Proceedings of

International Workshop on Bamboo Industrial Utilization

Sponsored by

International Network for Bamboo and Rattan

Hosted by

Hubei Provincial Government & Xianning Municipal Government

October 2003

Content

Forward

Preface --- **Opening Speech**
Jiang Zehui

Part 1 Bamboo Industrial Utilization

Structures of a Bamboo Culm Affecting its Utilization
Walter Liese
Recent development on bamboo utilization
Zhang Qisheng
Development of sustainable building and new bamboo construction material
Chen Xuhe
Technical Innovation to Increase the Competitive Capability of Bamboo Products
Jiang Zhengchan *and* **Yu Gang**
Technology of pigmentation of bamboo strips by carbonizing and dyeing treatment
Xie Manhua *and* **Guangjie Zhao**
Bamboo in Construction
Lionel Jayanetti
Bamboo, a sustainable building material in Western Europe
Pablo van der Lugt, **Andy van den Dobbelsteen & Jules Janssen**
Technology of Sawing Bamboo Veneer
Li Li，Yang Yongfu & Guo Jianfang
Technological Innovative Course and Prospect of Bamboo-based Panel of China
Zhao Renjie, Chen Zhe & Zhang Jianhui
Study on Properties of Bamboo and Manufacture
Wang Zheng, Guo Wenjing & Gao Li

Part 2 Bamboo Resources, Environment and Trade

Bamboo Resources, Uses and Trade: The future?
Ian Hunter
Studies on technical systems and comprehensive benefits of converting agricultural land into Bamboo in Sichuan
Chen Qibing & Sun Jun feng
Implement the Ecosystem Management in Bamboo Plantation to Improve the Synthetical Benefits
Xiao Jianghua
Present Situations and Development Countermeasures of Paper-pulp Bamboo Resources in Hubei Province
Xiong Deli
Promote Xianning Bamboo Industry and Develop Regional Economy
Zou Jizhou

Evaluation on Shoot Quality of Excellent Sympodial Bamboo Species and Hybrids
Wang Yuxia & Zhang Guangchu
Bamboo product processing industry and income of bamboo farmers
Chen Suijun
Silviculteral Technique of Dendrocalamus farinosus on Returning Steep Slope Cropland to Forestland
Dong Wenyuan, Gao Yanping & Liu jun
Study on In-vitro Rapid Propagation of the Clumping Bamboo
Zhang Guangchu, Wang Yuxia, Tan Yuanjie, & Li Xingwei
Why giant panda became extinct in Central China: An appraisal of mountain bamboos in Shennongjia
Zhaohua Li, Manfred Denich & Thomas Borsch
A Study on the Conservation and Development of Dendrocalamus sinicus, A Giant Bamboo From Yunnan
Hui Chaomao, Chen Fang, Zhang Guoxue, & Yang Yuming
The Retrospective and Prospective of China's Bamboo Industry
Wang Shudong

FOREWORD

The China Bamboo Trade Fair is held every two years and aims to promote sustainable development of bamboo industries in China, also in the world. The 4th Fair was held on 9-11 October 2003 in Xianning City, Hubei, China. It was co-sponsored by the State Forestry Administration of China, the Provincial Government of Hubei and the International Network for Bamboo and Rattan (INBAR) and hosted by the Xianning Municipal Peoples' Government. It was attended by more than 1,000 people. There were four concurrent events:

- The Bamboo Industry Expo and Xianing Economic and Trade Exhibition
- A National Forum on the Bamboo Industry
- Meeting of the Executive Directors of the China Bamboo Industry Association
- Cultural events reflecting the significance of bamboo in local lives

The Bamboo Trade Fair attracted more than 100,000 visitors. Bamboo products worth 1.2 million US dollars were sold during the fair and total contracts valued at 75 million US dollars were signed during the Fair. Many new products were on show.

INBAR with support from the local authorities – Provincial Forestry Administration of Hubei and Xianning Municipal Peoples' Government, organized the international Workshop on Bamboo, with an emphasis on bamboo industrial utilization. This workshop set the stage for exchanging and sharing the updated information on research and development of the bamboo cultivation and utilization of bamboo resources and utilization.

The workshop was attended by about 150 diplomats, scholars, entrepreneurs, policy-makers from around 30 countries of all continents. Notable amongst them were Prof. Jiang Zehui, Co-chair of the INBAR Board, and 20 diplomats from 18 embassies in Beijing and international organizations.

In the Workshop twenty international and Chinese speakers presented their papers. About 30 papers in English or in Chinese were shared on the workshop on the bamboo resource management and utilization. This proceedings are a compilation of the part of the papers presented at the workshop by the participants for disseminating the knowledge to a wider audience. It is our hope that this will encourage an increasing interests in utilizing bamboo resources for the purposes of environmental protection and poverty alleviation in the different parts of the world, esp. in Africa and South America where are rich in natural bamboo resources.

The workshop and the compilation of the papers would not have been possible without the hard work of a number of individuals and institutions. Full acknowledgement should be given to the Forestry Administration of Hubei Province and Municipal Government of Xianning, without whose marvelous facilities and considerable logistical support the workshop would not have run as smoothly as it did.

Finally, the workshop would never have happened without the full dedication and many long hours of hard work from our INBAR colleagues. Ms Hao Ying took on the thankless administrative and logistical burden, and Dr. Lou Yiping pulled together this compilation of the papers. Thanks and appreciation to them, and the others who participated in the process.

Ian Hunter
Director General of INBAR

Chen Xuhe
Deputy Director General of INBAR

April, 2004

Preface

Speech on the International Training Workshop on Bamboo Industrial Utilization by Professor Jiang Zehui

Distinguished guests, friends, ladies and gentlemen:

Good Morning!

First, on behalf of the Chinese Bamboo Society and the Board of International Network for Bamboo and Rattan, I would like to extend my warm welcome and sincere gratefulness to the ambassadors, diplomats, experts and scholars and guests participating this international seminar during the bamboo cultural festival.

The topic of this seminar is bamboo industrial utilization. As we all know, bamboo grows fast and can be used for many purposes, it has important economic, environmental and social value. Bamboo can play an important role in regional economic development and poverty alleviation if we improve bamboo processing technologies and management system, and accelerate the industrialization of bamboo utilization. This workshop will discuss and explore key issues concerning the above, which are significant for the future bamboo cultivation and processing development. Now, I would like to introduce the status of China's bamboo industry and the development of bamboo utilization, I will also give some suggestions for the future development of bamboo industrial utilization.

I. Main Progress in China's bamboo industry development and bamboo industrial utilization

China is the homeland of bamboo, it has the richest bamboo resources in the world. The number of species, plantation areas and biomass of bamboo in China are all among the world's top list. Bamboo utilization is one of the important part of Chinese culture. Bamboo is widely used in construction, transportation, furniture, pulp making, handicrafts, etc.. Since the implementation of the opening and reform policy, China's bamboo industry has been developing fast, from resource cultivation, processing to international trade, the bamboo sector has become a newly erected industry of the nation. The development of bamboo panel products and machine-made bamboo pulp indicates that China's bamboo industry has entered a new stage of modern industrial utilization.

China's bamboo industry has three characters: fast development; high involvement of science and technology; emphasis on ecological environment protection.

In the aspect of bamboo forest area: in the recent years, the world bamboo forest area has been increasing at the speed of 3% per year, although the world forest coverage is dropping dramatically. The world bamboo forest area now in total is about 22 million ha. China's bamboo forest area is 7.2 million ha, including 4.2 million ha of plantations and 3 million ha natural stands in high mountainous.

In the aspect of scientific utilization: As bamboo fast propagation technologies are extended and applied, the areas of intensive managed bamboo plantation are increasing continuously, the bamboo processing and utilization are widened, bamboo panel and bamboo pulp making technologies are getting matured, the bamboo processing and utilization is advancing towards finer finishing, completed utilization of the bamboo material and high added-values, the economic effects of bamboo industry is improved remarkably.

In the aspect of environmental effects: in the recent years, people began to pay more and more attention to the eco-function of bamboo. Bamboo is applied to soil and water control, conservation of water heads; rehabilitation and preservation of vegetation in habitats of rare wild lives, such as pandas and Snub-nosed monkeys (Rhinopithecus roxellanae), etc; it is also applied in the greening of urban areas, landscape construction and bamboo eco-tourism. Bamboo landscape plantation has just take on a look in Beijing, it will become a new scenery in the 2008 Beijing Olympic Game.

China's bamboo industrial utilization made significant advancements these years in the following aspects:

1. Various bamboo panel products

China has developed bamboo mat plywood, bamboo composite plywood, bamboo particleboard, bamboo skin laminated plywood, bamboo-wood composite board, etc. In China, bamboo composite plywood and bamboo flooring production now has grown and expanded to certain scale, the products are widely used for construction moldboard, the bottom board of trucks, trains and boats, and indoor decoration board.

2. Bamboo laminated board furniture

China has a long tradition of using bamboo culm for furniture processing, Chinese traditional furniture are of primitive simplicity, and are refreshed and elegant, they are often seen in Chinese restaurants and hotels. However, traditional bamboo furniture is disadvantaged for its big volume and inconvenience when knocking down or assembling, and high cost for storage and transportation. The International Network for Bamboo and Rattan, Zhejiang Forestry Research Institute and other collaborators introduced the pack-flat concept of wood products to the designing and manufacturing of bamboo furniture, and successfully developed bamboo pack-flat furniture, this new style of bamboo furniture has small volume and can easily be stored and transported at low cost.

3. Bamboo pulp and paper

Presently, only 12.2% of China's pulp industry use wood pulp; In the recent several years, China has imported paper and pulp to meet domestic demand, the value reached 5 billion USD. Because China is one of the biggest bamboo producers in the world, and bamboo is the second most important fiber material for pulp making, bamboo utilization in pulp making is significant to the development of China's pulp industry and industrial utilization of bamboo.

4. Bamboo fiber development and utilization

Fresh bamboo materials softened by high temperature can be manufactured into fibers for textile. Bamboo fiber is hollow inside, thus, it is breath-free, fabric of bamboo fiber and hemp or silk or wool has better performances than common fabrics. Bamboo fiber is the second Chinese invented new fabric material that has independent intellectual property after the development of soybean protein fiber, it is estimated that bamboo fiber will bring good social and economic effect in the future.

5. Bamboo Charcoal and Vinegar

Recent research shows that bamboo charcoal has comparatively larger surface area and adsorbability, it is good at purify water and air, as well as adjust the moisture. Bamboo charcoal contents many microelements such as calcium, magnesium, aluminium and kalium, etc., it can be utilized health products and anti-static products. Related products have been developed and put into market in Japan and Korea.

Activated bamboo charcoal has outstanding performances in adsorbing, is able to adsorb pigment and other impurities from gases or solutions; it can also be used as catalyzers or carriers of catalyzers in the industries of food, medicine, chemical, metallurgy, national defense. These shows that bamboo activated charcoal has a bright prosperous in the high-tech industries.

Bamboo vinegar is a by-product of bamboo charcoal, it contents certain chemicals and active bio-matters, can be used for deodorization, sterilization, plant growth promotion, soil improvement, it has a bright prosperity in agricultural, medical, health care and environment sanitation areas.

6. Effective elements in bamboo leaves

Bamboo leaves contents flavone, amino acid and microelements, these elements are of excellent biological efficacies in anti-oxidation, anti-consenescence, and strengthening human immunity, these functions have attracted attentions in the fields of food, nutrition and medicine researches. Up to date, health care products developed with flavone extracted from bamboo leaf, beverages contents bamboo leaf extracts are already developed and put into markets, these products attracts wide attention from all circles of the society.

II. Challenges in China's bamboo industrial utilization

As China's bamboo industry is developing, some challenges and problems come in the way and resolutions are needed:

One challenge is the construction of resource bases. Although China has such a rich bamboo resources as 500 hundred species, but only not more 20 are developed and utilized, the rest are still laid waste in the wild. More than 50% of the monopodial bamboo plantations in China are low-yielding plantations that needs improvement; 95% of the 1 million ha sympodial bamboo plantations are under extensive cultivation. It is extremely necessary to establish high quality, sustainable and efficient resource bases.

The other challenge is that most bamboo processing enterprises are of small-scale, with simple and lagged-behind equipments, low innovation capacity, low technologies, are weak at regeneration. Only a small number of China's bamboo enterprises have passed the ISO certification. However, none has passed the certification of ISO14000 environmental management standard systems. The world recognized forest certification system is another goal that Chinese bamboo enterprises should try to meet.

III. Suggestions to the future development of bamboo industrial utilization

Drawn on the new research results of China's Sustainable Forestry Development Strategy, the State Department recently issued the Decision on Accelerating Forestry Development, which urged the establishment of a sustainable development strategy prioritizing ecological construction, thus, establish a land eco-security system mainly with forest vegetation, and the integration of plantations and pastures, to achieve the goal of constructing a eco-civilization society.

In the past, the high growth rate of China's GDP was based on the increasing investments, industrial expansion and the mass consumption of resources. In the new historic period of forestry development, our bamboo industry should aim at the national goal of sustainable development, and follow the strategy of eco-construction, eco-security and eco-civilization, by improving technologies and personnel qualities, develop new types of bamboo industry with high-technologies, high economic efficiency, low resource consumption, low pollution and full play of personnel advantages. Therefore, I would like to propose the followings:

1. Pay attention to the construction of bamboo forest resource bases

Bamboo industrial utilization must follow the rules of sustainable development. The productions of pulp, fiber, panels, charcoal, as well as bamboo food products mainly with bamboo shoots and bamboo beer, need large amount of bamboo resources. It is necessary to apply industrial plantation management models and establish product oriented resource bases, which are of high-quality and high-yielding capacity and are intensively managed. The guarantee of resource supply, will improve t he efficiency of bamboo enterprises and increase farmers' income.

2. Enhance the upgradation of bamboo industry structure

In order to meet the needs of ecological construction and changes of market demand, the bamboo industry need restructure to prioritize the resource allocation, and form a new development pattern with efficient supply of bamboo resources, led by fine and deep processing industries, and sustained by technology improvement. The aims are improving the comprehensive utilization of bamboo, develop high-tech, high-added value and characteristic bamboo products, create famous band, and improve product competitiveness.

3. Enhance scientific innovation

It is important to strengthen the collaboration of production, study and research, gradually establish the technology innovation system centering leading high-tech enterprises, strengthen the researches and development of key technologies in industry structure upgradation and improvement of product competitiveness.

4. Enhance macro-guidance and trade management

Different bamboo producing regions of China have different local natural and social conditions, the development of bamboo industrial utilization should consider local facts and needs, and accordingly, make the plans for local resource development and utilization. Local government and Bamboo Societies should play the role of trade management and provide policy supports in bamboo resource management, protection and utilization, as well as improve local investment environment.

5. Further international exchange and cooperation

Initiated by China and Canada, the International Network for Bamboo and Rattan (INBAR) was established in November 1997. It is the first international organization headquartered in Beijing. In its 6 year's existence, INBAR has developed into a global network of 27 member states and 350 individual and institutional affiliate members. INBAR did not only improve bamboo and rattan researches, international cooperation and exchanges, but also helped the bamboo and rattan development in developing countries, which contributes to the economic and environment of these countries.

The Chinese Government has always been supporting INBAR's growth and development. President Jiang Zemin wrote the inscription of International Network for Bamboo and Rattan, the new INBAR headquarters building built by the Chinese Government was put into use. We will strengthen cooperation with INBAR in order to further our international cooperation in bamboo industrial utilization.

Lets collaborate our efforts and make new contributions to the sustainable development of the bamboo industry in China and in the world.

Thank you!

Prof. Jiang Zehui

Deputy Director, Population, Resource and Environment Committee of the Chinese's Peoples Political Consultative Conference

Co-Chair, Board of Trustees, International Network for Bamboo and Rattan

Chair, Chinese Bamboo Society

President, Chinese Academy of Forestry

12 October, 2003

Structures of a Bamboo Culm Affecting its Utilization

Walter Liese, Prof. Dr.

University Hamburg, Chair for Wood Biology, P.O.Box 800 209, D- 21002, Hamburg. Germany. Phone: +49 40 7223402. Fax +49 40 7228991. E-mail: Wliese@AOL.com

1. INTRODUCTION

The numerous possibilities to utilize a bamboo culm are considerably determined by its structural composition. Continuous research has focused to evaluate the relationships between structures, processing and product quality. At the International Symposium on Industrial Use of Bamboo December 1992 in Beijing some reviews were presented by Abd. Latif and Jusuh, Espiloy and Liese, which are to be elaborated further.

2. MAIN STRUCTURES OF A BAMBOO CULM

The anatomical construction of a bamboo culm appears rather uniform, compared with wood. The differences between the around 1.200 bamboo species are comparatively small. Nevertheless, certain differences exist, so that some species are preferred for certain uses, whereas others are neglected (Liese 1998).

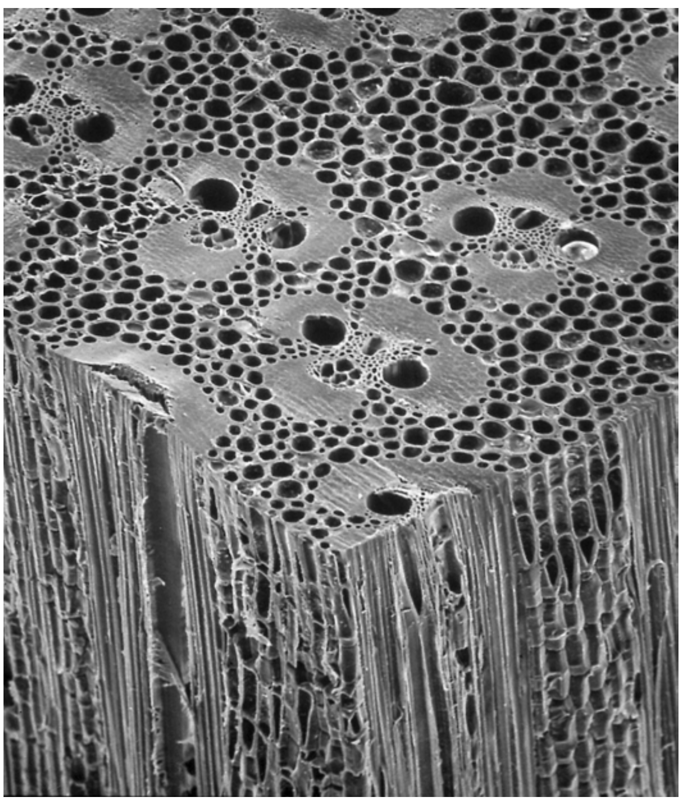


Figure 1 Three dimensional view of the culm tissue with vascular bundles and fibre sheaths embedded in ground parenchyma, *Oxytenanthera abyssinica*

In general, the culm wall consists of about 50% parenchyma cells, 40% fibres and 10% conducting tissue (vessels, sieve tubes with companion cells). The obvious structural characters on a cross-section are the darker vascular bundles with their fibre agglomerates (Figure 1). All the bamboo culms exhibit striking differences in the distribution of their cells within the culm wall. The percentage of fibres is distinctly higher at the outer third than in the inner one. The base contains more parenchyma, the upper part many smaller vascular bundles with a high portion of fibres, providing a superior slenderness.

3.STRUCTURES INFLUENCING CULM UTILIZATION

3.1 Culm morphology

The bamboo culm is separated by nodes into internodes. Its diameter tapers from bottom to top, with differences between species. Base and middle portions are utilized generally for construction work, furniture, mats and boards. The reduction in diameter is accompanied by a reduced wall thickness, whereby the outer, stronger part will remain at the loss of the inner more parenchymatous tissue. Culm diameter and wall thickness are positively correlated to shrinkages. The mechanical properties increase with height and density, but decrease with increase of internode diameter and culm wall (Abd. Latif and Liese 2002).
Internodal length differs considerably between species. It is longest in the middle of a culm. Long internodes are preferred for furniture. The strictly parallel arrangement of the fibre arrangement as sheaths and bundles is disturbed at the nodes, so that for splitting and weaving species with long internodes are preferred, like *Bambusa textilis* up to 60 cm.

3.2 Structures of an internode

3.2.1 Outer and inner layers. The culm wall is on both sides covered by a special tissue. Its outer part, the cortex, as a water-tight seal prevents any moisture loss of the living culm. The structural composition of compact fibre bundles with thick walls provides also a protection against mechanical wounding.
As consequences for processing hinders the compact structure the loss of moisture during drying of culms, as well later the penetration of any preservative liquid for protection against bio-deterioration. A surface decoration of culms by lacquer or varnish could be hindered by a siliceous-waxy layer on the epidermis, which may be removed by alkali pre-treatment.
At the inner side towards the central cavity, the lacuna, layers of parenchyma cells form a special tissue. These are often heavily thickened, may contain sclereids and exhibit distinct differences between species. A recently developed Vertical-Soak-Diffusion (VSD)-treatment by filling the inner space of fresh standing culms with preservative depends on the diffusion through this layer into the culm wall, so that structural obstacles can influence the preservative effect (EBF 2003).

3.2.2 Types of vascular bundles.
The vascular bundles consist of the two metaxylem vessels and the metaphloem (sieve tubes with companion cells). They are the obvious components on a cross section and the most varied structures within a culm. This is mainly due to the agglomerated fibres, which are attached as fibre sheaths or as additional fibre bundles. Their form and shape is genetically determined, whereby six types with 8 subtypes can be distinguished (Liese & Grosser 2000). Leptomorph species with individual culms, like *Phyllostachys edulis*, have four surrounding fibre sheaths, whereas the tall pachymorph species growing as a clump like the genera *Bambusa* and *Dendrocalamus* present isolated fibre bundles additionally (Figure 2). Apart from this diversification the large culms of the pachymorph genus *Guadua* show extensively formed fibre sheaths. The amount of fibres, as sheaths or additional bundles, is closely related to the specific gravity, which increases within the culm from base to top and influence consequently the strength properties.

Since no ray cells exist as in wood, the arrangement of the vascular bundles results in a higher radial shrinkage than tangential. Shrinkage starts both in wall thickness and diameter as soon as its looses moisture, unlike wood. This is due to the high amount of parenchyma cells, which loose their moisture first.
The typology of the vascular bundles influence also the visual appearance of bamboo products, like furniture and parquet.

Chopsticks are mainly made from leptomorph genera, like *Phyllostachys* , with only fibre sheaths.

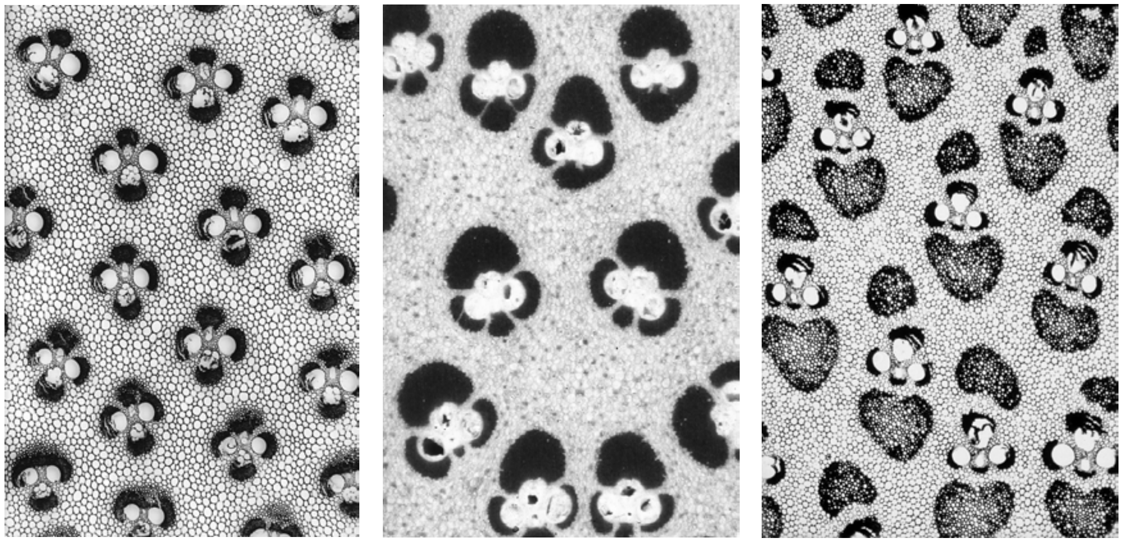


Figure 2 The composition of vascular bundles determines its appearance.
left: *Phyllostachs* spec., middle: *Guadua* spec., right: *Dendrocalamus* spec.

3.2.3 Metaxylem vessels.
The metaxylem consists of two large vessels and provides the water transport within the culm (Figure 1). They are considerable bigger at the inner culm part and smaller towards the outside. Their volume amounts to only about 6-8% of the total tissue. Consequently its easy conductivity is vital for the transpiration of the culms leafs, as well later for any axial treatment of the culm, like by the sap-replacement process. Properly applied the easiness of the water conductivity provides the best treatment result (Liese and Kumar 2003).

3.2.4 Fibres.
Fibres are present as sheaths and also as isolated strands at the vascular bundles. They amount to about 40% of the culm mass and 60-70% of its weight. Their length follows a definite pattern across the culm wall and along its heigth. It varies considerable between species, between 1.5 and 3.5 in the average, being much longer than those of hardwoods. Content and length influence specific gravity (0.5 to 0.9 g cm^2) and strength properties as well as pulping. Fibre length is strongly correlated to fibre diameter, cell wall thickness, as well as to the modulus of elasticity and to compression strength. The outer part of the culm with its denser arrangement of fibres has a far higher specific gravity than the inner, more parenchymatous part. In Vietnam, species with fibers up to 4 mm, like *Neohouzeaua dulloa*, are preferred for mats and weaving lady's hats.

The fibre wall is made up by numerous layers with a varied orientation of their microfibrils, especially at the outer part (Figure 3). This microstructure contributes to the great flexibility of fibres and culms. It also influences the fractured appearance of culms after breaking.

Bamboo fibres are increasingly used as matrix material, either for strengthening their properties or for filling. The behaviour of bamboo fibres being separated depends much on the species and specific defibration parameters. The fibre of the bundles are easier separated, but become twined with an unequal distribution during mat formation. Raw material preparation and fibre defibration were difficult working procedures during producing bamboo MDF (Xu et al. 2001).

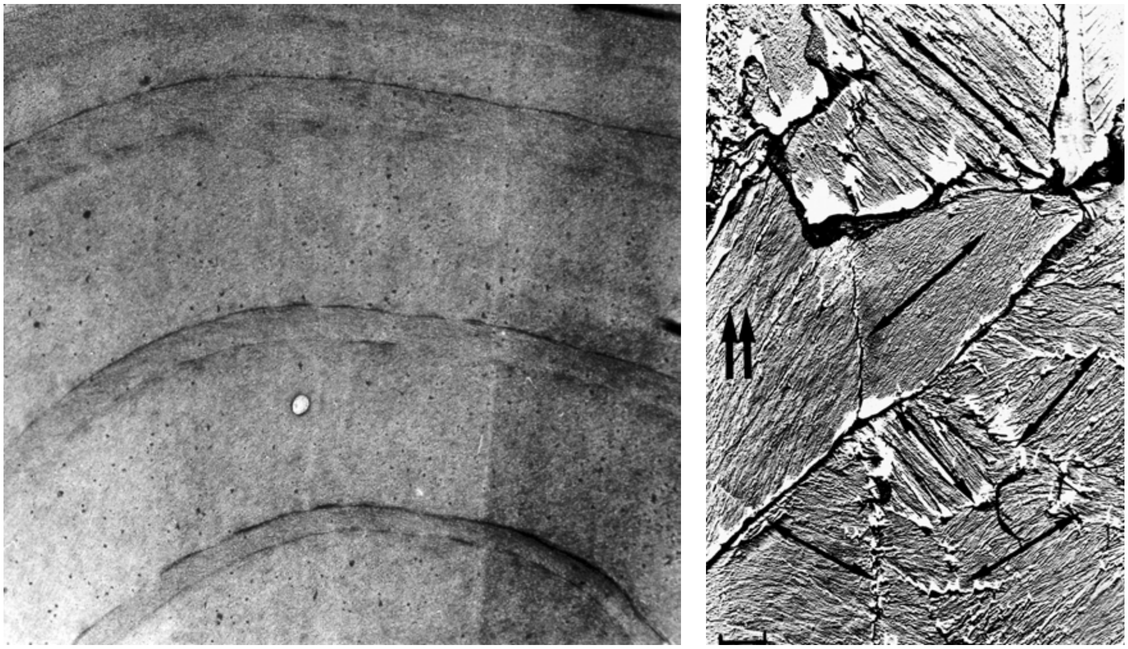


Figure 3 left: Cross section of a fibre wall with alternating broad and small lamellae,
right: Surface view on lamellae with different orientation of their microfibrills
Phyllostachys edulis

3.2.5 Parenchyma.

The parenchyma cells form the ground tissue, in which the vascular bundles are embedded. They contribute to the stabilility and also flexibility of the bamboo culm. The pits on their tangential wall ease a radial diffusion of liquids, like preservatives. Parenchyma cells are vital for the storage and mobilization of the culm's energy. Starch particles closely stacked fill the cell lumina and are mobilized before shoot production (Figure 4). As starch is the main attractant for beetles and also blue-stain fungi the changing content during the season helps to reduce the culms liability for infections. Nevertheless, *Bambusa vulgaris* is much preferred by beetles because of its general high content.

For later processing starch retards the setting reaction in cement-bonded particleboards, so that soaking or chemical additives should reduce the sugar content below 0.5% (Chew et al. 1992). Bamboo fibres suspension is also applied for stabilization of cement tubes.

Parenchyma cells contain also silica, which affects cutting and pulping properties. It is mostly located at the cortex and species dependent, so that the ones with a low content are preferred for furniture.

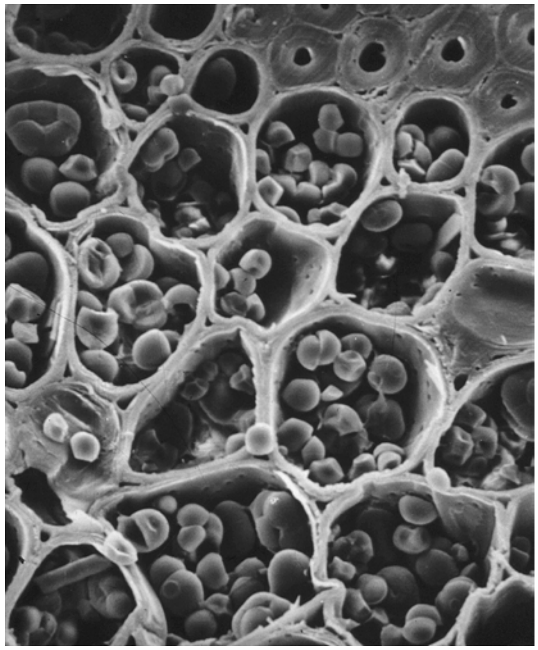


Figure 4 Starch particles filling the parenchyma cells, *Phyllostachys viridiglaucescens*

3.3 Structures of a node

At the nodes the parallel cell structures of the internode become diverted with intensive interconnections among the vessels as well as the sieve tubes to insure a horizontal distribution through the partition wall, the diaphragm. The fibres are shortest at the nodal region, so that young culms break easily at this level. Nodes have a great influence on the culm's mechanical strength due to their higher specific gravity, a lower volume shrinkage and lower tensile strength because of shorter fibres and distorted vascular bundles. Nodes have lower holocellulose content, but more extractives, pentosans, lignin and ash than the internodal portion. Nodes produce pulp of lower strength quality, but can hardly be excluded.

3.4 The rhizome

The rhizome is one piece of the modified branch of a bamboo plant. It serves for the uptake, transport and storage of nutrients as well as for the vegetativ production by forming the new shoots at their nodes. Leptomorph species show in contrast to their rather uniform culm structure distinct anatomical differences. Parenchyma and conducting tissue for storage and transport increase considerably on the expense of fibres, amounting to around 20% only. Remarkable is the presence of large air canals in the cortex of several species, like *Phyllostachys heteroclada*, *nidularia* and stimulosa (Figure 5) This structural speciality indicates its growth in an aquatic environment for soil establishment. (Ding et al. 1993).

3.5 Structural changes during life time

During life time the culms undergo an ageing process, specially during its maturation period of 3-4 years, but also still later (Liese & Weiner 1997, Murphy & Alvin 1997). This process changes certain structures and consequently properties and utilization. Fibres and also parenchyma cells exhibit a thickening of their cell walls by deposition of additional lamellae on the existing wall layers with subsequent lignification (Figure 6). The wall thickening is expressed by an increase of density and strength properties.

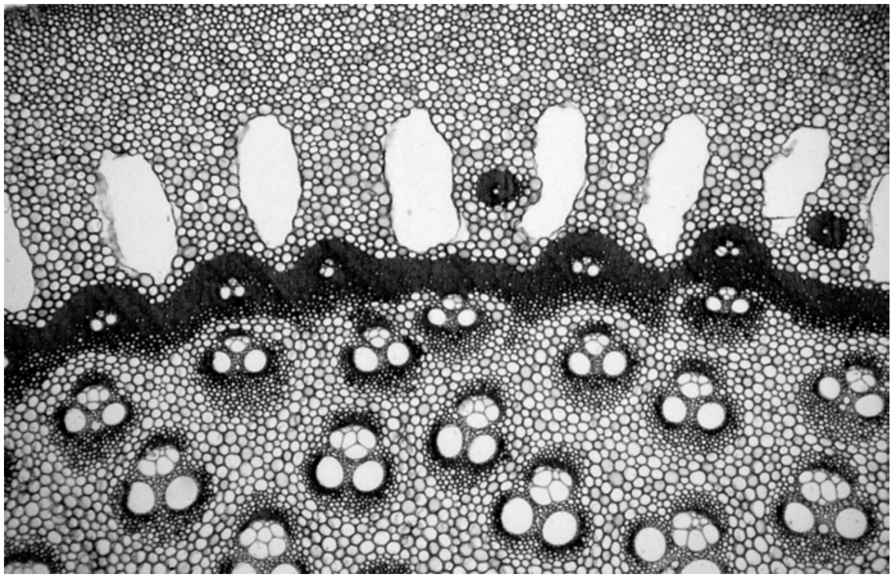


Figure 5 Cortex with large air canals, *Phyllostachys heteroclada*

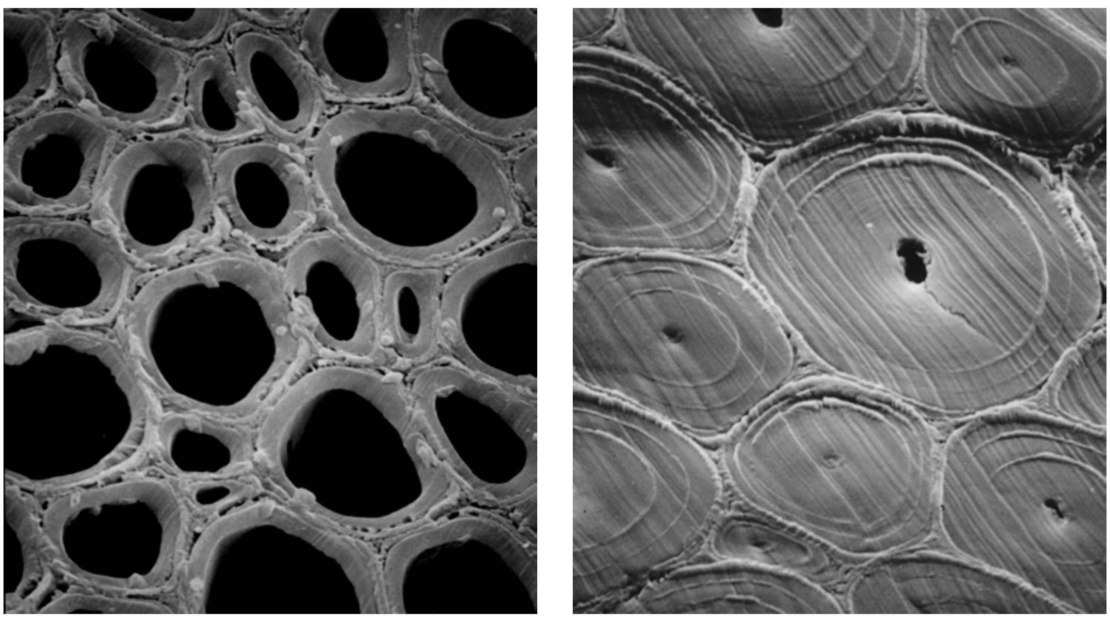


Figure 6 Fibres of a 1-year (left) and a 12-year-(right) old culm, *Phyllostachys viridiglaucescens*

Younger, immature culms with a lower lignin content can be more easyly split. They are preferred for handicraft work. The lower lignin content is also beneficial for pulping. However the harvest of young culms is detrimental for the vitality of the stand, since they have to produce and store the energy for the growth of the next year's generation.

Senescens of a culm-after around 10 years- affects the functional efficiency, but not the technological properties. This natural ageing occurs as blocking-off the water-conducting vessels by tylosis and slime-like substances and the "sugar" transporting sieve tubes by callose occlusions and tylosoids. The functional inefficiency results in the dying of an individual culm within a clump or grove.

Quite contrary appear the structural consequences for a dying culm after flowering. The tissue structure becomes brittle and the whole culm often bends down and breaks. Since this phenomenon is not associated with any bio-degradation, it must result from biochemical changes affecting the lignin-cellulose complex. In spite of the great impact for the utilization of the masses of dying culms, the processes are not yet fully understood.

Site conditions influence more the morphological characters then anatomical parameters, which appear as rather stable (Abd. Latif and Liese 2001). A higher fibre content, resulting in higher density and increased strength properties may occur in drier areas and on slopes.

Fertilization affects shoot production, but apparently not the anatomical composition and hence not the main technological properties.

The wounding of a living culm, either by borers or mechanically, produces structural defence reactions to protect the water conducting system against air blockage. The vessels will be filled up by slime and tyloses, produced by the surrounding parenchyma cells. Culm utilization will be ornamentally affected by a local discolouring of its surface and by a reduced permeability of the vessels for their drying and also for the entry of preservative solutions.

3. CONCUSIONS
4.

Research on utilization aspects is presently more properties then products oriented. It has to be intensified to recognize the prospects and limitations of the various species and to utilize their potentials in the best way. Notable is a "Bamboo Products Matrix" being developed by one working group of the ongoing EC funded Bamboo Thematic Network. In a cooperation of institutions and industrial partners from Europe and Asia it (i) combines the existing knowledge of bamboo properties and qualities with end uses of the material, (ii)focuses on applications for both rural and large scale industries in developing countries, and (iii) aims to provide means of identifying linkages of specific end uses and possible future applications of bamboo biomass. Special attention is paid to bamboo panels, boards and composite materials (BTN 2002).

REFERENCES

Abd. Latif M. and W Liese. 2001. Anatomical Features of *Bambusa vulgaris* and *Gigantochloa scortechinii* from four harvesting sites in Peninsular Malaysia. *Journal Tropical Forest Products* 7, 10-28.

Abd. Latif M. and W. Liese. 2002.Variability in culm characteristics of two bamboo species with age, height and site. In: *Bamboo for Sustainable Development*. Proc. V International Bamboo Conference Eds. A. Kumar, I. V. Ramanuja Rao, Ch. Sastry. VSP and INBAR, 257-268.

Abd. Latif M. and Mohd. Z. Jusuh 1992. Culm characteristics of *Bambusa blumeana* and *Gigantochloa scortechinii* and its effects on physical and mechanical properties. In: *Bamboo and its Use*,. Ed. S. Zhu, W. Li, X. Zhang. ITTO, CAF, Beijing, 118-128.

BTN: Bamboo Thematic Network. 2002. A project funded by the European Commission and coordinated by Oprins Plant NV, Belgium< www.bamboonetwork.org>

L. T. Chew, S. Rahim and K. Jamaludin. 1992. *Bambusa vulgaris* for urea and cement-bonded particle board manufacture. *Journal Tropical Forest Science*, 4, 249-265.

Environmental Bamboo Foundation (EBF). 2003. Vertical Soak Diffusion for Bamboo Preservation. Ed. Linda Garland, Ubub, Bali, 26 pp., <www.bamboocentral.org>

Z.B. Espiloy. 1992. Properties affecting bamboo utilization. In: *Bamboo and its Use*, Ed. S. Zhu, W. Li, X. Zhang, Z. Wang. ITTO, CAF, Beijing, 139-142.

W. Liese. 1992. The structure of bamboo in relation to its properties and utilization. In: *Bamboo and its Use*, Ed. S. Zhu, W. Li, X. Zhang, Z. Wang. ITTO, CAF, 1992, 95-100.

W. Liese. 1998. The anatomy of bamboo culms. *INBAR Techn. Rep.*, No. 18, 204 pp.

W. Liese and D. Grosser. 2000. An expanded Typology for the Vascular Bundles of Bamboo Culms. Proc. *Bamboo 2000 Intern. Symposium*, Chiangmai, Thailand. Eds. L. Puangchit, B. Thaiutsa, T. Songkram, 121-134.

W. Liese and S. Kumar. 2003. Bamboo Preservation Compendium. *INBAR Tech. Rep*., No. 22, 224 pp.

W. Liese and G. Weiner. 1997. Modifications of bamboo culm structures due to ageing and wounding. In G. Chapman, ed. *The Bamboos*, Linnean Society, London, UK. 313-322

R.J. Murphy and K.L. Alvin. 1997. Fibre maturation in bamboos. In G. Chapman, ed. *The Bamboos*, Linean Society, London, UK, 293-303.

Y. Xu, Y. Zhang, and W. Wang. 2001. Study on the manufacturing technology on medium density fiberboard from bamboo. *Symposium on Utilization of Agricultural and Forestry Residues*. Nanjing, China, 117-123.

Characteristic and Prospects of Processing Approaches for Bamboo Resources

Zhang Qisheng
Academician of Chinese Academy of Engineering
President of Zhejing Forest College
Professor of Nanjing Forestry University

Nanjing Forestry University, Xinzhuang No.9, Longpan Road, Nanjing 210037, P. R. China. Phone: +86-25-5427133/5428901. Fax: +86-25-5421325. E-mail: zhang-qs@jlongline.com

1. Processing characteristics of bamboo resource

Bamboo plants are in the subfamily of Bambusoideae, family of Gramineae. Both Bambusoideae and Gramisoideae are under the family of Gramineae. The differences are as follows: Plants of Bambusoideae are perennial with high-developed woody and hard stems. Members of Graminsoideae are herbs with herbaceous stems and most of them are annual. The stems of Graminsoideae plants have higher cellulose and lower lignin content such as straw with 35% to 36% cellulose and 9% to 15% lignin. On the other hand, the characteristic of Bambusoideae plants is that the content of both cellulose and lignin is higher than that of Graminsoideae ones. Fore example, bamboo stems include 40% to 60% cellulose and 16% to 34% lignin. Consequently, it is said that bamboo is similar to wood but not wood, and similar to herbage but not herbage. Bamboo is very woody, but its morphology is similar to Gramisoideae plant with the features of cylinder – formed stem with nodes, coating wax and silicon on the surface of stem, which is not being wetted with adhesive. Because of the special structure of bamboo, the processing and utilization methods for bamboo plants have their own characteristics that are different with woody plants. They are as follows: (1) Bamboo stems are small in diameter, hollow inside, thin in wall, large in taper, and different in component between inner, middle and outer layers. The diameter of most of *Phyllostachys pubescens*, which is larger in diameter among bamboo plants, ranges from 70 mm to 100 mm with average wall thickness less than 10 mm. A few of bamboo species are small in diameter ranging from 30 mm to 50 mm with mean wall thickness 4 –6 mm. So most of wood working machinery and technologies can't be indiscriminately applied in bamboo processing. As a result, the technologies used in bamboo processing get largely behind wood industry. (2) Most of bamboo products can be manufactured with machines, but a few procedures or products can't avoid of handwork, and not mension of continuous or automatic production. Consequently, the production rate of bamboo industry is several times even ten times less than that of wood industry. (3) Because the outer skin and inner players of a bamboo culm can't be wetted by adhesive, the very portion that can be used is mainly the middle portion of bamboo wall. So the utilization percent of bamboo is much lower, ranging from 20% to 50% of volume or weight. (4) Bamboo is difficult to be dealt like wood, which can be manufactured into boards or blocks of large size. It is usually machined into strips of 20 mm to 30 mm wide by 5 mm to 8 mm thick that can't be used directly. (5) The difference, not only in structure but also in chemical composition, between bamboo and wood is obvious because bamboo contains much more nutrition substances such as hemicellulose, starch, protein, sugar etc. As a result, bamboo products have lower resistance against insects and fungi. The properties against insects and fungi of a product should be strengthened if it will be used in outdoor circumstance.

Because of above characteristics, bamboo processing couldn't imitate wood working methods. Some of products can be made of wood but can't be produced by bamboo because of the troubles caused by technique or economy. For example, wood can be sawed into block or board but bamboo can't because of its special structure. Moreover, wood can be easily manufactured into 3 layers or multi-layered plywood via peeling, but bamboo is difficult both in technology and economy. If bamboo and wood plywood are in the same use, the peeled bamboo plywood is not feasible on the economic opinion though it seems to be feasible in technology. Consequently, bamboo utilization should be based on understanding its structure, properties, and processing characteristics.

2. Prospect of bamboo utilization approaches

China has tremendous bamboo resource. It is the number one both in bamboo forest area and in bamboo productivity. Last twenty years, the bamboo processing industry has been quickly developed because of the market demand to wood, which priced over international market for a long time, caused by the social and economical development, and the support and help from governments. At present, there are thousands bamboo processing enterprises in China with bamboo based panel and bamboo flooring productivity more than 100 million cube meters, and product value tens billions RNB. But most of enterprises are in small scale with behindhand equipment. Though some of bamboo products are reasonable and scientific in structure, which is called " exceeding wood", most of them belong to "labor-dense" ones without scientific innovation and to low value-added ones. Bamboo processing industry was developed during 1950' in Japan and 1960' in Taiwan, China. Since then it waned because of increasing labor cost. Along with the development in society and economy and the progress of economic combination around the world, the competing predominance of "labor- dense" products is coming down gradually. Consequently, we should think of bamboo utilization approach strategically. How to survive and develop in violent market competition is an important theme that bamboo industry has to face. In my opinion, the bamboo utilization approaches should be focus on the following:

2.1 These bamboo articles for daily use should be reserved and developed that can richly utilize local bamboo species, have enormous market potential, adapt to the shift of consumer's opinions, and have local particular features.

Bamboo articles for daily use, which suit the people who advocate and return nature, are composed of the bamboo culms of various diameters by means of a series of procedures such as sawing, splitting, planning, sanding, sculpting, weaving, and painting etc. Making and using bamboo articles have long history in China, but these products are still vigorous because of the progress of technology, consuming opinion change, and new products continuous emergence. Bamboo articles for daily use include chopstick, slip and toothpick, skeleton of joss stick, mat, cage, weaving articles, dead stocks, sculpt handicraft, fence, canopy, indoor decorate boards, furniture etc.

