Samples were obtained by taking the nodes at the height of 1.5 m above the ground. By counting that node as the first one, further samples were also taken from the third, fifth and seventh nodes further up of the culms. For studying the fibre length, pieces of culm were macerated in 50% HNO_3 at 50°C for 15 minutes. After washing in distilled water it was stained with 1% methylgreen in 10% acetic acid and mounted in 50% glycerin. The mechanical properties of the culm was determined by Baldwin instrument (to measure the tensile strength) and Amsler 6000 kg (to measure the static bending strength and the compression strength). The samples used for this study measured 30 cm x 2 cm x 0.5 – 1 *cm,* following the American Standard for Testing and Materials ASTM D 143 52 (1972) with some modification.

Results and Discussion

Anatomical properties: The fibre length showed that Dencrocalamus asper has the longest fiber (averaging 20.03 mu), followed by Bambusa vulgaris var. striata (18.92 mu, Dendrocalamus giganteus (18.84 mu), and Gigantochloa robusta (18.12 mu). Based on the position along the culm, the first node studied generally has similar fiber sizes (19-20 mu). The fiber length in the third node and above do not show a genera1 pattern (Table 1).

Mechanical properties: Sjafii (1984) showed that Dendrocalamus giganteus has the highest specific gravity (0.7 1) if compared to Dendrocalamus asper (0.61) Giganto-chloo robusta (0.55), and Bambusa vulgaris var. striata (0.52). However, there is no significant difference between various nodes of every species. With regard to the average rate of the modulus of elasticity, modulus of rupture and compression strength, Dendrocalamus giganteus also has the highest value, followed by Dendrocalamus asper, Gigantochloa robusta and Bamb'usa vulgaris var. striafo (Table 2). The tensile strength of Dendrocalamus giganteus (1907.33 kg/cm^2) is smaller than Dendrocalamus asper

Table 1. Fiber length at various nodes of culm

Species	Node	Fiber Length	Average
D. giganteus	1st	19.16	
	3rd	18.04	
	5th	19.16	18.84
	7th	19.0	
D. asper	1st	19.28	
	3rd	19.60	
	5th	21.16	20.03
	7th	20.10	
G. robusta	1st	19.66	
	3rd	15	
	5th	19.66	18.12
	7th	18.16	
B. vulgaris var *striata*	1st	19.92	
	3rd	20.24	
	5th	18.2	18.92
	7th		17.2

Table 2. Mechanical properties of various bamboos at various nodes (after Sjafii. 1984)

Species	Part of culm	Modulus of elasticity kg/cm^2	Modulus of rupture kg/cm^2	Compression strength kg/cm^2	Tensile strength kg/cm^2
D. giganteus	1	172097.92	1828.57	602.56	1836.16
	3	122463.95	1758.28	619.88	1945.91
	5	147912.10	1827.90	639.95	1880.20
	7	130352.42	2880.13	645.84	1965.87
	Average	143206.60	1823.72	627.02	1907.04
D. asper	1	122073.82	1637.81	639.30	2145.03
	3	149587.06	1741.61	592.35	2040.15
	5	129542.12	1595.74	622.20	2219.89
	7	123966.17	1578.62	565.93	2103.97
	Average	131292.29	1638.45	604.95	2127.26
G. robusta	1	94208.59	1384.48	533.12	1970.51
	3	92367.13	1294.27	509.97	1766.82
	5	109217.50	1398.23	510.95	1853.65
	7	97381.90	1345.62	529.62	2066.33
	Average	98293.78	1355.65	520.92	1914.33
B. vulgaris	1	60652 -42	1075.01	484.30	1391.94
		71931.76	1123.66	443.02	1196.15
var. striota		88297.55	1105.27	475.34	1351.66
	7	83939.92	1286.24	417.43	1346.46
	Average	76205.41	1147.54	455.02	1321.55

Table 3. Correlation betweenFiber length and E-Modulus, R-Modulus, Compression Strength and Tensile Strength

Linear Regression	Correlation Coeficient	F
E-Modulus: 30.568,72 + 4162.96 Fiber length	0.3	8.48' .
R-Modulus: 1485.08 + 0.33 Fiber length	0.0001	0.00096
Compression strengh: -42.69. + 31.33 Fiber length	0.03	11.09' .
Tensile strength: 1599,76 + 13.45 Fiber length	0.1	0.99

(2127.26 kg/cm and Gigantochloa robusta (1914.33 kg/cm^2), with *Bambusa vulgaris* var. *striata* has the lowest tensile strength (1321.55 kg/cm^2), The. result of the test of modulus of elasticity of *Bambusa vulgaris* var. striata. supports the findings of Limaye (1952), Janssen (1981) and Kawase (1981) who showed that the elasticity of the Iower culm is smaller than the upper one. The modulus of rupture of the 4 species studied also bears out the conclusion of Limaye (1952) who pointed out that the decreasing of moduilus of rupture follows the decreasing of specific gravity. The compression strength of *Dendrocalamus giganteus* and *Gigantochloa robusta* increases from the bottom to the top but not *so* in *Dendrocalamus* asper and *Bambusa vulgaris* var. striata. As pointed out by Limaye (1952) and Janssen (1981) the compression strength as well as the percentage of sclerenchyma fibre increase from the bottom to the top. According to Sjafii (1984), the modulus of elasticity can be used for detecting the modulus of rupture due to the highest correlation. Also, the compression strength and the tensile strength can be detected by the modulus of elasticity although the correlation is very small. Further analyses of the data obtained on the four e species studied indicate that the fiber length have a correlation with the modulus of elasticity and compression strength (Table 3) although it is very small- in the latter (r = 0.03). Further studies along these lines are now in progress on other species of utilized bamboos in Indonesia and it is hoped that the result will be beneficial in utilizing the anatomical properties for practical purposes.

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Fibre Morphology and Crystallinity of Phyllostachys pubescens with Reference to Age

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Abstract

The fibre form and crystallinity of Phyllostachyus pubescens we determined in relation to the age of the culm. This study helps to determine the age of the bamboo harvest.

Introduction

For purpose of investigating the fiber form and the relative crystallinity of cellulose of *Phyllostachyus pubescens* Maze1 ex H. de Lehaie, culms of different ages were used. The bamboo grows rapidly, and the different samples taken indicate the change of fiber form at each stage of growth in relation to its age.

Materials and Method

The materials were obtained from the stands of *P, pubescens* (from 1/2 1, 3, 7 years old) growing in Zhejiang province. From each bamboo culm, three portions from the base, the middle and the top were cut off. After air-drying, specimens of 2-3 cm in length were prepared from the central part of each joint. From the thick parts of the bamboo culm, specimens were taken, and named T_1, T_2, T_3, — and R_1, R_2, R_3 — for the tangential and radial faces respectively. The thin parts were divided into three parts, namely outside (To, Ro), middle (T_m,, R_m) and inside (T,, R,) .

The fibre form was examined according to the standard practice.

Each sample of crystallinity was crushed into powder with 80-100 mesh. The powder was dried over phosphorus pentoxide in vacuum at room temperature. Five hundred mg of the mixed powder was taken, pressed into tablet, and used for the x-ray measurement of crystallinity.

Results and Conclusion

The results (Table 1) (Fig. 1) show that average fiber length of bamboo is about 2 mm, average diameter is about 10.5-15.3 urn, double wall thickness is about 8-13.64 urn, and the ratio of length to breadth is over 100.

The fiber length of *P. pubescens* increases and the relative crystallinity decreases respectively with increasing age of the plant. In bamboos older than one year, the lignin content remains stable or rises slightly with years. The main structure, composed of cellulose fibers, are formed at an earlier period. Cell-wall growth and lignification proceed gradually.

Bamboo grows to full size within about 2-3 months, but it needs about 3 years for complete maturation of tissues. It means that bamboos that complete their growth and rotation at the end of this period or stage is considered satisfactory.

It is concluded that the study of fibre length variations would help to determine the period of harvest and recycling.

Table 1. Change on Fibre Form and Crystallinity of P. pubescens of Different Ages.

Age	Sample		Length (µm) $\bar{x}$	σ_{n-1} (s)	$\frac{s}{\bar{x}}\cdot100$	Width (µm) $\bar{x}$	σ_{n-1} (s)	$\frac{s}{\bar{x}}\cdot100$	Thickness of 2 walls (µm) $\bar{x}$	σ_{n-1} (s)	$\frac{s}{\bar{x}}\cdot100$	L/D	Relative Crystallinity (%)
	Base	Outer	1962	417.4	21.3	13.6	3.39	25.0	10.1	3.39	33.7	149	
		Middle	1666	373.4	22.4	13.6	4.39	32.3	9.2	3.57	39.0	123	
		Inner	1474	524.0	35.6	12.0	2.44	20.3	8.0	2.71	34.0	123	
		Outer	1742	709.7	40.7	14.3	3.20	22.4	10.8	3.34	30.8	122	
6 months	Middle	Middle	1628	631.8	38.8	14.0	3.78	27.0	10.6	2.46	23.2	116	63
		Inner	1612	655.5	40.7	13.4	3.08	23.0	9.9	2.65	26.9	120	
	Top	Outer	1506	606.6	40.3	12.1	3.30	27.2	10.0	2.93	29.5	124	
		Middle	1436	628.7	43.8	12.9	3.47	26.9	10.8	3.11	28.9	111	
		Inner	1566	655.8	41.9	12.5	3.08	24.7	10.8	2.97	27.5	125	
	Base	Outer	2186	699.6	32.0	14.5	4.02	27.7	12.6	3.83	30.3	150	
		Middle	2306	716.1	31.1	15.3	4.01	26.2	13.6	3.76	27.5	151	
		Inner	1790	508.4	28.4	13.9	4.05	29.2	12.3	3.87	31.4	129	
		Outer	1936	554.3	28.6	13.8	3.10	22.5	12.2	3.02	24.8	140	
1 year	Middle	Middle	2084	679.2	32.6	13.8	3.37	24.5	11.8	3.17	26.9	151	60
		Inner	1850	639.6	34.6	13.0	2.77	21.1	11.4	2.59	22.8	141	
	Top	Outer	1784	520.0	29.2	10.5	2.64	25.2	9.1	2.53	27.9	170	
		Middle	1942	507.9	26.2	11.8	3.00	25.5	10.0	2.88	28.9	165	
		Inner	1838	550.7	30.0	10.8	3.27	30.3	9.1	3.27	35.7	170	
	Base	Outer	2078	540.0	26.0	13.9	3.27	23.5	12.1	3.14	25.9	149	
		Middle	2136	547.3	25.6	11.5	2.82	24.6	9.8	2.82	35.5	186	
		Inner	1874	505.8	27.0	11.7	2.38	20.3	10.0	2.36	23.7	160	
		Outer	1917	603.1	31.5	14.8	2.67	18.1	12.9	2.65	20.6	130	
3 years	Middle	Middle	2140	594.5	27.8	12.6	2.88	22.8	11.1	2.97	26.7	169	58
		Inner	1908	424.2	22.2	11.7	2.30	19.7	10.1	2.26	22.5	163	
	TOP	Outer	2032	623.8	30.7	12.7	2.68	21.2	10.9	–	–	160	
		Middle	2244	572.9	25.5	12.1	2.56	21.1	10.5	2.53	24.2	185	
		Inner	2098	576.9	27.5	11.3	2.51	22.3	9.7	2.48	25.5	186	
	Base	Outer	2000	562.8	28.1	12.1	2.65	22.0	10.5	2.64	25.2	1166	
		Middle	2080	603.1	29.0	11.2	2.28	20.3	9.6	2.23	23.4	186	
		Inner	2054	583.2	28.4	11.3	2.37	21.0	9.7	2.25	23.3	182	
		Outer	2328	639.2	28.6	12.6	2.82	22.5	10.8	2.86	26.3	185	
7 years	Middle	Middle	2382	593.1	24.9	12.0	2.68	22.3	10.4	2.59	24.8	198	55
		Inner	2380	579.6	24.4	12.0	2.74	22.9	10.3	2.71	26.2	199	
	Top	Outer	2208	526.8	23.9	12.0	2.74	22.8	10.5	2.68	25.6	184	
		Middle	2137	464.7	21.8	13.2	2.99	22.7	11.6	2.94	25.3	162	
		Inner	2136	472.8	22.1	12.0	2.52	21.0	10.3	2.35	22.8	178	

Fig. 1. Change of fiber length of Ph. pubescens of the different age to the various height and part.

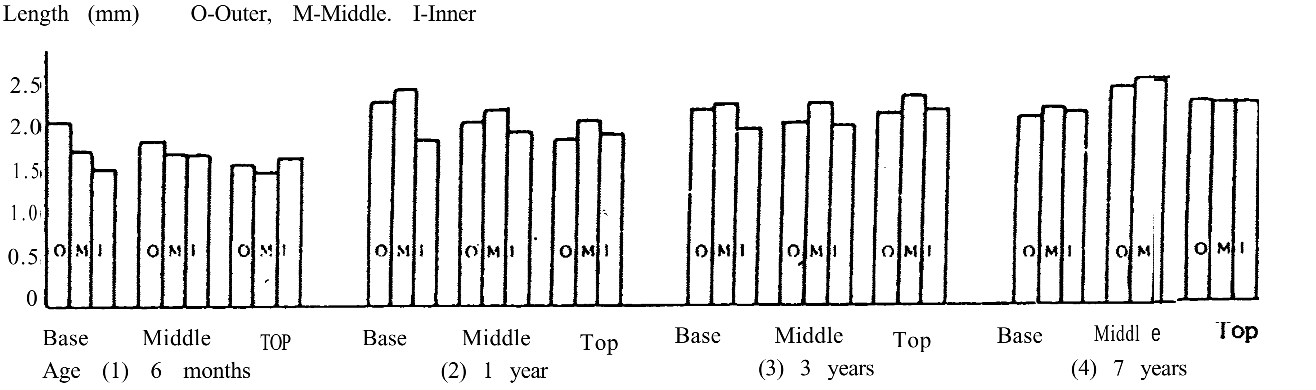
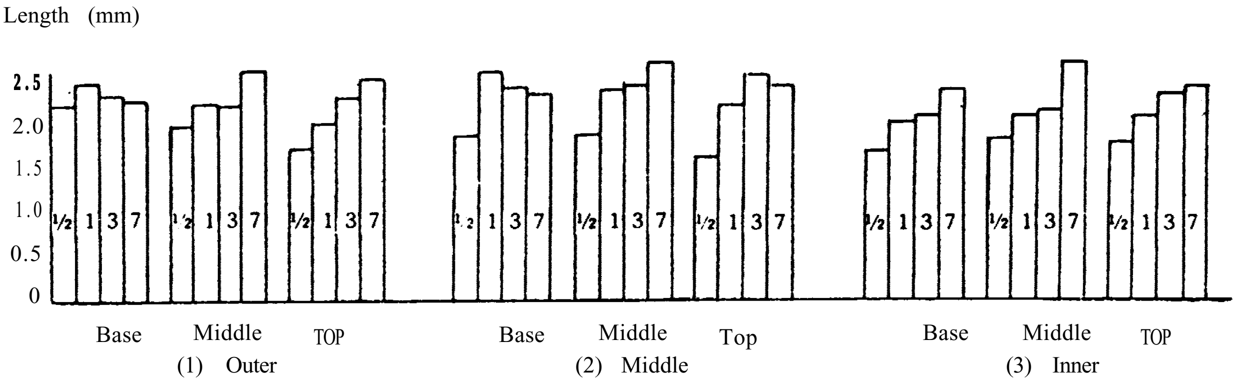


Fig. 2. Change of fiber length of Ph. pubescens of the same part at different ages.



The Mechanical Properties of Bamboo

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Abstract

Bamboo is compared with steel, concrete and timber in terms of the energy needed for production, safety, strength and stiffness as well as simpleness of production as a construction material. The outcome of the comparison places bamboo well ahead for construction purposes.

Introduction

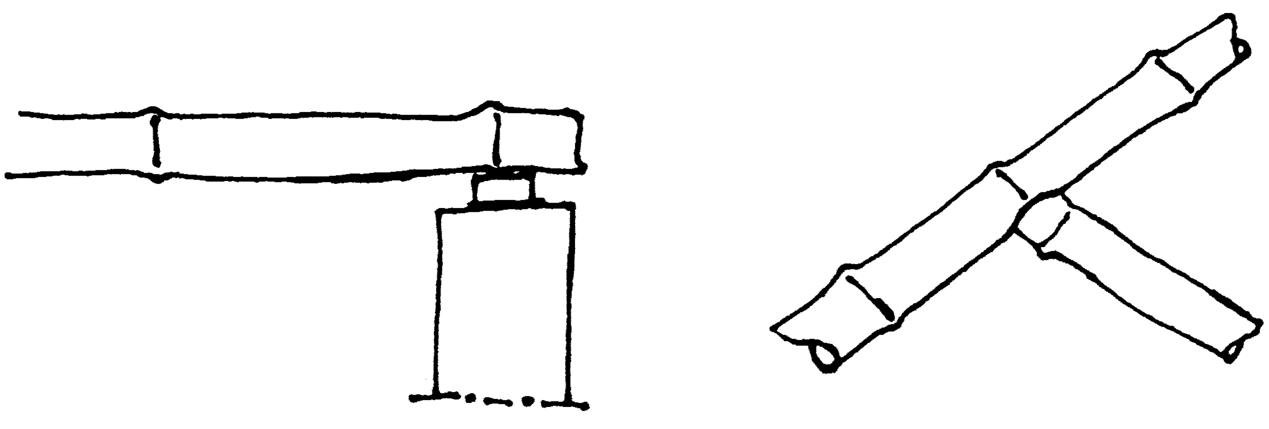
Bamboo compares well and favourably with other building materials like steel, concrete and timber over energy requirements during construction, strength and stiffness per unit area of material, ease and safety of use. To a great extent the versatility of bamboo is largely due to its anatomical structure which contributes to its mechanical properties.

1. The anatomy and the properties of bamboo:

Bamboo has promising mechanical properties, To understand this it is important to study its anatomical and morphological characteristics. In a circular cross-section bamboo is hollow. For structural uses this form has many advantages in comparison to a massive and rectangular cross-section (e.g. wood). Bamboo needs only 57% material when used for beam, and only 40% when used as a column. However, because of its tapered form bamboo is not viewed with favour by engineers – as the tapering causes a strength loss between 35-40%. In building structures beams and columns with the same strength along the full length are needed. But on careful examination this fact seems to be exaggerated because bamboo retains much of its strength in spite of the taper by the manner in which vessels and materials are distributed from top to bottom, e.g. a quarter sclerenchyma tissue more at the top than in the bottom of the culm (32% in the bottom, 41% at the top).

In the final analysis, there may be a total loss of about 15% only. The disadvantage does not disappear, but its influence is much less than many people fear.

The next factors affecting mechanical properties are the nodes and the diaphragms of the culm. These have a structural function in support, especially when two culms join together (Fig. 1).



At internodes the structure seems weaker. But the influence of diaphragms on the bending behaviour is still unknown. In Eindhoven we have carried out bending tests on full culms with and without diaphragms. The detailed analysis is still being carried out — the first impression shows no significant differences.

The outer skin of bamboo has a considerable amount of silica. It improves the natural durability but preliminary studies indicate that the mechanical strength of the culm is not tignificantly affected by its absence.

Bamboo is a composite. In mechanics a composite is a material composed of soft and weak material, stiff and strong material, In bamboo the former is cellulose and the latter lignin.

Other well known examples are reinforced concrete and glass fibre polyester. In materials-science composites are well known for their good properties, the properties of the whole being better than the sum of the component parts. The distribution of the cellulose in the cross-section of the wall of a culm contributes to the quality of strength of the material. On the outside the percentage of cellulose is as much as 60%, decreasing to a 20% on the inside. From a mechanical point of view the material on the outside is far more effective. As a result, the strength and stiffness of a bamboo culm is better than in a case where cellulose is distributed equally. Though the chemical composition of wood and bamboo do not differ very much, bamboo is twice as good in stiffness than wood. The reason for this is not known yet; the best hypothesis is the angle between the cellulose microfibrils and the cell-axis, being 20^0 for wood and only 10^O for bamboo. Bamboo does not have any rays. A ray is a weak spot, because it serves transport and storage of food. As a result, bamboo is far better in shear than wood, contrary to the general opinion. This last statement, however, is based on the thickness: 6 or 7 mm is normal for bamboo, but unheard of for wood.

2. The advantages of bamboo as a building material:

How does bamboo compare with three other common building materials: concrete, steel and timber? Evidently, such a comparison can only be rough and difficult as well, because each of these four consists a number of different variables. Given in the subsequent paragraphs are four factors for which comparisons are made. These are:

a. The energy needed for production: Energy has to be expended to produce any material, In the case of fabricating structural elements for the construction industry energy has to be used to produce a beam or column. One can measure the benefit of prodycing a column with different materials by working out amounts of energy needed to handle a certain amount of load. The energy needed for four constructing materials is given below in the table.

Table 1. Energy needed for production compared with stress when in use.

Material (1)	Energy for production MJ/kg (2)	Weight per volume kg/m^3 (3)	Energy for production MJ/m^3 (4)	Stress when in use N/mm^2 (5)	Ratio energy per unit stress (4)/(5)
Concrete	0.8	2,400	1,920	8	240
Steel	30	7,800	234.000	160	1.500
Wood	1.	600	600	7.5	80
Bamboo	0.5	600	300	12	25

Energy, needed for production, compared with stress when in use.

In column (2) data about energy is given which can be found in several handbooks on materials technology. The energy for wood deals with logging, sawing and transport, and the energy for bamboo with harvesting and transport only. Columns (3) and (4) are needed to obtain data on energy per volume, to be compared with the stresses in column (5). The result, the ratio between the energy for production and the stress in the material, is given in column (6).

It is seen from the last column that per equal unit of load bearing capacity, bamboo requires the least energy for its production. Timber is the second, reinforced concrete the third, and steel requires the most. These figures are not exact, they give only an order of magnitude. We can see, however, that steel and concrete make a heavy demand on a large part of the energy resources of the "missile" earth, contrary to wood and bamboo.

In fact, this table should be enlarged with the lifetime of the materials concerned, but then the energy demand of the several methods of preservation should be added as well.

Due to the fact that the energy in the production process is an important component of the price, it is tempting to state that bamboo is a very cheap building material, however this assumption is too simplistic and the temptation has to be avoided.

b. *The safety of the* material: Bamboo is considered generally a safe building material. Its capacity to survive an earthquake or a hurricane is well known. This capacity can be related to two mechanical properties.

i. The strain energy, i.e. the energy stored into the material during load bearing. The strain energy is defined as the surface of the stress-strain-diagram

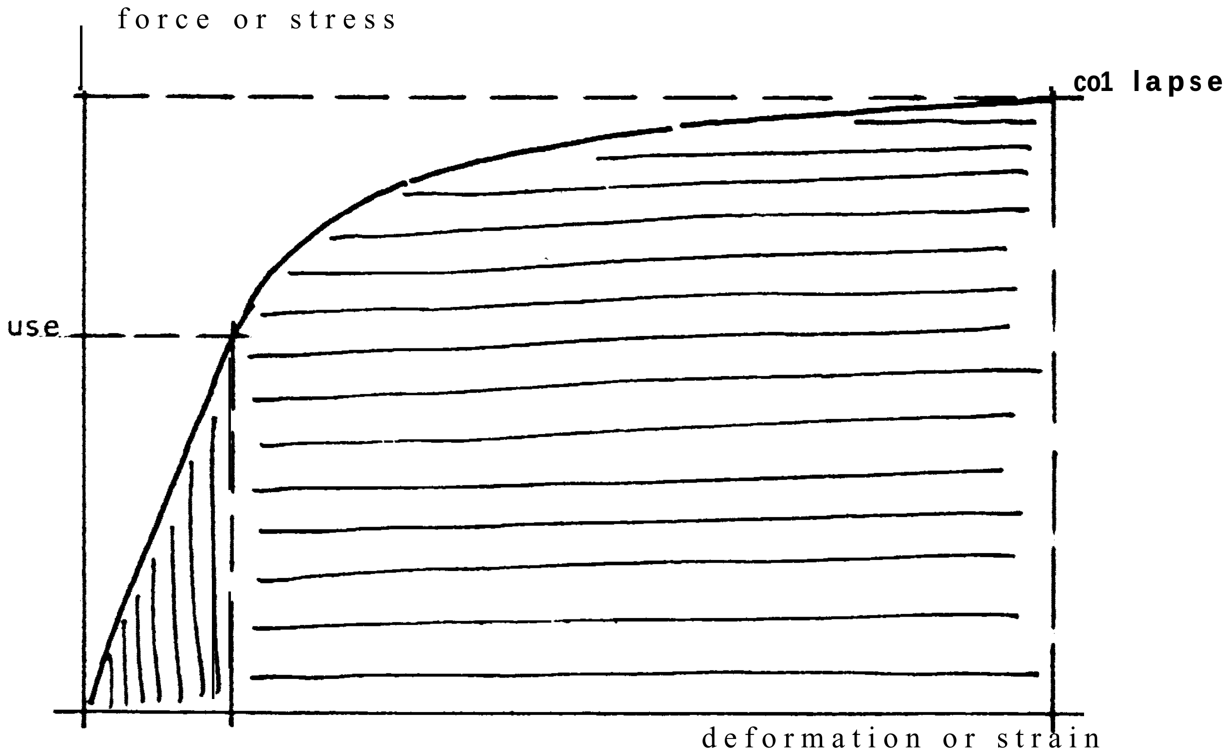


Fig. 2 Stress-strain diagram

A test on building materials results in a diagram, representing the relationship between the force, acting on the material, and the deformation of the material. The surface below this diagram represents the energy, 'stored in the material. (Fig.2)

The area, shaded vertically, represents the situation of a normal use of the material in a building,while the area,shaded horizontally, represents the situatjon of a collapse. Evidently, the ratio between the two areas is an estimation for the safety of the material. Calculations of this ratio show:

concrete	10
steel	1400
wood	20
bamboo	50

This means that from a safety point of view, steel is safest, bamboo second, wood the third and concrete last.

ii. A -second property deals with the deviation in the strength. Deviation means: when testing a building material, some specimens will behave very well, while others behave worse. The test results appear to be scattered around the mean value. In the case of steel, a well-controlled product, this scattering is very small and the allowable stress o can be about 60 percent of the mean strength om:

And the behaviour of concrete is in between these.

On the contrary, in the case of naturally grown products like wood and bamboo, the scattering is very wide, and consequently (to avoid the use of a bad specimen in a building) the allowable stress 'o', is only a 15 percent of the mean Strength om:

During an earthquake,cyclone,or any similar disaster, the stress in any building will increase, leaving from 'o', being the normal situation. In the above diagrams it can be seen that steel will collapse rather quickly, followed by concrete, with wood and bamboo in the last (and best!) place.

c. The strength and the stiffness per unit of material: In construction the strength and stiffness of a material is important. This can be measured by calculating the ratio between allowable stress and the mass per volume. Given below are figures for:

concrete	0.003
steel	0.020
wood	0.013
bamboo	0.017

in which bamboo appears to be the best one with respect to strength.

As to stiffness, the ratio between the Young's modulus and the mass per volume is used. (Figs. 3-5)

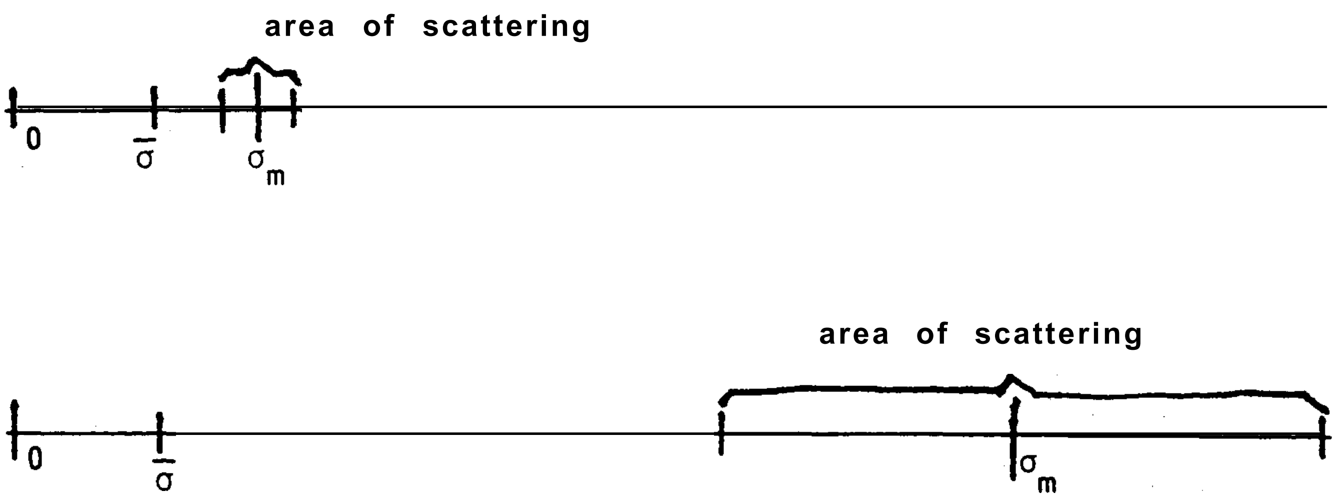


Fig. 3. Strength tests on (a) steel and (b) wood and bamboo

Taking all four together:

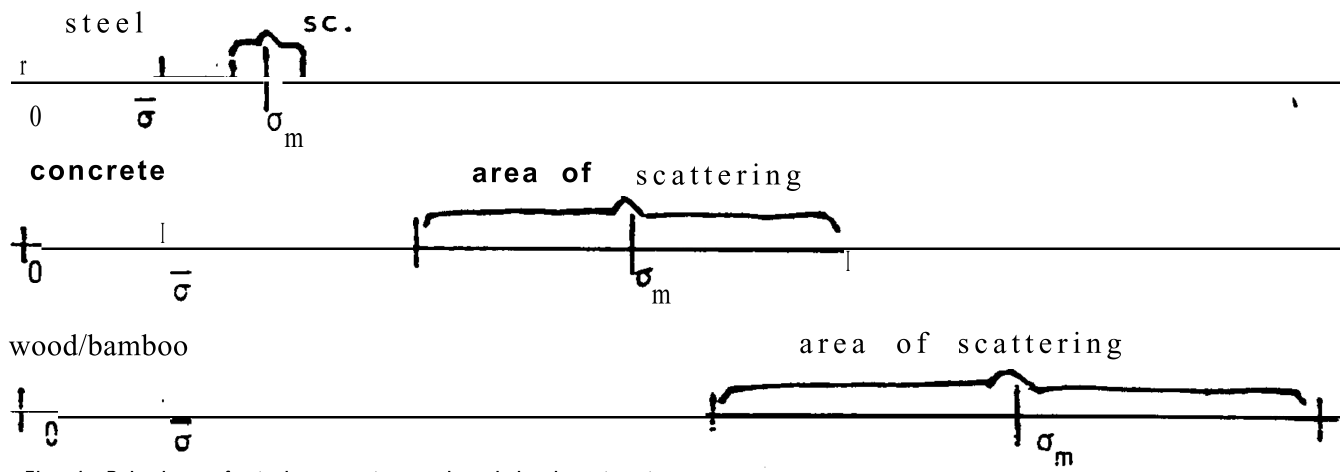


Fig. 4. Behaviour of steel, concrete wood and bamboo to stress.

concrete	10
steel	27
wood	18
bamboo	3 3

from which bamboo appears to be the best.

d. The simpleness of production: This aspect seems to be more "soft" than the three mentioned ahead; for the people who use bamboo, however, it is as important.

a. Building with steel and concrete does not belong to the normal possibilities for village people, in contradiction to wood and bamboo. However, in the case of wood one has to wait many years, but in the case of bamboo one can harvest the ripe culms each year.

b. An environmental advantage: in the case of wood a whole area is cut at once, but in the case of bamboo only the ripe culms are cut, while the younger culms (the majority!) are left. For the micro-climate and the environment this yearly partial crop is much better.

c. Due to its circular and hollow shape, only simple tools are needed for its cropping and use. With bamboo there is no sawing or logging like in the case of wood; waste material like bark and sawdust is unheard of.

d Bamboo is represented by many botanical species, each with its own properties. As a result one can find an appropriate bamboo for a variety of purposes.

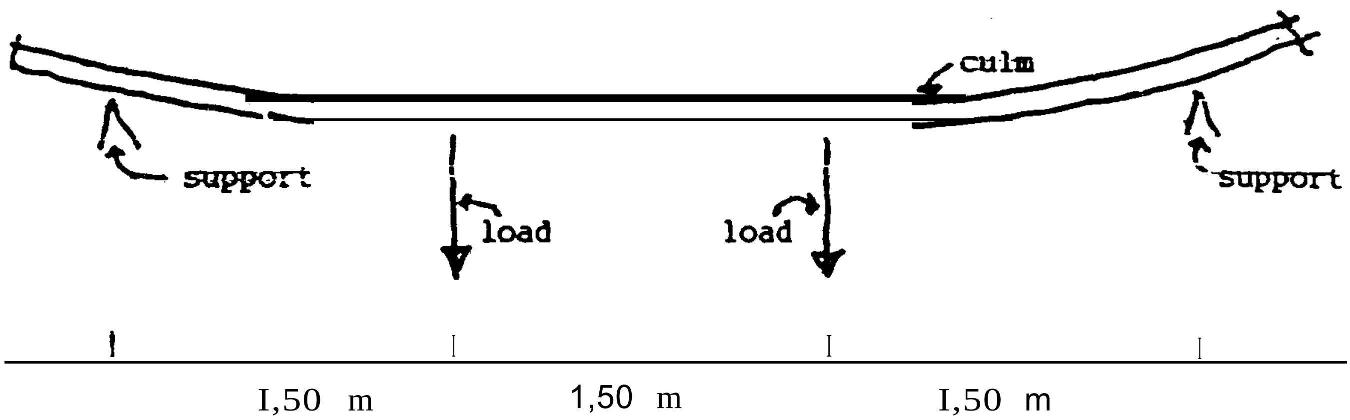


Fig. 5. Bending of bamboo Culm

3. The long term behaviour of bamboo under load:

Laboratory tests on the mechanical properties of bamboo are usually short-term tests. Building, however, is a long-term activity, and consequently we need long-term tests to learn about the long-term behaviour. Such tests have been carried out in the Eindhoven Bamboo Laboratory for the past three years (1982 – 1985). Tests have been carried out concerning the bending of bamboo culms, as follows:

Bambusa blumeana from the Philippines was obtained for the study and factors like

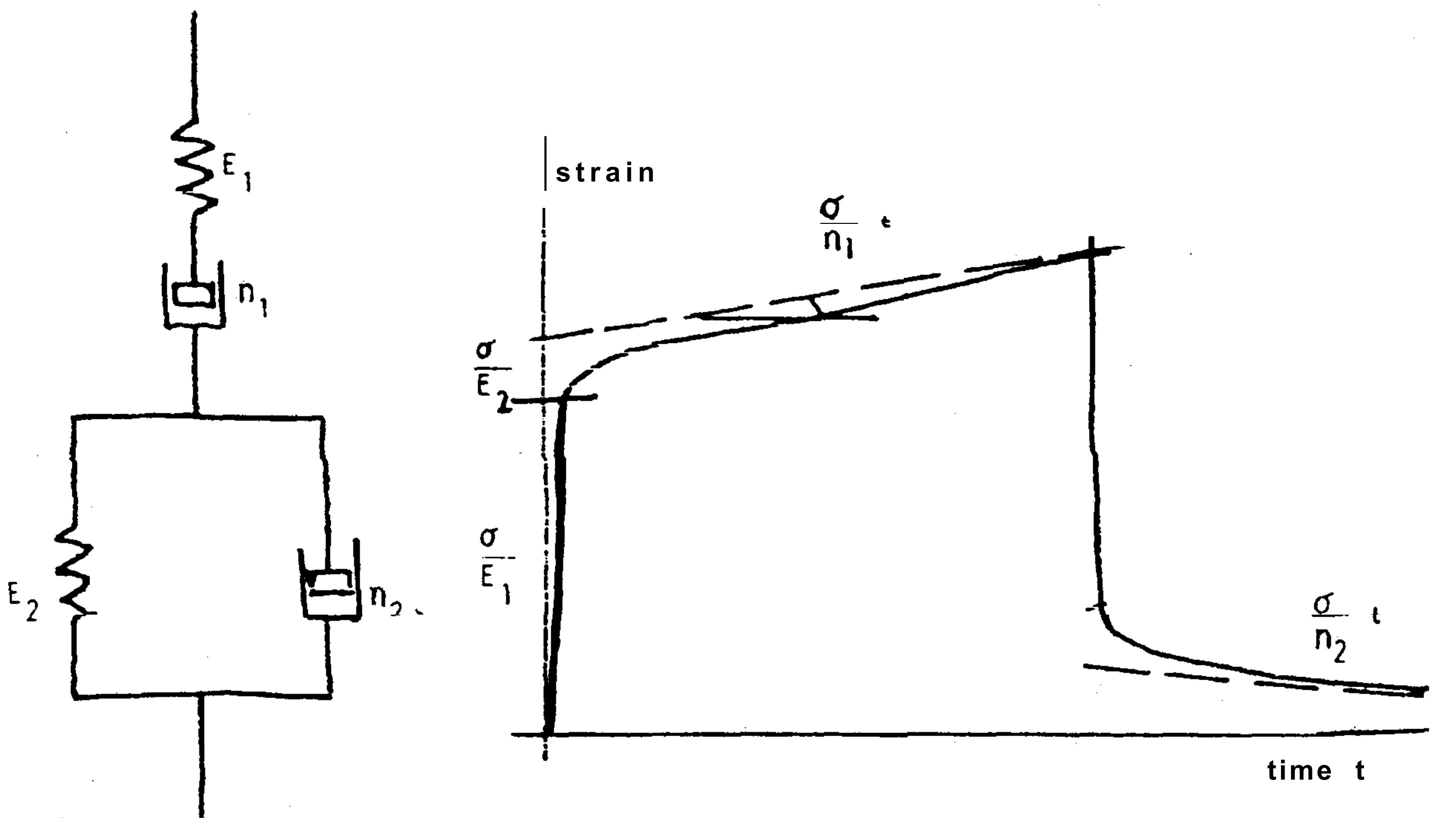


Fig. 6a & b. Creep and recovery using Burgers-model.

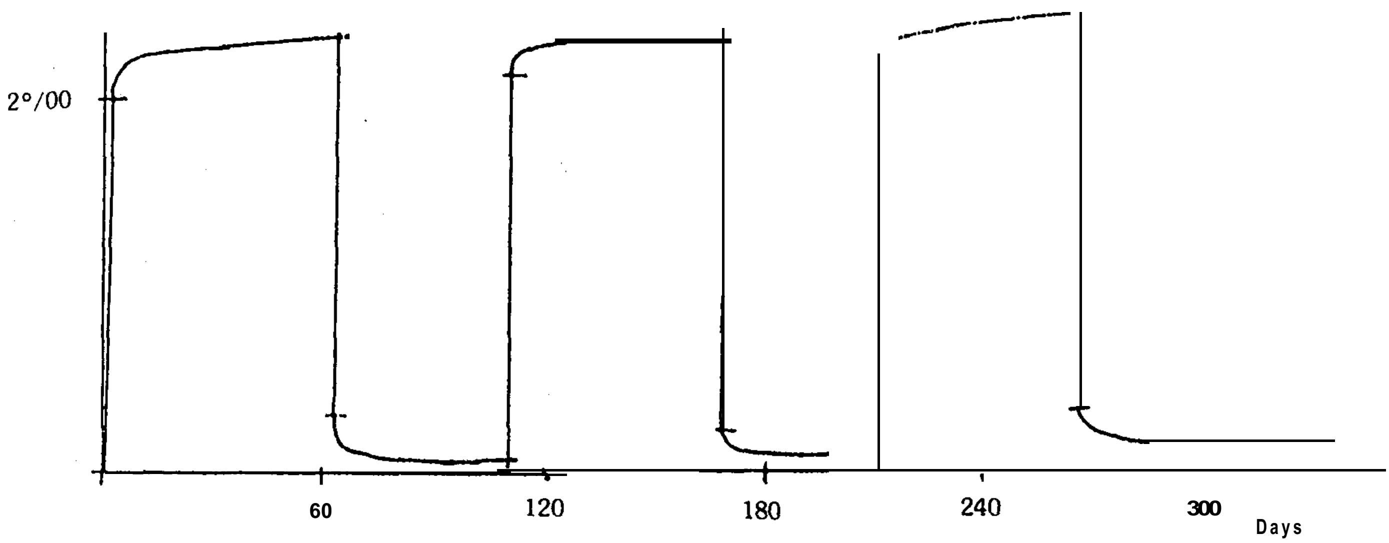


Fig. 7. Creep deformation

diameter, thickness of wall, mass per volume, fibre content and the angle between microfibrils and cell axis were taken into account. Samples were subjected to the test with and without diapraghms and outer skin with an m.c. of 8 and 12% with the ambient RH at 60 or 80%.

The load was applied in such a way that the initial strain was 2 pro mille. Creep and recovery were studied during eight to six weeks each and this was carried out four times. Unfortunately, the analysis has not been completed and preliminary trends can be seen. (Figs. 6. 7)

Firstly: creep and recovery in bamboo can be described with a Burgers-model, as follows:

in which:

σ is the applied stress, kept constant.

$\frac{\sigma}{E_1}$ is the immediate deformation, the immediate strain; the cellulose acting as a spring; this strain is elastic, it disappears with the load; it happens in the crystalline part of the cellulose.

$\frac{\sigma}{E_2}$ is the creep, the increase of strain with time.

η_1 is a viscous component, symbolized as a dashpot; it is a plastic deformation caused by a sliding between cellulose chains in the amorphous part of the cellulose, and by a deformation in the amorphous lignin; this strain disappears with the load.

η_2 is the permanent deformation, remaining after removal of the load.

The use of this mathematical model is to calculate the said E's and n's as physical properties.

Secondly, the deformation which remains after removal of the load, is for bamboo only 5 to 10 percent of the immediate deformation, to be compared with 50 to 100 percent in the case of wood. For practical purposes this is wonderful; detailed analysis has to be done to test the data for scientific rigour.

Physico-Mechanical Properties and Anatomical Relationships of Some Philippine Bamboos

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Abstract

This report includes the physico-mechanical properties and anatomical characters of Bambusa blumeana and Gigantochloa levis. Physico-mechanical properties such as relative density, shrinkage, moisture content, static bending and compression parallel to the grain were correlated to anatomical characteristics, e.g., fibrovascular bundle frequency and dimensions of fiber and vessel. Results showed that there is an increase in compressive and bending strengths towards the top portion of the culm of both species. This trend could be attributed to the significant increases in relative density and fibrovascular bundle frequency.

Introduction

Housing is one of the basic needs of man. The pressures of population on the dwindling supply of commonly used timbers for housing calls for research and development efforts on the use of non-timber forest products, particularly bamboo. Certain aspects of the properties and use of these resources have been neglected. If studied, the results may help the efficient use of bamboo materials for housing components.

A knowledge of the physical and mechanical properties in relation to the anatomical characteristics of erect bamboo is necessary in assessing its potential uses as building material for housing, furniture making and for general construction work and in converting it to a variety of finished products. Furthermore, the different properties of this resource will not only serve as a basis for promoting its acceptance but also for improving its market potential.

Several studies on characteristics and properties of *B. blumeana* and G. levis were undertaken (Tamolang et al., 1980). Velasquez and Santos (1931) studied five species of bamboos and claimed that *B. blumeana* was one of the most common and widely distributed bamboos in the Philippines, occurring in cultivation throughout settled areas at low altitudes.

B. blumeana was purposely introduced from Malaysia during pre-historic times (Merrill, 1916). It is, by far, the most valuable and popular species of bamboo used for construction in rural areas. The stem of B. *blumeana* consists of a hollow culm with distinct nodes and internodes. It grows from 10 to 25 m high and reaches a diameter of 80 to 150 mm. It is erect, nearly straight from the base'upward and gently bending ata the top. The basal portion of the clump is surrounded by a dense thicket, 2 to 3 m high, of spiny branches.

On the other hand, G. *levis* may be considered as an exotic species (Merrill, 1916). It grows in certain areas of the Philippines and also in dense forests, especially in moist places in ravines or depressions near streams. Its general appearance resembles that of B. *blumeana* although its culm is stout, straight and smooth with very much less prominent nodes than *B. blumeana.* It reaches a height of 10 to 25 m and a diameter of 100 to 200 mm. Brown and Fischer (1918) said that the stems of this bamboo species are only used as pipes for temporary water supply and for building fish traps; rarely used for building operations, except for walls of houses, because they are especially durable.

Bamboos, in general, belong to the Barn-. buseae tribe of the huge family Gramineae (Sineath et al., 1953)) characterized by hollow or rarely solid stems that are closed at the joints or nodes. The anatomical structure of the two species considered in this report were studied (Velasquez and Santos, 1931; Grosser and Zamuco, 1971; Zamuco and Tongacan, 1973). The compact fiber tissues are present in the outer part of the culm, whereas the inner part is mostly of parenchyma cells. A study of B. blumeana (Espinosa, 1930) showed that for all engineering purposes, a culm about 300 mm in circumference, when loaded at the center on a span of 1.52 m can support 500 kilograms weight. When used as a post or column of about 1.22 m, it can support 4,000 kg.

Espiloy (1979, 1983) studied the variability of specific gravity, silica content and fiber measurements in B. blumeana; a strong positive correlation was found to exist between specific gravity and cell wall thickness and silica content. The anatomical structure of the bamboo culm is the basis for understanding the physical properties of bamboo, and is responsible for specific gravity, silica content and fiber dimension to vary across and along the bamboo culm.

The chemical properties and eating qualities of shoots of three ages (7, 10 and 15 days after emergence) of B blumeana, G. leuis and four other species were studied (Gonzales and Apostol, 1978). Chemical analysis of the nutrient components showed that age level had no effect on nutrient content. Results of a taste test disclosed that 15 day-old B. blumeana shoots were the most acceptable as far as colour, texture and taste are concerned.

Escolano et al. (1964) found B. blumeana suitable for pulp and paper making and that this species yields good quality bond, airmail bond, onion skin, offset book, kraft, wrapping and bag papers. Likewise, Semana (1967) found the same species to be a suitable raw material for kraft pulps due to its pulp strength, pulp yield and acceptable level of silica content.

Bamboos. are very susceptible to the attack of decay fungi and powder-post beetles, particularly Dinoderus minutus Fabr. (Casin and Mosteiro, 1970). The presence of starch in bamboo contributes to its susceptibility to beetle attack (Liese, 1980). A tentative classification showing the natural resistance of some bamboo species to fungal attack was made (de Guzman, 1978), based mostly on percentage weight loss of specimens after four months of exposure. B. blumeana and G. *leuis* were considered moderately resistant.

Present Studies: In the present studies, the author determined the effect of fibrovascular bundle frequency, culm, wall thickness, diameter and length or span of material on the different physical and mechanical properties along the culm length. The interrelationships of the different physical and mechanical properties in relation to their anatomical characteristics within and between species were also evaluated to ascertain their suitability for various uses, especially in housing.

Five culms each of three-year old B. blumeana and G. leuis were used in this study. The culm length, diameter, length and number of internodes per culm were recorded. Representative sections of the butt, middle and top portions were cut into segments comprising of eight whole-length internodes. The segments and internodal sections were number-coded to indicate their original positions in the culm. Each eight-internodal section was further cut for use in the different tests. In general, the standard test procedure of the American Society for Testing Materials for small clear specimens of timber was followed for determination of physical and mechanical properties. The data obtained are the average properties of the material in green condition. The frequency of fibrovascular bundles per unit area was determined directly using a calibrated magnifier, "Scale lope" at 20 x magnification. The length, width, lumen diameter and cell wall thickness of fibers and vessel length and diameter were determined,

Physical and Mechanical Properties: Culm height, number of internodes per culm, length and diameter of internodes, and culm wall thickness of Bambusa blumeana and Gigantochloa leuis are presented in Table 1. *B. blumeana* has longer and more internodes per culm and thicker culm walls than G. leuis; the latter is taller and the diameter of its internodes is bigger than the former. The average

Table 1. Physical data forculms of B. blumeona **and G.** leuis **collected in Bayog,** Los **Banos. Laguna and Nagcarlan, Laguna, respectively.**

Property	Species	
	B. blumeana (Kauayan-tinik)	G. leuis (Bolo)
1. Culm height (m)	i2.9	14.9
2. Number of internodes per culm	40.0	36.7
3. Internode length (mm)		
a) Butt	284.00	200.4
b) Middle	432.7	455.4
c) Top	321.0	264.8
Average	345.9	306.9
4. Internode diameter (mm)		
a) Butt	101.4	121.2
b) Middle	80.5	94.1
c) TOP	41.0	40.0
Average	74.3	85.1
5. Culm wall thickness (mm)		
a) Butt	19.4	12.2
b) Middle	9.1	8.7
c) TOP	6.3	5.8
Average	11.6	8.9

Table 2. Average physical and mechanical properties of B. blumeana **and G.. leuis.**

Property	Species							
	B. *blumeano* (kauayan-tinik)				G. levis (Bole)			
	Butt	Middle	Top	Average	Butt	Middle	TOP	Average
1. Moisture Content (%)	194.7	114.0	98.8	135.8	143.0	115.1	93.8	117.3
2. Relative Density'	0.388	0.537	0.585	0.503	0.474	0.539	0.610	0.541
3. Shrinkage (%)								
a) Thickness	16.6	13.3	10.0	13.3	12.9	11.3	8.9	11.0
b) Width	12.0	6.2	4.8	7.7	8.0	6.5	5.2	6.6
4. Compression Parallel to Grain. Maximum crushing strength (MPa)								
a) Nodal	34.7	37.2	37.3	36.4	37.7	41.9	44.3	41.3
b) Internodal	35.9	39.5	39.5	38.3	38.7	41.7	43.4	41.3
5. Static Bending'								
a) Stress at proportional limit (MPa)	29.5	20.2	18.2	22.6	17.6	14.9	18.6	17.0
b) Modulus of rupture (MPa)	43.2	28.4	24.7	32.1	25.4	19.6	26.1	23.7
c) Modulus of elasticity (1000 MPa)	8.9	8.8	9.2	9.0	8.9	10.4	11.0	10.1

Based on volume at test and weight when oven-dry

• **From green to oven-dry condition**

Tested at green condition.

results of the different physical and mechanical properties of the two bamboo species are given in Table 2. The summary of analyses of variance based on the mean squares and statistical significance of physical and mechanical properties of the two species is shown in

Table 3. Summary of analyses of variance on physical and mechanical properties of B. blumeana and G. levis.

Source of Variation	Mean Squares and Statistical Significance							
	Physical Properties				Mechanical Properties			
			Shrinkage			Static Bending		
	Moisture Content	Relative Density	Thickness	Width	Compression parallel to grain (maximum crushing strength)	Stress at Proportional limit (SPL)	Modulus of rupture (MOR)	Modulus of elasticity (MOE)
Treatment (Butt. Mid, Top)	51129.90'	0.3321'	243.09'	239.38'	5443.019"	10884.936^{ns}	32240.700^{ns}	300.237"'
Block (species)	13038.32^{ns}	0.0300^{ns}	196.86^{ns}	45.88"'	24040.017"	24741.482"'	55126.533"'	908.900^{ns}
cv (X) %	63.88	29.60	68.50	80.12	3.97	48.67	54.35	17.26

- Significant at 95% level of probability
- Significant at 99% level of probability

ns Not significar

Table 3.

For both species, moisture content and shrinkages on thickness and width decreased towards the top while their relative density values increased towards the top. Results show that there is a significant difference in all the physical property values investigated at three height levels but none between species. There was a general trend of increasing maximum crushing strength (MCS) values from butt to top portions which was found highly significant at three height levels and between species. On the other hand, there was no distinct trend in bending properties, i.e., stress at proportional limit (SPL), modulus of rupture (MOR), and modulus of elasticity (MOE) although most of the highest strength values were observed at the top portions. However, such differences in bending properties at three height levels and between species were found insignificant. As in wood (Heck, 1956) the strength properties in bending of bamboo are correlated with specific gravity or relative density.

Anatomical Properties and Characteristics: Some anatomical properties and characteristics of the two species which include frequency of fibrovascular bundles and dimensions of fibers and vessels are shown in Table 4. B. blumeana averaged higher than G. *leuis* in fibrovascular bundle frequency, but their respective values increased from the butt towards the top portion. G. *leuis* averaged higher than B. blumeana in all vessel and fiber dimensions, except for fiber length. A summary of analyses of variance based on

Table 4. Some anatomical properties and characteristics of blumeana and G. leuis.