In many bamboo production areas, people took advantage of local bamboo species to make bamboo products with particular feature in a large scale, which won reputation home and abroad with themselves brands. These places where bamboo articles are outstanding are as flows: Anji county, Zhejiang Province is called "hometown of bamboo mats", and the mats is made of *Phyllostachys pubescens;* Shuichang and Quxian Counties, Zhejiang Province are named " hometown of bamboo charcoal" that is made of *Phyllostachys pubescens*, Chengxian and Xinchang Counties, Zhejiang Province are known well as

“ hometown of bamboo weaving” that is composed of *Phyllostachys pubescens*: Xinyi County, Guangdong Province is also called “hometown of bamboo weaving”, but the species is *Lignnania chungii*; Linan and Deqing Counties, Zhejiang Province are named “ hometown of bamboo shoot” that make use of *Phyllostachys praecox* and *P. primatina* ; Longmen County, Guangdong Province is famous as the name “ hometown of bamboo toothpick”, and the local species is *Lignnania chungii;* Guangning County, Guangdong Province is called “ hometown of skeleton of joss stick” and the local species is *bambusa textiles*. We hope there are more particular feature bamboo products in future. The bamboo articles market home and abroad. Setting up a plant needs less investment for simple machinery and the scale of the plant might be large or small. Though the selling price of bamboo articles is not high, the big productivity can bring good profit. So there are 38 plants producing bamboo articles with larger scale underling Zhejiang Bamboo Industry Association and hundreds in small scale. A few of new and particular feature products should be continually exploited in the production of bamboo articles in future.

2.2 Bamboo based panel industry should continually improve technique and exploit new products and avoid by all means to set up new plants blindly and subsequently to decline prices each other.

Three series of bamboo based panel products, e.g. platform floor for truck and bus, concrete forming, and laminated board or flooring, are successfully used as structural and ornamental materials for many years. They pioneered the industrial utilization of bamboo but isn’t only approach for bamboo. Based on existing products, it should be developed in a great deal the end products of laminated bamboo timber and flooring by utilizing large diameter bamboo resource. Moreover, the light and strong composite structure materials and decorative panels should be intensely exploited in future. Each plant must think of special conceptive products that will be potential in market. In the other word, every plant go itself way not be all through a narrow bridge. Only in this way can the bamboo based panel market be increasingly broadened.

2.3 Paying greatly attention to bamboo chemical utilization to exploit the application technologies of bamboo charcoal and vinegar

Researching bamboo charcoal and vinegar emerges last a few years. Preliminary research demonstrated that bamboo charcoal has strong capacity to adsorb harmful gas, to purify water and air, and to adjust indoor air humidity because of its large specific surface area. Bamboo charcoal contains a lot of microelements such as calcium, magnesium, aluminum, and kalium, etc., which can increase the microelements in water, lessen the water molecule to make it easy to be absorbed by human when bamboo charcoal is boiled in water for a certain time. Furthermore, bamboo charcoal made in higher temperature conducts electron well and can emit infrared ray. These properties can be used in health care and antistatic-electron fields. Above properties of bamboo charcoal are been studied home and abroad. Batch of products making use of these properties have exported to Japan, South Korea. They sell well in domestic market. Moreover, the bamboo briquette charcoal, which is made up from bamboo processing residue, is used to barbeque and has good market potential. The bamboo charcoal has very broad application prospect in killing-bacteria, decomposing harmful gas, and dealing with sewage etc after it is altered properties. Bamboo vinegar is a kind liquid with light brown color gotten by condensing smoke during pyrolyzing bamboo. It contains many chemical components and organic active substances and has broad prospect using many fields such as pesticide, medicine, health care, and sanitation etc. At present, we should fasten the speed of developing bamboo charcoal and vinegar to promote them into people’ daily activities for prolonging human being’ life span and improving indoor surrounding. Making bamboo charcoal and vinegar can realize the purpose of “full bamboo culm” utilization because it utilizes not only large or small culms but also processing residue.

Bamboo fiber for textile is a new product that was developed last year and is also a new innovation in bamboo utilization. It is made up from fresh bamboo that is immerged in a sort of special extraction liquid and then softened under high temperature. Textile can be greatly improved by blending this bamboo fiber with hemp fiber, silk, wool etc. So experts called this kind fiber a new spinning material with our own intellective property right besides soy protein fiber in China. It will benefit people in both society and economy.

There are more mysteries in bamboo development that need to be explored, especially in bamboo chemical utilization.

2.4 Highlighting on the research and exploit on precise and deep processing of bamboo

It is very important to exploit the value-added products requiring precise and deep processing technology and the our own intellective property right ones based on existing bamboo products in which most of them are labor-dense products not needing complicated techniques. Besides bamboo weaving products, bamboo flooring is one of highest value-added products because it needs exact match in color, precise processing, and refine painting in manufacturing. At present, the bamboo planned laminal sheets and rotary laminal veneer prolonged with tooth joint are been exploiting. They can form new decorate material by coasting them on the surfaces of panels or woody furniture. Of course, the producing technique is relative complicated and precise. Because of enormous market potential, they are worth developing.

2.5 Developing bamboo pulp and paper

Wood pulp consumed in our nation depends upon import for a long time because of insufficient forest resource. Pulp and paper making technology progressing recently, there is no obstacle technologically to take advantage of bamboo for papermaking. Especially, sympodial bamboo, which is planted on a large scale in southern China of Yunan, Hainan, and Guanxi provinces, is the good raw material for paper making because of big biomass, which is 7 to 10 time bigger than that of *Phyllostachys pubescens*, and high fiber content. The efficiency is no difference between bamboo and wood papermaking, but the sympodial bamboo cost is lower than that of wood. Consequently, it will benefit both nation and people to develop sympodial bamboo on a large scale forming bases and bamboo papermaking.

Promotion of Bamboo for Poverty Alleviation and Economic Development

Prof. Chen Xuhe

Deputy Director General, International Network for Bamboo and Rattan (INBAR), P. O. Box 100102-80, Beijing 100102, P. R. China. Phone: +86-10-64706122. Fax: +86-10-64702166. E-mail: xhchen@inbar.int

1. INTRODUCTION

Bamboo is a fast growing, renewable, wide spread, low cost, environmental enhancing resource with great potential to improve poverty alleviation and economic development. Bamboo forests and plantations are mainly distributed in rural areas. Bamboo industry， largely featured in labor intensive, low to medium investment, and simple in technology and equipment, is making important contribution in providing food, housing and income generation for 2.2 billion people in the world. As the market for environment friendly green bamboo products is growing, it is estimated that the world bamboo market would grow from the present size of US$ 8.5 billion to over US $ 20 billion by 2015.

2. BAMBOO DEVELOPMENT IN CHINA

China has long history in cultivation and utilization of bamboo, also been one of the major innovators of new bamboo products. In the past 20 years, bamboo resources in China increased at an annual rate of 1.8%, the total area of bamboo forests expanded from 3.67million ha in 1980 to 5 million ha at present, and bamboo industry is playing more and more important role in poverty alleviation and economic development.

At present there are about 3,000 companies around the country engaged in the production of various bamboo based panels, bamboo flooring, bamboo pulping, bamboo charcoal, edible bamboo shoots, and other daily use articles.

In 2002 the production of bamboo based panels was over one million m^3, bamboo flooring 10 million m^2, bamboo shoots canned products 250,000tons.

Bamboo based panels are used for building floors, walls, ceilings, and interior decoration of houses and platforms for lorry and train carriages. Thin bamboo panels made by DASSO have been used for ceiling at Madrid International Airport Terminal in Spain.

Bamboo has been made into paper for hundreds of years. More recently paper mills have begun to make laser-printer and photo-copier standard paper out of bamboo. INBAR uses such paper for routine purposes and considers that it should have a bright future in western markets provided environmental standards are adhered to.

At present, China produces bamboo pulp about 200,000tons and imports pulp and paper valued 5 billion USD annually. Three big bamboo pulp and paper projects (one each in Shichun, Guangxi and Guizhou) were launched in recent years, with total new capacity of 520,000tons.

3. INBAR/WWF -SUSTAINABLE BUIDLING PROJECT

Bamboo has been used as a housing material for millennia. In Bangladesh for example the majority of the population live in bamboo houses. INBAR has had a continuing program in improving the quality of housing for all levels of society although it takes a particular interest in housing for the poor. INBAR is working with an Ecuadorian NGO "Hogar de Cristo" in developing an extremely cheap bamboo house for the poor , only $10/m^2 of floor area with total cost of $380 per house, and attempting to transfer the technology for hosing to India and China.

INBAR formed a partnership with WWF-China in March 2002 to see if the team of Dutch architects who had been involved in the design of energy-efficient houses in Holland could achieve the same results in China. The key concept of this project is to link energy savings technologies and the use of bamboo /bamboo panels as part of the building materials. Four concept designs have been completed: Dai Village House, Mengzi Town House, Jinghong Hotel and Pingbian School.

The Embassy of Japan in China has made a direct payment of 620,000RMB to the Pingbian Education Bureau to construct the Pingbian School. Main construction of the buildings will be concrete floors and concrete columns but bamboo beams will be used for roof trusses and bamboo panels for walls of the building. The construction of the school building will be completed by February 2004.

3. INBAR's new efforts to assist bamboo development in eastern African countries

Co-funded by the Common Fund for Commodities (CFC), INBAR and the Forest Resources Research Institute of Uganda, a Regional Workshop on Market based development with bamboo in Eastern Africa was held in Kampala, Uganda, July 2003. Participants of universities/research institutions/NGO from the four countries and representatives from CFC, FAO attended. Representative of Minister of Environment of Uganda and Mr. Philips, Uganda Ambassador to China presented the Opening of the Workshop.

Actionable recommendations were made on developing production and markets for bamboo products to improve livelihoods in Eastern African countries including Uganda, Ethiopia, Tanzania and Kenya. Draft CFC/INBAR Project proposal "Market based development with bamboo in Eastern Africa " was prepared.

Invited by Ministry of Agriculture of Ethiopia, INBAR expert team visited Ethiopia in July 2003 to make field trips of typical bamboo resources and discuss with relevant officers on utilization of these bamboo resources and identify cooperation areas with INBAR. The team met with Chinese Ambassador, Vice Agriculture Minister, Mayor of Addis Ababa, Vice Minister of Industry and Trade, President of Ethiopia Chamber of Commence, Investment Authority. The Team made a field trip to three regions(Beni Shangul,Gambela, Southern) covering 3000kms visited lowlands bamboo forests & highland bamboo forests, Bamboo Handicraft Training Centers, enterprises, Regional Bureau of Agriculture , Wondo Forestry College, Ethiopia Agricultural Research Organization, Tourist Trading Enterprise, etc. It has found that Bamboo is very important to Ethiopia. In the country the high forest coverage is only 2.7%, and still decreasing but bamboo resources is rich, possessing 67% of that of Africa, development of industrial utilization of bamboo would help to solve problems of housing and furniture shortage and provide more jobs opportunities.

There are two indigenous species of bamboo in Ethiopia i.e. the highland or African alpine bamboo (*Arundinaria alpina K. Schumach.)* and a monotypic genus, lowland bamboo (*Oxytenanthera abyssinica (A. Rich.) Munro.*

The highland bamboo. Total area: 30,000ha, in attitude 2200-3500m at temperature 10-20^{0}C with annual rain fall 1500-2500mm; 12-20m tall, 5-13cm diameter, internodes 30cm, wall 5-16mm thick with density (OD) 0.48g/cm^3, mature stand 5870culms/ha, average biomass of the culms amounts to 51.3 tons/ha, annual increment 1000 new culms, yielding 8.6tons/ha. Current uses: furniture, construction, fencing, and handicrafts.

The lowland bamboo. Total area: 800,000ha; distributed in attitude 700-1800m with annual fall more than 1500mm. Culms 6-16m tall, 6-10cm diameter, internodes 20cm, wall density 0.61g/cm^3. Per ha 8000 living culms plus 4000dead culms, average biomass of culms amounts to 70.3 tons/ha. The mean annual increment of oven dry culms is 10.1tons/ha. Current uses: construction, fencing, and furniture.

It may be important for Ethiopia:

-- To give priority to bamboo development in both national level and international cooperation, including bilateral cooperation with the China

-- To set up National Bamboo Development Office under Ministry of Agriculture for Coordinating R & D in bamboo to improve networking in bamboo sector and Preparing sustainable bamboo development plan at national level

The following suggestions were also made for consideration by Ethiopia authorities:

a）to develop Bamboo mat corrugated board. At present, Iron corrugated sheet is used as the major roof materials. It needs imports and is poor in heat and sound insulation properties. Bamboo mat corrugated board can be made from Ethiopia bamboo and would be better in heat and sound insulation properties and more cost effective. Comparing with iron sheet board ,plastic composite board and asbestos board, the bamboo mat corrugated board has the best heat and good sound isolation properties, the lowest density，but high water absorption rate.

b) Sustainable management of bamboo forests in Ethiopia.

c) Introduction of exotic and economic important bamboo specie to Ethiopia for bamboo production security, as there are only two indigenous species of bamboo in Ethiopia.

d) Establishment of a demonstration bamboo base near Addis Ababa.

It is our wish that from the common efforts including the said CFC/ INBAR project, big progress can be made in the promotion of bamboo for poverty alleviation and Economic Development in eastern African countries.

Technical Innovations to Increase the Competitive Capability of Bamboo Products

Jiang Changzheng

President of Shengda Wooden Products Co., 27th Floor, Gangdian Shibaida International Mansion, Chengdu, Sichuan Province 610016, P. R. China. Phone: +86-28 67888818. Fax: +86-28 6746269.
http://www.shengdawood.com

Dr. Yu Gang
Director of Shengda R&D Center

Abstracts: Deep processing and developing of bamboo have become a new economic growth point of Chinese forestry. Shengda is a professional company producing bamboo and wood floorings. R&D on bamboo flooring to increase the key competitive capability of bamboo products are conformed to our long-term developing strategy. The latest R&D of Shengda on bamboo products was discussed in this article.

Key words: bamboo, bamboo fiber, re-combined bamboo, bamboo flooring, antimicrobial, fiber reinforced plastics

1. FORWARD

Bamboo forest is the second forest in the world. China has an abundant source of bamboo which consists more than 80% of the total bamboo forest in the world. Along with the adjustment of Chinese forest policy, the execution of prohibition for cutting natural forest and returning cultivated land to forest (or grassland), the deep manufacturing and developing of bamboo have become a new economic growth point in Chinese forestry. Shengda is a professional company producing bamboo and wood floorings. As the execution of "integration of forest and board" project and successful construction of Shanghai bamboo products factory, R&D on bamboo flooring to increase the key competitive capability of bamboo products are now conformed to our long-term developing strategy.

Based on mention-above, this article will discuss and forecast the latest R&D on bamboo products in our company.

2. ANTIMICROBIAL BAMBOO FLOORING

At present, most of the decorative materials function in making beautiful and comfortable livings for people. However, some of them give out organic gases or radiation emissions, which do harms to people's health. The sustainable development, which emphasizes the harmony between life and environment, has become the focus of society today. People are requiring higher quality for the interior environment after decoration. Beautiful looking, safe and reliability, health and care are all within customers' concerns.

However, there are various microbes, including bacteria, fungi (mildews, microzymes and agarics) and algae etc. in natural environment. They are hardly seen by naked eyes, but they are the very important components of the natural livings. Some microbes play significant roles in keeping circulation of elements such as carbon, oxygen and nitrogen in the natural world. On the contrary, some microbes are the pathogenic microbes of human, animals and plants, can bring about a great threat against health of human beings. Consequently, to inhibit harmful microbes from growing and propagating or kill them is a very important problem to be paid attention in scientific field as well as common people.

Unfortunately, while people are busy building a comfortable living space with warm in winter and cool in summer, however that also offers advantageous conditions for microbes to grow and propagate simultaneously, due to bamboo is the natural host for some parasites. Usually bamboo's growth age is 4-6 years (shorter than wood), and have plenty of live thin-wall cell and cell solutes, so the distillates of bamboo(mostly are starch, balata, amino acid, fatty acid，water-dissolvable color matter, inorganic salt and so on, which consists about 5-10% of the dry material's weight) is much more than that of wood (about 1.5-2 times of wood), which can supply abundant nutrition for aphids, mildews and spores of fungi to grow and propagate (the most common fungi in bamboo are aspergillus, penicillium and cladosporium). In addition, because bamboo is lack of phenolic compounds, so its natural antimicrobial capability is not as good as wood, especially for those new cut or half dry bamboo, and bamboo products using in moist environment, which are easy to be moth-eaten, mildewed and corrupted. So that, the performances of bamboo and its products will go bad (Being moth-eaten and corrupting cause decrease of physical strength or even make the products useless; mildewing, which causes the stain on the surface, will strongly affect the external appearance).

As for bamboo flooring, since our country located in subtropical zone with warm and rainy climate at most of the areas, especially have continual high temperature and moist days in summer or season of plum rains, during the process of bamboo's hag, transportation, manufacturing and using, it is very likely for bamboo to be moth-eaten, mildewed and corrupted. This is an important factor that restricts the development of bamboo flooring industry.

On the other hand, people frequently contact with the floorings in daily life, harmful microbes could be easily bred and spread on flooring, and thus threaten the health of people.

The property to inhibit microbe from growing and propagating is called microbe-inhibition, to kill the microbe or close the state of microbe free is called microbe-killing. The property, which has the characters of microbe-inhibition and/or microbe-killing is defined as microbe-resistance, which means bacteria-resistance and fungi-resistance, the latter can also be named mildewproof. Microbe-resistance is different from sterilization; the latter means can kill all of microbes absolutely.

Nowadays the bamboo flooring prevails in international market does not have the function of microbe-resistance. Although the high temperature carbonization can kill the insect and improve the protection of bamboo material, this method still can not eradicate the fungi and can deepen the natural color of bamboo. In fact, mildewing phenomenon is also found in bamboo flooring treated with high temperature carbonization (the mildew grows from the interior of bamboo strip to its surface, it can clearly be seen through the transparent paint coated on the surface of bamboo flooring), which will greatly affect the external appearance of bamboo products.

Considering the deficiency of technology and application in bamboo flooring industry of China, we use nanotechnology to explore the antimicrobial bamboo flooring based on our successful experience in antimicrobial laminated flooring.

We aim three aspects:

1) To prevent the performances of bamboo flooring become bad caused by moth-eating, mildewing and fungi-eroding;

2) To inhibit and/or even kill harmful bacteria on flooring surface, keep safe and healthy life surroundings;

3) To supply various products of good quality for our company－USP, unique sales point.

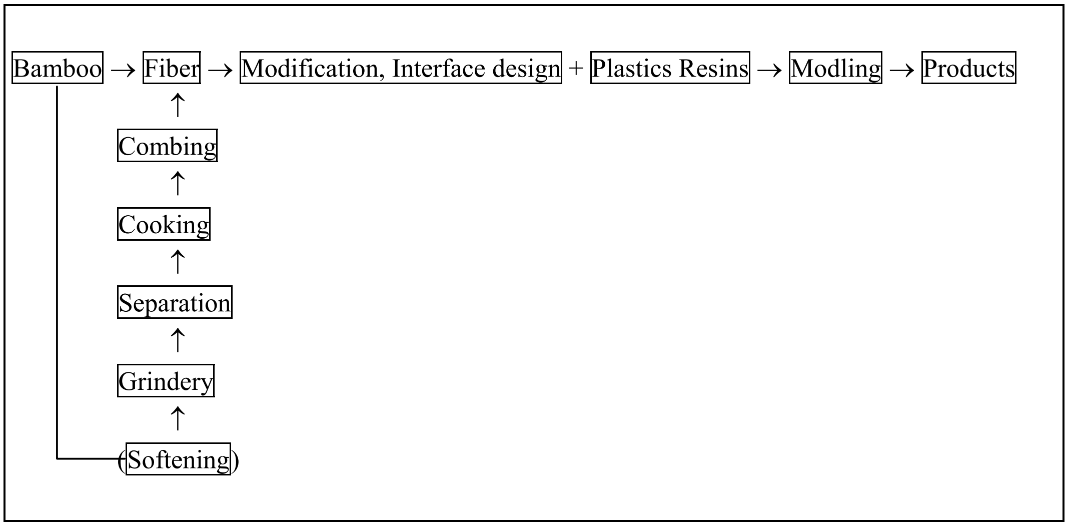
Comparing with traditional physical and chemical treatment methods, nano- antimicrobial-technology is high effective, broad-spectrum, long-term and safe, can also avoid the color change of bamboo and negative effect to human and environment.

3. HIGH PERFORMANCES BAMBOO FIBER REINFORCED PLASTICS (FRP)

It is well known that the composites of glass fiber reinforced plastics are widely used in various fields of national economy. From the point of environmental harmonicity view, using natural resources to develop FRP which is beneficial for environment has become the focus in R&D field of composites.

Our country has a long history of using bamboo as building materials. Among the natural fiber materials, bamboo is one resource with very high productive rate. The tensile strength of bamboo fiber is slight less than glass fiber, but the strength ratio and modulus ratio of bamboo fiber could be the same as or even over the glass fiber. Thus, we could name the fiber separated from bamboo as "natural glass fiber", and use it to product high quality floorings with environment friendly.

The manufacturing processing of bamboo FRP is as following:



In the production of bamboo FPR, the processing of surface treatment or interface design plays a very important role. According to the forms of bamboo fibers (the ratios of length to diameter) and the types of resins (thermosetting adhesives, thermoplasts), the molding methods including molding press, extrusion and injection could be used. It should be noticed that as a special natural material with fine structure, bamboo fiber contains plenty of water inside, special molding technology should be used, especially the rheological property of bamboo FRP should be tested.

The flooring or decorative board made from bamboo FRP can still maintain the natural texture of bamboo. Meanwhile, since the tiny hole structure of bamboo fiber, the properties of impact resistance and sound absorption are outstanding. In addition, due to the bamboo fiber can be modified with various physic and chemical methods conveniently, some new functions (microbe-resistant, waterproof, size stable, abrasion resistant, fireproof, heat conductive, etc.) could be added on common bamboo flooring. Therefore, the windows of design and manufacture for bamboo products could be expanded.

4. RE-COMBINED BABMBOO

Re-combined bamboo timber is a new type of bamboo material, made with re-combined fasciculi of inferior bamboo materials (such as branches and small diameter bamboo) through the processing of applying glue, base assembly and heating press. The fasciculi of bamboo are processed into the forms of continuum in horizontal orientation, incompactness in vertical orientation and cross each other by grinding equipment, so that the re-combined bamboo products have high strength, large scale in size and natural texture structure of bamboo.

What should be pointed is that above processing is based on the precondition of keeping the basic characters of bamboo and no distorting the fiber arranging. By this way, the using rate of bamboo is up to 90%, which is 50 to 70% higher than common bamboo flooring technology. The mechanical properties of re-combined bamboo products are much superior to common bamboo products.

Re-combined bamboo technology is no longer subject to traditional cutting method. Being the excellent character of post-mechanics processing, size and density can be customized to individual demand, it has practical prospect applied on bamboo flooring and bamboo-wood assembled flooring. For example, bamboo flooring made with re-combined bamboo technology is of the advantages of more size stable and no binding gap caused by the combination of bamboo strips. While the veneer made from re-combined bamboo timber can be used as surface decorative material of bamboo-wood assembled flooring.

Technology of pigmentation of bamboo strips by carbonizing and dyeing treatment

Manhua Xie
Beijing Forestry University, College of Material Science and Technology, Beijing100083, P. R. China.
E-mail：xiemanhua77@sohu.com

Guangjie Zhao
Beijing Forestry University, Material Science & Technology College. vice director, Male，Doctor, wood science professor, doctor tutor, phone：01062329685 E-mail：zhaogjws@263.net

Abstract: In order to show the advantage of bamboo acting as decorative material best, it is necessary to settle some problems existing in surface treatment when bamboo act as decorative material, and to seek a kind of environment-protective, nontoxic and new technology of making bamboo to be a sort of excellent decorative material, which can both avoid mildew and fungus and improve the surface character of bamboo. The paper discussed the surface character of pigmentation bamboo strips by carbonizing and dyeing treatment. The results indicate that the technology of pigmentation of bamboo strips by carbonizing and dyeing treatment is the primary technology of making bamboo products become environmental-friendly, nontoxic first-rate surface decorative material.

Key Words: Bamboo Strips, Carbonization, Dye, Pigmentation Treatment

1. INTRODUCTION

Bamboo is a kind of nicer ecological material. Besides, it can act as a very good decorative material because of its compact structure, warm and smoothly feel and clear grain. However, starch, sugar and protein inside bamboo are all more than wood, and most of fiber tissues array longitudinally, thus bamboo more easily suffers all kinds of mildew. But, the mildew-resistant treatment of bamboo is not solved thoroughly yet, especially the low-poison and long-effect mildew-resistant treatment technology is not still broken through, which will affect greatly the advantage of bamboo acting as a decorative material. Furthermore, fresh bamboo's color and luster is beautiful and bright, but the luster will lost gradually by a long period and even the color will change too[1]. Therefore, seeking a kind of environment-protective, nontoxic, both mildew-resistant and fungus-resistant and surface character- improving new technology, which can make bamboo become a sort of high-quality surface decorative material, is extremely important.

The paper performed pigmentation treatment of bamboo strips by carbonizing and dyeing, and discussed the color and surface character of carbonized and dyed bamboo strips

2. EXPERIMENT

2．1 Materials

These experimental specimens were air dry mao bamboo strips peeled off blueness and bleached, which were provided by Cibi city in Hubei province with the original moisture content of 9%. The dimension of the specimens was 110（length）×7（width）×2（thickness）mm or 230（length）×10（width）×3（thickness）mm.

2．2　carbonizing treatment experiment

The air dry specimens were placed directly in constant temperature drier side by side, and then carbonized under different temperature and time.

2．3 dyeing experiment

The specimens were put into dye solutions with different mix ratio and concentration, then were placed in the water boiler with constant temperature. The diverse dyeing effects were mainly obtained by adjusting the ratio of mixture dyes, concentration, temperature and time, etc.

3．RESULTS AND DISCUSSION

3．1 The surface character of carbonized bamboo strips

Figure1 is for untreated bamboo strips, and from figure2 to figure13 are carbonized bamboo strips under different condition. From these figures, we can see that the color of bamboo strips all changed at some extent after carbonizing treatment. Uncarbonized bamboo strips'surface is glabrous and smoothness, and the color and luster is bright and natural. However, generally for carbonized bamboo strips, the color is deep, elegant, simple and unsophisticated, and the clear bamboo grain can still be sawn (figure5,6,7,13). Figure2 and figure4'colors incline to red, and show bright and vivid, so the vision effect is excellent. Figure3 shows orange-yellow, it can show the noble and elegant flavor if as a decorative material. From figure5 to figure8, only the carbonization temperature is different, all the other treatment condition is the same, and yet the surface character show great difference and the color'deep degree is distinct too. And figure6 show deeper color and bigger chromatism(figure14) with higher carbonizing temperature. Figure7 and figure8 have almost the same chromatism(figure14) since their carbonizing temperature is uniform. However, among figure 9(a,b,c,d), the carbonizing conditions are completely uniform,but their surface character also show greater difference. Some color is deeper, some is lighter, and the surface isn't primely glabrous either and even exist white smear. The former is because of the difference of bamboo strips in

Figure 1　uncarbonized bamboo strips

Figure2 carbonization（一）

Figure3 carbonization（二）

Figure4 carbonization（三）

themselves, such as the difference in color deep due to the age, or the changes in color of bamboo as a result of insect and mildew. The later is owing to no going surface treatment before carbonization. This is because the bamboo strips bleached weren't cleaned out very well when bleach was finishing, and some bleacher still exist in the surface of bamboo strips. They didn't show up under air dry until carbonized, since the bleacher do not react in the course of carbonizing. Thereby, the carbonized treatment of bamboo strips is related with the quality and the surface character of bamboo itself. Figure10 and figure11 is with the same carbonization temperature, but different carbonization time. We see that the carbonized color is different. From the chromatism figure14, it can be known that the chromatism of the later is much bigger than the former. So the longer carbonization time is, the bigger the chromatism is, and the deeper the color is. Figure12 and figure13 is of the uniform carbonization time and temperature, only the bamboo strips of figure13 went through surface coating before carbonization. It can be seen that the surface effect is also

Figure5 carbonization（四）

Figure6 carbonization（五）

Figure7 carbonization（六）

Figure8 carbonization（七）

a

b

c

d

Figure9　carbonization（八）

Figure10　carbonization（九）

Figure11 carbonization（十）

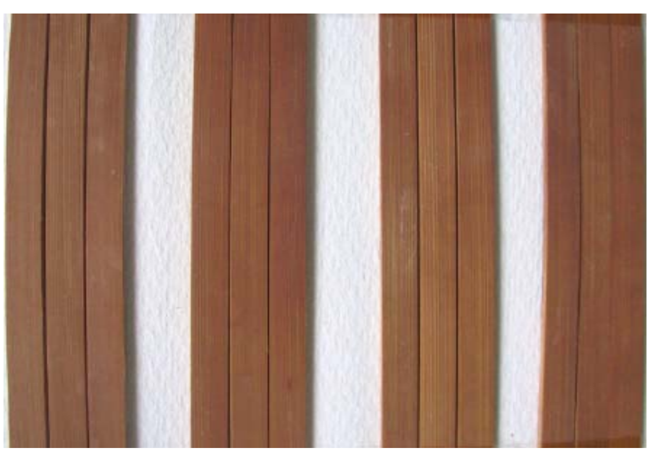


Figure12　carbonization（十一）

Figure13　carbonization（十二）

different, the later has more clear bamboo grain, but its visual aesthetic feeling is less than the former. In conclusion, the surface character of carbonized bamboo is related to carbonization temperature, time, the original surface quality and bamboo itself. Figure14 is the chromatism of all carbonized bamboo strips, which was measured at the standard of uncarbonized bamboo strips (figure1).

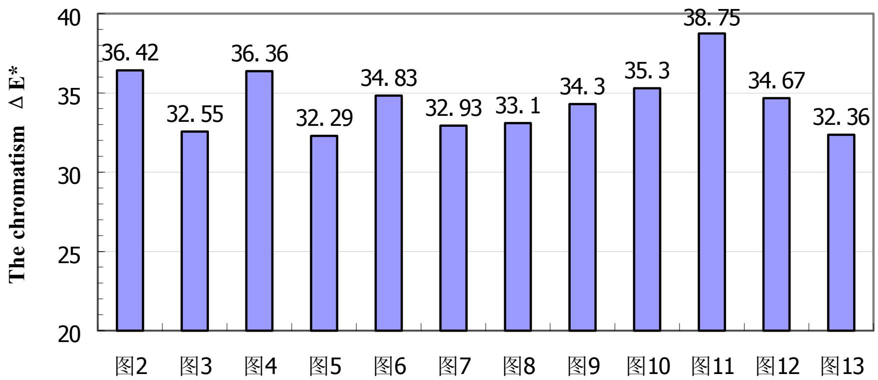


Figure 14 The chromatism of carbonized bamboo strips

3.2 The surface character of dyed bamboo strips

Figure16 is undyed bamboo strips, and the other figures are all for dyed bamboo strips. Figure15 show 30 pieces of bamboo strips with different dye proportion and dyeing technics, and the writing in them is carved by laser after dyeing. From the figures it can be seen that there are several asymmetric phenomena. Except for the surface quality of bamboo strips, it is chiefly since that these bamboo strips floated in the surface of dye solution during dyeing, so that the surface above dyed asymmetrically . Besides, though the gain of dyed bamboo strips isn't the same clear as the undyed bamboo strips, dyeing may properly cover up the surface defect of bamboo strips themselves, such as the color changes arose by insect and mildew. In addition, we can gained abundant colors by way of adjusting the dye proportion and dyeing technics，thus it may offer a larger stage for bamboo acting as decorative materials, and at the same, it can beautify the home living of people best.

Figure 15　The dyed bamboo strips by all kinds of dye solutions

Figure16

Figure17

Figure18

Figure19

Figure20

Figure21

Figure22

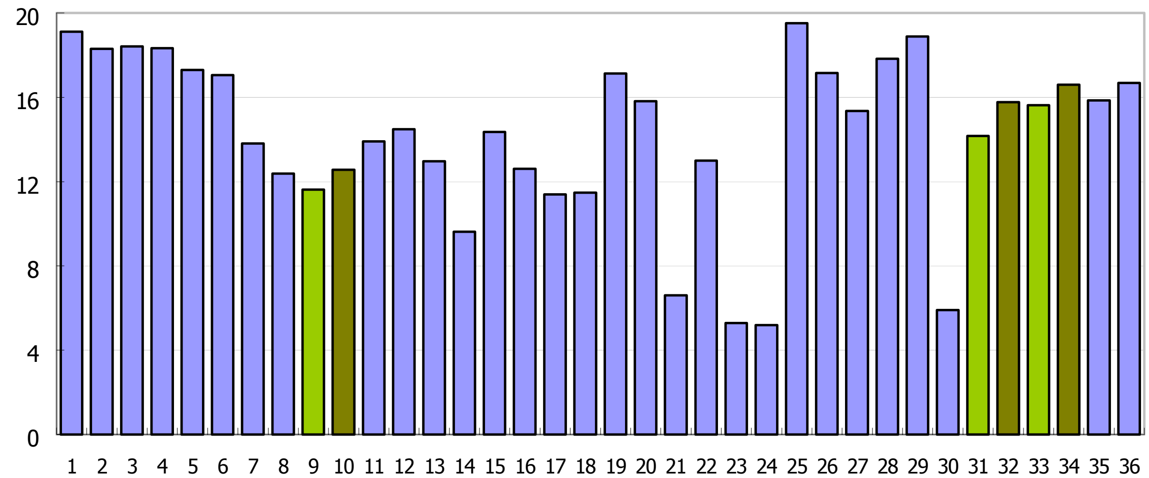


Figure 23 The chromatism of all dyed and undyed bamboo strips

Figure17 (number 31) and figure19(number 33) are of the same dye proportion with number 9 in figure15. Nevertheless, the number 31 bamboo strip has higher dyeing temperature and longer dyeing time than the number 9. Moreover , additive(NaCl) is added to the number 33 bamboo strip during dyeing, but it has a little lower dyeing temperature than the number9, and has the same dyeing time. Figure23 show that the chromatism of the number 31 bamboo strip is bigger than the number 9, and that of the number 33 is bigger than the number 31 again. Figure18(number 32) , figure20(number 34) and the number 10 bamboo strip is another group going simultaneously, it also show the same result(in figure23). So it is obvious that additive has greater influence on dyeing, except for dyeing temperature and dyeing time.

The significance of the processing and use of bamboo, especially the middle, small diameter bamboo, will be greater for the future**.** For decorative material, it doesn't need good mechanical capability, the most important is the fine appearance[2]. The surface quality of bamboo can be improved and all kinds of color can be achived by carbonizing and dyeing treatment. At the same time, the two sorts of technical products all accord with the idea of environmental-friendliness of modern people, namely nontoxic and hurtless to the health of people. So they are good environmental-friendly products. In a word, carbonization and dye is the key technique of making the bamboo products become high grade products.

4．CONCLUSION

（1） The surface character of carbonized bamboo strips is related with carbonizing temperature time, surface quality of bamboo strips before carbonization and age of bamboo. In general, the carbonizing temperature is higher, the time is longer, and then the chromatism is bigger. The older bamboo is, the more deep the carbonized color is if under the same carbonization condition.

（2） The surface character of dyed bamboo strips is related with dye proportion and dyeing technics. The concentration is bigger, temperature is higher, the dyeing time is longer, then the dyed color is much deeper and the chromatism is bigger.

（3） The surface grain of carbonized bamboo strips is still clear and seeable, smooth and glabrous. Carbonized bamboo strips can better show the feeling of reality than dyed bamboo strips. But for dyed bamboo strips, some inherent surface flaw is concealed, such as the color changes arose by insect and mildew.

References

1． Qisheng Zhang, Fengsheng Sun. The development prospect of bamboo industry in china. China forest products industry, 4(26)3～5,1999.
2． Yonglin Yan. The design of machine for peeling off green of bamboo. Forest machine and wood processing equipment,2(28):16～17,2000.

Bamboo in construction
-Status and potential

Lionel Jayanetti
Head of TRADA International

TRADA International, Stocking Lane, Hughenden Valley, High Wycombe Buckinghamshire HP14 4ND, U.K. Phone: +44-1494 569619 /563091. Fax: +44-1494 565487. E-mail: ljayanetti@trada.co.uk

1. INTRODUCTION

Bamboo is a well established cultural feature of many regions throughout the world. Its diversity and versatility are well documented - some 1250 species and 1500 traditional applications have been identified. Notably, the main users are the rural poor, and perhaps for this reason it has largely been taken for granted by the wider community. As such, bamboo has not received the mainstream recognition it deserves as a material resource.

Bamboo is the fastest growing woody plant on the planet, but it actually belongs to the grass family. Most species produce mature fibre in about 3 years, much faster than any tree species. Some species grow up to one metre a day, with the majority reaching a height of 30 metres or more.

Bamboo has exemplary 'green' credentials. It is adaptable to most climatic conditions and soil types, acting as an effective carbon sink and helping to counter the greenhouse effect. It is finding increasing use in land stabilisation, to check erosion and conserve soil. It can be grown quickly and easily – even on degraded land - and harvested sustainably on 3 to 5 year rotation. Bamboo is a truly renewable, environmentally friendly material

The bulk of bamboo is gathered from the wild or rural environment. However, in many areas bamboo resources have dwindled due to overexploitation and poor management, and this issue needs to be addressed through well organised and managed cultivation if bamboo utilisation is to develop on a sustainable basis. Plantations are already being raised in China and India to support the pulp and paper industry.

Plantation technology for large-scale cultivation of bamboo is known - standard practices have been developed with culm cuttings and tissue culture is gaining acceptance. National afforestation programmes can therefore be implemented to meet future demand. Furthermore, improved technologies for raising plantations of bamboo in degraded areas, on logged over forest and in agro-forestry initiatives can be achieved through further research into biodiversity, species selection and genetic improvement.

One billion people live in bamboo houses worldwide. For the most part they are low grade, impermanent buildings, which belies the material properties of bamboo and does little to promote its image as a viable construction material. At little extra cost, these buildings can be upgraded to provide safe, secure and durable shelter, benefiting the most vulnerable members of society.

Perhaps the major factor contributing to the view of bamboo as a temporary material is its lack of natural durability. Bamboo is susceptible to attack by insects and fungi, and its service life may be as low as one year when in ground contact. However, the durability of bamboo can be greatly enhanced by appropriate specification and design, and by the careful use of safe and environmentally friendly preservatives such as boron.

The main structural advantages of bamboo – its strength and light weight - mean that properly constructed bamboo buildings are inherently resistant to wind and earthquake forces. These properties can be effectively exploited through careful yet simple design and detailing.

Even when issues of durability and strength are resolved, the question of acceptability remains. A bamboo building need not look ‘low-cost’, nor need it necessarily look like bamboo! Imaginative design and the use of other locally available materials within the cultural context can make the building desirable rather than just acceptable.

2. BAMBOO – THE INTERNATIONAL VIEW

Bamboo has a long history as a building material. It is widely used in construction throughout the world’s tropical and sub-tropical regions, with a range of applications to match or even exceed those of timber. In Central and South America, bamboo buildings of every description can be found - from low-grade temporary shanties to exclusive, architect designed mansions.

Bamboo houses for the wealthy, Colombia

Bamboo products for use in construction are increasing in availability. These range from bamboo mat boards (flat and corrugated), through more sophisticated panel products such as fibreboard, ‘plyboo’ and flooring, to large laminated sections (currently under development) for use in external joinery.

Corrugated bamboo matboard (IPIRTI, India) and laminated bamboo flooring

Bamboo use is not restricted to building. Bamboo has been used as concrete reinforcement, and development work is continuing in this field. Bamboo is used for light traffic bridges, and the feasibility of constructing large span bridges carrying vehicular traffic has recently been demonstrated in Colombia. Bamboo as scaffolding is well known (40 storey construction is not uncommon in the Far East), and its use is set to increase as a result of the development of a design and erection guide in Hong Kong.

20m footbridge and 52m bamboo road bridge, Colombia

Bamboo scaffolding, Hong Kong

Other construction applications include ground stabilisation, through the use of retaining walls and piling, and coastal protection (recently trialled in Sri Lanka).

Bamboo retaining wall and bamboo-based erosion control system

3. BAMBOO –TRADA'S EXPERIENCE

TRADA has just completed the first phase of a project in India to develop and promote a cost-effective bamboo based building system. The project is designed to provide safe, secure and durable shelter at a cost that is within reach of even the poorest communities in developing countries.

The project has demonstrated that with careful specification, detailing and environment-friendly preservation, the life of bamboo can be extended to match that of other building materials. Prototype testing has been employed to provide an effective and visual demonstration of the performance and strength of components and assemblies, and the resistance of walls and roofs to wind, earthquake and impact forces.

A building system has been developed based around an integrated, resilient bamboo skeleton. Wire ties, bolts and straps ensure the entire framework is positively connected to become a single, composite unit. When cement mortar is applied to the walls, they become very strong but still retain their lightness and resilience. These characteristics make the construction inherently resistant to earthquake forces.

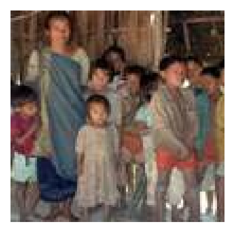
$20m^2$ bamboo house

The bamboo building system is sustainable and cost-effective. It is also simple to erect, strong and durable. As such, it incorporates all the essential requirements for affordable shelter. Moreover, the basic system can be enhanced through improved use of shape, space and colour at little or no extra cost. Overall, the system effectively demonstrates that desirability and quality are fully compatible with affordability.

$90m^2$ bamboo house

For the second phase, the project will be extended to Bangladesh and Sri Lanka, and the technology will be applied in the development of designs for larger community buildings such as schools and health clinics. In addition, the use of bamboo for the construction of footbridges in rural areas will also be investigated, with development and testing of prototypes.

4. FUTURE POTENTIAL



Taking into account all that bamboo has to offer, it is well placed to address four major global challenges:

4.1 Shelter security, through the provision of safe, secure, durable, affordable housing and community buildings.

4.2 Livelihood security, through generation of employment in planting, primary and secondary processing, construction, furniture and the manufacture of high value-added products.

4.3 Ecological security, by conservation of natural forests through substitution of primary timber species, as an efficient carbon sink, and as an alternative to non-biodegradable and high embodied energy materials such as plastics and metals.

4.4 Sustainable food security through agro-forestry systems, by maintaining the fertility of adjoining agricultural lands, control of erosion and, in the case of bamboo, as a direct food source.

The challenge now is how to share this knowledge – to bring it to the attention of a wider audience and demonstrate that the new technologies are equally viable in areas which have not had exposure to the "new thinking". Above all, to deliver the benefits it promises to the poorest members of society.

5. FUTURE REQUIREMENTS

5.1 Sustainable supply

A policy of organised planting, careful management of plantations and natural stands, and appropriate regulation of supply are prerequisites to any other interventions aimed at promoting bamboo as a building material.




5.2 Standardisation

The lack of guidance on the use of bamboo in building has been a major obstacle to its wider adoption. A recently drafted international standard is the first step to addressing this problem, and new or amended national regulatory instruments such as manuals, codes of practice, specifications, building regulations and standards are now required.

5.3 Research and extension activities

The will must exist at government level to explore the potential of alternative materials, and to put in place the resources and mechanisms to carry out the necessary material developments and evaluations. Where this capacity already exists, it is often necessary to reorient the approach of research institutions to link them directly with the building industry, together with their government and private sector clients.

5.4 Training

Curriculum revision is required to give greater emphasis to the new technologies. This would apply to institutions training high level artisans or technicians for the construction industry, as well as professionals such as architects, building technologists, civil, structural and mechanical engineers, and quantity surveyors.

5.5 Fiscal policy

Financial incentives are required to encourage the establishment and support of industries involved with the new technologies. In addition, the widespread policy which limits the advance of bank loans and mortgage on ‘bamboo’ houses must be reviewed.

5.6 Demonstration and quality

Effective dissemination aimed at popularising the new technologies is vital considering the negative perceptions held by many about bamboo in building. Even when issues of durability and strength are resolved, the question of acceptability remains. Bamboo buildings need not look ‘low-cost’, nor need they necessarily look like the materials from which they are made! Imaginative design and the use of other locally available materials within the cultural context can make the building desirable rather than just acceptable.

The construction of model buildings is therefore essential to overcome prejudice and boost the confidence of specifiers and users. In this regard the quality must be of the highest level achievable, since any shortcomings in the standard of construction, detailing and finish will be reflected, unfairly, on the building system as a whole.

Bamboo, a sustainable building material in Western Europe

Ir. Pablo van der Lugt

Graduated (masters) February 2003, Faculty of Architecture, Delft University of Technology, The Netherlands. Email: Pablovanderlugt@hotmail.com

Ir. Andy van den Dobbelsteen

Department of Building Engineering, Faculty of Civil Engineering and Geosciences, Delft University of Technology, PO Box 5048, 2600 GA Delft, The Netherlands. Tel: +31.15-2783563, Fax: +31.15-2781560, email: Andy.vandendobbelsteen@citg.tudelft.nl

Dr. Jules Janssen

Department of B-CO, Eindhoven University of Technology, PO Box 513, 5600 MB, Eindhoven, The Netherlands, Tel: +31 40 247 2948. Email: j.j.a.janssen@bwk.tue.nl

1. INTRODUCTION

In the building industry, the selection of a building material is mainly determined through its costs and durability. However, with sustainability as a key issue in the last decades, especially in western countries, the environmental performance of building materials has also become a more important criterion. Bamboo, as a fast growing renewable material with a simple production process, is expected to be a sustainable alternative for more traditional materials like concrete, steel and timber. Indeed, in many publications (e.g. EBF, 2002; Dethier, 2000; Kries, 2000) bamboo is qualified as a very sustainable material. However, this has never quantitatively been proven. The environmental impact of many building materials has already been assessed using an international (ISO) approved method, LCA (Life Cycle Assessment). In the study presented (Lugt, 2003) an LCA was conducted for bamboo, in its original form (the culm) and in an industrial product application (a wall panel).

2. RESEARCH OBJECTIVES

The first research objective of the study presented was:

- Gaining more insight into the environmental performance of bamboo (products) compared to building materials more commonly used in Western Europe.

For this objective, the following research question needed to be answered:

- What is the environmental impact of bamboo (products) in Western Europe compared to building materials more commonly used?

2.1 Restrictions

The following bamboo products were environmentally assessed:

- Air-dried culms of the bamboo species *Guadua angustifolia*, as produced during the National Bamboo Project in Costa Rica, based on use (including transport) in the Netherlands. Initially, an Asian bamboo species, *Phyllostachus pubescens*, would also be assessed. However, due to communication problems and lack of data this could eventually not be executed.
- Bamboo panels (*Plyboo* natural plain-pressed two-layered bamboo panel) produced in Shanghai (China) based on use in the Netherlands, used as cover for inner walls.

2.2 Research method

Data of the production process of both the bamboo culm and panel were retrieved by interviews with experts involved in the production process and literature study. The data were processed in the TWIN^{2002} model (NIBE, 2003), based on the LCA-methodology, by experts from the Dutch consulting company NIBE.

3. ENVIRONMENTAL ASSESSMENT OF BAMBOO

In 1990, Speth and Ehrlich & Ehrlich argued that in order to achieve sustainable development[1] in the future the pressure on the environment should be reduced by factor 20. This target has been adopted by many organisations and societies. One of the ways to achieve factor 20 environmental improvement in the building industry is using more sustainable and renewable materials.

3.1 Introduction LCA

Life Cycle Assessment (LCA) is the commonly acknowledged basis for environmental assessment of products. Principally, in an LCA all environmental effects occurring during the life cycle of a (building) product are analysed, from the extraction of resources until the end phase of demolition or recycling (‘from cradle till grave’). LCA was first developed in 1992 (Heijungs, 1992). Since then it has evolved to an international accepted ISO-certified method (ISO 14041).

The standard LCA includes environmental effects that can be quantified; some effects (e.g. ‘deterioration of eco-systems') are ignored until a generally accepted assessment method has been developed. Moreover, the standard LCA provides an outcome of different effect scores; a weighing method is not included and an overall judgement of products is therefore not possible. In order to obtain a single score and enable comparison of products, additional models are necessary. At present, many of these models are available, each one having advantages and disadvantages. The validity of these models is always subject to discussion, mainly about the applied weighing method (Dobbelsteen, 2002). The TWIN^{2002} model, developed by NIBE (2003), was chosen for the environmental assessment of bamboo and its alternatives. This model is based on the latest version of the LCA-method and includes estimative methods for environmental effects that a 'pure' LCA lacks. Furthermore, TWIN^{2002} adds a weighing methodology based on the principle of environmental costs: fictitious societal costs (monetary factors) connected to the prevention of environmental damage by certain interventions (e.g. emissions). The advantage of working with environmental costs, or eco-costs (Vogtländer, 2001), is the absence of a subjective weighing; the difficulty is the exact determination of monetary factors. TWIN^{2002} includes the latest LCA data and environmental costs of building products.

3.2 Nuances

A couple of uncertainties are attached to environmental assessments, as by means of LCA. The reliability of some of the used data is also debatable. In order to compensate for this, the environmental assessment of bamboo took place following a *worst case scenario*. Moreover, some environmental aspects that could be favourable to bamboo, like the annual production of biomass of a bamboo plantation (which is 3 times as great as for the average timber productive forest, see Table 1), were not included in the assessment.

Table 1 Annual production of plantations for producing wood and bamboo (Janssen, 2002; Sundquist, 2002)

Annual production (tons/ha)				
	green (total)	dry (total)	green (only culm)	dry (only culm)
bamboo	78,3	47,4	55,7	36,0
wood	17,5	13,5	14,0	10,8
Ratio bamboo/wood	4,5	3,5	4,0	3,3

[1] Development that provides in the needs of the current generations without threatening provision of the needs of future generations (Brundtland, 1987))

Furthermore, the environmental assessment was based on the use of bamboo (products) in the Netherlands. When used in the country that produces the bamboo (in this case Costa Rica), the environmental costs of bamboo will be considerably lower due to absence of sea transport.

3.3 Functional unit

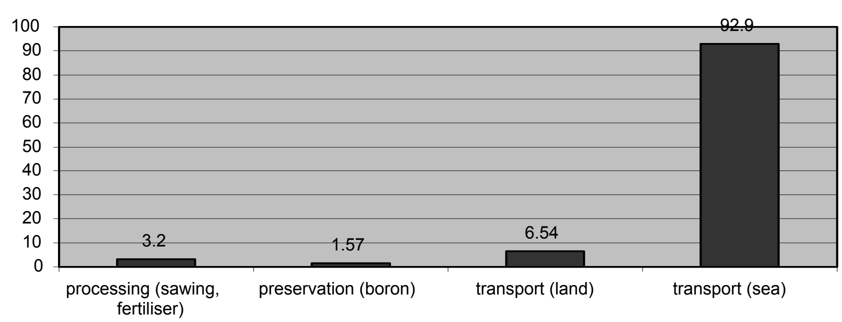
In the study presented, bamboo in its natural form (culm) and in an industrial form (panel) were environmentally assessed. Before an environmental assessment can be executed, a general basis for the alternatives compared needs to be defined. This basis is called the 'functional unit' (Arets, Dobbelsteen, 2002). For a correct comparison, the functional unit is of vital importance: measurements of the alternatives are determined by its technical and functional requirements (e.g. strength and stiffness). It means that weaker alternatives require more material, and that alternatives with a shorter life span need to be maintained or replaced more often (both leading to higher annual environmental costs).
For the bamboo culm, the chosen functional unit was a column, beam and rail as used in the walking bridge in the 'Cherry blossom garden' in the Amsterdam Woods (see Figure 1), each one with its original technical requirements. Bamboo was compared with the building materials most commonly used in this application: steel, sustainably produced wood (species: *azobé* and *robinia*), and concrete. Concrete was only assessed in the function as column because concrete is not normally used as a line element like the other functions and therefore incomparable.

Figure 1 Bamboo bridge in the Amsterdam Woods (photo: Pablo van der Lugt)

3.4 Results

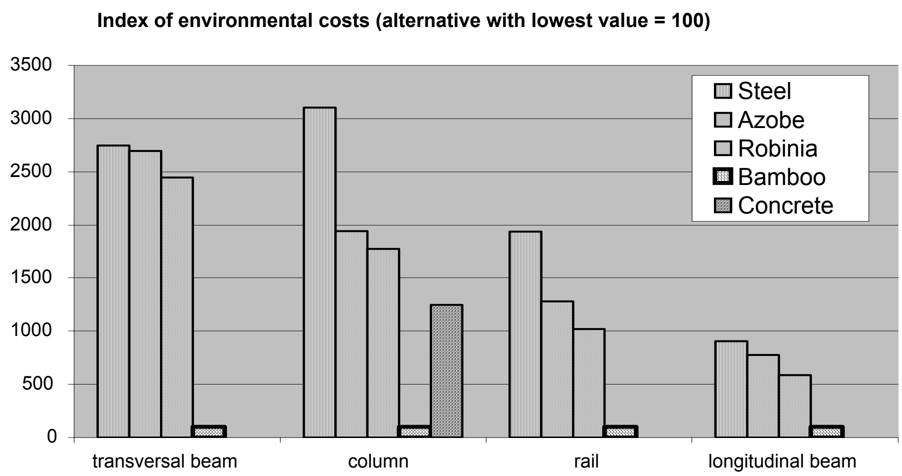
In order to obtain the environmental score of bamboo, all steps in the production process and life span of the bamboo culm needed to be analysed. For instance, for the culm this meant analysing the amount of boron used in preservation using the *Boucherie method* (Janssen, 2000), the amount of gasoline used for the chainsaws, the number of kilometres of transport, etc. After processing these data in the TWIN^{2002} model, the environmental costs of 1 kg bamboo culm over the production process could be analysed (see Figure 2, an adaptation of the original output). The results are given in micro-points (mPt), equal to environmental euros (e€). Figure 2 shows that almost all environmental costs originate from the (sea) transport from Costa Rica to the Netherlands.

Figure 2 Environmental costs (in mPt) of 1 kg bamboo culm including transport to the Netherlands per part of the production process.



In order to obtain the annual environmental costs, the environmental costs of each alternative (bamboo, wood, steel, and concrete) were divided by the life span. Also other aspects (e.g. the amount of waste, recycling of the material) needed to be integrated in the assessment. Figure 3 presents the final results. Note that the numbers are not absolute environmental costs, however represent an index. For the index, the score of the alternative with the lowest environmental impact (in all cases: bamboo) was divided by the score of the alternative compared.

Figure 3 Index of the annual environmental costs of the different elements of the bamboo bridge in the Amsterdam Woods.



The graphic of Figure 3 demonstrates that the bamboo culm, even when used in Western Europe, can be considered the most sustainable alternative by far in all functions. In some applications the earlier mentioned factor 20 'environmental improvement' is achieved. The difference in environmental performance of the longitudinal beam and the transversal beam is due to the fact that four bamboo beams instead of one are needed for the longitudinal beam to bear the loads. Note that the assessed timber species are sustainably produced, timber from regular, non-sustainable woods will have an environmental impact considerably worse (NIBE, 2003).

The good environmental performance of the bamboo culm has two distinct causes. First, its natural hollow design is structurally far more efficient than a rectangular massive section e.g. in case of timber (Janssen, 2000). This means that bamboo contains far less material mass in a certain function, compared to steel, concrete, and timber. The second cause is the simple, short production process (sawing, removal of branches, preservation, drying). Note that the assessed bamboo culm is dried in the open air without the use of a drying chamber (which would cost relatively more energy).

4. ENVIRONMENTAL COSTS OF THE BAMBOO PANEL

As an industrial bamboo product example, a bamboo panel was also assessed by environmental criteria using $TWIN^{2002}$. Bamboo panels are mainly used as parquet but can also be used in other applications like veneer or covering material. In the study presented the panel was compared with wood-based panels, applied as non-bearing internal wall covering.

Just as for the bamboo culm, the complete production process with corresponding environmental effects was analysed for the bamboo panel. However, the production process of the panel is far more complex. The bamboo culm needs to be sawn, smoothed, bleached, sandpapered, glued, pressed, etc., in order to obtain the required characteristics. Therefore, the environmental costs of 1 kg of bamboo panel are considerably higher than those of the culm. Figure 4 shows that the bleaching and preserving process by means of H_2O_2 has a great share in the environmental impact of this product. Again, (sea) transport has a great share in the total environmental impact of this bamboo product.

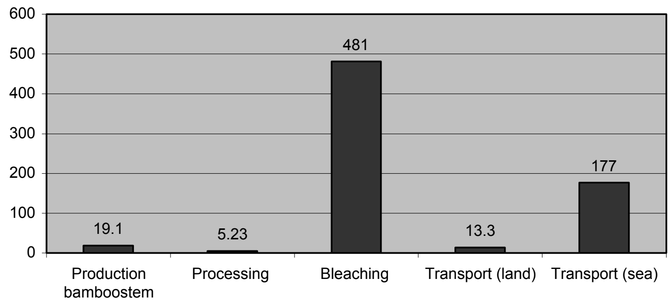


Figure 4 Environmental costs (in mPt) of 1 kg bamboo panel per part of the production process, including transport from China to the Netherlands.

If other life cycle aspects, e.g. the life span and waste, are added, the bamboo panel can be compared with other materials (see Figure 5). In this figure a theoretical version is also added in which the panel is not bleached but only preserved with boron, using the Boucherie method.

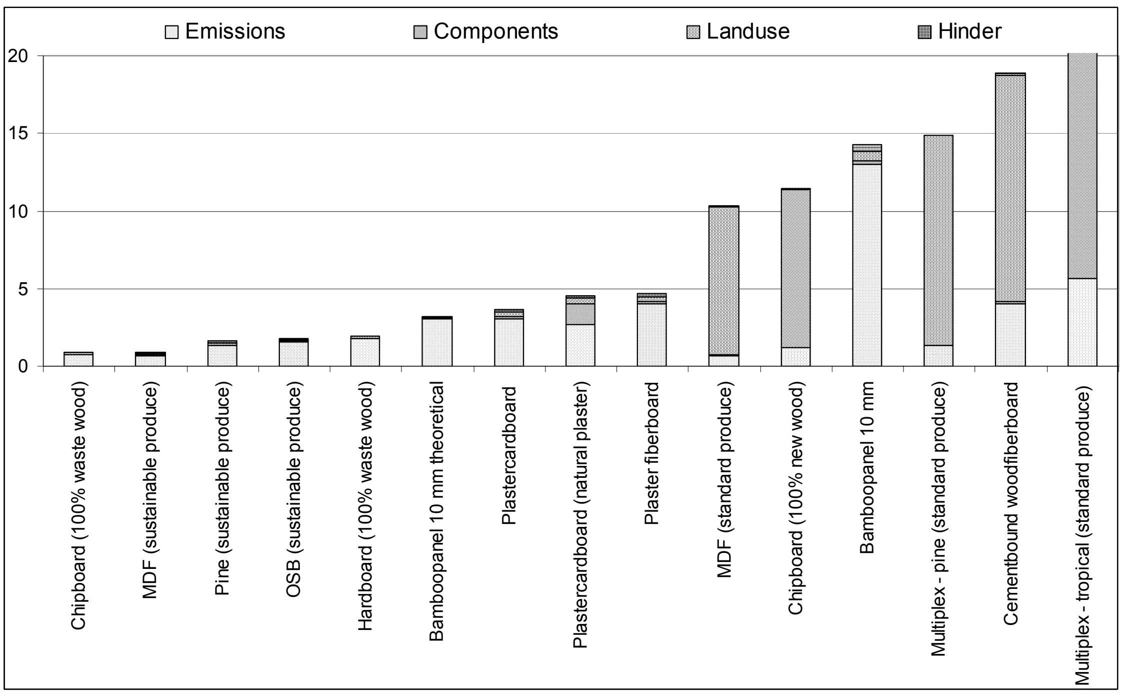


Figure 5 Environmental costs of wood-based panels for internal walls including the bamboo panel (NIBE, 2003).

The graphic of Figure 5 indicates that the environmental performance of the bamboo panel is slightly less favourable than most wood-based panels for non-bearing internal walls. However, the theoretical non-bleached version of the bamboo panel scores significantly better. Only panels with wooden material originating from sustainably maintained forests or panels made from 100% waste environmentally perform better than the theoretical bamboo panel. Concerning the limited availability of these products, the theoretical bamboo panel can be defined as a relatively sustainable alternative[2]. Note that panels based on metal and synthetic material were not included in Figure 5. The environmental costs of these alternatives are expected to be higher than those of wood- and bamboo-based panels.

[2] As a result of the outcome of the environmental assessment of their product, the manufacturer of the bamboo panel, *Plyboo Flooring International*, is analysing the production process to see if it can be adjusted to get a more sustainable product. This shows the possibilities of LCA as a stimulus to improve the production process in order to acquire a more sustainable product.

Nevertheless, especially compared to the relatively sustainable bamboo culm, the bleached bamboo panel cannot be considered a sustainable alternative. This is due to the disposal of features that made the bamboo culm a sustainable alternative: the efficient structural natural design of the culm is deteriorated through the laminating process. The intersection becomes solid, meaning more material mass is needed to fulfil the required function. Furthermore, the process to make a rectangular massive product of the bamboo culm is far more energy-intensive and complex, leading to considerably higher environmental costs.

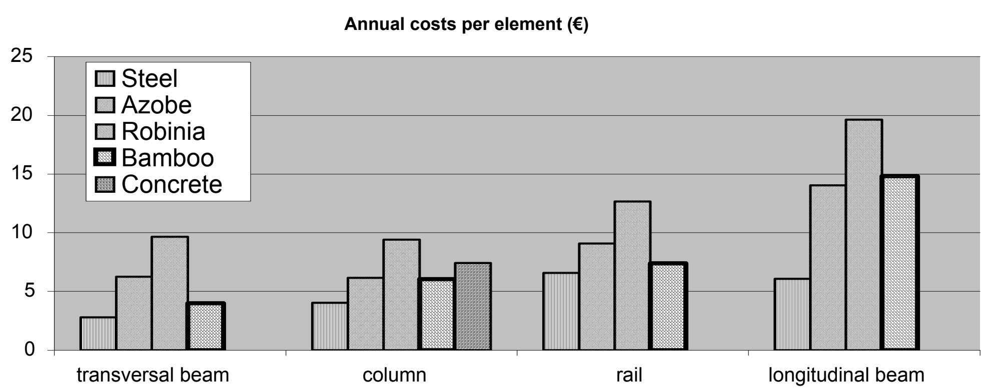
5. CONCLUSIONS ON THE ENVIRONMENTAL ASSESSMENT

The environmental assessment of the bamboo culm yielded very positive results. In several functions the environmental performance of the culm is 20 times better than building materials more commonly used, e.g. steel, wood, and concrete. When laminating the bamboo culm for flat-shaped applications, i.e. panels, the environmental advantage is diminished. Nevertheless, with some adjustments in the production process, a non-bleached sustainable alternative of the bamboo panel is possible.
These results form a dilemma: a problem with the application of the bamboo culm in Western countries is the irregular, hollow, round form, leading to problems in joints. By laminating, a rectangular section can be created, making joints easier. However, from an environmental point of view, the bamboo culm should be chosen, accepting possible problems of its geometry during implementation in the building process. These problems were analysed in the second part of the study (Lugt, 2003), however not presented in this paper.

6. FINANCIAL ASSESSMENT OF BAMBOO

For the analysed project (the walking bridge in the Amsterdam Woods), also a cost comparison was executed. The cost comparison was done in accordance with the environmental assessment on the same functions (column, beam, rail) and materials (see figure 8). The graphic in Figure 8 shows the annual costs of the various elements. In order to obtain the annual costs, all costs (e.g. costs for assembling, maintenance, disassembling, dump) occurring during the life cycle of the product were added to the purchasing costs and divided by the life span. Considering purchasing costs, bamboo is by far the least expensive. However, because of the shorter life span and the higher labour costs of assembling and disassembling (as a result of the irregularity of bamboo), on an overall cost level, steel turns out to be the most economic building material, due to the long life span.

Figure 6 Annual costs of the various elements and materials of the bamboo bridge in the Amsterdam Woods.



7. OVERALL CONCLUSIONS

The environmental and financial comparison demonstrates that bamboo can compete with building materials more commonly used in Western countries.

Nevertheless, practical problems (failure factors) when using the bamboo culm in Western Europe are numerous and have a couple of bamboo-related main sources: the shape of the material, the irregularity of the material and the lack of knowledge and building codes.
While many of the failure factors can be avoided in the future, some of them will remain. Bamboo is a natural product and will therefore always have some extent of irregularity. It is therefore suggested that in Western countries the bamboo culm should be used in functions were the measurement requirements are not entirely precise or fixed, as in temporary buildings, see Figure 7 (e.g. pavilions and tents) or small civil projects (e.g. bridges). Furthermore, bamboo can play a role as a finishing material (see Figure 8).

Figure 7 Bamboo theatre during the Festival of Vision, Berlin, 2000 (photo: Norbert Stück).

Figure 8 The bamboo culm as a finishing material (photo: Hulshof architects).

8. RECOMMENDATIONS FOR FURTHER RESEARCH

The environmental and financial comparison has been done for bamboo in a very specific application (column, beam, and rail, as used in the walking bridge in the Amsterdam Woods). For a broader perspective of the environmental performance of bamboo (products), additional environmental assessments by LCA are needed:

- With data from more plantations, species, and manufacturers, in order to increase the reliability of the results;
- Based on use in different countries (including the native country of the used bamboo);
- On another scale (complete joints, complete buildings);
- In other applications (using the bamboo culm internally, using the panel as parquet, using bamboo strips, etc.);
- In non-building applications (e.g. as biotic fuel).

For a broader perspective of the costs of bamboo (products) used as building material in the West, additional cost comparisons are needed:

- Of joints with other building techniques (e.g. lashing, joints with concrete).
- In another application (using the bamboo culm internally results in a longer lifespan)

- In another product (e.g. bamboo strips, corrugated board)

REFERENCES

Arets, M.J.P., A.A.J.F. Dobbelsteen, van den, 2002. Sustainable bearing structures. In: Anson M, Ko JM & Lam ESS, editors. *Advances in Building Technology*, Volume II, p. 1449-1456. Oxford, UK: Elsevier Science.

Brundtland, G.H. (ed.) et al. (The World Commission on Environment and Development), 1987. *Our Common Future*, Oxford, UK: Oxford University Press.

Dethier, J., 2000. 'The ZERI pavilion', In: A. von Vegesack, M. Kries, *Grow your own house*. Balingen, Germany: Vitra Design Museum.

Dobbelsteen van den, A., 2002. 'Rekenprogramma's voor duurzaam bouwen' (in Dutch), In: *Praktijkhandboek duurzaam bouwen*, Amsterdam, Netherlands: WEKA Publishers.

Ehrlich, P., A. Ehrlich, 1990. *The population explosion*, London, UK: Hutchinson.

Environmental Bamboo Foundation (EBF), May 2002. website, http://www.ebf-bamboo.org/

Heijungs R. (ed.), 1992. *Milieugerichte levenscyclusanalyses van produkten - Handleiding en achtergronden* (NOH rapport 9253 en 9254, in Dutch), Leiden, Netherlands: CML.

Janssen, J.J.A., 2000. *Designing and building with bamboo*, Beijing, China: INBAR.

Janssen, J.J.A., *Various interviews in 2002 and 2003*

Kries, M., 2000. 'Sustainability', In: A. von Vegesack, M. Kries, *Grow your own house*. Balingen, Germany: Vitra Design Museum.

Lugt, P. van der, 2003. *Bamboe als alternatief bouwmateriaal in West-Europa?* - Een studie van de duurzaamheid, kosten en bottlenecks van het gebruik van bamboe(producten) in West-Europa (in Dutch). Delft, Netherlands: Delft University of Technology, Faculty of Architecture.

NIBE, 2003. *Basiswerk Duurzaam & Gezond Bouwen* (in Dutch)- Dé leidraad bij het realiseren van duurzame en gezonde woning- en utiliteitsbouw (supplement 4); Naarden, Netherlands: NIBE Publishing.

Speth, J.G., 1990. 'Can the world be saved?', *Ecological economics vol.* 1, p. 289-302.

Sundquist, B., May 2002. website, http://www.alltel.net/~bsundquist1/index.html.

Vogtländer, J.G., 2001.*The model of the Eco-costs/Value Ratio, a new LCA based decision support tool*. Delft, Netherlands: Delft University of Technology, DfS.

Technology of Sawing Bamboo Veneer

LI Li[1], YANG Yongfu[1], GUO Jianfang[2]

1. College of Material Science and Technology, Beijing Forestry University Email: lili630425@sina.com

2. TCWOOD Email: gtcwood@163bj.com

Abstract: This paper introduces the technology of sawing bamboo veneer and the mini-nice frame saw as the machine to saw the bamboo veneer. The technology of sawing bamboo veneer with the mini frame saw form the laminated block with bamboo strips is one of feasible ways, after comparing it with the slicing and peeling veneer. The technology of sawing bamboo veneer could simplify the processing of the bamboo veneers, and increase the quality of veneer and the utilizable rate of the bamboo industrial utility.

Key words: Bamboo wood, Bamboo veneer, Frame saw

Bamboo-wood laminated floor is a kind of multi-layer composite floor made of bamboo veneer, wood or MDF. In recent years, the internal decoration level of our country has been increased every year, the decoration engineering costs and wood floor consumptions are also in a trend of going up yearly. But with the increasing pressure of environmental protection worldwide, the decreasing supply of wood, and the growing shortage of precious wood resources, the high quality wood materials with beautiful grains and colors for solid wood floor are restricted by the resources and in shorter supply, while the composite wood floor occupies gradually a larger part of the market. With distinctive grains and colors, the bamboo material has hard surface and wear resisting. The production of bamboo material has certain area limitation, but as it has short production period and grows fast, although its processing technology is complicated while its processing property is rather good, the bamboo-wood composite floor becomes favorite in both domestic and world markets.

1. The processing property of bamboo material

Bamboo is situated in Bambusoideae Nees in the grass family that is wide spread in China. Bamboo has more than 200 kinds with more than 20 genera. Bamboo grows fast and becomes mature and useful early, when it grows up to mature timber, it will make profits for many years. Bamboo is grown widely in south China, and the output holds the first place in the world.

Bamboo material as processed industrial material is mainly the bamboo culm, in the longitudinal direction bamboo is composed of a section of thick bamboo、bamboo node and a septum of bamboo node. In the thickness, its has bamboo skin、bamboo wall and bamboo with its green covering from outside to the inside. In most of the situations, the industrial processing of bamboo material is the bamboo wall after the bamboo skin and bamboo with its green covering to be removed. The bamboo is mainly composed of cylinder shaped parenchyma cell, fiber cell and tracheid cell. All the tissues, except those curving around the septum of bamboo node, are spread lengthwise along the bamboo, the bamboo material lacks crosswise parenchyma, with straight grains, is easy to crack. As a result, it is easy to process bamboo such as bamboo strip、removed bamboo skin and green covering、determinate width and thickness processing. The sawing process of bamboo veneer is to saw lengthwise along the bamboo grains, while sawing, the saw tooth cuts the bamboo material with its three edges, and one stroke of the saw will make three cutting planes --- the bottom of the kerf and both sides of the kerf. It is the same for both frame saw and circular saw. The main edge of the saw tooth cuts nearly section, the side edges of the saw tooth cut nearly crosswise. The main edge of the saw tooth cuts the bamboo fiber in the bottom of the kerf, and at the same time, its front face of the sawing tooth contacts and presses the fiber. While the saw tooth cuts deeply, the pressure of the front face increases gradually, when the pressure is big enough, the lay of bamboo material pressed by the front face of the saw tooth will be cut broken along the both sides of the kerf. The lay of bamboo material cut off will become bamboo chips under the pressure of front face of the saw tooth and the main edge. As bamboo lacks crosswise parenchyma and the grains are straight, the tapering is small, and has not much differences in the tissue structures of bottom and top parts of the bamboo, the resistance to lengthwise sawing processing is rather even, the cutting surfaces are rather smooth.

2. Sawing technology of the bamboo veneer

Bamboo material has high strength and toughness, dense structure and straight grains, with pithy color and smooth quality, it is easy to be bleached and carbonized. Bamboo material also has good tensile strength and decorative results, thus bamboo-wood composite processing is a major way to make use of bamboo with high benefit and to increase extra product value. In recent years, the industrialized use of bamboo will process the bamboo by splitting the section of thick bamboo into the strips with fixed width and thickness, then gluing the strips together with different combination forms to make laminated blocks, and the laminated blocks will be processed for use.

Presently, the general method is to glue the bamboo strips with fixed width and thickness together side-wise to make thin and wide boards, and then to glue several boards together to make laminated bamboo blocks. Then, the bamboo blocks will be cut into bamboo veneer with various specifications by different processing methods with different technologies, such as slicing, peering and sawing. For slicing bamboo veneer method, the bamboo blocks should make with bamboo strips with high moisture content or be softened by water or steam processing. Thus, there are strict requirements on adhesive and gluing technique, and such bamboo blocks are only suitable for making very thin bamboo veneer. The sawing processing can make bamboo veneer with thickness of 3-4mm from the laminated bamboo blocks made of dry bamboo pieces without water or steam treating, such bamboo veneer has no opposite direction crooked stress and cracks on the back.

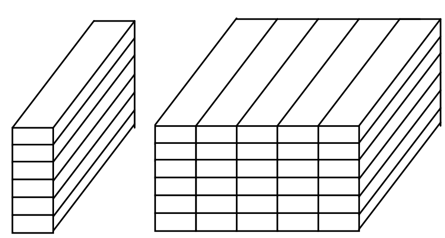


Fig. 1 Illustration of the laminated blocks with bamboo strips

General processing flow chart of bamboo veneer shows in Fig.2.

Bamboo block — strips of bamboo — the trim strips of bamboo — water and steam treating — drying — to plane the bamboo strips —— bamboo strips selecting —— gelatinizing — assembly —— gluing in wide-wise —— glue solidification —— thickness processing —— gelatinizing — assembly — gluing block — glue solidification —— to saw veneer —— veneer trimming —— packing

Fig. 2 Flowchart of the bamboo veneer processing

3. Sawing machine for bamboo veneer

Under present technical conditions, the veneer manufacturing methods mainly include peering, slicing and sawing. Peering and slicing can only make thin veneer. To be confined to the processing method and quality requirement on veneer, veneer thicker than 2mm will mainly processed by sawing, with mini frame saw and thin circular saw.

1. Working table 2. Feeding system 3. Sawing unit 4. Base

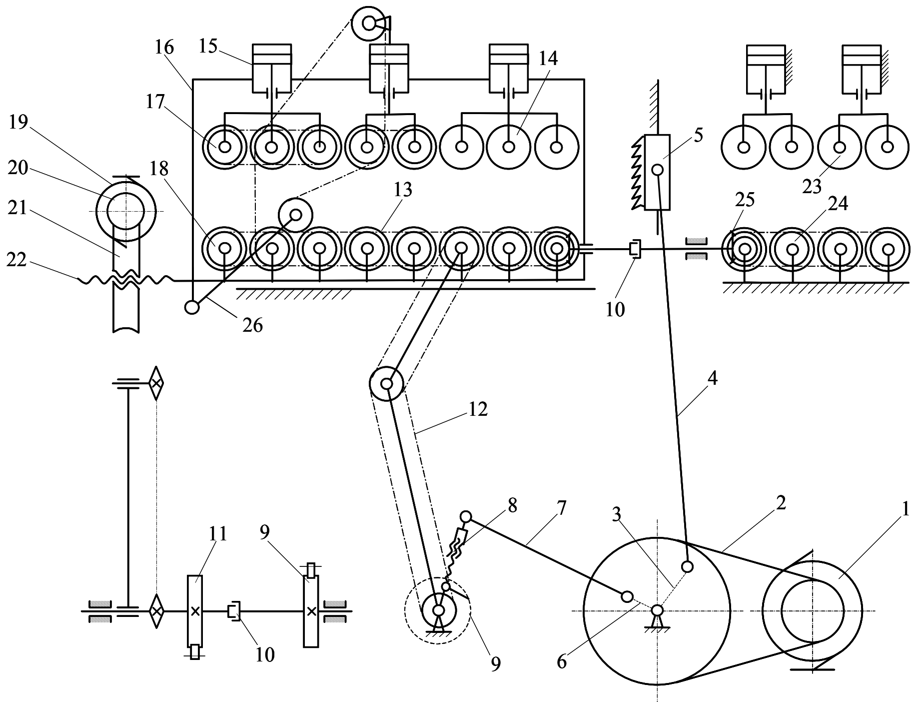
3.1 The basic structure of the frame saw

Figure 3 is the contour of the mini frame saw machine. The sawing and outlet unit 3 is fixed on the base 4. For the convenience of changing frame, checking, and maintenance, the working table is driven by an open/close motor that can be opened along the guide on the base relative to 3. There are gates all have joins with hinges in front and back part of the opening and the fixed sections.

3.2 The transmission system of frame saw machine

Fig. 4 is the mechanical transmission system of frame saw machine. The main sawing unit is composed of motor 1, transmission belt 2, and crank connecting rods unit (main crank 3, main connecting rods 4, saw frame 5 and base). The saw blades will be tensioned on the saw frame 5 that moves up and down repeatedly to saw the work-piece.

The feed unit is mainly composed of automatic ratchet wheels and feed system to realize interval feeding. The saw blades cut when the work-piece feeds and cut free when the work-piece stops to feed. To increase productivity, the feed in advance before the saw blades reach the upper stop point, that is feed in advance before the saw blade cut to compensate the clearance and increase the productivity. The advanced angel is 17^0~25^0。



1. Main motor 2. Transmission belt 3. Main crank 4. Main connecting rod 5. Saw frame 6. Sub crank 7. Feed connecting rod 8. Rocker 9. Feed ratchet wheel 10. Clutch 11. Counter reverse ratchet wheel 12. Connecting rod – chain combination unit 13. Transmission chain 14. Pressure roller 15. Cylinder 16. Movable working table 17. Upper feed roller 18. Lower feed roller 19. Driven motor for table movement 20. Worm 21. Worm gear 22. Guide screw for working table movement 23. Pressure roller 24. Output roller 25. Taper bearing

The work-piece feeds with rolling driven from the top and bottom. To guarantee that the work-piece stops feeding when the frame cuts free, the feed mechanism adopts interval feeding. The feed unit uses sub crank 6, sub connecting rod 7 and swing rod 8 to drive feed ratchet wheel 9 to make interval swings thus to transfer the movement to the connecting rod-chain combination unit 12, and then the chain transmission 13 drives upper and lower rollers 17 and 18 to make interval revolutions. There are two groups of upper feed rollers pressed by cylinder 15 that are controlled by the photoelectric sensors to press down firmly the work-piece according to its feeding position. Besides, there are a group of elastic pressure rollers 14 after these two groups of feed rollers to press down the work-piece. The upper and lower feed rollers are droved by transmission chain to guarantee them to make movements synchronously. When the upper driven rollers move up and down by the cylinder. The driving chain is tensioned by the chain wheel installed on the swing rod 26.

To prevent the work-piece reverse while the frame 5 cuts free, there is a counter reverse ratchet wheel 11 installed on the same axle with the feed ratchet wheel 9. It is installed in the opposite direction with the feed ratchet wheel to guarantee that the work-piece will not reverse under opposite pulling.

The adjustment of feed speed is made by adjusting the position of the guide screw nut on the rocker 8. When adjusting the length of the swing rod, the auxiliary crank turns a circuit then the turning angle of rocker 8 is adjusted. The adjustment is made through the hand wheel and the soft axle of steel wire to drive the guide screw on the rocker.

The outlet is composed of a group of driven rollers 24. The rear rollers and the feed rollers connected by the clutch 10 move synchronously. When the work-piece comes out, a group of rear pressure rollers 23 will press it, and the pressure valve in the compress air system to adjust the pressure will guarantee to give relatively little pressure to prevent the veneer from splitting.

For the maintenance and frame changing, the power of the outlet should be cut out by the clutch 10, the motor 19 will drive the worm mechanism (20, 21) to move away the feed mechanism and working table from the cutting and outlet facilities through guide screw 22, and open the machine. The connecting rods – chain combination unit 12 will adapt the position changes of the moving and the fixed parts of the machine automatically.

To minimize the wear and tear by friction between the clearance face of the sawing tooth and the bottoms of the kerfs in idle cutting stroke, and to increase the service life of the saw blades, the frame saw machine adopts oblique installation to make the saws keep off, so that the frame will keep out of the way in the idle cutting stroke to guarantee the spaces between the saws and the bottoms of the kerfs. The oblique installation structure is illustrated in Fig. 5, the oblique degree can be adjusted by adjusting screw.

3.3 Tensioning the sawblade

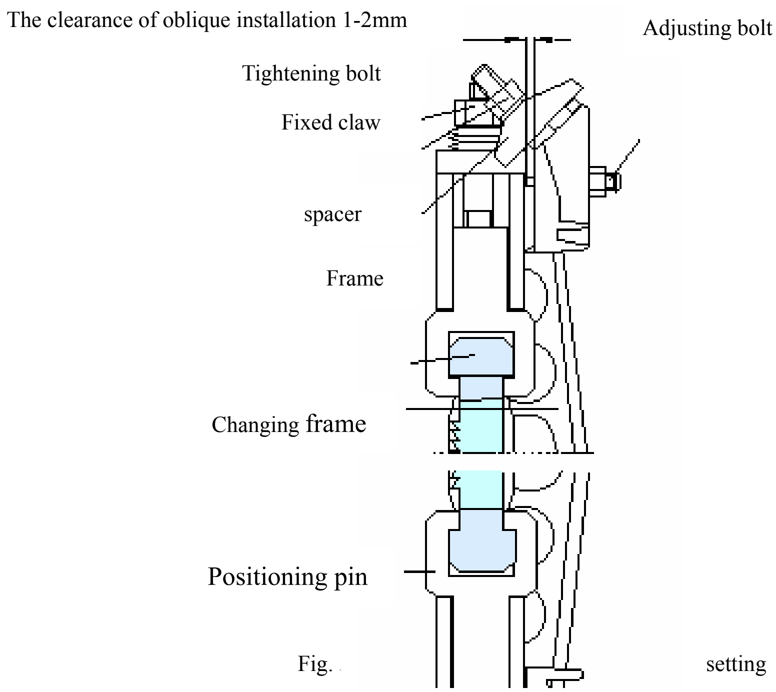
The saw blades require to be tensioned by rolling, the purpose is to introduce tensioning stress in the saw blades. When the saw blades are drew, the stress on the back of the saw blade changes to the tensioning stress at the teeth edge, so that the stability of the saw blade is increased and the kerf loss is minimized. After rolling tension, the back of the saw blade will have a certain bend. Table 1 shows detailed requirements.

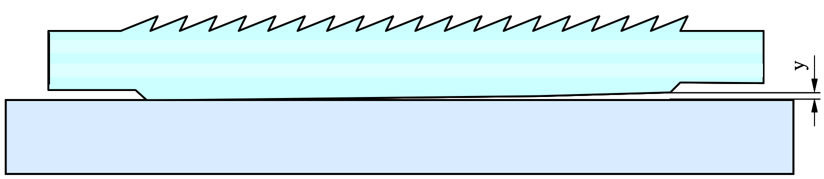
3.4 Drawing of sawblade

As illustrated in Fig. 5, the saw blades are pressed firmly by spacers and drawn by friction. After side pressing, three M20 bolts are used to pull them tightly. When cutting in groups, the tightening force of each bolt is M=10Nm.

$$M = \frac{d_2}{2} Q \tan(\alpha + \phi_v) + \frac{f}{2} Q (r + R)$$

The pulling force of a single bolt Q can reach 40000N.





Tab. 1 Measuring amount of back curve of sawbalde

Length of blade (mm)	380	420	455	505	610
Back Bend Measures y(mm)	0.3~0.5	0.4~0.6	0.5~0.7	0.7~0.9	0.8~1.0

4. Comparison of Mini-nice Frame Saw Cutting with Other Processing Methods

In wood processing, it is also possible to use slicing and peeling methods to process veneer with thickness of 3-4mm. Such methods will make high rate of utility of wood, but they damage the structure of the wood and make breaks on the back of the veneer as the veneer bends in opposite direction while being sliced or peeled. The bamboo material has its specific characteristics, the bamboo fiber mainly arranges in order along the direction of the length of the bamboo, there is little fiber in crosswise direction, so that slicing and peeling will always make crosswise cracks and breaks. Besides, with slicing and peeling methods, the bamboo blocks should be glued with high moisture content or the bamboo blocks should be sliced or peeled after hot water process that requires the glue to be used to be highly water-proof and to have high gluey strength. Frame saw cuts with multi saw blades to avoid structure damage of the work-piece that usually happens with slicing and peeling. There is no need of hot water process of the blocks so that the requirements to the glue and block gluing technology are lowered and the quality of the finished products are increased.

Table 2 Specification of Saw Blade and the Width of Kerf

Cutting height (mm)	≤80	≤120	≤150	≤200	≤250
Length of saw blade (mm)	380	420	455	505	610
Thickness of saw blade (mm)	0.8	0.8~0.9	0.9	0.9~1.0	1.1
Kerf (mm)	1.2~1.3	1.25~1.35	1.3~1.45	1.4~1.5	1.5~1.7

Compared with the gang circular saw, the frame saw machine seems to have low productivity. The feed speed of frame saw machine is generally 0.5 – 1.5m/min, and the feed speed of the circular saw is generally 10 – 20m/min that is more than 20 times faster than frame saw machine. But the gang circular saw machine installed saw blades number is less than frame saw and cutting height is lower. If the cutting height of frame saw machine is 200mm, the saw frame installs 40 saw blades, and the feed speed is 1m/min, to calculate the area of the products per minute, the productivity of the frame saw machine is $8m^2$/min. The kerf is only 0.7 – 1mm. If cutting the work-piece with the thickness of 200mm, the twin-shaft gang circular saw machine must be required to cut from opposite directions, the kerf is generally 2.6- 3.2mm, for the errors caused by position error of the twin saw blades and the transverse vibration of the saw blades, more processing tolerance is required for the later process, the rate of bamboo utilization is lowered. The comparison of kerfs of these two kinds of machines is illustrated in Fig. 7. Theoretically the kerf of frame saw machine is less than half of that of the circular saw. Compared with the circular saw and the band saw, the saw blades of frame saw machine has the highest stability. Based on the differences of the thickness of the veneer cut, generally the rate of bamboo utilization with frame saw machine is 15 – 50% higher than that with circular saw. Presently, the frame saw machine and its saw blades producers in Europe supply saw blades with cutting height of 80 – 250mm, thickness 0.8 – 1.1mm, and kerf 1.2 – 1.7mm. Table 2 is the specification and kerf of saw blades at different cutting heights. According to the statistic information, when cutting veneer with the thickness of 2mm, the of rate of material utilization with frame saw machine is 1.6 times more than the circular saw machine; Fig. 8 is the comparison of theoretical rate of material utilization of these two kinds of saw machines while cutting veneer with different thickness.

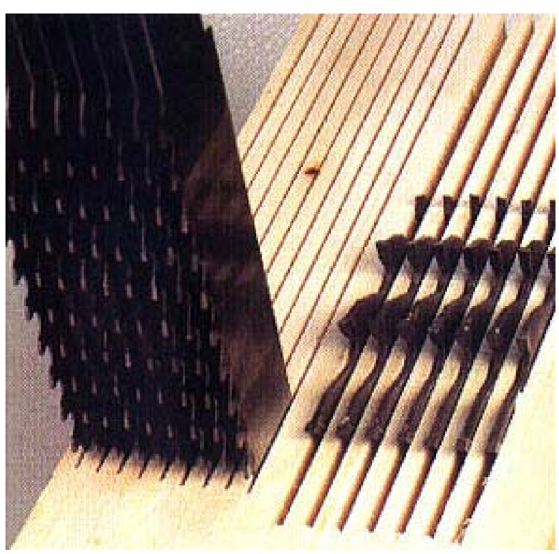


Fig. 7 Comparison of the kerf loss between the frame saw and the circular saw

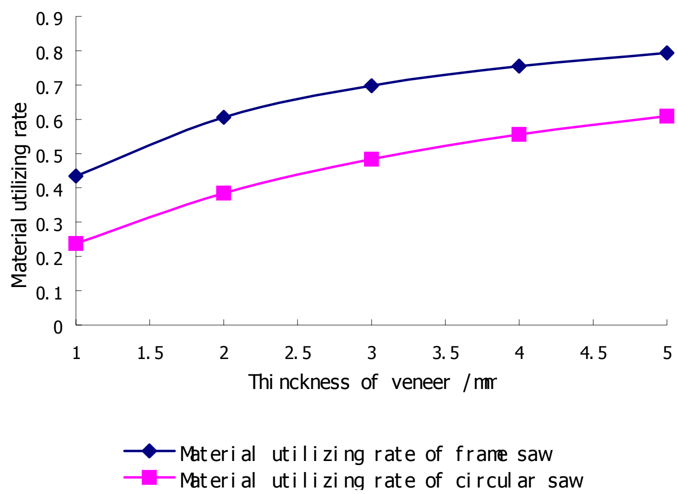


Fig. 8 Comparison of the bamboo utility rate between the frame saw and the circular saw

In addition, if only judging productivity from the feed speed, the frame saw machine is much lower than the gang circular saw machine, but the processing precision of frame saw machine is high that the circular saw cannot compare with it. Take for example the mini-nice frame saw machine model Clasic, its feed speed is 0.2 – 2.0mm/min with step-less adjusting, the cutting frequency of the saw blades is 450 times/min, and the feed per teeth is rather small. The thickness of sawing chip is 0.15 – 0.25mm (rough cutting), 0.07 – 0.1mm (medium cutting), and 0.03 – 0.05mm (precise cutting). Table 3 shows the thickness of sawing chip at different feed speed. As the tension of the saw blades of frame saw machine is rather high and the stability of the saw blades during cutting is high, the height of sawing trace on the cutting surface caused by the transverse vibration of the saw blades are very small, the cutting surface is smooth and straight. The production of solid wood laminated floor indicates that the veneer cut at the feed speed of 0.6-0.7m/min can be glued directly without any follow-up process, or glued after sanding processing, thus the processing costs and the material consumptions are reduced.

To consider comprehensively the complicacy of the processing technology, the specific characteristics of the work-piece to be processed, the productivity, the rate of material utilization, the processing quality and etc., in bamboo veneer processing, the min-nice frame saw machine has high superiority that reflects highly in respects bamboo laminated block no need softening, rate of material utilization and cutting quality.

Table 3 The thickness of sawing chip at different feed speed

Feed speed (m/min)	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
Sawing chip thickness (mm)	0.028	0.055	0.083	0.11	0.14	0.17	0.19	0.22	0.25	0.28

5. Conclusion

To produce laminated bamboo blocks by gluing and laminating, and then to cut the laminated bamboo blocks into bamboo veneer with different specifications is one of the ideal ways to use the bamboo resources of our country with high effects, and to increase the utility of the bamboo material and the added value of the products. The min-nice frame saw machine is the most ideal equipment to cut the bamboo veneer. The superiority of the machine mainly reflects in its simplified processing technology, increased rate of material utilization and product quality.

The frame saw uses tension processed thin saw blades which have high tensioning and stability, so that the kerf loss is reduced and the rate of material utilization is increased, it is specially suitable for thin veneer cutting process.

Compared with slicing and peeling, the frame saw cutting has no need to make softening process for the laminated bamboo blocks, so that the requirements to adhesives and gluing technology are lowered. Compared with the circular saw processing, frame saw processing has increased the material utility and product quality.

China has rich resources of the bamboo wood. The demand for furniture, laminated floor and other decoration materials is rather great. In recent years, the demand for bamboo material in decoration material markets in China and abroad is in the trend of increasing each year. Some solid wood laminated floor and pencil board producers in China have imported min-nice frame saw machines made by Neva of Czech and Winterseiger of Austria, their production practice has proved that frame saw cutting is an effective and practical way to process veneer. It is an effective way to increase product quality and reduce kerf loss. The practice has proved that frame saw cutting is a feasible technology in laminated bamboo blocks cutting, under the condition that the productivity is guaranteed, the processing technology can be largely simplified, the utilizing rate of bamboo material, the precision of finished products and quality of the sawing surface can be increased.

References

Bao Yipei, The Technology, Equipment and Economic Analysis of Laminated Bamboo Floor, 2001, Construction Wood-based Panel (2001) 3:27 – 30.

Cheng Ruixiang, Xu Bin, Zhang Qisheng, Study on Gluing Technology of Laminated Bamboo Blocks for Veneer Slicing, 2003, Wood-based Panel Report, (2003) 7:5-7.

Hu Changlong, Bamboo Furniture and Weaved Bamboo Utensils, 1983, Jiangsu Science and Technique Publisher.

Jiang Shenxue, Zhang Qisheng, The Status Quo of Bamboo Material Process and Application in China, 2002, International Wood Technology (2002): 10-16.

Tu Maoqing, To Develop Jiangxi Solid Wood Laminated and Bamboo Laminated Floor Production by Using Faster Growing Wood, 2000, Jiangxi Forestry Science and Technology

(2002)2:42-45.

Yang Rongfu, The Performance Analysis of Mini-nice Frame Saw Machines,2003, Wood Processing Machinery (2003) 2:5-9.

Zhao Renjie, Du Chungui, Long Strip Bamboo Laminated Floor, 1999, Forestry Science and Technology Development (1999) 6:10-11

Zhang Qisheng, Sun Fengwen, The Prospects for the Development of Bamboo Industry in Our Country, 1999, Forest Industry (26) 4:3-5.

Technological Innovative Course and Prospect of Bamboo-based Panel of China

Zhao Renjie Chen Zhe Zhang Jianhui

Central-south Forestry University, Zhuzhou 412006, Hunan Province, P. R. China.
Phone: +86-733- 8700032

Abstract: Based on the technology and facility of modern wood industry and rich bamboo resources in China and excellent characteristics of bamboo, bamboo-based panel series were developed, the course of which was summarized in this paper. And it elaborated technological innovations in improvement of structure, in craft and technology, in modification of adhesive and in development of special equipment for bamboo processing and the historical course of bamboo industrialized utilization. In addition, the developmental prospect of bamboo-based panel was also discussed in this paper.

Key words: Bamboo-based panel Technological innovation Industrialized utilization

1. Preface

Bamboo resource is very rich in China. According to the fifth investigation of forestry resource (1994—1995), there was 4,210,000 hectare bamboo forest and the total store is 110,870,000t, of which the area of mao bamboo reached to 69%. There are 2000 mao bamboo per hectare[1]. Compared with timber, bamboo is high in strength, toughness and rigidity and easy of be cut lengthways. Utilizing rich bamboo resources and excellent characteristics of bamboo, based on the technology and facility of modern wood industry, through proper process, bamboo-based panel serials such as bamboo mat plywood, bamboo curtain plywood, bamboo plate plywood, bamboo stripe laminated material, bamboo particleboard and so on were developed successively. The production of this series has the history of more than 20 years. Because of the structure rationality of bamboo-based panel, the shape and structure of bamboo has been changed greatly, the physical and mechanical properties of bamboo has been improved. The application scope of bamboo has been enlarged. Therefore, the production of bamboo-based panel is an important aspect that using bamboo sufficiently and improving bamboo properties. Nowadays, the development of bamboo-based panel is very fast and it has many species. The output in 2001 of all kinds of bamboo-based panel was about 2,000,000m^3, which was 9% of the annual output of domestic wood-based panel. And the industry basement of bamboo-based panel has been set up preliminarily. The new era of bamboo industrialized utilization in China has been inaugurated. The product history of bamboo-based panel is more than 20 years. Whether the improvement of structure, the innovation of process, the modification of adhesive or the development of special equipment for bamboo was a history of scientific innovation, which includes intelligence and painstaking efforts of a generation of experts. Technological innovative course of all the kinds of bamboo-based panel was reviewed in this paper, based on which its developmental prospect was prospected.