Property	Species							
	B. blumeona (kauayan-tinik)				G. levis (Bolo)			
	Bun	Middle	Top	Average	Butt	Middle	Top	Average
1. Fibrovascular bundle frequency (No. per sq. mm)	1.74	3.12	3.80	2.89	1.11	1.50	2 06	1.56
2. Fiber dimensions (mm)								
a) Fiber length	2.50	2.55	2.63	2.56	1.88	1.52	2.05	1 82
b) Fiber diameter	0.0148	0.0152	0.0142	0.0147	0.0165	0.0155	0.0159	0 0160
c) Lumen diameter	0.0046	0.0032	0.0034	0.0037	0.0056	00036	0.0065	0.0052
d) Cell wall thickness	0.0052	0.0061	0.0054	0.0056	0.0060	0.0058	0.0059	0.0059
3. Vessel dimensions (mm)								
a) Vessel length	0.8228	0.7068	0.8294	0.7863	1.1305	0.6776	0 5957	0.8013
b) Vessel diameter	0.1862	0.1366	0.1736	0.1655	0.2310	0.2308	0.1989	0.2202

Table 5. Summary of analyses of variance on some anatomical properties and characteristics of *B. blumeana* and *G. levis*.

Source of Variation	Mean Squares and Statistical Significance						
	Fibrovascular bundle frequency	Fiber dimensions				Vessel dimensions	
		Fiber length	Fiber diameter	Lumen diameter	Cell wall thickness	Vessel length	Vessel diameter
Treatment (Butt. Middle, Top)	179.681"	0.238^{ns}	3.22g^{ns}	19 769'	' 0.420'	1496.542"	43.972^{ns}
Block (Species)	837.801"	4.019"	43.471"	17.170"	6.914"	4945.081"	1314.614"
cv (X) %	56.55	14.49	26.85	38.09	5.49	20.64	24.33

ns — Not significant

' * — Significant at 99% level of probability

mean squares and statistical significance of their anatomical properties and characteristics is shown in Table 5.

Results show that differences in fibro-vascular bundle frequencies at three height levels and between species were found highly significant. Likewise, almost all fiber and vessel characteristics and properties between species and in three height levels were found highly significant except for length and diameter of fiber and diameter of vessel (Table 4).

Correlation of Physical and Mechanical Properties with Anatomical Structure: The physical and mechanical properties of the two species which were correlated with their respective anatomical structure are shown in Tables 6 and 7.

Table 6. Correlation coefficients of different physical and mechanical properties with some anatomical structure of *B. blumeana*.

	Fibrovascular bundle frequency	Fiber length	Fiber diameter	Lumen diameter	Cell wall thickness	Vessel length	Vessel diameter
Moisture content	0.035	0.2%	0.290	0.347	0.035	- .014	0.025
Relative density	-0.017	- 0.272	-0.186	- 0.331	0.111	0.363	0.463
Shrinkage (thickness)	-0.182	-0.162	-0.126	-0.268	0.079	- 0.059	- 0.010
Shrinkage (width)	-0.633'	-0.193	0.003	- 0.208	0.188	0.072	0.025
Maximum crushing strength	0.121	- 0.310	-0.181	-0.262	- 0.060	10.103	0.307
Stress at proportional limit	0.063	0.535'	0.517	0.492	0.243	0.188	-0.003
Modulus of rupture	0.121	0.468	0.417	0.417	0.154	0.317	-0.221
Modulus of elasticity	0.716'	-0.177	0.043	-0.067	-0.130	-0.068	-0.256

* Significant at 95% level of probability

Table 7. Correlation coefficients of different physical and mechanical properties with some anatomical structure of *G. levis*.

	Fibrovascular bundle frequency	Fiber length	Fiber diameter	Lumen diameter	Cell wall thickness	Vessel length	Vessel diameter
Moisture content	-0.170	-0.130	0.080	0.310	-0.100	0.230	0.320
Relative density	0.110	0.180	- 0.080	- 0.260	-0.080	-0.18	-0.270
Shrinkage (thickness)	- 0.366	0.095	0.011	-0.027	0.110	0.446	0.154
Shrinkage (width)	-0.528'	0.131	0.199	0.217	0.023	0.366	0.219
Maximum crushing strength	0.020	0.270	0.060	- 0.810'	0.170	-0.480	-0.280
Stress at proportional limit	-0.530'	-0.810'	0.420	0.490	-0.100	- 0.245	0.240
Modulus of rupture	-0.510'	- 0.220	0.250	0.460	-0.103	- 0.230	0.290
Modulus of elasticity	- 0.080	-0.090	0.160	0.130	0.004	-0.130	- 0.003

. Significant at 95% level of probability

Table 8. Correlation coefficients of physical characteristics of specimens with compressive and bending properties of B. blumeona and G. leuis.

	B blumeana (Kauayan-tinik)						G levis (Bolo)					
	Comprerssion parallel to grain		Static bending				Compression parallel to grain		Static bending			
Physical Characteristics of Specimen	Maximum crushing strength	Relative density	Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Relative density	Maximum crushing strength	Relative density	Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Relative density
Outside diameter	-0.230	-0.208	0.081	0.081	-0.260	-0.293	-0448'	-0434'	-0 124	-0.230	-0363	-0.789'
Length/Span	-0.290	-0.436	0.081	0.080	-0.261	-0.293	-0668'	-0.441'	-0.125	-0.230	-0.362	-0.790.
Culm wall thickness	-0.290	-0.436'	0.617'	-670*	-0 175	-0462	-0.668'	-0.441*	-0.120	-0.163	-0.795'	-0615'

'Significant at 95% level of probability

In B. blumeona (Table 6), fibrovascular bundle frequency is negatively correlated with shrinkage on width of specimens (r = – 0.528*), stress at proportional limit (r = -0.530*), and modulus of rupture (r = -0.510'). This means that an increase in fibrovascular bundle frequency towards the top portion of the culm may result in decreased shrinkage on width, stress at proportional limit and modulus of rupture values, as can be seen in Table 2.

There was also a negative correlation between stress at proportional limit and fiber length (r = -0.810') and between maximum crushing strength with lumen diameter (r = -0.810'). This implies that decreased stress at proportional limit towards the top portion may be due to increased fiber length and that an increased maximum crushing strength towards the top may' be due to decreased lumen diameter resulting in thicker walls, as can be seen in Tables 2 and 4.

On the other hand, the fibrovascular bundle frequency in G. leuis (Table 7) was also negatively correlated with shrinkage on width (r = -0.633') of specimens but positively correlated with modulus of elasticity (r = 0.716'). Stress at proportional limit was also positively correlated with fiber length (r = 0.535'). This implies that the increased modulus of elasticity towards the top portion is due to the increased fibrovascular bundle frequency where decreased shrinkage also occurred. The length of fiber has something to do with the increased values in stress at proportional limit towards the top portion of the culm, as seen in Tables 2 and 4.

Correlation of Physical Characteristics of Specimens with Compressive and Bending Properties: Table 8 shows the correlation of outside diameter, length or span and culm wall thickness of specimens with compressive and bending properties of the two species. In B. blumeano, the length or span and culm wall thickness with same values of (r = – 0.436') were negatively correlated with relative density in compression whereas the culm wall thickness was positively correlated with bending properties such as stress at proportional limit (r = 0.617') and modulus of rupture (r = 0.670'). This means that as the culm wall thickness decreases towards the top, there is a corresponding decrease in stress at proportional limit and modulus of rupture where increased relative density also occurred (Table 2).

In G. leuis, the outside diameter, length or span and culm wall thickness of specimens were negatively correlated with maximum crushing strength and relative densities both in compressive and bending properties. Likewise, there was also a negative correlation between culm wall thickness and modulus of elasticity (r = -0.795'). This implies that a decrease in any of the physical characteristics of specimens may result in a corresponding increase in relative density and maximum crushing strength of the materials (Table 2).

Conclusions and Recommendations

This study has disclosed some interesting facts regarding the different properties of B. blumeana and G. leuis.

Based from test results, *B. blumeana* was found to have a considerably lower relative density than G. *levis* which is associated with higher moisture content and shrinkage values. G. *levis* was found to have a higher maximum crushing strength than the former but was weaker in bending strengths, except for modulus of elasticity.

With regard to their anatomical structure, *B. blumeana* averaged higher than G. *levis* in fibrovascular bundle frequency but lower in all fiber and vessel dimensions, except for fiber length. Anatomically, relative density is regarded as a function of the ratio of cell wall volume to cell void volume. As such, it is affected by cell wall thickness and structure, cell width, the relative proportions of different types of cells, and the kind and amount of extractives present. Moreover, relative density is a measure of the strength properties of a material. The findings of other investigators were verified in this study. The general increase in compressive and bending strengths towards the top portion of the whole culm could be attributed to the significant increases in relative density and fibrovascular bundle frequency towards the same direction along the culm length.

Similar studies on other bamboo species should be undertaken. Further investigation is necessary to confirm these findings, which at this point can be considered preliminary. The findings must be interpreted with caution, since the results may not hold true for other bamboo species growing in another site and subjected to varying environmental conditions.

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Diseases

Bamboo Blight in the Village Groves of Bangladesh

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Abstract

Bamboo blight is an important disease of village grown bamboo in Bangladesh. The blight first affects new culms but may also continue into older ones. The symptoms of the disease *have been* briefly described. ***Coniothyrium fuckelii*** Sac. and ***Acremonium strictum*** W. Gams *are* commonly isolated from blighted bamboo *culms. The results of* isolation of fungi and pathogenicity tests *are* presented. In the experiments performed ***A. strictum*** produces blight symptoms. Previously infected *culms show a* higher incidence of disease *when* compared to new *culms which* developed from healthy parent *culms.* pH of soil of bamboo clumps, carbon and nitrogen contents of bamboo culms *are not* associated with the development and severity of blight.

Various control measures have been attempted which range from improued cultural practices to field tests with fungicides. Dithane M 45 is *able to* reduce *the* amount of blight developing *in culms.* Remouing blighted bamboos, burning debris **in situ** and putting new soil in clumps significantly increased the survival of *new culms.*

Introduction

Bangladesh lies between 20.75° and 25.75° North Latitudes and 88.30° and 92.75° East Longitudes. It has an area of 143,997 square kilometres. The climate of Bangladesh is tropical. Summers are hot and wet, while the winters are cool and dry. The temperature varies from 52°F to 84°F in winter and 70°F to 94°F in summer. Total annual rainfall varies from 1,200 mm to 3,500 mm. Nearly 80 per cent of the annual rain falls between June and October. Humidity is generally high through most of the year raising to almost 90 per cent in the rainy season. Bamboo is an important economic crop in Bangladesh and of the 18 commercially useful species described by Alam (1982), three are specially important. They are Bambusa balcooa, *B.* Vulgaris and B. tulda.

Bamboo blight was first noticed in some parts of Rajshahi district. General information on the symptoms and isolation of fungi associated with blighted bamboo tissues have been reported by Rahman and Ole Zethner (1971), Gibson (1975) and Rahman (1978). The latter also provided a review of reported bamboo diseases. Pawsey (1980) included some historical background and importance of the problem. Boa and Rahman (1983) reported the history of bamboo blight and its epidemiology, described the disease and recorded its etiology and on the spread of the disease. Rahman and Khisha (1981) ascribed Acremonium strictum W. Gams as a pathogen which can cause bamboo blight. Rahman, Khisha and Basak (1983) reported on some of the factors relating to regeneration and mortality of two bamboo species. This paper reviews earlier findings and reports more recent work on bamboo blight.

Symptoms Of Bamboo Blight

Mortality of bamboos, particularly those in the village groves, mainly occur in two stages: i) mortality of very young emerging culms generally within heights of 40 cm, and ii) mortality of newly growing culms which attain heights of about 1 m to 5 m. The former type of mortality is very common (Rahman, Khisa and Basak, 1983; Banik, 1983) but the actual cause of mortality of emerging culms is not known. Banik (1983) has suggested that eco-physiological conditions and genetic make up of each species and clump seem to influence the rate of mortality of emerging culm in bamboo. Mortality of growing culms, generally within heights of l-5 m, is by far the most damaging. The death of the small emerging culms, start as a light brown to brown discolouration of culm and culm sheaths. Discolouration may start either at the top or near soil level or along any side of the emerging culm. With the advance of discolouration and decay, the culms fail to develop and ultimately rot and disintegrate. The symptoms of the blight of growing culms have been reported (Rahman, 1978: Rahman and Khisa, 1981). Boa and Rahman 1983) and is covered more thoroughly by Boa, 1985 (in this proceedings).

Isolation Of Fungi

Fungi were isolated from diseased Bambusa balcooa collected from Chapai Nawabganj in Rajshahi (in the western part of the country) and also from Forest Research Institute campus; and from *B.* vulgaris from Chittagong, on the eastern part of the country, on Potato sucrose Agar or 2% Malt Agar medium using standard phytopathological techniques. Isolations of fungi from B. balcooa were from diseased (i) culm sheaths (ii) young culms (iii) older culms (iv) young branches (v) leaf sheaths and from healthy branches and culms. Details of the results of isolation have been published elsewhere (Rahman, 1978; Rahman and Khisha, 1981). These isolations predominantly yielded Coniothyrium fuckelii Sac. But from blighted young branches and leaf sheaths of B. balcooa, and also from blighted older culms and young branches of B. vulgaris, Acremonium strictum W. Cams, was most dominantly present. C. fuckelii was also isolated from blighted older culms of B. oulgaris. Other isolates including Fusarium ***moniliformae*** Sheld, F. equiseti (Corda) Sacc., Staehybotris bisbui (Sriniv.) Barron were isolated only to a lesser extent.

Pathogenecity Tests

Artificial inoculations with fungi C. fuckelii S. bisbvi. A. strictus and F. moniliformae were carried out on young culms of **B. balcooa** and ***B.*** Vulgaris. Inoculations were carried out with or without any artificial injury on the host. Spore suspension (S.S.) and artificially infected bamboo blocks (1.B.B.) were used as inocula for pathogenicity tests.

The data in Table 1 reveal that inoculation

Table 1. Results of artificial inoculation of Bambusa balcooa in Rajshahi by Coniothdum fuckelii. Stachvboris bisbvi and Fusarium moniliformae.

Inoculant	Inocula type	Part inoculated	Treatment replication		% infected	
					nodal bud	inter node
Coniothyium fuckelii	S.S.	culm sheath	Inoculated	— 40	3	0
			Control	— 20	0	0
	S.S.	nodal bud	Inoculated	22	50	50
			Control	— 9	33	22
	I.B.B.	internode	Inoculated	— 25	24	28
			Control	— 7	28	0
Stachybotris bisbvi	I.B.B.	nodal bud & internode	Inoculated	— 12	67	0
			Control	— 4	25	0
	S.S.	culm sheath	Inoculated	21	0	0
			Control	— 7	0	0
Fusarium moniliformae	S.S.	culm sheath	Inoculated	— 15	0	0
			Control	— 15	0	0

Table 2. Results of artificial inoculation of Bambusa balcooa and B. vulgaris in Chittagong by Acremonium stricturn •

Bamboo Species	State of growth of culms or branches	Treatment	No. of culms/ branches		Symptoms
			Inoculated	Infected	
B. balcooa	— Young branch from culm cutting in shade	Inoculation Control	13 13	10"' 1	Typical blight symptom
	— Young branch from culm cutting in the open	Inoculation Control	12 12	8' 0	Typical blight
B. vulgaris	— Young culm still covered with culm sheaths	Inoculation Control	25 25	13' 6	Typical blight symptom

' The data have been adapted from Rahman & Khisha (1981)

with either *C. fuckelii*. *S. bisbui* or *F. moniliformoe* did not show any significant infection as compared to the controls indicating that none of these fungi was a primary pathogen of bamboo blight.

Development of symptoms and resultant blight of young growing branches from ground layered culm cuttings of *B. balcooa* were severe when the host materials were grown either in the shade or in the open. In both the cases, higher numbers of inoculated branches developed blight symptoms as compared to the corresponding controls. Artificially infected branches also yielded *A. strictum* consistently. A significantly higher number of the inoculated culms of *B. vulgaris* developed infection as comapared to that of the controls. About one month after inoculation some of the inoculated culms were found to have developed necrosis on the culm sheaths. Removal of some of the culm sheaths revealed that discolouration also extended to the tender culm undernearth. *A. strictrum* was retrieved from the infected culm and culm sheath. Such culms developed a dead top within one month's time rendering the symptoms typical of bamboo blight (Rahman & Khisha, 1981).

In the present study *A. stricturn* has been found to be a primary pathogen of blight of *B. balcooa* and *B. vulgaris* (Table 2). This fungus has also been reported to cause leaf spot of Fig in Louisiana (Tim 1941). stalk rot (Gupta and Renfro 1972) disease of maize and leaf rot of Betelvine in India (Singh and Jeshi 1973), wilt of Chrysanthemum maximum in California (Chase, 1978, Chase and Munnecke 1980), stem necrosis of Sunflower IN Indiana (Richerson 1981), black bundle disease of corn (Barnett and Binder 1973). brown stem rot of Soybean (Presley and Allington 1947). Chase and Munnecke (1980) also noted that the host plant had to be stressed by excessive soil moisture or by the onset of flowering to obtain symptoms comparable with those on field symptoms. Unlike *A. stricturn* infections of Maize (Raju and Lal 1977) or *C. maximum* (Chase and Munnecke 1980). development of symptoms in bamboo was observed from the early stages of culm growth. It is suggested that in the case of bamboo blight, infections were soilborne and occurred before or during emergence of new culm through the soil.

Field Trials To Control Bamboo Blight

In a recent experiment six blighted clumps of *B. vulgaris* in Chittagong were treated with Copper oxychloride and five clumps with Dithane M 45 (a complex of zinc and maneb containing 20% managese and 2.5% zinc) as soil drench in late July 1984. Five almost similarly blighted clumps were kept untreated

Table 3. Effect of cultuml measures and fungicfdal treatments on the survival of new culms of bamboos.

Species (locality)	Treatments	Number of clumps	Number of new culms		% survival	CV%
			Developed	Survived		
B. balcooa (Rajshahi)	Blighted bamboos cut and removed, debris burnt in clumps and new soil added.	15	**568**	**263**	**43.30''**	**28.90**
	Blighted bamboos cut and removed, and new soil added.	**5**	**120**	**35**	**29.17**	**39.49**
	Controls	**9**	**338**	**99**	**29.29**	**21.77**
B. vulgaris (Chittagong)	Soil drenched with Cupravit	**6**	**305**	**91**	**29.84**	**68.11**
	Soil drenched with Dithane M 45	**5**	**188**	**101**	**53.72**	**36.74**
	Controls	**5**	**172**	**34**	**19.77**	**56.65**

and served as controls. The number of healthy and dead culms were observed at regular intervals from 3rd August, 1984 until January, 1985. The results of the above experiments on the survivality of new culms are presented in Table 3.

Cutting and removing blighted bamboos, burning the debris of clumps in situ and addition of new soil to clumps promoted the production of higher number of surviving healthy bamboos in comparision with that of the controls. Cutting and removing blighted bamboos and adding new soil to clumps (without burning) had no significant effect on the survival of new culms. Hence, the significant increase in the number of survival of new culms is most likely due to the direct and/or indirect effect of burning. The direct effect of burning may result in a reduction in the inocula potential of pathogenic fungus which existed in the debris or in the top few inches of soil. The indirect effect may be due to the addition of ash in the soil which might have acted as a manure. Drenching soils of the bamboo clumps which had bamboo blight with either Copper oxychloride or Dithane M 45 proved to be beneficial as compared to the control clumps. Dithane M 45 soil drench was better than Copper oxychloride treatment. The difference was not, however, significant because of high variability among the clumps.

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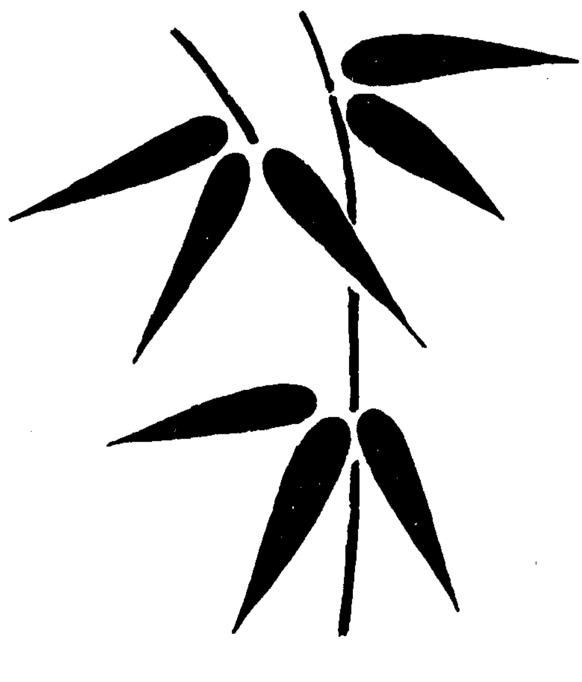

Fungal Diseases of Bamboo
A Preliminary and Provisional List

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Abstract

Information on the fungal diseases of bamboo is *collated* and the importance of *the* diseases is discussed. The need for further work is indicated and certain methods of study are suggested.

Introduction

This is the first attempt to collate information on fungal diseases of bamboo as recorded throughout the world. In practice, this will refer largely to countries in Asia, particularly India and Japan; only a limited number of records have been found for bamboo diseases in Africa and Central and South America. Within Asia there are several countries, for instances, the Philippines, Indonesia and Burma, for which little information is available. By comparison many records exist for bamboo in the U.S.A. (Anon, 1960) which reflects more on the activity of pathologists than on the impor: tance of either bamboo or bamboo diseases Several Japanese works have been consulted on bamboo diseases: Kusano (1908) lists bamboo leaf rusts whilst Kawamura (1929) and Hino (1961) are more general. Bamboo diseases in India are usefully summarised by Butler and Bisby (1960) and Bakshi (1976). These consider inter alia two very important and widespread bamboo host genera, Bambusa and Dendrocalamus. Japanese workers have been largely concerned with *Sasa* and its allies, and to a lesser extent Phyllostachys. Spaulding (1961) records many of the bamboo diseases. It is unfortunate, given the lack of data on symptoms and disease losses, that the original sources for the data which is presented are not given. This lack of information on bamboo diseases has, however, been a constant problem in any attempt to compile a comprehensive list of bamboo diseases. Even where I was able to consult original papers only a limited amount of detail was available.

Many of the original references to bamboo diseases are not available, often because of difficulties in obtaining journals. Several references were obtained from two annotated bibliographies (Elbourn, 1978; Ridout, 1983), which together cover the Review of Plant Pathology (RPP) from 1973-1982. Earlier issues of the RPP were also consulted.

Scope of Bamboo Disease List

Only fungal diseases are considered There are many records of deuteromycetea (Ellis, 1971, 1976; Sutton, 1980) on bamboo but most of these have no association with a disease.

I have treated many of the records of higher fungi (mainly polypores) producing rots on living bamboo with some circumspection. Bagchee and Singh (1954), for instance, give many instances of decay fungi which I have considered to be of dubious significance, and which have been omitted from below in the absence of data from another source. Those rot and decay fungal records that are listed should be treated with some caution (eg. Fomes spp.) since it is not clear which part of the bamboo is attacked – rhizome or culm.

One bacterial disease of bamboo in Taiwan (Lo et *al.,* 1966) has been included. However, viruses (Anon, 1977; Kitajima *et* al., 1977; Lin et al., 1977), mycoplasmas (Nayar and Ananthapadmanabha, 1977) and mistletoes have been excluded. Similarly decays and rots of cut bamboos are not considered. There is no suggestion that bamboo viruses cause any damage to their hosts. A series of papers by Kwan Soo Kim (1979) and Kwan Soo Kim and Ji-Yul Lee (1980) investigated the soil-borne fungi of ***Phyllostachys*** reticulata forests in Korea. None of these fungi were associated with any disease of bamboo.

Importance of Bamboo Diseases

The relative importance of the different diseases is difficult to assess because of the general lack of information accompanying each disease record. Despite this the overall impression is that many of the bamboo diseases are of only limited importance. It became apparent when compiling the list that the higher fungi (e.g. polypores and ascomycetes) had been more frequently recorded (perhaps because of their distinct fruiting bodies) than the deuteromycetes. The hyphomycetes in particular are much under-represented and this, I feel, represents a lack of investigation into bamboo micro-fungi rather than an absence of pathogens in this group. There is no suggestion that any of the many leaf spot fungi, leaf rusts and decay pathogens cause more than minor damage. Severe attacks by rust fungi on bamboo have been noted, but only infrequently and with only localized damage. By comparison the diseases of growing or young culms are much more serious, with extensive damage reported for bamboo blight (on ***Bambusa*** spp.) in Bangladesh, (Boa, this volume) and blight on Phyllostachys in China.

Bamboo Blight in Bangladesh

This important new disease of growing culms of Bambusa spp. is not included in the list of diseases below because we are still uncertain about its etiology. Elsewhere in these proceedings (Boa: Rahman) the sheath rot pathogen of rice Sarocladium ***oryzae,*** and Acremonium strictum are both linked with bamboo blight, particularly the former, but a connexion between a fungal and the disease has still not been adequately demonstrated.

Further Work Required

1. Many of the records of diseases are quite old. It is important that these be updated, together with a more complete picture of the disease; for example. a full description of symptoms and losses due to the disease.

2. The present records for bamboo disease do not adequately consider the very important although widely dispersed resource of rural village bamboos.

3. The ***growing*** culm has received little attention with regard to disease. Young, green, wet tissue is more likely to be damaged by pathogenic organisms, and to a greater extent, than mature culms.

There are several cryptic references to the death of new shoots at a very early stage. Pathological studies of these dying culms are required to establish whether this apparently widespread phenomenon is due to a living ***or*** non-living (e.g. soil conditions) agent.

4. The culm sheaths play a very important part in the development of new culms. If green culm sheaths and/or the not fully expanded internode below are damaged, for example by insects, this has an apparently dramatic effect on the proximal part of the growing culm. The effect certainly extends much beyond the area damaged and suggests that culm sheaths and the internodes that they protect are particularly susceptible to damage. Again this is an area to be investigated more fully.One of the difficulties here is that culm sheaths naturally have a very short existence (approximately four weeks for ***Bambusa*** vulgaris in Bangladesh) and it can be difficult to discern accurately the development of abnormal necroses.

Format of Bamboo Disease Listing

Diseases are listed alphabetically by the fungal (bacterium in one instance) associated with the symptoms. I have briefly described the type of fungus (e.g. Aphyllophorales (polypores), ascomycete etc.) the name of the disease, countries and hosts in which it occurs, are also given together with a list of appropriate references. I have not listed texts such as Bakshi (1976) and Browne (1968) unless these are the ***only*** references.

I have not listed authorities for either host or pathogen; this detail was not always available in the papers consulted.

List of Fungal Bamboo Diseases

(1) Aciculosporium *take* WITCHES BROOM (Japan; Taiwan)
Ascomycete
on Phyllostachys aurea; *P.* bambusoides; *P.* lithophila; P. malcinoi; *P.* nigra; *P..* nigra var henonis; *P.* pubescens.
C. Chen (1970, 1971); Kao and Leu (1976); Lin *et* al. (1981); Nozu and Yamamoto (1972) : Shinohara (1965) ; Spaulding (1961).

(2) Amauroderma rugosus (sic) CULM DECAY (India)
Aphyllophorales
on Bambusa
Banerjee and Ghosh (1942)

(3) Armillaria *mellea* PATHOGEN? (Kenya)
Agarioales
associated with Arundinaria alpina
Gibson (1960)

(4) Asterinella hiugensis BLACK MILDEW ON CULMS (Japan)
Ascomycete
on Phyllostachys bambusoides
Spaulding (1961)

(5) Astrosphaeriellafuscomaculans SPECKLED CULMS (Japan)
Ascomycete
on Phyllostachys nigra
This infection enhances the value of the culms!

(6) Balladyna butleri BLACK LEAF SPOT (India)
Ascomycete
on Bambusa sp.
Butler and Bisby (1960)

(7) Calocline chusqueae LEAF LESIONS (Ecuador)
Coelomycete
on Chusquea
Sutton (1980)

(8) Ceratosphaeria phyllostachydis SHOOT BLIGHT (China)
Ascomycete
on Phyllostachydis edulis

(9) Cladosporium graminum LEAF MOULD (U.S.A.)
Hyphomycete
on Phyllostachys aurea
Anon (1960)

(10) Clavaria spp. SHOOT ROT (Thailand)
Basidiomycete
on Bambusa spp.
Giatgong (1980)

(11) Coccodiella arundinariae LEAF SPOT (China, Japan)
Ascomycete
on Phyllostachys sp.
Spaulding (1961)

(12) Colletotrichum graminicola ANTHRACNOSE (U.S.A.)
Coelomycete
on Arundinaria gigantea
Anon (1960)

(13) Colletotrichum hsienjenchang CULM BLIGHT/ROT (Japan)
on Phyllostachys bambusoides; *P.* nigra var. henonsis
Spaulding (1961)

(14) Coniosporium bambusae SHOOT WILT (U.S.S.R.)
Hyphomycete
on Phyllostachys spp.
Beradze (1972), (1973a), (1973b), (1974), (1975a), (1975b)

(15) Corticium lcoleroga THREAD BLIGHT (LEAF AND CULM DAMAGE) (India)
Aphyllophorales
on Dendrocalamus sp.
Browne (1968)

(16) Dasturella bambusina LEAF RUST (India)
Uredinales
on Bambusa sp.
According to Bakshi (1978) the original specimen when re-examined showed the host to be Dendrocalamus strictus. He also noted that the telia of *D. bambusina* and *D. dioina* were the same.
Mundkur and Kheswalla (1943)

(17) Dasturella diuina LEAF RUST (India; Vietnam; Pakistan; Japan)
Uredinales

on *Dendrocalamus sp.; D. strictus; Oxytenanthera abeysannae* (fide Bakshi *(1968); Ox. abyssinica* (fide Thiruma-Iachar and Gopalankrishnan (1947)). Alternative hosts *Randia* and Xeromphis (Angiosperms).

Bakshi and Sujan Singh (1967); Spaulding ,(1961); Sujan Singh and Bakshi (1964)

18) *Dicellomyces gloeosporus* LEAF SPOT (U.S.A.)

Basidiomycete

on *Arundinaria tecta*

Anon (1960)

(19) *Diplodia* bambusae TIP BLIGHT (U.S.A.)

Coelomycete

on "other bamboo spp."

Anon (1960)

(20) *Encoelia helvola* CULM ROT (Indonesia)

Ascomycete

on Bambusa spp.; Bambusa *arundinacea; Gigantochloa apus*

Overeem (1926) ; Rifai (1983)

(2 1) *Epichloe bambusae* WITCHES BROOM (Indonesia)

Ascomycete

on Bambusa vulgaris; Dendrocalamus asper; Gigantochloa apus; G. atter; G. verticilliata

Rifai (1983)

(22) *Erwinia sinoclami* BACTERIAL WILT (Taiwan)

Bacterium

on "Taiwan giant bamboo"

Loetal. (1966)

(23) Fomes *lignosus* WHITE ROOT ROT (Malaysia)

Aphyllophorales

on *Dendrocalamus giganteus*

Browne (1968) ; Hilton (1961)

(24) *Fusarium moniliforme* BASAL CULM ROT (China)

Hyphomycete

on *Phyllostachys* pubescens

J. Chen (1982)

(25) *Fusarium solani* CULM BROWN ROT (China)

Hyp homycete

Lan (1980)

(26) Ganoderma *lucidum* ROOT ROT (India, Pakistan, Philippines

Aphyllophorales

on *Bambusa sp. B. arundinacea*

Bakshi (1957); Banerjee and Ghosh (1942) ; Butler (1909) ; Spaulding (1961)

(27) *Helminthosporium* sp. LEAF SPOT (U.S.A.)

Hyphomycete

on *"other bamboo spp."*

Anon (1960)

(28) Hughesinia *chusqueae* LEAF SPOT (C hile)

Hyphomycete

on *Chusquea*

Ellis (1976)

(29) *Hypoxy lon rubiginosum* CANKER/ WHITE POCKET ROT (India)

Ascomycete

on *Bambusa*

Bagchee and Singh (1954)

(30) *Hypoxylon fuscopurpureum* CANKER (India)

on *Bambusa*

Bagchee and Singh (1954)

(31) *Irpex flavus* SPONGY SAP ROT (India? Ghana? Pakistan)

Aphyllophorales

on *Bambusa* sp.

Browne (1968)

(32) *Leptothyrium cylindrium* LEAF SPOT (U.S.A.)

Coelomycete

on *Arundinaria tecta*

Anon (1960)

(33) *Loculistroma bambusae* WITCHES BROOM (China)

Ascomycete

on *Phyllostachys*

Anon (1911)

(34) *Meliola bambusicola* BLACK MILDEW (India)

Ascomycete

on *Bambusa* sp.

Browne (1968); Butler and Bisby (1960)

(35) Meliola *tenuis* BLACK MILDEW (U.S.A.)

on *Arundinaria gigantea; A. tecta*

Anon (1960)

(36) *Merulius similis* CULM DECAY (India)

Aphyllophorales

on Bambusa bambos

Banerjee and Bakshi (1945); Banerjee and Ghosh (1942) ; Banerjee and Mukhopadhyay (1962)

(37) *Mycosphaerella sp.* LEAF SPOT (U.S.A.)

Ascomycete

on *Phyllostachys bambusoides; P. nigra*

Anon (1960)

(38) *Mycosphaerella* arundinariae LEAF SPOT (U.S.A.)

on *Arundinaria tecta*

Anon (1960)

(39) *Myrangium* bambusae 'SEVERE PARASITE" (C hina)

Ascomycete

on *Phyllostachys pubescens*

Tai (1931)

(40) *Papularia arundia (= Arthrinium* state of *Apiospora* Hyphomycete *montagnei* fide Ellis (1965)) on *Bambusa* sp. CULM SOOTY STRIPE? (India)

Ellis (1971) makes no mention of this common bamboo fungus as a pathogen. I have frequently observed *Arthrinium* freely sporulating on dead culm and twigs. Bagchee and Singh (1954); Thirumalachar and Pavgi (1950) Phyllachora spp _LEAF SPOTS

Ascomycete

Five species recorded widely

(41) *Phyllachora arundinariae* (U.S.A.)

on *Arundinaria tecta*

Anon (1960)

(42) *Phyllachora bambusae*

(43) *Phyllachora malabarensis (India)*

(44) *Phyllachora shiraiana*

on *Bambusa* spp. Noted as being of little importance.

Butler and Bisby (1960)

(45) *Phyllachora chusqueae* (U.S.A.)

on "other bamboo spp."

Anon (1960)

(46) *Polyporus*

Aphyllophorales

on *Dendrocalamus strictus*

Cause of death noted as *Polyporus*, in conjunction with *Poria* and Rhizoctonia (see Sheikh et al. (1978)

(47) *Polyporus durus* DECAY (India)

on *Bambusa*

Banerjee and Ghosh (1942)

(48) *Polyporus* friabilis DECAY (India)

on *Bambusa*

Banerjee and Ghosh (1942)

(49) *Poria* rhizomorpha ROOT ROT (India, Bangladesh (given as Pakistan))

on *Melocanna baccifera*

Spaulding (196 1)

(50) *Puccinia* spp. RUSTS (U.S.S.R.)

Uredinales

on bamboo – no other information available.

Beradze (1972)

(5 1) *Puccinia arundinariae* LEAF RUST (U.S.A.)

on *Arundinaria gigantea*

Anon (1960)

(52) *Puccinia gracilenta* LEAF RUST (India)

on *Bambusa* sp.

Bakshi and Sujan Singh (1967); Butler and Bisby (1960)

(53) *Puccinia ignaua* LEAF RUST (U.S.A.)

(see also Uredo ignava)

on *Bambusa vulgaris*

Anon (1960)

(54) *Puccinia kusanoi* LEAF RUST (Japan, U.K.)

on *Arundinaria, Sasa, Semiarundinaria fastuosa*, Alternative host *Deutzia* (Angiosperm)

Reid (1978); Reid (1984) ; Spaulding (1961)

(55) *Puccinia longicornis* LEAF RUST (China, Indochina, Japan, U.K.)

Uredinales

on *Arundinaria, Bambusa arundinacea, Phyllostachys, Sasa.*

Reid (1978) ; Spaulding (1961)

(56) *Puccinia phyllostachydis* LEAF RUST (India, China, Japan, U.S.A.)

(Also as *P. melanocephala)*

on *Arundinaria suberecta; Phyllostachys aurea; P. bambusoides; P. nigra* var henonsis

Browne (1968) says that *P. phyllostachydis* is the correct name for *P. melanocephala* as given by, for example, Butler and Bisby (1960).

Other references: Anon (1960); Bakshi and Sujan Singh (1967); Spaudling *(1961)*

(57) *Puccinia xanthosperma* LEAF RUST (India)

Uredinales

on *Bambusa sp.*

. Bakshi and Sujan Singh (1967); Butler and Bisby (1960)

(58) *Pyricularia* sp. LEAF INFECTIONS (Japan)

Hyphomycete

on *Phyllostachys; P. oryzae;* Semiarundinaria spp.; S. viridis; Shibateae; *Tetragonocala mus.*

Itoi et *al. (1978), (1979)*

(59) *Pyricularia grisea* LEAF SPOTS (Pantropical)

on Bambusa

Ellis (1971)

(60) Rhizoctonia DEATH OF CULMS,' CLUMP (Pakistan)

Agonomycete

See note for Polyporus

(61) *Scolecotrichum graminis (= Scilecotrichum gra minis)*

Hyphomycete BROWN STRIPE OF CULM (U.S.A.)

on Arundinaria tecta

Anon (1960)

(62) *Sclerotium rolfsii* CULM ROT (U.S.A.)

Agonomycete

on *Bambusa vulgaris*

Anon (1960)

(63) *Selenophoma donacis* CULM SPOT (U:S.A.)

Coefomycetes

on "other bamboo spp."

Anon (1960)

(64) *Shiraia bambusicola* CULM SHEATH PATHOGEN? (China)

Ascomycete

on Phyllostachys sp

Tai (1932)

(65) *Stereostratum corticioides LEAF AND STEM RUST (China, Japan, Pakistan)*

Uredinales

on *Arundinaria. P. bambusoides, P. nigra var henonis*

Spaulding (196 1)

(66) Stereum percome DECAY (India)

Aphyllophorales

on *Bambusa*

Banerjee and Ghosh (1942)

(67) *Tomentella bambusina* CULM WILT (Brazil)

Aphyllophorales

(Tomentella = Trechispora)

on *Bambusa vulgaris*

(68) *Trametes corrugata* DECAY (India)

Aphyllophorales

on *Bambusa*

Banerjee and Ghosh (1942)

(69) *Tunicopsora bagchii* LEAF RUST AND TWIG DEATH/WITCHES BROOM (India)

Uredinales

on *Dendrocalamus strictus*

Bakshi et al. (1972); Sujan Singh and Pandey (1971)

(70) *Uredo dendrocalami* RUST (SriLanka. China)

Uredinales

on *Dendrocalamus.* D. latiflorus

Spalding (1961)

(71) *Uredo ignava* LEAF RUST (China. Cuba. Puerto Rico, Venezuela)

(See P. ignava)

on Bambusa arundrnacea. B vulgaris. Dendrocalamus sp.

Spaulding (196 1)

(72) *Ustilago shiraiana* SHOOT DEATH

WITCHES BROOM (China, Japan, Taiwan, U.S.A.)

Ustilaginales

on *Bambusa* spp., *Phyllostachys bambusoides, P. nigra*

Anon (1960); Hori (1905); Patterson and Charles (1916); Speulding (1961)

(73) Volutella tecticola LEAF SPOT (U.S.A.)

Hyphomycete

on *Arundinaria tecta*

Anon (1960)

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The Occurrence and Bamboo Blight in Bangladesh with Reference to Sarocladium oryzae

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Abstract

The symptoms of a blight of Bambusa spp. are described fully for the first time. The disease has only been recorded from Bangladesh and has been present since the early 1970s. Bamboo blight attacks village bamboos; in particular B. balcooa and B. vulgaris, the two most important species; the forest bamboos, dominated by Melocanna baccifera, are not affected. Details are given of the losses in bamboo clumps resulting from blight attack. Isolations from blight symptoms have consistently yielded Sarocladium oryzae, the sheath rot pathogen of rice. Limited artificial inoculations with this fungus on bamboo have resulted in symptoms similar to blight, but much more work is required before the cause of bamboo blight is fully understood. There is much insect damage in blighted culms and observations suggest that these insect(s) are responsible for introducing S. oryzae into Ihe culm via feeding holes.

Introduction

There are few serious diseases of bamboo. It was therefore with some alarm that a brief note by Rahman and Zethner (197 1) recorded a damaging new disease, which they called bamboo blight, from village bamboo groves of the Rajshahi district of Bangladesh. Subsequently little information was available on the disease, although there is no doubt that it continued to be a major source of worry to local farmers. Since 1982 a comprehensive research programme has been carried out by myself and Dr M A Rahman of the Forest Research Institute, Chittagong. A colour brochure which describes the disease in outline has been produced (Boa and Rahman, 1984); the present paper provides a more complete description of blight symptoms and reports the results of isolations of fungi from diseased and healthy tissues together with a discussion on the cause of the disease.

The chronology of research on bamboo blight is as follows: 1971 – Disease first recorded in a brief note by Rahman and Zethner (1971); 1975 Gibson (1975) during a brief visit to Bangladesh reported the disease from additional areas; 1978 – Rahman (1978) described the results of isolations from blighted bamboo; and 1982 – Bamboo blight project commences with the help of the British Technical Cooperation Programme.

Bamboo Species in Bangladesh and those which become Blighted

Bamboos in Bangladesh can be divided into two groups: the forest bamboos and the village bamboos. The latter are dominated by *Bambusa balcooa* (Fig. la), and are generally thick-walled and form compact clumps with large culms 15-20 m. The former are dominated by *Melocanna baccifera* (Fig. lb) and are thin-walled with small ‘culms up to about 10 m and both the species have pachymorph rhizome systems. The village bamboos are found throughout the flat. deltaic regions of Bangladesh and the forest bamboos in the upland regions (Chittagong Hill Tracts and

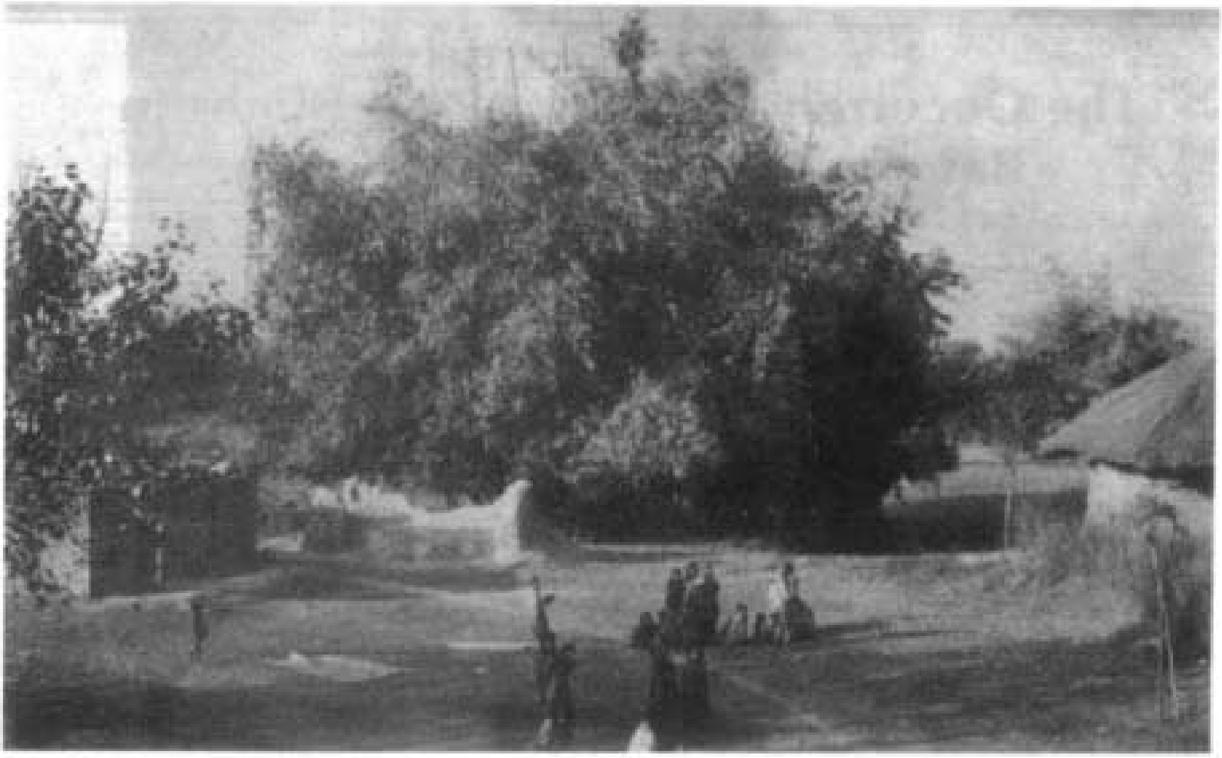


Fig. 1a. Village bamboo — *Bambusa balcooa*.

Fig. lb. Forest bmboo – *Melocanna baccifera*.

Sylhet region) although it is not uncommon to find M. baccifera growing in villages.

Table 1 shows the iwo most affected species are B. balcooa and B. vulgaris. "Jawa" bamboo is known only by its local name: on the basis of general appearance and fringed auricles on its culm sheaths. It would appear to be a Bambusa sp. B. tulda sensu lato (see Boa and Rahman, 1984, for a description) refers to a group of bamboos that are difficult to separate on the basis of vegetative characteristics and also show the same type of blight development. The grouping of these bamboo types into B. tulda s.l. is made here for practical purposes only and is not meant to have any taxonomic validity, Alam (1982). who provides a recent description of bamboo species in Bangladesh, separates B. tulda s,l. into three separate species. The species described by Alam which occur in villages, and are not mentioned in Table 1, are of little importance and none have been seen blighted, This includes Dendrocalamus giganteus Nunro, for example.

Bamboo blight has only been recorded from Bangladesh. Enquiries by the Forest Research Institute of India to State Forestry Departments yielded no records of blight

Table 1. Important bamboo species occurring in Bangladesh villages and the presence of blight.

Species	Notes on distribution	Over811 severity of field attaCk	Degree of disease development in *single clumps*
Bambusa balcooa Roxburgh	Widespread and abundant except for SE	+ +"	1 – 4[b]
B. glaucescens (Willd .) Sieb. ex Munro	Locally common in NE	NONE	NONE
B. polymorpha Munro	Sporadic in NE and SE, perhaps elsewhere	NONE	NONE
B. tulda sensu lato (see text)	Widespread though + often locally sparse except in N	+	1 -2
B. vulgaris Schrader ex Wendland	Dominant in SE but sporadic elsewhere	+ + +	3-4
"JAWA" (local name – ***Bambusa*** sp .?)	Common in W generally – absent elsewhere?	+ +	2-3
Cephalostachyum ***pergracile*** Munro	Apparently present in N only	NONE	NONE
Melocanna baccifera (Roxburgh) Munro	Generally E of Jamuna river, widespread though patchy and sparse	NONE	NONE

'+ low,+ + + high
bl (Minor) 25% new culms blighted; 2 (Mild) 25-50%;
3 (Moderate) SO-75%; 4 (Severe) 75%

(Sujan Singh, pers. comm.). Of the species listed in Table 'l which develop blight, B. ***vulgaris*** is the only one of widespread importance. Gamble (1896) states that B. *balcooa* occurs only in Assam and what is now Bangladesh . B. vulgaris, however, occurs extensively throughout Asia from India to Malaysia (Holttum, 1958), Indonesia and elsewhere. B. tulda s.1. is grown mainly in the Indian subcontinent (Gamble, 1896).

Symptoms of Bamboo Blight

Bamboo blight is easily recognized in the field. in its later stages, by the presence of truncated culms which show varying degrees of die back (Fig. 2a). Below this dead portion partial necrosis ("streaking" – Fig. 3) is usually present. Streaking may extend directly from the dead part of the culm or may occur lower down as discrete areas (Fig. 6a). Blight only attacks growing cuims and is thus best observed from about July through November. If a culm is still healthy after complete expansion has taken place, it will remain so. Culms are attacked at various stages of development, in some cases when they have already grown to 8 m or more, but observations of the first stages of disease development have been made on culms which became blighted when 1-4 m tall. Once a culm shows even slight development of blight symptoms – at which stage no die back or streaking is present – then it ceases growth.

Symptoms develop initially on internodes which are still growing and which are approximately 40-60 cm below (Fig. 4a – far left culm) the culm apex. At this stage of densely compacted internodes above -show no signs of symptoms either on the surface or internally although subsequently these will develop and the apex will die.- These initial symptoms on growing internodes cannot be deteced by external examination of the culm since the supporting culm sheaths are

Fig. 2a. Die back of 5 month-old culms. Note the different stages of culm growth at which blight attacks.

Fig 2b Die back ends at node

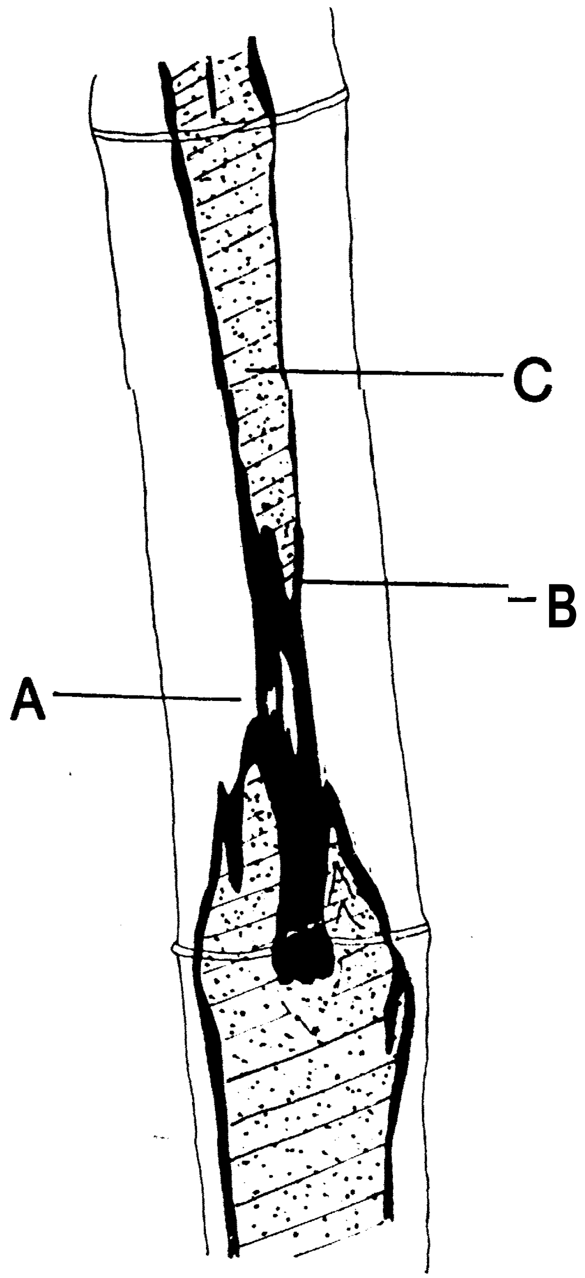


Fig. 3. Streaking of blighted culm. Three zones can be seen: A Orange/yellow discoloration, little or no stain below; B. Black/brown, stain below and usually insect channels; C. Culm wall dead, light brown, "dried out", often with fissures and long irregular cavities.

still in place, but their presence is indicated by a premature death of these culm sheaths. Removal of the culm sheaths reveals dark stained areas, almost always associated with insect holes and channels (Fig. 4b). The black staining extends above and below the insect hole, with reduced lateral spread, and often to the depth of the inner culm wall. Black stained areas eventually become necrotic. If necrosis develops sufficiently then die back will occur (Fig. 2b) otherwise the production of defence barriers (Fig. 5a) will restrict spread and result in streaks (Fig. 3).

Insects are obviously of great importance inspreading blight symptoms within the culm and also in introducing the disease. In several culms insects had eaten through a healthy culm sheath and burrowed into the underlying expanding culm tissue, where black staining was seen around the edge of the insect channels. In other cases the spread of symptoms was clearly linked with the burrowing of insects, for example as seen in older blighted culms (4-8 months) (Fig. 5). It is not clear whether the same insects are responsible for burrowing both into tender culm tissue and older harder tissue, and causing the blight. So far no attempts have been made to identify insect larvae found in culm walls. The development of blight in affected species is different, as shown in Fig. 6; for example culms of B. vulgaris are attacked at a much earlier stage of growth whilst culms of B tulda s.l. tend not to show any streaking.

A feature of blighted bamboo in Bangladesh is the failure of new culms to grow beyond a height of about 40 cm (Fig. 7b). At this stage internodes are densley compacted and only a premature death of the culm sheaths indicates that the culm is dying. When these dying young culms are split open (Fig. 7c) the origin of the disease can be seen at the base. The apex is still symptomless at this stage and the basal rhizome region healthy.

There are also reports of dying young culms from other countries where blight has not been observed. I have witnessed this phenomenon on Gigantochloa in the Botanical Gardens, Bogor, Indonesia; Ueda (1960) carried out an extensive investigation into dying young culms on Pbyllostachys spp. in Japan and Iisiung (pers. comm.) has frequently noticed this occurrence on Phyllostachys in China. It appears unlikely that dying young culms are part of the bamboo blight disease syndrome in Bangladesh although this topic needs more careful and detailed study to identify the cause of death.

Distribution of Bamboo Blight within Bangladesh

Bamboo blight has been seen throughout

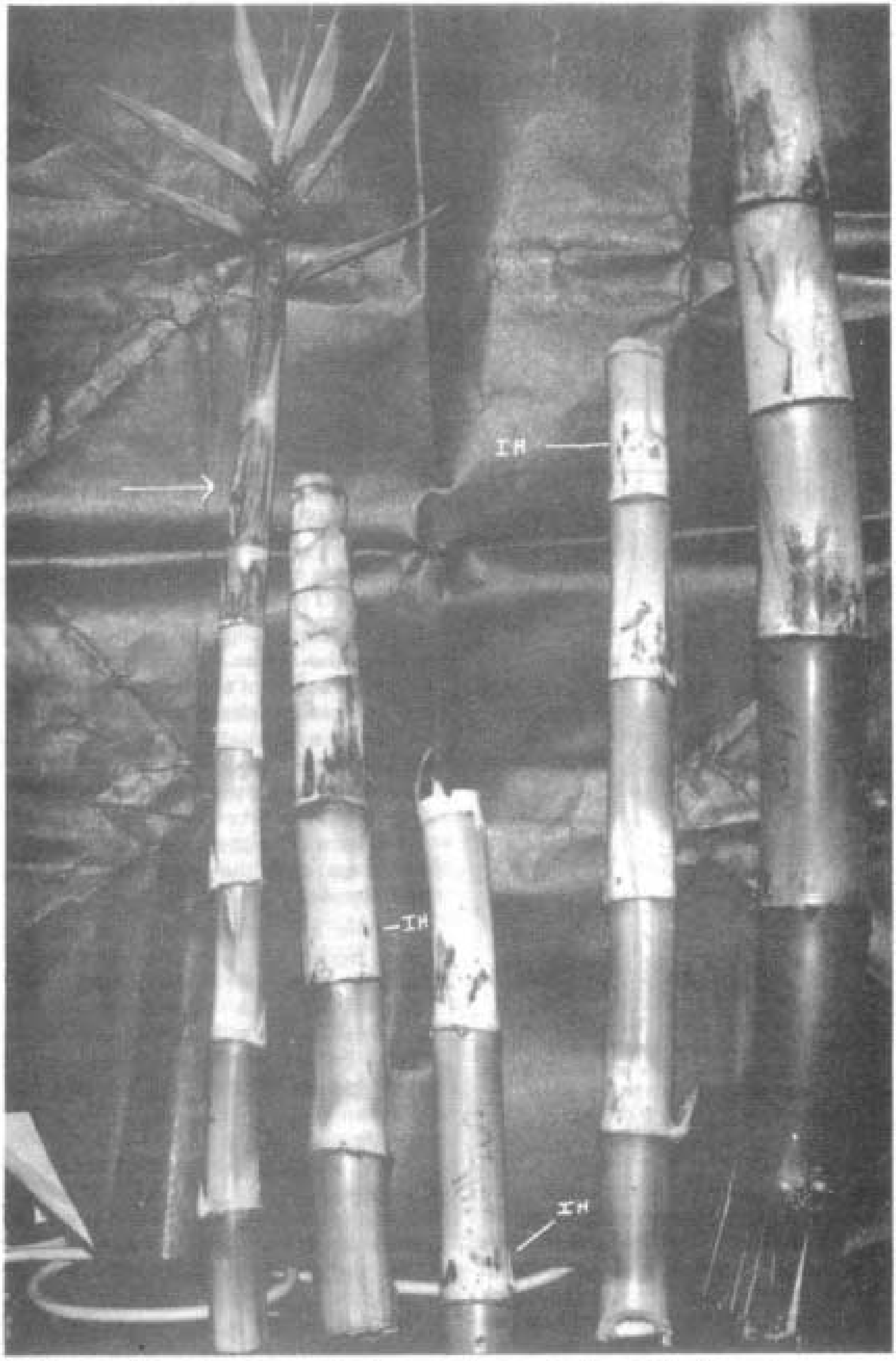
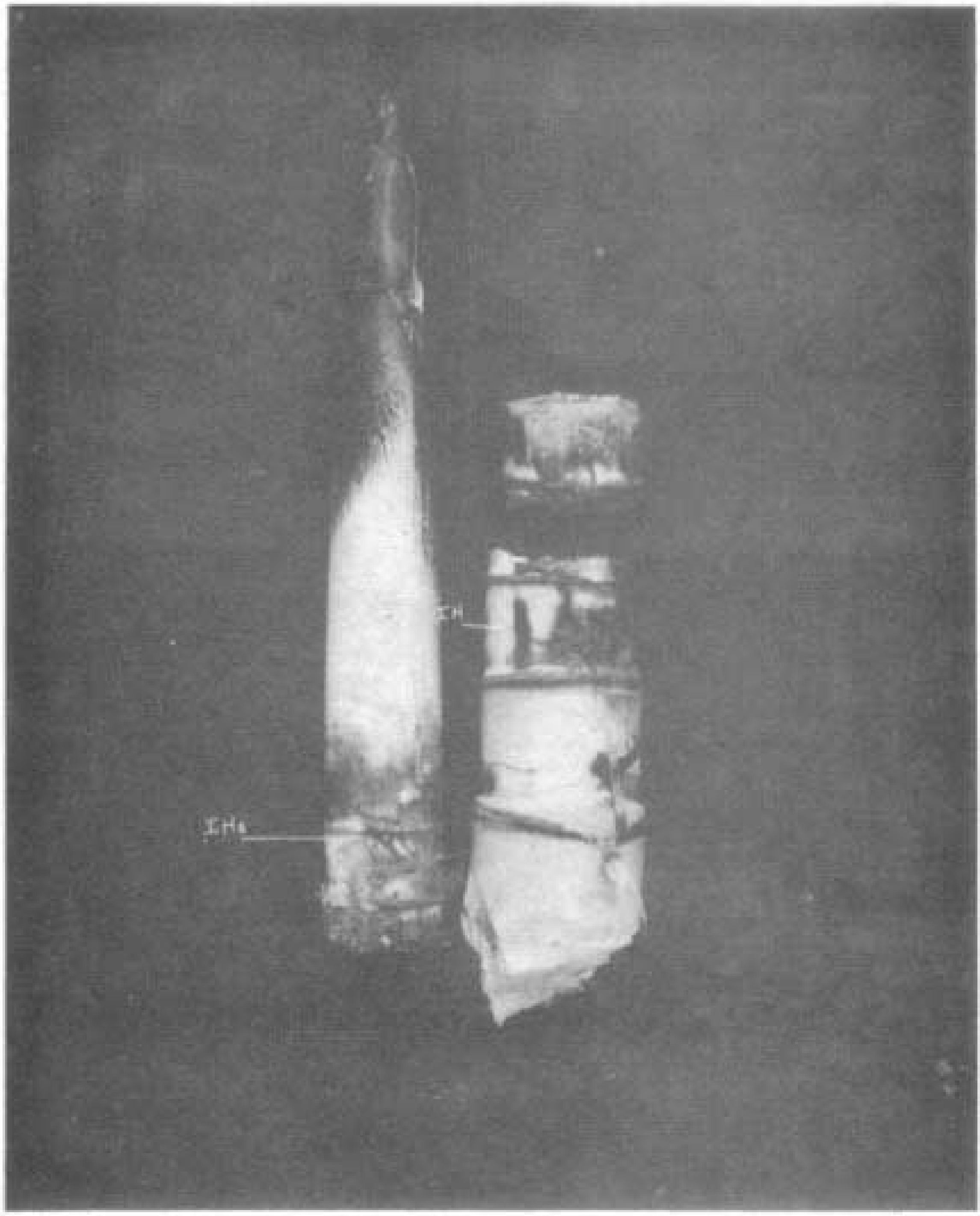


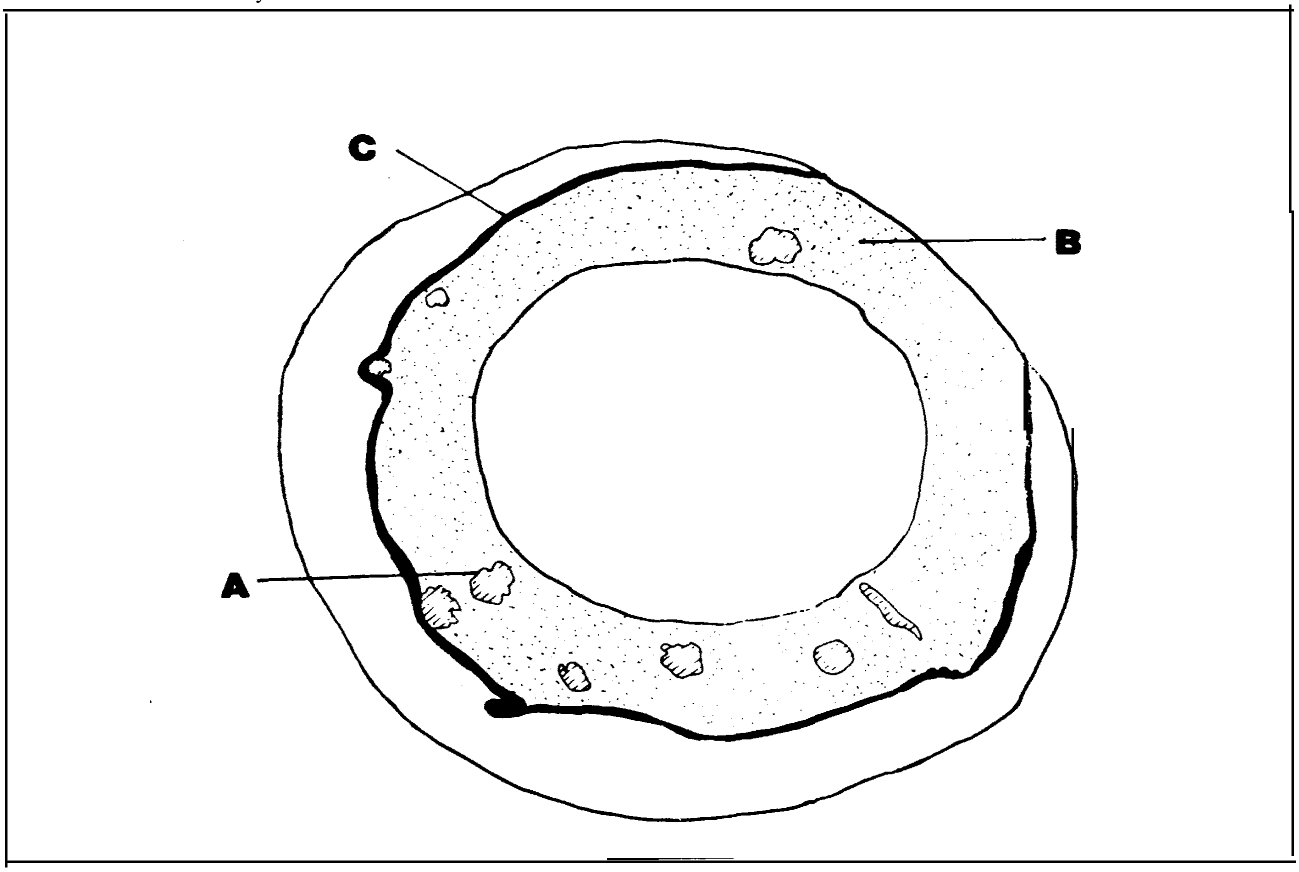
Fig. 4. *Bambusa vulgaris*. Young symptoms of blight. a) 3-6 week-old culms. Most culm sheaths have been removed to expose symptoms (note lighter colour of partially expanded internodes). Origin of first blight symptoms is shown by arrow; above is healthy. Insect holes (IH). b) 2-3 week-old culm. Extensive IHs and black staining. Basal culm sheaths removed.



4b

Bangladesh except the north-west (Fig. 8). The other main areas in which bamboo blight is absent are forest bamboos e.g. the east of Chittagong or village bamboos in areas near Barisal where blight occurs in relatively low numbers, The worst affected areas observed have been: 1) Dhaka and surrounding districts, particularly towards Comilla; 2) Pabna region (east of Rajshahi) and 3) Chittagong and surrounding areas. Outside of these three areas the presence of blighted clumps is patchy (Fig. 8). The absence of blight in the north-west can, to some extent, be accounted for by the dominance of *B. tulda s.l.* which shows a low incidence of blight in the other regions as well (Table 1). The absence of blight in the extreme south east might be due to improved conditions of growth for *B. vulgaris* compared to the Chittagong area, where non-blighted clumps of this species grow very poorly.

Fig. 5. Insect channels associated with internal staining: A) Oblique cross-section of 7 month-old culm. No external symptoms. (a) insect channels, (b) internal stain, (c) defence barrier restricts spread,* B) Longitudinal section through internode immediately below the extent of die back.



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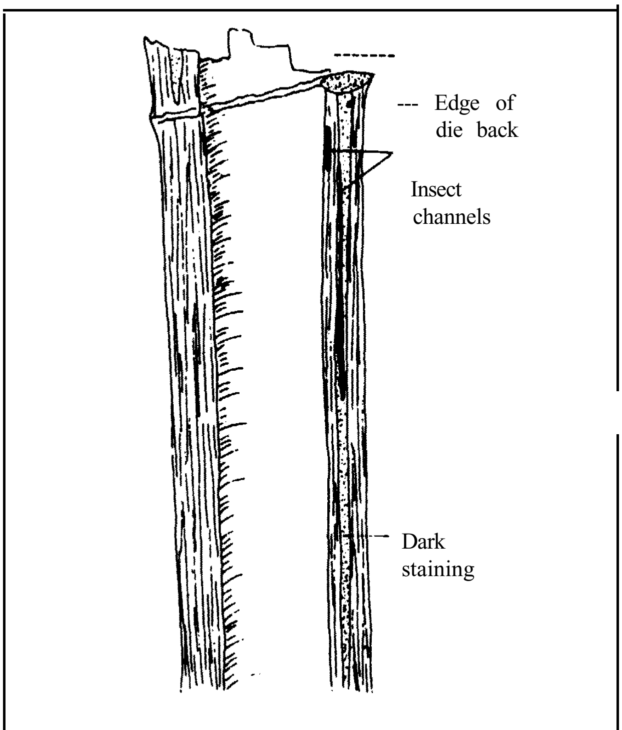

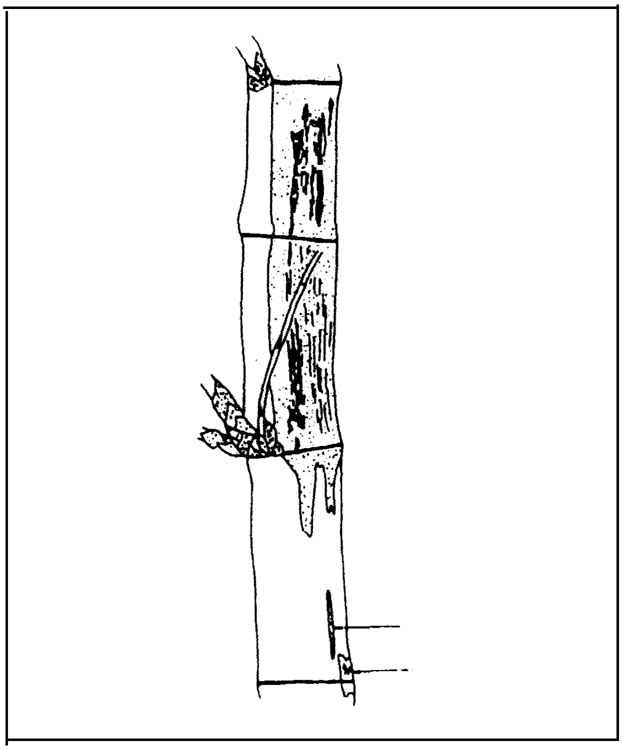

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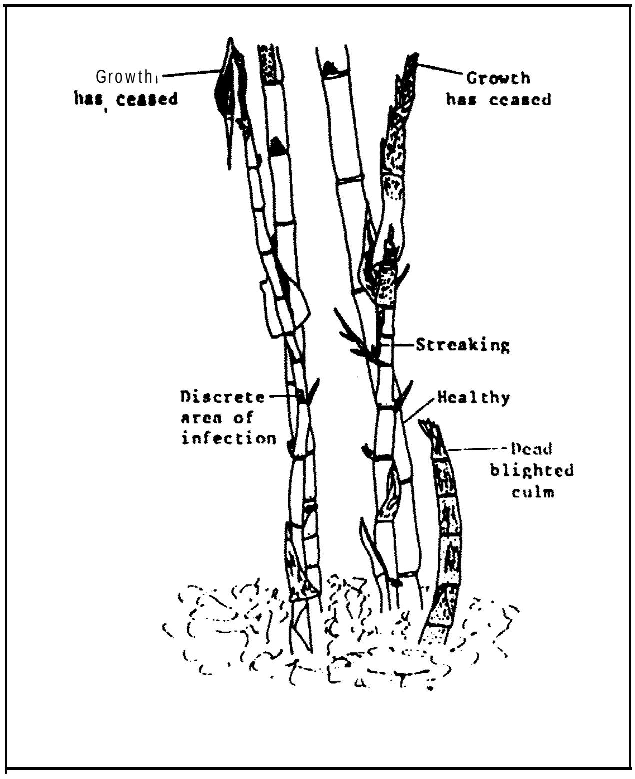
6b



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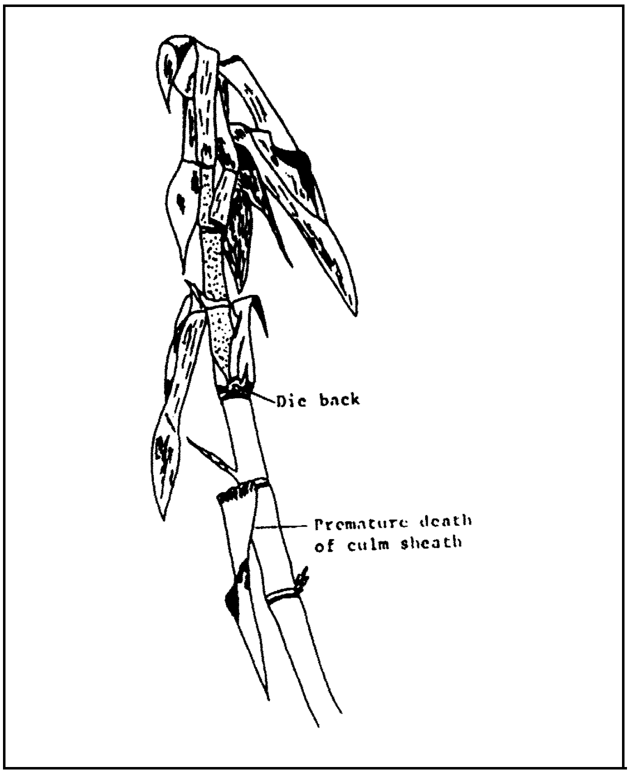


Fig. '6. Blight development in about 7 month-old culms: a) Bambusa balcooa, streaking on 8 m culm, die back (not shown) of above internodes. Note discrete areas of streaking (arrows); b) B. *vulgaris,* culms attacked at early stage of growth; c) 8. tulda s.1.

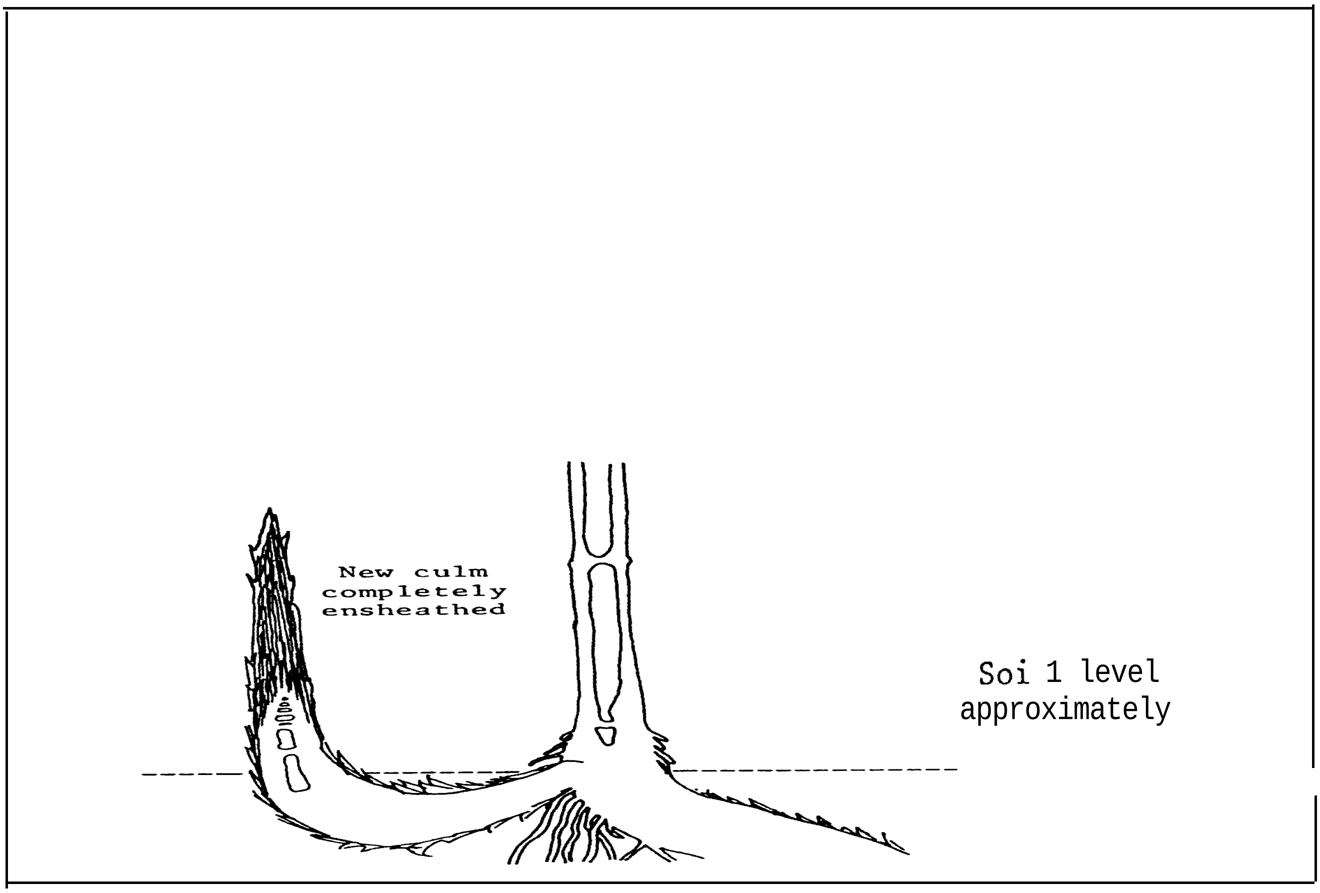


Fig. 7. New culms at early stage of development: a) New culm and mother culm from which it arises. The new culm is completely ensheathed at this stage; b) Dead new shoot of *Bambusa tulda* s.l. as seen in January; c) Dying new culm. f?. *balcooa,* wet stain in basal portion only, immature culm sheaths healthy.

7b

Spread of Bamboo blight between Clumps

Prior to 1982 there was little information available on either the extent of the disease or its severity in different regions. Initially blight was reported only from Rajshahi (Rahman and Zethner, 1971). Four years later Gibson (1975) recorded blight from Sylhet, in the north east (Fig. 8), as well as Khulna and Jessore. From 1982 to 1985 I have regularly visited different regions, in particular several small selected areas where healthy and blighted clumps have been kept under close observation, and there has been no evidence to indicate that blight is a fast spreading disease. In three cases only (all B vulgaris have healthy clumps adjacent to blighted clumps, become diseased It is therefore unlikely that bamboo blight first occurred only in the Rajshahi district: blight more probably arose in several different regions around the same time. It is difficult to envisage blight spreading from Rajshahi hundred miles to

7c

Sylhet in the space of four years. In 1985 blight was readily seen between Rajshahi and Nawabganj but there was every indication that the incidence had decreased, A high incidence of blight. was seen in Dhaka and other regions since 1982. This suggests that there has been wide spread of the disease but it also demonstrates that the status of blight is not static and may even be on the decrease.

Lasses in Bamboo clumps due to Blight

Selected clumps of healthy and blighted bamboo from Chittagong, Sylhet and Rajshahi were marked for all the new culms that appeared in 1983. and these new culms monitored monthly throughout the growing season. Final assessments were then made and culms divided into three classes: 1) healthy; 2) blighted; 3) dead yong culms (Fig. 7b). Observations were made mainly of blighted clumps of B. vulgaris and B, balcooa, Results show (Fig, 9) that more new culms in the B. vulgaris sample became blighted, although other observations have shown similar levels of disease in some clumps of blighted N. *balcooa,* Culms of B, vulgaris become blighted at an earlier stage in their growth, and subsequently blight symptoms extend further down the culm (Fig. 10). InB, *balcooa* there is a tendency for new culms to become blighted after expanding to 8 m or more (Fig. 2a); in B. vulgaris culms are attacked at a much earlier stage (Fig. 6c), the consequence of which is that more culms are completely killed (Fig. 10). This is an unusual event in blighted clumps of B. balcooa. In both species the progress of die back is limited (Fig. 2b) and only occurs during or soon after the growing season has finished. There is

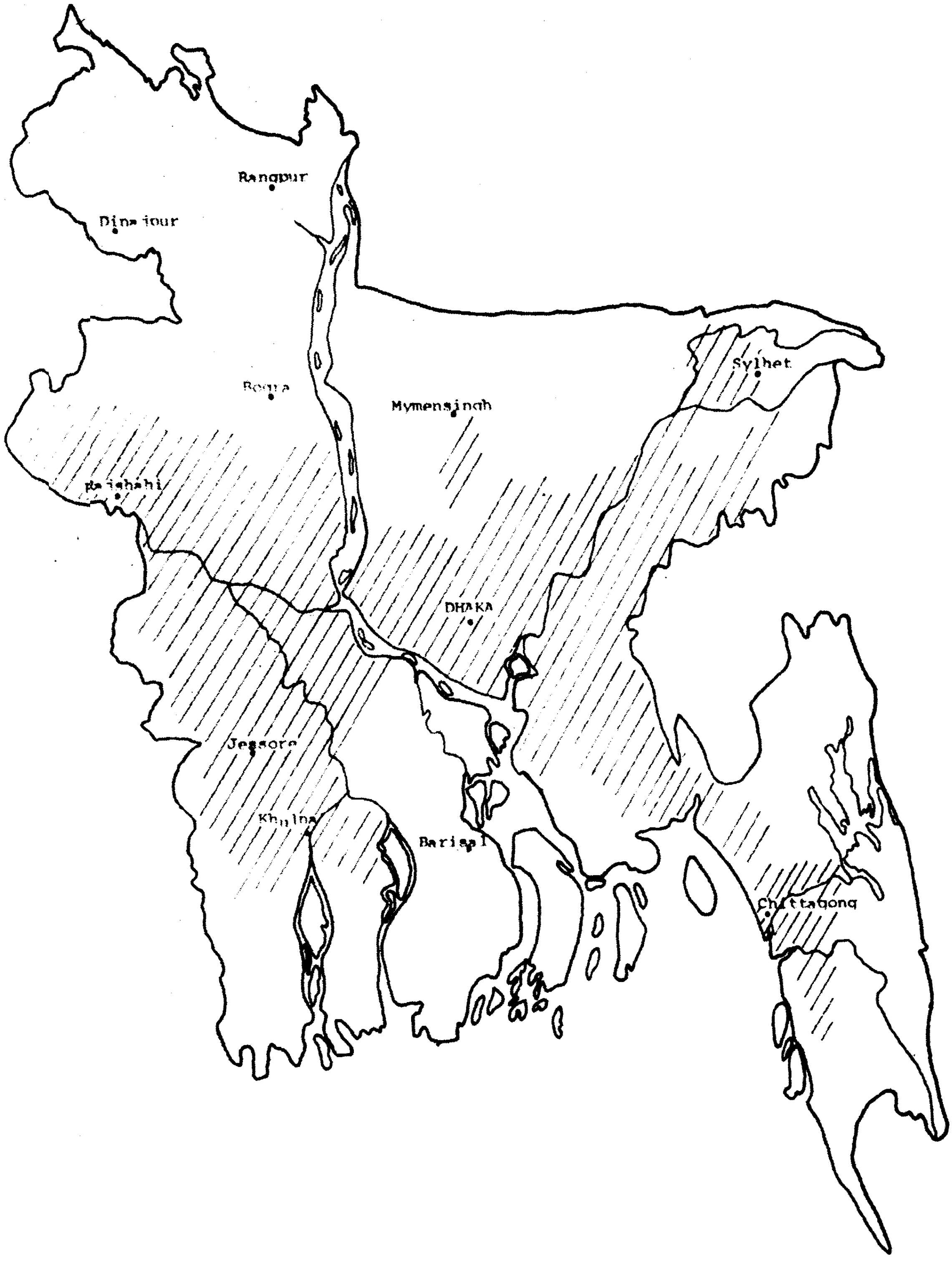
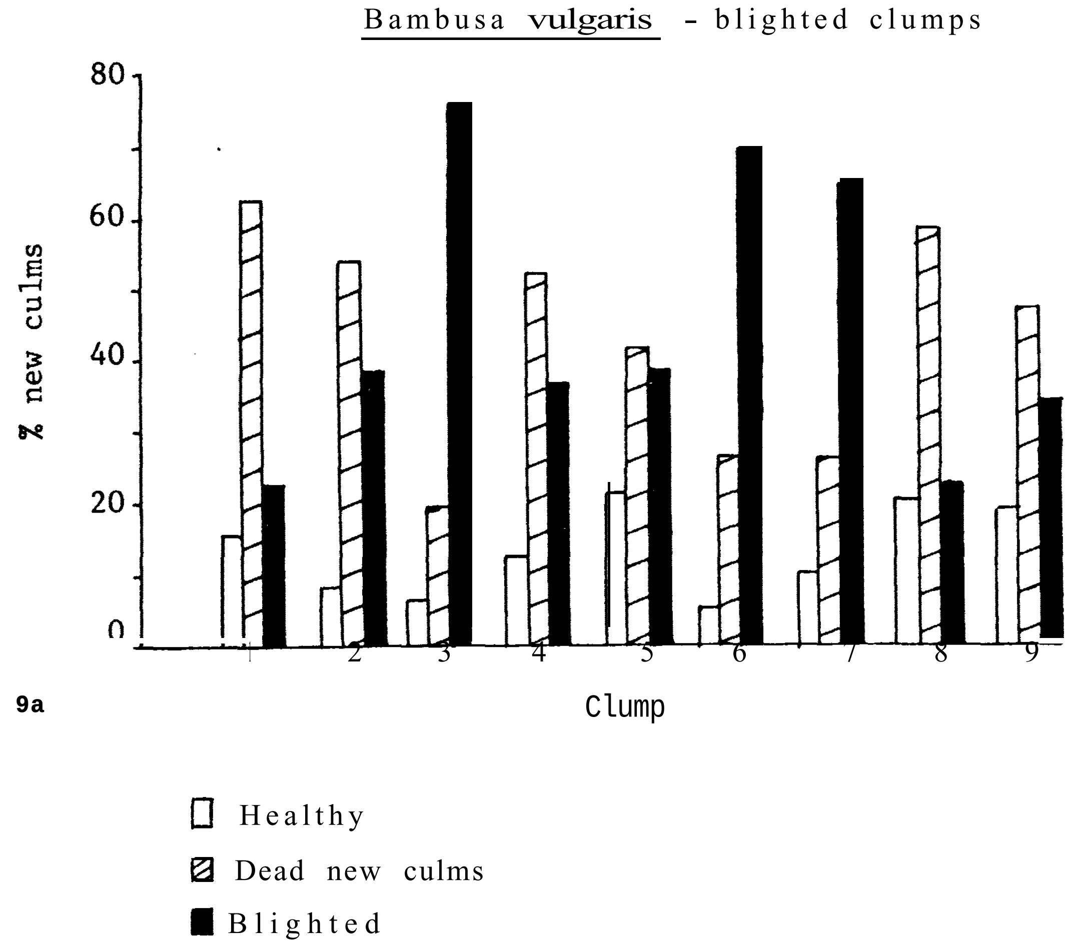


Fig. 8. Distribution of bamboo blight observed in Bangladesh as indicated by hatching.



9a

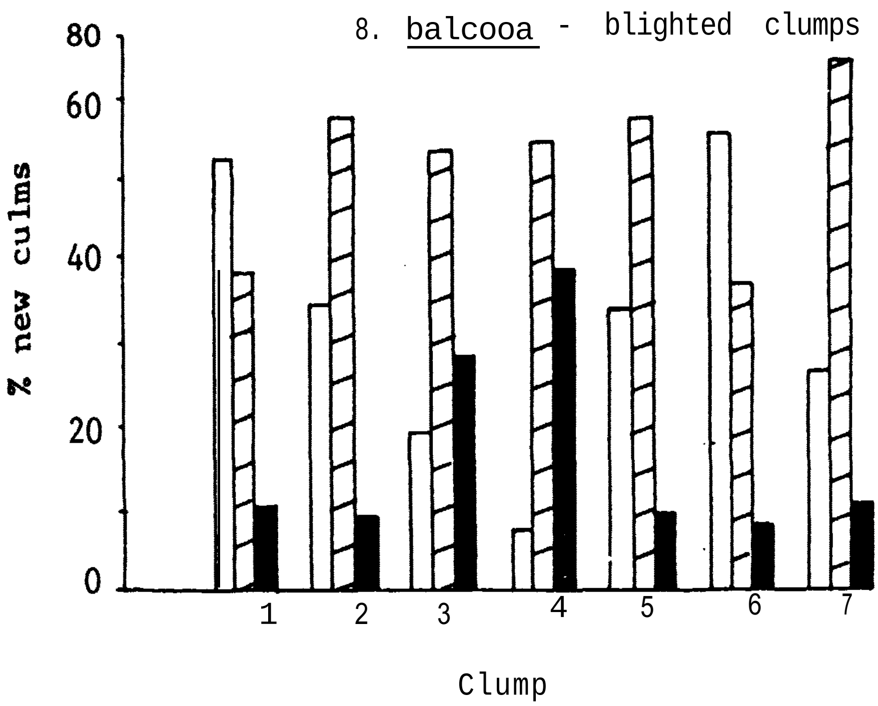
Fig. 9. The fate of new culms produced by healthy and blighted bamboo clumps in 1983: A) Bambusa vulgaris blighted clumps: B) B. balcooa blighted clumps; C) B. balcooa and B. vulgaris healthy clumps.

then no further development of blight symptoms although in following years new branches which develop (on the blighted culm) healthy portion may die back. A major source of loss in both healthy and blighted clumps is the failure of very young culms to develop (Fig. 9). This may be up to 60% of the new shoots in the case of blighted clumps of B. vulgaris. There was little difference in losses due to dead young culms in healthy and blighted clumps of B. balcooa. Ueda (1960) reported similar levels in healthy clumps of Phyllostachys spp in Japan. it is not clear whether the phenomenon of young culms failing to develop beyond a minimal height is therefore part of the bamboo blight disease syndrome.

What is the cumulative effect of blight on clumps over a period of years? Several of the clumps of B. vulgaris in Fig. 9 have died in either 1984 or 1985. Others will die in 1986. In all these clumps blight has been the main factor in their decline although the situation has been exacerbated by bad planning and over-cutting. In B. balcooa there is no direct indication that blight can kill clumps. Often the proportion of new shoots that become blighted in successive years remains more or less constant and the fact that culms grow to a much greater height before becoming blighted must contribute to the lessened effect of disease on the health of the clump. So far only anecdotal evidence and some indirect evidence (Fig. 11) exist to suggest that blight results in the death of some clumps of B. balcooa (Fig. 12)

Isolation of Fungi from blighted and healthy Bamboos

Pieces of culm tissue were taken from the edge of blight symptoms and healthy culm tissue and placed on tap water agar (TWA)



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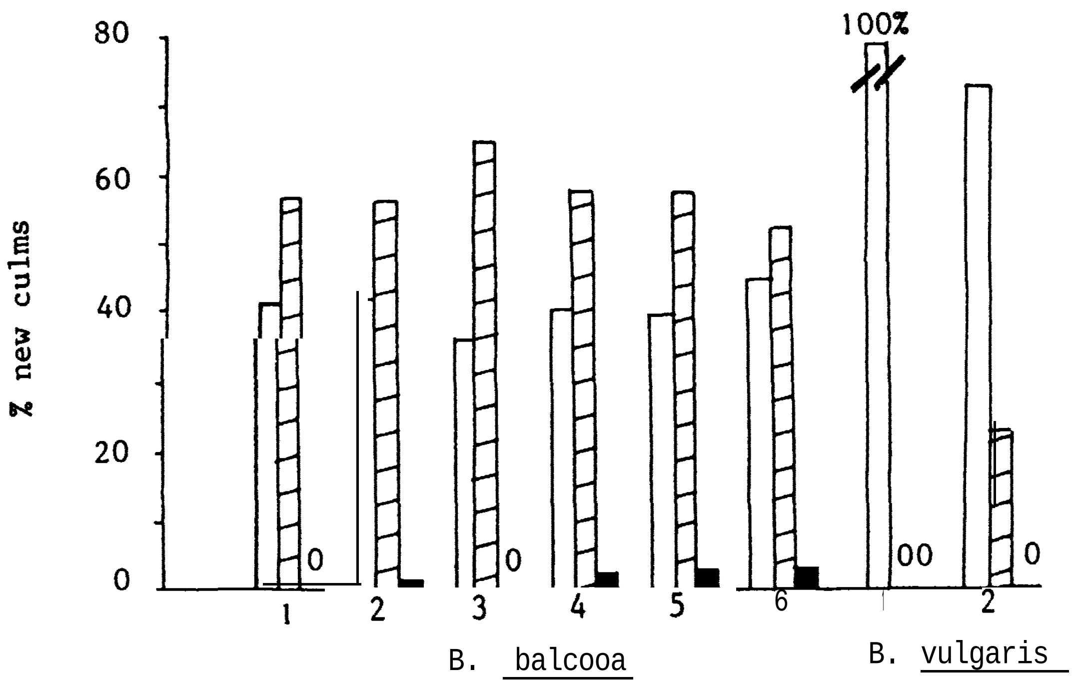
Healthy clumps



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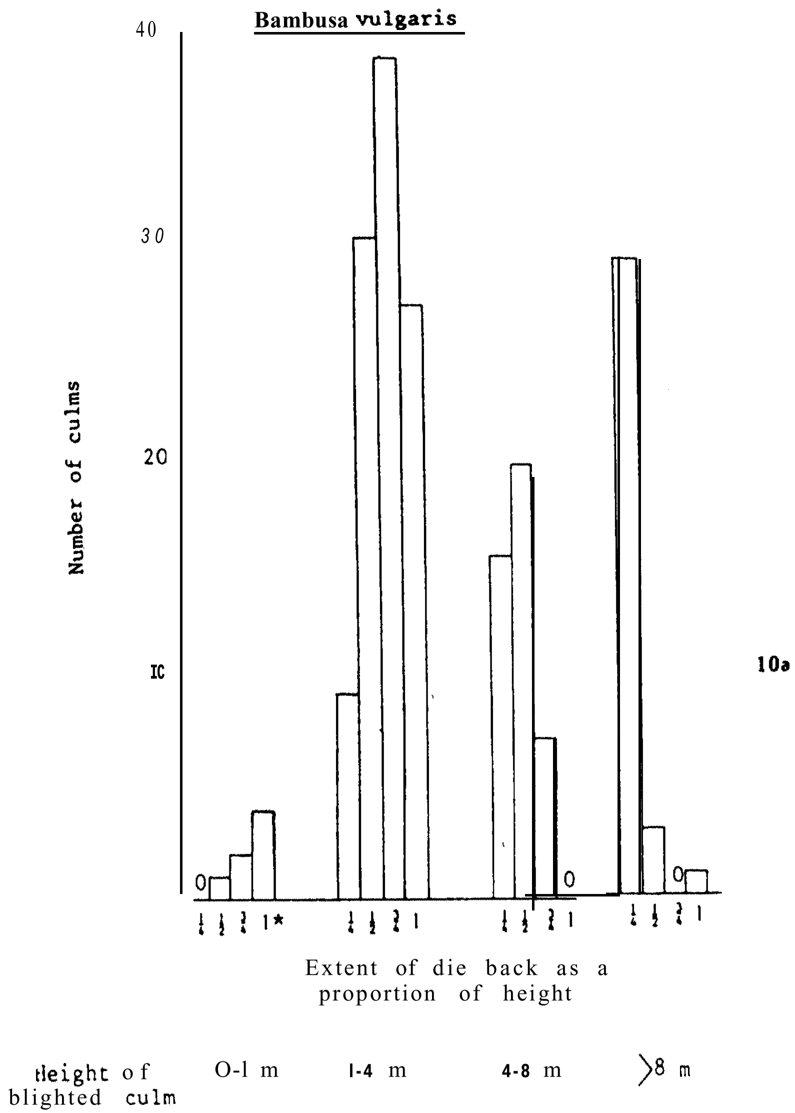
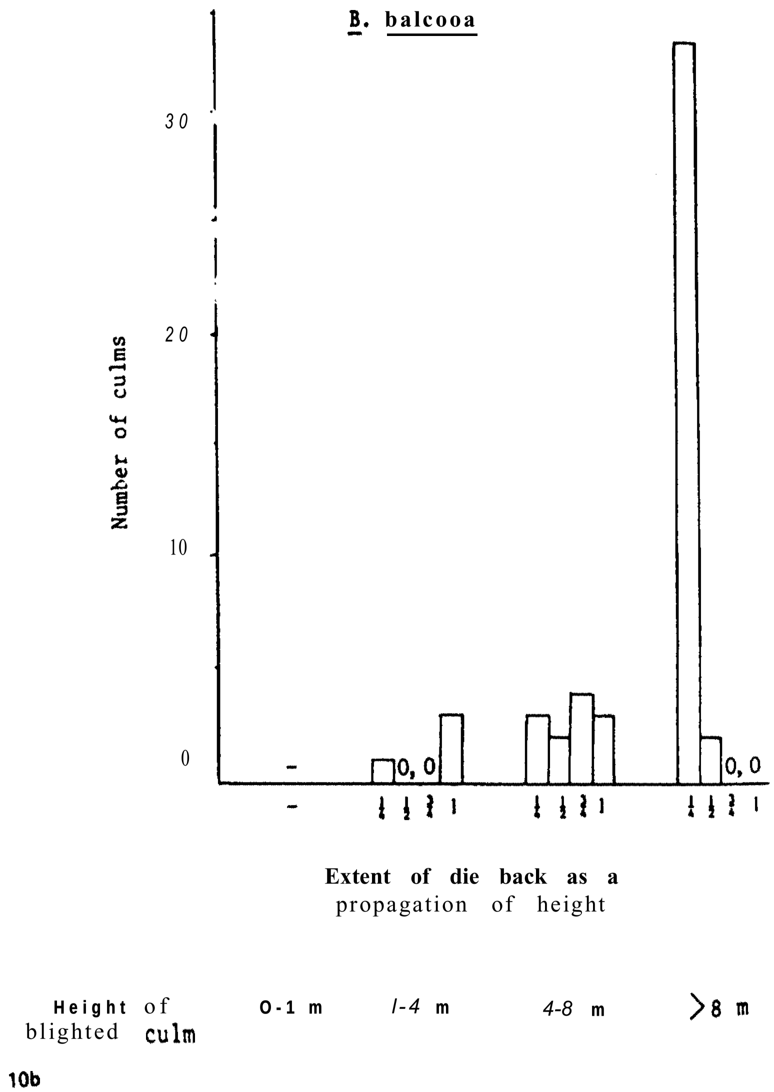
Clump





*Dead

Fig 10 Final extent of die back in new culms of blighted clumps: A) *Bambusa vulgaris* (9 clumps); B) *B.* balcooa (7 clumps)

Fig, 11. Bambusa balcooa rhizomes dug up from clumps reportedly killed by blight in the Faridpur district; to be used for fuel in brick making,

(1.5% w/v) and incubated at 30°C, TWA restricted the growth of the faster growing saprobic fungi which were commonly isolated, including Coniothyriurn fuckelii Sacc., Fusarium spp. and *Pteroconium* and *Arthrinium* anamorphs of A. piospora spp.

lsolations from older blight symptoms: The first set of isolations were made from blight symptoms on 4-8 month-old culms (Figs. 3 and 6). The fungus which aroused interest was the hyphomycete *S arocladium oryzae* (Sawada) W. Gams and D. Hawks. (Bady, 1980). the sheath rot pathogen on rice (Shahjahan et al,, 1977), and was isolated from several clumps. S. *oryzae was* obtained from 68 out of all clumps of blighted bamboo (Table 2). In several of these clumps die back symptoms only were present and if a separate sample is taken from these clumps of 13 clumps of B, *vudgaris* and 15 clumps of B. balcooa. all of which showed internal staining and insect channels in addition to die back, then the recovery of S. *oryzae* increases to 100% and 85% respectively.

Isolations from young blight symptoms: In a follow-up series of isolations tissues with early symptoms were sampled. from culms that were only a week old to 2-3 months (Fig. 4). The recovery of S. oryzae from blight symptoms on such culms was much higher (Table 3). Table 4 gives details of the tissues sampled from blighted and healthy clumps and the results of S, oryzae recovery. *S. oryzae* sporulates freely on TWA and can be easily seen (x 50) under a dissecting microscope, even when other faster growing fungi are present. Conidiophores tend to be simple and unbranched on the original isolation plate, the typical branched aerial conidiophores (Brady, 1980) best being seen on potato carrot agar subcultures,

In both f3, balcooa and B. *vulgaris, S, oryzae* was almost always isolated from the black staining surrounding insect holes (Fig. 4). The range of fungi found in early and late infections stages was similar. How ever one fungus. tentatively identified as *Periconia* sp., was often isolated from young symptoms and was also seen to freely sporulate on the outer surface of dying culm sheaths both on blighted and healthy culms. In some cases only bacteria developed from young symptoms, particul arly with samples from water soaked areas,

Fig. 12. Dying *Bambusa balcooa* culms sheath. Necrosis generally starts at top edge proper. Note hairs on sheath from which fungal isolations were made (see text for details).

Table 2. Isolation of *Saroc1udium oryzae* from older blight symptoms (Figs. 2b, 3, 5) on 4-8 month-old culms

Species	Number of blighted clumps sampled.	Isolation of *Sarocladium oryzae*	
		Yes	No
Bambusa balcooa	51	30 (59%)	21
B. tulda s.l.	15	10 (68%)	5
B. vulgaris	40	25 (63%)	15
“JAWA” (local	5	3 (60%)	2
name – *Bambusa* sp.?)	5	3 (60%)	2
TOTAL:	116	71(61%)	45 (39%)

‘One or two culms per clump were sampled.

Table 3. Isolation of *Sarocbdium oryzae* from young blight symptoms (Fig. 4) on O-3 month-old culms and from O-3 month-old culms in healthy clumps

Species	State of clump	Number of clumps.	Isolation of *Sarocladium oryzae*	
			Yes	*No*
Bambusa balcooa	Healthy. ’	9	8 (89%)	1
	Blighted	18	15 (83%)	3
B. vulgaris	Healthy . .	10	6 (60%)	4
	Blighted	13	11 (85%)	2

- One or two culms per clump were sampled.
- No die back or streaking was seen on any of the culms but insect holes and staining could be found in a few places only.

freely sporulate on the outer surface of dying culm sheaths both on blighted and healthy culms. In some cases only bacteria developed from young symptoms, particularly with samples from water soaked areas.

Where *S. oryzae* only grew from a sample it was described as “pure”, and “mixed” when other fungi were present (as seen x 50 on TWA). About half the samples from black staining at insect holes were “pure”; even where “mixed” the growth of *S. oryzae* was still marked. “Pure” *S. oryzae* was also obtained from symptomless parts of the culm (Table 4) in blighted clumps. These parts included the compacted area of culm sheaths inside the growing culm apex and below this from the edge of the uppermost culm lumens (Fig. 7a). *S. oryzae* was also isolated from one apex of a completely healthy new culm in a blighted clump of *B. balcooa* and *B. vulgaris*.

Isolations from culm sheaths: The presence of *S. oryzae* on culm sheaths of healthy and blighted clumps was investigated. Both *B. vulgaris* and *B. balcooa* have hairy culm sheaths (Fig. 12) and these hairs were sampled by placing a few directly onto TWA. Isolations were also attempted from surface sterilised necrotic patches on the culm sheath itself. *S. oryzae* was isolated from these early necrotic patches on some of the culm sheaths sampled (Table 4), but several other fungi were always present as well, with only small areas of *S. oryzae* developing on the TWA.

Table 4. Isolation of Saroclaodium oryzae from O-3 month-old culms in blighted snd healthy clumps according to type of sample.

Origin of sample	Isolation of Sarocladium oryzae					
	Bambusa balcooa			B. vulgaris		
	No. of clumps	Yes	No	No. of clumps	Yes	No
a) Blighted Clumps						
1. Black staining around insect holes (Fig. 4)	14	13	1	9	8	1
2) Black staining extending into culm wall without insect damage (Fig. 4)	Not seen			7	6	1
3. Surface discoloration of culm (Fig. 4a)	3	3	0	9	1	8
4. Dying young culms (Fig. 7)	1	1	0	1	1	0
5. Culm sheath necroses (Fig. 12)	6	4	2	5	3	2
6. Insect larvae from 1	3	0	3	3	3	0
7. Tissue showing no sign of symptom development (see text and Fig. 7a)	5	2	3	8	3	5
b) Healthy Clumps						
1. Black staining around isolated insect holes occurring on a few culms only	4	3	1	6	4	2
4. Dying young culms	2	1	1	1	0	1
5. Culm sheath necroses	3	3	0	5	2	3

The amount of growth varied from small areas 1-2 mm in diameter to other instances in which it sporulated up to 15 mm away from the hairs. In a study of healthy bamboos growing in the north west, where no blight is present, S. oryzue was recovered from nine out of ten clumps of *B. balcooa* and three out of four dumps of B. tulda s.l. Isdations from associated healthy culm tissue were not attempted.

Acremonium strictum on bamboo: Rahman and Khisa (1983) reported the isolation of Acremonium stricturn from blighted bamboos, isolates of which were used in artificial inoculation experiments. These isolates have recently been re-examined at the Commonwealth Mycological Institute and shown to be S. oryzae. The two fungi are in fact very similar as shown by the descriptions given in Holliday (1980).

Comments on the causes of Bamboo Blights

Only limited artificial inoculations have been carried out with S. oryzae on bamboo, both by Rahman and Khisa (1983) and myself. Rahman and Khisa showed that S. oryzae (A. strictum as mistakenly reported — see above) produced a necrosis and resulted in the death of young branches, which showed a pattern of symptom development similar to that seen in the field. I inoculated fully extended internodes of 5 month-old culms by wounding and which in turn developed a black staining spreading above and below the wound. No die back occurred or streaking. S. oryzae was re-isolated from these symptoms, It is only recently that it has been shown that the first symptoms of bamboo blight occur on growing internodes and future artificial inoculations will concentrate on introducing S. oryzae to culm tissue at a similar stage. Cross inoculations are also planned with bamboo isolates of S. oyzue on riee and with rice isolates on bamboo to see whether we are dealing with exactly the same fungus or whether a separate pathogenic race has developed on bamboo. It is interesting to note that sheath rot of rice was first reported from Bangladesh at the same time as bamboo blight (early 1970s). S. oyzae is seedborne in rice (Shahjahan et al., 1977) and it is suggested that this is how the fungus was introduced to Bangladesh (Dr S Miah, Bangladesh Rice Research Institute, pers. comm.). The fungus is now found throughout Bangladesh on both diseased rice and blighted bamboo and even on the culm sheath hairs of healthy bamboos in blight-free areas. The extent to which S. oryzae is present on culm sheaths of healthy clumps in blighted areas has still to be examined.

How important is Bamboo Blight?

Bamboo blight must be considered a serious disease if only because it attacks the growing cuim, stops any further growth and produces a die back which may in some case kill the cuim completely. Even if this only happens in a few cuims of a season's growth this could represent a major loss to the farmer. The importance of the disease in clumps of B. balcooa varies; some clumps may show one or two clumps which develop blight each growing season whilst in other clumps most of the new cuims become blighted. The effect of the disease on B. vulgaris is more serious, and blight can kill clumps, especially when the already significant effects of blight are compounded by overcutting and badly planned cutting. Although the disease is not causing widespread damage throughout Bangladesh, as was feared might happen, it is a major problem in several areas. Concern about the disease should not, therefore, be allowed to wane. Blight may have decreased in some areas but it has become more of a problem in others. The disease is at present only found in Bangladesh but S. oryzae is a widespread pathogen on rice and occurs throughout Asia along with various Bombusa spp. Priority areas of research must be to fully examine the pathogenicity of S. oryzae on bamboo and also investigate the role of insects both in introducing the fungus into the culm and facilitating the spread throughout the cuim (and between clumps).