2. Technological innovative course of all kinds of bamboo-based panel

2.1 Bamboo mat plywood

Bamboo mat, waved vertically and horizontally with bamboo strips, as the component of bamboo mat plywood, after added UF or PF resin, it is pressed into bamboo mat plywood with the "hot-hot "process. Some people call bamboo plywood as bamboo waving plywood. UF bamboo mat plywood, when thickness ranges from 2 to 6mm is also called thin bamboo mat plywood, which is mainly used as decorative and packing material. PF bamboo mat plywood, whose thickness generally is over 7mm, is also called thick bamboo mat plywood and mainly used as structural material. Bamboo mat plywood is the earliest product among bamboo-based panel series and at one time or another, it developed fast in some sort, and the national quality inspecting department published national standard of bamboo mat plywood **GB13123---91**and national standard of experimental methods of bamboo mat plywood **GB13124---91**in 1991. But now, on the one hand, its workload is very great and it consumes too much adhesive, furthermore, whether the usual adhesive spreading or glue dipping does not achieve the satisfying effect. As structural material, it has no advantages compared with other materials because of its low p/p (performance/price). On the other hand, it has clear surface roughness and the texture of bamboo mat also confines its utilization, so as the decorative material, it could not achieve ideal decorative effect. So because of the two above reasons, it is in the atrophic situation now. For the sake of improving decorative effect, Professor Zhao Li in Beijing Forestry University once made research of cover wood veneer on the surface of bamboo mat plywood, after sanding, painting, and its decorative effect increased greatly. But because this process was very complex and cost was very high it also had no advantages compared with the usual wood based plywood, so it was ignored by the market. So although bamboo mat plywood was the first to come out, technological innovation walked with difficulty and got little effect because of its disadvantages.

2.2 Bamboo curtain plywood

Bamboo curtain plywood was a scientific research fruit of Central South Forestry University in 1991. Although came out late, its technological innovation is very effective and has gotten many innovative fruits. So bamboo curtain plywood develops the fast, has the most output and the widest use among all the bamboo based panel serials.

Bamboo curtain plywood, a kind of structural material, is obtained by hot-pressing to bamboo curtains which have been dipped into PF resin and long and short curtains are assembled in crossing method. And its advantage is that lengthwise and transverse intensity can be adjusted by change the quantity ratio of long bamboo curtain to short bamboo curtain. Compared with bamboo mat, bamboo curtain is easy of being processed and being dried, and less adhesive consumed, so it has low cost and high mechanical capability. It can be used as bottom board of train and template for concrete-form.

Because of the great amount of demand for template for concrete-form in market, scientific research innovation of bamboo curtain plywood has been closely to the requirement of satisfying the capability of template for concrete-form. These innovations that aim to decrease energy consumption, to increase bamboo utilization ratio and to decrease cost consist in improvement of structure, in craft and technology, in modification of adhesive, in development of special equipment for processing bamboo curtain and in improvement of its capability.

2.2.1 Improvement of product structure

Used as template for concrete-form, groove in the surface of bamboo curtain plywood must be gotten rid of. In order to do that, instead of bamboo curtain, bamboo mat who have dipped into PF resin can be used as surface layer. Although its surface also has roughness bamboo mat took, it can be used as low-grade template. And it has still been used in the field of architecture so far. On this basement, in order to improve surface smoothness more and to increase water resistance and abrasion resistance, multi-plastics bamboo curtain plywood was obtained by the “cold–hot –cold” hot-pressing process to mat which had been assembled by adding PF or MF dipping paper to the surface of bamboo curtain. The improvement of structure boosted the grade of product and made this product has the most quantity and the widest using among bamboo based panel for template. Because of the using of bamboo mat, the surface of this kind of panel also exists roughness in some degree, and it only could be used as concrete template for houses. Later, inner bamboo curtain was replaced by cross grain wood veneer to promote its surface smoothness, thus boosted the level of product once more. It could be used as template for clear water concrete for bridge building of motorway and railway, so it was called bridge template.

Adopting radical cutting bamboo strips and radical bonding instead of the ordinary chordwise cutting bamboo strips and bonding, radical bamboo strips curtain composite panel was developed in Central-south Forestry University in 1999. This craft need not get rid of bamboo yellow and bamboo cyan, thus could improve bamboo utilization ratio and bamboo strips processing efficiency and decrease cost greatly. The potent number of processing of radical bamboo strips curtain composite panel is **CN131251**. Through the improvement of aspects above, bamboo curtain has formed reasonable structure basically.

2.2.2 Improvement of hot-pressing craft

Nowadays, one time hot-pressing process is mainly adopted to make multi-plastics bamboo curtain plywood and its hot-pressing craft is “cold-hot-cold”, which does not lead distortion and blister, but it also has some disadvantages, such as long hot-pressing time, low output, much energy consumption and water consumption, low thickness precision and uneven surface color, etc. In order to get over these disadvantages, some factories replaced one time hot-pressing forming process with double processing. First, base board was made by “hot-hot” craft, then base board sanded, and then dipping paper overlaying “hot-hot” pressing or film “hot-hot” pressing. Products made by double processing has high thickness precision and little surface abrasion, thus creates good conditions for export. The improving processing method of multi-plastics bamboo curtain plywood has gotten invention potent (potent number: **97 107942.0**).

2.2.3 Modification of adhesive

Adhesive is the main raw material of bamboo curtain plywood, the properties of adhesive affects the quality and cost of product greatly, it also has a important effect on the making-board craft. Nowadays, bamboo curtain plywood mainly adopts high temperature (150±5 ℃) curing and water-soluble phenol-formaldehyde resin, if adopting “cold-hot-cold” hot-pressing process, more hot steam will be consumed and hot-pressing cycle will be too long. if “hot-hot” hot-pressing craft is adopted, it will easily result in the mat 's blow, warp, distortion and so on. Therefore, we developed moderate temperature (120±5 ℃) curing phenol-formaldehyde resin through modification, which could have high curing speed under low temperature. At present, some of factories have used this new type of glue, and they gained favorable economic benefit. In addition, in double processing mode to overlay dipping paper, low-pressure and short

-cycle MF resin which could satisfy the demand of rapid overlaying has already replaced high- pressure MF resin as the adhesive to dip raw paper through modification. The modification research of these two types of glue above have already achieved success and applied to production.

2.2.4 Innovation of special equipment for bamboo processing

The industrialized utilization of bamboo, which must be provided with bamboo specific machining equipment, can satisfy the demand for the quantity and quality of semi-finished goods. Bamboo stripe is the raw material of weaving bamboo curtain and bamboo mat, which are the semi-finished products of bamboo curtain plywood. The demand for the bamboo curtain and bamboo mat is enormous. On the early part of 1990s, all these mats and curtains were waved by hand, which would not only result in inefficiency, but also could not insure the quality of products. Therefore, bamboo-knot removing machine, bamboo-culms cutting machine and bamboo stripes-cutting machine and so on were developed one after another, they all greatly improved the machining efficiency of bamboo stripes. At the same time, several kinds of length feeding bamboo-curtain weaving machines which had different structure came out in succession. Because of length feeding, the length of work distance restricted work efficiency of bamboo curtain weaving machine. Recently, cross-feed bamboo stripes weaving machine was developed, which improved the produce efficiency greatly.

The weaving of bamboo mat, not only handwork but also machining needs more time and labour force compared with weaving of bamboo curtain. It is especially difficult to develop bamboo mat weaving machine. Up to now, weaving of bamboo mat entirely is in handwork. It is delightful that two kinds of bamboo mat weaving machine with different structure have been produced recently from Hunan, one is hand-swinging sample bamboo mat-weaving machine, and the other is linkage-working bamboo mat-weaving machine. It can be forecasted that these two machines will be put into application before long.

In a word, on the improvement of structure, modification of glue and development of bamboo special machining equipment, bamboo curtain plywood came through continuous innovation, which has achieved great achievement and accelerated the development of bamboo curtain plywood. These innovations not only upgraded products many times, but also expanded the realm of application, especially increased output greatly. The annual capacity of bamboo curtain plywood reached 70,000,000 m^2, which was paid attention to by people in the world. The department of construction of China published the standard of bamboo plywood for template **JG/T3026-1995** in 1995. As building template with Chinese characteristics, bamboo curtain plywood is one of the three main building templates in China, bamboo curtain plywood, together with steel template and wood-based plywood template constitutes the huge template market in China.

In conclusion, for the sake of satisfying the demand for application of template for concrete-form, the structure of bamboo curtain plywood went through three stages which include bamboo curtain plywood, multi-plastics bamboo curtain plywood, radical bamboo strips curtain plywood respectively; the process of bamboo curtain plywood developed from one time hot-pressing forming to double processing; The grade of product developed from ordinary concrete template to rinsing concrete template for roadway and bridge, and even aim to template for export. At the same time, modification of glue and development of special bamboo processing equipment made great achievements.

2.3 bamboo plate plywood

Bamboo plate plywood is also named by bamboo plywood, which is a scientific research fruit of Academician Zhang Qisheng in Nanjing Forestry University. Its structure component is uniform thick bamboo plate with groove. Bamboo plate plywood, which has symmetry structure, can be obtained by hot-pressing to mat board in which close layers are assembled vertically. Bamboo plate is made by planishing and planing. Bamboo plate plywood can be used not only as common structure material but also as bottom board of motors through lengthening and surface processing. The National Forestry Department released the standard of bamboo plywood for bottom board of motorcar **LY1055-91** in 1991. Bamboo plate plywood developed very fast and formed some scale at one time. but it have some disadvantages, such as complex process, low bamboo utilization ratio, big cavities in plywood's section. In order to overcome the above disadvantages and exert its predominance, bamboo plate was used as surface layer and fast-grow wood (as poplar) veneer was used as core layer, after roller coating PF resin, mat assembling and hot-pressing, coated bamboo plate plywood was obtained. The multilayer compound structure could make the best of respective merits through assembling them reasonably. The coated bamboo plate plywood has some advantages, such as high intensity and rigidity and preferable surface abrasion resistance. After strictly killing bug and immunity disposal, coated bamboo plate plywood could be used as the bottom board of container for dry cargo, which expanded the realm of its application. At the same time, technicians used the bamboo plate plywood which had sanded with uniform thickness as base board, and wood veneer, PF dipping paper and MF dipping paper in order on the two surfaces of the bamboo plate plywood, then assembled them into mat board of tectorial bamboo plate plywood, and then pressed it into finished product. Tectorial bamboo plate plywood which adopted double processing mode had some advantages, such as high intensity, high thickness precision, bright surface and uniform color and luster, excellent water resistance and abrasion resistance. It is a template for concrete form of high quality.

2.4 Bamboo laminated material

Bamboo laminated material, a kind of structural material, is obtained by laminating parallel all bamboo component having being dried and adding adhesive. It has high lengthways intensity and mainly used as bottom board of train and motorcar. It is a very excellent wood replacer.

Bamboo laminated material has two kinds at present: bamboo strips laminated material and bamboo strips curtain laminated material.

2.4.1 Bamboo strips laminated material

Bamboo strips laminated material has been produced since 1980s, and chordwise bamboo strips with uniform thickness are its components, after laminated along the grain, it can be obtained by “cold-hot-cold” craft. After bamboo strips laminated material is cut into thin strip and processed shiplapped groove in it, it can be used as bottom board of cargo train. The railway department published the technological standard of bamboo strips laminated material for cargo train “**TB/T2412---93**” in 1993. Because of the low transverse intensity, it more often is made into thick board and used as trip material after it has been cut lengthways. During production term, bamboo strips are long and thin, have poor rigidity, which lead much inconvenience to drying, glue application, spreading and the transportation and store among processes, also can't realize mechanization and serialization. In particular, it is hard to spread mat evenly, which leads to large deviation of thickness and density. If the deviation of the thickness is great panel must be planed with uniform thickness. The great deviation of the density results in bad unification of quality and density of panels, even affects its utilization. For overcoming defects of bamboo strips laminated material in process and quality, Professor Zhao Renjie of Central-south Forestry University substituted bamboo strips curtain laminated material, which used radical bamboo strips bound curtain as core layer and used chordwise single bamboo strips curtain as face layer, for bamboo strips laminated material. This technology has achieved great effects through extensive application.

2.4.2 Bamboo strips curtain laminated material

The component of the bamboo strips curtain laminated material is bamboo strips curtain. Radical bamboo strips bound curtain as core layer and chordwise single bamboo strips curtain as face layer, it has parallel laminated structure. Compared with bamboo strips laminated material, it is added a process of waving bamboo strips to bamboo curtain, but the process can bring much convenience to production and improved panel quality greatly. Using radical bamboo strips bound curtain as core layer not only improves efficiency of processing bamboo strips but improves efficiency of waving curtain. Using two layers of chordwise single strips curtain as surface layer of this kind of panel can improve surface quality. In addition, owning to special elastic press stop which works as forming block in lay-up process and can control both thickness and width of board in hot-pressing process, which makes product reach thickness accuracy demand without planning, remainder of edge trimming could be reduced from formal 7-8cm to about 1cm, thus can improve utilization efficiency of board edge trimming greatly, So it can be said that bamboo strips curtain laminated material was a great innovation for the bamboo strips laminated material, and it can also be regarded as the upgrade product of bamboo strips curtain laminated material. Methods of bamboo strips curtain laminated material has already applied for invention patent on June 2003 and its application number is **03124434.3**.

2.5 Bamboo particleboard

Bamboo particleboard uses little diameter bamboo and remainder of bamboo processing as its raw materials. And particle is produced, through drying, glue application, forming and hot-pressing in order, it can be obtained. Bamboo particleboard is a good product which can made good use of small diameter bamboo and improve bamboo utilization ratio. Nowadays, ordinary bamboo particleboard is mainly produced and its property and function is similar to wood particleboard.

At present, few factories produces bamboo particleboard, because if this product is used for furniture and indoor decorative material to get good decorative effect, this kind of stuff must be overlaid, and ordinary painting effect is not very good; If bamboo particleboard is used as structural material, it's mechanical capability can not satisfy demand. Structure of particle sandwich composite board is obtained by using bamboo particle as core layer and strengthening stuff as surface layer in order to strengthen mechanical intensity of bamboo particleboard. Process is still one-time forming technology. First, put one or two layers of strengthening stuff on caul plate, then spread l bamboo particle, and then put one or two layers of strengthening stuff , last, they are formed by hot-pressing. There are two kinds of particle sandwich composite board with different structure and use. In the first structure, dipping paper is served as surface layer, bamboo curtain with adhesive dipping is served as inside layer and bamboo particle is used as core layer. Panel with this structure, whose property is closer to multi-plastics bamboo curtain plywood, mainly works as template for concrete form. And its patent number is **ZL98230707.1**. In the other structure, joint board of bamboo plate serves as surface board and core layer is composed of bamboo particle. One virtue of particle sandwich composite board is high bamboo utilization ratio and the other is that its physical mechanical intensity is greatly improved compared with bamboo particleboard. But its process is complex and mainly used as bottom board of container.

2.6 Bamboo floor

Bamboo floor is bamboo based panel with small size. And it is a kind of decorative material for indoor ground. Its color and lustre is simple and elegant and it is hard and wearproof. At present, the structure of bamboo floor is mostly solid floor, for instance, the pure bamboo floor, bamboo-wood compound floor and long-strip bamboo-wood compound floor and so on. The hollow bamboo serials have been developed successfully by Central-south Forestry University.

2.6.1 Solid bamboo floor

Pure bamboo solid floor was produced firstly among the variety of solid bamboo floor, and it has structure form: One is multilayer tangential section glued bamboo floor, and the other is single layer side jointing radical section bamboo floor. The national quality supervising, inspecting and quarantining bureau has already published standard **LY/T1573-2000** for these two sorts of bamboo floor. Two kinds of bamboo-wood compound floor have been developed in order to make good use of fast-growing wood. One is bamboo-**fir** composite floor, which has three-layer structure, bamboo plate as surface layer, and fir veneer as core layer. This kind floor has the same appearance and physical property as multilayer chordwise section glued bamboo floor, and it has a virtue of low cost. Another is long-strip bamboo-wood composite floor, rotary cutting bamboo veneer of big diameter bamboo serves as its surface layer, rotary cutting wood veneer of fast-growing wood works as core layer. This floor has the characteristics of lucent and elegant texture, exquisite and sumptuous style, good toughness and abrasion resistance and uneasily deform. Patent number of long-strip bamboo-wood composite floor is **ZL952373157**. Among all the kinds of solid bamboo floor, multilayer chordwise section glued bamboo floor has the maximum producer, the most output and the widest using.

2.6.2 Hollow bamboo floor

Hollow bamboo floor consists of core layer which is a kind of grid structure with bamboo plate of poor quality and surface layer which was made of bamboo plate of good quality by side jointing method. They are bonded together. There are three ways of among floor strips due to difference of edge structure when installing: tenon joint, loose tongue joint and built-in joint. Hollow floor with tenon and groove has side frame in its core layer's sides, and the j connecting methods is the same as solid bamboo floor. Loose tongue joint is a method of making bamboo plate insert groove which have been processed in the core layer of bamboo floor. As for built-in joint, bamboo plates of two sides in core layer extend to a certain length, and bamboo plate of other two sides of the core layer is a little short, two floors are connected through inserting extended bamboo plates of one floor in another one. Hollow bamboo floor serials can not only save stuff, has good sound insulation and thermal insulation, but not be easily deformed and may be processed into large size floor. Hollow bamboo floor can be used as door board, surface board and floor of stadium besides floor indoor.

2.7 Different style bamboo plywood

Bamboo curtain corrugated board is a kind of different style bamboo plywood. Bamboo curtain as core layer after adhesive dipping and drying, dipping paper as surface layer, they are assembled and pressed to make into corrugated board. It works as house wall stuff of temporary building and particularly is suitable for those units who move frequently. Bamboo corrugated board has lower density, higher pound resistance and impact resistance compared with asbestos-cement corrugated board; and it has good virtues of low water absorption and thickness expansion rate of water absorbing and good durability compared with corrugated wood-fibre board; and it is rustless and has better thermal resistance compared with corrugated board of sheet iron; and it is uneasy for transmission and warp compared to Glass fiber reinforced plastics corrugated board.

3. Developmental prospect

Bamboo is a reproducible resource and could be used constantly only under feasible management after becoming bamboo forest. Bamboo grows rapidly, matures early and can be logged between three and five years, and it has good mechanical capability, so it is a precious resource that can be used. The industry of bamboo-based panel in China developed rapidly and has form the base mainly because our country has influent resource and the advanced technique and we have entered the epic of the industrial using of bamboo. If we look forward to the industry of bamboo-based panel in China, we can find the followings will go on developing.

3.1 bamboo-based panel developing from single structure to multiply-way composite material

Now, many of bamboo-based panels are made by cementing by bamboo components of different shape and belong to single structure material. It has relatively poor properties. Multiply-way composite material is a kind of multi-interface solid material made of at least two kinds of material that have different physical and chemical nature. The composite material has good physical and mechanical function because of the composite effect, so many materials of excellent property all belong to it in our modern era.

Bamboo-based composite panel is obtained by compounding bamboo components of different shape with other materials. Superiorities of all kinds of material in bamboo-based composite panel can be made good use of, so it has good properties because some material's advantage can remedy the other material's disadvantage. This function can be assured by the reasonable design of structure and the advanced craft. The production of bamboo-based composite panel not only improves the function of product, enlarges the scope of raw materials and improves bamboo utilization ratio, but also reduces cost, so it will be the developmental orientation of bamboo-based composite panel.

3.2 Developmental orientation of craft and technology

Improvement of craft and technology include two ways bellow: first, craft and technology themselves; second, machinery instruments

3.2.1 Developmental orientation of craft and technology

With the exploitation and using of moderate temperature curing phenol-formaldehyde resin, the existing "cold-hot-cold" craft that exhausts energy heavily and has lower output will be replaced by "hot-hot" craft; high-pressure and long period overlaying craft will be replaced by low-pressure and short period one. "Hot-hot "craft will be the most primary and widest spread craft in the production of bamboo-based panel. Meanwhile, as for high-grade block board, one time hot-pressing craft will be replaced by double processing craft.

3.2.2 Improvement of mechanization and continuity of processing

Processing of semi-finished products of bamboo-based panel, such as cutting strips, waving curtain, waving mat and so on, was almost processed by hand inefficiently in 1980s. Because of the exploitation of instrument for a special processing including of cutting bamboo machine, cutting knot machine, cutting bamboo strips machine, length feed waving curtain machine, cross-feed waving curtain machine, waving mat machine and so on, nowadays it present the state of semi-hand and semi-machine. With the improvement of labour value, processing of semi-finished products in mechanization and continuity will be inevitable. As to the productive installation of bamboo-based panels, aided by the existing instrument of wood-based panel industry, it has certain level in mechanization and continuity. Of course, with the development of science and technology, the wide spread of unify of light, machine and electricity will be improved.

3.3 Modification of adhesive and exploitation of new adhesive

Now in the production of bamboo-based panel, all kinds of adhesive belong to formaldehyde series. Formaldehyde is poisonous. As to phenol-formaldehyde resin adhesive, it has both free phenol and free formaldehyde, and it pollutes the environment heavily, so low poisonous or poisonous adhesive's exploitation is an urgent problem to resolve.

The other aim of modification of phenol-formaldehyde resin adhesive is to reduce curing temperature and promote curing speed, which requires it has the curing temperature (115±5℃) and curing time (below100s) that urea-formaldehyde adhesive has under the situation of not reducing its function and not adding its cost. By doing so we may not only reduce the steam consumption in the hot pressing and shorten the time of hot pressing but also decrease the possibility of blister and warping when reducing pressure. At present phenol-formaldehyde resin adhesive's modification work has been carried on in many ways. For example, the way of putting resorcinol resin adhesive, polymer formaldehyde in resin or putting special adhesive in the water miscibility phenol-formaldehyde resin adhesive have been adopted in some bamboo-based panel enterprise. Potential of this wok is also very large and there are still lots of work to do.

3.4 Variety of bamboo materials

Nowadays, bamboo-based panel all belong to structural stuff, and because of high strength, good toughness, large rigidity of bamboo and wonderful characteristics of bamboo-based panel, they are mainly used as template for concrete form and bottom board of train, bus or container. They are usually used to replace wood as structural stuff, so bamboo-based panel has contributed greatly to "using bamboo to replace wood" and releasing the tight of wood supply in China. Bamboo also has the advantage of special grain and simple and elegant luster, it is a kind of raw material that has good decorative effect. For example, Choosing fine and large diameter class bamboo, in bamboo peeling machine and make the width of bamboo veneer be 0.2~0.4mm, then bleaching and drying, and reinforcing them by nonwoven fabric and paper, in the end paste them on the furniture and wood-based panel by cutting and matching to get good decorative effect. Zhejiang Forestry University used bamboo floor strips for material, utilized pressurized impregnating to increase moisture, then used special adhesive to make bamboo strips be lay-up in parallel and then used tangential cold pressing wet adhesive to square bamboo material, at last quarter sliced them to be 0.2~1.2mm micro-bamboo to use decorative stuff. Rotary-cutting bamboo veneer and slicing micro-bamboo both have fine bamboo texture and better decorative effect. They all large profit margin. It may be considered that many a bamboo-based panel belongs to structural stuff, and will go on taking effect on ‘‘using bamboo to replace wood" in the existing way. And newly bamboo decorative stuff should be exploited and pay more attention to, and bamboo-based panel that is used as decorative packing stuff will have broad exploited future. Variety of bamboo-based panel will be inevitable.

3.5 Trend of green industry

Bamboo itself is green natural stuff, but in the production of bamboo-based panel much pollution that has worse effect on human and environment can be appeared. First is air-pollution, which is caused by adhesive, because adhesives of bamboo-based panel mainly are phenol and formaldehyde that are heavily poisonous and easily volatile, especially formaldehyde. After they spread in the air, human and environment will be threatened and injured. And the second is water-pollution, for example, water used to wash kettle and installation of glue application and so on. And the third is noise pollution, which is created by the bamboo machine. Some noise reached so high that almost made someonedeaf. The last is dust-pollution, which mainly includes boiler coal dust, smoke dust, sawdust, etc.

With the increasing consciousness of environment, the improving power of government in protecting environment and the advancement in technology, these pollution problems of bamboo-based panel will be solved. Taking some measures, such as using natural resin that is no poison and no bad effect, the application of supervising system on noise and dust, banning releasing water-polluted and so on, will promote bamboo-based panel to develop towards green. The development of environment-protecting industry will make bamboo-based panel to be green products.

Reference

1. Zhong Maogong. Discuss of situation and development of bamboo industry of China. Periodical on bamboo research. 2002 <4>
2. Zhao Renjie, Yu Yunshui. Technology of bamboo-based panel. Beijing, the Publishing House of forestry of China, 2002.
3. Zhang Qisheng. Bamboo industrialized utilization in China. Beijing, the Publishing House of forestry of China,1995.
4. Zhao Renjie. Technological innovation and developmental orientation of bamboo curtain plywood. Message of panels.

Study on Properties of Bamboo and Manufacture Technology of Structural-use Bamboo Board

WANG Zheng[1] GUO Wenjing[1] GAO Li[3]
(Research Institute of Wood Industry, CAF[1], Beijing Forestry University[3])

Abstract: In this article, two kinds of sympodial bamboo, D.yunnanicus Hsueh *et D. Z. Li* and whangee (*D. Membranaceus Munro*), and a kind of monopoial bamboo, *P. heterocyclavar. Pubescens ohwi,* their physical-chemical properties, manufacture technology of structural-use board and properties of board were studied. Results of physical-mechanical properties test between two kinds of sympodial bamboo showed their properties reached the standard designed for structural-use materials and can be used as architecture materials. Chemical composition and fiber characteristics' comparison showed properties of whangee were better than those of Yunnanicus including anti-decay. In the research of laminated panel technology, mechanical strength of laminated bamboo panel exceeded standard of structural-use material. Comparing Yunnanicus with Pubescens, mechanical properties of laminated Yunnanicus panel was higher than those of laminated Pubescens panel, but dimensional stability was worse. In addition, after aging treatment, properties of laminated Yunnanicus decreased much more, it can be concluded that physical properties of laminated Pubescens panel was more stable.

Key words: Bamboo materials, physical-mechanical properties, chemical properties, structural-use board, laminated panel

Bamboo is one of important reproducible fast-growing forest resources. It is attributed to its rapid growth rate and high yield, can be long-term utilization with only once plantation and reasonable management. Compared with wood, bamboo has good strength and elasticity and high stiffness, for a long time it is used as one of important structural materials in our country and other countries in bamboo-produced regions of the world.

In traditional bamboo structural utilization, the bamboo logs are used directly. But as the large variation in diameter and characteristics, they are used only in the construction of simple inferior dwelling houses or temporary houses. Low fall-off bamboo also can be used as scaffold and so on. Nowadays the advanced architecture utilization of bamboo is the bamboo reconstruction technology. With this technology the different high-strength panels and bamboo square lumbers can be formed and be used on the superior buildings' construction.

At present the widely used bamboo species is Phyllostachys pubescens. It is a kind of monopoial bamboo, its stem is straight and even, low fall-off with high physical and mechanical strength, and it is widely used in bamboo flooring, carriage box board and concrete formwork.

Sympodial bamboo is another bamboo species having better utilized prospect. Compared with monopoial bamboo, sympodial bamboo grows rapidly and yields much and distributed aboard in South China. But sympodial bamboo stem is some bend and its physical and mechanical properties varied much, little study has been undertaken on it, and is not widely utilized in architecture. Therefore, keep deeply study on sympodial bamboo applied in the field of architecture is very important to the utilization of sympodial bamboo and improvement of people's living standard in these districts.

This article studied two kinds of big sympodial bamboo, D.Yunnanicus Hsueh and whangee (*D. Membranaceus Munro*), which distribute in Yunnan province. Their physical-mechanical and chemical properties have been studied. At the same time, using sympodial and monopoial bamboo as produce architecture materials, the process and properties were also been studied. These results will bring forward fundamental data to their utilization on architecture.

1. Bamboo materials

D.Yunnanicus Hsueh et D. Z. Li is a kind of big sympodial bamboo in the southeast of Yunnan province, its culms are 25 meters high, diameter is 11~18cm wide and length between nodules is 40~50 cm. Whangee (*D.membranaceus Munro*) is the other study object, it grows in Yunnan and other regions, its culm height and diameter are about 15m and 7~10cm respectively, less than *D.Yunnanicus Hsueh*, length between two nodules 30~40cm.

Despite good prospect in architecture, material waste may occur if use it directly because of their top bend. On the other hand, these two materials stem is big and stiff, if take use of new technique to reconstitute the two to form a new material and use it in architecture will bring good economic profits. *P. heterocyclavar. Pubescens ohwi* is also one of commonly used big bamboo species, it is a kind of monopoial bamboo, diameter is 180 mm and culms can be 20 meters high. The area of Pubescens takes more than 2/3 of total areas in our country, and it is the most widely scattered economic bamboo species and it is produced as bamboo flooring, bamboo furniture, bamboo-weaved goods and bamboo cement formwork. Due to deep studies had been carried out on physical-mechanical properties of pubescens, feasibility of using it as structural-use material and material characteristics were discussed in this article.

2. Physical-mechanical properties of two kinds of sympodial bamboo used on architecture

Physical-mechanical properties of sympodial bamboo including density, dry shrinkage, modulus of rupture (*MOR*), modulus of elasticity (*MOE*), compressive strength and shear strength were studied. The results also were compared with properties of wood species used on architecture.

2.1 Physical properties of sympodial bamboo

2.1.1 Density

Density of two kind of sympodial bamboo is showed in Table 1.

Tab.1 Density of Yunnanicus and whangee

Species	Air-dry density (g/cm^3)	Density at 12% moisture content (g/cm^3)	Oven-dry density (g/cm^3)
Yunnanicus	0.74	0.75	0.71
Whangee	0.85	0.86	0.81

From Table 1 we can see that the two kind of sympodial bamboos yield in Yunnan province, density of whangee is higher than Yunnanicus. In the experiment, the air-dry moisture content of Yunnan is 9.5%

while whangee is 9.0%. Test density of bamboo decreases with the increase of moisture content of bamboo. Density is one of the important factors that influence strength of materials. If density is higher, mechanical properties will be better.

2.1.2 Dry shrinkage

Dry shrinkage of the two is shown in table 2.

Tab.2 Dry shrinkage of two bamboos

Species	Air-dry shrinkage (%)			Oven-dry shrinkage (%)		
	Radical	Tangential	Longitudinal	Radical	Tangential	Longitudinal
Yunnanicus	3.70	3.70	7.29	5.56	6.22	11.61
Whangee	3.72	2.79	6.48	5.71	4.94	11.07

Table 2 indicated that radical dry shrinkage of Yunnanicus is lower than whangee while tangential and longitudinal dry shrinkage is higher than those of whangee. The reason may have something to do with cell structure of these two kinds of bamboo and their microfiberal angle. Longitudinal dry shrinkage of these two is higher than tangential and radical direction. At the same time, Yunnanicus's tangential dry shrinkage is higher than radical but whangee's dry shrinkage is the other way round. Dimensional change in use is influenced by material's dry shrinkage; therefore, to develop high-powered structural-use materials, these data provide evidence for the study on reconstitute technology of sympodial bamboo.

2.2 Mechanical properties of sympodial bamboo

2.2.1 Modulus of rupture (*MOR*) and modulus of elasticity (*MOE*)

There are *MOR* and *MOE* of the two in table 3.

Tab.3 *MOR* and *MOE* of two kind of sympodial bamboo

Species	*MOR*(MPa)		Air-dry *MOE*
	Air dry	12% moisture content	
yunnanicus	175.00	166.70	15.30
whangee	240.00	222.90	19.70

Table 3 shows that *MOR* and MOE of whangee are higher than Yunnanicus, and strength of bamboo decreases with the increase of moisture content of bamboo (the test value of air-dry moisture content is about 9%). Compared with *MOR* and *MOE* of wood, we can see from table 4 that these data of the two's *MOR* and *MOE* are not only higher than normal wood used in structure, but even approach or surpass hardwood such as oak.

Table .4 *MOR* and *MOE* of some kinds of wood

Species	*MOR*(MPa)	*MOE*(GPa)	Species	*MOR*(MPa)	*MOE*(GPa)
Chinese red pine	70~90	9~11	birch	135~140	13.6~14.9
fur	74	9~10	oak	180~190	17.7~17.8

*Cheng Junqing, 1981, Wood science, Forestry Publishing House of China

2.2.2 Compressive strength parallel to the grain

Compressive strength parallel to the grain of sympodial bamboo is shown in Table 5.

Tab.5 Compressive strength parallel to the grain of two sympodial bamboos

Species	Air-dry strength (MPa)	12% moisture content strength (MPa)
yunnanicus	71.10	65.00
whangee	95.46	85.14

Data in Table 5 shows compressive strength parallel to the grain of whangee is still higher than yunnanicus. Compared with wood, both of bamboo are higher than pine (40~50MPa), even surpass hardwoods like oak and so on(50~60MPa). The data indicate, in terms of material's properties, it is practical to use bamboo to take place of wood as bearing materials like steady pole.

2.2.3 Shear strength parallel to the grain

In the design of contractual structure, there are some requirements on material's shear strength of beam design. The material bears bending load, especially at its joint place where destruction may take place for shear strength. It is necessary to test shear strength parallel to the grain (table 6).

Tab.6 Shear strength parallel to the grain of two sympodial bamboo

Species	Air-dry strength (MPa)	12% moisture content strength (MPa)
yunnanicus	14.70	13.90
whangee	19.70	18.40

*Cheng Junqing, 1981, Wood science, Forestry Publishing House of China

Tab.7 Shear strength parallel to the grain of some wood

Species	Shear strength (MPa)	Species	Shear strength (MPa)
fur	4.7	maple	14.3
Red pine	5.8	Fraxinus	12.5
spruce	5.9	mongolica	11.5

*Cheng Junqing, (1981) Wood science, Forestry Publishing House of China

The results in table 6 and table 7 indicate that shear strength parallel to the grain of these bamboos approaches or even surpasses some hardwood.

The test results of physical and mechanical properties of two kind of sympodial bamboo show that Yunnanicus and whangee can meet the standards of structural materials for architecture, it is practical to develop new kinds of structural-use materials by reconstitute technology based on bamboo.

3. Chemical composition of sympodial bamboo

Chemical composition also is one of important factors for application of structural-use bamboo board. Chemical composition not only can explain change of physical-mechanical properties of bamboo, but also have important influence on gluing results of laminated bamboo board.

3.1 Chemical composition analysis

Table 8 lists the chemical components of Yunnanicus and Whangee. The results show that the Whangee contains the higher 1%NaOH and benzene-ethanol extractives, but the ash and lignin content are lower than that of Yunnanicus. The cellulose and hemicellulose contents are nearly same in the two kinds of bamboo. Higher benzene-ethanol extractive in whangee may be advantageous for anti-decay, also for its higher density, it was foreseeable that its products would be good at strength.

Tab.8 Chemical component of Yunnanicus and whangee

species	water content (%)	ash conten (%)	extractives (%)			Holocell-ulose (%)	Klason lignin (%)	pentosan (%)	cellulose (%)
			Hot water	1% NaOH	benzene -ethanol				
yunnanicus	5.2	2.35	8.40	23.94	5.71	70.28	25.52	17.58	52.70
whangee	5.75	1.79	8.60	25.35	7.17	70.23	23.22	17.78	52.45

Annotation: cellulose=holocellulose - pentosan

3.2 Fiber length, width and fiber distribution

Fiber length, width and their length/width ratios of Yunnanicus and Whangee are shown in Table 9. Results indicated that whangee had higher fiber length and fiber width than Yunnanicus, including higher length/width ratio. These indicated that the whangee bamboo had the better fiber characteristics.

Tab.**9** Fiber characteristics of Yunnanicus and whangee

species	fiber length (mm)			fiber width (μm)		fiber L/W
	fiber number	Weighted average	arithmetic average	fiber number	av. width	
yunnanicus	3264	1.86	0.40	116	13.64	136.4
whangee	6781	2.07	1.00	119	14.73	140.5

Annotation: fiber L/W ratio=Av. Wt./Av.Width

Figure1 and Figure2 showed fiber length distributions of Yunnanicus and Whangee. From Figure1, it can be seen that whangee had better fiber length distribution curve, whereas Yunnanicus had higher content (21.77%)of short fiber (<0.20mm), which was 5 times more than that of Whangee. With the increasing of the fiber length, Yunnanicus fiber distribution presents an irregular change. In addition, it also presents higher distribution ratio below 0.4mm than that of the Whangee. Therefore, Whangee bamboo is a better fiber material in structure-use panel processing.

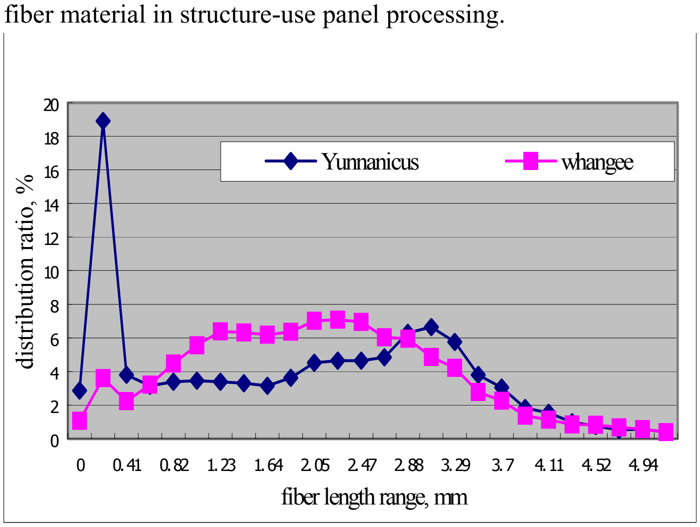


Fig.**1** The weighted distribution of Yunnanicus and Whangee

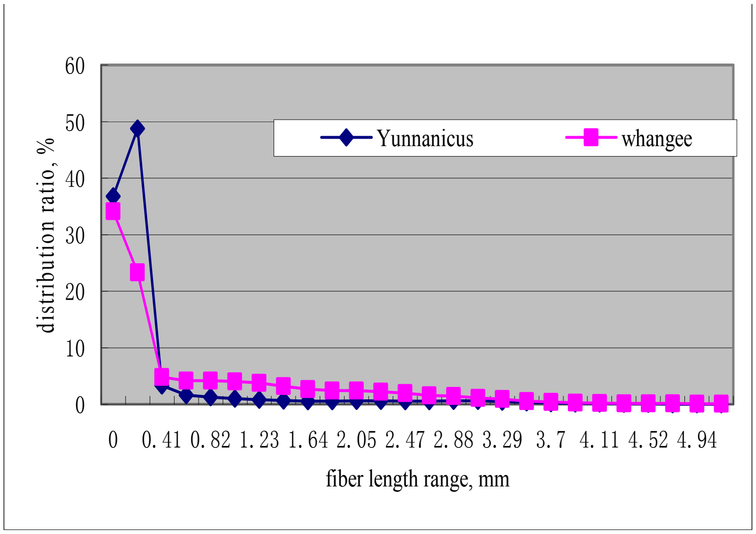


Fig.**2** The population distribution of Yunnanicus and Whangee

3.3 Fiber cell characteristics

Table 10 shows the fiber cell characteristics of Yunnanicus bamboo and Whangee bamboo. Results indicate that Yunnanicus bamboo fiber has bigger lumen and thinner cell wall than Whangee bamboo, whereas Whangee bamboo fiber has higher wall/lumen ratio, which gives higher fiber strength than Yunnanicus bamboo.

Tab.10 Fiber cell characteristics of two bamboo

species	lumen diameter(μm)	cell wall thickness(μm)	wall/lumen ratio*
Yunnanicus	4.24	4.15	1.96
whangee	3.29	4.59	2.79

Annotation: wall/lumen ratio: 2 × cell wall thickness ⁄ lumen diameter

Based on the analysis of chemical composition and fiber characteristics of Yunnanicus and Whangee, it has showed that the whangee is better material for panel processing because of its higher specific gravity, higher fiber length and its distribution rule, higher wall/lumen ratio. In addition, the higher benzene-ethanol extractives of the whangee can be an advantage for anti-decay in architecture processing and utilization. In conclusion, whangee is better than Yunnanicus.

4. Process of structural-use materials and characteristics

Producing laminated bamboo panel was main manufacture technology of producing structural-use bamboo board. The following part discussed process of structural-use materials and material characteristics.

4.1 Experiment methods

Bamboo culms —*rip*→ *bamboo pieces* —*trim*→ *bamboo strips* —*leaching*→ *saturated bamboo* —*dry*→

oven-dried saturated bamboo —*lay up*→ *mat* —*hot/cold-pressing*→ *laminated bamboo panel*

In this process, bamboo culms were cut into long pieces at longitudinal directions firstly, then trimmed as strips 0.5~0.8 mm thick and 20~30 mm wide, at the same time exterior layer was wiped off. When bamboo strips were air dried to 10~12% moisture content (m.c.), they were dropped into 37% PF adhesive. After surface of bamboo strips had adhesive, they were fished out and excessive adhesive was wiped off. After these saturated strips were dried to 16% m. c., they were laid up according to requirements and hot and cold pressed to products.

In this study, processing variables were as follows: adhesive adding content was 8%, suppose bamboo strips were 12~16% m.c.; hot pressing temperature was 140℃; hot pressing time was 1~1.5 min/mm (decided by m.c.); hot pressing pressure was 5 Mpa, density of panel was 0.95~1.00 g/cm^3; cold pressing pressure was 1.5 Mpa and time was 0.5 min/mm.

Bamboo strips were laid up in different directions, one was laid up along the grain, strips were laid up at the same direction; the other was crossed laminated, laid one layer or more than one layers together with adjacent layers crossed.

4.2 Physical-mechanical properties of structural-use bamboo board

This study mainly tested these physical-mechanical properties of laminated bamboo panel: modulus of rupture (*MOR*), modulus of elasticity (*MOE*), density, thickness swelling content (*TS*) after saturated in cold-water for 24 hours and in boiling-water for 2 hours. To testify its weathering resistance, property changes should be tested after accelerated aging. Two methods were adopted to test the aging property: one was the standard ASTM D3434 in America, the method was: to put laminated panel into 100℃ boiling water for 10 minutes and air-dry test pieces for 4 minutes at room temperature, then treat it in 107℃ oven for 1 hour, we call it a cycle. In this study, data of residual *MOR* and *MOE* were tested after 20 cycles. The other method was: to put laminated panel into boiling water for 2 hours, then at the temperature of 107℃, oven-dry it for 17 hours, test residual *MOR* and *MOE.*

4.2.1 Physical-mechanical properties of laminated bamboo panel

Table 10 showed physical-mechanical properties of two kinds of bamboo panel laid up at different directions.

Tab. 10 Physical-mechanical properties of two laminated bamboo panel

Species	Direction	Density (g/cm^3)	TS (%)		*MOR* (MPa)	*MOE* (GPa)	Compressive strength parallel to grain (MPa)
			24 hours in cold water	2 hours in boiling water			
Pubescens	Parallel	0.96	2.4	17.8	174.70	13.68	85.47
	Crossed	1.00	2.5	17.1	135.78	10.50	71.99
yunnanicus	Parallel	0.88	3.5	23.5	210.23	23.48	89.42
	Crossed	1.03	3.6	26.7	194.96	19.72	82.42

From the data of table 10, we can see that parallel and crossed Yunnanicus panel's mechanical properties were higher than those of Pubescens. *MOR* of Laminated Yunnanicus panel parallel to grain had reached 210.23 Mpa, MOR of crossed laminated panel was 194.96 Mpa. Made by the same process, Laminated Pubescens panel were 174.70 Mpa and 135.78 Mpa. There was trend in the test of *MOE*: *MOE* of Laminated Yunnanicus panel were 23.48 and 18.37 Gpa diversely, which were higher than those of Laminated Pubescens panel 8~10 Gpa. Also the same rule was happened on compressive strength, but the difference was less than MOE (it was mainly accorded to the amount of layers laid up). There was something to do with its' own strength. Table 11 showed comparison between Yunnanicus and Pubescens's physical-mechanical properties.

Tab. 11 Comparison between physical-mechanical properties of two kinds of bamboo

Species	Contra variant strength (MPa)	*MOE* (GPa)	Compressive strength parallel to grain (MPa)
Pubescens	140~165	11.7~12.5	65~79
Yunnanicus	175.00	15.30	71.10

Annotate:

①Data of Pubescens were come from Physical-mechanical properties of seven kinds of bamboo in China, Li Yuanzhe etc.

②Range in data of Pubescens were caused by bamboo age (range from 2~6 years, 2 years is the lowest)

③Data of 4 years' Yunnanicus were tested directly.

It can be seen from table 11 that one of important factors that affect mechanical properties was strength of Yunnanicus was higher than strength of Pubescens.

In manufacture, because of the higher strength of Yunnanicus, more energy are needed in its' panel manufacture. Considering that Yunnanicus is an important sympodial bamboo in South China and has not yet been utilized well, it is estimable to develop it as structural-use panel.

4.2.2 Dimensional stability of two laminated bamboo panel

There are data about panel's TS that was dropped in cold-water for 24 hours and boiling-water for 2 hours in table 10. Table 10 showed that *TS* of Yunnanicus panel was higher than *TS* of Pubescens panel after above treatments. Parallel panel and crossed Yunnanicus panel after cold-water's immersion were 3.5% and 3.6% separately, while data of Pubescens panel were 2.4% and 2.5%. After 2 hours' boiling, *TS* of two kinds of bamboo were increased to a great extent, *TS* of crossed Yunnanicus panel was the highest, the next was parallel Yunnanicus panel.

TS of the two laminated Pubescens panel after 2 hours' boiling were lower than those of Yunnanicus panel, and difference directions caused was not distinguishable. It was indicated that dimensional stability of Pubescens panel was better than that of Yunnanicus panel, factors that influence dimensional stability of laminated bamboo panel were not simple, such as their own properties of swelling-shrinkage, thickness and variability, properties of adhesive, process conditions and sum of laminated layers and density that would influence more or less. Deep studies should been taken on this respect.

4.2.3 Aging resistance of two kinds of laminated bamboo panels

Used as structural-use material, aging resistance or aging resistance during use is an important factor worth noticing. This study was according to standard ASTM D3434 in America to examine adhesive's aging resistance outside, which was: after 20 cycles of boiled in water and conditioned in hot wind, to test residual rate of those mechanical properties. They were compared with the results that after once aging treatment (boiled 2 hours and dried 17 hours).The results are showed in table 12 and table 13.

Tab. 12 Change of *MOR* of two kinds of laminated bamboo panel after aging

Species	Assembly style	Untreated (MPa)	Aging 1 (MPa)	Aging 2 (MPa)	Residual *MOR* (%)	
					Aging 1	Aging 2
Pubescens	Parallel	174.70	174.46	166.25	99.9	95.2
	Crossed	135.78	132.74	120.10	97.8	88.5
yunnanicus	Parallel	210.23	143.2	131.72	68.1	62.7
	Crossed	194.96	155.32	174.12	79.7	89.3

Data of aging 1: According to ASTM D3434 standard after 20 cycles

Data of aging 2: After 2 hours boiling and 17 hours at 107℃ in oven.

Tab. 13 Change of MOE of two kinds of laminated bamboo panel after aging

Species	Assembly style	Untreated (GPa)	Aging 1 (GPa)	Aging 2 (GPa)	Residual *MOE* (%)	
					Aging 1	Aging 2
Pubescens	Parallel	13.68	13.66	13.37	99.9	97.9
	Crossed	10.50	10.31	10.42	98.2	99.2
yunnanicus	Parallel	23.48	20.23	18.37	86.2	78.2
	Crossed	19.72	19.14	18.07	97.1	91.6

It can be seen from table 12 and table 13 that compared with laminated Pubescens panel, mechanical strength of laminated Yunnanicus panel decreased more than that of laminated Pubescens panel, and parallel panel decreased more than crossed panel. After 20 cycles' aging treatments according to ASTM standard, residual MOE was 68% of before; while residual *MOE* was 62% after the second aging treatments. After the two aging methods *MOE* of the two crossed panel remained 79.7% and 89.3% separately.

In this study, there was a phenomenon worth watching, that Yunnanicus panel of two different directions decreased differently after two aging treatments, parallel Yunnanicus panel decreased more after the first aging treatment, converse was the crossed panel.

MOR of laminated Yunnanicus panel met the same situation after two aging treatments, and showed the following characteristics:

①The extent that laminated Yunnanicus panel decreased was bigger than laminated Pubescens panel;
② Parallel laminated panel decreased more than crossed laminated panel;
③ Between the two aging treatments, the second made parallel panel and crossed panel decreased more than the first, this was different with crossed laminated Yunnanicus panel

Aging resistance of laminated Pubescens panel was better than laminated Yunnanicus panel. Residual *MOR* of parallel Pubescens bamboo after two aging treatments was 99.9% and 95.2% separately. It can be safely concluded that according to ASTM standard, almost no change happened on parallel Pubescens panel after 20 cycles, even under the more severe conditions where boiled for 2 hours and dried at high temperature for 17 hours made it decreased 4.8%. It showed good properties of aging resistance.

Strength of crossed laminated Pubescens panel decreased more than that of parallel panel after aging treatment. Residual strength after the first treatment was 97.8%, and the second was 88.5%.

MOE of laminated Pubescens panel after aging decreased still little. *MOE* of parallel Pubescens panel remained 99.9% and 97.9% separately and the crossed panel was 98.2% and 99.2% separately. The extent decreased was very trivial. We should notice that when *MOR* of crossed panel decreased a little more (residual rate was 89.3%), *MOE* of it decreased much less (residual rate was 99.2%). To find the reason more research was needed.

4.2.4 Conclusion

This part was mainly studied on the manufacture technology of laminated panel made of *D. yunnaicus Hsuch et D. Z. Li* and *P. heterocyclavar. Pubescens ohwi*, also compared their physical-mechanical properties in order to provide proof to produce architectural panel made by bamboo materials. Conclusions are as follows.

4.2.4.1 Laminated bamboo panel can be produced by adding adhesive and hot pressing. Mechanical properties reached or even exceeded pine properties used in architecture.

4.2.4.2 Comparison between physical-mechanical properties of laminated panel made of two kinds of bamboo we can see that properties of laminated Yunnanicus panel were higher than those of laminated Pubescens panel, but dimensional stability was worse.

4.2.4.3 From comparison between properties of laminated panel laid up at different directions can see that parallel panel had better mechanical properties than crossed panel, so it can used as I-beam bearing girder and straddle, while crossed laminated panel can be used as I-beam web or other complex components like wall board need not bearing.

4.2.4.4 Aging resistance of laminated Yunnanicus panel was worse. Parallel laminated Yunnanicus panel after aging decreased much more while laminated Pubescens panel decreased little. It showed that physical-mechanical properties of laminated Pubescens panel were more stable.

5. Conclusion

This article was studied on physical-chemical properties of two kinds of sympodial bamboo and manufacture technology of laminated panel. Through properties test, these results can be reached:

5.1 The test results of physical and mechanical properties of two kind of sympodial bamboo show that Yunnanicus and whangee can meet the standards of structural materials for architecture, it is practical to develop new kinds of structural-use materials by reconstitute technology based on bamboo.

5.2 Comparison between chemical composition and fiber characteristics of Yunnanicus and whangee showed that whangee was better for panel processing because of its higher specific gravity, higher fiber length and its distribution rule, higher wall/lumen ratio. In addition, the higher benzene-ethanol extractives of the whangee can be an advantage for anti-decay in architecture processing and utilization.

5.3 In the study of manufacture technology of laminated bamboo panel, the results indicated: laminated bamboo panel can be produced by adding adhesive and hot pressing. Mechanical properties reached or even exceeded pine properties used in architecture.

5.4 Comparison of physical-mechanical properties between Pubescens and Yunnanicus shows, through mechanical properties of Yunnanicus were higher than those of Pubescens, dimensional stability of Yunnanicus was worse than that of Pubescens. Laminated *Yunnanicus* panel after aging decreased much more while laminated *Pubescens* panel decreased little. It showed that physical-mechanical properties of laminated *Pubescens* panel were more stable.

References

1. ASTM D3043-87. (1987) Standard methods of testing structural panels in flexure. Philadelphia
2. ASTM D3434-00. (2000) Standard test methods for multiple-cycle accelerated aging test for exterior wet use wood adhesives
3. Cheng Junqing. (1981)Wood science. Chinese Forestry Publishing House of China.
4. Divid S. Gromala. (1996)Manual for engineered wood construction, Load and resistance factor design
5. GB/T15780-1995. (1995)Standard testing methods for physical and mechanical properties of bamboo
6. Jules Janssen. (2000)Designing and Building with Bamboo. INBAR Technical Report. 20
7. P. M. Ganapathy, Zhu Huanming, S. Zoolagud etc. (1999)Bamboo Panel Boards—a State of the Art Review. INBAR Technical Report. 12
8. Tang Yongyu. The bamboo utilization actuality and developing direction. The International Symposium of Bamboo Industrialization Utilization in 2001. The Government of Chishui City, GuiZhou Province
9. Yao Xishen, Liang Jingshen, Ma Naixun etc. (1992)The microstructure of Main Chinese Bamboos. Daliang Publishing Company
10. Zhang Qisheng, Sun Fengwen. (1999)The Development and prospect of bamboo industry in China. Chinese Forest Industry .4
11. Zhu Shilin, Ma Naixun, Fu Maoyi. (1993)Chinese bamboo class picture records. Chinese Forestry Book Concern

Bamboo Resources, Uses and Trade: The future?

Ian R. Hunter
Director General of International Network for Bamboo and Rattan (INBAR)

International Network for Bamboo and Rattan (INBAR), P.O Box 100102-86, Beijing 100102, P. R. China.
Phone: +86-10-64706161. Fax: +86-10-64702166. E-mail: ihunter@inbar.int.

1. INTRODUCTION

The purpose of this article is to review the current situation with regard to bamboo resources and trade and to make predictions as to its likely development. Since the subject of this seminar is resources and trade the paper will emphasise products that might enter into international trade. However the distinction will not be applied rigidly since to do so might lead to anomalies – discussing international trade between two small countries while ignoring internal consumption patterns in giant countries like China and India.

2. THE CURRENT SITUATION

2.1 Bamboo Trade

Bamboo products are well established in many countries as products of first choice for containers, mats, housing. Bamboo products are also well established on the world market. It is difficult to estimate the exact size of domestic and international markets. Domestic markets are not quantified exactly. International markets suffer from the difficulty that the custom codes have not been revised to reflect changes in the pattern of trade. INBAR with it's member countries has been leading the effort to obtain this revision in the world Custom's Organisation. Even with revision, difficulties will remain in identifying composite products (bamboo and wood for example). However we know that the current volume of world trade is $2.5 billion we believe that the total may exceed $5 billion. China generates a very significant fraction of the exports. The EC and USA take 80% of imports. Bamboo is therefore a very significant component in world trade, having export sales as great as bananas and only slightly less than cotton. Tropical timber by comparison has a trade of $14 billion.

For countries where we can gain some estimate of the size of the domestic market in relation to the export market we believe it to be at least five times as great.

2.2 Bamboo Resources

Bamboo occurs as an understorey component in many forest types in the tropics and warm temperate latitudes (e.g Widmer 1998). It occurs naturally as pure stands often as an altitudinal belt on mountains. It also occurs as nearly pure stands in certain semi-natural situations. These may have arisen as a result of large-scale disturbance in the forest cover. Forest recovering from natural or man-made disturbance may trend towards a distinct bamboo-dominated sub-climax for reasons that are not always clear (e.g. Stern 1995, Lei and Koike 1998) . Man can easily assist this process and produce "Bamboo Seas" with relative ease. Bamboo is generally easy to regenerate artificially. Bamboo will grow in isolated clumps on parts of the farm with, unlike isolated trees, no loss in wood quality. It takes only three or four years for bamboo to start producing yield and thereafter, every year, it produces the same amount until overtaken, after 50 or more years, by gregarious flowering.

There are however over 1500 species of bamboo and less than 50 species are routinely cultivated. The remaining species rely on their natural forest habitat for survival and that habitat, as the joint WCMC-INBAR project showed, is disappearing. Greater effort is needed both for in- and ex-situ conservation of threatened species.

For the cultivated species, there has been a pattern of expanding plantations and more clumps on farms in parallel with expanding demand. Bamboo as a crop rather uniquely dovetails with the short planning horizons of the human species.

2.3 The future

2.3.1 Bamboo Resources.

Only a narrow range of the available species has currently been domesticated. For industrial usage domestication has clearly favoured the tall growing, large-culmed species. A distinct set of small to very small species have been selected for the important but entirely separate landscape market. However there are many large growing species that are not routinely used. It is the impression of this author (supported by studies like those of Wang, 1997) that while bamboo species do differ between themselves in key wood characteristics they do not differ as much as different species of trees in this regard. However, differences in wood characteristics for certain uses (Hasnin *et al* 1999), splitting characteristics and other handling criteria have sometimes been mentioned as reasons for not preferring certain species. Nevertheless it seems probable that as knowledge of bamboo uses expands more species will be domesticated.

People with a peripheral knowledge of bamboo routinely make the mistake of thinking of it as a tropical plant. In fact there are bamboo species growing well into the cool temperate zones of Asia and high up in mountains where the climate is distinctly cold (INBAR News 2001a). The INBAR "species-to-site matching" project identified over 25 species that could tolerate winter minima less than -20^0C and three that could tolerate -29^0C (INBAR News 2001b). It is fair to say that bamboo will grow into the high fifties latitude where oceanic influences moderate winter temperatures (e.g Western Canada, Western Europe). The EC-funded project "Bamboos for Europe" established trial plantings of 17 species at sites across Europe (Table 1), including a site on the north German plain. Yields ranged from 7 t DM/ha/year at the northerly sites to 15t DM/ha/yr at warmer, wetter sites. With this level of productivity, bamboo is a serious contender for biomass production. For Europe it has been place in the top five contenders because it's productivity is good; it can yield continually; it stays green all year (which is a very useful characteristic from a landscape perspective); it has a higher water-use efficiency than other contenders and it has desirable physical qualities for biomass energy conversion (El Bassam and Jakob 1996, INBAR News 2001a). Europe and America have much surplus agricultural land which could easily be used. Thus the prospects for a large increase in both the scope and scale of bamboo resources are good.

Bamboo is also a very tolerant plant of poor soils. This is important in a world where there are large areas of degraded soils. A key INBAR project near Allahabad in India showed that bamboo species could be used to rehabilitate soils that were heavily degraded as a result of brick-field mining. Bamboo established and grew on the residual soil and within a few years provided the shelter and soil-improvement that enabled other cash-generating crops to be grown. Bamboo has also been shown to be useful in artificial wetlands for effluent treatment (INBAR News 2003)

2.4 Uses

2.4.1 Bamboo Houses

Around the world many people live in houses and use buildings that are vulnerable to earthquake, landslip and other natural disasters. Yet with good design, many of these events are survivable. Good design does not necessarily mean great expense. Two of the Millenium Development goals address this concern directly:- improvement in the conditions of life for slum dwellers and provision of education and health care (for which buildings will be needed).

On March 2, 1987, a series of earthquakes measuring up to 6.5 on the Richter Scale shook the Rangitaiki Plains, parts of which subsided by up to 2.05 metres. Rifts opened in the ground, buildings and a dam were damaged, as were roads and railway lines, and a railway locomotive was toppled on its side by the shake. A crack 7 kilometres long opened in the Rangitaiki Plains near Edgecumbe. 50 % of the houses in Edgecumbe were damaged. It was estimated that the damage caused by the earthquake cost $150 million. One person died from a heart attack, possibly caused by the shock of the earthquake, but there were no other deaths. This low casualty rate was because all the buildings, most of which were wood-framed, were built with earthquake resistance in mind. Rainer and Karacabeyli (1999) surveyed the performance of wood-frame construction in a number of recent earthquakes: Alaska, 1964; San Fernando, California 1971; Edgecombe, New Zealand 1987; Saguenay, Quebec 1988; Loma Prieta, California 1989; Northridge, California 1994; and Kobe, Japan 1995. They concluded that wood-frame construction can withstand the shaking from large earthquakes without serious distress and often without damage provided that appropriate anti-seismic procedures are followed by designers, builders and owners.

Bamboo houses built using a pole structure have many of the components of wood-framed houses and offer many of the same disaster-resistance benefits. They are light, yet strong. INBAR has done much to advance the design of such houses (Janssen 2000). However as yet they lack clear building codes to guide architects and builders. They also need further design work on joint strength; rigidity and cross-bracing if they are to offer exactly same benefits as wood-frame houses.

It has been known for a fairly long time that split bamboo can be used with confidence as re-inforcing for concrete (Glenn, 1950: Brink and Rush 1966). This design principle can be used in combination with bamboo pole construction or other forms of construction to produce wall panels for houses; reinforced floors and ceilings. The principle is already well-known in the Latin American bahareque style of building.

Difficulties with jointing bamboo poles and the weakness of bamboo poles in tension (hence in long-span roof members) has led to the development of glue-laminated “bamboo lumber” from bamboo matboard. The design concepts follow those used for plywood beams and trusses (Singh 1996, Wang and Guo 2003a and 2003b). This “bamboo lumber” is being used to fabricate roof trusses for a school building in China.

One very great advantage of building with bamboo is that much of the raw material for the building can be accessed close to the building site, which limits transport requirements and makes building in poorly accessible places easier.

2.4.2 New Tradable Uses for Bamboo

Bamboo can substitute directly for wood in many of its uses. Bamboo articles are particularly hard and durable. Bamboo therefore tends to substitute for hardwood products. As world population and standards of living rise, the supply of hardwood products comes under greater pressure. At the same time there is a growing concern amongst environmentally-aware consumers that using hardwood products might exacerbate deforestation – particularly in the tropics. Thus we must expect that a current tendency to wood substitution will continue.

The need to substitute wood pulp with bamboo pulp either in entirety or mixture may also be driven by demand and supply constraints. New, large consumers of these products are entering the world stage. Two of these consumers – China and India – accounting for 40% of the world’s population - have very limited forest resources to draw upon. For example annual consumption of wood in China is forecast to rise to some 233 million cubic meters. This would be commensurate with a shortfall in supply of 60 to 70 million cubic metres. In 2000 China imported some 3.4 million tons of wood pulp and 3.7 million tons of waste paper. Just one year later these imports had jumped to 4.9 and 6.4 million tons respectively. The 2001 figures reveal that 38 percent of China’s total paper pulp requirements are being met from imports. The cost in that year alone was over US$2.7 billion. China is also a major producer, consumer and importer of finished paper products. In 2001, total production and consumption of paper and cardboard ranked second in the world surpassed only by the USA. Development of a bamboo-based industry has been strongly suggested.

One of the critical factors enabling an explosion of new uses for bamboo has been the relatively development of glue-laminated technology. This has enabled the development of parquet flooring (currently a $50 million export industry from China); panels; mouldings (INBAR News 2003b) and many containers and daily-use items. Bamboo parquet flooring compares very well with good hardwood flooring (Schwab and Schlusen 1999).

In 2002 INBAR sponsored a design competition for modular or “pack-flat” furniture using glue-laminated bamboo boards (INBAR News 2002a). Bamboo boards have a very hard surface and are very suitable for heavy wear furniture such as desks and tables. This type of furniture is already in production.

Bamboo matboard has been made for many years (INBAR 1996). It consists of woven mats of split bamboo pressed together to form a product that resembles plywood but thickness for thickness, is stronger. Bamboo matboard is being used in China instead of tropical plywood for concrete formwork. It is used as the floor of the tray of light trucks. It can be used structurally in light houses. Now, it is being corrugated to substitute for galvanised iron in roofing panels (INBAR News 2003c). International trade in plywood is large and bamboo matboard could substitute for some of it.

Paper has been made from bamboo for millennia. India has a moderate size industry in kraft-type pulp from bamboo. However recently China has begun to fabricate laser- and photo-copy paper from bamboo. INBAR reported on tests of this paper in comparison with wood-based paper in its News Magazine (2002b). Bamboo pulps tend to have relatively long fibres accompanied by substantial amounts of fines. Bamboo fibres differ from wood fibres leading to a fast beating time for the pulp but a higher beating energy. The presence of the fines probably explained the different drainage resistance of bamboo paper that was found. Tear strength and burst index were similar to hardwood pulps. Tensile strength and stiffness tended to be lower than softwood pulps but could be improved by removing the fines. The bamboo paper was not as bright as some wood based papers and this is thought to be due to coarser fibres and light absorption by fines. The coarser fibres gave a rougher surface. All in all, the testing laboratory concluded that the bamboo paper was not as good as spruce/birch paper. However to the untrained eye the differences are minimal and INBAR, which has used this paper in its office for three years, finds them of no practical significance. With further refinement of manufacture such bamboo papers could also become a major traded item.

The international market for bamboo shoots has grown to over $150 million per year from China alone. Approximately half goes to Japan. Bamboo shoots are exported canned, packed in plastic and dried. There is interest from restaurants in America and Europe. To further stimulate interest INBAR collaborated in the production of a “fusion” cookbook combining Western cuisine with the use of bamboo shoots. INBAR has also sponsored research into the use of bamboo flour in new products (INBAR News 2002c).

There is a small established market for medicinal products made from bamboo. There has, as yet, been little systematic development of this market.

Bamboo charcoal is valued as an air purifier and for a range of other anti-pollution uses. Activated bamboo charcoal is now traded internationally. Activated charcoal from bamboo has a higher surface area than that from wood and is therefore more effective weight for weight (Mishiro *et al*. 1999).

3. CONCLUSION

Resources of the domesticated bamboos can be expanded speedily and easily to match demand. There is little likelihood therefore of a great imbalance between demand and supply. The non-domesticated species face a more uncertain future.

Uses and trade in bamboo have grown rapidly in recent years. Bamboo can substitute for wood in many of it’s uses. It is to be expected that as demand for wood-like products increases and environmental concerns about deforestation remain strong, bamboo will increasingly substitute for wood. Likely areas of further penetration include flooring, panels, paper and bamboo matboard for plywood.

Bamboo is also likely to make inroads into house and building construction particularly in the developing world as new designs show that it can be used to construct culturally acceptable yet strong and safe buildings.

References

Brink F.E. and Rush, P.J., 1966: Bamboo Reinforced Concrete Construction
U. S. Naval Civil Engineering Labaoratory; Port Hueneme, California USA. Accessible at
http://www.romanconcrete.com/Bamboo/BambooReinforcedConcreteFeb1966.htm

El Bassam, N. and Jakob, K., 1996: Bamboo - a new source for raw materials. First experimental results. Landbauforschung Volkenrode. 1996, 46: 2, 76-83.

Glenn, H.E., 1950: "Bamboo reinforcement in portland cement concrete," Engineering Experiment Station, Clemson Agricultural College, Clemson, South Carolina, Bulletin No. 4, May 1950.

Hasnin, S.M.M., Biswas, D., Sheikh, M.W., Ali, M., 1997: Particleboard making characteristics of three bamboo species. Bangladesh Journal of Forest Science. 1997, publ. 1999, 26: 2, 19-22.

INBAR 1996: Bamboo mat board: a new bamboo-based building material from India.
International Network for Bamboo and Rattan, International Development Research Center, Regional Office for South Asia; New Delhi; India

INBAR News Magazine 2001a: "Interview with Dr El Bassam". INBAR News Magazine Volume 8 no 2 page 10.

INBAR News Magazine 2001b: "Bamboo in Winter". INBAR News Magazine Volume 8 no 2 page 16.

INBAR News Magazine 2002a: "Bamboo manufacturers..". INBAR News Magazine Volume 9 no 1 page 10.

INBAR News Magazine 2002b: "Writing on Bamboo". INBAR News Magazine Volume 9 no 1 page 14.

INBAR News Magazine 2002c: "Bamboo Cookies" INBAR News Magazine Volume 9 no 1 page 11

INBAR News Magazine 2003a: "Bamboo in artificial wetlands". INBAR News Magazine Volume 10 No 1 page 4.

INBAR News Magazine 2003b: "Bamboo mouldings". INBAR News Magazine Volume 10 No 1 page 3.

INBAR News Magazine 2003c: "Corrugated Bamboo Matboard" INBAR News Magazine Volume 10 no 1 page 2.

Janssen JJA; 2000: Designing and Building with Bamboo. International Network for Bamboo and Rattan (INBAR), Beijing, China. 208 pages

Lei, T.T., Koike, T., 1998: Functional leaf phenotypes for shaded and open environments of a dominant dwarf bamboo (*Sasa senanensis*) in northern Japan. International Journal of Plant Sciences. 1998, 159: 5, 812-820.

Mishiro, A., Ikarashi, Y., Kim ByungRo., Yashiro, M., Kim, B.R., 1999: Some physical and chemical properties of carbonized wood wastes (I). Research Bulletin of the Niigata University Forests. 1999, No. 32, 1-18.

Rainer, J. H. and Karacabeyli, E: 1999: Performance of Wood-frame Building Construction in Earthquakes Vancouver: Forintek Canada Corp. 28pp

Schwab, E. and Schlusen, K., 1999; Properties of bamboo parquet elements. Holz als Roh und Werkstoff. 1999, 57: 1, 63-68.

Singh, S.P., 1996: Utilization of bamboo for structural wood and other panel products. Journal of the Indian Academy of Wood Science. 1996, recd. 1997, 26 27: 1 2, 61 64

Stern, M.J., 1995:An inter-Andean forest relict: vegetation change on Pasochoa Volcano, Ecuador. Mountain Research and Development. 1995, 15: 4, 339-348

Wang, Y.C., 1997: Evaluation on technological utilization value of some bamboo species grown in Taiwan (II). Forest Products Industries. 1997, 16: 3, 363 374

Wang, Z. and Guo, W., 2003a: Current status and prospects of new architectural materials from bamboo. INBAR Working Paper 47. International Network for Bamboo and Rattan (INBAR). 10 pages. Accessible at http://www.inbar.int/publication/pubdetail.asp?publicid=109

Wang, Z. and Guo, W., 2003b:Laminated Panel Manufacture of Two Kinds of Bamboo for Architecture Material and Property Comparison. INBAR working Paper 48. International Network for Bamboo and Rattan (INBAR). 5 pages. Accessible at http://www.inbar.int/publication/pubdetail.asp?publicid=110

Widmer, Y., 1998: Pattern and performance of understory bamboos (Chusquea spp.) under different canopy closures in old growth oak forests in Costa Rica.
Biotropica. 1998, 30: 3, 400 415.

Table 1: Bamboo Species grown in N. Europe

Phyllostachys vivax
P. aureosulcata
P. propinqua
Fargesia. mureliae
F. nitida (two varieties)
P. humilis
P. nigra
P. praecox
P. viridoglaucescens
P. var ‘Zwijnenburg’
Pseudosasa japonica
Sasa disticha (syn Pleioblastus distichus)
S. keguma
S. palmata
S pumila
Semiarundinaria kagamia

Studies on technical systems and comprehensive benefits of converting agricultural land into Bamboo in Sichuan

Chen Qi-bing

Forestry Department of Sichuan Agricultural University, Yaan 625014. Phone: +86-835-2242531/ 2230570. Fax: +86-835-2223253or +86-28-5184466. E-mail: cqb@sicau.edu.cn

Sun Jun-feng

Sichuan Agricultural University, Yaan 625014. Phone: +86-835-2242531/ 2230570. Fax: +86-835-2223253.

Abstract: Based on the comprehensive soil substrate of the converting agricultural land and the local economic condition in Sichuan province, the bamboo-foresting model has been selected out as one of the main methods of the construction of converting agricultural land into forests. The accompanied technical system has been thoroughly studied.

Key words: Converting agricultural land into Bamboo, Technical system, Synthetic benefits

Bamboo-plants have played an important role in the construction of the converting agricultural land into forest in Sichuan. As this kind of construction has been regarded as the vital important biological construction, it is of most importance to carry on the study of technical systems of it, as well as the evaluation on the synthetic benefits of it. It has still remained untouched as far as the study and evaluation mentioned above, which is aimed at the *Bambusa Pervariabilis*×*Dendrocalamopsis Oldham (BPDO)* and the *Dendrocalamus latiflorus Munro (DLM).* In this article, the systematic study and the evaluation of it aiming at the two species of bamboos are done at the first time, which includes selecting technologies, rapid cultivating technologies, accompanied afforesting technologies, ecologically positional observation, and the economic benefits, the social benefits, as well as the industrialization of it, etc.

The main results gained from the trials are listed as the following:

1 Brief introduction of the experimental areas and the experimental materials

1.1 Basic conditions of the experimental areas

According to the distribution characteristic of the converting land in Sichuan province, Muchuan county of Leshan city and Yaan city, which are abundant of bamboo plants, have typically selected out as the experimental bases. The two large areas have represented the major type of the converting into bamboo in

Sichuan. What is regarded as the core is that these two regions both have the big-and-middle-sized papermaking enterprises, especially the Sichuan Yongfeng paper industry and Yaan Zhong's bamboo paper industry. The basic circumstances of the twp regions are listed as follows:

The main experimental position in Yaan city is located on the second grades of the terraces alongside the Qingyi river valley, north latitude 30^{o}8 ', and east longitude 103^{o}14 ', which has the average temperature of 25.3 ℃ in the hottest month (7th months) and 6.1 ℃ in the coldest month (1 month), from which the average mark can get out, which is about 16.2 ℃ with the elevation of 600m , yearly rainfall 1774mm, annual average sunshine 1039h, frost-free period 304d, accumulated heat, which is higher than 10 ℃, is 5231 ℃. The soil is purple soil, and the original texture of it is the slope product composed of irrigated purple sand shale, which has been built up in the Cretaceous Period, with the thickness of 80~120cm, quality of a material of soil layer, and organic nature content 1.31%, PH6.6. Different places of standard surroundings were selected out as the assisting to the trial place.

Muchuan county is located in the southwest edge mountain area in Sichuan Basin, the geographical position is between east longitude 103o32 ' 45 ″ s ~104o07 ' 47 ″ s , between north latitude 28o45 ' 57 ″ s ~29o15 ' 54 ″ s. It is primary that the major physiognomy has mountainous region, hills and high lands and flat, and among them mountainous region occupies 65%, hills 34%, high and flat occupies 1% . The river valley climate of Muchuan belongs to subtropical zone monsoon climate area, annual 17.3 ℃ average temperature, the coldest moon all warm 7.2 ℃s, the hottest moon all warm 26.2 ℃, and the 2842.4 ℃s' effective accumulated temperature of 10 ℃ 327d, counted 968.3h during sunshine year precipitation 1332.1mm, air relative humidity 84%, frost-free period. Soil in whole county is divided into purple soil, mountainous region yellow earth and big kind in yellowish soil three to the river regional the washed hair soil category yellow earth.

1.2 experimental materials

For the main content and studying objective for accomplishments, more than 10 species of bamboos were studied in the trials based on the actual circumstances of Sichuan and the changing of bamboo market. Among them, the *BPDO*'s four asexual systems of 3 and 6 and 8 and 20 and the *Dendrocalamus latiflorus,* the *NeoSinocalamus affinis,* the *Dendrocalamus cinicus,* and the *Bamboosa rigida* are regarded as the most importance of all.

When used as paper fiber and shoots, these bamboo species all are fine. Among them, the *BPDO*, the *Dendrocalamus latiflorus*, and the *NeoSinocalamus affinis* are the imported ones. The others are the local species in Sichuan.

2 The experimental results

2.1 Technologies of selecting of the excellent economic species of bamboos

There are above 10 species of bamboos, which proved to suitable to being cultivated in the converting area in Sichuan, being selected out. Through the observation upon the biological and ecological characters of the immigrant species, calculating the probability of the surviving and the conservation as well as the indicators of power in growing, anti-adversity, anti-germs and pests and so on, several excellent species were selected out. As can be seen from the selecting trial, the *BPDO* and the *DLM* generally grow well in the areas of Sichuan, which have the aptitudes under 1000 m, and even have get much better marks than the local bamboos have done as far as the economic and ecological indicators are considered. The probability of the surviving of the *BPDO* gained the marks of 95%, as well as the rate of the conservation was upon 90%; It has the normal ability of growing shoots, which has achieved with the rate of 100%. The average ground diameter of the immigrant bamboos of the BPD, which has been cultivated for 1 year, is 1-3.0cm, among which the largest ones can reach the point of 4cm, with the average ground diameter of 2cm as well as the average height of 4m. The year across living ones have the average ground diameter of 5.1cm and the average height of 6.8m; These have embody the excellent character of the *BPDO.* And the probability of the surviving of the DLM is 94%, with the conservation of 91%, as well as the shooting rate of 100%. The one-year living seedlings has the ground diameter of 1.5~3.5cm, among which the largest one can get the mark of 4cm, and the average ground diameter is 2.5cm accompanied with the average height of 4.0m, and the year-across living ones have the average ground diameter of 4.5cm, with the average height of 7.5cm. The best area for cultivating the *DLM* has the altitude lower than 800m. The species of the bamboos mentioned above have been confirmed not to have the serious germs disaster or the insect pests. The serious frostbite did not found.

2.2 Techniques for the quick reproduction of the excellent economic bamboo species:

This technical system is mainly composed of the selecting of the seedling cultivated method, which has been changed and developed on the basis of the traditional ones to solve the technical problems of the stem soil sank, the main twig cutting, the subsidiary and side living twig cutting, and the indoor meristems cultivating is carried on also, which has been studied on the subject of cultivating basis, the using of hormones. It has been proved by the trials that the soil quality has the great effect on the surviving rate, with the pattern of sand soil＞sand and mold soil＞mold soil＞light cement soil＞cement soil; And the cultivating methods of cutting of stem sank, stage sank, main twig and subsidiary twig have gotten the high marks of surviving rate, as well as the effective result. When the ages of the seedlings, the seasons and the various of methods are considered, credible conclusion are drawn through experiments. In order to get higher rate of the surviving, the stems used for seedling raising by heeling in stem or heeling in knot should be the ones that have growing well for1~2years without any germs or pests, having the main stem and derivative ones. In the study of meristems cultivating, taking the bud on the living year’s branch of the *BPDO* as the experiment object, choosing wide spectrum culture medium MS's culture medium + hormone (NAA and BA)+2,4-D to organize initial research cultivating. The result is bright, and it is successful that the Boot cultivating to propping the organization is cultivated, has guided sprouting, and needs further research to give later continuous effect. At the same time, multitudinous correlation studies at the selection hormone are made up to using BA, and probably BA is fairly important as for the breeding course of many kinds of bamboo mostly. Without BA, material-breeding coefficient may reduce. Seen from the trial result, up to the present, during the cultivates of hybridized bamboo BA still can not be negative. It has the effective benefit to the production quantities of the bamboo seedlings to be covered with plastic pellicles, which has the production power of 2000~3000 seedlings per mu.

2.3 Technological system of the forest building in the construction of converting agricultural land into bamboo forest

The systematical techniques of the converting into bamboo forest mostly include the afforesting method selecting, the best fertilizer method, and the biological control in the comprehensive prevention of the disaster and the insect pests. What can be seen from the trial is that the best methods are stem sand and seedling cultivating in building of bamboo forest, with the density of 2.5×3.5~3.5×4.5cm, as well as the best method of land preparing is the method being done in square and block. The method of stem sand can enhance the surviving rate to the level of upper 150%, when compared with the traditional methods. Composting is the needed method for the bamboo afforesting. The trial has indicated that the effect of using the multiple fertilizer of SiO_2, as well as the PP_{333} is clear, which can improve the production of the shooting and the bamboo timber with the low cost and the high level of production. The most serious pest disaster is the elephant-insect pest, which did not been destroyed in the past, has been controlled by the using of white muscardine and green muscardine in the trial, yet the effect in a long term can't be considered until the improving study has been down.

2.4 The best model for the bamboo afforesting

The study on the *BPDO and the DLM* has indicated that the most suitable converting model for the *BPDO* is to being aimed at timber using, with the density of 50~60 individual seedlings per mu, which has the low cost in the pure forest construction, and the productive commodities are mainly composed of bamboo timbers used for paper production, and the most suitable converting model for *the DLM* is to aim at the object of shooting used forest, which should be cultivated in the density of 40~50 seedlings per mu, being afforested to the pure forest, or the multiple forest (the formal woods should be kept in the forest land), with the main production of shooting.

2.5 Ecologically positional observation as well as the evaluation on the ecological beneficial results

The most horribly ecological problem lies on the serious soil erosion, thus the converting construction must solve the recovering issue of sloping cultivated land vegetation above all, and then the realization to the utilization going on moving back the cultivated land could be hold on. Our research has an observation and analysis on several kinds of models of the bamboo forest, and reaches the following conclusion:

After moving back to the bamboo forests, the activities of water and soil conservation of the bamboo forest have had the clear improvement. For instance, in hybridization bamboo forest, the yearly runoff of the soil and water is low down to $3.96m^3$, lower than the contrasted cultivated land reduction in the 37.9%, runoff conversion into 24.67kg, one-tenth erosion modulus for 246.7t.km2.a, lower than contrasted cultivated land reduces by 43.4%, water and soil conservation effect hybridizing the bamboo is worth certainly.

After analyzing the moving back to bamboo forest ground, we found that the layer soil weight is notably lower than the agricultural cultivated land, while the lower levels unit weight is not notable with the agriculture difference of cultivated land. The sequence of the upper soil weight is : Pure bamboo forest ＜ broad-leaves forest ＜combined woods and bamboo ＜ combines woods and grass ＜ grass.

The scouring of the soil of the rebuild bamboo forests is lower extremely than that of the agriculture cultivated lands, and as far as the different growth stage of standing forest, that of the grown bamboo forests is much higher than the growing ones, and as far as the land with the type, fast living hybridization bamboo forest＞ grassland ＞ generally forest＞ cultivated land, and as far as the soil texture, resisted nature losing gluing heavy soil is more than loose soil.

The major nutrient of soil and organic nature content's changing. Most kinds of the ground's upper quick resulted nutrient content of soil is more than the lower levels, and the difference is notable. Quickly resulted element N and quickly resulted element Ps of the converted lands is all terrifically notably lower than that of the agricultural cultivated lands. The difference of all the converting lands is not very clear. Recovering the model of the hybridization bamboos to be the most perfect one based on the synthetic analysis on physics and chemistry of soil improvement action.

2.6 Evaluation on the economic beneficial results

Taking the Muchuan county as the example, the peasant's every year could offer 400 yuan for the enterprise in the type of raw material, which can be regarded as the income, and is close to 1 / 4 of the average income of the peasants. The resources cultivating, and the development of the enterprise have increased the revenue greatly, has promoted, on the county level, the economically development, and the mechanize paper factories, among which the Yongfeng corporation being regarded as the leader, have realize the output value as hundred million yuan, which occupies 53% the whole county industry output, and value turned over to the higher authorities reaches 13400 thousand yuan of tax, and it is neatly 10000000 yuan which will be used as the financial fund for the Muchuan country used to afforest every year, which occupies the near 1/3 of whole county revenue.

2.7 Evaluation on the social beneficial results as well as the industrialization of bamboo

Based on the central idea of the *ecological beneficial need by the country, developmental need by the local area, and the well-off need by the peasants,* the industrialization model has been given out as the following: *the leading enterprise+ the peasants+ the studying academy.*

The smooth implementation of the experiments of engineering has opened up a new road for peasant to build welcome life. The bamboo construction has added new content to the "experimental unit of industrialization for county in agriculture", establishing the solid foundation for the active accomplishing of the converting agricultural land into forest, and at the same time also has provided the new raw material for papermaking enterprises, and especially has provided the advanced technology and the model of aged for the active process of the engineering of the converting agricultural land into forest in the area of Sichuan province. For the purpose of changing the resources superiority into the economy superiority, the masses positively throw working to build the economic road, which leads to wealth. On the border of Muchuan, there are approximately 300 kilometers of newly increased highway in forest zone, which has made the traffic condition get improvement. The raising of the bamboo industry has found the way out for the surplus labor in rural area. There are more than 30 thousand persons to be engaged in specially the management of bamboo industry every year and has relieved the society from the burden ofemployment. In addition, with the power to drive the developments of trade such as the transportation industry, the food sailing and amusement etc, the bamboo construction has promoted the mountainous area's masses to shake off poverty to become rich, and has established the foundation of the continued development for the economy in bamboo area.

Implement the Ecosystem Management in Bamboo Plantation to Improve the Synthetical Benefits

Xiao Jianghua

Chief, Bamboo Research Division, Institute of Subtropical Forestry, CAF, Fuyang 311400, Zhejiang Province, P. R. China. Phone: +86-571-3310004. Fax: +86-571-3341304/3322719. E-mail: bmbuxiao@public.fy.hz.zj.cn

Cao Yonghui

Institute of Subtropical Forestry, CAF, Fuyang 311400, Zhejiang Province, P. R. China.

Abstract

The great achievements, main problems and causes of problems of bamboo plantation management in China were discussed. It was suggested that the ecosystem management in bamboo plantation should be put into practice to improve the synthetic benefits, protect the biodiversity and ensure stable sustainable management of bamboo plantation. The essential differences between the ecosystem management and the traditional management was discoursed from the management purpose, object, method, theory, technique and measure and so on. The strategies and methods of ecosystem management for bamboo plantation were put forward that the managers of bamboo plantation should firstly unify the realizations to establish thought foundation for ecosystem management, new management theories; and technique systems of bamboo plantation should be established to direct and support the implement of ecosystem management; and then step by step to implement the ecosystem management in the whole bamboo regions around country.

Key word: Bamboo plantation; Ecosystem management; Synthetic benefits

1. INTRODUCTION

China is one of the countries in the world that has the most abundant resources of bamboo species, the longest history of cultivation and utilization and the most splendid culture of bamboo. Since 1980's, Chinese bamboo industry has been industrialized from traditional handicraft industry, the utilization field and method were enlarged, which improve the bamboo industry development greatly. At the end of the last century, Chinese bamboo industry has became a new industry which has an annual production value of 30 billion RMB, so it play an important role in accelerating economic development of country in bamboo regions and breaking farmers away from poverty. It has an annual volume of 2 million m^3 bamboo-veneer, which was applied on traffic, architecture, paper making and so on, so timber consumption is reduced. It is very important for protecting the nature forest and eco-environment.

Bamboo resource is the basal chain in the bamboo industry, its quantity and quality not only directly influence on the scale and benefits of the bamboo industry, but also relate to the ecological function and benefits. Bamboo management relates not only the three benefits (economic, ecological, social benefits) of bamboo plantation, the protection of eco-systematic biodiversity of bamboo plantation. So, China attaches importance to bamboo cultivation, and has achieved prominent effects. However, there are some limitations on the present theory and technique of bamboo management that can't adapt to the development of modern bamboo industry. Update on management theory and technique must be carried out. This paper will expatiate the purpose, sense, necessity and pathway of implementing the ecosystem management to improve the synthetical benefits of bamboo plantation.

2. THE MANAGEMENT STATUS IN QUO OF BAMBOO PLANTATION IN CHINA

In China, in the past 50 years, a series of research achievements about cultivation theory and techniques of bamboo plantation, besides the political factor, have been playing an important role in developing bamboo resources, enhancing management level and increasing economic benefits of bamboo plantation.

2.1 Enlarge Bamboo Plantation Area

The area of artificially established bamboo plantation was about 1.3 million ha in the early 1950's, more that 3.8 million ha in the early 1990's and reached 5.0 million ha at the end of 20 century. Its culm volume has increased correspondingly.

2.2 Increased Bamboo Yield

With advanced techniques for bamboo cultivation applied to bamboo production, the potential for bamboo production has been well exerted, with bamboo yield and product quality enhaced significantly. Each hectare of high-yield bamboo plantation for the purpose of culm production produces 15-20 tons of culms annually and it also reach at 30 tons per ha. For fresh bamboo shoot production, a high-yield plantation has an annual yield of 10-15 tons/ha and it also reach at 30 tons/ha. At the end of 20 century, in area, high-yield and mid-yield plantations account for 10% and 40% of the total respectively.

2.3 Increased Economic Returns from Bamboo Plantations

There are breakthroughs in the processing and utilization of both culm and bamboo shoot, as a result, the price for culm and bamboo shoot has been increased by a very large margin. The high-yield bamboo plantation for the purpose of culm production has an annual production value of 15,000-25,000 yuan per hectare, and the high-yield bamboo plantation for the purpose of bamboo shoot production has an annual production value of 40,000-60,000 yuan per hectare. In main bamboo producing regions of China, 1/4-1/3 of farmers' annual economic income comes from bamboo plantation.

2.4 Increased Bamboo Cultivation Level

In China, since the 1950's, cultivation of bamboo species has gone through three stages from remodeling of low-yield bamboo plantation, cultivation of high-yield of bamboo plantations to classified management and directional cultivation, and in the course of cultivation, a scientific theory and series techniques for bamboo cultivation have been established. Extension and application of a quantity of research achievements in regulation of bamboo population structure, management of soil fertility and comprehensive control of pests and diseases have greatly improved the management level and economic returns of bamboo plantation.

But there are still exist some noticeable problems in the management of bamboo plantations, most of those are as follows:

- The simplification of mixed forest with bamboo is pricking up, so it results in the decrease of ecological functions in the bamboo plantation ecosystem.
- The stronger harvest (such as cutting bamboo, digging bamboo shoot) and more frequent cultivation of soil lead to the structure of bamboo plantation becoming worse, the growth form declining and the productivity of woodland decreasingl.
- The unreasonable utilization of chemical materials, such as fertilizers, pesticides and weedicides, is endangering the sanitary security, polluting the environment and destroying the biodiversity of bamboo plantation.

The existence of those problems has baffled the healthy development of bamboo resources and sustainable management. As searching the causes, with the exception of farmers' being drived by the short-term benefits, the limitations of management theory, techniques and measures are crucial. The prominent representations of the limitations are that taking the bamboo plantation as factory for producing bamboo culm and shoot, targeting at obtaining the more most bamboo products and the largest economic returns, only making the bamboo plantation as the main body of management objective and without the consideration of the existence and utilization of bio-resources and non-biological resources in the bamboo ecosystem. Therefore, the management theory and technique of bamboo plantation must be innovated to ensure enhancing the comprehensive benefits and the stable sustainable management of bamboo plantation.

3. NECESSITY OF IMPLEMENTING ECOSYSTEM MANAGEMENT IN BAMBOO PLANTATION

Forest ecosystem management is the base theory and technique of forest sustainable management. Bamboo ecosystem management. Bamboo ecosystem management is to regard the bamboo plantation as an enormous and complicated ecosystem, improve the systematic structure of bamboo plantation, enhance the functional level and the stability of the system by implementing effective management measures.

Bamboo ecosystem management is different in nature from traditional bamboo ecosystem.

3.1 Management Purpose

Ecosystem management objective is to obtain optimal comprehensive benefits, such as economical benefit, ecological benefit and social benefit, within the scope of bamboo ecosystem.

Traditional management aims at only economic output, such as bamboo culm and shoot.

3.2 Management Objects

Management objects in ecosystem management include the whole bamboo ecosystem, not only the bio-resources including the whole plants and animals, but also the non-biological resources including soil, mine element, water, air, sunlight, heat and so on.

Traditional management only takes bamboo as the object.

3.3 Management Method

Management method of ecosystem is multi-fact, it includes bamboo culm, shoot, useful plant and animals, and rest, tour in bamboo plantation.

Traditional management method is very simple and single, mainly including bamboo culm and shoot.

3.4 Management Theory

The theory of ecosystem management is based on knowledge of systematic ecology, ecological economics and ecological engineering.

The traditional management theory is mainly based on sivilculture.

3.5 Techniques and Methods

Ecosystem management aims at improving synthetical benefits and maintaining the stability of long-term productivity. The synthetical techniques and methods that focus on perfecting system structure and improving system function are adopted and prescribed.

Traditional management aims at improving the yield of product, taking control of system structure and management of soil and fertilizer as a core of management technique and measure.

Turning the traditional management theory and method to ecosystem management is essential to enhance synthetical benefits, protect the biodiversity and ensure stable sustainable management of bamboo plantation.

4. STRATEGIES AND METHODS OF IMPLEMENTING ECOSYSTEM MANAGEMENT IN BAMBOO PLANTATION

Implementing ecosystem management on bamboo plantation is an innovation of management theory and technique. Chinese bamboo management establishes good material and technical foundation for the implementation of ecosystem management, but it can't be accomplished in one action.

Firstly, ideology should be unified. Managers of bamboo plantation, industry and some related government department need to have a correct ideology about the purpose, sense, necessity and meaning of ecosystem management of bamboo plantation.

Secondly, because there are many essential differences between ecosystem management and traditional management on bamboo plantation, new management theory and technical system must be set up to direct and support the implementation of ecosystem management of bamboo plantation. At present, the study and utilization on the special system structure of rhizome——bamboo and physiological conformity performance, the study on the regeneration ability and regulation of bamboo plantation, the study on the interrelationship among ecosystem components, the establishing of sorts of management models and optimized cultivation patterns on the mechanism level, and so on, should be fully attached more importances to realize the control based on ecosystem level and maintain the long-term productivity of bamboo plantation.

The last, ecosystem management of bamboo plantation is a new thing in bamboo plantation management. It needs to be implied designedly and step by step. When successful experimental units are achieved in some places where conditions are better to trial, the ecosystem management could be implied widely. The experimental units can preferentially select some bamboo plantations which have been established by the government for the commonweal and ones for the commercial purpose in the developed bamboo regions.

References:

Jiang Zehui. Bamboo and Rattan in the World. Liaoning: Liaoning Science and Technology Publishing House.2002

Zhou Shengxian. Historic Turns in Chinese Forestry. Beijing: Chinese Forestry Publishing House.2002.

Zhou Fangchun. Bamboo Plantation Cultivation. Beijing: Chinese Forestry Publishing House.2001.

Zhang Zhida,et al. Bamboo Plantation Cultivation in China.Beijing: Chinese Forestry Publishing House.1998

Present Situation and Development Countermeasures of Paper-pulp Bamboo Resources in Hubei Province

Xiong Deli

(*Hubei Forestry Institute, 430079 Wuhan Hubei*)

Abstract This paper calles on that bamboo forest should be integrated with paper-pulp in Hubei province. Species, sectional, engineering and administrative countermeasures of bamboo forest coextended with paper-pulp industry are suggested by means of analysis of present situations in papermaking industry and investigation into bamboo resources.

Key words Hubei; paper-pulp; bamboo; countermeasure

Bamboo is an important pulping material with fiber middle or long in length. Pulp made from bamboo not only can decrease import amount of pulp-paper, but also can substitute long-fiber conifer wood pulp. More importantly, it can increase quality and class of paper product, and produce document paper, invoice paper, transparent paper, thin printing paper, offset paper, art paper, paper board, paper used for industrial technology, packing paper etc.