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Utilisation

The Role of Bamboo as a Potential Food Source in Thailand

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Abstract

This paper summarises the information on *bamboo shoot production in Thailand, the main components and food value of bamboo* shoots, possible increase *in* production for *the next five years, and potential economic benefits.*

Introduction

Thailand's total area is 513,115 km^2. The country is located in Southeast Asia, between the latitudes 5° and 21°N and the longitudes 97° and 105°E. The humid tropical climate is influenced by seasonal monsoon and the local topography. The forest types are varied, with rich flora ranging from tropical evergreen forests on the Peninsula to dry, deciduous, dipterocarp forest scattered in the northern, central and north-eastern parts of the country. The species of bamboo in Thailand are abundant including 12 genera and 41 species. Bamboos grow naturally as scattered undergrowth in all forest types throughout the country. There is only one area where bamboos are found as pure stands, in Kanchanaburi province, about 200 km west of Bangkok. In Thailand, bamboos are used for a variety of purposes, including food, household construction, supporting poles, pulping, basketry and other handicrafts.

The Sprouting of Bamboo

Bamboo shoots develop from rhizomes during the rainy season. The buds on rhizome-nodes enlarge for several months in the soil. The shoots emerge out of the ground in the form of tender, pointed cones covered with imbricate sheaths inserted at the nodes. These shoots then elongate rapidly, and after one month they will develop into mature woody culms. The number and period of sprout-emergence out of the ground vary according to the species, the size and vigour of the clump, and also the environmental condition of the locality. It varies from 50 to 60 days between early and late-sprouting. The sprouting is strongly influenced by rain in May and June. An investigation on bamboo sprouting was carried out during the rainy season in 1970 (Watanabe, 1972) with results shown in Table 1.

Nutritive Value of Bamboo Shoot as Food

The young and tender shoots of most of the edible bamboo species are consumed fresh or made into pickles, vegetables and

Table 1. Period of bamboo sprouting.

Species	Beginning	Ending	Period (days)
Bambusa arundinacea	May 10	June 25	46
Bambusa vulgaris	May 1	June 22	52
Bambusa tulda	May 25	June 27	33
Thyrsostachys siamensis	May 15	June 1	47

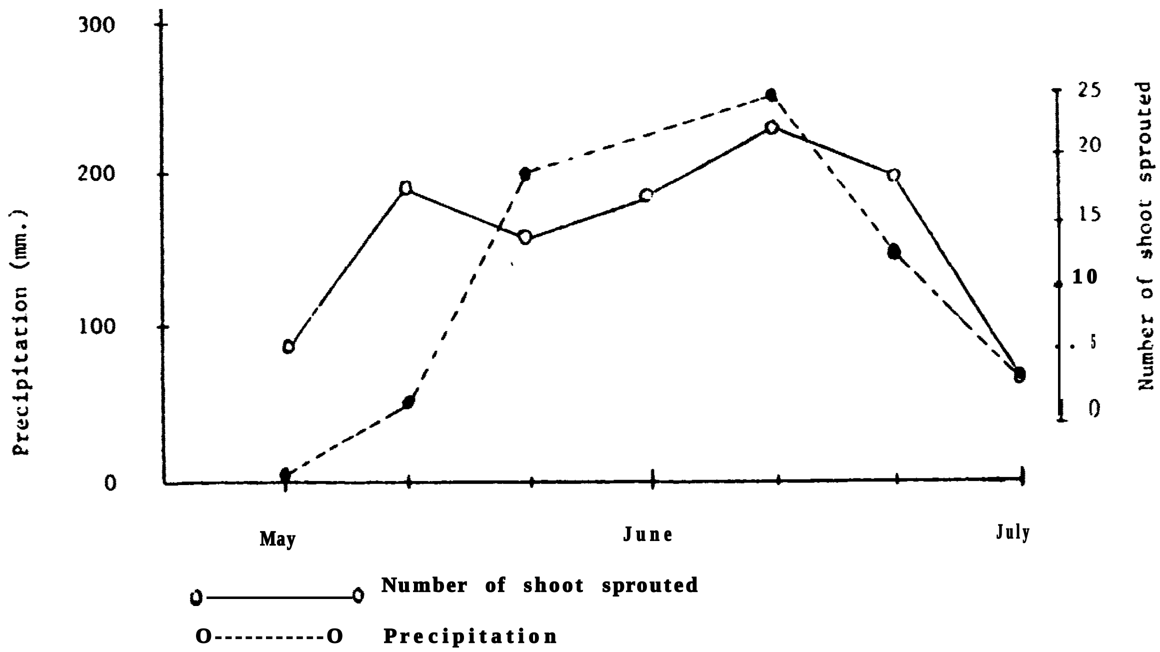

Fig. 1. Relationship between the number of bamboo sprouts emerged out of the ground and the precipitation.

dried forms that are considered delicacies.

Quantities of shoots at three ages (7, 10 and 15 days after emergence) have been studied (Tamolang et al., 1980). The nutrient components such as protein, fat, ash, total carbohydrates, crude fiber, calcium, phosphorus, iron, thiamine (Vitamin Bl) and ascorbic acid (Vitamin C) were chemically analysed. Results showed that age has no relationship to nutrient contents. The shoots were made up of more than 75% water.

The contents of nutrients in bamboo shoots vary according to the different parts of the bamboo sprout. The soft tissue, close to the apex, contains less coarse fibers and are protein rich. The lower parts, especially the portion where the sheaths were peeled off, contain less protein and more coarse fibers. Results of a study of nutrient components of Phyllostachys edulis sprout were reported (Resources Bureau Reference Data No. 34, 1960) and are given in Table 2:

Bamboo for Food Production

Young and tender bamboo shoots are used as daily food for Thai people because of its good taste and low cost. The shoots are highly nutritious, palatable and can be cooked and prepared in many delicious ways. Most bamboo sprouts consumed are harvested from natural forests. Only one species comes from commercial plantation of Dendrocalamus asper, which appears to top the list of edible bamboo species. The edible species of bamboo in Thailand commonly used for food are as follows:

1. Pai Tong – ***Dendrocalamus asper***
2. Pai Seesuk – ***Bambusa blumeana***
3. Pai Ruak – ***Tbyrsostachys siamensis***
4. Pai Ruakdam – ***Thyrsostachys oliverii***
5. Pai Bong – ***Dendrocalamus brandisii***
6. Pai Sangdoi – ***Dendrocalamus strictus***
7. Pai Rai – ***Gigantochloa albociliata***

Besides local consumption, bamboo shoots are also exported. (Table 3).

Table 2. Analytical results of bamboo sprouts (per 100 g fresh matter).

Nutrient		Fresh matter	Canned food
Crude protein		2.5 g	1.9 g
Crude fat		0.2 g	0.1 g
Carbohydrates	– Sugar	2.9 g	2.9 g
	– Crude fiber	1.0 g	1.8 g
Water content		92.5 %	92.8 %
Calorie.		23 cal.	20 cal.
Ash		0.7 g	0.4 g
Lime		1 mg	1 mg
Phosphorus		43 mg	26 mg
Iron		7 mg	1 mg
Vitamin	– A	50 i.u.	50 i.u.
	– B_1	0.10 mg	0.05 mg
	– B_2	0.08 mg	0.05 mg
	– C	10 mg	0 mg

Table 3. The export of bamboo shoots of Thailand.

Types \ Year	1983		1984		1985	
	Quant. Tons	Value. US$	Quant. Tons	Value. US$	Quant. Tons	Value. US$
1. Fresh, chilled bamboo shoots	288.8	222,821	338.9	382,062	238.5	165,873
2. Dry Bamboo shoots	29.7	129,182	15.2	48,332	–	–
3. Canned bamboo shoots	5,864	3,030,309	8,557	3,406,347	–	–

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

It is difficult to obtain accurate information on the real consumption of natural bamboo shoots, since there is no restriction for collection of bamboo shoots from forests. The original bamboo plantations are mainly in Prachin Buri Province, 120 km east of Bangkok, and others were subsequently established successfully in *every* part of the country. The agricultural areas converted to plantations of Dendrocalamus asperare 6,000 ha at present and expected to double to 12.000 ha by 1991.

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The Changes in Nutrient Composition of Bamboo Shoots at Different Ages

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Abstract

The moisture content of bamboo shoots of three different ages increases gradually with age, *and finally averages* at about 92%. The rough fibers also increase with age, as the ***tissue grows old. In contrast, the nutrient composition such as protein, amino-acids, fat, carbohydrate, other minerals. inorganic salts etc., decrease with age. Therefore, the right time to gather the spring bamboo shoots is*** when they ***are still underground. It will certainly affect the*** quality **of** ***bamboo shoots if the gathering time is prolonged.***

Introduction

Phyllostachys ***pubescens, also*** called Mengzong Bamboo Shoots is China's bamboo. They are cultivated extensively for their shoots. China's output of these shoots is the highest in the world. The quality of bamboo shoots largely depends on the number of days after the sprouts' appearance on the ground which is also taken as the age of bamboo shoots. Both qualitative and quantative analyses of the nutrient composition of bamboo shoots are made to provide scientific basis for the gathering time of quality shoots. Better quality shoots fetch higher prices.

Samples and Methods

On April 4, 1984, in the bamboo groves of Wuxing Village, Miaoshan Township in the suburbs of Ningbo, Zhejiang Province, 23 bamboo shoots, the sheaths of which appeared on the ground, with the sprouts still underground, were selected as samples for analysis. On that day, five shoots were gathered and the others were marked, which were subsequently gathered once every five days, seeing to it that they were almost of the same size. At first collection, the average shoot length was 19.53 cm and the perimeter was 20.37 cm. On April 9, the second collection, the average length and perimeter were 25.23 cm and 20.74 cm and during third collection the averages were 36.41 cm and 2 1.06 cm respectively.

The gathered shoots were transported to laboratory in refrigerated flask. They were peeled instantly and the unedible part was cut off with a stainless steel knife. In order to do away with individual differences as much as possible, each shoot was first cut vertically and then horizontally, forming small squares. These squares were thoroughly mixed and 500 g was taken as samples. Of this, 20 g was dried at 10°C in an oven for 20 minutes, fresh samples were used for analysis of moisture content. The other samples were then dried at 80°C in a drier. The dried samples were ground into powder and stored in bottles for further use.

Methods of analysis: 1. Protein was determined by K's nitroimetric analysis. 2. Amino-acids were determined by Hitachi 835-50 Model amino-acids auto-analysis instrument. The qualitative and quantitative analyses were made of protein- hydrolysate amino-acids. 3. Fat was determined by residues. 4. Sugar and soluble sugar were determined by colorimetric analysis. 5. Fibers were determined by acid-alkali analysis. 6. Ash content was analysed by dry ash determination. 7. Phosphorus was determined by anti-calorimetric analysis of Molybdenum and antimony. 8. Calcium and iron were determined by atom-absorption spectrometric analysis. 9. Moisture content was determined by drying at 105°C in an oven. lg of carbohydrate produces 4,000 calories;

1 g of fat produces 9,000 calories; 1 g of protein produces 4,000 calories. 11. Vitamin C was substracted with 1% oxalic acid and determined by titrimetry of 2.6

Except the data for amino-acids, the data for other items are the averages of the three analyses. In order to compare the present data with other vegetables, the data are converted into percentage of fresh bamboo shoot weight.

Analysis and Results

The changes of protein and amino-acids: The bamboo shoots of the three different ages (one with sprouts underground, another with sprouts appearing on the ground five days, and still another with

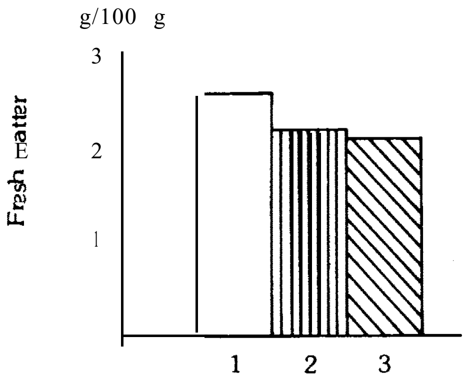

Fig. 1. The changes of protein in bamboo shoots of the three different ages.
(1) Sprouts underground.
(2) Sprouts appearing on the ground 5 days.
(3) Sprouts appearing on the ground 10 days

sprouts appearing on the ground ten days), have a high content of protein, higher than any other varieties of vegetables. However, protein decreases with age; every five days, the protein is reduced by 11.7% to 3.7% (Fig, 1)

The bamboo shoots of the three different ages contain 18 varieties of protein hydrolysate amino-acids. They are ASP, THR, SER, GLU, GLY, ALA, CYS, VAL, MET, ILE, IEU, TYR, PHE, LYS, NH^3, HIS, ARG, PRO, etc. (See Fig. 2, a.. .r indicate the peak amount of various amino-acids).

From part of the data shown in Fig. 2, we got Chart I. The bamboo shoots of the three different ages contain the highest amount of TYR, almost accounting for 3.51% of the weight of the dried bamboo shoots, which increases with age. TYR amounts to 4.8% in the bamboo shoots ten days after the sprouts appeared on the ground. That is unfavourable for bamboo shoots processing and canning for it produces some white **coaguia,** greatly affecting the quality of boiled bamboo shoots. Besides TYR, GLU and ASP are also rich; their content decreases with age. Young bamboo shoots of small size is delicious because they are rich in GLU. The content of PRO, IEU and ALA amounts to over 1% respectively, that of the former decreasing with age while that of the latter, though varying, a little, remaining almost stable. Nutrients contained in bamboo shoots are CYC and HIS, which are stable, too. The total content of amino-acids decreases with the age of bamboo shoots.

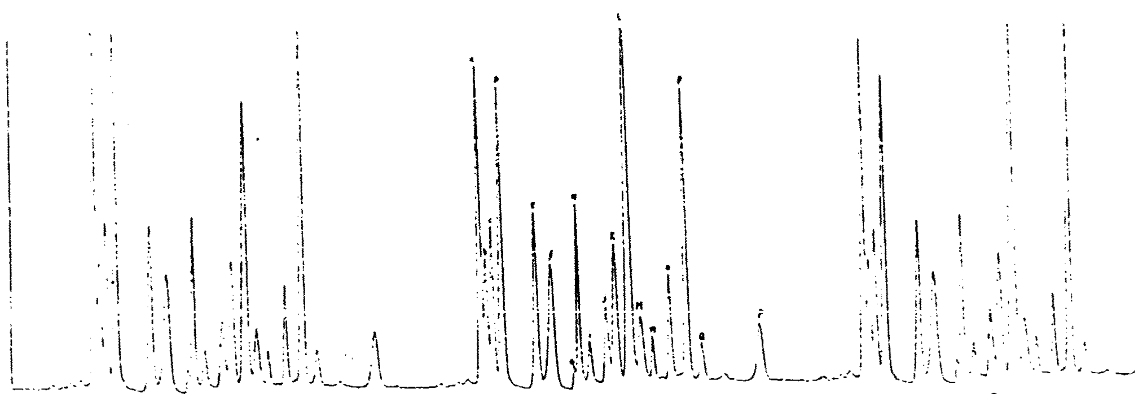

Fig. 2. The changes of amino acids in bamboo shoots of the three different ages

Table 1. The changes of amino acids in bamboo shoots of the three different ages (per 100 g dried matter).

Portion	sprouts underground	Sprouts appearing on the ground 5 days	10 days
ASP	3.31474	2.42582	2.54518
THR	0.72376	0.75652	0.70892
SER	0.79628	0.79064	0.71882
GLU	3.22632	2.71544	2.7336
GLY	0.7221	0.77014	0.71612
ALA	1.12158	1.1923	1.05694
CYS	0.22232	0.20068	0.22068
YAL	0.947	1.0026	0.91458
MET	0.3095	0.35472	0.29906
ILE	0.63158	0.70166	0.61968
LEU	1.13114	1.24632	1.10554
TYR	3.51496	4.8589	4.81126
PHE	0.70734	0.81078	0.73556
LYS	0.64868	0.68206	0.52818
NH_3	0.69698	0.52746	0.7234
HIS	0.30132	0.32292	0.28432
ARG	0.89742	0.92424	0.79932
PRO	1.2212	0.7913	0.5865
Total.	21.13422	21.0745	20.10766

The changes of fat in bamboo shoots of the three different ages: Though very little, fat is richest compared with the fat content of other varieties of vegetables. Fat increases progressively with the age of bamboo shoots though the change is very little (See Fig. 3).

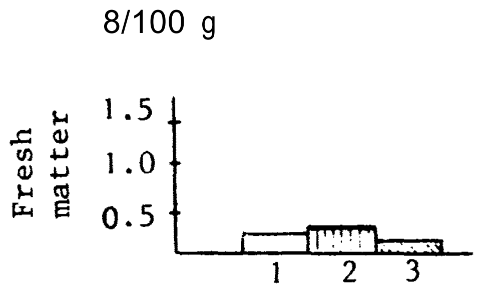

Fig. 3. The changes of fat in bamboo shoots of the three different ages.

The changes of carbohydrate in bamboo shoots of the three different ages: Carbohydrate in bamboo shoots include sugar, soluble sugar, rough fibers, etc. For the content of sugar, soluble sugar and rough fiber, see Fig. 4. With age, sugar and soluble sugar increase by 13.3% to 17.0% in five days and by 26.6% to 32.2% in ten days. Five days after the sprouts' appearance on the ground, the rough fibers increase by 14.6%, and ten days by 18.8%. The tissue grows older and gradually becomes inedible.

The changes of moisture content and quantity of heat in the bamboo shoots of the three different ages: The analysis shows that moisture content in the bamboo shoots of the three different ages increases with age (90.83% – 91.72% – 92.05%) till it reaches a period of steadiness. In contrast, the quantity of heat decreases

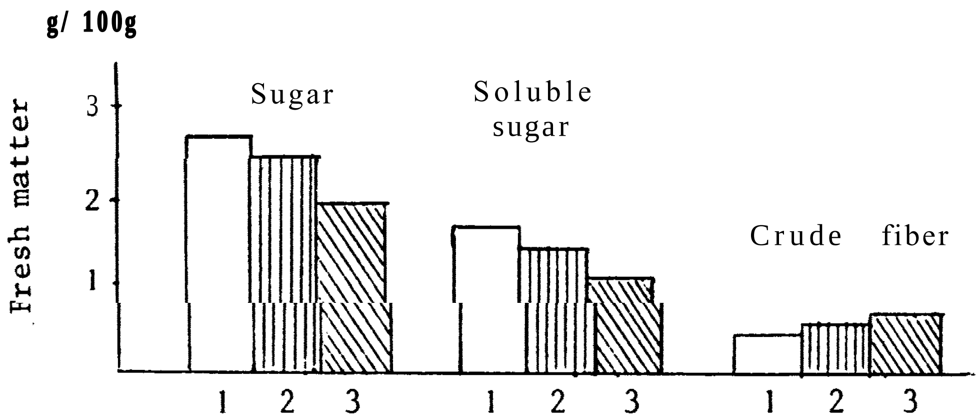

Fig. 4. The changes of carbohydrate in bamboo shoots of the three different ages

progressively with age (23.56% 21.05% – 18.7 1%) . In terms of the structure of quantity of heat (energy) bamboo shoots are relatively rich with nutrients (Fig. 5).

The changes of inorganic salts in the bamboo shoots of the three different ages: Bamboo shoots are rich in ash content with the average of 0.74 g in 100 g of fresh samples. The changes in ash content are little (from 0.73% to 0.75%) with age. Phosphorus and calcium decrease by 16.0% and 37.5% respectively five days after the sprouts' appearance on the ground, and by 25% and 43.8% respectively ten days after the sprouts' appearance on the ground. Iron steadies between 0.29 mg to 0.44 mg (See Fig. 6).

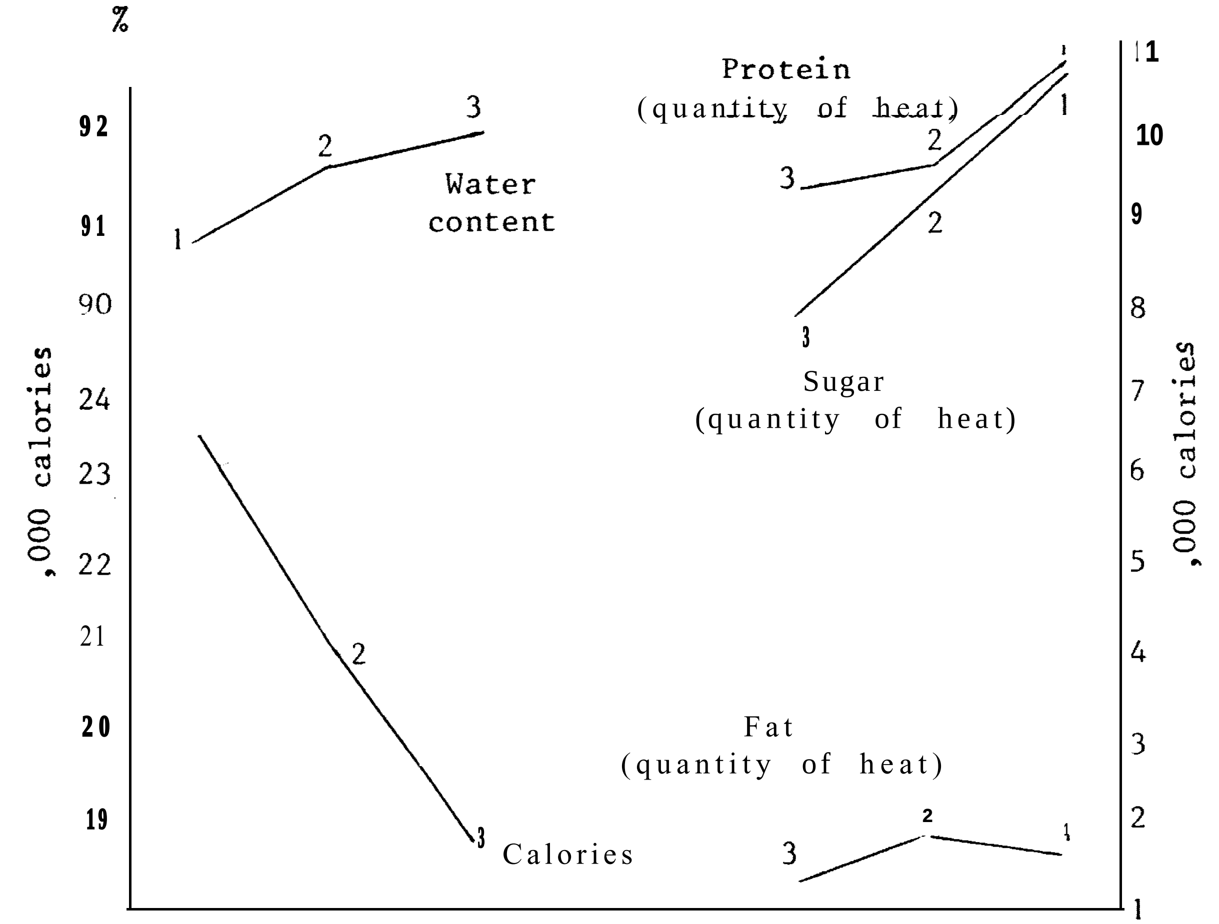

Fig. 5 The changes of moisture content and quantity of heat in the bamboo shoots of the three different ages

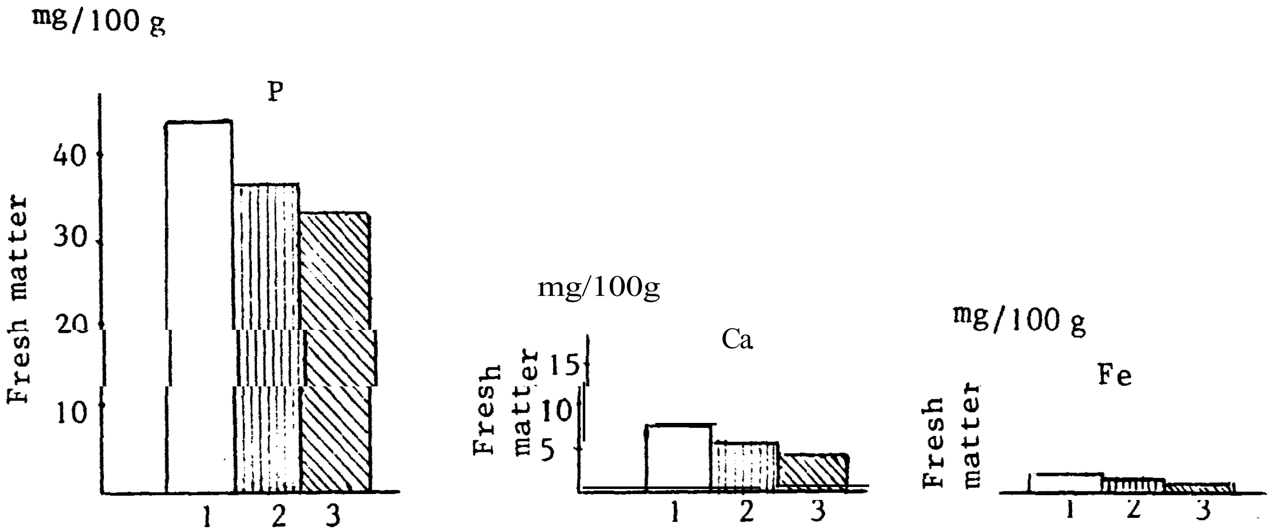

Fig. 6. The changes of inorganic salts *in* the bamboo shoots of the three different ages.

Vitamin C and other nutrient contents are very little, accounting for about 0.001% in the iced bamboo shoots.

Conclusions

The above analyses show that bamboo shoots are nourishing vegetables. With the age of bamboo shoots after the sprouts' appearance on the ground, moisture content increases slowly till it steadies at about 92% Rough fibers increase with age, and as a result, the tissue grows old, and the bamboo shoots become inedible. In contrast, protein, amino-acids, fat, carbohydrate, quantity of heat and inorganic salts, etc., decrease variably with the age of bamboo shoots. Therefore, in terms of nourishment, it is wrong to put off the gathering time of bamboo shoots, which results in higher output but of poor quality. In terms of processing, early gathering of bamboo shoots results in high quality though lower output. In particular, the increase of white coagula greatly affects the quality of boiled bamboo shoots. Therefore, it is the right time to gather bamboo shoots when they are still underground with sheaths just appearing on the ground. Quality deserves greater attention for bamboo shoots which are to be eaten fresh or to be canned. In recent years, there appears a tendency in certain places in the countryside to put off the gathering time for bamboo shoots. That raised the output a little, but greatly lowered the quality of bamboo shoots. The edible parts becoming less, suitable for canning and suitable only for drying.

The following three references give additional information. •

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Characterization of Steam-Exploded Bamboos for ‘Cattle Feed

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Abstract

By steam-explosion process bamboos such as Mosochiku (Phyllostachys pubescence) and Chishimazasa (Sass kurilensis) were converted to easily hydrolyzable materials *(EXBs) by cellulase, and the EXBs were digested* remarkably *by the ruminants. The* different *values were as follows: Saccharification, 95% and 87% of cellulose of the respective EXBs, and in vitro* digestibility of *the* Mosochiku *EXB, 50% of dry matter (DM). These values are comparable to those* of exploded *wood (EXW)* of white *birch (Betula platiphilla and better than* those of Japanese larch (Larix leptolepis) *EXW. The results* indicated that *the* utilization of bamboos *for cattle feed and fermentation are* promising *by the steam-explosion process.*

Introduction

Wood including bamboo is by far the most abundant biomass on earth, and it can be endlessly renewed. The need to develop renewable alternatives to petroleum, and to meet the world’s growing requirements for fuel and food are important. However, because of chemical and structural heterogeneity the wood conversion process is still not economically feasible. Wood is a composite material composed of cellulose. hemicellulose and lignin, and that cellulose is embedded in a matrix of lignin-hemicellulose complexes. Papers on the conversion of wood to ruminant feed are published (Jackson, 1977; Klopfenstein, 1981). It is known that for enzymic saccharification and digestion of wood by ruminants, delignification or cleavage of the lignin-carbohydrate linkages is a prerequiste. (Tsao *et al.,* 1978). We have investigated the steam-explosion of woods and bamboos to accomplish economically feasible separation of cellulose, hemicelluloses and lignin of woody materials for chemicals, pulp and enzymic saccharification (Tanahashi, 1983; Tanahashi and Higuchi, 1983; 1985; Tanahashi *et* al., 1983). This paper reports on the enzymic saccharification and ruminant digestion of the steam-exploded bamboo (EXB).

Materials and Methods

Chemical analysis of bamboos: The culms of Mosochiku (*P hyllostachys pubescence)* and Chishimazasa . (Sasa kurilensis) were pulverized to 60-80 meshes and analyzed by a standard wood analysis method.

Preparation of steam-exploded bamboos (EXBs): Chips (500g. ca. 30 mm x 20 mm x 15 mm) of Mosochiku and Chishimazasa were treated with saturated steam at 28kg/cm^2, about 230°C for 1, 2.4.8 and 16 mins. Then steam pressure was instantaneously released to the atmospheric pressure via a ball bulb to give the EXB. White birch *(Betula platiphilla).* Japanese larch **(Laix** *leptolepis)* and rice straw were exploded at a similar condition. For the enzymic saccharification and determination of *in vitro* digestibility, wet EXB and EXW were freeze-dried and milled by a Willey mill with 1 mm meshes filter.

Saccharification of EXBs and EXWs with cellulase: Two hundred mg of freeze-dried EXBs. EXWs. and untreated bamboo and wood powder (40 meshs pass 80 meshes on) were subjected to *Trichoderma* cellulase

(Meicelase 8000 units, kindly donated by Meiji Seika Co.) digestion in 10 ml of acetate buffer (OIOZM, pH 5.0), at 40°C for 48 hrs by using a Monod-shaking incubator. After enzymic hydrolysis the sample was heated in a boiling water bath for **1** min and filtered. One ml of the filtrate was diluted to 100 ml and the total reducing sugars or glucose was determined according to Somogi-Nelson method or by a glucose analyzer.

in vitro Digestibility ofEXBs and EXWs: Freeze-dried EXBs, EXWs, untreated bamboo and wood powder were analyzed for dry matter (DM), organic matter (OM), crude protein and fat by the standard method. Separately, EXBs and EXWs were treated with a pronase solution and separated to insoluble cell wall structural fraction (CW) and soluble fraction according to the Abe's method (Abe et al., 1979). In vitro digestibility of EXBs and EXWs was measured by treating the samples with a mixture solution of the stomach juice of a sheep and an artificial saliva of McDougall at 38°C under CO_2 stream for 48 hrs. After the treatment the sample was centrifuged and treated with the pronase. Then, DM, OM, and OCW were determined, and in vitro digestibility of the respective fractions was calculated (Togamura et al., 1983).

Results and Discussion

Chemical composition of bamboos used in the present investigation is shown in Table 1. Cellulose contents of both bamboos were about 50%. Fig. lA-D shows scanning electron micrographs of the fibers of white birch EXW (Tanahashi et al., 1983). Vessels (a), fibers (b) and amorphous substances (c) are seen in Fig. 1A. Most of vessels were destroyed to small fragments. Fibers suffered from some damage as a buckling (Fig. IA-D), a cleft along the fiber axis (Fig. 1B) rupture at the middle of a fiber (Fig. lC), expansion in a dome shape (Fig. 1D). The appearance of EXBs was similar.

Mosochiku and Chishimazasa EXBs, and EXWs of white birch and Japanese larch were subjected to enzymic hydrolysis using a Trichoderma cellulase (Meicelase). The results are shown in Figs. 2 and 3. Untreated wood and bamboo powder gave less than 5% saccharification with the enzyme, whereas Mosochiku EXB, Chishimazasa EXB and white birch EXW gave 59%, 44% and 68% saccharification, corresponding to 95%, 87 % and 98% of cellulose of the samples, respectively. However, Japanese larch EXW (28kg/cm^2, 4 min) gave 37% saccharification. The poor saccharification of the larch EXW with the cellulase could be ascribed to anatomical differences of wood, higher Iignin content, and structural differences of lignin. Coniferous woods are composed of mainly tracheids, and the lignin is composed mainly of guaiacyl lignin which is more condensed than guaiacylsyringyl lignin in hardwoods and grasses. However, we recently found that pretreatment of electron beam irradiation of conifer wood chips or after ball milling of conifer EXWs gave almost the same saccharification as in hardwood EXWs (Tanahashi and Higuchi, Unpublished data). Hence, it was indicated that EXBs and white birch EXW were suitable for enzymic saccharification and ruminant feed.

in vitro Digestibility of EXBs and EXWs: Bamboo, wood and rice straw contain large amounts of cellulose and hemicellulose but are low in values as ruminant feed, because of their low digestibility due to physical and chemical linkages between polysaccharides and lignin in the materials. However, by steam-explosion these linkages were cleaved and these materials were converted

Table 1. Chemical composition of bamboos

	Ash	Solubility in Hot-water	Solubility in 1% NaOH	Solubility in Alcoholbenzene	Cellulose	Pentosan	Lignin
	(%)	(%)	(%)	(%)	(8)	(%)	(%)
Mosochiku	1.3	20.0	32.2	4.6	49.1	27.7	26.1
Chishimazasa	1.9	13.1	38.7	9.2	52.3	25.0	19.4

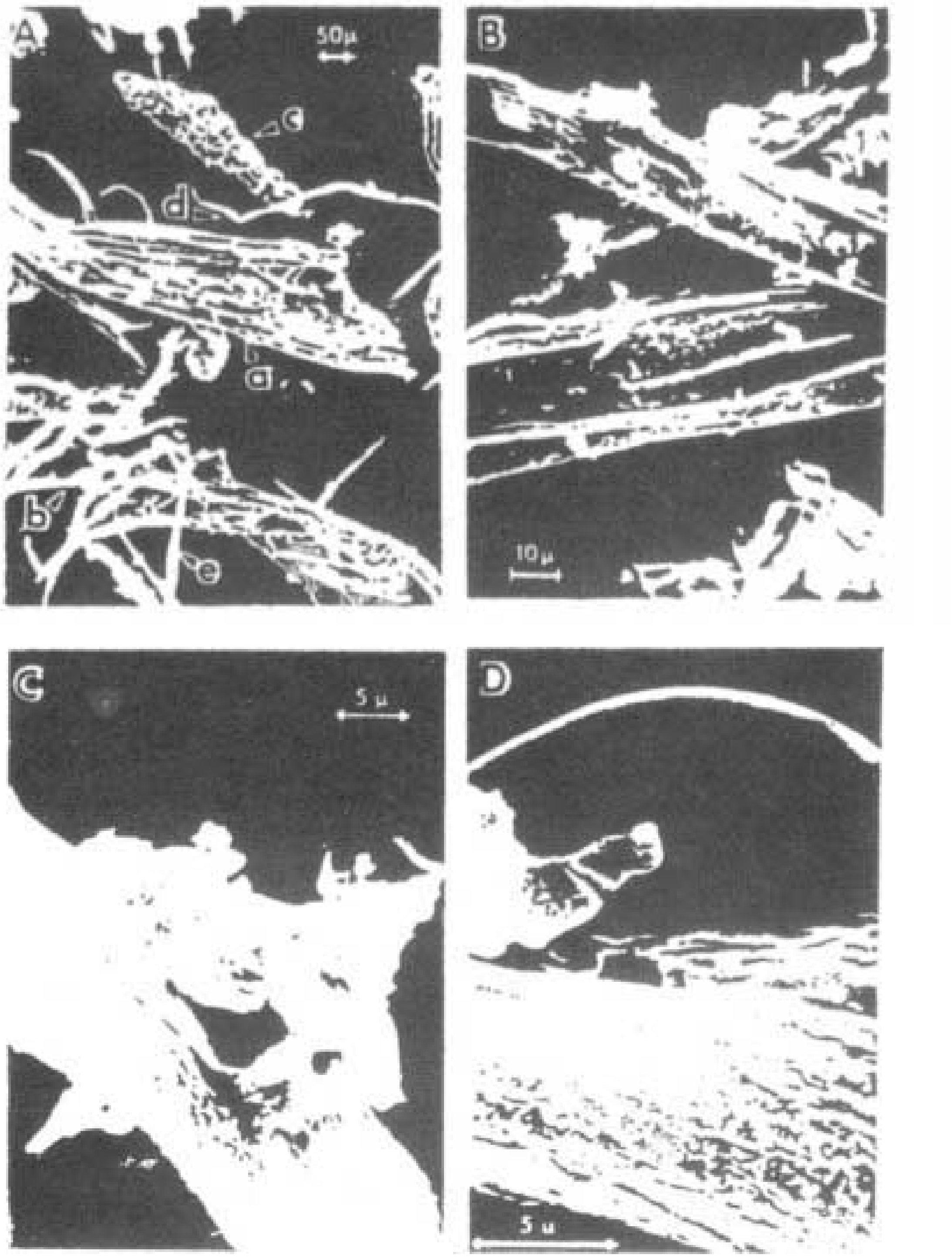

Fig 1 Photographs of white birch EXW (28 kg cm^2, 2 mm 1 (Scanning electron microscope

A, (a) vessels, (b) ftbers, (c) arnorphous substance. (d) buckling and (e) exponslon of a fiber

B, a cleft along a fiber

C. explosion of a fiber

D, expansron

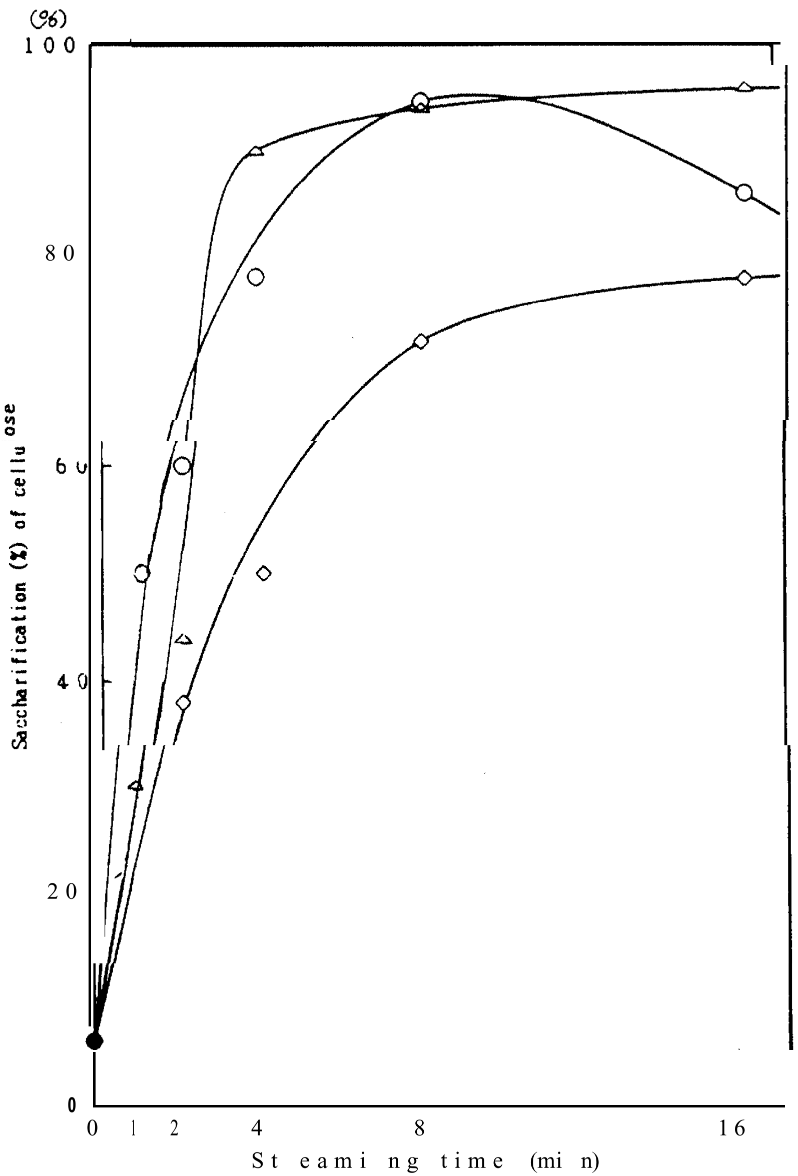

Fig 2 *Saccharification* (%) of cellulose of Mosochiku *EXB*

0 : *steam* pressure, 28 kg/cm^2
Δ : *steam pressure. 24 kg/cm2*
0 : *steam pressure. 20 kg/cm2*
● *unexploded bamboo powder*

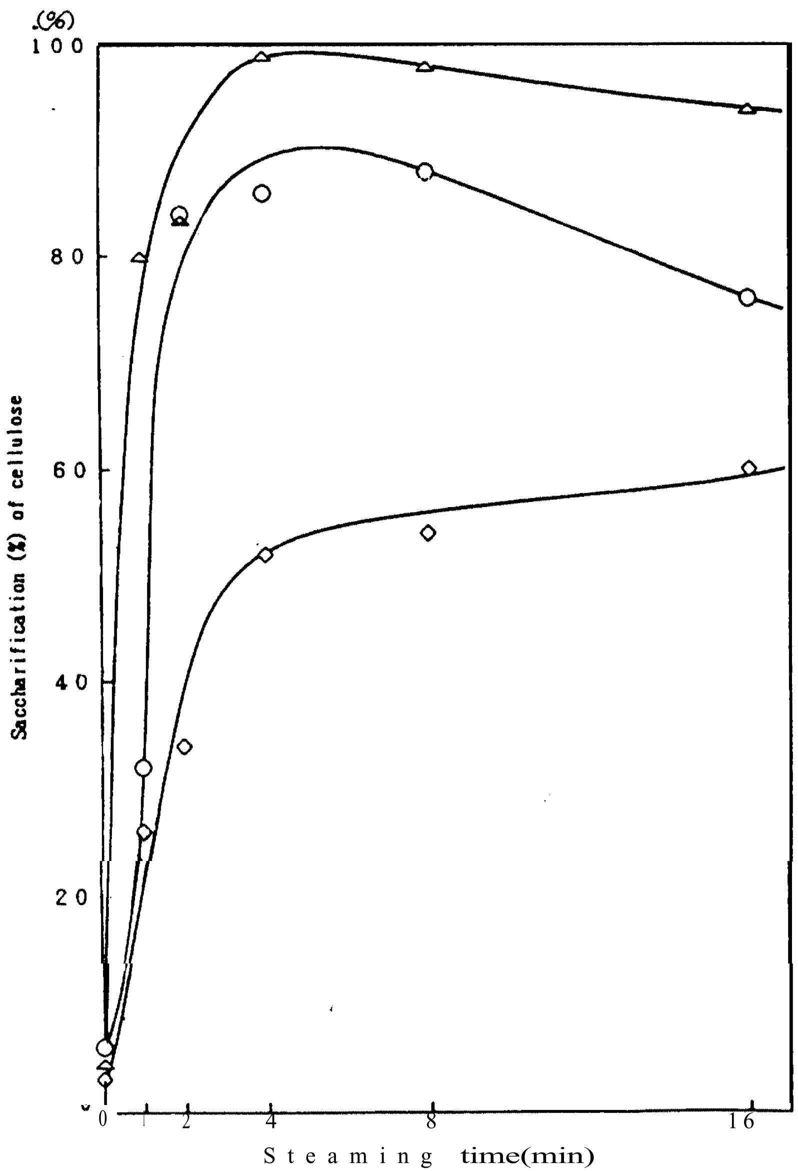

Fig. 3 Saccharification **(%) of cellulose of exploded materials**

O : Chishimazaso (steam pressure, 28 kg/cm2)
A . white birch (steam pressure, 28 kg/cm2)
0 : *Japanese larch (steam pressure. 28 kg/cm^2)*

Table 2. Nutritional analysis and digestibility of exploded Mosochiku

Samples (Mosochiku)	Steaming time (min)	Nutritional analysis DM (%)	OM	CW	ocw	Ash	in vitro Digestibility DM (%)	OM (%)	ocw (%)
			% of DM						
Unexploded	0	92.4	98.0	94.1	93.2	2.0	9.6	8.0	3.2
	1	93.3	98.0	73.0	72.4	2.0	32.6	31.8	7.1
	2	94.5	98.8	72.3	71.6	1.2	33.8	33.5	8.1
Exploded	4	91.8	99.0	71.1	70.3	1.0	47.8	47.3	25.8
	8	91.9	98.9	81.0	80.1	1.1	48.6	48.7	36.6
	16	91.2	98.9	82.3	81.5	1.1	50.0	49.8	39.1

Table 3. Nutritional analysis and in vitro digestibility of exploded materials

	Nutritional analysis DM (%)	OM	Crude protein	Crude fat	OCW	in vitro Digestibility DM (%)	OM (%)	ocw (%)
			(%) of DM					
Mixed hey of orchardgrass and timothy	85.8	90.9	18.1	2.0	61.9	70.2	68.5	53.7
Alfalfa	86.5	89.9	20.1	2.4	46.4	64.0	64.4	31.1
Rice straw (unexploded)	86.1	85.1	5.2	1.8	60.9	43.6	43.7	20.9
Rice straw (exploded) (24 kg/cm^2, 4 min)	90.2	84.6	4.5	2.2	56.8	69.1	75.0	64.2
Bagasse (unexploded)	92.0	97.2	–	–	93.7	41.6	41.8	39.6
Bagasse (exploded) (27 kg/cm^2, 2 min)	91.9	96.9	–	–	77.5	63.3	65.8	57.2
Japanese larch (unexploded)	90.3	99.8	–	–	88.4	11.6	12.1	0.6
Japanese larch (exploded) (28 kg/cm^2, 4 min)	92.3	99.7	–	–	72.1	29.1	29.4	2.4
White birch (unexploded)	94.9	93.7	–	–	83.5	13.3	13.4	2.8
White birch (exploded) (28 kg/cm^2. 4 min)	87.4	86.8	–	–	51.4	76.5	76.5	60.6
White birch (exploded) (26 kg/cm^2, 4 min)	25.2	99.8	0.6	3.4	75.8	52.7	54.0	41.0
EXW with P. valioti (26 kg/cm^2, 4 min, 40°C. 14 days)	40.7	97.2	7.2	0.9	82.7	52.4	52.7	45.4

to easily digestible materials in a mixture of the stomach juice of a sheep and artificial saliva of McDougall. Exploded Mosochiku and rice straw gave 50% and 75% digestibility of organic matter (OM) in comparison with 8.0% and 44% of those in the unexploded samples, and 39% and 64% digestibility of organic cell wall (OCW) (unexpioded samples, 3.2% and 21%). respectively. Thus, digestibility of Mosochiku EXB and white birch EXW is comparable to that of standard feeds, orchard-timothy (68.5%) and alfalfa (64.4%) (Table 2 and 3).

Digestibility of white birch EXW by cattle and goats in a preliminary investigation also showed a better value (90%) than that of hey cube (73%). Body weight of the goats fed with white birch EXW were the same to those of control (Kameoka et al., unpublished data). In addition, we recently found (Tanahashi et al., in press) that the culture of Paecilomyces varioti which was developed by Forss et al. (1976) to produce microbial protein, with white birch EXW considerably improved nutritional quality of EXW (crude protein content increased to 7.2%. Table 3) as ruminant feed. Sugars derived from hemicelluloses, phenolic compounds from lignin, and 5-hydroxymethylfurfural in water soluble fraction of the white birch EXW were almost completely catabolized by the culture. It is thus concluded that EXB and EXW are suitable for fermentation and ruminant feed. It was also shown that the steam-explosion process is one of the best pretreatment of bamboo and woody residues for enzymic saccharification, and preparation of ruminant feed and wood chemicals.

Acknowledgement

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The use of Bamboo as Waterpipes

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Abstract

Tanzania is one of the poorest countries in the Third World. About 10 years ago the Tanzanian gouernment, guided *by the National Political Party, the CCM, introduced a village settlement policy. Around the same time, the Ministry of Water, Energy and Minerals, started the Bamboo Project in support of the* village *settlement* policy and *to reduce dependency on imported materials as* well as *to* provide *water to the rural population by quickest and cheapest means. Most of the activities were centered on the use of bamboo as a piping material, The use of bamboo in the Tanzanian rural life is feasible and about 100,000 people are getting water through bamboo water systems. The whole construction activity is labour intensive carried out at village level with the exception of the design work. The Tanzanian government* has *adopted this technology as a viable alternative for rural water supply and a division has been formed within the Ministry of Water, Energy and Minerals.*

Introduction

The Bamboo Project has been active now for a decade in researching and promoting the use of bamboo as water pipes within Tanzania. We started investigations on the use of locally available materials as water conduits to reduce reliance on conventional materials. The usage of these materials should be undertaken with an eye on economisation and reduction of the foreign exchange component in construction works. Fields of application could be village water supply systems and small scale irrigation works. Although bamboos have been traditionally used as water conduits in many parts of the world, scientific information regarding its behaviour as a water pipe is very scant. Morgan (1974) reports the use of bamboo pipes in Ethiopia and the Indonesian engineer Sudjarwo constructed a six kilometer pipeline on the slopes of the Merapi Volcano, Java. In Tanzania the use of bamboo as water conduits was unknown, although van den Huevel (1981) reports on one village where bamboo was used as a water pipe. The project has so far constructed 150 km of bamboo pipe lines in 28 villages, supplying water to a 100,000 people who are benefitted. Though there was initial resistance from the Ministry of Water against this "backward'* technology, the project is gaining more recognition for its activities and since July, 1985, it has become a division within the Ministry. The project is regarded as a good example of the theory of "self-reliance" as expressed in the Ujamaa policy of Tanzania.

Types Of Bamboo

The first bamboo water supply scheme at the shores of lake Victoria was constructed of *Oxytenantera abyssinica* and *Bambusa vulgaris* (Clayton, 1979). In South of Tanzania vast forests of bamboo are found most of 1500 meter a.s.l. The indigenous bamboo is abundantly available here and is very suitable for water piping. *Arundinaria alpina,* or the green mountain bamboo grows gregariously but not in clumps (monopodial). The density is about 5,000 stems per hectare. Culms grow up to 18 mtr and show the internal diameters between 50 – 85 mm. Because the project does not practise clear cutting, the forest regenerates after 4 – 5 years. No specific records are available on flowering of *Arundinaria alpina* in Tanzania. (Wimbush, 1945); the other sympodial species used in the project is Bambusa vulgaris which was brought to Tanzania during the German colonial time (1890 – 1918). It is less straight than the green bamboo, and cutting it into right sizes is also more labourious. However these disadvantages are offset by its bigger diameters, up to 125 mm and its greater pressure bearing capacity. It is abundantly found north of lake Nyasa (Fig. 1), where it Is also used in housing construction. When all engineering and preservation problems are solved they can be used satisfactorily.

Measurement to determine variation in bore size along the bamboo stem of Arundinaria alpina. revealed that the portion of the bamboo starting from one meter above the ground up to five meters was of uniform bore size and thickness. For a 50 mm (internal diameter) bamboo pipe there was an average difference of 1 mm over the 4 mtr. while for a 75 mm pipe this difference was almost nil. Experiments carried out to ascertain pressures which bamboo can withstand revealed that the material-is capable of taking very high instantaneous pressures. For Arundinaria alpina values up to 6 bar were recorded and for Bambusa vulgaris it sometimes reached 10 bars. However the pressure withstanding capability differs very much from bamboo stem to stem and that maximum values drop considerably when the stem is exposed to those pressures for longer times. No parameters could be established which can correlate or predict the pressure withstanding capability. From experience gathered in the field. it was concluded that the working pressure for Arundinaria alpine should not exceed 1 bar and for Bambusa vulgaris 2 bars. When the bamboo is reinforced by putting wire aroud it. these values-can reach 2 – 3 bars. The low real working pressure for the bamboo pipe may be caused by the water hammer impact. The installation of water hammer absorbing devices may lead to enhanced working pressure ranges. From discharge – pressure measurements conducted at the Hydraulics section of the Department of Civil Engineering, University of Dar es Salaam. the variation of the friction factor (X) was determined by the Darcy Weisbach equation with Reynolds number (Re) (Fig. 2). The plotted Moody diagram clearly depicts the values plotted in the turbulent flow zone. Consequently the use of the exponential formula would be justified. The values of Manning's and Hazen-William's roughness coefficient were determined and found to vary between 0.013 – 0.016 n and 75 – 90°C respectively. The lower n-value indicating good node removal and the higher ones poor node removal.

Preservation

When burried in the ground as a pipe, unprotected bamboo will deteriorate rapidly and in the first village constructed it was observed that part of the pipes were destroyed within two months time by termites. It is not feasible to construct the pipe line Above ground. Cattle and people will damage it easily, while cracks develop rapidly when water flow stops. Because forest and village are in most cases widely seperated, replacements are not done easily.

The problem of termite attack was solved by the use of chlorinated insecticides and the chemicals are sprayed in the trench as solutions of 0.5% aldrin or 1% chlordane. Pipe and chemicals are kept at a distance by partly backfilling the trench before the bamboo pipe is laid. Possible contamination of the watek through these chemicals was investigated by the Tropical Pesticide Research Institute at Arusha. Tanzania, and the laboratory of the water chemistry group of the Delft University of Technology, the Netherlands. Results showed that no health hazards arise from the use of these pesticides. (van den Heuvel 1981). Their persistance in the environment makes them very useful for long-term protection and since 1977, no failures due to termite attack have been reported (Lipangile 1985). In November 1984 a case of termite attack was reported in the first village constructed, Likuyufusi. This continued occasionally this year, indicating that retention values of the pesticide in the soil are becoming less which is in accordance with reported data (Matsumura 1972). Depending on soil condition, temperature, pH and organic material a reapplication of the chemical will be necessary after 7 to 15 years. Rot becomes a severe problem in bamboo water pipes after 3 – 5 years. An early experiment with tar culms gave good results (up to 8 years and not for life), though this was temporarily abandoned. Another strategy adopted was the intermittent chlorination of bamboo water schemes. This killed spores of fungi as well. Since starting this practice there has been a remarkable improvement in performance for the existing schemes. More research should be done to determine the concentration and period of usage. Resuming, present preservation technique involves: a) spraying of the trench with chlorinated pesticides; b) coating the outside with tar and c) intermittent chlorination.