Bamboo is a characteristic tree species in Chinese forestry. Paper made from bamboo is an effective weapon for Chinese paper industry to match aboard paper-pulp industry. It not only can facilitate production scale to be developed toward large-scale, but also make large-scale enterprise be developed toward grouped enterprise; more importantly, it will cause very many middle-and-small-scale enterprises to be developed toward specialization. Twelve provinces located in south of Yangtze River (Jiangnan) are the main production regions of Chinese bamboo and the specific regions in Chinese forestry. Through developing paper-pulp bamboo forest, Jiangnan paper industry would be characterized by bamboo specificity.

In Muchuan county, YaAn county of Sichuan province, in Simao county, Shuangjiang county of Yunnan province, in Guangning county, Nanxiong county of Guangdong province, in Liujang county of Guangxi province, and in Chishui county of Guizhou province, etc, developing paper-pulp bamboo forest on great scale has obtained quite obvious results in converting land for bamboo on scale, bamboo-cultivating in wild mountains and controlling watershed, has also realized transitory development of Chinese forestry and paper industry. In Hubei province that has numerous paper factories and very many bamboo species, developing long-fiber bamboo species and bamboo cultivating on scale still is good important pathway to effectively relieve the supply and need contradiction of raw material. Therefore, it was necessary to explore problems in aspects of paper made from bamboo, bamboo-industry facilitated by paper industry, and synergetic development between paper and bamboo on basis of survey into bamboo resource within the whole province.

1. Paper industry development in Hubei province urgently needs specific material bases

1.1 Domestic enterprises have cultivated special forest for pulp in order to solve critical difficulty in raw material

Paper industry is a mainstay industry in national economy and recognized as an inexhaustible promising industry. It not only provides commercial material for packing, printing, publishing and information industries, but also can lead development of forestry, machinery and chemical engineering etc. The association effect among these industries is biggest, and the influence coefficient is high up to the first among all trades.

However, china has numerous papermaking enterprises, approximately 4000 companies. The average annual yield is not up to 7000 ton, only taking account of 1/6 of average scale for global pulp-paper industry. The varieties of domestic paper and paperboard are near 600 only taking account of 1/2 of the varieties produced in developed countries. The proportion for high-rank paper product is lower, only taking account of 20% of whole paper product. Wood pulp usage in Chinese paper industry is taken account of only 23%

of totally consumed pulp, far below 90% proportion of wood pulp in global paper industry. Moreover, domestic wood pulp is only taken account of 10% of totally-consumed pulp, and the shortage of wood pulp are completely depended upon import, so Chinese import amount guides and effects market price of global pulp-paper. In 2001, china imported 4.90 million ton of wood pulp, 5.59 million ton of paper and paper board, and spent 6 billion dollar of foreign exchange, equal to investment in constructing half of Three Gorges hydraulic engineering in Yangtze River (11.7 billion dollar). The paper industry has become one of the three biggest trades in exchange usage for importing related merchandise together with petroleum and steel industry.

It was forecast that the supply-need gap for domestic pulping wood is 7.1 million m^3 in 2005 and 7.4 million m^3 in 2010. The supply-need situation for paper-pulp raw material will be increasingly rigorous. Therefore, many talents have actively cultivated large-scale fast-growth paper-pulp forest, which not only includes middle-and-short-fiber raw material forest so as to decrease import of broad-leafed wood pulp, but also contains long-fiber raw material forest such as pine so as to decrease import of needle-leafed wood pulp. According to incomplete statistics, by the end of 2000, there had been 31 companies who had cultivated special pulp forest in whole country, with total area above 410 thousand hectare. Among which, Nanping paper industry group corporation and Qingshan paper industry corporation in Fujian province had cultivated artificial forest above 50 thousand hectare; Jiangxi paper industry group corporation and Guangzhou paper-making limited corporation had more than 30 thousand hectare; Yunjing forestry paper corporation in Yunnan province, Yibing paper industry corporation in Sichuan province, Jilin paper-making limited corporation, Yueyang paper industry group corporation in Hunan province had more than 10 thousand hectare. In southern forest region, there also doesn’t lack of talents who insist on bamboo-cultivating such as Longyan papermaking industry corporation and Yuexiu shaowu paper-pulp corporation in Fujian province, Liujiang papermaking plant in Guangxi province, Golden Shaoguan high-yield-forest corporation, Golden Qingyuan high-yield-forest corporation, Golden Qinzhou high-yield-forest corporation, and Guangning paper industry in Guangdong province.

1.2 Hubei paper industry with lower production capacity and more plants is lacking of characteristic special pulp forest

Now, Hubei province has 112 papermaking enterprises, totally produced 580 thousand ton of paper and paperboard in 2001, and is listed eighth rank in the whole country. The annual average yield is 5 thousand ton, much lower than average level of the whole country. Of which, there is only one company whose annual yield is larger than 100 thousand ton (150 thousand ton) i.e. Chenming paper industry limited corporation in Hanyang district of Wuhan city, but there are up to 32 companies in the whole country. There are only two companies whose annual yield is larger than 50 thousand ton i.e. Chenming paper industry corporation in Chibi county (50 thousand ton) and Shuailun paper industry in Hubei province (50-100 thousand ton, dividing into subordinated Wuhan, Shashi and Huangshi sub-corporations). There are only 38 companies whose annual yield is larger than 10 thousand ton. Nevertheless, the others are small factories whose annual yield is less than 10 thousand ton.

According to development plan of light industry, 300 thousand ton of annual production scale must be surpassed by chemical wood pulp plant newly built or extensive, and 50 thousand ton must be exceeded by chemical non-wood pulp plant newly built or extensive. The small quantity of pulping must be eliminated and closed, that is, small pulp plants must be closed which has partial chemical pulping and less than 5 thousand ton of annual yield; chemical pulping plants must be closed, stopped, annexed or transformed which have severe pollution hopeless to control, either to make pulping concentrated and paper scattered, or to stop pulping and maintain paper production, even to change into using merchantable pulp or waste paper. Thus, Hubei paper industry has a current production status that doesn’t allow being optimistic.

The raw material for papermaking is predominated by grass as common reed, wheat straw and the like, and is adulterated with poplar and miscellaneous bamboo. Owing to lacking of raw material, slightly higher price, lower product-rank, unreasonable product structure and bigger competitive press, many small plants are on the verge of being closed while the middle and large-scale paper plant can’t fully exert its potential production capacity. The provincial pulp market is occupied at very low percentage i.e. 2% or so.

Presently, the paper-used wood and miscellaneous bamboo are purchased through commercial department. The development of paper and forest is not fast, because raw material wholly come from market and has not fixed bases, moreover, there exist fierce competition among paper industry-used wood and panel, snack chopstick and other processing enterprises, the purchased quantity and price are completely fluctuated with market. Because the used miscellaneous bamboo is mostly produced outside the fittest transport radius, the factory-reached price can't be born by paper industry, and the purchase isn't large and successive. Therefore, most of paper plants within the boundary are submerged and floated in the marketplace, which production is in a very unstable and disordered development state.

It is a pressing task for Hubei paper industry to cultivate such middle-and-short-fiber raw material forest as fast-growth poplar, such middle-and-long-fiber raw material forest as bamboo forest and other special pulp forest on scale within feasible transport radius. It was worthy of making a mention that bamboo pulp can substitute higher-price long-fiber conifer pulp, moreover, and that Hubei is main production region of bamboo, to develop bamboo pulping is very possible to aid requirement for conifer pulp in Three North Regions while meet requirement to long-fiber pulp for the whole province.

2. Suitably-growth pulp bamboo species is numerous, but lower proportion is allocated to paper-pulp in existing bamboo supply-need balance

2.1 Numerous pulp bamboo species in Hubei province would provide very large best-chosen space for base construction of pulp raw material.

In the division of bamboo distribution over china, Hubei province crosses Yangtze River–Nanlin mixed bamboo region including western Hubei and southern Hubei and bamboo region in upper stream of Huaihe River and Hanshui River of subtropical humid climate among the Yangtze River–Yellow River scattered bamboo region that is Northern Hubei. According to our investigation, it was found that there are 20 genera and 163 species including subspecies class of bamboo in the whole province which is respectively taken account of 50.6% and 26.4% of 40 genera and 617 species in the whole country, of which 13 genera and 65 species are naturally distributed and predominated by scattered bamboo species, but 15 genera and 98 species are introduced and suitably grown for years, and 6 genera and 32 species in table 1-2 are rich in resource or suitable to develop for pulp bamboo including shoot-used bamboo species on scale.

Development, introduction and domestication of cluster pulp bamboo are important contents of bamboo research in Hubei. Since 1950s, forestry and horticultural worker have frequently introduced many species. After domestication in several years or dozens of years, the main preserved cluster bamboo are listed in table-2. It can be known from this table that the same bamboo species has larger difference on the display in various regions of this province, and the number of suitably-grown bamboo species in various regions follows the order from more to less--western Hubei, southern Hubei eastern Hubei, Jianhan plain and northern Hubei. According to the study by Malaixun et al. in 1997, bamboo should be classified into five classes, and *Neosinocalamus affinis, N. affinis cv. viridiflavus, N. affinis cv. Flavidorivens, Bambusa rigida, B. chungii, B.textilis, Dendrocalamus minor* in table 2 should belong to the first-class pulp bamboo. However, productivity of various bamboo species in four production regions excluding northern Hubei is worthy of comparison because this province is located at marginal zone of cluster Bamboo distribution.

2.2 Nearly no bamboo timber flows into paper-pulp enterprises although the existing bamboo resource is relatively rich

There is 106 thousand hectare of bamboo forest in the whole province, which was listed, eighth rank in the whole country. Hubei province is also main region of raw bamboo timber and bamboo product supplied for Three North Regions. Nearly 30% of produced Bamboo timber was transported to Henan, Shandong and other provinces used as scaffold, shed stand, handle timber in raw timber form. Above 65% of bamboo timber was processed into various kinds of bamboo products to meet requirement for market in this province or to be sold to northern regions. These products are for building industry such as bamboo molding panel, bamboo treadle etc, or for upholstery industry such bamboo-based panel as furniture, wallboard. Ceiling, floor board and compartment board in vehicle, or for farm tools such as hamper, sieve, basket, dust-pan, cane pole, sun mat, and field rail, or for living tools such as steamer, shallow basket, sharp top lid, cooker basket, bamboo chopstick, bamboo toothpick, bamboo cotton stick, bamboo cap, bamboo chair, bamboo couch, bamboo mat, bamboo cushion, bamboo fan, cool mat and so on. The general layout of resource distribution is listed in table-3.

2.2.1 General distribution layout and production-sale balance of *Phyllostachys heterocycla cv. Pubescens*

There are nearly 90 thousand-hectare of *Phyllostachys heterocycla cv. Pubescens* forest, taking account of 84.69% of bamboo forest area in the whole province, and listed the eighth rank in *Phyllostachys heterocy-*

cla cv. Pubescens resource in this country. As shown in table-3, southern Hubei and eastern Hubei are concentrated-distributed regions, where bamboo timber is easy to collect and purchase, and is either processed into panel, chopstick, scaffold and so on, or is sold to northern scarce-bamboo regions directly in raw timber form, while the local pulp enterprises are very difficult to purchase bamboo timber within feasible price. Northern Hubei, western Hubei and JiangHan plain are odd distribution regions, where bamboo timber is very little with high purchased price and high expenses collected in bulk, and is mostly consumed by local people for agricultural and living tool uses, while owing to large transport distance, bamboo timber is seldom flowed into paper industry.

2.2.2 General distribution layout and production-sale balance of miscellaneous bamboo

There are 16 thousand hectare of miscellaneous bamboo forest taking account of 15.31% of total bamboo area in the whole province. It can be known from table-1 that four different concentrated-distributed regions were formed according to different germ-plasma and location, that is, *Phyllostachys nuda* distribution region in southern Hubei representative as Yangxin county, *P. glauca* distribution region in eastern Hubei representative as HongAn county, *P sulphurea cv. viridis* distribution region in northern Hubei representative as Zhoushan county, *Neosinocalamus affinis* distribution region in western Hubei representative as Laifeng county. Most bamboo timbers are used as shed stand, handle timber, or woven into various living tools. Such relatively concentrated production region as Yangxin county, Nanzhang county, Laifeng county and Zhoushan county is relatively rich in miscellaneous bamboo timber. Small-diameter timbers from above regions usually amass severely and should be cut, occasionally flown into paper industry for pulping.

Table 1 Scattered Bamboo Species Distributed and Suitably grown in Hubei Province

No	Bamboo species	Distribution range	Existing resource	Diameter class	Existing main use	fiber[8]		
						Proportion %	length μm	Ratio of length to width
1	*Phyllostachys heterocycla cv. Pubescens*	Whole province especially in south-eastern Hubei	89784hm^2	large	Panel, chopstick, agricultural use	31.6	2250	165
2	*P. bambusoides*	Whole province	+++++	Middle to large	Weave, shed stand		2150	137
3	*P. b. f. lacrima-deae*	Whole province	++++	Middle to large	Weave, shed stand	43.4	1590	
4	*Pl. heteroclada*	Whole province	+++++	Small	Weave	38.4	2092	174
5	*P. nigra var. Henonis*	Whole province	+++	Middle	Weave, shed stand		1950	200
6	*P. glauca*	Mainy in eastern and southern Hubei	+++	Middle to large	Weave, shed stand	44.3	1833	121
7	*P. nidularia*	Whole province	++	Small	shed stand	44.5	1480	166
8	*P. sulphurea cv. viridis*	Mainly in northwestern Hubei	+++	Middle to large	Handle bamboo, shed stand		1560	116
9	*P. nuda*	in Yangxing county, in western Hubei	+++++	Small	Weave, shed stand	37.8	2210	180
10	*P. propinqua*	In Yangxing county	++++	Middle	Weave, shed stand		1694	118
11	*P. praecox*	Introduced for shoot-use	+	Middle	Shoot-use, shed stand	38.6	2078	178
12	*P. prominens*	Introduced for shoot-use	In trial	Middle to large	Shoot-use, shed stand	46.3	1821	103
13	*P. iridescens*	Introduced for shoot-use	In trial	Middle to large	Shoot-use, shed stand	44.9	1712	123
14	*P. dulcis*	Introduced for shoot-use	In trial	Middle to large	Shoot-use, shed stand	31.6	1546	96
15	*P. glabrata*	Introduced for shoot-use	In trial	Middle to large	Shed stand Shoot-use	46.1	1540	160
16	*Pleioblastus amarus*	In southern Hubei, and western Hubei	+	Middle	Weave, shed stand, music instrument	40.6	2129	148
17	*Pseudosasa amabilis*.	In southern Hubei, and western Hubei	+	Small	Shed stand, handle bamboo	53.2	2338	153

Table 2 Cluster bamboo species naturally distributed and suitably grown after introduction

No	Bamboo species	Growth range	Cold damage	Distribution or domestication	Existing main use	Fiber[9]		
						Propor-tion %	length μ m	Ratio of length to width
18	*Neosinocalamus affinis*	Western, southern ,eastern, Wuhan, Jingzhou	No	Natural forest	Weave, garden	47.8	2270	146
19	*N. a. cv. Viridiflavus*	Western, southern, Wuhan	No	Natural forest	Weave, garden	53.0	2450	151
20	*N. a. cv. Striatus*	Wuhan	No	Domesticated	Garden	51.0	2367	155
21	*N. a. cv. Flavidorivens*	Wuhan	No	Domesticated	Garden	52.2	2590	147
22	*Bambusa pervariabili*s	Yichang, Xianning, Wuhan	Wilt in apical shoot in Wuhan	Domesticated	In trial	44.1	1930	192
23	*B. longispiculata*	Yichang, Xianning, Wuhan	Wilt in apical shoot in Wuhan	Domesticated	In trial	44.5	1930	113
24	*B. tuldoide*s	Xianning, Wuhan	Wilt in apical shoot in Wuhan	Domesticating	In trial		1806	113
25	*B. rigida*	Yichang, Xianning	Wilt in apical shoot in Xianning	Domesticating	In trial	54.1	2230	163
26	*B. albo-lineata*	Yichang, Xianning ,Wuhan	No	Domesticated	Garden		1968	122
27	*B. multiplex*	Western, Southeastern, Jingsha	No	Domesticated	Garden		2200	157
28	*B. chungii*	Yixhang,Xianning,Wuhan	No	Domesticated	Garden	42.4	2507	190
29	*B. textilis*	Wuhan, Xianning	Wilt in apical shoot in Wuhan	Domesticating	In trial	47.5	2480	166
30	*Dendrocalamus minor*	Wuhan, Xianning	No	Domesticating	In trial	37.8	2284	143
31	*D. m. Var. amoenus*	Yichang, Wuhan	No	Domesticating	In trial	49.1	2600	164
32	*D. farinosus*	Western Hubei, Wuhan, Xianning	Wilt in apical shoot in Wuhan	Domesticating	In trial		2350	148

Table 3 General distribution layout of bamboo resource in Hubei province

Region	Southern Hubei	Eastern Hubei	Northern Hubei	Jiianghan plain	Western Hubei
Range	Xianning, Ezhou, Huangshi	Huanggang, Xiaogan, Suiz-hou	Xiangfsn, Shiyan	Wuhan, Jinzhou, Jinmen, Qianjiang	Shengnongjia, Yichang, Enshi
Moso bamboo area (hm^2)	79854	6207	163	1798	1746
Moso bamboo proportion (%)	88.94	6.91	0.02	2.00	1.94
Miscellaneous bamboo area(hm^2)	10078	762	1576	850	2896
Miscellaneous bamboo proportion (%)	62.09	4.69	9.71	5.24	17.84

2.3 Urgent reinforcement is required on science technology and management of bamboo industry

2.3.1 Technical talent is extremely wanted and management mechanism is fragile

In the whole province, there are few of professional talents who engage in cultivation of bamboo forest, exploit and utilization of bamboo resource. The in-service education is deficient for the existing bamboo production personnel. The newly established Xianning bamboo research institute is so severely deficient in scientific research expenditure that it is difficult to obtain substantial progress in its scientific research work. There are little of scientific research achievement and thesis. A series of technique suitable to bamboo forest management in this province is urgent to be reinforced to explore. Bamboo forest is still in a predatory manner. The specialized institution in bamboo industry management has not been established in forestry system of whole province yet. The newly established Ruifa bamboo Industry Corporation in Congyang County is mainly managing and producing shoot-use bamboo forest. The just-established Chiba forestry Paper Corporation is chiefly producing pulp bamboo seedling for Chengming paper Industry Corporation in Chibi City. Both of them don't take the overall responsibility for bamboo industry development, base construction, bamboo forest management and technical extension. The extremely wanted technical force and management system is entirely unsuitable to requirement of bamboo industry development in Hubei province.

2.3.2 Unifiable planning is deficient and industry chain is frail

The resource of bamboo species is less clear, and the development direction is less defined. Up to now, there is not development division of varieties, base construction planning of oriental cultivation, and layout and planning of scale development in bamboo processing industry. Because forest is managed separately by farmers, it is difficult to extend bamboo technique. There lacks of unifying coordination in processing industry. Product information is gotten less quick, product competitive power in market economy is less strong. All those are affecting bamboo industry's development forward large scale and groups so that it is difficult to gain scale economic benefit.

3 Countermeasures in germ-plasma, regional, engineering and management of pulp bamboo development

Papermaking industry is the largest cooperation partner to bamboo industry in Hubei province, while the latter is an important support for Hubei paper industry to go out of raw material crisis. Pulp made with bamboo urgently required of special bamboo forest concentrative and zonal on scale, while bamboo facilitated by paper industry needs adopting order from paper industry. Synergistic development between paper and bamboo required constructing special bamboo forest on large scale in order to make bigger and stronger both paper industry and bamboo industry, which are listed the like eighth-rank of the whole country's. In the catalogue of superior industry invested by foreign trader in middle-and-western region in 2000, national economical and trade committee, planning committee and foreign trade ministry associatedly issued a document to bring comprehensive utilization of bamboo resource into the list of 14 industries in Hubei province, which clearly demonstrate direction of paper industry and bamboo industry.

3.1 Germ-plasma development countermeasure main with cluster bamboo and auxiliary with scattered bamboo

According to general distribution layout of bamboo species within the province like table-2 and the inter-special difference in bamboo timber yield on unit area of forest land, the germ-plasma utilization direction for pulp bamboo is suggested as follow: Firstly, such cluster bamboo species in table-2 be preferably developed as *Neosinocalamus affims*, *N. affinis cv. Viridiflavus, N. affinis cv. Flavidorivens, Dendrocalamus minor,* and *D. minor var. amoenus. Bambusa textilis, B. tuldoides, B. pervariablis, B. longispiculata* be properly developed only in western Hubei. Secondly, such scattered bamboo species in table 1 be auxiliary to develop as *Phyllostachys heterocycla cv. Pubescens*, *P. bambusoides, P. bambusoides f. lacrima-deae, P. glauca, P. sulphurea cv. Viridis, P. nigra var Henonis, P. prominens, P. praecox, P. iridescens, P. dulcis, and P. glabrata*, which bamboo timber be provided for paper–pulp industry while their shoot-use potential be fully utilized. This development countermeasure different from other main production region is determined by water and heat condition in Hubei province.

3.2 Regional development countermeasures main in western Hubei and southern Hubei, auxiliary in eastern Hubei and Jianghan plain

According to water and heat condition in various regions within the province, based on productivity and adaptability of first-class pulp bamboo in table 2, the preferable development sequence of various regions for pulp bamboo are western Hubei, southern Hubei, Jianghan plain, eastern Hubei and northern Hubei.

Western Hubei is a naturally distributed region of *N. affinis,* and will be the most potential region for development of cluster pulp bamboo, simultaneously is the most possible region where shoot-timber double usage forest of cluster bamboo could be formed on scale. Therefore, it should give the superior land to these shoot-timber double usage bamboo such as *N. affins cv. viridiflavus, N. affinis cv. Flavidorivens, D. minor var. amoenus*, while cultivating *N. affinis, B. chungii, B. textilis*. Southern Hubei and Jinghan plain are the suitable-grown regions of such exotic bamboo species as *N. affinis*, and the concentrated-distributed regions of paper-pulp enterprises also, therefore, these regions are suitable to develop such special pulp bamboo as *N. affinis* and *B. chungii* on large scale.

3.3 Exploitment countermeasures of lands on both sides of road and ditch channel, middle-and upper-streams of watershed, converted land, slashing, and around gardens, lakes and reservoirs

3.3.1 Bamboo-cultivating project along green channel

Cobweb-like highway and vein-shaped ditch are the specificity of Hubei province. On both sides of national road and provincial road, there have mostly been planted with fast-growth poplar and Chinese wing nut. However, on both sides of road leading to township and countryside, village and group, there still exists high proportion of bare land, where is huge space to develop pulp bamboo especially cluster bamboo. Middle-and-small ditches are important water channel, where have been planted also with few of water fir and poplar. On both sides of which, a number of land areas are suitable to development of cluster pulp bamboo. On both sides of countryside path and water channel, planting such garden plants as cluster bamboo not only can beautify environment, conserve water and soil, but can provide superior raw material for pulp industry also.

3.3.2 Bamboo-cultivating project for watershed control

Hubei is a province taken water body as its specificity. There are over 35 large-scale streams, which respectively merged into Qingjiang River, Hanjiang River and Yangtze River. In southern Hubei, Junshui-lushui water system and Fushui water system are the concentrated-produced regions of *Phyllostachys heterocycla cv. Pubescens*, and *P. nuda*. In eastern Hubei, Qihe watershed, Donghe-Xihe-Xihe water system, Xinchanghe-Bahe water system, Jushui watershed and Daoshui watershed are the main production regions of *Phyllostachys heterocycla cv. Pubescens*, and *P. glauca, P. heteroclada and P. bambusoides*. In Western Hubei, Xiangxi stream, Baishuihe stream and Gongshuihe stream and Qingjiang River watershed are the main production regions of *N. affinis*. In northern Hubei, Duhe watershed, Malanhe-Nanhe-Qingxihe water system and Zhanghe River watershed are the main production regions of *P. sulphurea cv. viridis, P. nigra var. henonis, P. bambusoides*. In the middle stream of these watersheds, on both banks of river and stream, and plain valley, there grow with many kinds of bamboo forest. In their sources and slight sloping zone of hill slope, small fragments of bamboo forest can be observed. In the hill cavity and valley, there distributed more bamboo species growing better. Presently, odd distributed bamboo species within these watersheds only can meet the requirement for traditional weaving and handle uses, and is difficult to enter into pulp and paper industry due to not being able to form scale production.

At present, watershed bamboo-constructing engineering should be implemented mainly with *P. heterocycla cv. Pubescens*, *N. affinis* and *B. tuldoides* in junshui-lushui water system of southern Hubei, to solve shortage of raw material for Jinchang in Chongyang county and Chengming in Chibi county paper industry corporations; mainly with *P. heterocycla cv. Pubescens*, *P. glauca* and *N. affinis* in Donghe-Xihe-Xihe water system centered by Bailianhe stream in eastern Hubei, to supply middle-and-long-fiber bamboo timber for Huangzhou pagoda paper factory and Wuxue paper industry as soon as possible; mainly with *P. sulphurea cv. Viridis, P. nigra var. henosis,* and *P. bambusoides* in Duhe stream watershed and Zhanghe River watershed in northern Hubei, to solve raw material difficulty for Yunyang pulp-making factory, Danjiangkou first pulp-making factory, and Huahai paper industry in Nanzhang county; mainly with *N. affinis, D. minor var. amoenus* and *N. affinis cv. viridiflavus* in Qingjiang River watershed in western Hubei, to supply material for Hongfa paper industry in Changyang county as soon as possible while conserving water & soil and beautifying environment.

3.3.3 Bamboo-cultivating project for converting land

Bamboo is a kind of plant that is planted only once, but makes successively benefit for people in many years. The individual bamboo culm has short fiber-formed period about 4 or 5 years. The new-planted bamboo forest enters repayment period after 3-6 years, and the cost of tending management is less high. Mature bamboo forest could provide 6-18 ton of timber per hectare every year. The income from shoot thinning and timber cutting per hectare could reach above 530 dollar, higher than or equal to agricultural crops. Selective cutting manner of bamboo forest can keep green land forever. Bamboo's cost producing 1 ton of pulp is lower 170 dollar than pine's, nearly 110 dollar than Eucalyptus'. All these characteristics determine that bamboo should take account of higher proportion in converting land for forest. Experience from other provinces showed that establishing bamboo raw material base and depending upon its industry chain not only can make peasants really withdraw and firmly keep back after land-converting, but can protect ecological environment also. A pulping factory which annual yield is 100 thousand ton pulp would directly bring farmers 18 million dollar of yearly income, according to the common sense that 5 ton bamboo timber can be made into 1 ton of pulp, and the existing purchase price which is 40 dollar for every ton of bamboo timber. Presently, bamboo cultivation in odd distribution region should be concentrative and zonary to reach a goal –over 6.6 hectare in village and over 66 hectare in township in order to decrease cutting and logging cost for raw material.

3.3.4 Bamboo-cultivating project for slashing reconstruction
On slashing of forest tree, bamboo can grow fast, propagate strongly, regenerate easily, and soon recover into secondary forest. On the land of hill and mountain in southeast Hubei, there grows high proportion of Masson pine and Chinese fir forests which have become main material source for JuNing and Jukesong panel processing enterprises. However, successive cultivation on slashing will bring such bad effect as slow-growth of forest tree and so on. If bamboo was planted in zone on these slashing, or bamboo cultivation in strip is combined with rotational cutting in conifer forest strip, the puzzle of afforestation on slashing would have been solved. *P. heterocycla cv. Pubescens,N. affinis* should be chosen as main species in bamboo-cultivating project on cutting land, especially in the low hill region, the middle and lower part of high mountain.

3.3.5 Bamboo-cultivating project in gardens
Bamboo is an important horticultural plant, a characteristic of Jiangnan garden and watery kingdom's garden. In order to enrich garden-used bamboo resource and apply to greenery industry in Hubei province, 15 genera and 98 species of bamboo have been introduced for years. However, this kind of odd planting layout is limited to few of gardens and around habitat, and is unable make such integrative effect and scale benefit as Chengdu plain. The traditional garden-used bamboo is seldom cut for timber utilization, whose material is difficult to collect, whose purchase price is higher than feasible level. Moreover, this garden-used bamboo within this province hasn't been managed as intensively as other countries. At present, garden bamboo forest should be developed on scale mainly with *N. Affinis*, and be made a break-through in carrying on intensive management.

3.3.6 Bamboo-cultivating project round lakes
Hubei is a laky province spotted with lakes and lakelets, large and small reservoirs. Around these water bodies, a number of cluster bamboo species could grow better on the land distant from watersides. This project not only can effectively keep back lakes and reservoirs from allusion and silt, and improve microclimate, but also can produce large amount of pulp bamboo timber. At present, related research work should set about as soon as possible.

2.4 Administrative countermeasures in talent education, technique-deepening and fund injection
In order to promote development of bamboo industry in Hubei headed by pulp bamboo, it should be kept in mind that talent is fundamental, technology is key and fund is guarantee. In order to make bamboo industry increasingly develop and mature in Hubei forestry economy, corresponding talent and technique support system should be established immediately.

International bamboo and ratten organization has established. Many years ago, Japan, Canada and America established respective national bamboo research organization. China has organized Chinese bamboo industry association, bamboo sub-society of Chinese forestry society, national bamboo research center. China national forestry ministry has set up management office for bamboo industry. Since 1984, Fujian, Zhejang, Yuannan, Sichuan, Jiangxi, Hunan, Kuangdong, Kuangxi, Anhui, Guizhou, Hainan province have successively established bamboo sub-society of provincial forestry society, provincial bamboo industry association (or provincial bamboo and ratten association), provincial bamboo research and development center or provincial bamboo research institute. Many prefectures, cities and counties in above-mentioned provinces have set up respective bamboo industry section, bamboo industry Development Corporation, or corresponding bamboo industry society. Establishment of these organizations has provided important support in information, technology, talent and fund for bamboo industry and related paper-pulp industry, panel processing industry, and bamboo shoot processing industry, etc, and guided fast and healthy development of bamboo industry.

Firstly, to suggest that bamboo industry development and research center in Hubei province be organized and established in forestry academy of Hubei province under the support of provincial forestry bureau. The center should take the head of bamboo industry, and assist provincial professional technology college in adding bamboo forest cultivation course, to train urgently-needed and reserve special talent by bamboo industry. To forestry staff in such important pulp bamboo regions as Xianning, Huanggang, Yichang and Enshi district, the center should intensify technical training of bamboo industry. The recent goal should be realized that there are 4-5 senior scientific and technical talents for provincial forestry department, 2-3 middle-class scientific and technical staff for county's or city's forestry department, 1-3 technical staff in key township, and there are talent and technique support system suitable for production requirement in every deeply-processed enterprise,

Secondly, to suggest that bamboo industry management office be established in provincial forestry bureau, and recently perform a role of bamboo industry association. Main bamboo counties should set up corresponding bamboo industry development corporation or bamboo industry section that is responsible for extension and implementation of bamboo cultivation technology.

Finally, to suggest that local government should make much account of bamboo like crops, forestry department should plant bamboo like cultivating poplar, paper industry department should make bamboo forest like making paper. After the model of "Ten Biggest Bamboo Counties", tax rate of bamboo industry should be decreased to stimulate production of bamboo forest. After the model of Chishui city in Guizhou province, YaAn city in Sichuan province, Nanxiong city in Guangdong province, Xinping county in Yunnan province, documents related to commending bamboo-cultivating should be bring out, a chain of privilege policy for bamboo industry should be stipulated, and talent, technique and fund should be actively thrown into six biggest bamboo-cultivating projects.

Promote Xianning Bamboo Industry and Develop Regional Economy

Zou Jizhou

Xianning Forestry Bureau. No. 158 Yingqun Road, Wenquan in Xianning, 437100, Hubei Province, P. R. China. Phone: +86-715-8139518. Fax: +86-715-8139519

Abstract: Xianning is one of the main bamboo producing areas in our country. Bamboo industry is one of the leading industries for the economic development in Xianning. Viewing on the cultivation techniques, base scope, processing benefits, economic share, it is feasible to promote Xianning bamboo industry; viewing on the overall situation of regional economic development of agriculture, industry and tourism and so on, it is necessary to promote Xianning bamboo industry. Therefore, we must grasp the opportunity that our country attach great importance to the forestry and ecological construction, to further strengthen the pillar position of bamboo industry, to speed up resource cultivation, to carry out profound processing, to activate developing mechanism. We would transform the traditional resources superiority to the clear economic superiority; make more contribution for building new ecologic garden city of Xianning.

Key words: Bamboo industry Regional economy Development Countermeasure

Xianning lies in the south of Hubei Province, which is on the southern bank of the middle reaches of Changjiang River. In 1998, the system of district is removed and the system of city is build. Now it has jurisdiction over six county (city, district): Xian'an, Jiayu, Chibi, Tongcheng, Chongyang, Tongshan. The total population is 2.78million, and it covers a total area of 9861 sq. km. It is the subtropical typical monsoon climate in Xianning. In its boundary most of the lands are low mountains and hills and the soil is deep and fertile, which is the favorable conditions for the production of forestry. In Xianning the area of bamboo has got to 411067 hectare, the bamboo forest covers an area of 102467 hectare. The forest coverage is 52.3％. Xianning is one of the main bamboo production areas in our country, it always has got the good fame of "Bamboo Hometown of Southern Hubei". Bamboo industry is one of leading industries of the economic development in Xianning. With the process of urbanization speeding up, the bamboo industry would play a more and more important role in regional economic development.

1. BAMBOO INDUSTRY HAS BEEN THE CHARACTERISTIC LEADING INDUSTRY OF XIANNING

It has always had the tradition of breeding bamboo and using bamboo for Xianning people. Especially since the reform and opening up, the bamboo production and processing mainly on Mao-bamboo (*Phyllostachys pubescens*) has made great development.

1.1 Bamboo Cultivation Has a Long History

The bamboo cultivation has a long history in Xianning. Long ago in Tang Dynasty Xianning had been “thick forest of trees and tall bamboos, lush and green”. In 《A Trip to Jiugong》, a poem written by Zhutingli who was the poet of Ming Dynasty, a line is written as “At the end of clouds and bridges we can see thousands of bamboo, stone house and clouds can be seen dimly among the green bamboos”. A bamboo-root carving lion (National 2-level Cultural Relic), which is made in Qianlong Kingdom of Qing Dynasty, is collected in the museum in Tongcheng County. All the previous party committees and governments have attached great importance to the development of bamboo industry. Since the National Bamboo Working Conference in 1991, special subject meeting would be held, the chief leaders would attend the meeting personally, to investigate to solve the problems in the bamboo industry construction and development measures. The idea of “one garden of bamboo would make descendants rich” has become the common understanding of the people in bamboo hometown. Stress on the tending of bamboos in summer and autumn and stress on new afforestation in winter and spring have been the conscious activities of the bamboo peasants. In the latest years in the boundary of Xianning, the recultivated bamboo forest is average 20,000 hectare a year; the newly afforested bamboo forest is average 6667 hectare a year.

Over a long-term production practice, the people in bamboo hometown have explored a series of experience on scientific breeding bamboo. The experience of “saving four, taking out six and removing eight” (save the tender and strong bamboos of less than 4 years; choose to cut down the six-year old bamboo which is too thick; remove the old bamboos of 8 years old) and “grandparent and grandson don’t meet; mother and son don’t separate” (cutting the first generation while the third generation growing up) summarized by Wangzhihuai from Xingxing Village of Xian’an District are spread in our country. Mr. Wangzhihuai was successively tow times elected as the Representative of the National People’s Congress. Swiss friend Mr. Albin Harow praises him as “Bamboo Congressman”. Forestry Scientific Research Institute of Xian’an district pursues the technique of deep ploughing, re-cultivation, protection of bamboo shoots, and conservation of bamboo; the amount of growing bamboo is average 6000 per hectare. And the average diameter breast-high of the bamboo reaches over 10.6cm. Xianning Forestry Scientific Research Institute tackles the scientific problems. The quick growing and high yield Mao Bamboo forest and seedling breeding techniques have made great progress, the scientific research achievements is in the lead in our country.

1.2 The Bamboo Resource Superiority Is Outstanding

The climate and soil in Xianning is suitable for the growth of bamboo. Now there are 150 varieties in 12 genera. Through a long-term afforestation, closure, management and cultivation, 178 Mao-bamboo bases over 67 hectare have been built, and 26 Mao-bamboo bases over 667 hectare have been built in the boundary. The Mao-bamboo forest covers an area of over 1333 hectare in Huangsha, Honggang, jiugong, Chuangwang, Xiapu of Tongshan County and Gangkou, Guihuaquan, Tiancheng, Lukou in Chongyang County and Huanglong of Tongcheng etc. The area of Mao-bamboo forest in the two towns of Tingsiqiao and Damu of Xian’an District have already reached over 3333 hectare. In Guantangyi Town and Lushuihu Agency of Chibi, the area of Mao-bamboo forest has topped 6667 hectare. In the boundary the area of Mao-bamboo forest has reached 9800 hectare, the growing bamboos are 220 million, and the annual output of bamboos are 2 million. The area, storage and output of bamboos are over 80% of Hubei Province. Among the main producing area of commercial bamboo, the output climbs from the ninth to the seventh. After Chongyang have succeeded in introducing the Lei-bamboo (*Phyllostachys praecox*), it regards

Lei-bamboo as the leading industry of the county. The prospect of all trades and professions building bases and innumerable families constructing grounds appears. Through 5 years' effort, Lei-bamboo bases of 3333 hectare have been built in the county. The Ci-bamboo (*Sinocalamus affinis*) forest for the paper pulp raw material of 667 hectare is newly developed in Chibi.

1.3 The Obvious Increase in Value of Bamboo Processing

Over 230 processing enterprises with Mao-bamboo as main raw material have been set up in our city. More than 600 varieties in 10 series have been exploited. 12 brands of bamboo plywood, bamboo floorboard and bamboo sleeping mat have won the Golden Reward of the National Forest (Bamboo) Industry Exhibition. The Xinjing Jointly Operated Bamboo plywood Company in Chongyang produces daily over 40 cubic meters bamboo formwork. The annual output value is 30 million RMB; the profit is over 3 million RMB. Hubei Xinglin Bamboo Industry Group directly under the Forestry Bureau has put it in the ranks of the top 35 "the Province-level Key Leading Enterprises of Agricultural Industrialization" in Hubei. The Longquan Company of this Group exploited more than 50 varieties of bamboo handicrafts. The additional value of processing rises from 10 RMB to 100 RMB per bamboo; and the highest reaches 300 RMB. The production lines of bamboo-wood mid-density fiberboard of 80,000 cubic meters have been constructed and put into production in Juning Forest Industry Group in Xian'an. In Chibi the laser processing technique has been introduced from Wuhan, 80,000 sets of bamboo slip handicrafts in the style of ancients were produced in 2002. The output value reached 25 million RMB; the profit tax is 2.5 million RMB. The Mao Bamboo rises in value of 6 million, and the peasants' income increases 4 million. Through various ways, the additional value of the bamboo shoots processing has been greatly improved. The gross output value of industry in 2002 is 360 million RMB.

1.4 The Vitality of the Bamboo Economy Is Remarkably Demonstrated

At present, over 80% of the towns in the city are developing bamboo. Some towns have adjusted the base area to over 60% of the total area. 310,000 people in the population of 2.78million take the bamboo as the main resource of their livelihood. 10,000 people in 50,000 agricultural labors are engaged in the production of bamboo industry. 60,000 people for circulation are active all over the city and county-side. Two-thirds of the forestry income stems from bamboo. Every bamboo peasant family in Shiqiao Town of Xian'an is engaged in bamboo processing. In Wuhan three streets for articles made of bamboo are formed. Huawen and other towns in Xian'an exploit the tourism of bamboo forest, which the annual income is nearly 100 million RMB. Chaoliqiao Town of Chibi invites outside investment to develop the bamboo economy. The bamboo income is 16 million dollars, which is one-third of the gross agricultural income. The surfboards made by Xinjingmeng Bamboo and Wood Articles Company, which is solely owned by the Hongkong businessman who settles down in Chaoliqiao, are sold far in Europe. The company earns the foreign exchange of 600,000 dollars through export annually. This town has built a bamboo and wood market of 5000 square meters by the 107 National Highway. The annual volume of operation and sell is over 25 million RMB. According to the statistics, in 2002 the income of bamboo industry of the whole city reached 580 million RMB, which is one-tenth of the Gross Agricultural Output Value. Bamboo industry has been one characteristic industry, superior industry and an industry that makes the people rich.

2. PROMOTING THE BAMBOO INDUSTRY IS THE INEXORABLE DEMAND OF THE DEVELOPMENT OF XIANNING ECONOMY.

Facing the 21st century, the Municipal Party Committee and the Municipal Government form "the Strategic

Concept of Xiannning City Marching to the 21st Century", resolve to carry out the key "Five strategies" of characteristic agriculture, prospering the industry and strengthening the market, the tourism bringing along, hastening to realize the leap from the rural economy to urban economy, and building Xianning as a new ecological garden city.

2.1 Promoting Xianning Bamboo Industry Is the Demand of Carrying out the Strategy of Characteristic Agriculture.

There are many hills and waters in Xianning, which is rich in resources. It enjoys widespread renown as "the hometown of *Osmanthus fragrans*", "Hometown of *Phyllostchys pubenscens*", "Hometown of *Boehmeria*", "Hometown of Tea". The "Six Industries" of nursery stock, vegetable, *Actinidia chinensis*, live pig, Lei-bamboo and fruit develop very fast. In order to meet the demand of agricultural market, we must rely on the resource superiority of "Four Hometown and Six Industries", readjust much greater the agricultural structure, and hasten the development of characteristic economy.

Mao-bamboo in Xianning is tall and thick in trunk with thick pulp and sparse joint. The top and the root of the bamboo are well proportioned, and this bamboo strip is tough. As Xianning lies in the north of the bamboo breeding area, people of Hubei and other northern provinces and cities always try to be the first to buy the Mao Bamboo. The Lei-bamboo shoots can go o the market during the period of New Year's Day and Spring Festival. It is a delicious and nutritious health care food with high protein and low fat. The "Ruifa" brand Lei-bamboo shoots product in Chongyang is regarded as green food, " the satisfying product for the customers of Hubei". It sells very well. Ci-bamboo is a kind of bamboo for the paper pulp of high quality. The supply of the order for goods and purchase of Chenming Paper Industry falls short of demand. The bamboo production has the characteristics of low investment, high benefit, long profit and broad market; and would open up a vast range of prospects for the development. Therefore, promoting the bamboo industry in Xianning is the important way to bring about the advance of agricultural benefit, increase the peasants' income.

2.2 Promoting the Bamboo Industry in Xianning Is the Need of Carrying out the Strategy of Prospering the Industry and Strengthening the Market.

Industrialization is an unavoidable important stage of the social economy. Xianning is at the stage of quickening development of industrialization. The pillar industries of machinery and electrics products, spinning and weaving, forest industry, building materials, foodstuffs and medicines have been preliminarily formed. Among them, the forest industry develops very fast. The four leading enterprises of Juning Group, Chenming Paper Industry, Xinglin Fire-proofing Chipboard Factory and Deren Group invest the total volume of over 800 million RMB. The annual processing capability is 450,000 cubic meters.

With the expansion of the scope of forest industry enterprises, the supply of raw material is in great demand day after day. Bamboo is a quick-growing wood forest species for its quick growing, growing into full timber early, high yield and serving many purposes. In order to mitigate the contradiction between supply and demand, the state plans to newly build and remake the bamboo forest of 4 million hectare within 15 years. Among them, 100 million hectare is newly built, and 300 million is remade. The state is going to take the way of "bamboo replacing wood", provide precious opportunity for the development of bamboo industry. At the same time, the overall level of bamboo processing in Xianning is not high yet, which has great potentialities. Therefore, hastening the construction of bamboo bases and developing the profound processing are an urgent and arduous task to guarantee the supply of industrial raw material and invigorate the bamboo enterprises.

2.3 Promoting Xianning Bamboo Industry Is the Need of Carrying out the Strategy of Tourism Bring along the Economy.

Green is the synonym of Xianning. Ecology is the natural capital of Xianning. In the boundary of Xianning, tourism resource is rich with the green mountains and clear waters. The scenery is pretty bright. And Xianning stands in the superior situation with convenient communication. She has the developing superiority and potentiality in bring along the tertiary industry overall developing with the tourism as the lead.

Bamboo is not only a elegant ornamental plant, but an ideal protective tree. The fresh and green bamboo and vast bamboo forest are the key scenic spots at Jiugong Mountain of National-level Scenic and Interest Spot and Wenquan, Lushuihu and Chibi of Sanguo Ancient Battlefield Site of Province-level tourism scenic spots. Especially the Xingxing Bamboo Forest and Suiyang Bamboo Forest are renown in overall country and attract the international friends from over 50 countries and districts and tourists at home and abroad for its “spring green, autumn brisk, winter warm, summer cool”; and being like spring all the year round. According to the statistics, over million of tourists come to the Bamboo Hometown of Xianning for tour and sightseeing each year. Therefore, expanding the bamboo forest resource and breeding the bamboo forest landscape propels the most directly and effectively optimization of ecological environment and the characteristic tourism of E’nan of scenery and ecology.

3. SEVERAL COUNTERMEASURES FOR PROMOTING XIANING BAMBOO INDUSTRY

In order to transform the traditional resource superiority to the clear economic superiority, Xianning bamboo industry must take the way of “building bases on mountains, processing down mountains, opening up markets outside mountains, and creating high benefits by science and technology”. Large-scale bases will be cultivated, wide-ranging markets will be built. The developed industry system of the integration of forest and trade and a coordinated process of production, supply and sell will be constructed step by step.

3.1 Strengthen the Pillar Position of Bamboo Industry with the Ecological Construction as Turning Point

With the environment problem push forward day by day and the establish of Continuingly Developing Strategy, the Party Central Committee and the State Council attached great importance to the construction of forest and ecology, required us to take the civilized developing way of “developing production, well-to-do life and good ecology” and made 《the Decision on Hastening the Development of Forestry》. New period has entrusted to the forestry dual tasks of optimizing ecological environment and promoting economic development. The forestry has met the golden opportunity of development. “Seven-tenths of mountains, one-tenth of water and two-tenths field” is the condition of the first importance of the city and the forestry. In this sense, the superiority, potentiality and hope of Xianning economic development all lies in mountains. Starting forestry to make the people rich is the only road for the development of Xianning economy, and it is the most realistic choice. Bamboo is not only the ecological forest but the economic forest, which is the leading variety for Xianning to develop green industries and build ecological homelands. When implementing the continuingly developing strategy, the bamboo industry shall be entrusted important position; in the ecological construction of the city, the position of the first importance shall be entrusted to the bamboo industry; when promoting the regional economic development, the pillar position shall be entrusted to the bamboo industry. In 2010, the base area will be expanded to over 133333 hectare. The objective of the struggle that the output value of bamboo industry will exceed 1 billion RMB; and the profits tax will reach 200 million RMB will be realized. Xianning strives to promote the overall level of Xianning bamboo industry, to bring about continuous and rapid advance in regional ecoomy.

3.2 Hasten the Breeding of the Resource of Bamboo Forest with Starting Bamboo Forest with Science and Technology as Security

Science and technology are the primary productive forces. We would strengthen the spread of applicable techniques for bamboo with the fact that Tongshan and Chongyang are placed among the ten breeding demonstration bases of the high yield bamboo forest as the turning point. The key high yield techniques of cutting weeds and re-cultivation, thinning bamboo shoots and breeding bamboos, management of marking bamboos, bamboo-groadleaf mixed plant to the timber forest; to the forest for the dual purposes of bamboo shoots and timber, the key high yield techniques of deep ploughing, green manuring, marking bamboos, ticking off the branches of the bamboos, injecting the growth hormone, the prevention and control of plant disease and elimination of pests, three-dimensional management are spread; to the forest for the purpose of bamboo shoots, the key high yield techniques of deep ploughing, applying fertilizer, covering, ticking off the branches of the bamboo, and the prevention and control of plant disease and elimination of pests. We strive to spread the techniques of cut the bamboo off with the stake, or breaking through the bamboo joints to make the stake rotten and advantage the subterranean stems traveling and bamboo growing up. We should strengthen the technique training and on-the-spot guidance, encourage the science and technology personnel to go down to the countryside to launch the service of science and technology and the contract of research topic, to help the mass to solve the difficult problems of technique.

We should grasp the opportunity of the State carrying out the engineering of returning the field to forest and planting the forest of quick growing and high yield, to devote major efforts to developing the resource of bamboo forest. On the one hand, we will stress on the cultivation of new bases. According to the distribution of “developing the timber forests on high and far mountains, developing the forest for the dual purposes of bamboo shoots and timbers on the near and low mountains, developing the bamboo shoots forests at the gardens beside the houses, developing the tourism bamboo forest in the scenic spots”, 50% peasants are mobilized to plant over 20 bamboo each family, 6667 hectare of bamboo are newly built annually. On the other hand, we will stress on the reform of the old bases. The forests where the amount of standing bamboo is below 120 are re-cultivated, close off hillsides for forbidden to cut bamboo, applied fertilizer to breed; the quality of the standing forests are to be raised quickly. The forests where the slopes are below 22 degrees are deeply ploughed to make the soil loose and strong the subterranean stems and large bamboo grow up. The forests where the slopes are in 20-30 degrees are re-cultivated in the girdle shape. Growing bamboo (bamboo shoots) are raised through the tending techniques of re-cultivating, deeply ploughing, fertilizing, covering etc. and reform bamboo forest 20,000 hectare every year. By hard working, the area of bamboo has expanded to 120,000 hectare; the amount of standing bamboo has reached 280 million. The area of Lei-bamboo has expanded to 6667 hectare. The output of fresh bamboo shoots has rose to 50,000 ton. The area of bamboo on the purpose of paper making mainly of Ci-bamboo has reached 6667 hectare.

3.3 Develop the Profound Processing of Bamboo and Bamboo Shoots with the Market Demand as the

Guidance

According to the thinking of "expanding the bamboo articles of industrial products, perfecting the bamboo articles of everyday use, exploiting the foodstuffs, promoting the bamboo handicraft articles, introducing the bamboo products of high and new techniques", we launch the profound processing, raise the additional value. The enterprises of Jinxing in Tongshan, Xinjin in Chongyang, Xingzhu in Xian'an shall expand the scope and produce the industrial products and ornaments of Bamboo Plywood, Bamboo Floorboard, the carriage board which are very popular in the market. We shall stress on the key production lines of the bamboo-wood fiberboard with the annual production of 80 thousand cubic meters and the item of the annual paper output of 200,000 tons of the Chenming Company in Chibi. The Chibi Forest Product Company and others should improve the handicraft to produce the articles of everyday use as bamboo sleeping mat, the bamboo curtain, and the multi-functional bamboo bed. The enterprises as Chongyang Ruifa Enterprise should develop in series the foodstuffs as the Can of Qingshui Bamboo Shoots, bamboos sold in soft packages which needs less investment; stress on the key processing item of ten thousand tons of Lei-bamboo shoots of Chongyang Ruifa Company. The enterprises as Longquan Company should enlist the skillful craftsmen to produce the handicraft articles as bamboo woven articles, tree-root carving, tea sets and vase. The enterprises as Chibi Chutian Laser Company and Huasheng Bamboo Industry Company in Xian'an should explore the new handicrafts to produce the new products as bamboo-wood compound board, the bamboo veneer pinup picture furniture, the imitation of the ancient bamboo slip, the drink of bamboo juice, to raise the comprehensive utilization rate to 80%.

We should activate the leading enterprises of Juning in Xian'an, Chenming in Chibi and Xinglin of Hubei. Through the ways of grafting and reform, linking up and relying on and uniting, purchasing and annexing, expanding scopes, improving the quality, we would promote the enterprises to a certain scope and grade, and to produce new brands, to raise the benefits, to reach the standard of "unifying the rules of techniques, unifying the standard of quality, unifying the trademarks and brands, unifying the expanding of market", to improve the market possessing rate. At the same time, we would hasten the market construction. Three large-scale wholesale markets of bamboo and wood are built with 107 National Highway and Beijing-Zhuhai expressway as the thread, with the bamboo and wood markets in Chaoliqiao Town and Guantangyi Town of Chibi, Henggouqiao Town of Xian'an as the base. New "window" markets are set up in the large and middle cities; the sell network for bamboo and wood is strengthened; the process is promoted by selling.

3.4 Activate the Development Mechanism of Bamboo Industry with Deepening the Reform as the Methods.

The practice proves that if the mechanism is flexible, the facilities will be prosperous. We should seriously carry through the policy of "give much, ask for little, make free" of the Party's Central Committee and the State Council and make great issues of the "Three Making-free". Firstly, the mechanism is made free. We should devote great efforts to spreading the successful experience of "centralizing to exploit, auction and management, rolling development" and "the owner right and managing right separate, the division of benefits, the administration of justice just". We would deepen the reform of the management system of the forest, propel the right of the use of the forest fields to circulate properly. The strengths of the whole society are encouraged to take part in the development of bamboo industry in order to make the non-public-ownership over 80% of the total volume with developing the civil-managed forest industry as the main part. Secondly we would relax the management. We should fulfill the classifying management of the forest, run strictly the ecological public good forest, make free the commercial forest. For the forest industry companies and large self-employed laborers who invest on the newly made forest, the lumbering targets are listed in plan, given the priority of approving and issuing. The protection policies of hanging out the shingle are carried out to the large companies of bamboo industry development. The managers can come in and settle down and win some profits. We would build the relaxed environment for the development of bamboo industry, arouse the enthusiasm of diversified investment. Thirdly we would lower the tax. We would carry through the gist of "the Decision on Hastening the Development of Bamboo Industry" from the Party Central Committee and the State Council. We would decrease the too high tax, forbid the improper charge. The field for agricultural purpose used to develop the production of bamboo industry will only levied the Agricultural Tax. To those who open up the barren hills and build forests, the regulated fees of forestry will all be half collected. So the enthusiasm of the different quarters from the society of investing to build forests is really aroused.

Reference:

1. Sun Zhensheng. The Research on Xianning Development Strategy. Wuhan: Hubei People Press, 2001
2. Zhang Zhida. Bamboo Forest Breeding in China. Beijing: China Forestry Press, 1998

Evaluation on Shoot Quality of Excellent Sympodial Bamboo Species and Hybrids

Wang Yuxia Zhang Guangchu

Guangdong Forestry Research Institute,
Guangzhou Guangdong, 510520, P. R. China

Abstract

Experimental results on evaluation of bamboo shoot qualities were reported among 10 sympodial bamboo species and 4 hybrids growing in same conditions. By means of integrated evaluation on fresh eating quality, processed property, and content of nutritious ingredients, three types of bamboo species, which are excellent in shoot qualities, were classified. The first type has the character of good fresh shoot taste, higher content of nutritious ingredients, long period of shooting, and high yield of shoots, including species of *Dendrocalamus hamiltonii, D. brandisii, D. latiflorus ×D. hamiltonii No.1.* The second type of bamboo includes species of *D. latiflorus, Gigantochloa levis × D. latiflorus No.1, G. levis,* whose shoots are good at being processed easily, and are large in volume, they have high yield annually, the color and luster of dried shoots are beautiful, but fresh shoots taste worse and the content of nutritious ingredients is lower. The last type bamboo species are with shoots having good fresh eating quality and processed property, their shoots can both be tasted fresh and be easily processed into dried shoots, they usually have character of good adaptation of environment, well bearing of chill, and high quality of timber, *Bambusa pervariabilis, D. minor, D. minor × D. latiflorus No.5, B. pervariabilis × D. latiflorus No. 7* are all belonged to this tape.

Key word: Sympodial bamboo, Quality of bamboo shoots, Evaluation.

Bamboo is used widely and bamboo forests grow rapidly and can be renewed easily. Bamboo forests have huge impact to protect balanced ecology, to promote economy and other social benefits. Therefore, bamboo industry is a sustainable green line. So far, there have been more than 100 species of sympodial bamboo in our country, among which many are publicly recognized as excellent shoot-producing ones. How to explore and utilize such resources reasonably is essential to the sustainable bamboo industry. In recent years, sympodial bamboo is widely grown in the southern and southwestern provinces of China. In this paper, the shoot quality of the major excellent sympodial bamboo and hybrids is evaluated comprehensively so as to offer scientific instructions to bamboo production and to lay theoretical foundations to the protection, development and reasonable exploit of resources of sympodial bamboo.

MATERIALS AND METHODS

1. Experimental materials

Select 10 species of good sympodial bamboo shoots and 4 species of good hybrids from areas in the south of China, used for the evaluation of fresh-eating quality, processing property and content of nutritious ingredients. Those are: *Bambusa gibboides* W.T.Lin, *Dendrocalamopsis beecheyana var. pubescens* (P.F.Li)Keng.f, *B. pervariabilis* McClure, *D.vario-striata* (W.T.Lin) Keng.f, *Dendrocalamus minor* (McClure) Chia et H.L.Fung, *D. latiflorus* Munro, *D. oldhami* (Munro) Keng.f, *D. hamiltonii* Nees et Arn.ex Munro, *D. brandisii* (Munro) Kurz, *Gigantochloa levis* (Blanco) Merr., *B. pervariabilis* McClure× *D.latiflorus* Munro *No.7*, *D. latiflorus* Munro×*D.hamiltonii* Nees et Arn. ex Munro *No.1*, *G.levis* (Blanco)

Merr. ×*D.latiflorus* Munro *No.1*, *D.minor* (McClure) Chia et H.L.Fung×*D.latiflorus* Munro *No. 5*.

2. Experimental Methods

Collect all the experimental bamboo species and plant them into sandy alluvial soil in our bamboo garden. Manage all the species of bamboo with the same nursing methods for more than four years. And fertilize once with carbamide every April and July , and add some burned soil with k_2co_3. Then take some shoot samples to evaluate and analyze during July to August in 1998.

1) How to select bamboo shoots

Select two shoots of medium size from each bamboo species. Cut off the edible parts above the shoot basis in early morning when the bamboo shoots are about 25cm above the ground. Within two hours ensued, shell them to sample for test and evaluation.

2) Preparation for fresh-eating samples and evaluation on fresh-eating quality.

2.1 Preparation

Cut the bamboo shoots into two halves with a stainless-steel knife after shelling. Steam them in a wok, and then cut into strips at 10×0.8×0.2 cm.

2.2 Methods for evaluation

Invite ten people as evaluators. According to the marking standards in table 1, they are to give a mark to each fresh sample ranging their taste, texture and luster. Average the marks for all properties, then total them to get the whole mark . The highest mark indicate the most excellent quality.

Table 1. Marking standards for fresh bamboo quality

Quality and property	Sweet			Fresh			Bitter			Tenderness & crispness			Rancidity			Luster		
	nill	thin	thick	nill	thin	thick	nill	thin	thick	nill	little	strong	nill	little	strong	white to lurid	yellow to dark yellow	black and motley
Scores	0	1	2	0	0	1	2	-1	-2	0	1	2	0	-1	-2	0	-1	-2

3 Methods for evaluation on processing property

3.1. Methods for making shredded bamboo and evaluation on its luster

Refer to the methods in 2.1 to get bamboo strips done. Bake them in an oven at 85℃. Then evaluate the luster.

3.2. Preparation for boiled fresh bamboo and comparison of luster.

Take shoots of *D.hamiltonii, D. brandisii and D.latiflorus ×D.hamiltonii No.1*. Shell them and cut into 6×4×1cm. After that, put into bottles and pour water to immerge. Then sterilize in high-pressure steam. Waiting for cool, put them into a refrigerator at 2-4℃ and store for two months. Periodically, observe the change of color in the duration of storage.

4 Measure moisture, protein, fat, total saccharides and the content of amino acid in bamboo shoots

4.1 Treatment of the shoot samples

Cut the shelled shoots into strips, and take a share of them to measure the moisture. Put the rest of them in an oven to bake them for 15 minutes at 105±2^{0}C, then lower the temperature to 65±2^{0}C to dry. Finally, seal them in a jar for future survey of the content of protein, fat, total saccharides and amino acid.

4.2 Measurements

The survey of moisture, protein, fat, total saccharides of the shoot samples is carried out according to National Standard GB5009.3-85, GB5009.5-85, GB5009.7-85 of the People's Republic of China. The content of amino acid is measured by Hitachi Analysis Model 835-50.

RESULTS AND ANALYSIS

1. Evaluation on fresh shoot quality

Ten people are invited to mark taste, texture and luster of fresh shoot samples of ten sympodial bamboo species and four hybrids according to the certain standards. The results are listed in the following table.

Table 2 . Evaluation on fresh shoot quality of 10 excellent sympodial bamboo species and 4 hybrids

Bamboo Species	Average marks of each property						
	Sweat	Delicate flavor	Bitter	Rancidity	Crispness and smoothness	Luster	Total
Bambusa gibboides	0.7	0.7	0	0	1.9	-0.9	2.4
Dendrocalamopsis beecheyana var. pubescens	0.8	0.8	-0.9	0	0.9	0	1.6
Dendrocalamopsis vario-striata	0.3	0.6	-1.8	0	1.5	-0.2	-0.1
Dendrocalamus latiflorus	0	0.7	-1.9	0	1.5	-0.2	0.1
Dendrocalamopsis oldhami	0.5	0.8	-1.1	0	1.4	0	1.6
Bambusa pervariabilis	0	1.2	-1.0	0	2.0	0	2.2
Dendrocalamus minor	0	0.7	-1.7	0	1.6	-0.3	0.3
Dendrocalamus hamiltonii	2.0	2.0	0	0	2.0	-0.3	5.7
Dendrocalamus brandisii	1.7	1.4	0	0	1.2	-0.6	3.7
Gigantochloa levis	0.1	0.2	-1.8	-2.0	1.1	-0.3	-2.7
Bambusa pervariabilis × *Dendrocalamus latiflorus*	0	0.6	-1.7	0	1.4	0	0.3
Dendrocalamus latiflorus × *Dendrocalamus hamiltonii No.1*	1.6	1.8	-0.1	0	2.0	0	5.3
Gigantochloa levis × *Dendrocalamus latiflorus No.1*	0	0.4	-1.9	0	1.2	0	-0.3
Dendrocalamus minor × *Dendrocalamus latiflorus No. 5*	0	0.6	-1.8	0	1.7	-0.2	0.3
Average	0.55	0.89	-1.12	-0.14	1.49	-0.22	1.46

Therefore, we draw conclusion that only five bamboo species have good sweet taste, among which *D.hamiltonii* , *D.brandisii* , *D.latiflorus*×*D,hamiltonii No.1* are the best, Bamboo shoots with the best fresh taste in turn are *D.hamiltonii*, *D.latiflorus*×*D. hamiltonii No.1*, *D.brandisii*, and *B. pervariabilis*. Shoots with the best crispness and smoothness are *D.latiflorus*×*D.hamiltonii No.1*, *D. hamiltonii* , *B.pervariabilis* , *B.gibboides*, *D.minor*×*D.latiflorus No.5* and *D.minor*. Only *D. hamiltonii*, *D.brandisii*, and *B.gibboides* are bitter-free. *D.latiflorus*×*D.hamiltonii No.1* is slightly bitter, and *D.oldham*i and *B.pervariabilis* is not very bitter, while other species are heavily bitter. Only *G.levis* carries a rancid taste. As far as color and luster is concerned, there are not any discrepancies among all the fresh shoot samples. Generally, color appears from light yellow to dark yellow. Bitter-free shoots are relatively darker.

The average scores are: sweet taste 0.55, fresh taste 0.89, crispness and smoothness 1.49, bitter taste –1.12, rancidity –0.14 and color and luster –0.22. Such shows that, in the whole, shoots are prominent in crispness and smoothness, fresh and bitter taste. But there are big discrepancies between different bamboo species— Most shoot species have a heavily bitter taste, on the contrary, sweet species take up small ratio.

The total scores fluctuate from –2.7 to 5.7. In detail, *D.hamiltonii* arrives the top, while *G.levis* hits the bottom. The average score is 1.46. In light of the total scores, the bamboo species can be classified into four groups. The first group prefers to those with marks ranging from 3.7-5.7. It includes *D.hamiltonii (*5.7), *D.latiflorus*×*D.hamiltonii No.1* (5.3) and *D.brandisii* (3.7). It also indicates that the three bamboo species have excellent fresh quality. The second range from 1.6 to 2.4. Especially, *B. gibboides*, *B.pervariabilis*, *D.beecheyana var. pubescens*, and *D. oldhami* has a good fresh quality. The third range from –0.3 to 0.3. The fresh-eating quality is just so-so. However, only *G.levis* belongs to the last group at –2.7. Its fresh-eating quality is the worst. Therefore, it is not suitable to cultivate it as a fresh-eating bamboo species.

2. Comparative evaluation on the processing property of bamboo shoots

Dried shoots and boiled shoots (packed into cans and soft materials) are the two major processed product series. Experiences have seen that the shoots color and luster of the same bamboo species is relatively stable in the drying and boiling process, i.e., the color is determined by genes of the bamboo. It is also the main factor to affect the quality. Therefore, it is important to inspect the color and luster change on procession to make a comparison among different species.

The color and luster of shredded shoots from the 14 bamboo species is listed in table 3.

Table 3. The color and luster of shredded shoots from the 14 bamboo species

Species	Color and luster
B.gibboides	Lurid
D.beecheyana var. pubescens	Dark golden
D.vario-striata	Golden
D.latiflorus	Golden
D. oldhami	Slight dark yellow
B. pervariabilis	Slight dark yellow
D.minor	Dark golden
D.hamiltonii	Lurid
D.brandisii	Lurid
G.levis	Golden
B.pervariabilis×*D.latiflorus No.7*	Golden
D. latiflorus×*D. hamiltonii No.1*	Slight brownish yellow
G. levis×*D. latiflorus No.1*	Bright golden
D.minor×*D. latiflorus No. 5*	Golden

There are eight shredded bamboo shoots in golden or dark golden. *D. oldhami* and *B. pervariabilis* are slightly dark yellow. *D.latiflorus*×*D.hamiltonii No.1* is slightly brownish yellow. *D.brandisii* and *D.hamiltonii* are lurid and *B.gibboides* is black brown. The comparison between these results in **1**, shows bamboo shoots with bitter taste become golden after being processed into dried shoots. It proves that shoots with bitter taste have a better processing property. With the bitter taste decreasing, the luster turns dark gradually. Bitter-free shoots turn lurid to black brown during procession. So they are not suitable to be processed into dried shoots products.

An observation of the change of luster from *D.hamilton*ii, *D.brandisii* and *D.latiflorus*×*D.hamiltonii No.1*, in the course of cold storage shows that , in the early stage of cold storage, the color is clear- bright. As the time prolongs, the three species become darker and darker to certain degrees. Especially, *D.brandisii* even become lurid, and the red has a tendency of thickening. Among the three , *D.latiflorus*×*D.hamiltonii No.1* is the most lustrous and purest, followed by *D.hamiltonii* next, and *D. brandisii* the last.

3. Evaluation on the major nutritious ingredients of bamboo shoot

The surveying results of the major nutritious ingredients are listed in table 4.

Table 4. Content of the major nutritious ingredients of bamboo shoots

Bamboo Species	moisture	protein	fat	Total saccharides	Amino acid in protein	Amino acid for human
Bambusa gibboides	92.46	16.26	1.18	38.48	11.48	4.56
Dendrocalamopsis beecheyana var. pubescens	92.62	16.93	1.09	49.20	11.75	4.20
Dendrocalamopsis vario-striata	91.31	20.97	1.19	38.50	16.08	5.98
Dendrocalamus latiflorus	92.00	22.08	1.34	35.40	16.36	6.00
Dendrocalamopsis oldhami	92.42	20.37	1.09	35.70	14.11	5.43
Bambusa pervariabilis	91.84	27.48	1.82	30.19	20.42	7.31
Dendrocalamus minor	91.52	22.20	1.37	30.79	17.06	6.48
Dendrocalamus hamiltonii	91.70	23.49	1.41	35.82	17.73	6.55
Dendrocalamus brandisii	91.55	24.80	1.31	36.02	17.61	6.41
Gigantochloa levis	92.58	16.57	1.18	41.00	11.94	4.29
Bambusa pervariabilis × *Dendrocalamus latiflorus No.7*	92.62	19.16	1.20	34.94	15.11	5.71
Dendrocalamus latiflorus × *Dendrocalamus hamiltonii No.1*	92.95	25.09	1.34	35.81	16.91	6.57
Gigantochloa levis × *Dendrocalamus latiflorus No.1*	92.00	21.30	1.40	32.41	14.42	5.36
Dendrocalamus minor × *Dendrocalamus latiflorus No. 5*	90.48	19.05	1.67	37.74	15.71	5.55
Average	92.00	21.13	1.33	36.57	15.48	5.74
The ratio: the highest to the lowest	1.027	1.690	1.670	1.630	1.779	1.740

3.1 Content of moisture

The content of moisture from all bamboo shoots differs slightly. Among them, *D. latiflorus*× *D. hamiltonii No.1* is the highest of 92.95%, while *D. minor*×*D. latiflorus No. 5* is the lowest with 90.48%. The average is 92.00%. On the whole, the content of moisture is high.

3.2 Content of protein

The content of protein ranges from 16.26% to 27.48% of the net weight of the dried shoots, the average being 21.13%. The highest is 69.0% as much as of the lowest. The highest is *B.pervariabilis* with *D.latiflorus*×*D. hamiltonii No.1* and *D. hamiltonii* followed. And *G.levis* and *D.beecheyana var. pubescens*, come next in turn. While the lowest is *B.gibboides*. On the whole, the content of protein is high, but big discrepancies occur between different species.

3.3 Content of fat

The content of fat ranges from 1.09% to 1.82% of the net weight, and the average is 1.33%. The highest is 67.0% as much as of the lowest. *B. pervariabilis* ranks the top, followed by *D.minor*× *D.latiflorus No. 5*, *D.brandisii*, *G.levis*×*D.latiflorus No.1* and *D. hamiltonii* in turn. And *B.gibboides* and *G.levis* come next. The lowest are *D.beecheyana var. pubescens* and *D. oldhami*. On the whole, the content of fat is low, but great discrepancies between different species appear.

3.4 Content of total saccharides

The content of total saccharides ranges from 30.19% to 49.20 of the weight of the dried shoots, and the average is 36.57%. The highest is 63.0% as much as of the lowest. The highest is *D.beecheyana var. pubescens*. And *G.levis* and *D. vario-striata* and *B.gibboides* rank the second. While the lowest is *B.pervariabilis*, and *D.mino*r and *G. levis* ×*D. latiflorus No.1* takes the third position. On the whole, the content of total saccharides is high, but the difference between different shoot species is big.

3.5 The total content of amino acid in proteins

Table 4 illustrates the total content of amino acid in the 17 proteins of bamboo shoots and the amino acid ratio needed by human body.

The total content of amino acid in proteins fluctuates from 11.48% to 20.42% of the net weight, averaging 15.48%. The highest is 77.9% as much as of the lowest. *B. pervariabilis* is the top followed by *D.hamiltonii* , *D.brandisii* , *D.minor* and *D.latiflorus*×*D.hamiltonii No.1* . However, the lowest is *B.gibboides* , and *D. beecheyana var. pubescens* and *G.levis* come next in turn.

8 amino acids, which are necessary to human body , take up 4.20% to 7.31% of the net weight . And the average is 5.74%. The highest is 74.0% as much as of the lowest. The highest is *B.pervariabilis*. *D.latiflorus*×*D.hamiltonii No.1*, *D.hamiltonii*, *D.minor* and *D.brandisii* ranks next. While the lowest is *D.beecheyana var. pubescens*. *G.levis* and *B. gibboides* take the third, forth respectively.

In all, the change of total content of amino acid in proteins and relevant amino acids absorbed by human body has nearly the same tendency.

4.Comprehensive evaluation on shoot fresh-eating quality, processing property and content of nutritious ingredients

Arrange the marks of shoot fresh-eating quality and the content of each nutritious ingredient in order. The results are shown in table 5.

According to the arrangement and shoot processing property, also considering the growing traits and texture traits of the bamboo species, three excellent sympodial bamboo species turn out.

The first type is excellent for fresh food. It includes *D.hamiltonii*, *D.brandisi*i, *D.latiflorus*× *D.hamiltonii No.1*. They are characterized as good fresh, high content of nutritious ingredients, long period of shooting and productivity, but the processed dried shoots are not lustrous.

Table 5. Arrangement according to the marks on bamboo fresh-eating quality and the content of nutritious ingredients (from high to low)

Bamboo Species	Marks of fresh-eating quality	Protein	Fat	Total saccharides	Amino acid in protein	Amino acid needed by human body
Bambusa gibboides	4	14	10	4	14	12
Dendrocalamopsis beecheyana var. pubescens	6	12	11	1	13	14
Dendrocalamopsis vario-striata	9	8	9	3	7	7
Dendrocalamus latiflorus	8	6	6	10	6	6
Dendrocalamopsis oldhami	6	9	11	9	11	10
Bambusa pervariabilis	5	1	1	14	1	1
Dendrocalamus minor	7	5	5	13	4	4
Dendrocalamus hamiltonii	1	4	3	7	2	3
Dendrocalamus brandisii	3	3	7	6	3	5
Gigantochloa levis	11	13	10	2	12	13
Bambusa pervariabilis × *Dendrocalamus latiflorus No.7*	7	10	8	11	9	8
Dendrocalamus latiflorus × *Dendrocalamus hamiltonii No.1*	2	2	6	8	5	2
Gigantochloa levis × *Dendrocalamus latiflorus No.1*	10	7	4	12	10	11
Dendrocalamus minor × *Dendrocalamus latiflorus No. 5*	7	11	2	5	8	9

The second type is excellent for procession. It includes *D. latiflorus*, *G.levis* ×*D.latiflorus No.1*, and *G.levis*.Their shoots are easy to process, and are large in volume. Also they are productive. The processed dried shoots are the most lustrous among the three, but the fresh shoots taste worse and the content of nutritious ingredients is normal or lower.

The last type integrated both good fresh-eating quality and good processing property. Their shoots are fresh and also easy to process, but also they have a common or higher content of nutritious ingredients. *B.pervariabilis*, *D.beecheyana var. pubescens*, *D.oldhami*, *D.minor, D.minor* × *D. latiflorus No.5*, *B.pervariabilis*×*D. latiflorus No.7* all belong to this type. They are usually characterized as strong adaptability to the environment, chill-resistance, and high quality of texture. As species good for shoots and timber, they are potential for expansion in north areas from North Guangdong province.

DISCUSSION

1. This reports covers the comparative study on the shoot quality of different bamboo species growing in the same conditions for the first time. The results show that shoot quality is influenced mainly by their hereditary genes.

In former reports on this subject, frequently, the researchers take shoot samples growing in different conditions or even in different provinces, and study the nutritious ingredients in shoots of different species of bamboo. The growing conditions, such as fertilizer, soil, sunshine and water supply and so on, influence greatly the quality of bamboo shoots. They can evidently affect shoots taste and their content of nutritious ingredients. Therefore, experimental results are not comparable if the sample shoots are taken from different growing conditions. The sample shoots in this experiment are all taken from bamboo grown in our experimental garden. All the bamboo species are cultivated and managed in the same conditions for more than four years. So we have excluded the influence to the experimental results by different growing conditions. By means of evaluation on the fresh-eating quality, the processing property and nutritious ingredients of ten excellent sympodial bamboo shoots and four hybrids from the south areas of China, we have proved that shoot quality is mainly affected by their hereditary genes.

We carried out evaluations for two times on shoots quality for the bamboo grown in our experimental garden. Though the two evaluations were carried out more than ten years away from each, a comparison of the results from the two evaluations shows that the fresh-eating quality, the content of nutritious ingredients and the processing property of bamboo shoots are stable to a certain degree. For example, *D.hamiltonii* are fragrant, sweet and tasty. The texture is crisp and tender. *D.brandisii is* slightly sweet and the texture is a little worse. The content of protein and amino acid in shoots of *B.pervariabilis* is the highest, while the total saccharides are the lowest. *G.levis* tastes rancid with low content of protein and amino acid.

2. Sympodial bamboo grows vigorously and it has great potential to increase production. The three types of excellent sympodial bamboo species chosen in this experiment have many fine qualities. It is well worth exploiting the resources of excellent sympodial bamboo if the classified shoot production is carried out in accordance to market demands.

Shoots from different species of bamboo differ in their qualities. Three types of excellent sympodial bamboo are chosen in this experiment. Using excellent fresh-eating bamboo species including *D.hamiltonii*, *D.brandisii* and *D.latiflorus*×*D.hamiltonii* No.1, top-grade fresh shoot production can be carried out. Using excellent processing bamboo species including *D.latiflorus, G.levis*×*D.latiflorus* No.1 and *G.levis*, processed shoot production can be carried out. Using shoots that have both good fresh-eating quality and good processing property including *B.pervariabilis* , *D.beecheyana var. pubescens*, *D.oldhami*, *D.minor* , *D.minor*×*D.latiflorus No.5* and *B.pervariabilis*×*D.latiflorus No.7*, production of both fresh-eating shoot and processed shoot can be carried out.

Reference

1. Liu Yaorong et al. Study on the Nutritious Ingredients of Eleven Edible Bamboo Shoots. Asia Forest Science and Technology, 1985(4): 23-28
2. Hu Chaozong et al. The Change of Nutritious Ingredients of Mao Bamboo of Different Age. Journal of Bamboo Research, 1986, 5(1): 89-95
3. Liu Aiying. Analysis on the Nutritious Ingredients of Common Bamboo. Bamboo Research, 1987(2): 52-60
4. Hu Chaozong. Cultivation and Processing of Bamboo Shoots. Publishing House of Chinese Forestry . 1987: 7-14
5. Zhang Guangchu et al. Preliminary Reports on the Selection of Excellent Bamboo good for shoots. Forestry Science and Technology of Guangdong Province,1993(2): 9-13
6. Hu Chunshui et al. Anatomy of Winter Shoots of Mao Bamboo and Survey on Their Nutritious Ingredients. Journal of Bamboo Research , 1998, 17(2): 14-19
7. Hu Chunshui et al, A Comparison of the Content of Amino Acid in Shoots of Mao Bamboo, Journal of Bamboo Research, 2000, 19(2): 44-4

Bamboo product processing industry and income of bamboo farmers *

Chen Suijun, Hu Bao

Agricultural Modernization and Rural Development Research Center, Zhejiang University
Hangzhong, Zhejiang, Chain, 310029

Abstract: Under market economy, bamboo product processing industry can lead to economic growth of bamboo sector, augment income of bamboo farmers, and improve the economic status of women in bamboo areas as well. Governments of bamboo areas can effectively stimulate economic and social development of local communities by means of establishing market economic system for bamboo sector, and providing public products and services.

Keywords: Bamboo processing industry income farmers

Bamboos vegetating in their favorite areas grow faster than arboreal plants. Also, they can be widely used. Furthermore, the next round of forestation is possible if bamboo forests are appropriately managed, which will benefit local communities year after year and result in sustainable bamboo exploitation. The bamboo sector in Zhejiang Province, especially in Anji County, has accomplished remarkable success during the past 20 years. The accomplishment is so much so that the saying spreads as "China takes the lead in global bamboo sector, while Zhejiang takes the lead in China"[1]. However, can Zhejiang's experience in developing bamboo sector be universally adopted? In other words, we are not sure if such experience can be successfully applied to areas with relatively underdeveloped bamboo sector, although these areas are suitable for bamboos' growth. Financed by INBAR (International Network for Bamboo and Rattan), we have undertaken a research focusing on this problem.

1 MATERIALS AND METHODS

1.1 Sampling

1.1.1 Assessment of Development Models of Bamboo Sector in Zhejiang Province

Although the total area of bamboo forests doesn't rank the first among the areas of China, Zhejiang is list on to top in terms of its bamboo culms and shoots production, as well as the whole sector's production value, which shows the advantage of Zhejiang's development model of bamboo sector. In Anji County of Zhejiang Province, bamboo resources are above 50% of the whole county's forest areas, and provide a direct annual income of more than 2000 RMB per capita for over 100,000 local bamboo farmers. Anji's annual bamboo-processing production values are beyond 1 billion RMB. Anji's bamboo development model is typical in Zhejiang, and has been spread around the province. Thus this report focused on Anji's

* This research was funded by the International Network for Bamboo and Rattan (INBAR). Data were provided by Yong'an City Bureau of Forestry, Fujian Forestry College, Anji Forestry Bureau, and Xinchang Forestry Bureau.

situation as a representative for the province's bamboo development model, and data from other counties are also used as supplementary information when required.

1.1.2 Selection of Representative County (city) of Fujian Province

In order to carry on an in-depth study on the application of Zhejiang's bamboo development model in Fujian Province and meet the demand of a typical analytical method, Yong'an City (a county-level city) was identified as the research site for this study. The other reasons of choosing Yong'an included that Yong'an has suitable bamboo growing conditions (mainly for Mao bamboo) and bamboo has a high proportion in its overall economy.

1.1.3 Research Methods

In consideration that there have been many studies on Zhejiang's experiences in developing bamboo sector, we use literatures study method to summarize the development model of Zhejiang's bamboo sector.

For the study of Fujian's bamboo sector, typical analytical method was used for study of Fujian's bamboo sector development. Yong'an City was chosen as the site for this case study. With the support of Yong'an Forestry Bureau, the Agricultural Modernization and Rural Development Research Center of Zhejiang University designed research questionnaires. According to economic development levels and district distribution, 10 towns with continuous bamboo forests in Yong'an were determined for the household survey. Six farm households were sampled for the questionnaire survey in each town. The burden scroll of each town was used for randomly selection of the sample households. 60 valid responses were obtained from the household questionnaire survey. Interviews were also done with local bamboo-processing enterprises, and general information related to local bamboo sector were also gathered, and compared with similar information of Anji and Xinchang of Zhejiang Province. Using SPSS software, statistic analysis was done for further theoretic analysis and, at the end, constituting a model to explain stakeholder cooperative performance in bamboo sector development.

2 ZHEJIANG'S DEVELOPMENT MODEL OF BAMBOO SECTOR

2.1 Bamboo Farmers Become Independent Land Use Managers and their Investment in Bamboo Forests is Encouraged and Protected

In middle 1980s, Zhejiang Government handed the use right of most collective forests and forests to forest farmers in forms of self-retained forests (Ziliu Shan) or contract forests (Chengbao Shan). Thus Zhejiang forest farmers enjoyed a long and steady use right and benefit right for the management of bamboos. At the same time, it magnificently inspired bamboo farmers' enthusiasm in bamboo sector. While allocating self-retained forests and contract forests, An'ji used "estimated potential bamboo production" as the index for bamboo forest allocation rather than using "land area" which was used by most of other areas. Using such approach, it ensured equity for all bamboo farmers in generating income from their bamboo forests while maintained a continuous block of bamboo forests for better management. At later land reallocation due to population change in each household, Anji Government took the measure of "transferring monetary value rather than forests", and, at the same time, fulfilled the policy of "no change of land area with population change" for the settlement of the conflict between population change in farm households and keeping relative stability of bamboo management. During the land reallocation, all bamboo farmer households handed their bamboo forests to the village committee and were paid based on the original estimation of bamboo production yield, then the committee reallocated bamboo forests to them according to the existing population. In such manner, every villager can equally share the outputs of collective bamboo forests, while the bamboo farmers can receive newly added bamboo forest production capacity and benefits after reallocating bamboo forests. Therefore, the dissatisfaction among population-growing farm households is avoided, and investment in bamboo forests is encouraged and protected.

2.2 Open Bamboo Processing and Marketing and Regulate Bamboo Sector Management by Market Mechanism

From 1985, Bamboo timber was ranked as the 3rd category commodity, thus can be put into free purchase and sale and multi-channeled circulation in China. Under the situation of national reform on fixed quotes of agricultural and sideline products, Zhejiang Provincial Government definitely advanced the policy of equal development of different economic components, i.e. state-runs, collectives and individuals. It persisted in activating circulation, permitting the management of enterprises and long-distance transportation of farmers. Only in Yonghe Town of Anji County, there were several tens of farm households selling bamboo products to Shanghai. Driven by them, a professional bamboo-product sales group which involved more than 3000 farmers came into being. The group made provision, transportation, stock and sale on a line, and constantly fed market information back to bamboo managers. As a consequence, instead of the damage of bamboo resources, production and exploitation of bamboo can be carried out according to market demand. Sustainable development of Anji's bamboo sector is facilitated[3].

2.3 Focus on Bamboo-processing, to Bring along Bamboo Sector Development

Bamboo sector development of Anji has experienced a relatively long course. During the 1980s, Anji owned 55,000 ha of bamboo forests, listed on to top of bamboo production areas of China. But the use of bamboo resources was mostly limited in the sale of raw bamboo culms and bamboo shoots, with only a small portion entering into manmade tools and necessities. Raw bamboo and bamboo shoots were often unmarketable and of low economic efficiency[4]. Some bamboo farmers whined to local leaders for open raw bamboo market outside the county. In February, 1984, the State Council enacted *Rules for Organizing and Developing On-spot Processing of Agricultural and Sideline Products*. Anji took the opportunity and set up one of the earliest national bamboo veneer plants -- Anji State-Run Manmade Veneer Plant, and put it into production. The foundation of the plant opened up Anji's mass production and deep processing of bamboo products. The introduction of Taiwan-financed enterprises -- Mingzhi and Gongyuan bamboo mat companies in 1989, which further stimulated the fast development of Anji's bamboo sector. Besides state-run and external investment, Anji encouraged and supported civilian entities to set up bamboo-processing enterprises. The maximum number of Anji's bamboo shoot processing enterprises was once 43, while bamboo-processing enterprises once peaked at the number of 1200. Numerous bamboo-processing enterprises not only completely resolved the sale problems of 18 million bamboo poles and bamboo shoots every year, they also imported 5 million bamboo poles from outside the county. The settlement of bamboo products' sale and the augmentation of their price increased Anji's bamboo groove areas and bamboo stocks by 14.05% and 17.09% respectively during 1989 and 1998. During the same period, bamboo timber outputs and bamboo shoot outputs increased by 37.03% and 94.67% respectively[2]. In 10 years, bamboo-processing production values got an increase of 1 billion RMB.

2.4 Formulate Bamboo Industrial System and Share Benefits Rationally among Stakeholders in Bamboo Sector

When focusing on bamboo-processing industry, the county promoted the development of integrated bamboo industrialization management system through market spontaneous regulation and government's positive induction. According to production scale and local resources, the relationships between leading bamboo enterprises and bamboo farmers have different patterns. In such an integrated bamboo development system, Bamboo forest management, bamboo culms and shoots transportation, preliminary processing, bamboo products sale, supplies for bamboo processing enterprises and other social services were organically combined. As a result, bamboo farmers, usually disadvantaged group in trade, are well protected in economic benefit, and leading bamboo enterprises are guaranteed with stable supply of raw materials, and such development also promoted the development of other sectors such as transportation, supply and marketing, mechanism, architecture, necessities, dietetic services. Consequently, impartial business among stakeholders of bamboo sector can be realized which in turn constitutes internal impetus of the development of bamboo sector.

2.5 Establish layout to investment in science and technology, and increase production ability of bamboo grooves as well as economic benefits of bamboo sector

With the successful step in bamboo-processing and bamboo farmers' benefits protected, bamboo farmers demonstrated high enthusiasm in investment of bamboo management. Zhejiang started making appropriate bamboo sector development plan, and promoting research on applied technologies. Various extension methods were used to provide farmers with technologies of cultivation, improvement of low yield stands, and high-yielding of bamboo forests to quick increase the productivity. The increase rate of farmers' income is much higher than the expansion of bamboo forest area. In the 1980s, for example, Anji's scientific and technologic activities began focusing in comprehensive exploitation technologies of bamboo resources. In the 1990s, Anji's research was mainly on how to promote bamboo economy and purpose-oriented cultivation technologies, focused on the key technologies to promote bamboo production and economic benefits. Such technologies brought about considerable economic and social benefits. More than 40 research results were highly appraised at different levels of governments, and Anji was honored by the Central Government as "National Demonstrate County of Managing Forests by Application of Sciences and Technologies"[5].

In 1995, Anji found their own bamboo resources (shoots and culms) could not be meet the county's processing industries. The County Government suggested to hasten the exploitation of bamboo resources. On one hand, funds were raised broadly, and much more was invested in the exploitation of bamboo resources, so that the whole county's bamboo groove areas would increase, and bamboo stocks would be much more. On the other hand, bamboo and bamboo shoot processing enterprises were uniformly planned and rationally arranged. Also, processing enterprises with low benefits, inferior quality and serious waste were neatened and rebuilt in a limited period in order to promote additory value. In 1998, county government issued *Anji's Exploitation Plan on Winter Bamboo Shoots*. In 2000, local government issued *Construction Plan of Anji Ecological Demonstrate Areas*. Above measures expedited Anji's bamboo exploitation to actively adapt new situations.

2.6 Simplify Management Procedures, Reduce Taxes and Fees to Bamboo-Based Business, and Strengthen Services to Maximize the Benefit of Bamboo Farmers

Because bamboo farmers in Anji County have mastered and self-consciously applied scientific bamboo harvest techniques. Under the new harvest scheme, only bamboo culms with more than 5 cun (about 15 cm) in girth can be harvested. According to the basic data of area of bamboo forests and their growth, the forest bureau issue harvest quotes to all townships, and further down to the farmers, which significantly simplified harvest certificate declaration procedure required every time bamboo farmers wanted to harvest their bamboos. The fresh bamboo culms can be freely transported within the county, and removed retraction of bamboo among township that was practiced earlier. Compared with other provinces, bamboo-related taxes and fees of Zhejiang is relatively low. In the light of Anji's rule, tax and fee of every 100 bamboo culms is about 9%+16RMB. For a fresh bamboo culm with a price of 6 RMB, the actual tax rate is 11.7%, while national permitted tax standard is as high as over 24%.

2.7 Summary on Zhejiang Bamboo Development Model

We can see from above that, with Anji County being a representative, the development model of bamboo sector in Zhejiang Province is firstly constructing institutional environment in which market economic system can effectively exert its function. Bamboo forest farmers, bamboo processors, transportation people and traders can all become independent market economic entities. They actively optimized their behaviors during management process. Secondly, Zhejiang stimulated the development of bamboo sector by developing bamboo-processing sector, resolved the problem of encashing and increment of bamboo products, emphasizes on partnership to increase benefits of all in the formation of industrial organizational system, and especially pays attention to protecting farmers' benefits. Thirdly, the government provides public products demanded by bamboo sector development, such as market order, planning and induction, extension of scientific technologies, education and training, basic infrastructures and so on, and benefited bamboo farmers, so as to increase comparative benefits of bamboo economy.

3 TYPICAL ANALYSIS: APPLICATION OF ZHEJIANG BAMBOO DEVELOPMENT MODE IN FUJIAN

The total area of bamboo forests of Fujian Province is 820,000 ha, highest among all provinces of China. However, Fujian's annual bamboo production value is 4.6 billion RMB, far less than that of Zhejiang. In 2000, Fujian advanced the idea of "forest and bamboo of the same importance, with priority to bamboo"[6]. Yong'an City is ranked the 2nd in bamboo forest area in Fujian Province. Yong'an has emphasized on bamboo sector since the 1990s, and now it goes ahead in Mao bamboo management system reforms in Fujian Province. In developing bamboo sector, Yong'an used Anji's model as a reference, and for several times organized county-level and town-level governmental officials and technological persons from all bamboo sectors to visit Anji and exchange experiences in developing bamboo sector. This research studied the application of the development model of bamboo sector of Zhejiang Province to Fujian Province, with Yong'an being the case study site.

Yong'an City of Fujian Province is situated on 116°56'-117°47' east longitude and 25°33'-26°12' north latitude. It runs 82 kilometers from east to west and 71 kilometers from south to north. Yong'an has a long summer and short winter, with a mild and humid climate with an mean annual temperature of 19.1°C. Its non-frost period is 301days, and the average annual sunlight is 1,766.1 hours. The city has an average annual rainfall of 1,688 mm with 130-169 rainy days. Yong'an is suitable for the growth of subtropical trees such as evergreen broadleaf trees. It is a mixed area of sympodial and monopodial bamboos. The rural population of the city is 182,800 (46,112 households). The city has arable land of 18,760 ha, and 0.103 ha per capita for bamboo farmers. In the 246,200 ha of forest land, fresh bamboo forests possess 47,270 ha in area, averaging 0.26 ha per capita for bamboo farmers. Farmers of Yong'an own the highest bamboo forest area per capita in China. In 2000, Yong'an City was honored as "Chinese Hometown of Bamboo for Shoots"[8].

3.1 Basic Conditions of Farmers Investigated

General conditions of the 60 investigated farm households are shown in table 1, and their average conditions are demonstrated in table 2. Total population of the 60 farm households is 269, and it is easy to get the data of the per capita from table 2.

Table 1 General Conditions of Investigated Farm Households

Number of farm households	Total population	Number of labors	Area of paddy fields	Area of dry lands	Area of Mao bamboo	Area of mixed bamboo
60	269	161.5	19.8ha	5.4ha	293.6ha	24.5ha
Area of timber forests	Area of tea orchards	Area of self-retained forests	Area of contract forests	Average educational level of householders		Maximum educational level of householders
28.0ha	31.1ha	19.3ha	255.5ha	8.8 years		10.1 years

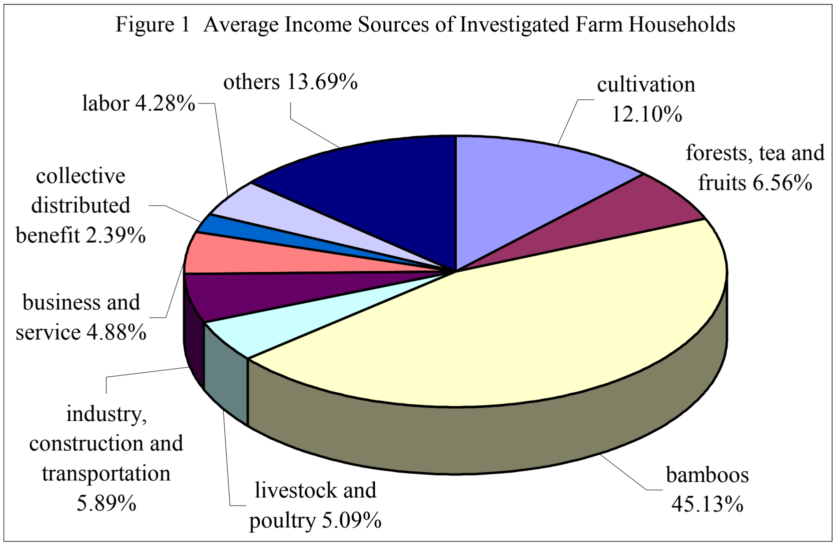
Note: Educational level is expressed by means of the fixed number of year one received education.