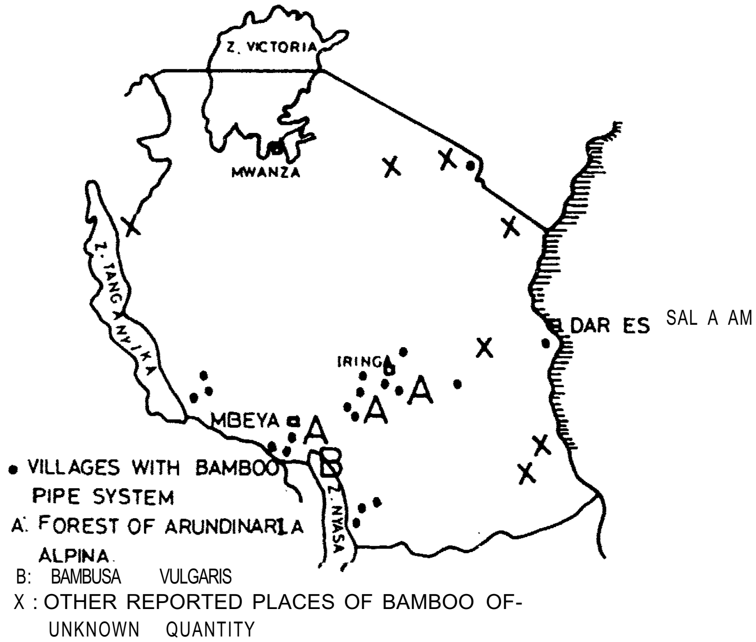
Extensive research has been carried out to impregnate the bamboo culm with other preservatives and all such tests failed because of the leaching of the preservative into the water. It is thought that enhanced durability should be possible by coating the pipe (inside and outside) with epoxy materials. When necessary a fungicide (copper sulphate) could be impregnated in the culm before applying the coating. It has been observed that durability of the bamboo pipe is increased by: a) clean water; b) careful design and construction aimed at a water saturated pipe; and c) construction of schemes at higher (= colder) altitudes. Taking these observations into account, present preservation techniques should protect the pipe for more than 10 years.

All the bamboo water schemes constructed so far are by gravity flow. The intake is normally a weir across a perennial stream. The design of the scheme is mostly based on a 24-hour flow demand from intake to storage tank and for the distribution system on a peak-flow demand. Breakpressure chambers are constructed where the head exceeds the pressure ratings of the bamboo pipes.

The pipe making and laying process involves the following:

- Mature stems of over 3 years age are cut in the forest. Presently the project uses only one forest near Mbeya (Fig. 1)
- 4 meter pieces are transported to a nearby river.
- the nodes are partly removed and the stems are submerged for at least three months in the river to allow desapping. If fresh bamboo are used, the water will get a horrible smell.

FIG. 1: MAP OF TANZANA



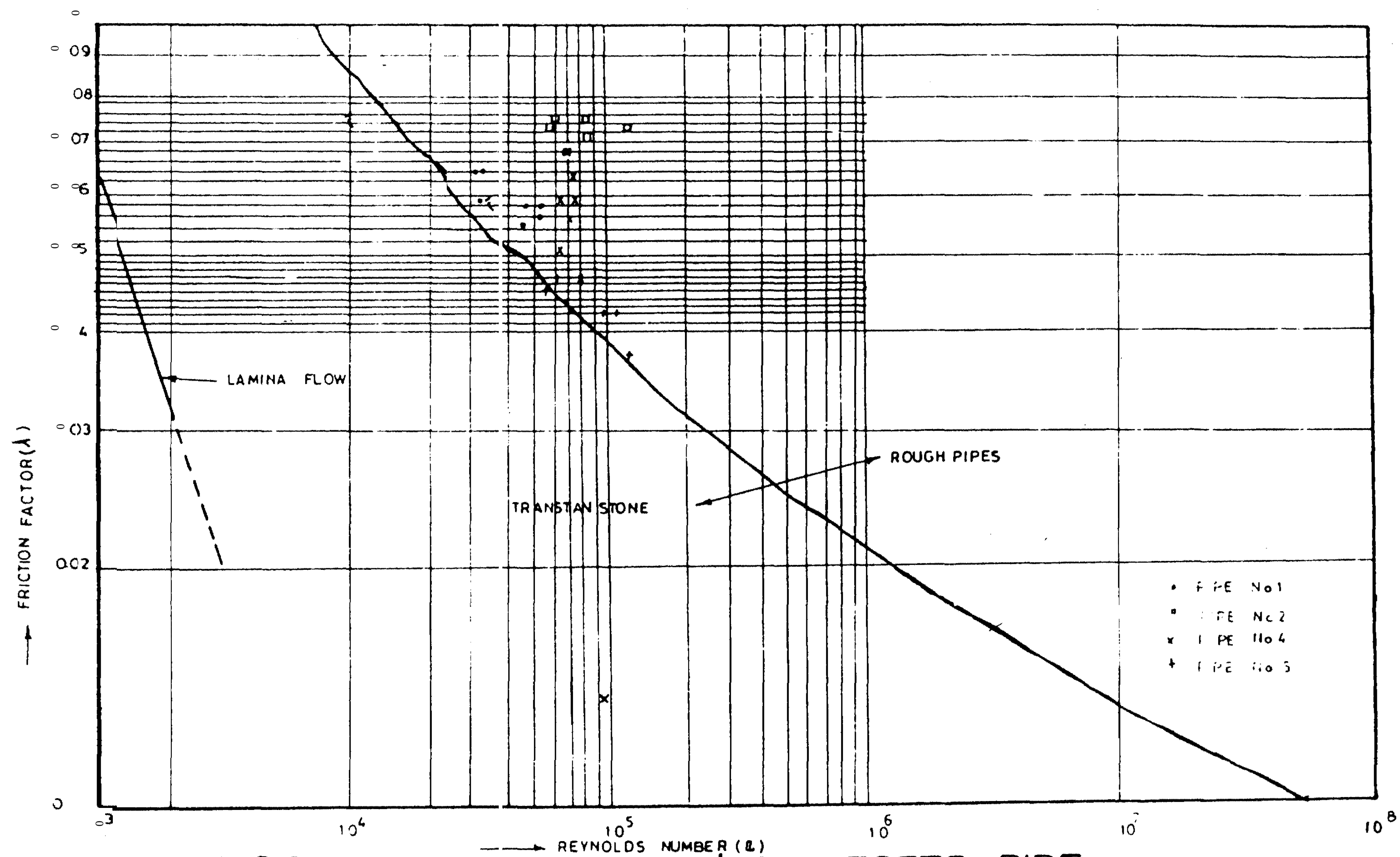


FIG 2 FRICTION FACTOR λ OF TESTED PIPE
ON MOODY DIAGRAM

- from this centralized pond the bamboos are transported to the village construction sites.
- here again the bamboos are stored in a pre-constructed pond.
- the bamboo pipes are reinforced with galvanized wire.
- the butt-ends are sharpened by knife to fit the joint.
- nodes are manually removed by drilling with a 2.5 mtr. long steel rod on which augers of different sizes (to fit the different diameters of the bamboo) can be screwed.
- bamboos are air-dried before they are submerged in a boiling tar solution for 2-3 minutes. Coating is only applied on the outside.
- After drying the pipes are transported to the trenches.
- the trenches have been sprayed with a 0.5% solution of afdrin and are partly backfilled.
- the pipes are laid and jointed by pieces (20 cm) of polyethylene, class B (6 bar).
- Before inserting the bamboo pipes the joints are slightly heated to allow expansion. The pipes are hammered into the joints, which will form upon shrinkage a leak-proof joint.
- the trench is backfilled with some soil. On top of this again afdrin solution is sprayed.
- finally the whole trench is backfilled.

In this construction methodology all fittings, T's, connectors, reducing sockets, breakpressure chambers and domestic points used are of conventional materials.

Maintenance

During construction period two villagers are selected and trained in construction activities. After completion of the scheme they receive a supply of spare bamboos and other materials to enable them to carry out repair works. They are also supplied with a stock of chlorine lime. Each month they are obliged to send a maintenance report to the HQ at Iringa. In this report they should indicate the number of failures during previous month (1 failure = 1 pipe of 4 mtr has been replaced) and the cause of these failures. They also report depletion of stock. From these reports the average number of replacements received in a month / per scheme can be calculated.

Failures could be due to:

- the use of ungafvanized wires for reinforcement and rusted wire, the plugs used to fill the insect holes often become loose, especially during the first months.
- Excessive water pressure developed (Msimbe, 1984).

  Very seldom termite attack is reported but, if the bamboos rot, then the whole operation has to be repeated.

Economics

A 63 mm bamboo pipe is about 4 times cheaper than a focally purchased plastic pipe of the same diameter (Lipangife 1984). The economics of bamboo pipes were estimated by an independent evaluation mission to the Bamboo Project, paid for by the Swedish International Development Agency (SIDA). They came to the conclusion that bamboo pipes are cost competitive both in terms of financial — and economical annualized costs (Broconsuft 1983). From these cost analyses it is apparent that transport contributes greatly to the total costs (up to 50%). This can be reduced considerably by using bamboos in the nearby forests and by exploiting more than one forest. The economic advantage of a bamboo pipe depends also on what size of pofythene pipe it is going to replace. Msimbe, (1985) reports that at low gradients increased flows will be conveyed more economically by bamboo pipes.

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CCA Impregnation of Bamboo– Leaching and Fixation Characteristics

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Abstract

Leaching tests *carried out on CCA (Copper. Chrome, Arsenic) impregnated* Arundinaria alpina *bamboo by Boucherie method, revealed that As was leaching excessively. An average of 15 % Cu, 17% Cr and 34 %* As *could be removed by submerging 2 cm bamboo rings in water. Concerning total salt retehtion, Boucherie impregnation was successful. An average of 12.0 kg* salt per *cubic meter of bamboo was retained. The leaching results were in marked contrast to earlier laboratory findings with CCA impregnation of bamboo sawdust. These experiments showed that good fixation is possible when sufficiently high (= 5 – 10 %)* concen*trations* of *CCA are used. Differences are explained by discrepancies between the pathways of fixation that are followed. Within the bamboo culm, fixation is mainly the result* of *the formation* of Cu – Cr – As complexes *in the vascular bundles. From these vascular bundles the* metal *ions diffuse slowly to the surrounding tissue. In sawdust, fixation takes plalce through the formation* of *CCA complexes with the bamboo constituents – cellu*lose and lignin-. *In* this process fixation of chromium *onto cellulose and lignin is the key-step.*

Introduction

Chromated Copper Arsenate (CCA) formulations have been in use as commercial wood preservatives for more than 45 years and these are the most effective wood preservatives, first developed by Kamesam in 1933. He conceived that copper sulphate, a proven fungicide, and arsenic pentoxide, a proven insecticide, in combination with potassium dichromate, a fixing agent, should contain the properties of an excellent wood preservative. Since the early development of Ascu, as the first copper-chrome-arsenic preservative was called, others have become available on a commercial scale. These included Tanalith C, Celcure A and Boliden K33. They differ in ratio of the used components. Copper is used in the form of copper oxide or copper sulphate. Chromium can be found as chromium trioxide, sodium chromate or potassium dichromate. Arsenic is used as arsenic pentoxide of different water of crystallization. The experiments described in this paper were carried out with Tanalith C. Its composition is given in the experimental part of this paper.

From the available data all of the CCA formulations appear to be excellent wood preservatives, especially for soft woods. In hard woods, early failures may occur. The wide spread use of these chemicals in wood protection was greatly encouraged by its adherence property to the wood. Arsenault (1975) reported the use of CCA treated timber in all kinds of structures where resistance to leaching and high fixation degrees were needed and proven i.e. cooling towers. water storage tanks, flumes, mushroom trays, tomato and grape stakes. Dunbar (1962) described the fixation of water-borne preservatives in cooling tower timber. Henshaw (1978) reported the fixation of copper, chrome and arsenic in softwoods and hardwoods. The leaching of copper, chrome and arsenic from CCA impregnated poles was reported (Evans, 1978). All of them are good fixatives with low leaching rates.

With this background information, the Bamboo Project in Tanzania was started to investigate the use of CCA as a preservative for bamboo water pipes. The aim of the project is to develop a technology which replaces imported hardware elements in village water supply works by materials made out of locally available wood and bamboo. Bamboo could be a viable piping material when its durability could be guaranteed for more than 10 years. The well-defined components of the CCA preservative, the known toxicity and tolerance standards, the fixation properties and its protective working against termites and rot could make it an excellent preservative for bamboo water pipes if indeed protection and fixation could be proven for this case. Unprotected bamboo water pipes buried in the soil will be destroyed rapidly by termites (van den Heuvel, 1981). By spraying the trench with chlorinated insecticides (aldrin or chlordane) this problem could be overcome. Since the project started using these insecticides in 1977, no damage due to termite attack has been recorded (Lipangile, 1985). However rot is not prevented in this bray. Service data records show that without any additional protection bamboo pipes must be replaced within one to five years. Present preservation technique involves spraying the trenches with chlorinated insecticides, coating the outside with tar and intermittent chlorination of the constructed schemes (Msimbe, 1985), while careful design and construction – aimed at 100% filled pipes – may add to the life-span of the pipe. CCA impregnation of the bamboo culm would enhance life-span, reduce costs and facilitate the manufacture of the bamboo pipes.

Very little data is available on the use of CCA as a preservative for bamboo. In a report of the United Nations (1972). recommendations were made for the protection of bamboo in use under different conditions. A few other publications mentioned the advisable solution strength of CCA for bamboo treatment. Wimbush (1945) gives2%, Bleyendaal (1978) 10% and Purushotham et al (1965) 8%. The last author also reported that a retention of 5 – 6 kg/m^3 is needed for a 10 – 15 year protection. No data was available on the leaching and fixation of CCA in bamboo: Van den Heuvel (1981) reported the first part of this research on CCA impregnation of bamboo water pipes. The aim of the research was to investigate if CCA could be safely applied in bamboo water pipes. CCA impregnation of bamboo sawdust was carried out and assessed for leaching and fixation characteristics. According to these laboratory findings, field trials were performed with CCA impregnation of bamboo culms by Boucherie method. Most chemical analyses were performed in the Delft laboratory, while field experiments were carried out in Tanzania.

Results and Discussion

Type of bamboo: When not otherwise mentioned, all experiments were conducted with the bamboo *Anmdinaria alpha,* also called the green African mountain bamboo. It is the species most abundantly available in Tanzania and because of its size (internal diameter 50 – 75 mm) and straightness, it is very suitable as a water pipe.

Type of CCA: All experiments described in this paper were carried out with Tanalith C. A CCA-type preservative had the following composition (as % w/w) :

45% potassium dichromate ($K_2Cr_2O_7$) – molar ratio Cr 2.2; 35% coppersulphate ($CuSO_4.5H_2O$) – molar ratio Cu 1; and 20% arsenic pentoxide ($As_2O_5.2H_2O$) – molar ratio As 1.1.

It resembles closely the CCA type C, defined according to the American Wood Preservers Association standard PS-74. This standard defines the molar ratio for CCA type C as Cr/Cu/As as 2.0/1.0/1.1.

Tanalith C was chosen because it is the CCA preservative most widely used in Tanzania.

Chemical analysis of copper, chromium and arsenic: Copper and chromium were determined according to standard procedures for the atomic adsorption technique. An air-acetylene flame was used. The Tanzanian laboratory used a Pye Unicam SP 9, the Delft laboratory the Varian Techtronic 1100. When the concentrations became very low or the matrix influences high, the flameless technique was used in the Delft laboratory. The instrument. a Perkin Elmer S300. Arsenic was determined in the Delft laboratory by the normal hydride generation technique. AsH_3 was atomized in a quartz tube with an air-acetylene flame and measured with the Varian Techtronic 1100. At the Government Chemist laboratory, Dar es Salaam. AsH_3 was led through a solution of silver diethyldithiocarbamate (SDDC) and the red coloured complex measured at 540 nm with a spectrophotometer.

Determination of Cu, Cr and As in bamboo tissue: The total amount of copper, chromium and arsenic in the CCA treated bamboo was determined through digestion. Pieces, varying from 3 – 6 grams, were dried at 105°C and accurately weighed. They were transferred into glass tubes (ø , 4.0 cm x 30 cm), 25 ml of concentrated nitric acid was added and the tubes were slowly heated in an aluminium heating block at 40° – 60°C. After a few hours, another 25 ml of conc HNO_3 was added and heating continued at 160°C The digestion was stopped when all the bamboo had dissolved and the evolution of nitrous fumes had stopped. The solution was transferred quantitatively to a measuring flask and water added to make up a final volume of 100 ml. Concentrations of copper, chromium and arsenic were measured with the techniques mentioned and expressed as grams per kg of bamboo tissue.

CCA fixation onto bamboo sawdust: The CCA reaction in wood is a fixation reaction involving the reduction of hexavalent chromium to trivalent chromium, followed by the formation of a complex mixture of insoluble salts. According to Dahlgren and Hartford (1972 II and III) the final equilibrium fixation products are ion-exchanged Cu to the wood, $CrAsO_4$, $Cu(OH)CuAsO_4$ and $Cr(OH)_3$, although highly basic chromic chromates, persist for a long time. Depending on the pH, the various Cr^{VI} anions exist in equilibrium with one another as follows:

$$Cr_2O_7^{2-} + H_2O \rightleftharpoons 2HCrO_4^- \rightleftharpoons 2CrO_4^{2-} + 2H^+ \quad \text{(eq. 1)}$$

The reduction of chromium than takes place according to the following reactions

$$Cr_2O_7^{2-} + 14H^+ + 6e \rightarrow 2Cr^{3+} + 7H_2O \quad \text{(eq.2)}$$

$$HCrO_4^- + 7H^+ + 3e \rightarrow Cr^{3+} + 4H_2O \quad \text{(eq.3)}$$

$$CrO_4^{2-} + 4H_2O + 3e \rightleftharpoons Cr(OH)_3 + 9OH^-$$

The last reaction only takes place under alkaline conditions and is of no interest for the CCA – wood/bamboo system. During the course of chromium reduction, the pH will increase due to the depletion of H^+ ions. pH increase in time was measured for the CCA – bamboo system. 8 grams of bamboo sawdust was mixed with 8 ml of CCA solution of different strength (2%, 5% and 10%). The samples were placed in the dark and the pH measured in time with a flat-membrane pH electrode, The results are given in fig. 1, The date clearly indicate that there is a sharp initial rise in pH (pH of a 5% CCA solution = ± 2). An instant change in proton activity of this magnitude cannot possibly be explained by

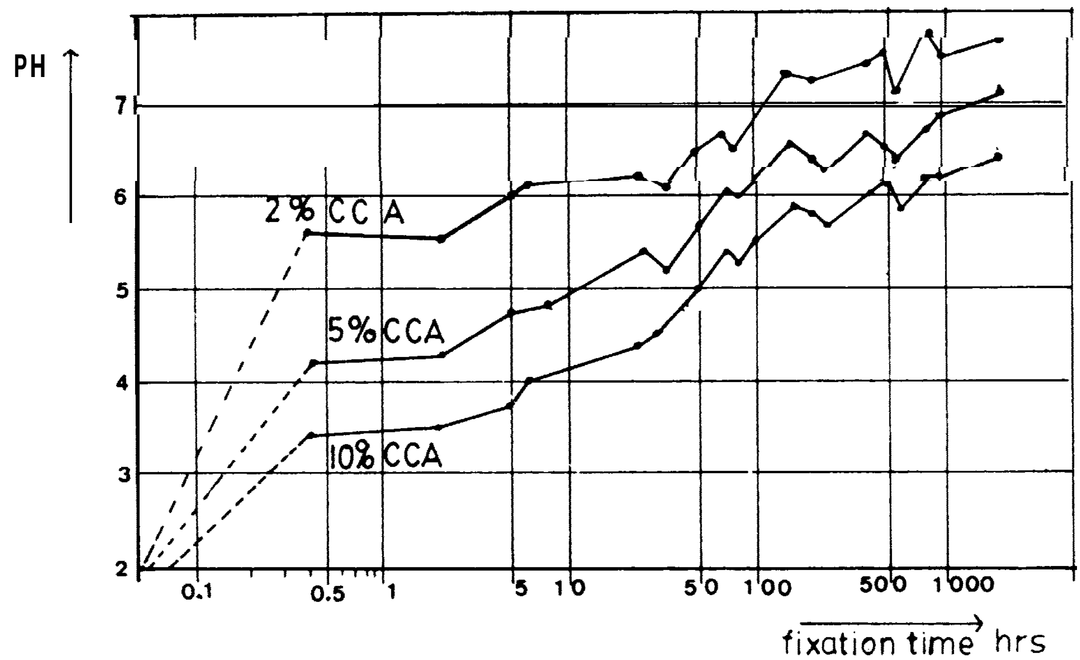


Fig. 1. The pH changes during fixation of CCA onto bamboo sawdust for different concentrations of CCA

chromic acid oxidation of bamboo tissue. Dahlgren and Hartford (1972 I) observed the same phenomenon for wood, although the effect was not so pronounced. The pH increased from 2.03 to 2.55 after 3 minutes for a 5% Tanalith C solution on pine wood. He attributed this to an absorption of chromic acid onto the wood constituents. However, in Tanalith C, the bulk of proton activity is generated through hydrolysis of arsenic. pentoxide, producing arsenic acid (H_3AsO_4) , which will be partially ionized. Bamboo tissue must be capable of taking up H^+ ions (buffer capacity) resulting in the large instant pH increase, although it cannot be ruled out that rapid cdmplexing of chromium and arsenic anions contributes to the observed effect. The observed oscillating pH effects at the end of the fixation time can be attributed to conversion reactions of already precipitated materials into more stable compounds. Dahlgren and Hartford (1974 IV) postulated the conversion of primarily formed acidic copper arsenates into basic copper arsenates under release of arsenic acid, which in its turn reacts with the earlier formed chromic chromates. Pizzi (1981 I and 1982 IV) could not find copper arsenate complex in precipitates obtained after reaction of CCA type C with wood and its separate constituents – glucose/cellulose and guaiacol/lignosulphonate – and he postulated that the oscillating pH at the end of the fixation time was due to rearrangement of lignin complex under influence of the slow release of Cr^{III}.

For arsenic fixation, chromium reduction is essential. All the arsenic is precipitated as $CrAsO_4$ which can form complexes with lignin or stay loosely bound to cellulose (Pizzi, 1982 III). For chromium reduction, it is necessary to have: 1) sufficient H^+ ions – during chromium reduction H^+ is consumed causing the slow pH increase; 2) sufficient oxidizable material – chromium reduction is only possible when another compound is oxidized.

The formation of precipitates is favoured by: 3) a high final pH -- the higher the pH, the more insoluble the complex. Dahlgren (1975) gave a pH of 6, above which all salts were precipitated; 4) a low ionic strength – K_s (solubility product) is the product of activities. The higher the ionic strength, the lower the coefficient of these activities, the higher the concentrations.

To verify the above assumptions, bamboo sawdust was treated with different concentrations of CCA (2%, 5% and 10%) under addition of acetic acid (HAc) as a source of protons and sugar as an easily oxidizable material. The redox potential (E) and the pH were measured with flat-bottom electrodes during a two month period. Samples were kept in the dark. pH and E are plotted against each other in Figs. 2, 3 and 4 for the different solution strengths and the different additions.

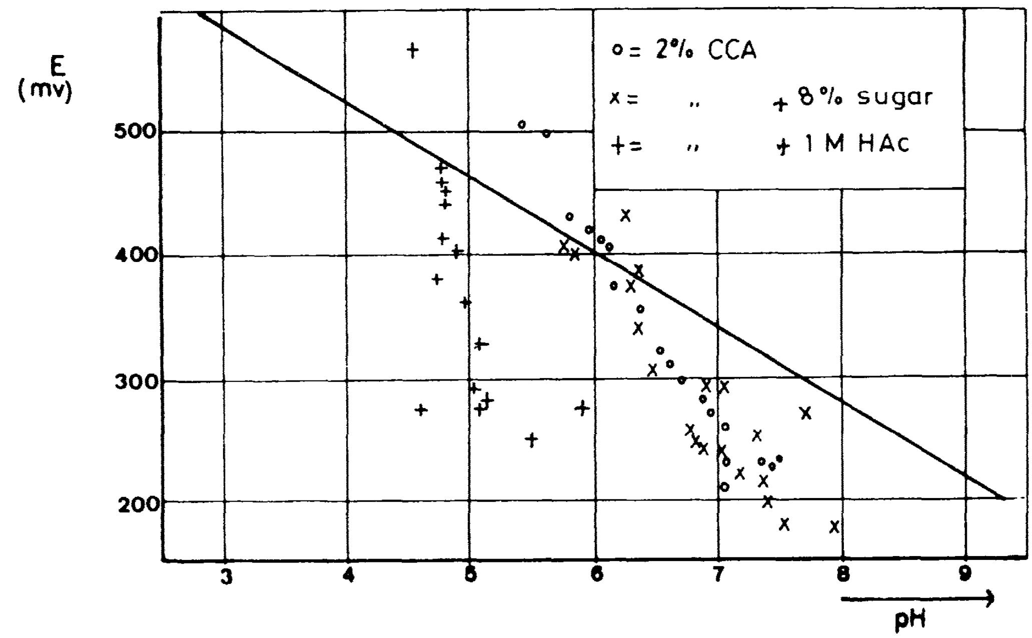


Fig. 2. E versus pH graph for the fixation reaction of 2% CCA (and different additions) onto fixation reaction. The straigth drawn line depicts how E changes with pH in a pure 2% CCA solution.

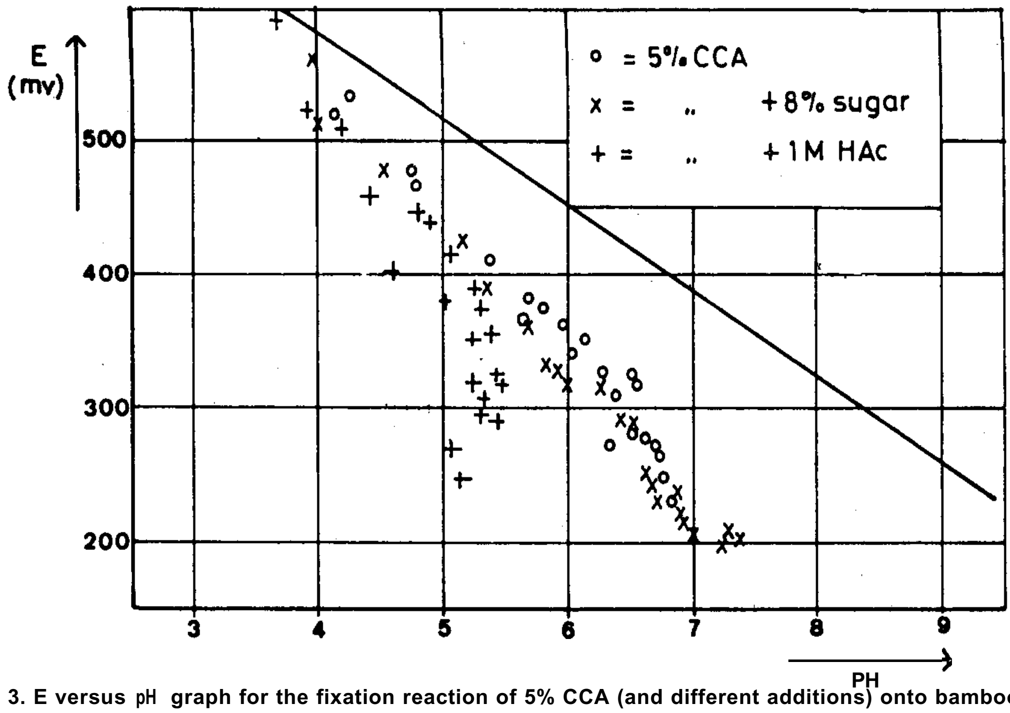


Fig. 3. E versus pH graph for the fixation reaction of 5% CCA (and different additions) onto bamboo sawdust. The straight line depicts how E changes with pH in a pure 5% CCA solution (for details, see text).

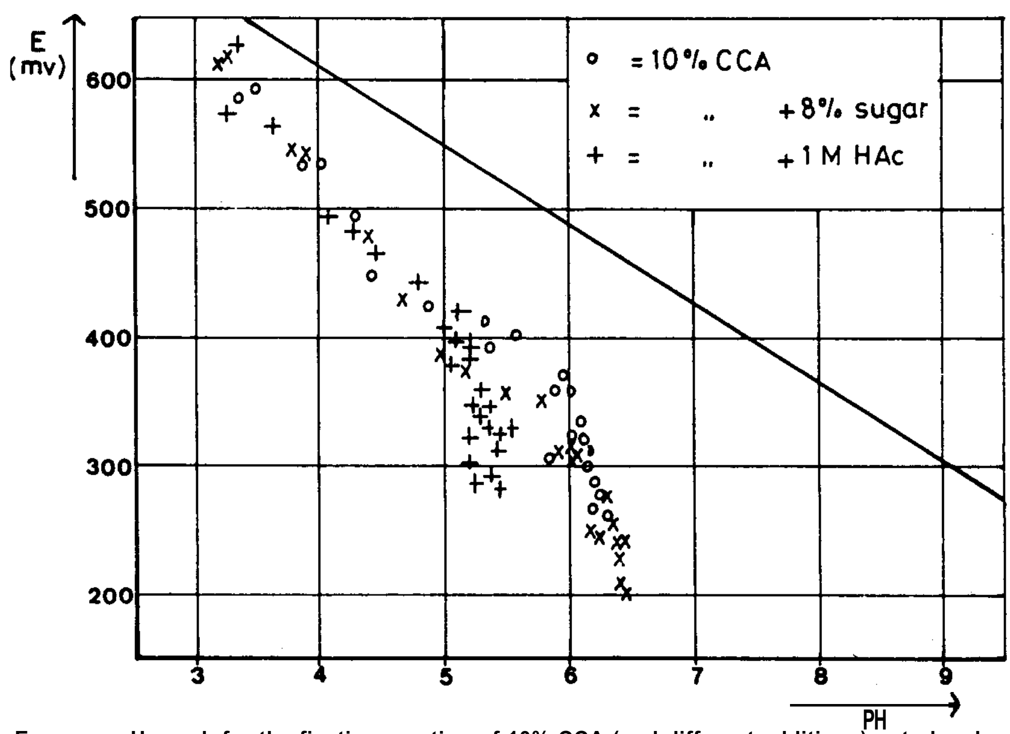


Fig. 4. E versus pH graph for the fixation reaction of 10% CCA (and different additions) onto bamboo sawdust, The straight line depicts how E changes with pH in a pure 10% CCA solution.

The straight lines in these figures depict how E changes with pH when no chromium reduction takes place. The further the point from this line, the more chrome VI has been reduced. After this fixation time the sawdust was washed twice with 100 ml deionized water to determine the amount of unfixed copper, chromium and arsenic and the concentrations in the washing liquid were measured. Table 1 gives the values of washed out copper, chromium and arsenic in mg per gram bamboo and as a percentage of total copper, chromium and arsenic retention. Table 1 also shows that with a low loading of CCA on bamboo, the fixation was very poor. A 2% Tanalith C solution gave a leaching of 13% for Cu, 30% for Cr and 29% for As. Dahlgren and Hartford (1975 V) reported the same phenomenon for Douglas fir. Ponderosa 'pine and to a lesser degree

Table 1. Leaching of copper (Cu), chromium(O) and arsenic (As) from CCA impregnated bamboo sawdust, using different concentrations of CCA and different additions for impregnation.

	2% CCA	+ 8% sugar	+ 0.2M HAc	+ 1.0M HAc	+ 4.0M HAc
copper	0.30 – 13%	0.37 – 16%	0.15 – 6%	0.63 – 27%	0.90 – 39%
chromium	1.22 – 30%	0.67 – 16%	0.32 – 8%	0.63 – 15%	0.99 – 24%
arsenic	0.87 – 29%	0.63 – 21%	0.51 – 17%	0.66 – 22%	0.95 – 32%
	5% CCA				
copper	0.16 – 3%	0.18 – 3%	0.18 – 3%	0.92 – 16%	2.18 – 37%
chromium	1.20 – 12%	0.26 – 3%	0.21 – 2%	1.61 – 16%	3.68 – 36%
arsehic	0.14 – 2%	0.16 – 2%	0.18 – 2%	0.79 – 11%	1.74 – 23%
	10% CCA				
copper	0.31 – 3%	0.24 – 2%	0.32 – 3%	0.98 – 8%	4.21 – 36%
chromium	2.06 – 10%	0.21 – 1%	0.94 – 5%	3.22 – 16%	10.51 - 51%
arsenic	0.24 - 2%	0.19 – 1%	0.23 – 2%	0.94 – 6%	3.02 – 20%

All values are expressed as mg metal leached per gram sawdust.
The percentages are of total retention of the metal ion.

Southern yellow pine when treated with 2 – 2.5% preservative solutions, although he mentioned unexpectedly high As leachability. Doubling the concentration also gave normal leaching rates. When we interpret the leachability of Cu, Cr and As for the different solution strengths with the results drawn in Figs. 2, 3, and 4, we can conclude that these high leaching figures for the 2% solution are due to poor chromium reduction. The figures also show that addition of sugar resulted in more chrome reduction at the end, although the reaction did not proceed any faster. The fixation of chromium was improved for all solution strengths when sugar was added (Table 1). Addition of acetic acid solutions gave 1 M and 4 M a larger chrome reduction (Fig. 5). However, because of the low final pH (pH ± 5) and the high ionic strength, precipitates *were* poorly formed, causing high leaching rates (Table 1). From Fig, 5, it can also be concluded that when H^+ is in excess. a

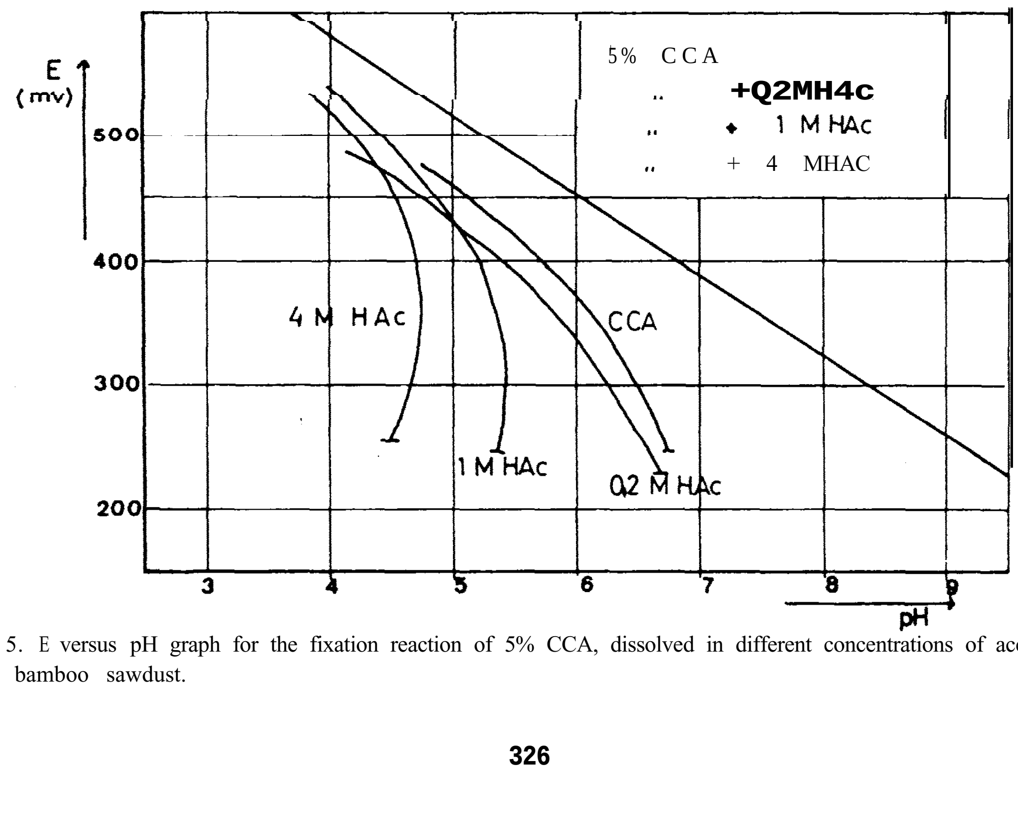


Fig. 5. E versus pH graph for the fixation reaction of 5% CCA, dissolved in different concentrations of acetic acid onto bamboo sawdust.

buffer of pH 4 – 5 will be formed (the natural pH of bamboo}. When we used a smaller quantity of HAc (0.2 M HAc), chrome reduction will be somewhat quicker, while the end pH hardly differs from that of the CCA solution without HAc. This indicates that the added protons were used. Chrome fixation is improved for all solution strengths.

From the prevailing data it is obvious that the availability of H^+ ions and oxidizable groups is not a hindrance for chrome reduction. When this should be the case, leachability of As for the 5% and 10% solutions should be the same or higher then for the 2% solution (the amount of bamboo was kept constant). Final pH and ionic strength do influence the sofubility of the complexes, but in normal reaction circumstances, ph is sufficiently high and ionic strength low, to guarantee low solubility .

With the model of fixation as postulated by Dahlgren and Hartford (1972 II and III) and Dahlgren (1975). it is difficult to explain the results obtained. The mere formation of precipitates as model of fixation appears very simple. Our date support the results of Pizzi. Pizzi (1981 I, 1982 II, III and IV) based his model on the reactions of hexavaient chromium with the different wood constituents. He concluded that this reaction takes place in three different reaction zones depending on PH.

First zone: Low initial pH, $Cr_2O_7^{2-}$ the dominant chromium anion

Cr^{VI} + cellulose kads $[Cr^{VI}$ – cellulose] complex

$Cr_2O_7^{2-}$ + lignin k_1 $[Cr_2O_7^{2-}$ – lignin] complex

Second zone: pH has increased, $HCrO_4^-$ the reacting chromium anion

Cr^{VI} + cellulose kads $[Cr^{VI}$ – cellulose] complex

$HCrO_4^-$ + iignin k_2 $[HCrO_4^-$ – iignin] complex

Third zone: further pH increase albeit slow, all Cr^{VI} removed from solution

$[Cr^{VI}$ – cefiuiose] kred $[Cr^{III}$ – Cellulose] Cr^{III} + cellulose

For the CrO_3/wood system, the reaction rates (k) were determined for the different zones (Pizzi 1981 I). For the first zone kads > k_1. This gives at the end of the first zone more Cr^{VI} complexed on cellulose. For the second zone $\leqslant k_2$. The reaction of the second zone hardly adds to the total amount of Cr^{VI} – cellulose complex. Reduction of chromium takes place through a rapid formation of Cr^{VI} – cellulose complexes in the first zone, followed by a "slow" *in situ* reduction on cellulose. The Cr^{III} – cellulose complex can release trivalent chromium into the solution where it forms complexes with arsenates. The second zone kads hardly contributes to the total amount of Cr^{III} formed. First and second zone reactions are rapid compared to the kred of the Cr^{VI} – cellulose complex. As was earlier mentioned, the pH of the CGA/bamboo system rises sharply at the beginning (Fig. 1). The effect is more pronounced for the 2% solution then for the 5% and 10%. Total chromium reduction depends on the length of time of the first zone. First zone reactions continue as long as the $Cr_2O_7^{2-}$ is the dominant chromium anion. Due to the sharp initial rise in pH for the CCA-bamboo system $Cr_2O_7^{2-}$ will be rapidly replaced by HCr04- (see eq. 1). Consequently only little Cr^{VI} will be complexed on cellulose and thus only little Cr^{III} will be available for chrome arsenate complexes, From Fig. 1 it can be concluded that the 2% solution forms the least Cr^{III} causing the high leaching rate of arsenic.

The effects of adding sugar and H^+ ions can also be explained by this model. Addition of sugar merely raises the initial concentration of the complexing cellulose/sugar. Because of this higher concentration, more Cr^{VI} will be complexed on cellulose/sugar and arsenic leaching will be reduced (sugar also reduces Cr^{VI}). Figs. 2, 3 and 4 show that in case of sugar addition, the reactions do not proceed faster but more Cr^{III} will be formed at the end. This is in accordance with the presented model. Addition of H^+ in the form of 0.2 M HAc gives for the 2% CCA solution a lower initial pH (Fig. 6). extending the period of the first zone reactions and therefore enhancing the total amount of chromium reduced. Arsenic leachability will be reduced (Table 1). Extensive washing of bamboo sawdust before CCA impregnation (sap removal) also gives lower leaching rates. Washed and unwashed bamboo sawdust was impregnated with 5% CCA solution. After four weeks arsenic leaching was determined. The washed bamboo gave very low leachability (1.1%). while for the unwashed bamboo, this figure

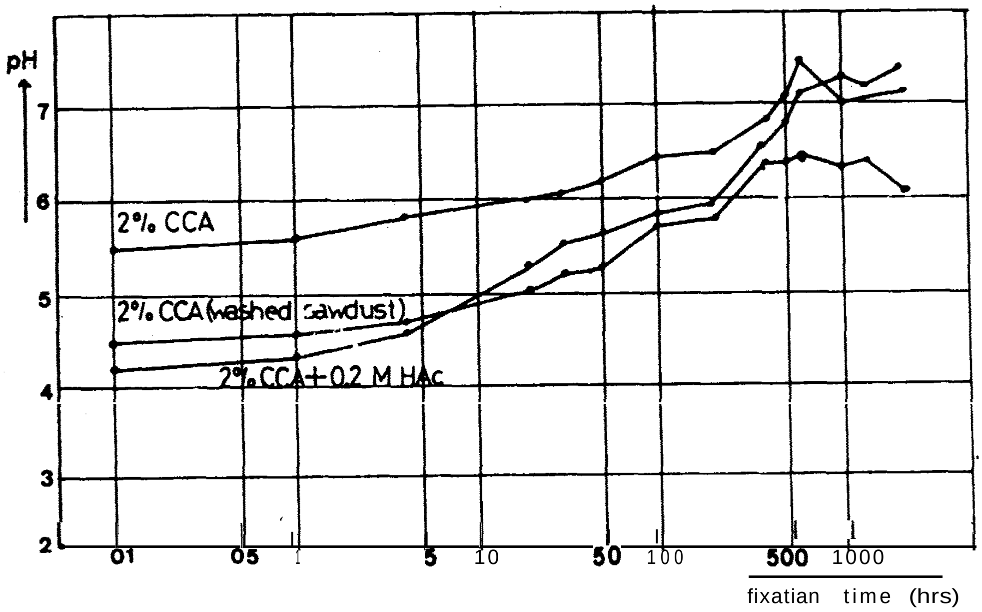


Fig. 6. The pH course during fixation of 2% CCA (with and without HAc) onto washed and unwashed bamboo sawdust.

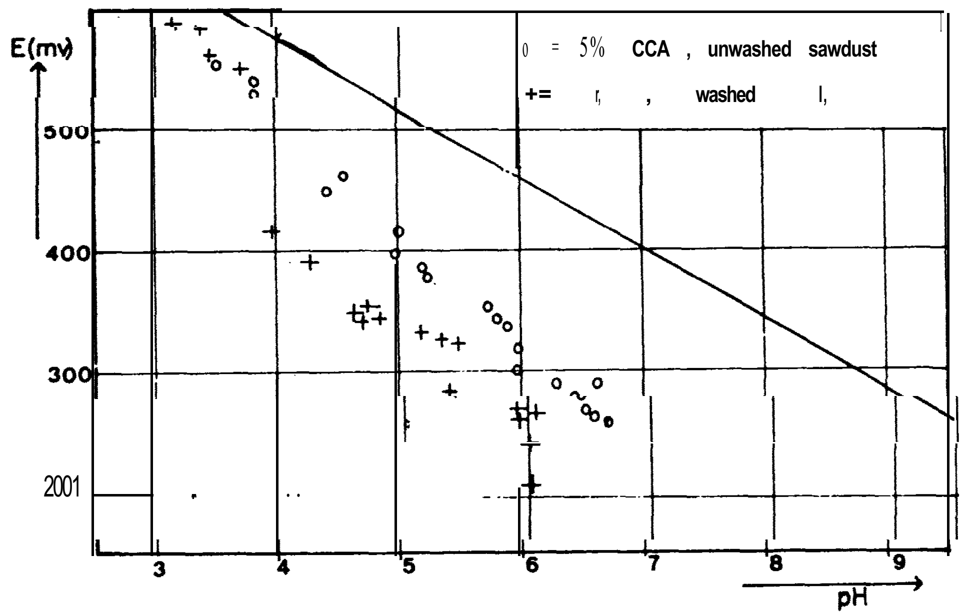


Fig. 7. E versus pH graph for the fixation reaction of 5% CCA onto washed (sap removed) and unwashed bamboo sawdust.

was 10% .-From Fig. 6, it can be seen that sap removal causes a lower initial pH. More chromium will be reduced according to the model presented earlier. This is verified by the E – pH diagram (Fig. 7). Washing may also result in a lower ionic strength, favouring the formation of precipitates.

The model presented does not offer an explanation for the behaviour of copper and chromium leachabilities. According to Piui, Cr^{VI} – lignin complexes are quite stable and not. easily leached out. Our data indicates that Cr^{III} is necessary to a certain extent for fixation of chromium into the bamboo (through the formation of chromic – chromate – lignin complexes). It is recalled that Pizzi obtained his results with guaiacof and lignosulphonate as model compounds for wood fignin. which is present in soft wood mainly as guaiacyl units and in hard woods as guaiacyl and syringil. The lignin of bamboo is a typical grass lignin of mixed dehydrogenation polymers of coniferyl-, singapyl- and p-coumaryl alchohois (Higuchi and Kawamura, '1966; Nakatsubo et al, 1972). Apparently the type of complexes and the rate of complex formation will be effected by this difference. Piui (1982 II) reports that 10 – 20% of the Cu is fixed onto lignin as $CuCrO_4$ complex and the remaining is ion-exchanged fixed to lignin and cellulose with a preference for lignin. No explanation can be offered for the observed lower leachability of copper in case of higher solution strengths and addition of H^+ ions. Sugar has no influence, probably indicating that Cr^{III} is not involved in copper complexing. A lower initial pH seems to favour Cu complexing onto bamboo.

From all the above, it can be concluded that the fixation mechanism of CCA onto bamboo resemhles closely the fixation mechanism of CCA onto wood, the main difference being the high initial rise of pH (due to the buffer capacity of bamboo). This causes for low solution strengths a poor chromium reduction and therefore high leaching rates of arsenic. Although the data presented in Table I gives the amount of easily removed (and thus not precipitated or complexed) copper, chromium and arsenic, severe leaching conditions will lead to additional removal of the different compounds. Tests carried out, representing severe leaching conditions (bamboo sawdust was put into a column and eluted with 10 1 of water), indicate that for a 2% CCA solution + 0.2 M HAc still as much as 24% copper, 11% chromium and 12% arsenic could be removed after washing. For the 5 and 10% CCA solution these figures respectively were 15% – 2% – 6% and 2% – 5% – 3%, again in favour of the high solution strengths.

CCA impregnation Of Bamboo Pipes by Boucherie Method

Liese (1980) and Tewari (1981) described the different methods to impregnate bamboo with water soluble chemicals. Van den Heuvel (1981) reported the experiments carried out by the Tanzanian Bamboo Project to impregnate CCA into the bamboo culm by different methods. He reported that methods using air-dried bamboos failed because of the high percentage of cracking. Steeping of fresh bamboos, hot and cold bath and sap displacement techniques were extensively tested. The steeping method gave satisfactory salt retentions (5 kg/m^3), but radial distribution was very poor. The inner part of the culm was poorly treated and the up-take through the inner wall was higher than from outside. However, the main disadvantage of the' steeping method was the crystallization of the salt on the inner- and outer culm wall, giving rise to health hazards during handling and usage, Steeping methods tested on bamboos with the partition walls intact were not successful because of the low retention of the CCA. Sap displacement techniques gave poor longitudinal distribution, although retention at. the butt-treatment end was sufficient. For further experiments, it was decided to use the modified sap displacement technique, namely the Boucherie method. Boucherie impregnation was carried out using gravity pressure. In the area where the Arundinaria alpha (green African mountain bamboo) grows, selection of a suitable site was easy. The supply vat was placed on top of the hill and connected through a 12.5 mm plastic hose with the distribution system at the foot of the hill. The gravity pressure applied was 20 m. For research purposes three separate systems were installed to run the different tests concurrently. Each of the systems had five connections for bamboo. Fig. 8 gives in schematic drawing the distribution system. The most difficult part of the Boucherie installation was the connection between the bamboo and the installation (the *'cap"). We used a piece of polyethylene, class B 0 63.5 mm, inserted in an ordinary poly connector. The cap operated well and was leak-proof when suitable (i.e., with the right diameter) bamboos were selected. As it was the aim to investigate retention, distribution and leaching, the installation was sophisticated enough. However for large scale operations, a cap should be developed which makes coupling and uncoupling easier and more rapid and which fits different diameters of bamboo. Boucherie impregnation was carried out with 5% Tanalith C solution. This solution was chosen following the results of bamboo sawdust impregnation. The use of a 10% solution led to rapid blocking of the vessels. .Bamboos, 4 m long, were treated, varying the treatment time. The normal procedure was overnight (O/N) treatment. Before leaching experiments were conducted, the bamboos were stored for more than three months in a shed. They were covered and kept wet.

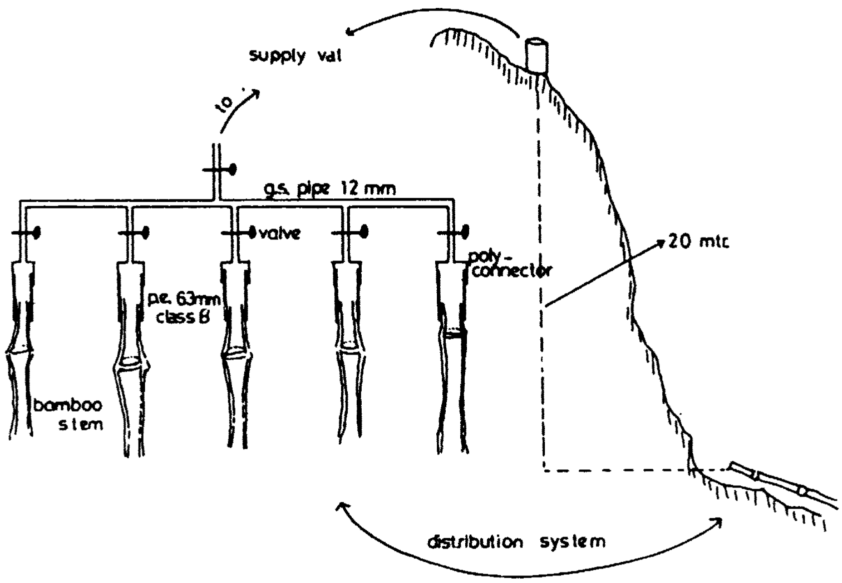


Fig. 8. Boucherie installation (gravity fed pressure).

Retention and distribution: Retention values (as kg salt/m^3 bamboo) were calculated from the -concentrations of copper, chromium and arsenic as found in the digestion experiments. When the first leaching experiments were performed, the amount of salt leached out was added. The tissue density of -the Arundinaria alpina was calculated to be 0.66 10" kg/m^3. The average retention for a 5% CCA solution was 12.0 kg/m^3. This was calculated from 23 bamboos, the standard deviation being 4.3. It is suggested that expressing retention values as kg salt/m^3 bamboo (as is the international practice in the wood preservation) is not very practical. Densities differ from stem to stem and species to species, while measurements of volume are laborious. It would be more convenient to use gr salt/kg bamboo. This gives an average retention value of 18.1 g CCA per kg bamboo (st.d. 6.6). Table 2 shows the average retention of copper, chromium and arsenic (g/kg bamboo) and their molar ratios within one stem. The last data clearly indicates that the salt composition has changed considerably during the Boucherie treatment. The amount of arsenic retained in the bamboo is lower compared to the original solution.

Table 2. Average retention of copper (Cu), chromium (Cr) and arsenic (As) for a number of bamboos and their respective molar ratios.

Bamboo	Retention (gr/kg bamboo)			Molar Ra tio's		
	Cu (st dev)	Cr (st dev)	As (st dev)	cu	Cr	As
1	1.05 40.20)	2.67 (0.89)	0.85 (0.20)	1.5	4.5	1.0
2	1.31 (0.43)	2.38 (0.65)	0.97 (0.18)	1.6	3.5	1.0
3	1.14 (0.50)	1.86 (0.65)	0.77 (0.16)	1.7	3.5	1.0
4	1.02 10.35)	4.51 (1.72)	0.92 (0.14)	1.3	7.1	1.0
5	0.93 (0.23)	2.13 (0.51)	0.95 (0.32)	1.2	3.3	1.0
6 A'	2.13 (1.15)	1.61 11.21)	0.88 (0.59)	2.9	2.7	1.0
B	1.92 (0.971	1.99 (0.62)	1.12 (0.18)	2.0	2.6	1.0
7 A	3.61 (2.30)	3.96 (1.64)	2.22 (0.511	1.9	2.6	1.0
B	2.81 (1.57)	2.82 (1.31)	1.50 (0.26)	2.2	2.7	1.0
8 A	1.15 (0.38)	2.39 (0.65)	1.85 (0.43)	0.7	1.9	1.0
B	3.04 (2.20)	2.36 (1.25)	1.39 (0.42)	2.5	2.4	1.0
			TANALITH C –	0.9	2.0	1.0

• A indicates that samples were taken 50 – 100 cm from butt-treatment-end.
B samoles were taken 250 – 300 cm from butt-treatment-end.

For copper this is reversed (copper is best retained). From the large standard deviations of average retention of the different compounds within one stem (Table 2), it can be concluded that longitudinal distribution is very unequal throughout the culm. Fig. 9 depicts how retention increases with time for the different parts of the culm. It is seen that a certain length of time (the Minimum Treatment Time = MTT) is needed to guarantee sufficient retention throughout the culm. From the same figure it can be concluded that arsenic passes most rapidly (so fixes most poorly), while chromium fixes best. The uptake of copper continues for the longest period, indicating that copper diffuses best. The MTT depends on bamboo stem, species of bamboo, pressure applied and solution concentration. It is easily determined by measuring the specific gravity of the effluent preservative (which should closely resemble that of the original solution). Not surprisingly, it correlates well with the flow velocity of the preservative through the culm. It was observed that flow velocity decreases during treatment time. This was true not only in the case for CCA solutions but also when water was flushed through the stem. Initial flow velocity is strongly reduced in aged stems and will also drop considerably if the period between cutting and treatment is prolonged. We failed to impregnate bamboo by Boucherie method three days after cutting. For good treatment the time between cutting and impregnation should be as short as possible.

MTT longitudinal distribution will not be determined by distance to the butt-treatment end and longitudinal distribution is not equal. Large differences are observed (standard deviations in Table 2), but they do not correlate with the distance to the butt-treatment end. These differences are explained by the fact that complexes of precipitates are formed in the vessels (crystal growth). It is also clear from Fig. 9 that when the MTT is observed, longer treatment time would not enhance retentions. Radial distribution was investigated using rontgen-scanning techniques. Energy dispersive rontgen-spectra were made from different parts of the bamboo. Fig. 10 shows the spectra for a vascular bundle of untreated and treated bamboo and Fig. 11, for the parenchyma tissue for different energies. From these spectra it can be concluded that the bulk of the salt is retained in the vascular bundles and gradual diffusion to the surrounding tissues takes place (to detect the metals in the parenchyma tissue, higher energies had to be used). From these results it is obvious that the outer part of the culm is better protected due to the higher density of vascular bundles in this part. The results support the idea that retention and longitudinal distribution is mainly dependent

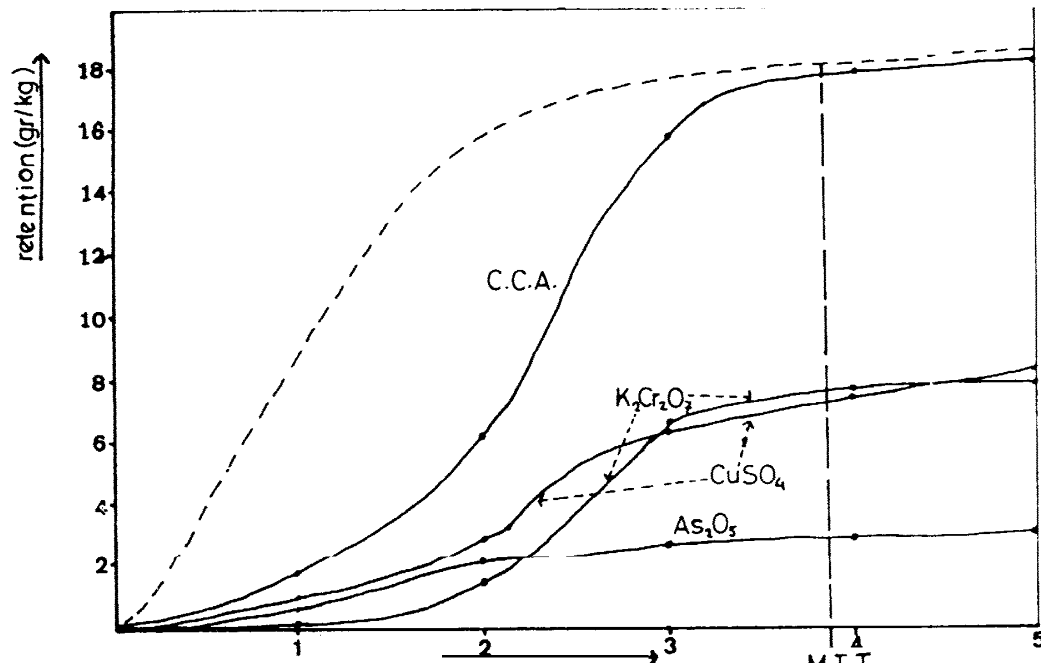
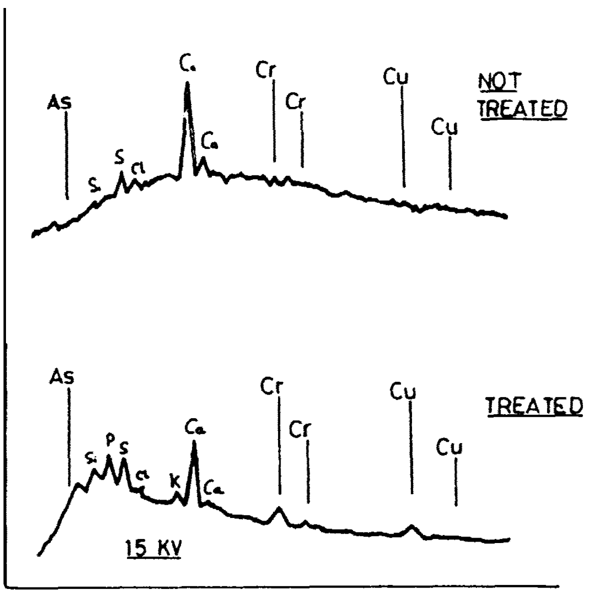


Fig. 9. Retention of $CCA/K_2Cr_2O_7/CuSO_4/As_2O_5$ as function of time determined at 3 m from the butt-treatment-end. The dotted line predicts how retention will increase near the butt-treatment-end.



Fig, 10, Rontgen spectrum of treated and untreated bamboo. The scan taken in a vascular bundle.

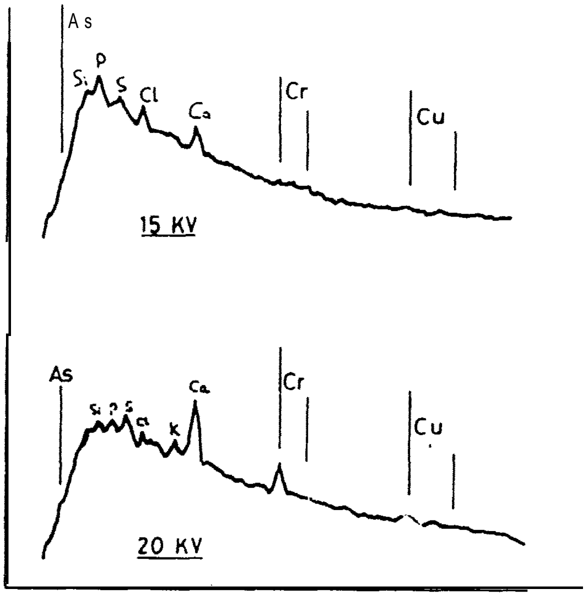


Fig. 11. Rontgen spectrum of parenchyma tissue of treated bamboo using different energies.

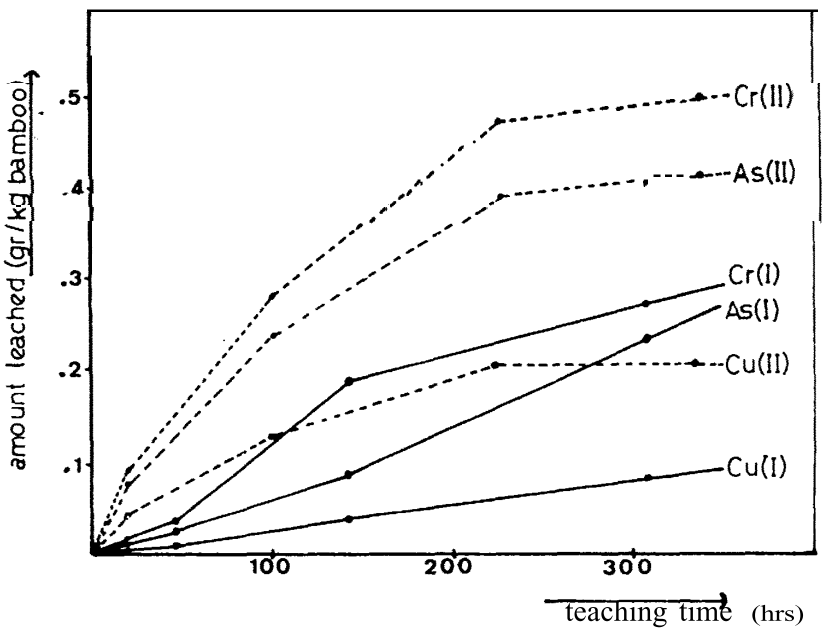


Fig. 12. Leaching of Cu, Cr and As from bamboo beakers (I) and 2 cm bamboo rings (II).

on formation of Cu – Cr – As complexes within the vascular bundles.

Leaching and fixation: To investigate leaching patterns. three kinds of experiments were conducted. In the first, pieces of CCA treated bamboo were placed in a glass column (ø 10 cm x 50 cm). The sawn ends were sealed with a silicone kit. The column was filled with water and this water in time analysed for copper, chromium and arsenic. In the second experiment rings of 2 cm were placed in water. This time the ends were not sealed. The third experimental set-up simulated most closely the use of bamboo as water pipe. Water was circulated with a pump (so under pressure) through the bamboo. From total water volume, content of the bamboo pipe and discharge, it could be calculated how many meters of pipe line correspond with one hour of pumped circulation. Figs. 12 and 13 show the characteristic leaching patterns for the different experiments. Leach-

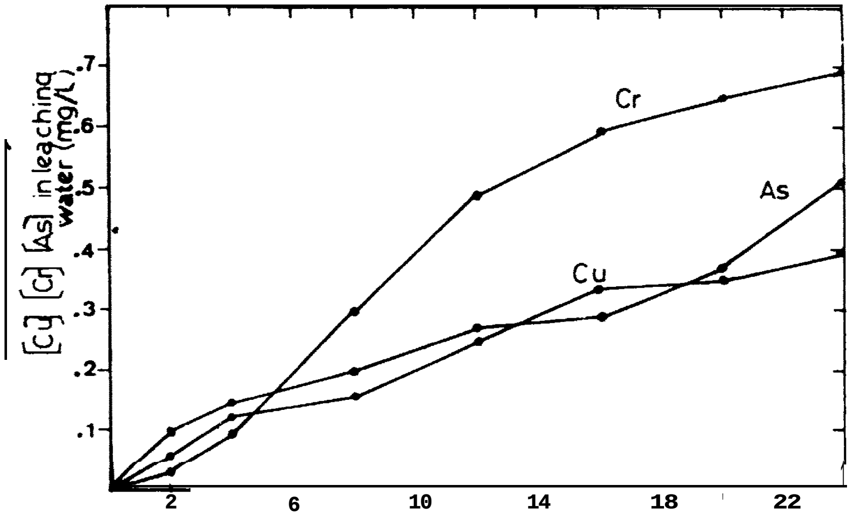


Fig. 13. Leaching of Cu, Cr and As from bamboo pipes through pumped water circulation.

ing is most severe in experiment II, due to the high surface/tissue ratio deliberately caused by not sealing the ends. After 20 days of submerging in water, leaching seems to have terminated for these experiments. Percentages of totally leached copper, chromium and arsenic were determined from these experiments II. For copper. the values ranged from 5 – 28%. average 15%. for chromium from 4 – 36%. average 17%. for arsenic from 7 – 68%. average 34% (Table 3). From Fig. 12, it appears that the leaching of CCA proceeds at an almost constant rate. This may be explained by assuming that leaching is a first order process, which is only dependent on the concentration of CCA in the bamboo; r = k CCA, r being the leaching rate and k the first order rate constant. Because CCA is present in large excess, the CCA concentration may be regarded as constant during the leaching experiment I. This gives a pseudo zero-order process. The leaching rate (r). mg/kg hr, and the first order leaching rate constant k = r/CCAtot (hr-‘) were calculated for Cu, Cr and As from the experiment I. Results are given in Table 4. Copper, chromium and arsenic leaching for the different pipes can be best compared by looking at the first order leaching rate constants, because in k differ-

Table 3. Retention (as gr metal ion per kg bamboo) and Leaching (% of retention) of copper (Cu), chromium (Cr) and arsenic (As) from 2 cm bamboo rings.

Bamboo	Copper		Chromium		Arsenic	
ring *	ret.	leac.	ret.	leac.	ret.	leac.
1	0.89	23%	2.04	24%	0.70	46%
2	1.35	14%	2.60	19%	0.97	41%
3	1.20	13%	1.95	15%	0.77	41%
4	1.09	24%	3.67	20%	0.92	24%
5	0.92	28%	2.32	30%	0.95	55%
6 A	3.12	5%	2.46	21%	1.21	42%
B	2.37	13%	2.51	11%	1.30	30%
7 A	5.84	9%	5.55	18%	2.66	33%
B	4.32	10%	4.05	22%	1.72	43%
8A	1.06	12%	2.82	4 %	2.05	11%
B	4.20	14%	3.47	5 %	1.81	14%

* = A indicates that samples were taken 50 100 cm from butt-treatment-end
B 250 – 300 cm from butt-treatment-end.

Table 4. Leaching rates (r = mg metal ion per kg bamboo per hour) and first order leaching rate constants ($k = 10^{-4}\ hr^{-1}$) for copper (Cu), chromium (Cr) and arsenic (As) in a number of bamboos,

Bamboo	Copper		Chromium		Arsenic	
	r	k	r	k	r	k
1	0.30	2.5	0.78	2.5	0.25	2.5
2						
3	0.28' 0.11	2.3 1.2	0.90 0.41	4.2 2.1	0.67 0.34	6.8 4.3
4	0.21	2.1	0.73	1.7	0.17	2.0
5	0.47	4.9	0.95	4.8	0.58	6.2
6 A'	0.28	2.5	0.61	7.8	0.84	15.1
B	0.14	1.0	0.27	1.8	0.42	4.5
7 A	0.36	2.6	0.83	3.5	1.10	6.1
B	0.71	5.4	1.60	10.0	1.70	13.2
8 A	0.06	0.5	0.20	1.0	0.26	1.6
B	0.18	1.0	0.31	2.5	0.45	4.6
average	0.28	2.4	0.69	3.8	0.62	6.1

• A= 50 – 100 cm fmm the butt-treatment-end.
B = 250 – 300 cm from the butt-treatment-end.

ences in loading of CCA are levelled out. From the data it is clear that copper leached less and arsenic most as a percentage of total retention. However because of the higher r values, chromium will contaminate the water more. There is a positive correlation between chromium and arsenic leaching.

All experiments show that when these pipes are used for transportation of drinking water. high concentrations of Cu. Cr and As can be expected in the water. A 2 m long CCA treated bamboo pipe was washed in the river for one month. After this washing time it was connected to the circulation installation (experiment III) and water was pumped through it for ten hours representing 500 m of pipeline. The next concentrations of Cu, Cr and As were measured:

500 m bamboo pipe	Cu	=	0.2 mg/l
	Cr	=	0.2 mg/l
	As	=	0.3 mg/l
Tanzanian standard	Cu	=	3 mg/l
allowed in	Cr	=	0.05 mg/l
drinking water	As	=	0.05 mg/l

These results do not need further elaboration.

Although the experiment II shows that leaching may terminate in time, extensive washing procedures on a large scale are not recommended because of high environmental pollution. It should even be questioned if the salt retained after extensive washing is sufficient for protection. The amount of salt retained was determined in a pipe installed as test pipe three years ago, and found to be down to 3.4 kg. Leaching and fixation were investigated for different procedures of Boucherie impregnation (first flushing with water – sap removal – or acid, following the results of bamboo sawdust impregnation). However, possible effects were masked by the very irregular leaching patterns of normally 5% CCA treated bamboo.

In the Bamboo Project, the results obtained with CCA – Boucherie impregnation of bamboo pipes were disappointing, High leaching rates of the toxic compounds make the use of a CCA – Boucherie treated bamboo pipe as water conduit impossible. This result is in marked contrast to the results obtained with CCA bamboo sawdust impregnation. For this system, good fixation could be reached when sufficiently high concentrations were used. Selective adsorption and diffusion of the different metal ions during and after the Boucherie process and invalidates the model as presented for the CCA – bamboo sawdust system. Experiments for CCA – bamboo sawdust impregnation revealed that a high instantaneous loading of CCA is necessary for good fixation (more than 50 g CCA per kg bamboo). This condition will be realized in the vessels, when we look to the amount of CCA in direct contact with the bamboo tissue. This is confirmed by the measurement of the pH of the effluent preservative. Immediately after starting the treatment, the pH of the collected sap reached 5.16 (the natural pH of the Arundinaria alpina bamboo). During the course of the treatment, the pH dropped to + 3.5. However, the CCA in the vascular bundles was hardly exposed to the reactive groups of the bamboo tissue and this low pH would not result in good chromium reduction (as in the sawdust system). Fixation of CCA is merely the result of the formation of precipitates within the sap vessels and even for this the situation is not optimal (low pH). Investigations of CCA – Boucherie treated bamboo pipes buried for three years in the soil as test pipes revealed that the bamboo was still sound, although slight nibbles of termite attack could be seen on the outside. The control pipes were totally destroyed by termites and rot. The total salt retained had dropped considerably due to the severe leaching' conditions. All experiments indicate that CCA – Boucherie treated bamboo will be well protected against termite attack and rot for a long time when not exposed to severe leaching conditions. By using different techniques of impregnation, it is possible that sufficiently high fixation can be reached. All techniques depend on diffusion of the' metal ions and therefore resemble closely the Boucherie impregnation. Experiments carried out with pressure impregnation gave an average leaching of arsenic of 44%.

Acknowledgements

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Bamboo Plywood — A New Product of Structural Material with High Strength Properties

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Abstract

The paper describes the procedures involued in making bamboo plywood. It then discusses the comparative merit of the *product.*

Bamboo plywood is a panel consisting of an assembly of plies of bamboo sheets bonded together with the direction of the grain, in alternate plies at right angles. An adhesive of phenolic resin is used. The bamboo species used for the raw material is Phyllostachys pubescens (Mazd) which averages 9 cm in diameter at the breast height.

The processing procedure is as follows:

Bamboo culm is first crosscut into four or so with the desired lengths and the inner and outer surface layers are scraped out on equipment specially designed. The cuts are then split open into two or three pieces. Following a pretreatment by soaking the pieces in a cooking vat for several hours, the pieces are dipped in a vessel with a medium at a temperature far beyond 100°C so as to enhance the temperature of the pieces to a certain degree to soften the wood. This serves to thermoplasticize the Iignin and hemicellulose more effectively. The treated pieces are then spread out, flattened, dried and stabilized through a heated press and a breathing drier, specially used for processing bamboo sheets. The pieces are planed smooth and edged straight on both sides. This prepares, the material — faces, backs and crossbands — for the manufacturing of bamboo plywood. The forthcoming procedures are just the same as the manufacture of plywood. Bamboo plywood is extremely high in bending strength — modulus of rupture (MOR); modulus of elasticity (MOE) and it probably ranks as the highest among all of the structural boards and even as good as the solid wood of high density commercial timbers. Bamboo coupled with wood is a material of heterogeneity and anisotropy. This property may be evaluated as a disadvantage on the one hand and an advantage on the-other. Some may place this property of bamboo at a disadvantage in competition with other products. In fact, many of the disadvantages, real or implied, as decay and insect attack, could be overcome by intelligent use of bamboo, based on a comprehensive knowledge of its characteristics.

It is known that bamboo is exceptionally anisotropic in nature and this character could be overcome by crossbanding to a certain extent as desired. The problem is in developing the resulting characteristics to a much higher degree as we do in oriented strand board (OSB) and also in oriented strand composite plywood (OSCP). Bamboo plywood serves this purpose. As the orientation of fibers in bamboo is nearly perfect along the grain, the bending strength of the product is remarkably superior to those of OSB and OSCP. It is also high in flexible rigidity. In comparison with other structural materials other than wood and wood products, they are mostly isotropic and there is no way to strengthen the bending strength and stiffness as expected.

A tentative comparison of strength properties of a few structural materials is shown in Table 1.

We understand that the nature of the cell wall substance and its distribution as a system of thin-walled tubes makes wood very efficient in flexible rigidity. So does bamboo. This high flexible rigidity is most effective in members as beams in which length is far in excess of depth. In comparison with other structural materials, the weight — strength ratio for bamboo product is very favorable for some applications. This high stiffness — to — weight ratio exhibits a characteristic which is considered to be an important criterion for evaluating the mechanical properties of a

Table 1. Comparison of five wood based materials.

Material	Strength MOR (Kg/cm^2)	Properties MOE (Kg/cm^2)
Particleboard (random)	235	34,483
OSCP	740	42,200
Bamboo Plywood	1,175	211,000
Oak, Chinese species	1,506	149,000
Oak, American species	1,655	163,448

material and this form of cellular organization is also a highly efficient means for obtaining the maximum moment of inertia from a minimum amount of material. The moment of inertia of a bending member is vastly increased if a given amount of material is arranged as a tubular structure rather than a solid rod. For this reason, bamboo products have a high index of rigidity in comparison with solid structural materials and is well suited for use in situations that require elastic stability. Compared with wood, bamboo product is at least nine times as good an energy-absorbing medium as steel. This makes it an excellent material for floors and similar applications where energy absorption is important.

Bamboo, being similar to wood, is a cellular substance and in the dry state the cell cavities are filled with air, which is one of the poorest conductors known. Because of this fibrous structure and the entrapped air, bamboo has an excellent insulating property. The common building materials used in house construction with the exception of wood are not good insulators. In comparison with wood, the heat loss through common brick is six times and through a glass window eight times as great, whereas concrete and steel are fifteen and three hundred ninety times as conductive as wood respectively. Experiments show that the coefficient of heat conductivity of bamboo product is a little higher than that of wood, but the difference is too small to be taken into account.

Bamboo plywood associated with wood and wood products provides thermal insulation the year round. It is effective not only in winter against cold, but also in the summer against heat. Combined with wood, it is a remarkable structural material for shelter where an effective thermal insulating property is necessary.

Wood structures can withstand an impact load twice as great as that of static loading. It is also true for bamboo products. This exceptional impact strength gives it a considerable mechanical and economic advantage for structures designed to resist earthquakes or for situations where abrupt loads are imposed. Bamboo is susceptible to fungi and insect. Experiments demonstrate that no damage of decay and insect attack has occurred, when phenolic resin is used as the binder of the bamboo plywood. This is also the case in fire resistance. There is no reason why, if properly used, bamboo products should not last indefinitely. Because of the shortage and uneven distribution of forest resources in China, the supply of timber is far below the ever-increasing demands of the country. Therefore China's scientists explore all possibilities to use wood efficiently and develop new product replacement for it. The manufacture of bamboo plywood is perhaps one such achievement in this field.

China is lucky in having extensive bamboo resources with more than 300 species. There are 3,401,800 ha of bamboo stands of which 2,418,600 ha is made up of Phyllostachys pubescens. The growing stock is about 3,759,890,000 (3.796 thousand million) bamboo culms. On a hypothetical rotation of six years, the annual harvesting will be about 632,648,300 culms. An estimate on the number of culms of bamboo of 9 cm diameter needed for making 1 m^3 of bamboo plywood has been made on a pilot plant. The results show that 150 culms would be sufficient to meet the need at the present running level. This means a total of 4,217,650 m^3 of bamboo plywood which is equivalent to four times the present production of all the wood-based materials, could be made annually.

A Brief Introduction to the Bamboo Tower in Zurich, Switzerland

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Abstract

The details of a bamboo tower construction undertaken in Switzerland are described.

Introduction

Based on the sketch by Mr Peter Staub, a well-known plastic artist, a bamboo tower was set up as one of the exhibits in the "phenomena" Exhibition held in Zurich, Switzerland in 1984, and it really provided a rare opportunity in displaying the graceful bearing of a bamboo building. The tower was successfully completed through a joint effort by the Kunming Architectural Design Institute and the Kunming Construction Company. Facts proved that the sponsors of the Exhibition had actually made a wise decision with foresight and sagacity. The building added lustre to the Exhibition and was widely acclaimed. It was later reconstructed in Rotterdam, Holland in the middle of 1985. With the maximum height of 22.50 m, it was divided into five floors, from bottom up each with 5.40, 4.05, 4.05, 6.0 and 3.0 meters high respectively. Furthermore, one large spiral slide with 19.50 m in height, 60 m in slope length and three small slides with 5.4 m in height were also provided. Since the building of this kind had hardly been seen, it attracted a good deal of attention and interest from the architectural circle and bamboo researchers.

General Considerations of Design

An equilateral triangle 2.40 m length for each side was taken as a basic plan unit. 49 honeycomb spaces were made up by means of a separation of floors, which had advantages of stable plain and fewer members in kind. In addition, the architectural appearance was very obvious. All these made the configuration of the building varied and colourful.

Details of Technical Treatment

The combined pillars were made up of 3-6 pieces of bamboo and bundled up at every meter by at least 10 strands of bamboo strings at each point. The lower end of the pillar was connected to its foundation through a steel plate. A timber was provided on the horizontal bamboo pole under the floor to form the combined upper chord of bamboo-wood which dispersed loads and reduced bending stresses as well as helped fix wood boards. The tongue and groove boards were arranged along the different directions to make the floor more even.

The following joints were used. i) the butt joint with wood/bamboo core plus bamboo pins, ii) the bake-bent joint, iii) the shear joint with a bracing piece, iv) the tenon joint with or without wood core, v) the screw joint with holding boards (used for central joint in three hinged arches), and vi) the joint with scooping-out plus bamboo pins. In the regular hexagon plain unit, spiral stairs were designed. The radial foot rest passed through the straight vertical pillars outside and central tubes were decorated with bamboo slips. Through ingenious arrangement of the bamboo poles, the entire stair hall was well revealed giving an appearance of the bamboo structure.

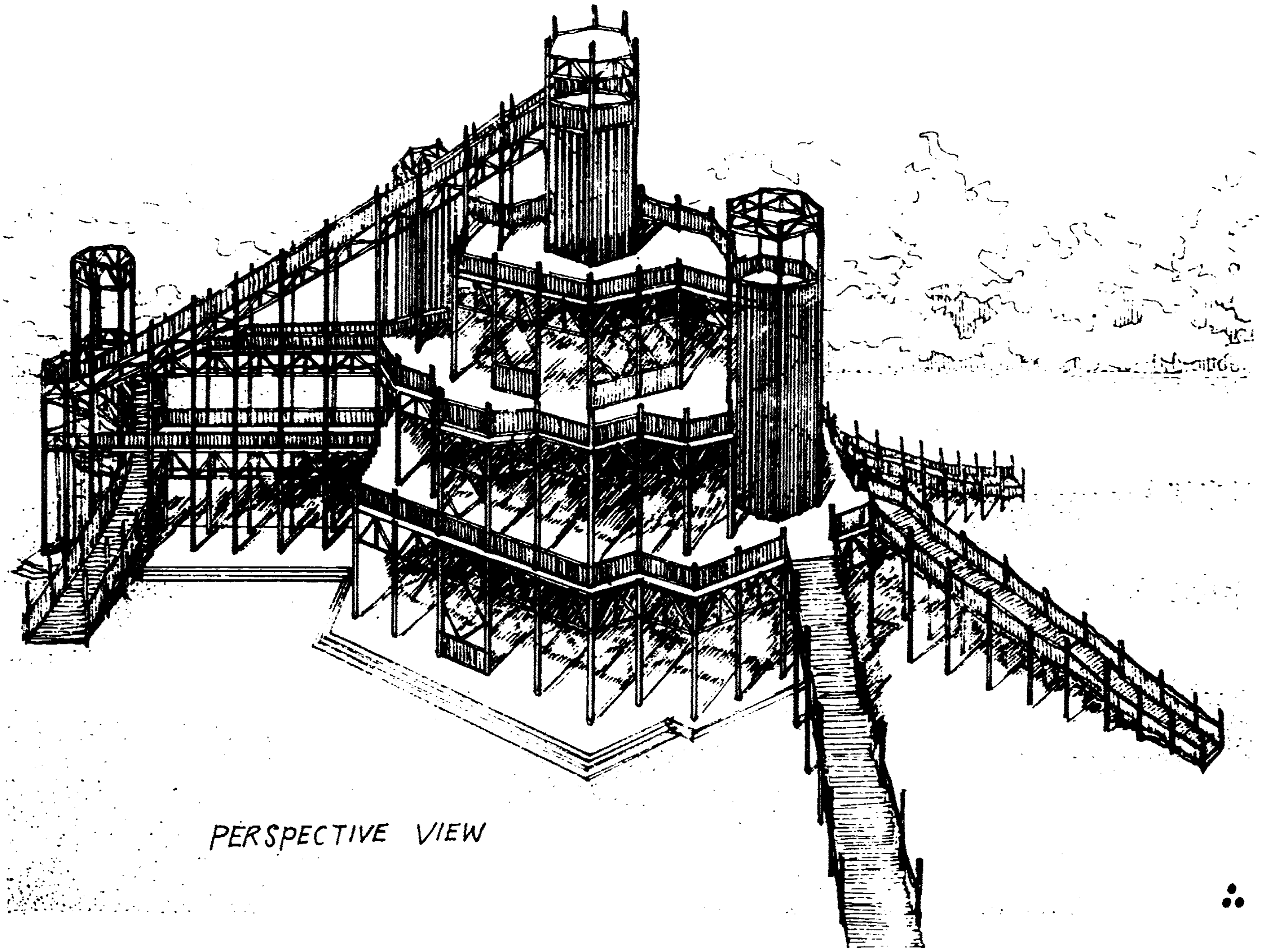
The following measures were taken preventing the bamboo from rot, crack and decay. i) The bamboo was cut over in the late autumn or early winter, ii) Insecticides was sprayed on ends of the bamboo. iii) The bamboo was strengthened by means of fire-baking and was cleared of any greasy dirt. This also brought the natural colour and lustre of the bamboo surface, iv) Bamboo strings are used in important sections to prevent the bamboo from cracking. v) Good care was taken of the bamboo material during transportation and storage to avoid deformity and damage.

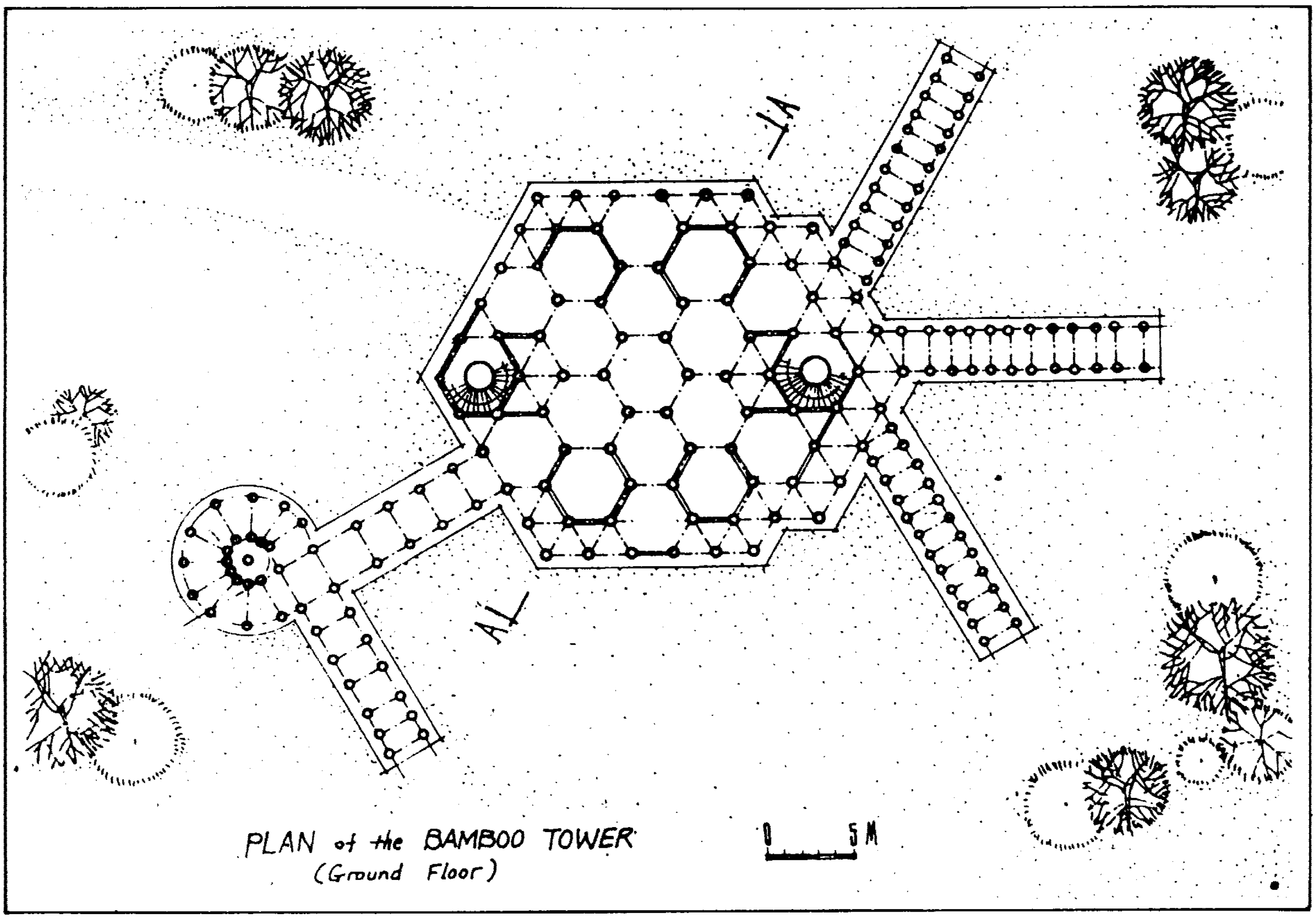
Main Points in the construction of the tower

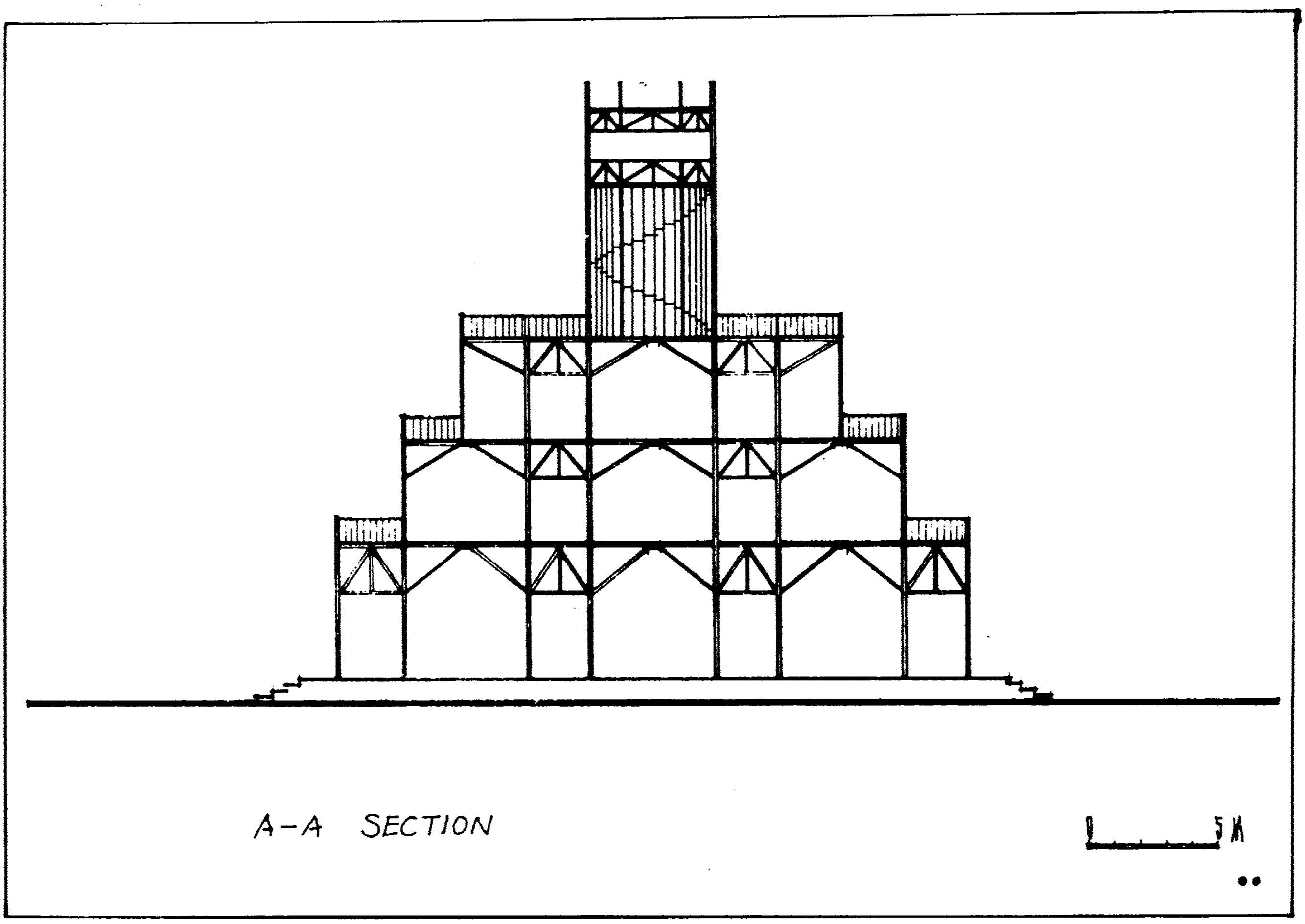
The project involved all together 6,000 pieces of bamboo with over 100 mm in diameter, and 5,000 pieces of other kinds and dimensions. With a net weight of 120 tons all of the required bamboos was purchased and shipped to Zurich The selected bamboos were more than 4 years' old, straight and free of rot, The bamboo used was straightened and surface treatment carried. out prior to processing. The frames on processing were numbered, classified and packed in containers,

The large bamboo tower in Zurich was attractive and contructed by joining.

Mr Yang Benkuan and Mr Tian Jianong of our Institute, also participated in constructing the Bamboo tower.




A
A
PLAN of the BAMBOO TOWER
(Ground Floor)
0 5 M


A–A SECTION
0 5 M

A Study on Bamboo Cellulose Triacetate (B-CTA) Ultrafiltration Membranes

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Abstract

The methods for making B-CTA and C-CTA (cottqn-cellulose triacetate) ultrafiltration membranes and the factors affecting the membrane properties are described here. The storage of the membranes in 95% ethanol and H_2O_2 aqueous solution is mentioned. The results for trialof the membranes in pharmaceutical and food processes are also reported.

Introduction

Ultrafiltration (UF) is a new technique of membrane separation . The filtration process involves sieving effect and chemical behaviour of the substance on the surface of the membrane. Solvents and materials with low molecular weight pass through the membrane under a given pressure, and suspended matters and macromolecules are rejected, therefore the filtration, separation or purification of liquids treated are obtained. UF techniques were used only in laboratories before 1960. Various types of ultrafilters have been subsequently manufactured with the successful development of the UF membranes. UF has become an independent unit operation in chemical engineering. Widely used in food, chemical and pharmaceutical industries abroad. The applications of UF were tested in treatment of eiectrophoretic paints, purification of dyeing waste, separation and concentration of biological products and clarification of beverages in our country. Some of these tests have been applied in corresponding productions. It is important to choose and use membrane materials correctly with proper membrane-making technology according to the requirement of production and industry. It was more than 20 years since Loeb and Sourirajan successfully developed asymmetric CA membranes. Although other membrane materials have been widely studied by many membrane scientists during this period, to date CA is still the main membrane material at home and abroad, The main reasons for this are as follows: Compared with other membrane materials, the resource of raw material for CA is easily available and the price is cheap. The technology for making CA membranes is simple, and the membranes have good separation properties, are resistant to chlorine and non-toxic. However there are a few limitations for the applications. In order to expand the range of applications of CTA membranes, and to utilize the abundant bamboo resources, fully B-CTA ultrafiltration membranes with different pore size were made by the industrial Bureau of Suichang county, Zhejang Province.

Preparation Of Filters

1. Components of cast solution: Cotton-velvet CTA, B-CTA, acetone, Dioxane, methaiene dichloride, formamide, ethanol and water.

2. Preparation of cast solution: The CTA was dried in the oven at 105°C for about 1 hour, and the temperature droped to ambient. The CTA, solvents and additives were added in proper proportion into a glass flask with an agitator. The mixture in the flask was agitated for dissolution, then filtered and stilled to make it bubble free.

3. Preparation of membranes: The room for preparation of membranes was air-condi-

tioned and humidity-controfled. The cast solution was decanted into the slot of casting knife mounted on the casting machine, and the casting machine was allowed to run. The cast solution passed through the casting knife, and was spread into thin layers of solution under controlled solvent evaporation. After gelation in water bath, the wet UF membranes were formed. The dry UF membranes could be made when the wet membranes were treated with post-treatment agents.

4. Measurement of the membrane properties: The dry UF membranes were cut into proper size and shape, and mounted into ultrafilters. The water flux and cut-off of molecular weight were measured under given pressure, using distilled water and different protein solutions as feed respectively.

Results and Discussion

Membranes with good rejection and high flux are essential for the application of UF. The composition of cast solutions and the processing conditions in making the membranes are decisive factors for preparing UF membranes with good properties. We have made a comparison on the properties between the B-CTA and C-CTA membranes, and a systematic investigation of the effects of the membrane-making conditions on the properties of the membranes. These are summarized as follows:

1. Effects of contents of B-CTA and C-CTA in cast solution on properties of the membranes: For the last 20 years, asymmetric C-CTA membranes have been made in our laboratory but we do not have any knowledge of making B-CTA membrane. Through a series of experiments, it was found that B-CTA 84038 was suitable for making membranes. At the beginning, we prepared the B-CTA ultrafiltration membrane using the recipe for making C-CTA membrane.

The structure of the membrane as seen under electron microscope is shown in Fig. 1. The flux was low and the cut-off of molecular weight was also poor for these UF membranes. Therefore further experiments were made to determine proper composition of cast solution. The results are summarized in Table 1.

The properties of the UF membranes for the two kind of CTA were basically similar after dozens of sifting test, and their microstructures were also similar (Fig, 2).

2. Effect of additive contents on the membrane properties: The results are summarized as shown in Table 1. Both kinds of additives and the different amounts of the same additive have a great influence on the dissolvable state

Table 1. Effect of contents of B-CTA and C-CTA in cast solution on the membrane properties.

B-CTA 84038 (Wt%)	C-CTA 82855 (Wt%)	Flux (ml/cm^2 hr)		
5	5	490	760	472
6	4	462	692	644
7	3	442	708	580
8	2	438	668	512
9	1	414	448	452
10	0		708	710
0	10		738	716
Temperature of feed water	(°C)	10	14	10

Measurement apparatus: Ultrafilter with effective membrane area 10 cm^2
Measurement conditions: Operating pressure 3 kg/cm^2. feed tap water.

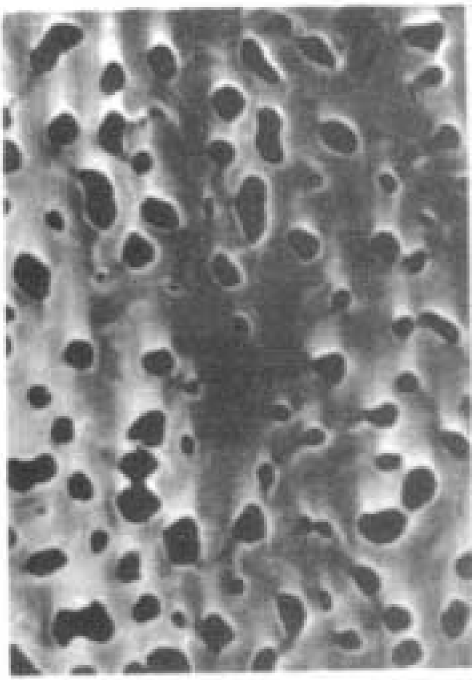


Fig. 1. Electron micrograph of B-CTA ultrafiltration membrane (3000 x)

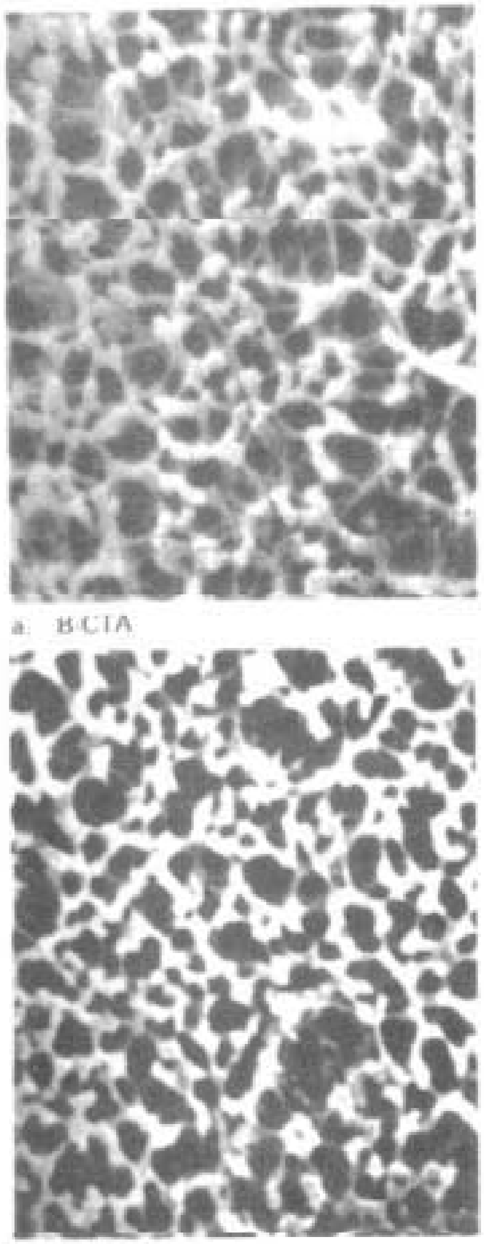


Fig. 2. Electron micrographs of B-CTA and C-CTA ultrafiltration membranes (10,000 ×)

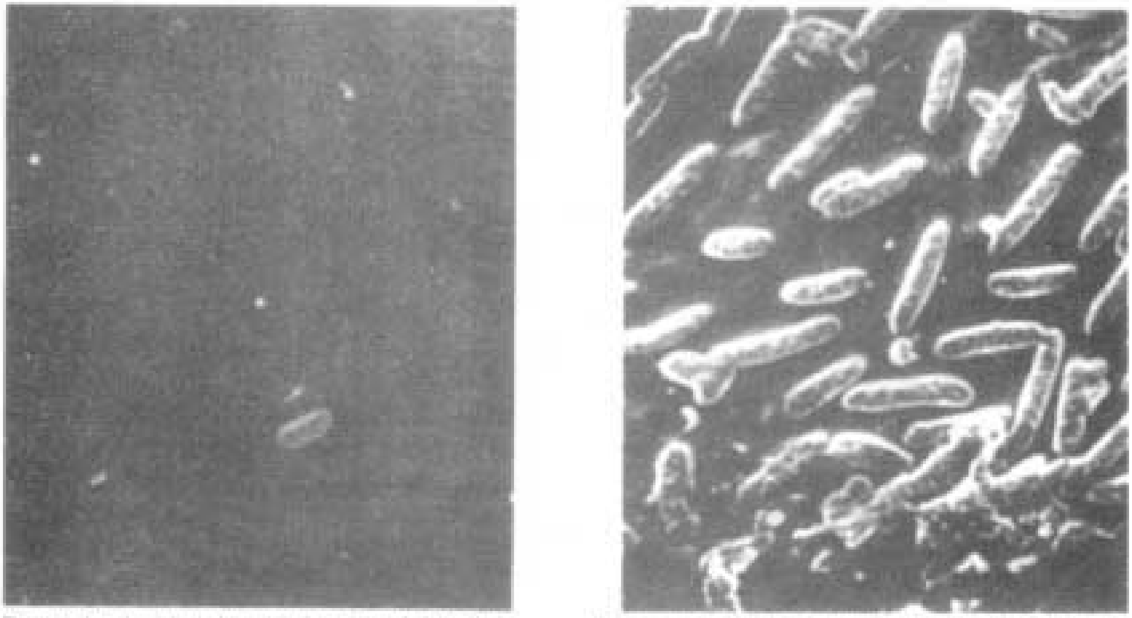
of cast solution. It is therefore very important to choose a proper additive as a pore-forming agent in making UF membrane with excellent properties. It was found that the mixture of formaldehyde and ethanol was a suitable additive for B-CTA after a lot of times in sifting the additive. The effect of the additive contents on the membrane properties is shown in Table 2,

It can be seen from Table 2 that water flux was increased with the increase of additive content. When the ratio of the additive in cast solution was more than 70 %, it was hard to dissolve the polymer, Various membranes

Table 2. Effect of additive contents on the membrane properties,

Additive content (Wt%)	15	20	25	30	35	40	45
Water flux (ml/cm² hr)	21	174	216	276	306	408	495
Additive content (Wt%)			50	55	60	65	70
Water flux (ml/cm² hr)			504	585	714	798	856

Temperature of feed water: 9°C
Other measurement conditions are the same as in Table 1



a. Dense skin layer of the niembrane with low flux (2000 ×)

b. Loose skin layer of the membrane with high flux (2000 ×)

Fig. 3 Electron micrographs of skin layers of two different UF membranes.

with different water flux can be made to satisfy the requirements of corresponding applications.

3. Effects of membrane-making conditions on the properties of membranes: There were many great differences in properties of the membranes which were prepared from the same cast solution, hut under different membrane-making conditions. More dense membranes with lower flux were formed under certain conditions, but the membrane with high flux and large pore size could be obtained by changing some of these conditions. The microstructures of the two kind of membranes are shown in Fig, 3,

(i) Effect of gelation temperature on membrane properties* The more important step for preparation of UF membrane from cast solution is to dip the just-cast membrane into water ~ the gelation medium The exchange rate between water, solvent and additive is faster in water with high temporatures than at low. The pore size and water flux of the membrane obtained from the bath at high temperatures are higher than those from the bath at low temperatures The expcenmental results are listed in Table 3.

As may be seen from Table 3, the exchange rate between water, solvent and additives increased with the increase of temperature. The flux reached maximum at the gelation temperature of about 30° The membranes became denser and their flux were also low when the gelation temperature was higher than 30°C, this might be caused by the change of gelation mechanism.

(ii) Effects ofincreasing temperature and time on the membrane properties: The UF membranes need to be sterilized at high temperature when they are used for purification and separation in pharmaceutical and food processes. Thus the membranes were put into hot water at different temperatures for a certain period to test the changes of their properties, The results are shown in Tables 4 and 5.

Table 3. Effect of temperature of gelation medium on the membrane properties.

Gelation temperature (°C)		Water flux (ml/cm² hr)
0.5	304	300
5	428	420
10	508	504
15	548	540
20	680	628
25	844	780
30	1074	1062
35	828	720

Measurement conditions: temperature of feed water 6°C other conditions are the same as in Table 1

Table 4. Effect of increasing temperature on the membrane properties.

Annealing temperature (°C)	30	40	50	60	70	80	90	loo
Water flux (ml/cm^2 hr)	840	824	680	672	592	580		548
Water flux (ml/cm^2 hr)	956	912	686	786	762	568	540	512

• The annealing period: 30 min.

Table 5. Effect of annealing on the membrane properties

Annealing period (hr)	0.5	1.0	2.0
Water flux (ml/cm^2 hr)	540	386	342

• The annealing temperature; 100°C.

It was obvious that the flux of the membrane decreased with the increase of annealing temperature. Because annealing is a process of "dehydration and shrinkage" of the membrane. UF membranes with different properties (flux, pore size and surface structure) could be prepared by adjusting annealing temperature.

The flux of the membranes decreased and the strength of membranes increased with extension of annealing period, indicating contraction of the pore sizes in the membranes. The flux of the membrane was still acceptable after annealing of the membrane at lOO°C for 2 hours.

(iii) Effects of the concentration of plasticizer and drying temperature on the membrane properties: Dry membranes are convenient for storage, transportation and operations in the manufacture of modules, and bacteria was also eliminated in the dry membranes. The membranes dried naturally at ambient condition were brittle and poor in strength. The reason for this might be the large surface tension between water and the wall of pore in the membrane: and crevices were then created at the wall of the pore after water evaporated from these pores. If the action between water and CTA is decreased by lowering the surface tension between them,

Table 6. Effect of plasticizer concentration on the membrane properties.

Plasticizer concentration (Wt%)	0	10	15	20	25	30	35
Water flux (ml/cm^2 hr)	768	936	748	736	624	580	868
	852	702	630	570	668	812	652
	676	472	560	744	1075'	548	612
	644	368	528	723	1023 .	516	524
apperance of the membrane	dry and white, brittle and breakable		Flexibility of the membrane is increased with the increase of glycerol concentration. Usually 15-20% glycerol was chosen for drying membrane.				

• Temperature of feed water: 78°C. other temperature: 12°C.

the loss of water in the membranes does not cause the cracks on the pore wall. We tested a few surfactants and plasticizers, and finally glycerol was chosen as plasticizer, as it is non-toxic and suitable for food and pharmaceutical processes. Table 6 shows the effect of concentration of plasticizer on the properties of membrane.

The drying of the membranes was faster at high temperature's than at low. Effect of drying temperature on the membrane properties was tested in order to find a proper combination between drying temperature and period for casting membrane continuously by machine. The results are given in Table 7.

It can be seen from Table 7 that drying temperature only had a slight influence on the properties of the membrane. Drying temperature at 60-70°C was chosen for convenient operation, and the membrane could be dried in 5-10 minutes at this range of temperature.

(iv) Storage experiment: In order to satisfy the requirements in food and pharmaceutical industries, the membranes were dipped into 95% ethanol and medical H_2O_2 aqueous solution for a certain period to see the change of membrane properties. The results are shown in Table 8.

Table 8 shows that there was no change in the properties of B-CTA ultrafiltration membrane after storing them for more than 3 months under the above conditions.

(v) Effect of feed temperature on the membrane properties: UF membranes have high flux. The operating conditions, such as feed temperature, etc, have a great influence on the membrane properties. The effect of feed temperature on membrane flux was tested with tap water as feed. The results are given, in Table 9.

As shown in Table 9, the flux increased with the increase of feed temperature. This is because the viscosity of water at high temperature is smaller than that at low temperature, and the resistance to water passing through the membrane also shows the same trend.

4. Trial of B-CTA ultrafiltration membrane in food and pharmaceutical processes: There are no phase change and thermal effect in UF process and therefore UF process plays a very important role in food and pharmaceutical industries. For example, in UF of beverages, the impurities are removed, bacteria eliminated and the colour, flavour and nutrients of the beverage are preserved, making the beverage more tasty. The preliminary results on UF of wines are shown in Table 10.

Table 7. Effect of drying temperature on the membrane properties.

Drying temperature (°C)	9	30	40	50	60	70	80	110	126	142
Water flux (ml/cm^2 hr)	248	452	384	400	393	450	462	–	–	–
	476	363	–	–	–	360	336	336	318	544

Table 8. Effect of storage on membrane properties under different conditions*

Date of measurement	April 15, 1985	May 6, 1985	July 18. 1985
Flux of membrane stored in 95% ethanol (ml/cm^2 hr)	226	224	216
Flux of membrane stored in medical H_2O_2 aqueous solution (ml/cm^2 hr)	219	218	210
Flux of dried membrane (ml/cm^2 hr)	248	–	250

* The flux of wet membrane: 248 ml/cm^2 hr
measurement conditions are the same as in Table 1.

Table 9. Effect of feed temperature on the membrane properties.

Feed temperature (°C)	7	15	30	50	78
Water flux (ml/cm^2 hr)	339	447	672	1278	1872

Table 10. Ultrafiltration of wines.

name	corn alcohol	sorghum wine	hangzhou	Xiangqu
before UF	There are flaked coagulants at 50°	Flaked coagulants and black precipitants present	Grey and black precipitants	Milky white and grey particles
after UF	Clear bright	Clear transparent tasty	clear transparent tasty	tasty no particles

In addition, UF was used in glucose infusion and the maximum of finished product was raised from original 85%) to 99%. According to the results reported elsewhere, UF was successfully used in food, pharmaceutical, chemical engineering and electronic industries. UF will also be widely used in the production of ultrapure water, separation in chemical engineering, pharmaceutical and food, industries in our country.

Conclusion

Experiments were carried out to compare the properties of C-CTA and B-CTA ultrafiltration membranes.

The properties of B-CTA ultrafiltration membrane are similar to that of C-CTA.

B-CTA with degree of polymerization 300 can easily be dissolved, but the conditions for making membranes are more severe.

Cast solution of B-CTA is clear and transparent. B-CTA is slightly better than C-CTA in resistance to acids and alkali. so the range of application for B-CTA ultrafiltration membrane is wider than that of C-CTA.

Traditional Preservation of Bamboo in Java, Indonesia

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Abstract

The traditional method of bamboo preseruation by immersion in water, followed by the rural Javanese is adequate. The immersion for a *month* decreases *the starch content of the treated bamboos and provides considerable resistance against the powder post beetle, Dinoderus minutus and D. brevis. The Javanese felling season "mangsa" XI helps to* prevent *damage by beetles.* Traditional *preservation of Dendrocalamus asper indicates an improvement in the resistance. On Gigantochloa apus and G. atter the* effect *is insignificant,* but these two bamboo *species have the least starch contents and highest degree* of *resistance. The immersion treatment does not work sufficiently for Bambusa vulgaris due to its high content of* starch. *The* treated bamboos indicate *a considerably better performance at least for one year.*

Introduction

Bamboo is an important, cheap, and plentiful resources in Indonesia. It could be found almost everywhere, mostly in the islands of Java and South Sulawesi, consisting of more than 30 species, distributed geographically up to 2000 m above sea level (Hildebrand, 1954). A survey conducted in the Province of Yogyakarta on 30 "kecamatan" indicated that bamboos grow everywhere, planted by the rural communities (Haryono Danusastro et al., 19'79; 1980; 1981). It has been observed that 13 species of bamboo are grown by rural people in their homeyards; four of which have been most extensively used, especially for construction purposes, i.e., *Gigantochloa apus* Kurz, G. *atter (Hassk.) Kurz ex* Munro, *Dendrocalamus asper Back., and Bambusa* sp. (Abdurachim, 1967; Hildebrand, 1954; Heyne, 1950; Widjaya, 1980). Utilization of bamboos for construction is about 13% in the rural areas of the provinces of Yogyakarta, Central Java, East Java, and Bali; its role increasing to 30% for residential building construction; it is used for roofing, partition wall, and ceiling frames (Anon., 1977; Anon., 1982) .

Bamboo is more susceptible to biodeteriorating agents as compared to timber, such as fungi, termite, and especially insect borers (Liese, 1980). Among the insect borers observed in his study, Sulthoni (1981; 1983a) considered powder post beetles *Dinoderus minutus* Fab. *and D. brevis H*orn. the most damaging.

Untreated bamboos used in open places and on ground are generally destroyed in about one or two years (Varmah and Pant, 1981). Treatment of bamboos with preservatives is widely regarded as necessary, but however it is seldom carried out; the reasons are a lack of knowledge about possible use of chemical preservatives, the uncertainty about the advantage of bamboo preservation, and the lack of market for treated bamboos (Liese, 1980).

Preservation Of Bamboo

Two methods of preservation could be done either chemically or non-chemically. Chemical treatment of bamboo using preservatives could be applied on dry or green or fresh bamboos, and some techniques for preservation are the following (Tewari and Bidhi Singh, 1979) :

1. **Washing and coating:** A variety of coatings such as tar, lime wash, tar and lime wash, and tar sprinkled with sand are used in Indonesia by house builders. These coatings are successful only when continuously done on cut surfaces, exposed internodes, abrasions and splits.

2. Brushing, swabbing, spraytng and dippling: These surface treatments are for temporary protection of bamboo in storage or before it is given impregnation treatments. Various chemicals used are aqueous emulsion of insectisides like dieldrin 0.03%, aldrin 0.015%, or D.D.T. 7-10% in kerosene oil. In Japan, mercury and tin salts have also been used for protection against borers and fungi respectively. Other chemicals such as sodium pentachlorophenate, borax and boric acid are also used.

3. Soaking: Air-dried bamboos have only to be submerged in the preservative solution (oil or oil solvent type) for a period depending upon the species, age, thickness and absorption required. The penetration is predominantly by capillarity. The soaking method requires little equipment and technical knowledge, provided the schedule of treatment, such as type of preservatives, their concentration and the period of dipping, is worked out. The absorption of preservative is more in half round specimens in comparison to round ones.

4. Boucherie process: In normal Boucherie process the Bamboo is treated by preservative through gravity from a container placed at a height. In India this method was modified later on by using a simple hand pump. By means of air pressure of 1.0 to 1.4 kg/cm^2 applied to the preservative container, the preservative is pushed through the tissues of the green bamboo. This modified procedure reduces the period of treatment significantly and under the pressure the treating solution forces the sap out of the walls and septa of the bamboo through the open end and replaces it in course of time.

The penetration and absorption of the preservative depend upon several factors, such as concentration, treatment time, nature of chemical used, age and dimension of the bamboo, moisture content, etc.

5. Steeping method: This method generally consists of allowing freshly cut culms, with the crown and branches intact, to stand in a container holding the preservative solution to a depth of 30 to 60 cm. Through leaf transpiration current, the solution is drawn up to the stem. The period of treatment depends upon the species, the length of the culm, weather conditions, preservative used, etc.

6. Sap displacement method: Green round or split bamboos are immersed partly in water based preservatives. The preservative rises gradually to the top through absorption due to replacement of the sap.

7. Hot and cold bath process: When pressure facilities are not available, the hot and cold bath or open tank process can be applied for dry bamboos similarly to that used for timber. Absorption of creosote up to 70 kg/m^3 is reported to have been obtained by this process. Research studies at the Forest Research Institute, Dehra Dun indicate that the period of heating significantly influences the absorption of the preservative. By increasing the heating period from 1 hour to 6 hours, the absorption increases'upto 100%.

8. Diffusion process: This process can be employed using water soluble preservatives, either in the form of solution or paste to treat green bamboos.

In this process the toxic chemicals diffuse from the place of application at high concentration to other zone through the water medium. With enough time the chemical preservative spreads to almost the entire volume of the green material. This diffusion process appears most suitable in the case of bamboos which are difficult to impregnate under pressure in dry conditions. This process requires simple equipment and are popular in many countries such as Germany, Canada, U.S.A., Australia and New Zealand. It appears that permeability of bamboo to preservatives is significantly increased after ponding. Though the service life of the bamboos treated by any process mentioned earlier may not be equal to that obtained by pressure and open tank method (where greater degree of quality control is possible), yet the method is cheap, simple and requires simple equipment, applicable even in remote areas and further-gives reasonably good protection to the treated bamboos.

9. **Pressure processes:** Pressure process is suitable for treating dry bamboos. When the bamboo moisture content is reduced below 20%, satisfactory penetration and absorption is obtained by this process. The drying of bamboos is generally carried out in the air under cover. To prevent deterioration of bamboos during drying, it is important to impart prophylactic treatment with suitable chemicals. For the installation of pressure treatment plants, heavy investment is usually required which the average in user cannot afford.

Cracks are usually developed in bamboos if treated under high pressure which reduces their strength. It has been observed that species having thin walls are susceptible to cracking when treated under low pressures (5-7 kg/cm^2). Round specimens of Dendrocalamus strictus treated under high pressure of 14.06 and 28.12 kg/cm^2 absorbed 88.12 and 107.00 kg/m^3 of creosote-fuel oil mixture respectively, while half split specimens absorbed 91.54 and 108.81 kg/m^3 of the preservative.

Traditional Preservation of Bamboo

Insect borers such as powder post beetle are a serious problem. These included Dinoderus minutus Fab., D. ocellaris Steph., and D. brevis Horn., which is popularly known as bamboo "ghoon" in India (Beeson, 1961; Sen Sarma, 1977 and "bubuk bambu" in Java Kalshoven , 195 1).

A non-chemical traditional method of preservation is practised quite often in the Asian countries to prevent bamboo against powder post beetle. This method is applied by soaking the cut bamboo culm under the water. It costs almost nothing and can be carried out by the rural people themselves without any special equipment, It is more suitable for the reasonably cheap and easily available bamboo raw materials (Liese, 1980).

The susceptibility of bamboo to borer attacks depends on the species, its starch content, age of the culm, felling season, and the physical properties of the bamboo (Plank, 1950). But further studies indicate that starch content in bamboo is an important factor influencing the susceptibility to borer (Plank, 1950; 1951); the damage caused by the borer has been found proportional to the starch content of the bamboo (Purushotham. et al., 1953; Beeson, 1961; Liese, 1980; Tamolang et al., 1980; Sulthoni, 1984).

Plank (1950) and Beeson (1961) observed that during the soaking period in the water, the starch contents of the bamboo tissue is reduced. It is therefore said to be less attractive thereby improving the resistance level against borers (Liese, 1980; Tamolang et al., 1980). This assumption, however, remains to be proved because not much is known about the real effectiveness of this traditiona! method of preservation (Liese, 1980) .

The rural Javanese have been traditionally practicing this method of bamboo preservation; not only by soaking the half-finished bamboo materials in the water or muddy water, but also in determining the best felling season of the selected bamboo species. They cut the bamboos for their use at a certain season what they call "mangsa tua", which they believe to be the most appropriate time, to obtain better quality of bamboos such as Gigantochloa *apus* and G. after, used for constructions. The Javanese have their own seasonal calendar what they call "pranatamangsa" (the rule of season). It is actually a solar calendar system, but explicitly ecologically oriented to be in harmony with the sequence of their agricultural activities. During the year there are two main seasons (dry and rainy), which are further divided into four detailed seasons, i.e., "marengan" (pre-dry season, 88 days before the real dry season), "katiga" (88 days of real dry season), "labuh" (pre-rainy season, 95 days before the real rainy season), and "rendengan" (94 or 95 days of real rainy season). Each detailed season is divided into 3 "mangsa". but with uneven number of days within each "mangsa". Mangsa I – VI is grouped as "mangsa muda" (young season) and mangsa VII – XII as "mangsa tua" (old season) (Daldjoeni, 1983).

Justification of the Javanese Traditional Method of Bamboo Preservation

Research has been conducted by the present author, supported by IDRC on this subject (Sulthoni, 1983b). The main goal of the study was to support with scientific reasons the rural Javanese tradition in handling bamboo for longer service life against powder post beetle Dinoderus sp.

Two specific objectives were formulated, to, quantify scientifically the time of felling "mangsa tua", and to assess the efficacy of the effect of water immersion of bamboo in improving the resistance performance against borer.

Four species of bamboo were used: 1. Gigantochloa apus. the most favoured for construction. 2. G. otter. specifically favoured for furniture and musical instruments. 3. Dendrocalamus asper, indefinite, but occasionally favoured for poles due to its tallness. 4. Bambusa vulgaris. minor value and not favoured for constructional purposes.

The first objective of the research was to justify whether the fluctuation of the natural relative population of the borer synchronized the best felling season of the "mangsa tua". The favoured and not favoured bamboo species were studied by determining the starch contents of the monthly consecutive felling of the bamboo samples, and the corresponding degree of susceptibility.

The second objective was to determine the decrease of the starch content of the immersed bamboo samples in water for various immersion periods, and hence to evaluate their corresponding degree of borer attacks. Southwood method (1978) was used to measure the natural relative population of the borer. while Humphrey's and Kelly's method (1961) was used to determine the starch contents of the bamboo species. The degree of susceptibility in the bamboo species against attacks was assessed using the method of Beeson (1961) by counting the borer's hole per sample.

Results Of The Studies

1. Felling season of bamboo: The relative population level of the borer Dinoderus minutus and D. brevis has a tendency to decrease in the "mangsa tua", and the lowest in "mangsa" XI (April 20 – May 11) (Table 1). Mangsa XI is the best season the Javanese use to cut the bamboos for their own use. In terms of the biological process of the bamboo clumps, "mangsa" XI is about the end of the sprouting period of the shoots. Felling the mother bamboo at this time is not damaging to the shoots.

Mangsa XII is actually the last "mangsa" of the "mangsa tua", but the rural people considered it too late to cut bamboos. In Table 1 it can be observed that the population of the borer increases considerably.

It is concluded from the data in Table 1, that the felling period followed by the Javanese rural people can be recommended.

2. Selection of better quality of bamboo species: It has been mentioned earlier that the rural people in Yogyakarta, Java, prefer Gigantochloa apus and consider Bambusa vulgaris as of minor quality. Table 2 shows the average highest starch content in B. vulgaris, which fluctuates between 0.48 up to 7.97% within a year. In G. apus and G. atter it fluctuates between 0.24 to 0.71% and 0.24 to 0.64% respectively. The degree of susceptibility that the four bamboo species indicate is proportional to their respective starch contents (Table 3). B. uulgaris shows 0.12 to 13.87 boring holes per sample. while G. apus and G. atter show the most resistant with boring holes of 0 to 0.81 and 0 to 1.25 respectively. D. asper has its susceptibility degree between B. uulgaris and Gigantochloa. with its starch contents fluctuating between 0.27 – 2.80% and boring holes between 0 and 5.56. It is clearly proved therefore, that classification followed by the rural people is scientifically justified.

3. Effect of water immersion on split bamboo: The results of the study are shown in Tables 4. 5, and 6. with different periods of immersion of one. two and three months. The data in the three tables are self explaining: all treatments are effective in improving the degree of resistance in the bamboo treated. either in running or stagnant water or mud. and the periods of immersions. It is concluded that one month immersion is enough. Bamboo species with less than 1% starch content is considered as good quality bamboo useful for construction.

4. Service life of water-immersed bamboo: Traditional preservation has indicated to improve the resistance performance, but it depends primarily on the bamboo species. One year of service life of the treated bamboo species is indicated in Table 7. In B. *vulgaris* the service life is still poor and this is due to its high content of starch. D. asper on the other hand indicates good performance.of one year service life with only 2.08 holes of borer attacks. G. apus and G. after show the best, even on the control specimen. It is again a stronger indication that least starch contents in the two latter species promotes better quality.

Table 1. Fluctuation of the relativepopulation of Dinoderus beetle in the campus area ofGadjah Mada University Yogyakarta. Indonesia (113 m above sea level. tempemture range max. 30-30°C, humidity range max. 75-90% at 2.00 p.m.

Months	Relative pobulation of power post beetles related to months			Javanese "mangsa" and days		Relatrve populatron of power post beetle related to "mangsa"		
	a	b	C			a	b	C
June. 1980	591	439	116	XII	(May 12 – June 21) (41-t	515	380	8 6
July. 1980	461	82	30	I	(June 22 – Aug. 1 I (41)	551	143	45
Aug. 1980	490	63	17	II	(Aug 2 – Aug. 24) (23)	416	53	lb
Sep., !980	293	119	19	111	(Aug 25 Sept. 19) (24)	223	94	32
Oct . 1980	413	164	12	IV	(Sept 18 Oct 12) (25)	220	46	9
Nov. 1980	610	189	11	V	(Oct. 13 – Nov 8) (27)	625	194	12
Dec . 1980	230	138	6	VI	(Nov 9 – Dec 21) (43)	4 %	246	10
Jan . 1981	105	88	4	VI1	(Dec 22 Feb 2 I (43)	172	128	
Feb.. 1981	155	6	0	VIII	(Feb 3 – Feb 28) (26)	136	6	0
Mar. 1981.	250	219	1	IX	(Mar 1 – Mar 25) (25)	206	198	0
Apr. 1981	93	130	1	X	(Mar 26 – Apr 19) (24)	115	126	2
May. 1981	10	lb	0	XI	(Apr 20 – May 11) (23)	26	39	0
Total	3 701	1 653	217			3 701	1 653	217

Notes: a -- *Dinoderus minutus* and *D. brevis* (Fam. Bostrychidae)
b – *Conarthrus praeustus*, *G. filiformis* and *Myocalandra exarata* (Fam. Curculionidae)
c -- *Laemotmetus rhizophagoides* (Fam. Passandridae)

Table 2. Average starch content (%) of four bamboo species, based on 12 consecutive monthly fellings.

Felling months	B. vulgaris			D. asper			G. apus			G. atter		
	b	m	a	b	m	a	b	m	a	b	m	a
May, 1980	4.39	3.86	4.00	0.72	0.81	1.18	0.46	0.39	0.28	0.63	0.54	0.42
June, 1980	2.77	2.83	5.49	0.41	0.78	0.49	0.29	0.31	0.31	0.49	0.43	0.33
July, 1980	0.83	3.42	1.63	0.29	0.31	0.60	0.32	0.47	0.37	0.31	0.30	0.29
Aug., 1980	1.33	2.87	3.80	0.27	0.27	0.85	0.27	0.32	0.28	0.54	0.44	0.64
Sept. 1980	2.61	3.61	4.53	1.40	2.01	2.80	0.27	0.32	0.24	0.33	0.25	0.24
Oct.. 1980	3.55	4.21	6.44	0.35	0.50	0.63	0.26	0.27	0.26	0.29	0.29	0.38
Nov., 1980	5.22	5.49	7.97	0.29	0.42	0.66	0.25	0.53	0.71	0.28	0.33	0.34
Dec.. 1980	2.31	2.56	3.59	0.26	0.51	0.67	0.25	0.32	0.36	0.30	0.32	0.39
Jan.. 1981	0.48	0.51	0.52	0.34	0.48	0.62	0.25	0.27	0.27	0.31	0.34	0.33
Feb.. 1981	0.65	1.60	2.39	1.06	1.17	1.48	0.35	0.31	0.27	0.33	0.24	0.35
Mar., 1981	2.62	3.63	5.62	2.32	2.52	1.42	0.31	0.27	0.26	0.44	0.34	0.31
Apr., 1981	1.32	1.66	3.00	0.31	0.33	0.32	0.30	0.46	0.49	0.33	0.31	0.54

Notes: b – basal part of culm
m – middle
a – apical
All bamboo samples are about two years old

Table 3. Average Dinoderus beetle attacks (in number of holes) of four bamboo species, based on 12 consecutive monthlyfellings, corresponding to the related starch contents shown in Table 2.

Felling months	B. vulgaris			D. asper			G. apus			G. atter		
	b	m	a	b	m	a	b	m	a	b	m	a
May. 1980	13.87	10.50	6.50	0.15	1.43	5.56	0	0	0	0.06	0.06	0
June, 1980	4.63	5.32	2.12	0.06	1.06	1.62	0	0	0	0.18	0	0
July, 1980	4.75	4.68	3.06	0.06	0.18	1.00	0.18	0.18	0	0	0	0
Aug., 1980	7.37	6.37	3.18	0	0.18	0.06	0	0	0	0	0.12	0.12
Sept. 1980	5.37	2.87	1.93	4.25	2.43	4.00	0	0	0	0	0	0
Oct., 1980	7.37	7.81	4.37	3.00	3.62	3.06	0	0	0	0	0.06	0
Nov., 1980	8.43	11.06	5.31	0.81	0.75	0.12	0.25	0.62	0.81	0	0	0
Dec.. 1980	5.43	6.37	4.18	1.25	1.43	1.62	0.06	0	0.06	0.18	0.06	0.12
Jan., 1981	3.93	0.44	4.62	2.00	2.62	2.62	0	0	0	0.62	1.25	0.81
Feb., 1981	3.25'	1.68	2.00	1.87	2.87	0.87	0	0	0	0.43	0.75	1.06
Mar., 1981	1.18	2.93	1.81	5.25	4.43	3.25	0.06	0	0	0.25	0.18	0
Apr.. 1981	0.12	0.37	0.18	0	0	0	0	0	0	0	0	0

Notes: b – basal part cf culm
m – middle
a – spical
All bamboo samples are about two years old.

Table 4. Starch contents and the corresponding powder post beetle attacks of 4 bamboo species after 1 month immersion in water.

Bamboo species	Immersion treatment	First felling		Second felling		Third felling	
		a	b	a	b	a	b
1. B. vulgaris	Control	4.09	45	3.69	39	1.96	28
	Running water	3.16	19	3.48	4	1.50	1
	Stagnant water	3.39	16	3.38	0	0.33	11
	Mud	3.31	16	3.29	0	1.61	5
2. D. asper-	Control	0.90	6	0.56	12	0.40	1
	Running water	0.33	0	0.55	0	0.35	0
	Stagnant water	0.47	0	0.42	0	0.39	0
	Mud	0.48	0	0.40	0	0.36	0
3. G. apus	Control	0.37	0	0.30	0	0.38	3
	Running water	0.30	0	0.25	0	0.35	0
	Stagnant water	0.23	0	0.32	0	0.26	0
	Mud	0.33	0	0.32	0	0.38	0
4. G. atter	Control	0.53	2	0.41	4	0.30	1
	Running water	0.33	0	0.28	0	0.30	0
	Stagnant water	0.39	0	0.28	0	0.29	0
	Mud	0.29	0	0.40	0	0.26	0

Notes: a – Starch contents in percent
b Powder post bettle attacks in number of holes after 1 year exposed in open
All bamboo samples are about two years old

All bamboo samples are about two years old. (The results presented in Table 4 and 5 are for the same treatment Eds)

Table 5. Starch contents and the corresponding powder post beetle attacks of 4 bamboo species after 2 months immersion in water.

Bamboo species	Immersion treatment	First felling		Second felling		Third felling	
		a	b	a	b	a	b
1. B. vulgaris	Control	4.09	45	3.69	39	1.96	28
	Running water	2.70	0	2.83	1	1.38	2
	Stagnant water	2.87	1	3.28	8	0.27	2
	Mud	3.35	2	2.98		1.39	0
2. D. asper	Control	0.90	6	0.56	12	0.40	1
	Running water	0.32	0	0.40	0	0.31	0
	Stagnant water / Mud	0.28 / 0.43	0	0.25	0	0.31 / 0.33	0
3. G. apus	Control	0.37	0	0.30	0	0.38	3
	Running water	0.28	0	0.23	0	0.27	0
	Stagnant water	0.26	0	0.32	0	0.21	0
	Mud	0.35	0	0.24	0	0.28	0
4. G. atter	Control / Running water	0.26 / 0.35	2 / 0	0.24 / 0.25	4 / 0	0.30	0
	Stagnant water	0.30	0		0	0.25	0
	Mud	0.30	0	0:27	0	0.22	0

Notes: a – Starch contents in percent
b – Power post beetle attacks in number of holes after 1 year exposed in open
All bamboo samples are about two years old.

Table 6. Starch contents and the corresponding powder post beetle attacks of 4 bamboo species after 3 months immersion in water.

Bamboo species	Immersion treatment	First felling		Second felling		Third felling	
		a	b	a	b	a	b
1. B. vulgaris	Control	4.09	45	3.69	39	1.96	28
	Running water	2.46	1	1.70	0	0.52	1
	Stagnant water	3.27	0	1.91	1	0.23	13
	Mud	3.27	0	1.58	0	1.05	0
2. D. asper	Con trot	0.90	6	0.56	12	0.40	1
	Running water	0.31	0	0.39	0	0.25	0
	Stagnant water	0.25	0	0.24	1	0.20	0
	Mud	0.33	0	0.22	0	0.24	0
3. G. apus	Control	0.37	0	0.30	0	0.38	3
	Running water	0.29	0	0.22	0	0.24	0
	Stagnant water	0.26	0	0.24	0	0.25	0
	Mud	0.27	0	0.17	0	0.25	0
4. G. atter	Control	0.53	2	0.41	4	0.30	1
	Running water	0.29	0	0.21	0	0.27	0
	Stagnant water	0.24	0	0.25	0	0.25	0
	Mud	0.25	0	0.18	0	0.18	0

Notes: a – Starch contents in percent
b – Powder post beetle attacks in number of holes after 1 year exposed in open
All bamboo samples are about two years old

Table 7. Powder post beetle attacks of stagnant water-immersed bamboo species as Indicator of the first year service life

Felling months	Powder post beetle attacks on mdividual bamboo species, in number of holes															
	B vulgaris				D. asper				G apus				C atter			
	a_0	a_1	b_0	b_1	a_0	a_1	b_0	b_1	a_0	a_1	b_0	b_1	a_0	a_1	b_0	b_1
May 1980	10	0	49	19	1	0	7	0	0	0	0	0	0	0	2	0
June 1980	5	0	49	0	1	0	12	0	0	0	0	0	0	0	3	0
Jufy I980	5	6	35	8	0	0	0	0	0	0	3	0	0	0	2	0
Aug. 1980	6	0	53	0	0	0	0	0	0	0	0	0	0	0	4	0
Sept. 1980	3	0	45	1	2	0	61	1	0	0	0	0	0	0	1	0
Oct. 1980	8	0	27	0	4	0	12	0	0	0	0	0	0	0	0	0
Nov. 1980	11	0	27	61	1	0	7	1	1	0	2	0	0	0	2	0
Dec. 1980	6	0	63	35	1	0	2	0	0	0	0	0	0	0	0	0
Jan. 1981	4	0	21	24	3	0	17	0	0	0	0	0	1	0	15	0
Feb. 1981	2	0	29	14	3	0	7	4	0	0	0	0	1	0	15	0
Mar.. 1981	3	2	38	20	4	2	44	19	0	0	0	0	0	0	3	0
Apr. 1981	0	0	17	0	0	0	1	0	0	0	0	0	0	0	0	0
Total	63	6	453	182	20	2	170	25	1	0	5	0	2	0	37	0
	5.25		37.75		1 66		14.16		008		0.41		0 16		3 08	
Average		0.5		15.66		0.16		2.08		0		0		0		0

Notes: % – untreated specimen
a_1 – 1 month immersion in stagnant water
b_0 – untreated spectmen
b_1 1 month tmmerston in stagnant water

Data m a_0 and a_1 are recorded after one month off from the water immerston. whtle b_0 and b_1 after one year off

Conclusion

The Javanese traditional method of bamboo preservation is justified to some extent. The felling season followed is suitable. Immersion in water improves the quality of **Dendrocalamus** asper. Chemical treatment is not economical and beyond the means of the users.

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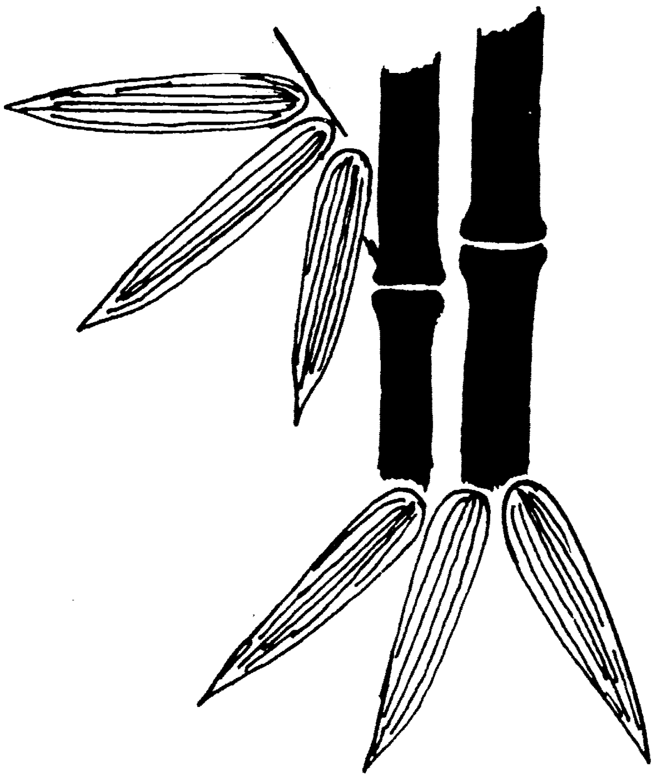

Socio-Economics

Role of Bamboos in Rural Development and Socio-economics: A Case Study in Thailand

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Abstract

Bamboo *plays an important role in rurai* ***deoelopment*** *of Thailand. Bamboo shoots* ***provide the rural people with an income in rainy season*** *during which no products are* ***obtained from the major agricultural crops. Bamboo culms are commonly used as construction material of the households in rural*** *area* ***whereas bamboo handicrafts provide an important additional incTTome. The wide uses*** **of** ***bamboos give more employment opportunities and better income distribution. Millions*** **of** ***bamboo culms and thousands of tons*** **of** bamboo ***shoots are*** haruested annually. ***The outputs*** **of** ***bamboo utilization from different study sites are presented and the problems*** **of** ***bamboo resource are discussed.***

Introduction

Bamboo is the most universally useful plant known to man. For over half the human race, life would be completely different without it. Ubiquitous, it provides food, raw material, shelter, even medicine for the greater part of the world's population (Austin et al. 1983). Bamboos are abundant in Thailand due to its tropical climate. However, the taxonomic studies of bamboo species in Thailand is still in its infancy. 12 genera and 41 species have been described (Smitinand and Ramyarangsi, 1980). Although bamboo has long been recognized as a multipurpose species, very useful in rural areas, it is harvested without any concern for conservation measures and research has been virtually ignored. In the recently formulated Sixth National Economic and Social Development Plan beginning 198'7, bamboo has been selected as one of the species to be developed. This means that the government will have a definite policy on bamboo resources. Bamboo will play a more significant role in rural development, bamboo cultivation will be promoted and more effective uses of bamboo will in turn be expected.

Uses and Applications

The uses of bamboo both in Thailand and elsewhere are so broad and the variety of applications so numerous, only the more important commercial and common types are covered in this discussion. Fig. 1 shows the location of the places referred to in the text.

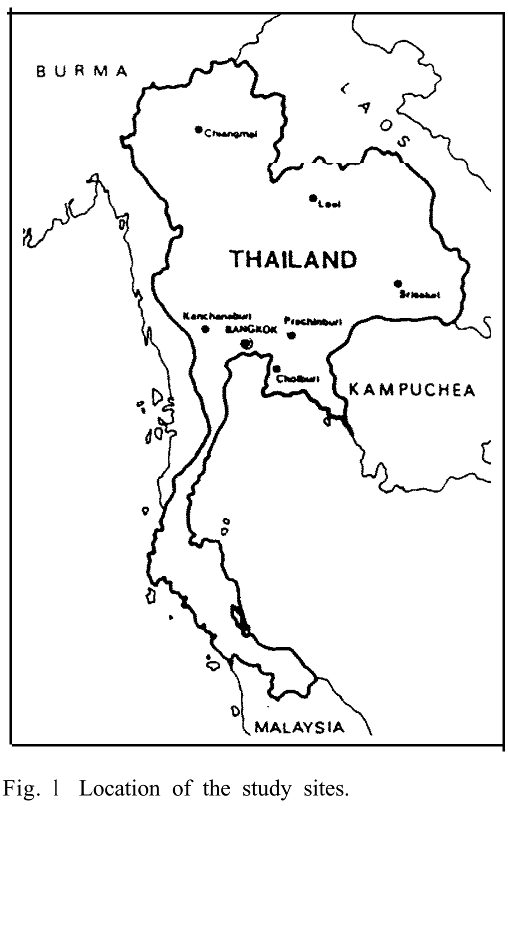

Fig. 1 Location of the study sites.

Bamboo pulp: Bamboo is an excellent resource for pulp and paper making, used in India, Japan and other Asian countries for a long time. Because of its tong fiber, mixing it with other pulp is not necessary and can be used as the sole raw material for making paper. The Kanchanaburi Paper Mill, producing paper from bamboo, was established in 1936 by the Ministry of Industry, and it was a successful operation. But the paper mill had never been a real money earner. The red tape had plagued the operation and, as a result, the mill was closed in September 1984. Although the only mill producing paper from bamboo is no longer under operation, the use of bamboo for this purpose is still going on under the experiment by Phoenix Pulp and Paper Co. Ltd. in Northeast Thailand. There is a potential that bamboo may *serve* as an important raw material for pulp and paper making at this mill.

Bamboo plywood: Because of its colour and its shiny surface, bamboo has been used as a decorative material for centuries. More recently bamboo has been made into an attractive plywood for buildings. There are two manufacturers of bamboo plywood in Thailand, one in Kanchanaburi and the other in Lampoon (near Chiangmai). Since the production requires quite a lot of raw materials, there are thousands of people engaged in various activities, such as factory workers, bamboo cutters, villagers who weave the bamboo mats. The thickness of bamboo plywood ranges from 1 mm to 10 mm, the size being 120 **x** 240 cm. The production capacity is about 20,000 boards per month in each factory.

Food: Bamboo shoots are widely used as food in Thailand. The most popular species is Dendrocalamus asper, cultivated commercially in. Prachinburi where 37,975 tons of bamboo shoots were harvested last year. The other varieties are harvested from natural forests throughout the country. Although there is no actual figure of bamboo shoots harvested from natural forests, it can be estimated that some hundred thousands tons of bamboo shoots are harvested annually. Bamboo shoots are preserved in three different ways: dried, steamed, and soured bamboo shoots. The export value of bamboo shoots, mainly in cans, was 80 million Baht in 1984 (US$l = Baht 26.90).

Construction material: In areas where it grows naturally, bamboo is a traditional building material. Houses can be made exclusively from bamboo. Larger culms are used for the piles, stilts and the major framework. Smaller sized pieces are used for floors, windows and door frames. The bamboo can be split into slats for weaving into mat walls. When the culms are split in half and the nodes removed, they can be used interlockingly to form waterproof roofs. The same ingenious application of bamboo is also carried through for furniture, fences, cages, mats, farm implements, ladders, and blinds. Pipes for irrigation and guttering can also be fabricated when the nodes are removed. Bamboo scaffolding is commonly used in building construction since bamboo is extremely resilient and longlasting. Many construction workers also believe that bamboo is safer than rigid tubing. One seldom hears of bamboo scaffolding collapsing even when it is used in multi-storey construction.

A great variety of bamboo handicrafts are made in the rural area throughout the country. They provide the rural people with an additional source of income, Apart from domestic consumption, the 1984 export value of bamboo handicrafts was 70 million Baht. Bamboo handicrafts are also regarded as an old Thai tradition.

Role of Bamboo in Rural Development

Most of the rural people in Thailand are in the agricultural sector, with major crops being rice, corn and cassava. They plant bamboo as a living fence from which bamboo shoot will be used for food and bamboo culm for building material and handicrafts. These people have no income from their agricultural crops during rainy season but they will have bamboo for compensation. The surplus of bamboo shoots can be sold in the local market or preserved by steaming or pickling for future consumption. Bamboo culms can be cut and made into a variety of bamboowares for use in the household as well as for additional income when sold.

For those living close to the forest, bamboo always shares a major part of their houses. It is typical that people in remote rural areas are poor. Their earnings from agricultural crops are not sufficient to cover their yearly expenditure, many of them being heavily in debt. Fortunately, bamboo can relieve such problems. These people will gather bamboo shoots from the forest and sell them to the trader for further processing, The roadside price of fresh bamboo ranges from 1 to 5 Baht per kilogram depending on the time of the year.' One can gather as much as 100 kilograms of bamboo shoots in a day. With a six-month season one can earn quite a lot of money. With such opportunity for earning the poor people in the rural areas will be better off and, as a result, the rural areas are developed both directly and indirectly.

A variety of bamboo handicrafts can be found throughout the country. They represent a unique local tradition which differs from place to place. The rural people in eastern Thailand have the reputation of making very fine bamboo handicrafts while the heavy-duty ones are made in the western region. Many people both Thais and foreigners are astounded to see the very tiny baskets, 1 cm in diameter. In Srisaket and Chiang Mai tourists enjoy their shopping for a great variety of bamboo souvenirs. Bamboo is the most versatile raw material for home industry in the rural area. Bamboo has managed to establish such preeminance because bamboo craftmanship is comparatively simple. While a certain level of competence is necessary, one need not possess a high degree of skill to fashion bamboo into an object that will stand up for practical use. In fact, there have always been a good many people making baskets for their own use. Nowadays, specialist craftsmen are outnumbered by farmers for whom working bamboo is secondary trade. Even school children can make simple bambooware for commercial purpose.

Housing in the rural area needs quite a great quantity of bamboo as construction material, especially for a new settlement in the remote area, using bamboo as a substitute to timber and other material which are scarce and costly. The versatility of barnboo as construction material mentioned in the previous section indicates the great potential role of bamboo in rural community development.

Socio-Economics of Bamboo Production

National bamboo culm production: The quantities of bamboo culms harvested from natural forest and their values from the years 1981 to 1984 are presented in Table 1. The average annual production is 52 million culms are worth 270 million Baht. The figures represent only the output recorded by the Royal Forest Department when bamboo culms are transported through the check points. In fact, a great number of bamboo culms are cut and used in the rural area and are not included in those recorded by the Royal Forest Department. Consequently, the actual figures of culm production may be five to six times greater than those presented in Table 1. The greater part of the culm production is that of Thyrsostachys siamensis and T. oliveri, the rest being Bambusa arundinacea, B. blumeana, B. nana, B. tulda, Dendrocalamus *strictus,* D. hamiltonii, D. membranaceus, Cephalostachyum pergraile, *C. virgatum*, and some other minor species. There is no record of the quantity of bamboo shoots harvested in the whole country. The figure one may get is only the estimate. However, the only records of bamboo shoot production are obtained from bamboo farms and bamboo shoot proceasing factories. It must be kept in mind that such records represent only a small part of the total production.

Table 1. Outputs and value of bamboos harvested from natural forest in Thailand.

Year	output culms	Value Baht'
1981	**63 187 919**	**259 272 947**
1982	**52 981 878**	**344 924 205**
1983	**45 022 244**	**232 827 187**
1984	**48 933 933**	**247 583 463**

'U.S. $1 = Baht 26.90
Source: The Royal Forest Department 1981,1982. 1983. 1984 Annual Reports.

Bamboo in the north: From tourist souvenir to bamboo plywood industry: Thailand's major forest resources are found in the north. This means that the region is very rich in bamboo resource as well. Apart from the uses of bamboo in the households that represent an old culture of this region, bamboo is used to make a variety of products for commercial purposes ranging from tiny items to plywood. There are at least 23 manufacturers of a variety of bamboo products in Chiangmai and its neighbouring town, Lampoon (Table 2). The production capacity can indicate that these manufacturers need a great quantity of bamboo raw material. Bamboo-based industry differs from other industries in a way that more rural people participate in the production process. The bamboo plywood factory in Lampoon is a good example.

The factory produces the standard-sized bamboo plywood, 1.20 x 2.40 m, with different thickness: 1, 2.5,4,6, and 10 mm. The production capacity is 20,000 pieces per month under 60 percent of full capacity. Bamboo plywood is composed of layers of bamboo mats glued and pressed together, Only *Dendrocalamus strictus* and *Cephalostachyum virgatum* are used. The factory provides the members of village farm cooperatives with bamboo raw material. The villagers will split the bamboo into thin strips, weave them into 1.30 x 2.55 m mats before sending them to the factory. The net income of the villagers ranges from 35 to 45 Baht per person per day.

There are about 1,000 families of the rural community who are involved in the production of bamboo piywood. There is a labour shortage in the industry during the rainy season when the members spend most of the time on the paddy fields and other farm lands. Nearly half of the labour force for bamboo mat making is shifted to for cultivation activities. The situation is worse during harvesting period when people earn more money and want to relax from hard work. However, the problem is not as serious as it should be since the factory and the mat makers are dependent on each other. The factory cannot operate without the mats from the rural community, without the factory the members of the cooperatives will have no additional income in order to improve their living condition. Therefore, both sides have to adjust their view to achieve a good cooperation. They are symbiotic.

Tiny bamboo baskets and sweet bamboo shoots in the northeast: The rural people in Srisaket Province have the reputation of making very fine bamboo baskets. Apart from those larger-sized items used in the households, the very tiny baskets, as small as 1 cm in diameter, are made from very fine bamboo slats. These slats are as fine as a thread, therefore skill and patience are required when these slats are woven. The technique has been passed on from generation to generation and it symbolizes the old tradition of the province. The miniature bamboo baskets are made for, commercial purposes as tourist souvenirs, decorative pins in particular.

There are four villages where such bamboo basket making is concentrated. The results of the survey in July 1984 reveal that 53.50 percent of the households in four villages, or 313 out of 585 households, engage in this

Table 2. Bamboo products in Chiangmai and Lampoon Provinces.

Type of products	Number of producers	Production capacity units/month
1. Bamboo plywood	1	20 000 (1.20 X 2.40 m)
2. Trays	3	15 000
3. Handicrafts	9	4 300
4. Souvenirs	3	3 800
5. Jugs	1	3 450
6. Handicrafts for lacquerware making	2	2 000
7. Lanterns	2	1000
8. Sticks	1	7 000 kg.
9. Toothpicks	1	1 000 packs

activity. There is one village in which every household makes the bamboo baskets for commercial purposes. The income from the products for each household ranges from 3,600 to 6,000 Baht per year. This additional income is very important to the rural people, most of whom earn rather little from their main livelihood. There are 24 villages in Loei Province where the people plant the so-called "sweat bamboo". It is called sweet bamboo because the taste of its shoots is not. bitter. The species are Bambusa burmanica and Dendrocalamus whose species is not known to the author. There are 585 farmers who plant these two species on their landlot. The size of the bamboo farm ranges from 0.5 to 10 hectares. However, nearly every household plant sweet bamboo on their home garden, three to five clumps being the most common.

When planted on the farm land, sweet bamboo can produce 1,600 to 2,400 kilograms of shoots per hectare. Each clump in the home garden can produce shoots weighing up to 100-150 kg. The local market price of sweet bamboo shoots is 10 to 15 Baht/kg. This can demonstrate that even the rural people who plant sweet bamboo on their home garden or as a living fence can earn a significant additional income. In the northeastern part of Thailand many people still believe that planting bamboo will bring them death. In the ancient times, bamboo poles were used for carrying coffin. These people would not plant any bamboo since they believe that they would die when the bamboo they planted are big enough to use as carrying poles. This might be one of the reasons why there is very little bamboo resource in the northeast compared with the other regions. This belief is gradually fading out and the people are beginning to plant more bamboos on their land. They have realized how important bamboo can be in their rural development.

Bamboo products: The lifeblood of the rural peoplein Prachinburi: Bamboo is commercially most important in Prachinburi, with many concentrated bamboo farms that support a variety of home industries. The discussion will cover only the utilization of bamboo for commercial purposes. The rural people in Prachinburi usually spend their free time making items from bamboo. Broom making is popular among the young and old people who do not engage in farm work. The broom handle is, of course, bamboo. A skilled person can make as many as 50 to 60 brooms in a day, the profit being 1000 to 1500 Raht per month per person. Since the brooms are used in every house in Thailand there will be a good potential for broom market.

Cephalostachyum pergracile is a typical bamboo for use in hat weaving in one district. The bamboo culm will be split into very thin strips. The strips are woven into bands of 2 cm width, before being sewed into a hat. Three hats can be made from one bamboo internode. The villagerscan make 60 m of bamboo band in a day from which they can earn about 10 Baht per day. Although it is a rather small earning, the rural people can enjoy their additional income.

Bambusa blumeana is used for basket making and mat weaving. This bamboo species is usually planted as a living fence from which the culm, 8 to 10 m long, are obtained and are worth 10 to 12 Baht when sold. The net profit the villagers will get from the baskets and the mats they make is about 15 to 20 Baht per day.

Bamboo furnitures in Prachinburi are made from Bambusa nana and Thyrsostachys ***siamensis.*** The survey for furniture making was made in one village of Prachantakam. There are 213 households in the village, 40 of which are involved in bamboo furniture making. The yearly income for each household is about 16,000 Baht. The production requires 90,000 culms of Bambusa nana nearly all of which are brought from Ubonratchatani and Yasothorn Provinces, 400 to 500 km to the northeast. Faced with the problem of raw material, there is a potential that more Bambusa nana will be planted in Prachinburi in order to avoid material shortage and long distance transport of bamboo culms.

Dendrocalamus asper was brought from China and introduced to the farmers in Prachinburi Province about 80 years ago. This province has since become the most well known centre for bamboo farms. The information about bamboo farms in Prachinburi is presented in Table 3. The f.o.b. price of the fresh bamboo shoots ranges from 2 to 8 Baht per kilogram depending on the time of the year. Nearly all of the bamboo shoots harvested from

Table 3. Shout production from Dendrocalamus asper plantations in Prachinburi Province in 1984.

District	Planting area ha	Productive area ha	output tons/ ha	Total output tons	Number of factories
Muang	2 368	2 0 %	11.250	23 580	17
Prachantakam	480	400	10.625	4250	2
Kabinburi	458	256	9.375	2400	2
Nadee	409	320	10.625	3400	1
Srakaew	640	400	9.375	3 750	–
Srimahapote	56	32	10.000	320	–
Aranyapratet	46	24	8.750	210	–
Kokpeep	8	8	8.125	65	–
Total	4 465	3536	–	37 975	22

the farm are sold to canning factories. Steamed bamboo shoots in cans serve both domestic and foreign markets. The number of canning factories can very well guarantee the future of bamboo farms.

The art of bamboo handicrafts in Cholburi Province: A very fine bamboo handicraft can be found in Panatnikom District of Cholburi Province. Cephalostachyum pergracile is widely used not only for handicraft but also for other purposes. The market price of one internode about l m long, is 5 Baht. There are four bamboo culm dealers in Panatnikom who sell about 12,000 internodes per month. The nodes can be used as fuel which is also sold at 10 Baht per sack or 0.5 Baht per kilogram. Ten baskets. 12 inches in diameter, can be made from the strips of three internodes. The villagers receive 17 Baht for one basket. It is very promising work for the rural people who invest 15 Baht for three bamboo internodes to get 170 Baht for ten baskets made. However, it must be kept in mind that this does not happen every day since people cannot devote much of their time for such work.

A special survey was made at the Handicraft Cooperatives of one village in PanatnikOm. The cooperatives were founded in 1976 in order to organize the activities of the members for better quality of products. better marketing, and more benefits. Before the cooperatives were founded, the income from bamboo handicrafts was 400 to 600 Baht per household per month. Such income was raised to 900-1,200 Baht per month during the first six years of the cooperatives. The income has been 1,300 to 1,600 Baht per month since 1982, higher income being expected during the years to come.

Kanchanaburi: The centre of bamboo utilization: The most concentrated area of bamboo growth in Thailand is in Kanchanaburi area, 130 km west of Bangkok. Logically, Kanchanaburi is the centre of bamboo utilization in Thailand. It is worth mentioning that Kanchanaburi is the only province in Thailand where 12 species of bamboo are legitimately controlled species. These species are Thyrsostachys siamensis, T. oliveri, Arundinaria pusila, A. ciliata, Bambusa arundinacea, B. blumeana, Cephalostachyum pergracile, GigantochIoa albociliata, Melocalamus compactiflorus, Melocanna humilis, Schizostachyum aciculare and Teinostachyum griffithii.

21.95 million culms were harvested from natural forest in 1982, 22.45 million culms in 1983 and 14.96 million culms in 1984. These bamboos were used in different kinds of industries both in Kanchanaburi and neighbouring provinces.

A special survey was made for the amount of bamboo shoots harvested from the forest. It is impossible to ger the real figure. but the data from some specific study sites will reveal the concentration of bamboo shoot utilization. The data was gathered from

Table 4. Production of sour sliced bamboo shoots in Thongpapoom, Kanchanaburi Province.

Producer No.	Number of working days	Workers		Production kg
		Number	Monthly wage Baht/person	
1	120.	25	800	294 700
2	120	15	1 100	195 000
3	120	4	900	62 500
4	90	5	1 200	125 000
5	60	5	1000	45 000
6	60	8	800	36 000
Total	–	62	–	758 200

those who make sour sliced bamboo shoot in Thongpapoom, the district next to the Burmese border. The information about sour sliced bamboo shoot making is presented in Table 4. These producers employ only 62 workers, whose working period ranges from 60 to 120 days in a year. Occasionally. other people are also involved. They are the bamboo shoot cutters who sell bamboo shoots on roadside for 2 Baht per kilogram on average; the shoots are those of Bambusa *arundinacea*, *Dendrocalamus brandisi* and D. strictus. The quantity of sour sliced bamboo shoots made in this district can demonstrate how the' income is distributed to the rural people. There is one bamboo canning factory in the city of Kanchanaburi that produces steamed bamboo shoots for export to Japan. The production capacity is about 350-400 tons per year. Thyrsostachys *siamensis* and *T. oliveri* are the only species to be used. Kanchanaburi is and will continue to be the centre of bamboo utilization in Thailand. This means that the rural people in this region can still enjoy using this precious gift of nature.

Conclusion

The uses of bamboo have long been very well known to man. Since bamboo is ubiquitous, people always harvest bamboo without any conservation measures. The natural bamboo resource will diminish in relation to the depletion of forest area. The scarcity of bamboo resource in the future will force people to plant more bamboos for use in their households and sell the surplus, if any, for additional income.

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Genetic Diversity and Socio-Economic Importance of Bamboos in India

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Abstract

India has the richest diversity of bamboos and the total annual production is one of the highest in the world. Distribution of bamboos in the country, socio-economic role of bamboos, conservation of gene pool and plant imprvoement are discussed.

Introduction

The bamboo is an important economic plant intimately associated with mankind since ancient times. It is a natural gift to the people in areas where it is abundant. It provides the basic necessities of life i.e. food, shelter and clothing. Besides these, it also provides raw material for cottage and paper industry. Thus it provides livelihood for millions of people. It is no more a poor man's timber as it serves both the poor and the rich with its numerous useful products. It is a renewable source of energy in the form of fuel for the rural population.

Bamboo is a fast growing grass with woody habit. It is widely distributed all over the world. Sharma (1980) has reported about 75 genera and 1250 species distributed in different parts of the world, mostly confined to South-east Asia. India has a rich diversity of bamboo genetic resources. Bahadur & Jain (1983) reported 113 species of bamboo belonging to 22 genera whereas Sharma (1980) reported nearly 136 species of bamboos occuring in India. The notable among these are Bambusa arundinacea and Dendrocalamus strictus. Although bamboo occurs in tropical, subtropical and temperate zones, it prefers humid and warm climate for best growth.

India has perhaps the world's richest resources of bamboos, with almost 50% of the species present in north-eastern region. Bamboos occupy about 9.57 million hectares of forest area, which constitute about 12.8% of total land area under forests (Vermah and Bahadur, 1980). The estimated annual production of dried bamboos is 3.23 million tonnes which is about one fifth of total wood production of the country (Vermah and Bahadur, 1980). It is reported that about 2 million tons of bamboo is consumed every year by the paper and rayon industries in India (Subha Rao. 1966).

Distribution of Bamboos

Out of 22 genera in India, 19 are indigenous and 3 exotic, introduced for cultivation. The indigenous genera are: ***Arundinaria, Bambusa, Cephalostachyum, Chimonobambusa, Dendrocalamus, Dinochloa, Gigantochloa, Indocalamus. Melocanna. Neohuzeoua, Ochlandra. Oxytenanthera, Phyllostachys, Pseudostachyum, Schizostachyum. Semiarundinaria, Sinobambusa Teinostachyum,*** and ***Thamnocalamus.***

Other genera like Guadua, Pseudosasa and Thyrsostachys — are occasionally cultivated. Vermah and Bahadur (1980) reported the bamboo distribution in India as follows: ·

In India, as elsewhere, bamboos form rich belts of vegetation in moist deciduous, and semi-evergreen tropical and subtropical forests. Very few species occur in the Himalayas of north-western India. The states particularly rich in bamboos are Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram. Nagaland. Sikkim. Tripura and

West Bengal. Bamboos are also rich in Andamans. Baster region of Madhya Pradesh. hills of Uttar Pradesh. Bihar. Orissa and Western Ghats.

Flowering in bamboos is rare and erratic. In some species it takes place after 3-4 years, in others they flower once in 30 or 40 years, once in a life cycle. Cultivation of bamboos is done by seeds or offsets or by other vegetative methods of propagation. Plant height varies from small to very tall. Yield of bamboo varies from 2.5 to 4.0 tonnes per hectare, depending upon the intensity of planting, stocking and varieties available. A felling cycle of 3 or 4 years is normally adopted.

	Region	Number of Genera	Number of Species	Genus (Species)
1.	North-eastern India	16	58	Arundinaria (9), Bambusa (12). Cephalostachyum (5). Chimonobambusa (6). Dendrocalamus (7). Dinochloa (2). Gigantochloa (2). Melocanna (1). Neohouzeaua (2). *Oxytenanthera (2),* *Phyllostachys (2).* Pseudostachyum (1). Semiarundinaria (1). Sinobambusa (I), Teinostachyum (1), *Thamnocolamus (4).*
2.	North-western India	5	14	Bambusa (4). Chimonobambusa (2). Dendrocalamus (4), *Phyllostachys (2),* *Thamnocalamus (2)*
3.	Indo-Gangetic Plains	4	8	*Bambusa (4),* *Cephalostachyum* (1). *Dendrocalamus (2).* *Oxytenanthera* (1).
4.	Peninsular/South India (Eastern & Western Ghats)	8	24	*Bambusa (3).* *Cephalostachyum* (l), *Chimonobambusa* (l), *Dendrocalamus* (1). *Indocalamus (3).* *Ochlandra (9).* *Oxytenanthera (5).* *Teinostachyum* (1).
5.	Andaman	6	7	*Bambusa (2).* Cephalostachyum (I), *Dendrocalamus* (1). Dinochloa (1). Oxytenanthera (l), *Schizostachyum* (1).

Socio-economic Role of Bamboos

Bamboos occupy a very important place in the economy of the countries in which it is commonly available and in abundance. Every part of the bamboo is utilized in one way or another. It is one of the most useful indigenous natural resource in India. Out of nearly 10 million tonnes of bamboo (annual world production), about 3.5 million tonnes are produced in China (Sharma. 1980) and 3.23 million tonnes in India (Vermah and Bahadur. 1980). It provides raw material for cottage industry and employment for millions. It is estimated that harvesting of bamboos in India itself requires about 71.25 million man days every year (Vermah and Pant. 1981).

Bamboo has been utilized for paper for a long time, but- its utilization for large scale manufacture of paper is very recent. Nearly 80 paper-mills are dependent wholly or partly on bamboos in India. as they provide long-fibred resource easily available at cheap prices (Sharma. 1980). 'in Asia, India is the largest consumer of bamboos for the manufacture of paper. Most of the paper mills have been established in the region of large scale bamboo growing areas. Approximately 2 million tonnes of bamboo are at present being utilized for paper in India. and this leads to a production of nearly 600.000 tonnes of paper-pulp every year (Vermah and Bahadur. 1980). There are many advantages of using bamboo for making paper-pulp as compared to other resources. Bamboo being very fast growing, without bark. long-fibred. cheaply available. supports paper industry with raw material for the manufacture of newsprint. quality paper and card-board paper.

Commercial exploitation and Bamboo improvement

Out of more than 100 species of bamboo growing in India, only about ten species are commercially exploited. A few other species are utilized to a limited extent in cottage industry. Some of the economic bamboo species are: Bambusa arundinacea. B. balcoa. B. polymorpha. B. tulda, B. vulgaris, Dendrocalamus brencisii, D. hamiltonii, D. strictus, Ochlandra scriptorea and 0. travancorica (Haque 1984). Bamboos are being utilized in a number of ways. The quality of its fast regeneration, strong. straight, smooth, light and hard wood. easy transportation. splitting. cutting and its glossy surface make it suitable for making a large number of products for daily use. The commonly used articles are mats. basketeries, ropes, beds, brooms, bridges, umbrella handles, pipes, fans, brushes, nails, anchors, fishing rods, furniture poles, agricultural implements, ladder and others. The present revenue derived from bamboo is estimated at about Rs. 66.77 million per year which can be further increased by encouraging bamboo industry (Vermah and Bahadur, 1980).

Inspite of modernisation in industry, demand for bamboos is increasing, There has been constant efforts to increase cultivation area to meet the demands. Nearly 160,000 hectares of new land has been brought under bamboo cultivation in different states of India. Recently bamboos are used as water pipes in Bihar state (Vermah and Pant, 1981). Bamboos are extensively used in building construction. Recent research at F.R.I. Dehradun has successfully used ,it as a reinforcing material, replacing steel in various cement concrete construction, such as roof shed, beams, electric posts etc.

Use of bamboo shoots as pickles, in chutneys etc has been increasing. Some species have very succulent shoots which are highly nutritious and palatable. These are consumed in a variety of ways. Cultivation of edible bamboos can increase foreign exchange and therefore bamboo-shoot farms are important. Leaves of some species form good fodder, especially for elephants. In some species, there is a bitter element – hydrocyanic acid present in the leaves, poisonous to' the animals. Bamboo seeds are used as food grains at the times of famine.

Living bamboos provide good fencing along farm houses, gardens and bungalows serving as ornamentais as well. Some of the dwarf types of bamboos are used as ornamental plants in trays and pots.

Bamboos are also used in the pharmaceutical industry. Extraction of an important drug – Taibashir from the dry-cuims of some species of bamboos is well known. The sugar silica from the cuims is used as a cooling tonic and an aphrodisiac.

Rhizomes of bamboo species are cut into small pieces for use as buttons. Bamboos are also grown for afforestation of denuded lands to check soil erosion. It is a fast growing source of fuel wood for the rural people. Bamboo charcoal is preferred in gold-smithy.

In India, there is an urgent need to check devastation and protect natural vegetation of bamboos and to increase bamboo cultivation for meeting the increasing demand. There is a lot of scope in the export of bamboo handicrafts. Bamboo plantations raised solely for pulp and paper would not be profitable, as the royalty generally paid by the mills is very low as compared to the cost of raising the plantation, but bamboo raised for cottage industry pays good profit as they are sold by the number of culms. Therefore when the bamboo plantation is raised for pulp and paper, some of the plants should be earmarked solely for the cottage industry. Some subsidy should also be paid to farmers cultivating bamboo for commercial purposes. According' to one estimate, bamboo consumption in India for;, housing construction is about 16%, for rural uses about 30% and the rest are for paper-pulp and other uses (Sharma, 1980). For increasing bamboo cultivation, the crop should be included under the social-forestry programme.

Since vast genetic diversity of bamboos is available in India, there is an urgent need to conserve different species available. Forest Research Institute, Dehradun (India) has maintained the richest collection of bamboo germplasm at present. It has conserved more than 35 species of bamboos in several arboreta and are being used for taxonomic studies, breeding for improved types, timber-engineering, pulp and paper technology, silviculture and tissue culture for quick multiplication. Research on physiology of flowering in bamboos is also in progress at various universities in India.

Recently, bamboo has been included as one of the multi-crop programme for study. under "All India Coordinated Research Project on Under-utilized and Under-exploited Plants", scheme approved by Indian Council of Agricultural Research (ICAR) with headquarters at National Bureau of Plant Genetic Resources, New Delhi and research centre for bamboos at I.C.A.R. Research Complex for North-Eastern Hills is at Basar in Arundachal Pradesh (India). Activities on survey of bamboo genetic resources in north-eastern region, and their collection have been initiated from 1984-85. Germplasm of bamboos will be collected, evaluated and conserved at the centre.

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Economics for Bamboo Forestry Research: Some Suggested Approaches

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Abstract

Bamboo is a commodity of historic economic value in Asia, Within the context of a steadily declining total natural forest stock in Asia, bamboo is becoming an increasingly scarce resource. Public and private *initiatives to reverse this trend, should consider bamboo cultivation as a viable alternative benejitting people* both *in* public *(social) and private (market) lands. Bamboo research and subsequent , development programmes should include economic analysis as an integral component for developing appropriate technology and in investing* resources for *employing that technology. Specific techniques of economic analysis; i.e. benefit-cost analysis, marginal analysis, budgetting* and *market research; are suggested vis-a-vis specific bamboo research and development objectives. Foresters are encouraged to involve experienced micro-economists in their research and/or undertake specialized* short-term relevant micro-economics *training.*

Introduction

From the information provided at the 1980 Workshop on 'Bamboo Research in Asia' (Lessard and Chouinard, 1980), and in other publications (Austin *et al.,* 1983); it is obvious that in Asia, bamboo is ecologically, socially and commercially an important plant. From, this same literature, plus the results of recent research as presented in this workshop; it is equally obvious that there exists a potential to significantly increase the production of bamboo .and improve its productivity in present and alternative uses, In other words, bamboo has 'value'. It is seen as a relatively scarce resource (due to low productivity of natural stands) with many uses in manufacturing, as a food and in making paper. Its collection and/or cultivation, processing and consumption involve people from different socio-economic groups in society. With new technology in such areas as — controlled flowering, seed technology, tissue culture, insect control, preservation, etc; it will be possible to increase extensive and intensive production and improve processing, employing many more physical and human resources of land, labour and capital.

By definition, economics is a study of the proper method of allocating scarce resources among competing uses (Ferguson, 1972). It attempts to answer the three basic questions of (Sammedson and Scott, 1968) 1. What to produce? — what mix of different outputs? 2. How to produce? — what techniques should be used to produce output? 3. For whom to produce. — who should receive the output produced? These are relevant questions with respect to scientific research and national development activities on bamboo to improve people's lives.

This paper is a limited attempt to provide a rationale for economic analysis of new technology for bamboo production and preservation. The arguments for conducting economic analysis, and the suggestions for using specific techniques, draws heavily from the work in Farming Systems Research (FSR) (Banta, 1982 Anon, 1984 Anon and Department of Agriculture Nepal, 1980), and Post-Harverst Research (PH) Austin, 1981; Edwardson and MacCormac, 1984) in Asia,

Bamboo as a Natural Forest Resource

Historially, in countries (or regions within a country) with a very low population density, the forest was considered a "common property natural resource". No single user had exclusive rights to the forest nor could he prevent others from sharing in its exploitation. As long as the annual 'cut' or harvest from the forest was less than or equal to the annual net natural growth of the 'stock' of the forest, people's needs were assured. There was no incentive to control or limit access to the forest. This situation no longer exists for Asia today. Since the end of World War ll, rapidly increasing population, with associated demands for fuel and farm land, and the fact that the developed country wood demand outpaces supply; has resulted in a significant decrease in land under forest in Asia. Between 1960-80, one-half of the increase in food supply in Southeast Asia came at the cost of extending crop areas in forests' (Barney, 1980).

The remaining forest areas are generally, in principle, subject to laws regulating their use. However, the effectiveness of these laws are limit&d due to needs of shifting cultivation, the needs for fuel which can be obtained without cash by rural (and urban) people, and the ability of special interests to disregard the laws without penalty. What this means is that traditional 'natural' forest stands cannot maintain or increase supplies of wood. While information on individual species is often difficult to obtain, it is reasonable to assume that the forest stock of bamboo and the total annual net growth has and will continue to decrease significantly under present conditions in Asia. Increasing forest (including bamboo) output over time by extending the area under cutting is no longer a long-term option. The raw material for an expanding wood products (including bamboo) demand will be found by intensifying production (Scott, 1982), (perhaps with the exception of Indonesia).

The Potential for Economic Intensive Bamboo Cultivation

Scott (1982) and Sedjo (1982) discuss the potential for intensive forest production in Asia. While they focus mainly on monocyclic and polycyclic timber (plantation) systems, several relevant points are made which are important regarding the economic feasibility of bamboo cultivation. Both polycyclic and monocyclic systems produce significantly higher mean annual increments (MAI) than natural forests, The extra costs of physical and management inputs should be offset from direct increased production, and there are other indirect national benefits in increased employment for production and wood processing. Bamboo has a rapid natural early growth which can be increased with application of fertilizers, Traditional techniques and 'industrial infrastructure' for processing bamboo exists, therefore expanding production should be quickly followed by an expanding processing sector, provided a market exists for the extra production.

The shorter the forest species rotation cycle, the less time this 'capital' (growing stock) has to be held before disposal. Related to this is that the longer the rotation cycle, the longer input costs are compounded and the longer future benefits must be discounted back to the present. Bamboo's very short rotational cycle makes it very attractive in terms of cash flow vis-a-vis other hardwoods and softwoods. This makes it attractive for those with little capital. The comparative net benefit over time would of course depend on factors such as the relative magnitude of costs and expected future prices of the species.

Monocyclic plantation systems require large areas and present evidence suggests that relative to polycyclic systems; they present a greater environmental threat due to a lack of flora-fauna mix and by sudden extensive destabilization of water flows by the disturbance of moisture absorbing watersheds. Bamboo seems well suited to poiycyclic harvesting, can be grown on steep hillsides and along banks of rivers, its interlocking root system and leaf deposit inhibit soil erosion (Austin, 1983). In Asia, countries have. little high quality arable land left for expanding crop area. Efficiency in the use of water and maintaining soil quality in even marginal agricultural areas, have both direct and indirect benefits to food producers and consumers.

Related to some of the above arguments is the issue (mentioned earlier) of the competitiveness of forestry versus agriculture. As Asian countries move closer to the 'cleared-forest' society, the success of forestry will depend upon its relative (to farming and urbanization) costs and benefits. Bamboo, either as a plantation or integrated into a farming system as a crop has potential, for many of the reasons stated earlier. However, it is important to note that in such a situation, the decision to maintain a forest crop (as bamboo) becomes highly decentralized. Region or site specific factors of environment, market demands, relative resource costs and product prices, etc will be the key determinants. A second characteristic is that the decisions become more micro-economic rather than socio-political (unless the government is willing to incur costs in the form of subsidies or transfer payments for a perceived social benefit). This means that local communities or associations and individual farm households will also decide if bamboo should be cultivated. This also means bamboo must be economic (per unit land area) not just compared to other tree species but compared to agricultural crops too. Or at least, it must complement crop production without reducing farm household income. It would appear that bamboo does have significant potential for economic intensive culture. Scientific research to produce the necessary technology must be accompanied by economic analysis to evaluate the ability of that technology to achieve private and social development goals.

Suggested Economic Analysis Approaches

This section is not a detailed "how to" manual for conducting economic analysis for specific bamboo forestry problems. That would require a lengthy presentation complete with detailed examples and take several days to present. Instead, some specific economic analysis approaches are listed followed by specific bamboo forestry research and/or development objectives, to which the economic approaches could be applied. It is understood that bamboo research and/or development projects can have more than one objective. How this is handled usually depends on the specific situation, Usually, secondary objectives. are expressed as constraints for selecting techniques to achieve the main objective (Gregersen and Contreras, 1979) (i.e. increasing bamboo output for paper making is the main objective but environmental objectives help determine harvesting techniques). It is up to researchers to be aware of the social and private decision makers' objectives and the relative weighting they give to those objectives, in the design and evaluation of new bamboo production and processing technology.

Benefit-Cost Analysis

Economic (Social): This form of economic analysis has been widely used in the natural resources to help assess the economic efficiency, from society's point of view, of new technology. It attempts to identify and quantify costs and benefits to society (not just individuals) by utilizing resources over a specified time period. It is not dependent only on known market prices for inputs and outputs but estimates values for such things as increased or decreased soil erosion, reduced unemployment, improved foreign exchange earnings, and other public "bads and goods". In the case of bamboo, this type of analysis can, for example, be used where the objective of research is to – develop and implement techniques for environmental soil and water conservation, soil improvement, shelterbelts, and increase the area under forest. The costs and benefits of those objectives are not only shared or consumed by specific individuals but by 'society' or groups within society. This analysis calculates the "net benefit" or "return" to society employing alternative bamboo techniques.

Financial (Private): This form of analysis calculates the costs and benefits to identified individuals and organizations using market prices only. The same methodology of discounted (over time) cash flow is used as in Economic Benefit-Cost Analysis, however the focus is on calculating the net benefit and return to the actual equity capital invested in the new technology. In the case of bamboo, this type of analysis can, for example, be used where the objective of research is to – maximize economic'output per unit time for a variety of market uses, i.e. paper-making, furniture, food; minimize costs of production and processing for a given quantity of bamboo cultivated or processed; and to develop economical techniques for improved quality of bamboo and bamboo products.

In both forms of Benefit-Cost Analysis, there are three main criteria by which a single or set of techniques can be assessed and compared. These are: (i) Benefit-Cost ratio: This is simply the total of the present worth of expected benefits divided by the total of the present worth of expected costs. Only technologies with a ratio of greater than 1 are economically efficient in terms of resource use. (ii) Net Present ***Worth*** (sometimes referred to as net present value): This is the difference between the present worth of the expected benefits less the present worth of the expected costs. All technologies which result in a positive net present worth are economically efficient in terms of resource use. (iii) Internal Rate of Return: This is defined as the average earning power of the value of resources used from the application of the technology. Only technologies that give a rate of return higher than the existing market interest rate are resource efficient.

The formal mathematical statements of these criteria are given below (Gittinger, 1976) :

$$\text{Benefit-cost ratio} = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

$$\text{Net present worth} = \sum_{t=1}^{n} \frac{Bt - Ct}{(1+i)^t}$$

Internal rate of return is that discount rate i such that

$$\sum_{t=1}^{n} \frac{Bt - Ct}{(1+i)^t} - 0$$

where,

Bt = benefits in each year.

ct = costs in each year.

t = 1, 2 ,........ n.

n = number of years.

i = interest (discount) rate.

It should be noted that in comparing alternative (bamboo) technologies if due to resource constraints, only one of the alternatives can be employed, a comparison of the net present worths of the alternatives is the appropriate selection criteria.

The Single Variable Input-Output Production Relatioship .

Consider a product Y (bamboo, in kg), whose yield depends only on one input X (fertilizer, in kg) assuming all other inputs are used at a constant level. Where a unit of fertilizer is added, total output increases by some amount. Extra output resulting from 1 kg increase in fertilizer is called the marginal product of fertilizer (MPx). When multiplied by the price per kilogram of bamboo, we obtain a monetary measure called the marginal value product (MVPx) . The MVP represents the value of extra bamboo resulting from the application of an additional kilogram of fertilizer. On the cost side, the addition of a kilogram of fertilizer increases costs by a certain amount. This is called the marginal factor cost (MFC). It is equal to the price of the fertilizer, since increasing the use of fertilizer by one unit increases cost by an amount equal to the price of the fertilizer. Hence, using the rule stated above, the use of fertilizer should be increased as long as its MVP is greater than its MFC. To identify the optimum level of fertilizer, that is, the level where profits are maximized, we need to observe how production responds to fertilizer application. Assume that the output-input relationships are as shown in columns l and 2 in Table 1.

These show that when fertilizer (x) is increased, bamboo yield (Y) generally increases. At Iow fertilizer levels, the increase in yield from each 10 kg of fertilizer used is large. However, the yield increases from each unit of input (10 kg fertilizer) become smaller at successively higher levels of the input. In other words, extra yield (marginal product) tends to decrease at successively higher fertilizer levels if all other inputs are held constant. This observation is usually referred to as the law of diminishing marginal returns and applies to all input-output situations. In Table 1, percentage of yield increase begins to decrease when more than 30 kg of fertilizer is applied. This reflects the law of diminishing returns. Total yield begins to decrease when more than 100 kg of fertilizer is applied, but this decrease in total yield is not a necessary condition of the law of diminishing returns.

Column 3 of Table 1 shows the marginal product as fertilizer is increased in 10 kg units.

Table 1. Illustration of a simple input-output relationship.

Fertilizer (kg)	Yield (kg)	Marginal Product (kg)	Value of extra output (M)[a]	cost of extra input (M)
0	2000	–	–	
10	2100	100	110.00	40
20	2300	200	220.00	40
30	2600	300	330.00	40
40	2800	200	220.00	40
50	2900	100	110.00	40
60	2950	.50	55.00	40
70	2980	30	33.00	40
80	3000	20	22.00	40
90	3010	10	11.00	40
100	3010	0	0	40
110	3000	-1	-11.00	40

[a] M is used as monetary unit.

At fertilizer levels above 30 kg, yield increases but marginal product decreases. We say diminishing returns has set in at 30 kg fertilizer. Assuming bamboo price is 1.10/kg, column 4 shows the value of extra output, or the marginal value product (MVP), which is obtained by multiplying MP by the unit price of bamboo. MVP equals the additional value of output resulting from each 10-kg increase in fertilizer. Column 5 shows the cost of extra input or the marginal factor cost (MFC), which equals the increased cost of each additional 10-kg bag of fertilizer. If fertilizer price is 4/kg, a 10-kg increase in fertilizer will raise cost by 40. Therefore, marginal factor cost equals 40 because we are dealing with 10-kg bags of fertilizer,

Using this information, we can determine the quantity of fertilizer that will maximize profits by following the rule that additional fertilizer should be applied as long as extra return (MVP) is greater than extra cost (MFC). It is sufficient to compare columns 4 and 5. We can see it pays to increase fertilizer use up to 60 kg because value of additional output (MVP) is greater than additional fertilizer cost at levels lower than 60 kg.

Does it pay to increase the fertilizer level up to 70 kg? The larger value of the bamboo obtained from using more fertilizer is 33. Additional cost is 40. The farmer would be losing 7. Clearly, this will mean a reduction in net profit. Hence, he should stop at 60 kg where profit maximization occurs. To confirm that profit is maximized at 60 kg of fertilizer, compute total profit at each fertilizer level. This is illustrated in Table 2.

Columns 1 and 2 are the same figures as in Table 1. Column 3 is obtained by multiplying yield by the bamboo price (1.10/kg). Column 4 is obtained by multiplying the amount of fertilizer applied by its price per kg (4/kg). Column 5 shows net return, which equals value of production less total cost.

Note that profit increases as fertilizer is increased from 0 to 60 kg. Maximum profit is obtained at 60 kg fertilizer. Beyond 60 kg, net return decreases. Note also that maximum yield (at 90-100 kg fertilizer) does not mean maximum profit.

Although this illustration is simple, it provides a guideline for determining maximum profit level of input use. We compare the marginal value product with the marginal factor cost. This analysis shows information on marginal productivity of an input can be expressed in monetary terms and compared with the input price. When $MVPx > Px$, less input is being used than would maximize profits. When $MVPx < Px$, too much input x is being used. Because the law of diminishing returns generally holds for all input-output relations, the profit maximimizing level of any input will be less than the yield maximizing level. Note that yield was highest at 90 kg fertilizer but profits were highest at 60 kg fertilizer.

Table 2. Illustration of how to compute total profits.

Fertilizer (kg) 1	Bamboo (kg) 2	Total Value of production[a] 3	Total Cost of fertilizer[b] 4	Net returns[c] 5
0	2000	2200	0	2200
	2100	2310	40	2270
[illegible]	2300	2530	80	2450
30	2600	2860	120	2740
40	2800	3080	160	2920
50	2900	3190	200	2990
60	2950	3245	240	3005
70	2980	3278	280	2998
80	3000	3300	320	2980
90	3010	3311	360	2951
100	3010	3311	400	2911
110	3000	3300	440	2860

[a]Column 2 x 1.10. [b]Column 1 x 4. [c]Column 3 less 4

Budgets

Budgets are one of the simplest yet most widely used techniques in economic analyses. Budgets are used: i) to compare economic profitability of · different technologies; ii) to indicate whether a proposed change (i.e. new technology) will be profitable under a given set of circumstances; and iii) to explore conditions under which certain technologies become profitable or unprofitable.

Enterprise budgets, partial budgets, and parametric budgets are the three common types.

(i) Enterprise budgets: The process of producing a particular commodity is called enterprise. Small farms in tropical Asia usually are multi-enterprise farms — they produce more than one commodity possibly including bamboo. Enterprise budgets enable us to evaluate costs and returns of production processes. Comparing relative profitability of new technology with existing technology helps to show how the enterprise can be more profitable. The new technology may change existing technology to show a better way to grow bamboo or to compare possible new cropping patterns including bamboo.

A budget is a formalized way to compare production process benefits and costs. If benefits exceed costs, profit was earned. If benefits are fess than costs, a loss was incurred. The difference between gross returns and variable costs is called the gross margin (also referred to as returns above variable costs). Gross margin measures the contribution of an activity to profitability. Input quantities and values used in production process (costs) and output quantities and values (benefits) are the basic data required for budgets.

(ii) Partial budgets: Partial budgets are used to evaluate the effects of a proposed enterprise change. A partial budget is useful only when the change is relatively small. A partial budget highlights variations in costs and returns caused by proposed changes in the enterprise. Only items affected by the change are included in the budget. Levels and costs of all unchanged inputs are not included. When constructing a partial budget identify: costs that will increase or decrease, and returns that will increase or decrease.

Table 3 shows a basic partial budget. The left side shows negative effects of a proposed change — added costs and reduced returns of changing from an old to a new technology. On the right side are the positive effects — added returns and reduced costs. If positive effects exceed negative effects, proposed practice is more profitable than the existing production practice.

(iii) *Parametric budgets:* For any new technology, estimates of inputs and outputs are approximate, and prices are subject to change. Therefore, it is useful to explore how sensitive benefits are to changes in assumed levels of inputs, outputs, and prices. We often want to learn what yields and/or prices are necessary to make a technical change profit-

Table 3. Partial budget to estimate change in annual net cash income resulting from some change in resource use.

a. Added costs	c. Added returns M
b. Reduced returns	d. Reduced costs M-
Subtotal A: M	Subtotal B: M
	Estimated change (B-A) M

able. Parametric budgets, also called sensitivity analyses, answer these questions. The simplest situation to consider is the change in profit if one parameter is varied. Gross margin is then calculated as:

$$GM = (PXY) - VC$$

where

GM = total gross margin
Y = bamboo yield (the factor to be varied)
P = the price of bamboo, and
VC = total variable cost.

Gross margin can now be calculated for any yield within the range that yields are expected to vary. Table 4 presents gross margin for a range of yields between zero and 4,000 kg/ha. The data are also plotted in Figure 1. The figure shows that a yield of less than 1,198 kg is a loss for the enterprise. This yield is usually called break-even yield, calculated by solving for Y when (PY) - VC = 0. It is where the producer just recovers variable costs.

Market Research

Market research is an important type of economic research with respect to the development and recommendation of new technologies for growing and/or processing bamboo. For a,government or private institution (or private individual) to invest in new bamboo technology, it is essential to have data on input markets (resources used in bamboo production or processing) and output markets. The main marketing aspects to be considered in a market study are (Ranaweera, 1984) : (i) input supplies, (ii) expected output increases, (iii) market potential (demand), (iv) capacity of the marketing system to handle increased output, and (v) anticipated government interventions.

Table 4. Effect of changes in yield on gross margin . .

Yield (kg/ha)	Gross margin (kg/ ha)
0	-1258
1000	208
2000	842
3000	1892
4000	2492

'GM = (Y x 1.05) - 1258.

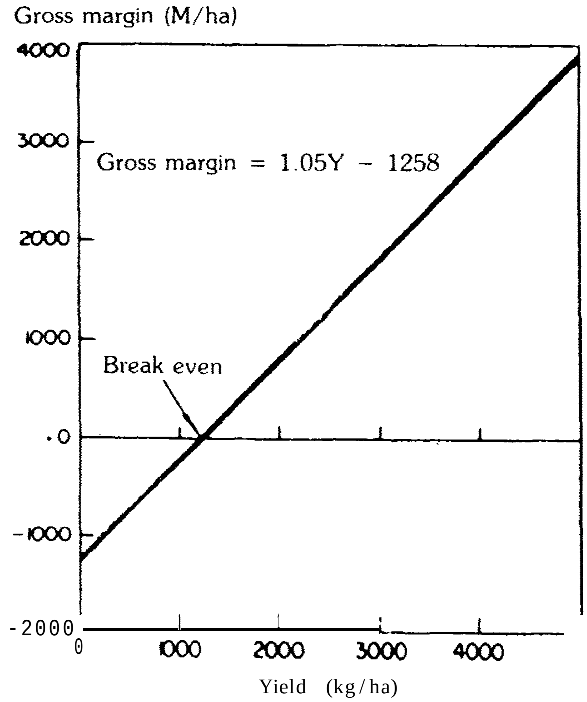

Fig. 1. Effects of changes in yield levels in gross margin.

Conclusions

This paper has had two objectives. First, define a role for economic analysis as part of a total research effort to develop new technologies for bamboo cultivation and utilization, and second, suggest specific economic analysis procedures that could be used. The material presented for the second objective is very superficial, in that the reader is strongly recommended to consult the references cited for developing even a basic understanding of the related economic concepts and techniques. It is also recommended that agricultural or resource economists with experience in micro-economic analysis be encouraged to undertake this research. Much of this analysis could be done by foresters if they have received appropriate training (a minimum of 6-8 weeks) from economists. The decisions to include an economist and/or train foresters in basic micro-economics for this research should depend on: (i) how 'basic' or 'applied' the bamboo research is, (ii) the existing availability of interested and/or experienced economists, and (iii) the research and training resources available.

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Reports on Sessions

Reports on Technical Sessions

Technical Session.1

Chairman: **Prof. Mu Zhowg Lun**

Rapporteur: **Prof. A. N. Rao**

In the technical session I on Monday, 7 October 1985 six papers were presentd during the morning and afternoon sessions.

1. In the first paper presented by Mr Sharma, the general importance of bamboos in the *Asia Pacific region* was stressed. The present status of bamboo production and use in India, Bangladesh, Thailand, Malaysia, Philippines, Indonesia, Papua New Guinea, Sri Lanka, Burma, Korea, Japan and China was briefly reviewed. The assessment for the total bamboo resources is available only for some of the Asian countries, especially those where bamboo is used as raw material for paper industries. The importance of a good assessment for each country was emphasised especially where bamboo is an important component of the cottage and rural industries. Both the research output and the improvement of cultivation techniques are important to increase the bamboo resources and altogether about 12 suggestions are offered. The paper was well received and during discussion particular points regarding gregarious flowering habit, hormonal and water relationships, utilisation of abandoned land, suitability of bamboos to be used as water pipes, salt tolerant varieties and the other related aspects were covered.

Professor Wu Bo presented his paper on 'The present condition of bamboo research and production in *China*' and reviewed the development of bamboo industry in his country. For most of the audience this was an excellent introduction to the status of bamboo research undertaken in China and the high quality bamboo production in enormous quantities.

In the next paper presented by Dr Salleh Mohd. the bamboo resources in *Malaysia* was reviewed with plans and strategies for further development. In view of the other forest resources available in great abundance due emphasis is not given so far for bamboos. The annual production of bamboos for the whole country is not estimated, though figures for certain states like Kedah, are available. Several cottage industries in the country using bamboo as basic material are adequately sustained. Regarding the development strategies enough technology should develop to improve the bamboo based, rurally centred smafl scale industries and the techniques for harnessing and managing the raw materials should improve. After presentation there was some useful discussion on the virtue of selective cutting, usefulness of aerial surveys and proper methods for the administration of bamboo projects and other related aspects.

Bamboo in *Indonesia* — a country report was the next paper presented by Dr Haryanto. The cultivation of bamboo is an ancient art in Indonesia and along with banana as well as coconut (popularly known as BBC), they provide both food and building materials for the rural population. The small holdings around villages Pekarangans are millions in number covering about 31,700 ha as against 50,000 ha of bamboo land as part of the natural forests. Research on cultivation and utilisation is carried out in universities and research institutes and further progress is necessary to meet the demand of the people in the 21st century. Many questions were asked about the selective harvesting, curing and treating of bamboos.

Professor Lantican was the next in presenting the paper on 'Bamboo production and utilisation research in *Philippines*'. Bamboos are extensively used in Philippines in the fishing, banana and furniture industries. The handicraft and furniture industry, based on bamboo resources brings considerable foreign exchange. Other uses of bamboo in building construction, for flooring, pulp and paper industry were explained. Research needs to improve the production and utilisation of different species were outlined and the research priorities were listed. After the paper presentation there was some discussion on the rate of bamboo production/given land area and the dissemination of information on bamboos in the region.

The next paper was the 'country report — Sri Lanka' by Dr Vivekanandan. Bamboos are mostly used for rural housing. Of the seven genera and 21 species present in the country only Dendrocalamus strictus has been planted on a large scale, The progress of research work done in the previous year as a part of the IDRC project was outlined which concerns about the stem propagation methods in *Bambusa vulgaris.* Other conditions suitable or large scale propagation were explained and discussed. After the presentation there was discussion on the suitable method of planting and the effects of hormone treatment to improve the growth of the propagules .

As the last paper of the session I, Dr Boa presented a brief report on 'Bamboos in Bangladesh as the other invited members from Bangladesh could not attend the seminar. There is a total area of 54,000 ha of bamboo forest in the country in addition to bamboos grown in and around the villages. Recently an inventory was prepared for the whole country and the cultivation of bamboo is increasing. However, there is very little space available for bamboos growing and due to water logging bamboos die in certain areas. Forest bamboos are thin and mostly used for paper. Both overcutting and extraction are the real problems. Many improvements to remedy the situation were suggested.

After the presentation of all the papers the rapporteur summarised the main points that emerged from the presentation of papers and the discussion followed, which included the following:

1. There should be some standardisation in the recognition of the various species.

2. A good network for the exchange of information on bamboos is urgently required.

3. The cost of production and the relative effectiveness of different methods presently followed should be carefully studied since the bamboo resources are fast disappearing in many countries.

4. There is an urgent need for extra propagation material in every country to use bamboos as soil binders and to prevent soil erosion.

5. Destruction of bamboos for better land use is a myth since most of them grow only on marginal soils.

6. Greater attention should be paid to recognise genetic variability available within the species to select better varieties for cultivation. Many of the taxonomic problems need to be solved to eliminate duplication of species and to establish the new ones, if need be.

At the very end of the session a request was made to all the authors to submit the original copies of their papers including graphs, figures, diagrams etc. Wherever necessary each paper will be discussed with the individual authors to make the necessary amendments and to establish proper format for publication of the proceedings,

Technical Session II

Chairman: **Prof Geng Bojie**
Rapporteur: **Prof Y M L Sharma**

Six papers were presented during the session.

In the paper presented, Mr Stapleton, (Nepal) spelt out the efforts initiated by him on vegetative propagation techniques in barnboo (few important species) for evolving an efficient and appropriate technology to suite the topographic, climatic and biotic factors prevailing in Nepal. His paper stressed on the efforts to induce quick rooting of bamboo species to achieve maximum percentage of success in the field.

In an interesting and illustrated paper, Mr Hansken of Panda Products, USA, detailed the efforts made to propagate Phyllostachys ***pubescens,*** and raise seedlings for supply to the people. It is a very enterprising venture aimed at propagating Phyllostachys ***pubescens,*** and reminds of some private farmers in Tamil Nadu of India raising seedlings for supply to cultivators for raising bamboos in the agricultural sector.

Mr Fu Maoyi in his paper highlighted the benefits of the application of fertilisers to raise the bamboo crops including the methods of application, dosages and the result of application of such fertilisers. It has been reported that the fertiliser application helps greatly the growth of bamboos. In fact the current trend is the use of more and more of fertiliser in forestry crops.

In her well presented paper, Miss Chen Fangne highlighted the hybridisation work on bamboos carried out in China. She has also highlighted the characters of pollen of bamboos and other features like the period of seed ripening, stressing the importance of the viability of pollen as the key factor in the success of these hybridisation work.

Presenting his paper, Dr Eric Boa detailed the different pests and diseases of Bamboo in Bangladesh. The culm sheath regions were

reported to be the vulnerable places of infection. He has also cautioned about the drawbacks in raising large scale monoculture of bamboos.

In his second paper, Dr Eric Boa highlighted the incidence of bamboo blight disease in some parts of Bangladesh, especially in the village bamboos. He stressed the need for a more intensive study of the subject, and to determine the predisposing factors. It was also suggested by the Rapporteur the possibility of growing bamboos in mixtures with tree crops, and the need to prevent the spread of the disease across the borders of Bangladesh.

Technical Session III

Chairman : **Prof Hsiung Wen-yue**
Rapporteur: **Dr Salleh Nor**

Three papers were presented in this session.

According to Dr Anan Anantachote, bamboo is a very important resource in Thailand, but it is decreasing in quantity; the silvics unknown. Thus, his study focussed on the basic flowering characteristics of economic bamboos in Thailand. High variability in seed germination percentage, the correlation between moisture content and presence of seed borne fungi are important. During discussion, clarifications were sought on actual seed M.C., which is the air dry M.C. and on the seed borne fungi which has not been used for inoculation tests yet. On the question of physiological changes before flowering, Dr Anan replied that when clumps do not produce new shoots, it is likely that they will flower the next dry season.

Dr Usui of Japan discussed in detail the studies on morphology of a number of Japanese bamboos. Morphological studies must be supported by other basic research in anatomy and taxonomy. On a question whether branching of bamboo is regulated by arrangement of prophylls in a bud, it was left unanswered.

In his presentation, Prof Rao, Singapore, focussed on the growth, anatomy, taxonomy, cytology and reproduction of certain bamboos in Singapore. Following there was a second presentation on the preliminary work on tissue culture of certain bamboos.

Details on tissue culture of bamboos created some interest with questions on the explants used for the experiments and the meristemable tissues.

Technical Session IV

Chairman: **Dr Walter Liese**
Rapporteur: **Dr Celso Lantican**

Ten papers were presented in this session.

The paper on Anatomy and Properties of Bamboo was presented by Dr Walter Liese. With the aid of slides, Dr Liese gave a comprehensive account of the present state of knowledge about the anatomical, chemical, physical and mechanical properties of bamboos. For many of the properties, he indicated that variations exist along the height and across the wall of a culm.

During discussion the following questions were raised.

1. Is penetration of preservatives possible through the stomata of the center walls?

   Preservatives enter by diffusion. There are no stomata on the walls.

2. You mentioned that bamboo shrinks even when it is still green. Can you tell us what the fiber saturation point of bamboo is?

   This is a subject that still needs to be investigated.

3. When is a culm mature and why does a culm senesce?

   Little research has been done on anatomical changes as the culm gets older. The work of Dr Chen at Nanjing has shown that there is a dramatic and puzzling increase in the elements of older culms. We do not know why a culm senesces and why it becomes brittle and loses its strength.

The next paper was by Dr Higuchi on Characterisation of Steam-exploded Bamboos for Cattle Feed. The paper, presented with slides, described the use of the steam explosion process to convert bamboo chips into a form that can be hydrolysed by cellulose. According to the author, the process is promising for the production of cattle feed and obtaining the material for fermentation.

Questions were raised during discussion:

In Germany, it has been observed that in cattle dungs the parenchyma cells bearing the warty layer are not digested. What is your finding on EXB's?

Ruminants cannot digest the ceils if they are covered with lignin. EXB's are devoid of lignin as this is separated in the process.

The paper on Anatomy and Properties of Bamboo by Dr Janssen dealt with the structure, properties and advantages of bamboo as the building material. The information given centered on mechanical properties that are useful for designing bamboo structures.

In the next paper, Mr Li showed that strong bamboo structures, much bigger in area and taller than ordinary houses, can be successfully built as has been done in Switzerland.

The discussion followed the presentation.

How do you put the base of the culm on the ground?

It is erected on a concrete foundation with a steel plate bolted.

What material was used to tie the culms together for the columns of the building?

Bamboo skin strips and steel strips.

I am of the opinion that construction with bamboos require a lot of skill, which is absent in Malaysia. Are there any schools or courses dealing with construction of bamboo structures in China?

Yes, some schools have. (Note: Some participants offered the information that some publications dealing with the subject are available).

Did you have to secure permits and insurance for the bamboo building you put up in Switzerland?

These were arranged by the Swiss government.

Mr Achmad Sulthoni presented the paper on Traditional Preservation of Bamboo in Java. The results of a study involving the use of certain traditional methods of improving the service life of bamboo were outlined. It was concluded that the existing practices regarding the time of cutting and water immersion has scientific basis and therefore the methods outlined are recommended.

The following questions were raised.

Did you try to relate the biological life cycle of beetles with the occurrence of beetle attack?

I studied the beetles involved but was not able to correlate the life cycle changes and the occurrence of the attacks.

The loss of starch in culms soaked in water is it caused by bacterial action rather than by leaching?

I believe it is due to bacteria because starch is not soluble in water.

Mr J N Lipangile presented the paper on Use of Bamboo as Water Pipes.

This paper discussed the engineering characteristics, preservation, construction methodology, maintenance, and economics of bamboo used as water pipes. The paper reported, that bamboo pipes are four times cheaper than locally purchased plastic pipes of the same diameter.

Mr Slob presented his paper on CCA Impregnation of Bamboo.

The paper presented the results of the study in which CCA was impregnated into bamboo pipes of the species Arundinaria *alpina* using the Boucherie process. High leaching rates of the toxic compounds were observed; hence, it was concluded that CCA-treated bamboo is not appropriate for use as water pipes.

Dr Liese and Dr Higuchi advised the Tanzanian delegates (Lipangile and Slob) to "be very careful" in using preservatives on water pipes as they can endanger human lives and pollute the environment,

Role of Bamboo in Rural Development and Socio-economics: A Case Study for Thailand was presented by Mr Songkram Thammincha. The use of bamboo in the national economy and on the improvement of the quality of life of the rural poor was outlined. A cost-benefit analysis of bamboo farming was presented. Destruction of bamboo in some parts of Thailand is rampant. Efforts should be made to stop this. It was also suggested that shoot management be studied to ensure sustained yield.

Socio-economic Role of Bamboo in India and Their Genetic Diversity was presented by

T A Thomas. The paper indicated the species present in the country, their distribution and socio-economic role. It pointed out the high genetic diversity of bamboo in the country where 22 genera and more than 136 species are present. It also indicated that bamboo research on collection and conservation is being carried out at FRI, Dehra Dun.

Economics for Forestry Research: Some Suggested Approaches was presented by C W MacCormac. This paper suggested specific techniques of economic analysis VIS-A-VIS specific bamboo research and development objectives. The discussion included the following.

1. in conducting a benefit-cost analysis, how do you measure the intangibles?

   This is a very important issue. There are no rules available. My suggestion is that the scientist should work with an economist in the estimation of values.

2. Which is more economical, shoot production or culm production?

   Research on this is needed.

Concluding Remarks from the Chairman

The Chairman commended the speakers, the discussion leaders and the rapporteurs, as well as the interpreters for doing their jobs well.

Research Needs and Priorities

Introduction

The information, ideas and concepts enumerated in the following paragraphs are a summary of the final session of the workshop. There was recognition among participants that the present workshop was taking place after a period of five years, since the first one held in Singapore in May 1980. Though considerable effort had gone into activating the research agenda that was identified in 1980 much needed to be done if the bamboo culture, cultivation and utilization is to contribute meaningfully to the economies and peoples of the region.

Information

The major difference between what was documented in Singapore and the present one was the expression for a bamboo information centre or service. The bamboo community, be it research, commercial or consumer has been growing at a rapid rate. The present flow of information was inadequate to the needs of the community and therefore an urgent need existed for the establishment of an information collecting and disseminating facility to serve Asia in the first instance and the rest of the world subsequently.

Conservation

Fears were expressed at the erosion of the genetic pool not only because of excessive exploitation especially in the S. Asian region but also because of the extensive habitat destruction in the S. E. Asia region. It is therefore highly desirable that urgent steps be taken to collect all of the germplasm available in each region for conservation purposes in situ (through bamboo gardens) or ex situ in special ecological reserves.

Taxonomy

The classification, nomenclature and identification of bamboos still continues to vbe a major problem in South and S. E. Asia. On going research work has to be enhanced to expedite studies in other areas like breeding especially for increasing yield, disease and pest resistence etc. The need for an Asian bamboo taxonomic monograph still exists and some initiative should be taken immediately to produce this.

Silviculture

Much is known about the ecology and silviculture of bamboos in some countries while in others little information is available. Especially in the case of the latter, where sympodial bamboos are concerned, research needs were expressed for the following studies:

- The phenological characteristics of all commercially important species. Information was especially needed on factors inducing or inhibiting flowering behaviour; the ageing of bamboo, physiological mechanisms of shooting, etc.
- The root characteristics of the principal sympodial species.
- Appropriate propagation and nursery technologies to assure large and continuous supply of seedlings.
- Suitable plantation technologies for establishing industrial scale plantations and the risks associated with monocultural situations.
- Options for establishing multicropping systems with bamboo as one of the components.
- Options for using bamboo to rehabilitate devastated lands, control of canal and river banks,
- The types, level and methods of application of fertilizers, associated economics as well as growth studies in man made plantations.

- Pest and disease situation among bamboo stands.

Management and Harvesting

The science of managing bamboos is new to a number of countries and specific prescriptions will have to be worked out for each environment. The following studies were considered important on the basis of traditional presumption that bamboos have to be worked through culm selection:

- cultural operations to bamboo stands from the time of formation
- clump and culm spacing
- moisture retention techniques
- felling intensities and methods of felling
- fabrication of improved tools for cutting, splitting and binding bamboos.

Utilization

The forum reiterated the need to continue research on the topics identified by the 1980 workshop, as progress has not been as rapid as expected. Further some of the following studies were suggested for inclusion in the agenda:

- A detailed study on the variability being encountered in terms of durability within species.
- A closer study on the correlations between species' properties and traditional utilization.
- The functions of the various tissues and cells (eg. parenchyma, phloem, nodes) and their impact on preservation, seasoning etc.

  The quality of the culm with reference to their maturation and/or senescence.
- The chemistry of bamboo and its subsequent application in chemical utilization (manufacture of plastics, membranes, conversion to fodder, pulping etc) .

Socio-economic studies

The forum expressed a need to undertake cost-benefit studies on bamboo cultivation given the fact that land is a scarce resource in the region and the promotion of bamboo forestry should be seen in the context of other crops.

Further, data has also to be gathered on the social value of bamboo especially as a feature of water and soil conservation.

Education and Extension

Unanimously it was pointed out that bamboo serves multiple uses and therefore in parts of the Asia Pacific region where bamboo has not been recognized for its potential in improving rural incomes a concerted effort should be made through the use of demonstration, plantations, training rural social workers with multi-media materials and organizing formal courses within a forestry curriculum.

G. Dhanarajan

International, Bamboo Workshop (China)
October 6-14, 1985
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Post Script

We have spent considerable time and effort in editing the proceedings solving many of the problems and difficulties connected therewith. These were mostly concerned in editing the manuscripts. reducing their length. wherever necessary or even rewriting some of them which were Gi very poor quality to begin with either in terms of language, expressron or accuracy of facts or all of them. We were completely familiar and anticipated the various problems before we started the work. Some of them could be solved by ourselves, whereas in case of others the manuscripts had to be returned to the authors to implement the necessary correcttons or changes and to provide proper explanations and/or illustrations Obviously all these exchanges delayed the publication We appreciate the patience and endurance of other authors who would have liked to see or receive the publication much earlier.

The papers included in this proceedings contribute a wealth of information on bamboos that would help the researchers and the students who are studying the various aspects of these interesting plants. We hope that this volume like its predecessor will also serve as an useful source of reference for many years to come.

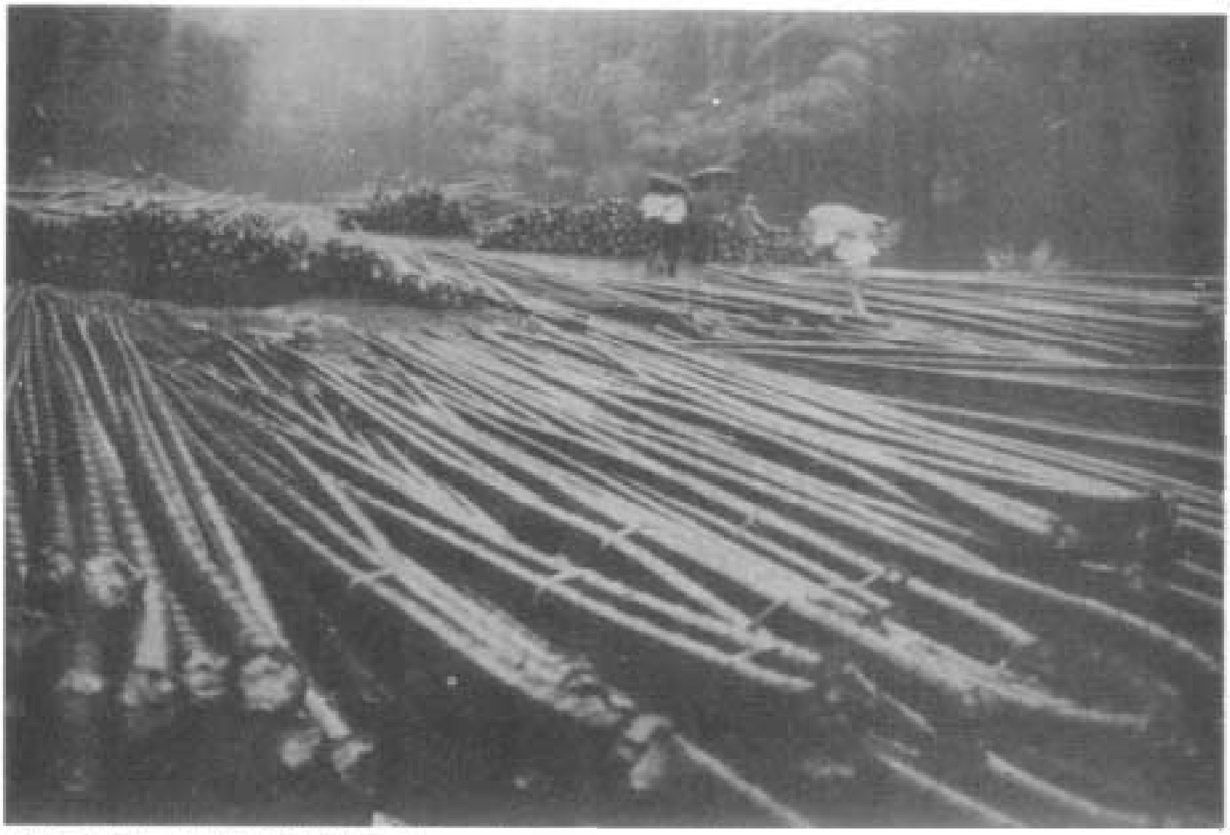
We are indebted to Mr Kevin Tan for his enormous patience and cooperation in rescheduling the printing programme of this volume many times. Equally grateful we are to many of our colleagues who helped us in many matters. in one way or the other.

– Editors

The gateway — that all entered and came out happily with more ideas.

The person who answered all questions — almost all, the problem solver, Mr Fu.

Bamboo Road to success.



After harvest ready for shipment.

Participants in the plantation-discussing the rate of growth.

Expriment in progress.

The Workshop Participants

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