Table 2 Average Income Sources of Investigated Farm Households

Item	Grains	Plantation	Timber	Bamboo	Tea and fruits	Livestock and poultry	Industry	Construction
Income (RMB)	1826.05	672.50	24.27	9320.84	1330.00	1051.17	283.34	24.17
Item	Transportation	Business and service	Other business	Collective distributed benefit	Waged Labors	Others	Total income	
Income (RMB)	910.00	1008.34	800.00	493.34	883.34	2028.09	20655.4	

Note: The income of each item is the average of incomes in 2000 and 2001, and the aim is to eliminate the influence of good year and normal year of mao bamboo forests. The investigation shows that the phenomenon of good year and normal year of mao bamboo forests is significant. 60 investigated farm households received a total income of 486,830 RMB in 2000, and 431,670 RMB in 2001. The total income decreased by 11.33%.

According to table 2, the income from bamboo forests amounted to 45.13% of total income for farm households at bamboo production areas of Yong'an City, and it reaches as high as 65.52% of agricultural income. The average household income source is shown in figure 1.



Note: For a plain expression, some data of table 3 are combined in figure 1. Grains income and plantation income are united as cultivation income; timber income and tea and fruit income are united as forest, tea and fruit income; industry income, construction income and transportation income are united as industry, construction and transportation income; income from other household operation and other income are united as income from others.

4. ANALYSIS OF BASIC INSTITUTIONAL FACTORS AFFECTING BAMBOO FARMERS' INCOME

4.1 Land Tenure System

Questionnaires answered about Yong'an contracted bamboo forests as shown in table 11. Because of the difference in understanding, some farm households take the fixed year number (30 years) of the second round contract after the first round of contract period (15 years) as the fixed year number of bamboo forests contract, which is in agreement with the Chinese farmland system reforms and the schedule of handing agricultural and forest management rights to farmers. However, the standards are different in the number of contract bamboo forests per household even at village level. Most villages give priority to impartiality, and only take current population in each farm household into account (This can partly explain the strongly explicit positive relevance between total income and householder age, because householder numbers are explicit positively relevant to householder age). But there are still many villages emphasizing efficiency. They determine contract areas by the contract funds each farm household would like to offer, which provides more convenience for managing bamboo forests. Besides, those who fail to get contract bamboo forests will receive certain economic compensation (introduced into non-management income in statistics). As some villages adopt both standards at the same time, the total households divided by contract standards are more than 60. Although bamboo forests contract pattern of Yong'an City is different from that of Anji County, farmers of both areas own the same independent management rights and revenue rights.

Table 3 Contract Conditions of Bamboo Forests for Farm Households in Yong'an

Item	Years of contract			Contract standards			due contract payment
	1982-1985	1996-2000	Others	by population	by contract funds	others	
Number of households	35	15	10	43	19	5	48

4.2 Sale Arrangement of Bamboo Products

Since 1985 China has unloosened forest and bamboo market, and allow farmers to sell forest and bamboo products in the market. But among the investigated farm households, only one household managing mixed bamboo forests carries out self-selling in the market, two other households directly sell their bamboo products to bamboo-processing factories, and the remaining sale their bamboo products through dealers, while there is none selling the products through cooperative organizations or purchase and sale organizations. Such a phenomenon indicates that, on one hand, the market of bamboo products has been completely unloosened, but on the other, cooperative organizations have been yet introduced into the sale areas of bamboo products in Yong'an City. Bamboo farmers and bamboo-processing enterprises are more likely to trade by means of intermediators.

4.3 Influence of Bamboo-Processing Enterprises to the Income of Bamboo Farmers

The development of bamboo and bamboo shoots processing sector enhances the requirement for rural labor by direct and indirect means.

Practice of intensive cultivation of bamboo forests is an indirect manner and always neglected. According to investigation result, total man-days devoted into the 2-year bamboo management of the 60 farm households are 26305 (exclusive of waged labors), averaging 41.5 man-days per ha. The labors devoted to bamboo production accounted for 37.75% of the total 69679 man-days of production operation (including waged labors) during the same period. Given that 250 man-days from each labor every year, bamboo forest management accounted for 32.58% of labor resources, while the surplus labor rate is 18.13%. On one hand, bamboo forest management has settled nearly 2/5 of bamboo labor employment; on the other one, there is still considerable potential in intensive bamboo forest management. Calculated by unit cost of improving low yield bamboo stands: deep soil cultivation 268 RMB/year, 75 RMB for fertilization, 172 RMB in weeding, 45 RMB for tending, 450 RMB for harvest, and 700 RMB in bamboo shoots digging, yielding a total 1710 RMB/ha. The above excludes the labor input into other forest managing measures such as the construction and maintenance of fire prevention forest belts and roads in forest areas. Using 20 RMB/man-day rate, about 90 man-days are needed for management of one hectare of bamboo stands every year. There are 356 farmers, 285 ha of bamboo forests and 36 ha of paddy fields in Longling Village, Gongchuan Town of Yong'an. 70% of local farmers' income comes from mao bamboo. Although there are few labors going out, they are not sufficient in bamboo shoots digging period, thus casual labors are needed. In addition, 9 households have set up cisterns on bamboo forests, and laid conduits to carry out jet irrigation.

The other is direct operation in processing, transportation, purchase and sale of bamboo and bamboo shoot products. Processing enterprises have to deal with vast amount of raw materials, especially in preliminary processing that requires plentiful labor-intensive simple work. Take bamboo veneer production as an example, the production of 1 m^3 veneer will consume 100 mao bamboo culms with 10-cun (33 cm) in girth (250 culms with 6~7-cun in girth). Just the cutting, tearing and the successive weaving processes will cost 20~23 man-days, valuing at 480 RMB. A veneer factory with annual production of 10,000 m^3 can consume bamboo culms from 5,000~7,000 ha of bamboo forests, providing 200 or so positions suitable for rural labors. The total income of the labor can reach 1.3 million RMB, averaged annual 6500 RMB per capita. Moreover, such a factory can offer another tens of practician positions. As for the referred Longling Village of Gongchuan Town, there are 5 farmers dealing with purchase, sale and accounting of bamboo and bamboo shoots perennially, which not only benefits local communities, but brings for themselves considerable profits.

From the above, we can enumerate bamboo farmers' income increase from employment in bamboo-processing enterprises.

At current operation level (low level of extensive operation):

$$A_p=(100*41.5/150+5.4+20)BC=53.07BC \qquad (1)$$

Where A_p stands for increased salary income of bamboo farmers (selling price of bamboo culms include land rent, value transferred of production supplies, and labor value in bamboo production ---- salary cost); B stands for bamboo veneer output (m^3); C stands for income standard of bamboo farmers (RMB/man-day); 53.07 stands for employment opportunity provided by the production of 1m^3 of bamboo veneer (including the labors entering into bamboo forest management and bamboo processing) (man-day).

Sources of the parameters in this formula are:

100 ---- number of bamboo culms consumed by the output of 1m^3 bamboo veneer;

41.5 ---- man-days per ha of bamboo forest management;

150 ---- number of bamboo culms produced from 1 ha of bamboo forests.;

5.4 ---- man-days required by the output of 1m^3 bamboo veneer (200 rural labors is demanded in the output of annual 10,000m^3 of bamboo veneers, averaged 270 days per capita per year);

20 ---- man-days required by the output of 1m^3 of extensively processed articles.

Using 20 RMB per man-day, salary income increase resulted from 1m^3 of bamboo veneer product is 1061.33 RMB.

If the sale outlet of bamboo products is settled by developing bamboo-processing enterprises, bamboo farmers will manage bamboo forests in an intensive way for the restriction of limited land resources. Therefore, formula (1) will become:

$$A_p'=(100*90/600+5.4+20)BC=40.4BC \qquad (2)$$

Where A_p' stands for achieved salary income of bamboo farmers by intensive operation; meanings of B and C are the same of those of formula (1); 40.4 stands for employment opportunity provided by the production of 1m^3 of bamboo veneer (including the labors entering into bamboo grooves and bamboo processing) (man-day).

Sources of the parameters in this formula are:

90 ---- man-days required for intensive management of 1 ha of bamboo forest;

600 ---- number of bamboo culms produced from 1 ha of intensively managed bamboo forests.

and the sources of other parameters are the same as those in formula (1).

In intensive management of bamboo forests, income generated for bamboo farmers from $1m^3$ of bamboo veneer production will decrease by 23.87%, because output of per ha bamboo forest is far more than the input to bamboo forest management. If the price of bamboo culms reduces due to the increase of productivity in bamboo production, bamboo veneer factories will benefit from depressed material costs.

But during intensive operation, will bamboo farmers' income decrease owing to depressed culm price? Excluding bamboo processing, the comparison between intensive operation and extensive operation can be expressed as:

$$A_a''=(600-150)P - (90-41.5)C=450P - 48.5C \qquad (3)$$

Where A_a'' stands for the difference of bamboo farmers' salary income for the two kinds of operation conditions; P stands for bamboo culm price (RMB); C stands for income standard of bamboo farmers (RMB/man-day); 600 stands for the number of bamboo culms 1 ha of bamboo forest produces in an intensive way; 150 stands for the number of bamboo culms 1 ha of bamboo groove produces in current way; 90 stands for man-days required for intensive management of one hectare bamboo forest; 41.5 stands for man-days required for current management level of one hectare of bamboo forest.

We can make sure from formula (3) that, when $P/C>48.5/450$, $A_a''>0$. If, in intensive operation, the cost of production supplies (fertilizers, etc.) for per culm of mao bamboo is higher than that in current operation level, and if bamboo labor price C = 20 RMB/day, bamboo farmers and leading bamboo enterprises will both benefit from a bamboo timber price higher than (2.15+a) RMB/culms and lower than current level.

What bamboo-processing enterprises care for is the decreasing space of bamboo timber price through the improved productivity of intensive bamboo management, while bamboo farmers are more concerned whether or not they can benefit from limited bamboo forests under the same situations.

From the formulae above, we can concluded that at current operation level:

$$A_a=[41.5+(5.4+20)*1.5]\ C=79.6C \qquad (式 4)$$

Where A_a stands for increased salary income of bamboo farmers at current level; C stands for income standard of bamboo farmers (RMB/man-day); 41.5 stands for employment opportunity provided by the production of 1 ha of bamboo forest at current level, composed of labors entering into bamboo forests (41.5 man-days) and bamboo processing (man-days of (5.4+20)*1.5).

Sources of the parameters in this formula are:

1.5 ---- number of bamboo veneers that can be produced annually from one hectare of bamboo forests at current management level (m^3);   and the sources of other parameters are the same as those in formula (1). Further, if B in (1) equals 1.5, the corresponding result will be the same as that of formula (4).

Under intensive management situations,

$$Aa'=[90+ (5.4+20) *6]\ C=242.4C \qquad (5)$$

Where Aa' stands for increased salary income of bamboo farmers at intensive level; C stands for income standard of bamboo farmers (RMB/man-day); 242.4 stands for employment opportunity provided by the production of 1 ha of bamboo forests at intensive level, composed of labors entering into bamboo forests (90 man-days) and bamboo processing (man-days of (5.4+20)*6).

Sources of the parameters in this formula are:

6 ---- bamboo veneer products from one hectare of bamboo forests in one year at intensive level (m^3); and the sources of other parameters are the same as those in formula (1).

Comparison of the results from formula (5) and (4) indicated that, intensive management will provide more employment opportunities than extensive management by 100%, especially more opportunities in bamboo-processing sector than that in direct bamboo forest management. When there are insufficient surplus labors among bamboo farmers (e.g. the surplus labor rate of investigated farmers is only 18.13%), intensive management and bamboo-processing sector will not only increase their income, but also provide large amount of employment opportunities for local surplus labors, thus enhancing their income and bringing along local economic development.

What formula (3) demonstrated is the difference of bamboo farmers' salary income from intensively managed against conventionally managed bamboo forest of one hectare with same price (including bamboo timber price and labor price). If intensive management is popularly chosen by bamboo farmers, labor price and bamboo timber price will change compared with current situations, the former increasing and the latter decreasing. At this point, total influence of managing one hectare bamboo forest on local bamboo farmers and bamboo-processing farmers will be:

$$A_t=(600P_{bf}+152.4C_{lf}) - (150P_{bc}+38.1C_{lc}) \qquad (6)$$

Where A_t stands for total impact on farmers income (both bamboo forest management and processing) generated from future intensively managed one hectare bamboo forest against the current management level; P_{bf} stands for future bamboo price; C_{lf} stands for future labor price; P_{bc} stands for current bamboo price; C_{lc} stands for current labor price; 600 stands for annual bamboo products per ha at intensive management level; 152.4 stands for labor man-days required to process bamboo produced from one hectare bamboo forest into bamboo veneer at intensive level, or (5.4+20) *6, referring to the explanation of formula (1); 150 stands for current bamboo products of per ha of bamboo groove; and 31.8 is reached from (5.4+20) *1.5.

4.4 Influence of Bamboo-Processing Enterprises on Income of Women Labors

It should be stressed that, intensive bamboo forest management and development of bamboo-processing enterprises will provide more employment opportunities for female labors than for male labors in bamboo areas, mainly because most of the processing procedures require deliberation other than strength. Still take bamboo veneer production for example, in the phase of preliminary semi-manufactured goods processing and manufacturing, the ratio of male to female labors is about 1:2.5 and 1:3.5. In addition, fertilization, pesticide scattering, weeding and bamboo shoot digging in bamboo forest management can also be carried out by female labors. If in this phase the ratio of male to female labors is 3:2, we can get from (4) and (5):

$$A_f=[41.5*2/5+(5.4*3.5/4.5+20*2.5/3.5)*1.5]\ C=44.33C \qquad (7)$$

Where A_f stands for increased female labor income from per ha of bamboo forest management and successive bamboo veneer production at extensive level; C stands for labor price.

Sources of the parameters in this formula are:

2/5 ---- the proportion of female labors in bamboo forest management;

3.5/4.5 ---- the proportion of female labors in bamboo veneer production;

2.5/3.5 ---- the proportion of female labors in preliminary processing of semi-manufactured goods of bamboo veneers; and the sources of other parameters are the same as counter parts in formula (4).

At intensive level, formula (13) becomes:

$$A_f'=[90*2/5+(5.4*3.5/4.5+20*2.5/3.5)*6]C=146.91C \qquad (8)$$

Where A_f' stands for increased female labor income from per ha of bamboo forest management and successive bamboo veneer production at intensive level; C stands for labor price. And the sources of other parameters are the same as counter parts in formula (7) and (5).

4.5 Influence of Bamboo Forest Management on the Income of Bamboo Farmers

The benefits from bamboo forest management by bamboo farmers show the following characteristics:

$$Bn=Yb*Pb - Cc - Tt \qquad (9)$$

Where Bn stands for net benefits; Yb stands for bamboo yields; Pb stands for bamboo price; Cc stands for the cost of bamboo production, transportation, sale and management; Tt stands for the tax fee the bamboo farmers should hand in.

Yb is restricted by soil's cultivation conditions and technical levels that include species. Facing the continually depressed bamboo price (The purchase price of former year being 100, bamboo price index has been in decline these years, which of Fujian was 94.8% in 1999 and 80.8% in 2000, with a decrease of 23.4% in 2 years), bamboo farmers have to accept such kind of Pb passively. For the production cost in Cc, bamboo farmers are unable to control the price of manufacturing materials, but they can improve it through improved efficiency and cutting the costs by means of technical advancement. Transportation is relevant as a public products, thus requiring rational mechanism to ameliorate itself. Sale and maintenance costs can be reduced by industrialized management. Tt is connected with governments and local rules. As a result, local communities, governments and industrialized management all directly affect the net benefits of bamboo farmers.

5 COMBINATION PATTERNS OF LEADING BAMBOO ENTERPRISES AND BAMBOO FAMERS, AND QUALIFICATONS FOR THEIR EXISTENCE

Although bamboo forest products are still in the buyers' market, individual bamboo farmer won't directly go to trade with bamboo-processing enterprises because of the small scale of their production. Instead, they wait for the incomers to purchase, or else the dealing cost (for negotiation, transportation, accounting, etc.) of per culm of bamboo will be very high. Currently, with the difference in technical requirements and production scales, there are 4 kinds of combination patterns of bamboo farmers and leading bamboo enterprises in Yong'an:

(1) Leading bamboo enterprises practice direct purchase;

(2) Leading bamboo enterprises purchase raw bamboo materials from middlemen;

(3) Leading bamboo enterprises purchase preliminarily processed products from processing units;

(4) Leading bamboo enterprises set up bamboo production bases as well as professional bamboo purchasing and preliminary processing factories.

5.1 Pattern one: Direct Purchase of Raw Materials

In this pattern, enterprises randomly purchase bamboo shoot and bamboo products from bamboo farmer in the light of markets status and their own processing needs and by their credit standing. Farmers and enterprises don't make any advanced contract, depending on current market price. Such deals take place only through their competition in market price. The advantage of this pattern is that bamboo farmers and processing enterprises can choose traders out of their inclination, so as to achieve maximum market benefits.

Direct purchase is the simplest dealing pattern in the market, and it requires following preconditions:

a. The distance between farmers and enterprises is relatively short, so that transportation cost is reduced;

b. Enterprises and farmers are familiar with each other, so the qualities, standards and prices of raw materials are transparent and easy to control;

c. Enterprises bear small demands on raw bamboo materials;

d. Enterprises bear relatively strict requirements on freshness of raw materials.

Two examples are showed as follows:

Example one: bamboo shoot processing factories

Bamboo shoot processing relates to the purchase and transportation of large quantities of bamboo shoot materials. Moreover, for the insurance of the quality of bamboo shoot products, it is requested to deal with bamboo shoots as fast as possible after harvest. Consequently, bamboo shoot processing factories are often in the center of bamboo areas. Products from some processing factories are not terminal ones. On the contrary, they are provided to downstream factories for further processing, while the latter are always settled in cities or suburbs. In spite of it, only the purchasers are different, and bamboo farmers won't be directly affected.

Example two: small bamboo-processing factories

Generally, such factories don't invest much, and the processing is mainly focused on physical deformation, such as producing intermediary bamboo sticks. The consumption of bamboo is not heavy, and for the small volume of products, a loose requirement is on transportation qualifications. Factory areas are always small, and in order to reduce cost, they are often located in the center of bamboo areas, similar to bamboo shoot processing factories. Commonly, a small factory consume around 10,000 culms of mao bamboo annually, which only involves about 70 ha of bamboo areas. Factories being settled in the center of bamboo areas, linear distance of material transportation is less than 500 m. Given that the villages are originally in bamboo forests, material transportation cost is always neglected.

5.2 Pattern two: indirect purchase of raw materials

In this pattern, enterprises deal with bamboo farmers indirectly. Instead, they consign middlemen to purchase bamboo forest products from bamboo farmers by their request, and then they pay the clients a commission or purchase from them. Either enterprises or clients can transport raw materials. Preconditions for this pattern are:

a. Enterprises bear demand of large quantities of raw bamboo materials, and a wide range of bamboo areas is involved;

b. The distance between farmers and enterprises is relatively long, and accordingly transportation cost is relatively high;

c. Enterprises and farmers are not familiar with each other, so the information about qualities, standards and prices of raw materials are not easy to get in time;

d. Clients in bamboo areas are available for enterprise;

e. Enterprises bear relatively loose requirements on freshness of raw materials;

f. Whether or not raw materials are preliminarily processed in local communities has little influence on the cost of the enterprises.

The advantage of this pattern is to reduce dealing cost of both sides in above conditions. For enterprises, they can benefit if the commission paid to clients or the increased price from clients is lower than their expenses in direct purchase. And bamboo farmers would rather deal with familiar clients even for a relatively low price than risk dealing with enterprises. The benefits the three sides can get may refer to the analysis of pattern three.

Example:

There is a bamboo chopstick factory with a relatively large number of products in Gongchuan Town, Yong'an City. It consumes 80,000 sticks of raw bamboo annually and employs 30 workers. Purchase of the factory is in the charge of transporting households. The payment standard is 0.3 RMB per culm (larger than 9 cunes/30 cm in girth) for households from the same village and 0.5 RMB per culm for those from out-of-village. It appears to the factory that the transporting households aim to take assignments, while to the farmers, it is much more lucrative to sell raw materials to transporting households even for a lower price. For the transportation households, they are satisfied to benefit from both sides. However, this factory pay for the raw material cost higher than that paid for none in transportation by 5~10%. Facing such a problem, the factory has the bamboo heads cut and sell them to another bamboo-processing factory. Thus the bamboo heads can be further used to produce floorings. The remaining parts of mao bamboo will then be used to make chopsticks. In this way, raw material values are fully exploited. Of course, it is the huge consumption of raw materials that makes the factory provide batches of semi-manufactured goods with commercial values, which can be seen as resulted from expansion of economic scale.

5.3 Pattern three: indirect purchase of preliminarily processed articles

Compared with pattern two, this one requires the clients to provide preliminarily processed articles other than raw materials. And its preconditions are:

a. Enterprises bear demand large quantities of raw bamboo materials, and a wide range of bamboo areas is involved;

b. The distance between farmers and enterprises is relatively long, and accordingly transportation cost is relatively high;

c. Enterprises and farmers are not familiar with each other, so the information about qualities, standards and prices of raw materials are not easy to get in time;

d. Clients in bamboo areas are available for enterprise;

e. Whether or not raw materials are preliminarily processed in local communities has considerable influence on the enterprises' transportation cost, labor cost and management cost;

f. Products are deeply processed, but preliminarily processed articles require low processing techniques and intensive labors;

g. Upper processing is required at a high level, investment scale of fixed asserts is large, and techniques and finance are intensive;

h. Finished products have a big volume, and certain levels of roads are required in transportation.

In the above conditions, it is not convenient for leading bamboo enterprises such as bamboo veneer factories to be located in deep bamboo areas where transportation is not easy. The priority should be given to the transportation and organization of raw bamboo materials for the sake of working order.

The most typical characteristic of pattern three is the relationships between bamboo veneer factories and processing/purchasing units as well as bamboo farmers. Processing units can conclude a contract with leading enterprises such as bamboo veneer factories, and then purchase bamboo from bamboo farmers according to the contract. For bamboo farmers, they take part in a direct trade in the market. After that, processing units conduct cutting and tearing by the demands of leading enterprises, and then sell flake timbers to leading enterprises for the direct production of bamboo flooring and vehicle board. Or after bamboo farmers wove bamboo shades or bamboo mats, purchasing units pay them by the sizes and numbers, and then sell the bamboo shades and mats to bamboo veneer factories. Processors are not necessarily the provider of raw bamboo materials. However, such a manner offers bamboo farmers with opportunity to conduct preliminary processing after they sell bamboo timbers, so it is applauded by bamboo farmers.

In pattern three, the price was determined from behind to front. Product pricing of bamboo veneer factories are restricted by the base price of peer sector (Base price is the result of the competition among different cyclostyles of products in building market instead of monopoly pricing by nation or peer sector), so it is often fluctuant and inclined to approach the price level of average social profit). Hence, the purchasing price of semi-manufactured article can only be determined after management cost, sale cost, tax and expected profit of upper procedures are eliminated, as:

$$Ps = Pc - Cb - Bp - Tt \qquad (10)$$

Where Ps stands for purchasing price of semi-products; Pc stands for market selling price of completed products; Cb stands for cost in management and business of enterprises; Bp stands for expected profits of enterprises; Tt stands for total tax of enterprises.

For processing/purchasing units, Ps is the same as Pc, and it is of crucial importance to bamboo price and processing charges offered to bamboo farmers. So the following can be established:

$$Pb + Pp = Ps - C'b - B'p - T't - T'tb \qquad (11)$$

Where Pb stands for purchasing price of bamboo timbers; Pp stands for processing charges; C'b stands for cost in management and business of processing/purchasing units; B'p stands for expected profits of processing/purchasing units; T't stands for total tax of enterprises, such as value-added tax, income tax and so on; T'tb stands for fund, tax and charge of bamboo paid by processing/purchasing units, in which fund stands for cultivation fund, tax stands for agricultural special tax and charge stands for forestry construction and protection charge.

C'b involves transportation charges in selling, purchasing, management and so on of processing/purchasing units. Although formula (11) indicates that Pb and Pp is determined by leading bamboo enterprises and processing/purchasing units, it doesn't imply that they can randomly reduce Pb and Pp.

The link and operation of farm households ---- processing/purchasing units ---- leading enterprises chain is maintained by economic benefits. That all sides share the benefits from cooperation is the precondition of the maintenance of their cooperation. Though leading enterprises can determine the benefits of each side, whether or not such distribution can be enforced is restricted by the profit space to share with processing/purchasing units and bamboo farmers and by whether such a distribution can ensure the participants to receive more than non-participants as well. In terms of institutional assignment, this kind of cooperation is Paletto improvement. For bamboo farmers, the existence of processing/purchasing units bring them processing enterprises from faraway, which saves large amount of dealing costs, reduces dealing risks, widens employment channels and enhances income for them. For the part of enterprises, they can save the unavoidable expenses in direct purchasing and preliminary processing of raw materials. Estimated by a bamboo veneer factory in Yong'an, more than 1 RMB of costs can be reduced from per shade of bamboo veneer, so a bamboo veneer factory with the annual productivity of 10,000m^3 can cut 330,000 RMB of manufacturing costs only by cooperation. For processing/purchasing units, they get according returns through linking farmers and enterprises. Thus, all sides increase their welfare with none damaged. However, when leading enterprises are faced with an excessively small profit space for certain reasons, such a pattern can no longer be maintained. The main reason lies in that competition are from external parts, such as raw material price, finished product price, labor price, tax base, etc, which are inherent and irreformable in an industrial chain itself.

5.4 Pattern four: establishment of bases and professional purchasing/processing enterprises of raw bamboo materials

In this pattern, leading bamboo enterprises set up professional purchasing/processing enterprises of raw bamboo materials by all means, then they set up raw material bases with relatively steady communication through them. Qualifications of pattern four are:

a. Provision of raw materials is relatively scarce;

b. Leading enterprises require a uniform provision and freshness of raw bamboo materials;

and the other qualifications are the same as those for pattern two or three.

As bamboo forest resources are limited, the development of bamboo-processing sector is inclined to lead to scarcity in provision. In light of the requirements of industrial operation and uniform manufacturing, enterprises also wish bamboo farmers to fell bamboo timbers appropriately, so as to reduce variable funds and ensure material qualities. Although no such patterns exist in Yong'an currently, some leading bamboo enterprises have invested in bases of raw bamboo materials and they provide guidance in production techniques as well as contract purchasing contract. Hence, bamboo farmers are guaranteed to achieve more benefits from the development of bamboo-processing sector. The attention then should be paid to preventing the monopoly of leading bamboo enterprises in bamboo processing.

6 CONCLUSION

Yong'an has experienced significant development in bamboo sector since they learned from Zhejiang Province, with the increase of 21.4% in bamboo forest area, 8,300 ha more than that of 1990. Also, planted bamboo has increased from 1,545 sculms to 2,250, and the breast diameters from 6.8cm to 8.2cm. Basic scale of bamboo processing and usage is formed, with the steady increasing processing values of 180,000,000 RMB. Furthermore, bamboo management system is complete day by day and bamboo income has become the main channel for farmers' revenue, which shows the intrinsic rationality and university of Zhejiang's development model of bamboo sector by means of the preconditions of market economy system, the key of bamboo-processing sector and the public products needed provided by governments. Therefore, such a model can be successfully spread and applied in areas suitable for bamboo growth but lack of industry, so as to enrich the farmers in bamboo areas, benefit finances, develop economy and finally stimulate social evolution.

References

Chen Jianyan, Hu Zhengjian, Zheng Jianjia. Achievements, Problems and Strategies of Anji's Scientific Input in Bamboo Sector. Forest Sci-Tech Development. 1997:2

Lai Qingyuan. Balanced Development of Bamboo and Timebr with Bamoo as Entry Point. Yongan Bamboo. 2000:2

Li Qin, Wang Kuihong, Hua Xiqi. Development Status in quo and Urgent Problems Faced by Bamboo Sector in Zhejiang Province. Zhejiang Forestry Technology 2001; 3.

Qi Lele, Sun Guliren. 1996. Anji Bamboo: from unmarketable to high market. Zhejiang Daily. November 1, 1996.

Wu Jilin. Present Situation and Development Thoughts of Yong'an Bamboo Industry. Yong'an Bamboo. 2001:1

Wu Zhiyong, Wang Yunzh. Present Situation and Future Development of Anji Bamboo Sector. Bamboo Research. 2000:4

Zhu Yongfa, Sheng Wenming, Hu Zhengjian. Current Situation and Development Strategy of Anji Bamboo Industry. Zhejiang Forestry College Journal. 1996:1

Data provided by Yong'an City Forestry Bureau.

Silviculteral Technique of *Dendrocalamus farinosus* on Returning Steep Slope Cropland to Forestland

Dong Wenyuan[1] **Gao Yanping**[1] **Liu jun**[2]

1. Bamboo and Rattan Research Institute, Southwest Forestry College, Kunming 650224
2. Forestry inventory and designing institute of Yunnan, Kunming 650200

Abstract: Silviculteral technique of *Dendrocalamus farinosus* on returning steep slope cropland to forestland and measures of restoring the ecosystem have been explored and summarized from the aspects of site selection, soil preparation, planting density and season, quality of bamboo seedlings, planting technique, tending of young growth and bamboo growth. The study will provide the basis of theory and practice for returning cropland to bamboo forest.

Key words: *Dendrocalamus farinosus*; returning cropland to forestland; silvicultural technique

Dendrocalamus farinosus is a kind of medium-sized sympodial bamboo species and excellent for both shoot and timber uses. Now it has developed into one of the main silvicultural species in the project of returning cropland to forestland of Northeast Yunnan. Up to now, there exists deficiency in systematic research in the silvicultural technique of *D. farinosus*. Primary explorations were made in this article from the aspects of site selection, soil preparation, density and spacing of planting spots, bamboo seeding cultivation, planting season, planting technique, tending of young growth and bamboo growth. In order to provide a theory basis for the practice of returning cropland to *D. farinosus* forest in according to the primary outcome of research carried out in Yuele Town, Daguan County, Zhaotong, Yunnan since 1999.

1. SITE SELECTION

D. farinosus is widespread in north Zhaotong at an altitude between 300m and 1400m,which enjoys warm and humid climate and belongs to the most north species of *Dendrocalamus* in natural distribution and the most cold-persistent species within. On the whole, it requires a yearly average temperature above or equal to 14℃, the extreme cold temperature not less than -7℃ and a yearly average rainfall between 800mm and 1400mm, Red, yellow or purplish soil at riverside, vale, hillside and the four sides, equally, house side, village side, roadside and water side are appropriate for the growth of *D. farinosus* and especially suitable sites have deep-layered, fertile and damp soil. Plots with soil layer depth above or equal to 50 cm in the returning cropland can be chosen. And those land with thin soil layer and high quantity of rock and located at mountain ridge should be excluded.

2. SOIL PREPARATION

The planting site is on the slopes (＞25°) so site preparation is not necessary. To reduce soil erosion, spot soil preparation should be adopted and the preparation is done as planting. The dimension is 0.6×0.6×0.4m. When digging a hole, the depth is required to be above 40 cm and cultivated soil and subsoil should be put on different places, picking up rocks.

3. PLANTING DENSITY AND SPACING OF PLANTING SPOTS

As *D. farinosus* has a large canopy and in order to make the newly-planted bamboo forest close canopy and gain the benefits of ecology and economy, a rational closely spaced planting is promoted.In the general site situation, the distance between hills and rows is 3×4m, and 4×4m or 4×5m can be adopted on the deep-layered, fertile and humid soil. The equilateral triangle planting is acceptable to make full use of the soil and water conservation function in a new bamboo forest.

4. BAMBOO SEEDLING CULTIVATION

The main method of seedling cultivation for *D. farinosus* is burying cover culm between February and April; After a period of time between 15 days to 20 days bud bursting and leaf spreading took place; then after one month or so roots appeared, propagating in the later 50 to 60 days; between June and July shooting took place; up to September the seedling is 4.5m high with a base diameter between 2cm and 3cm and each cluster concludes 5 to 9 ramets. A qualified one-year-old seedling can be outplanting.

5. PLANTING SEASON

According to the climate in the north of Zhaotong city and the bioecological characteristics of *D. farinosus*, the planting time can be between February and March or before rain season.

6. PLANTING TECHNIQUE

Remain the 60cm long culm of one-year-old bamboo seedling and cut off the branches and leaves. After seedling harvesting and puddling the roots, wrap up the roots with straw and plastic sheet. And in order to avoid water loss of the seedling during transportation as much as possible, planting is performed the moment they are harvested. Cloudy days, rainy days or cloudy days after rainfall are the best weather for planting. When planting, the surface soil is put first to the bottom of the hole. Then 10kg barnyard manure or 1kg phosphate fertilizer per hole are mixed with the surface soil and put into the hole with a thickness between 10cm and 15cm. When the seedling is put in the hole, the stump should be put in the center of the hole and impinge on with soil by putting and pressing soil layer by layer. The last node's buds should be above ground. After planting, water abundantly and cover the seedling with plastic sheet to avoid the evaporation of water. By doing this, the survival rate of seedling will increase.

7. TENDING OF YOUNG GROWTH

7.1 Mixing farming of green manure and bamboo

The returning cropland usually has a low fertility. In addition, there is a thinly scattered bamboo in the first to third years in a new bamboo forest, which makes much waste open space on the land where weeds grow fast. Therefore, after bamboo planted, the green manure are grown between the rows of bamboo in first year, then cut down to let it cover the ground, which can increase the soil fertility, improve the soil structure and promote the growth of bamboo.

7.2 Thinning for tending

When shoots are excessively abundant in the newly planted bamboo forest of *D. farinosus*, weak ones should be thinning and two or three strong shoots should be remained in each cluster. Four or five shoots should be remained to let them grow as mature bamboo as the shoots of two-year-old bamboo are bursting more. The shading density of three-year-old ones is above 0.6.

8. ANALYSIS OF BAMBOO GROWTH

The comparative study on the cultivation of *D. farinosus* under different site conditions was carried out in Yuele Town, Daguan County, Yunnan in March,1999. The outcome is as follows:

8.1 General condition of the experiment site

The site is located at Eight-angle Temple, Yuele Town. The altitude is between 1000m and 1100m and the slope is not less than 25° and the hillside is yellow soil.

8.2 Testing methods

The sets of one-year-old bamboo seedlings were planted separately in plot 1 and plot 2 at a expanse of $1hm^2$ in March, 1999. The dimension of preparation is 60×60×40cm, and the distance between hills and rows is 3×4m. Water was thoroughly given after planting. Sweet potato was mixed in the first year as cultivation. Every year's September after planting was the season of shoot bursting. Remain the strong shoots and cultivate them to grow mature.

Table 1. Site condition of experimental area

Experimental plot	Exposure	Soil depth (cm)	Quantity of rocks (%)	Soil humidity	Site evaluation
Plot 1	NE33°	54	5	moisten	medium
Plot 2	NE47°	37	8	dry	below average

8.3 Results of experiment

8.3.1 Comparison of DBH growth

The DBH of newly-grown bamboo was becoming bigger year by year after planting. And the average DBH in plot 1 was obviously bigger than that of plot 2. (Fig. 1)

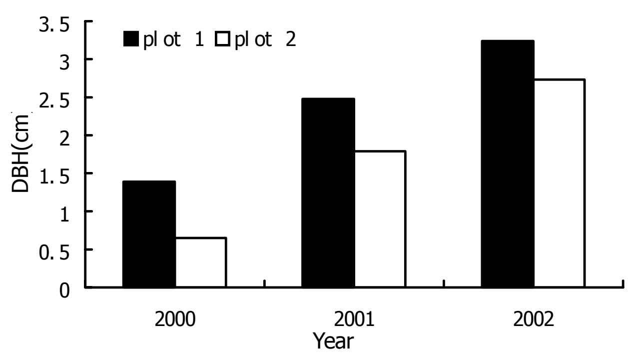


Fig.1 The comparison of DBH growth of *D.farinosus* with different experimental plots

8.3.2 Comparison of height growth

The height of each year's newly-grown bamboo was increasing. In plot one, with better site context compared to plot two, the average height of bamboos in plot one was as 1.53, 1.34, 1.25 large as that of plot two from the year of 2000 to 2002.(Fig. 2)

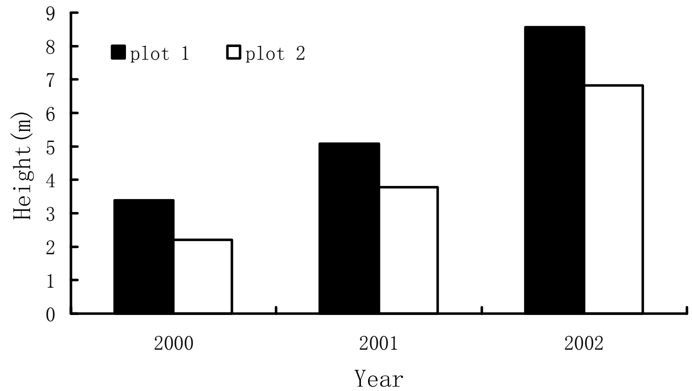


Fig. 2 The comparison of height growth of *D. farinosus* with different experimental plots

8.3.3 Changes in crown density

With the increase of the quantity of new bamboo, DBH, height and quality of branches and leaves in the newly-planted bamboo forest, the crown density was improving. In four years when new bamboo grew mature and branches spreaded out, the crown density in plot one was up to 0.8 and plot two 0.6, accomplishing complete shade.(Fig.3)

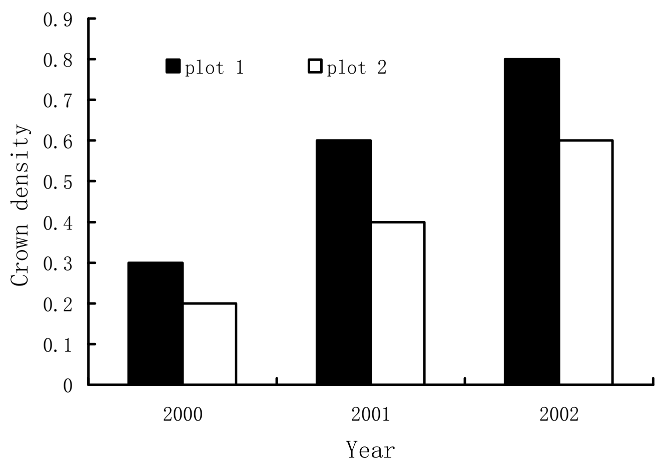


Fig. 3 The change of crown density of *D. farinosus* with different experimental plots

8.4 Conclusion

The results indicates that if site, season, bamboo seedling and technique are appropriate, *D. farinosus* can grow into a forest in three years and have wood in four years and be useful in the project of returning cropland to forestland in it's ecological, economic and social effects.

REFERENCES

Dong Wenyuan.. The status of bamboo resources in northeastern Yunnan and its sustainable development countermeasures. *Ecological economy,* 1999, 80：32-36.

Dong Wenyuan, Studies on the high-effective raising seedling technique of sympodial bamboo. Jiangsu forestry science & technology, 2001, 28(5)：30-32.

Dong Wenyuan, Cultivation technique of bamboo plantation on the slope of mountain in Yunnan province. China forestry science and technology, 2001,15(4)：60-62.

Dong Wenyuan, History opportunities for the sustainable development of China’s bamboo industry in 21st century. World forestry research,2003,16(1)：42-45.

Study on In-vitro Rapid Propagation of the Clumping Bamboo

Zhang Guangchu, Wang Yuxia, Tan Yuanjie and Li Xingwei
Guangdong Forest Research Institute, Guangzhou 510520, Guangdong, P. R. China. Phone: +86-20 87033558/87705646 ext. 2615. Fax: +86-20 87031245/87634445.

Abstract: The report covers the in-vitro culture methods of 20 species of clumping bamboo, 15 of which have obtained plantlets. The critical techniques of the cultivation of juvenile and mature bamboo in all stages are illustrated with details. On the present questions during bamboo in-vitro rapid propagation, the authors emphasize that attention should be paid to clone bamboo hereditary quality, and to the protection of bamboo genetic diversity. In order to reduce the cost of plantlet production and the risk of bamboo forests early flowering, bamboo propagation should be combined with propagation conventional techniques.

Key words: clumping bamboo, tissue culture, in-vitro rapid propagation

Bamboo, an important economic plant in the tropics and subtropical zones, is closely related with people's life. It is called "timber for the poor", " the precious present from God". Planting bamboo and developing bamboo industry has become the common interests of the people in the developing countries. Besides, it is also a good way for the people in mountainous areas to enrich themselves.

Bamboo seldom blossoms and produces fruit. Traditional way of propagation is to separate a rhizome from a maternal bamboo or to make a cutting from a branch. However, this way of propagation presents a series of problems, such as a waste of maternal plants, inconvenience in transportation, high labor intensity, low rate of propagation and so on. In order to seek new ways of propagation, scientists begin to do research in tissue culture for bamboo. In 1984, Nadgir et al reported tissue culture for three kinds of bamboo, from which *Dendrocalamus strictus(Roxb.)* obtained a few plantlets.[1] Since then, in-vitro rapid propagation of bamboo has gradually aroused attention in many countries. Guangdong Forest Research Institute has started to do research on in-vitro rapid propagation of bamboo in 1989. In the last more than ten years, in order to exploit the resources of clumping bamboo in our country and to popularize fine varieties of bamboo, we have done researches successively on tissue culture for more than 20 species and varieties of bamboo. For most of the materials, we have obtained plantlets, and some of them have been put into production in factories. As a result of all these researches, we have accumulated ripe experience. As to the application of these techniques, we also have our own idea. We here put them into word to share and discuss with the experts in the same field.

1. MATERIALS AND METHODS

1.1 Materials

The explants are respectively obtained from maternal embryo (with or without endosperm), stems from juvenile bamboo and mature bamboo. Juvenile bamboo is that whose physiological age is less than ten years (from the time when the seed germinates to the time when the bamboo is obtained). Mature bamboo is that whose physiological age is at least twenty-five years. Table 1 is a list of all 20 species and varieties of bamboo with their scientific names and the materials required in the experiment.

1.2 Sterilization of the explants

After cleaning the surface of the materials obtained, immerse them for 15~30min in mercuric chloride with a concentration of 1‰~2‰ or Javel water with a concentration of 2.5‰. Then rinse them for 3~5 times using sterile water.

1.3 Medium

Basic culture medium: Refer to MS (Murashige & Skoog 1962) Culture Media for the basic culture media.used here. Among them, macroelements, growth-regulating materials have undergone proper changes. Vitamin: Refer to B_5 (Gamborg 1986) Culture Media roelements, Iron Salt, Saccharide, Glycin and INOSITOL are all the same as in MS, pH5.8~6.2

The quantity of macroelements (KNO_3 NH_4NO_3, KH_2PO_3, $CaCL_2$, $MgSO_4$) used in every stage is either the same as MS standard quantity, or 3/4, or 1/2 of the standard quantity. In the following, they will be shortened respectively as 1MS(m), 3/4MS(m) and 1/2MS(m). MS (m) stands for the macroelements of the culture media.

The concentration of the growth substance is as follows: BA1~6mg.L^{-1}, KT0~1.75 mg.L^{-1}, NAA1~6 mg.L^{-1}, IBA1~6 mg.L^{-1}.

In every stage of cultivation, we refer to Orthogonal Chart L_9 (3^4) as to whether a certain culture medium will be chosen or not. According to the statistics on the chart, a better prescription will be chosen and the prescription needs modification depending on the growth of the bamboo.

1.4 Conditions

In every stage of cultivation, the temperature in the laboratory is to be controlled at 28~30 ^{0}C. Daily sunshining is 10 hours at the intensity about 1600Lx.

2. RESEARCH RESULTS

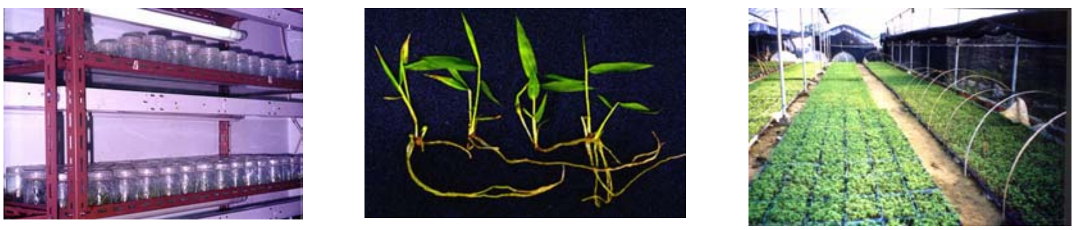
The results of the propagation of 20 materials of bamboo using tissue culture are listed in table 1 and figure 1.

Table 1 Results of propagation of clumping bamboo using tissue culture

Name	In-vitro parts	Results
Dendrocalamus latiflorus Munro	Maternal embryo Bamboo shoots Stems from juvenile bamboo	Three of the cloned plants have been chosen and put into mass reproduction in factories. Some of the seedlings have been used for forestation
Dendrocalamopsis *oldhaml*(Munro) Kenf.g	Maternal embryo Stems from juvenile bamboo	Test-tube seedlings have been transplanted to the forestlands
Dedrocalamus sinicus Chia et J.L. Sun	Maternal embryo	Quite a few of the cloned seedlings using tissue culture are growing in in the field and are under observation
Dedrocalamus Brandisii f.	Stems from juvenile bamboo	Undergoing mass reproduction in factories. Test-tube seedlings have been used for forestation
Dedrocalamus sp. (Pai Dong Keu)	Stems from juvenile bamboo	Five of the cloned plants have been hosen and put into mass reproduction

		in factories and some of the seedlings have been used for forestation
Bambusa pervariabilis McClure	Stems from juvenile bamboo	Test-tube seedlings have been transplanted to the forestlands
Dedrocalamus asper (J. A. et J. H. schult.)	Stems from mature bamboo	Undergoing expansion of propagation. Some of the test-tube seedlings have been transplanted to the nurseries.
Dendrocalamus minor var. amoenus (Q. H. Dai et C. F Huang) Hsueh et D. Z Li	Stems from mature bamboo	Undergoing expansion of propagation Some of the test-tube seedlings have been transplanted to the nurseries
Thyrsostachys oliveri Gamble	Stems from mature bamboo	Plantlets have been obtained.
Thyrsostachys siamensis (Kurz ex Munro)	Stems from mature bamboo	Clumping buds have been induced.
Bambusa vulgaris cv. Vitata Schrader ex Wendland	Stems from mature bamboo	Clumping buds have been induced.
Dendrocalamus hamiltonii Nees et Arn. ex	Stems from mature bamboo	Clumping buds have been induced.
Dendrocalamus brandisii (Munro) kurz	Stems from mature bamboo	Clumping buds have been induced.
Chimonocalamus dilicatus Hsueh et Yi	Maternal embryo	Plantlets have been obtained.
Fargesia yuanjiangensis Hsueh et Yi	Maternal embryo	Plantlet have been obtained.
B. pervariabilis x D. latiflorus No.7	Stems from mature bamboo	Undergoing expansion of propagation. Test-tube seedlings are used for forestation.
B. pervariabilis x (D. latiflorus+B. textiles)	Stems from mature bamboo	Undergoing expansion of propagation. Some of the

		test-tube seedlings have been transplanted to nurseries.
B. textiles x *D. latiflorus* No.11	Stems from mature bamboo	Undergoing expansion of propagation. Some of the test-tube seedlings have been transplanted to nurseries.
D. latiflorus x *D. hamiltonii* No.1	Stems from juvenile bamboo	Clumping buds have been induced.
B. pervariabilis x *D. hamiltonii*	Stems from juvenile bamboo	Undergoing expansion of propagation. Some of the Test-tube seedlings have been Transplanted to nurseries.



(1) Proliferating cultivation (2) Test-tube buds rooting (3) Transplantation in the canopy

Figure 1 In-Vitro Rapid Propagation of Clumping Bamboo

From the table, we can draw this conclusion: Propagation of juvenile bamboo (including maternal embryo and stems from it) using tissue culture is easier. Propagation of juvenile bamboo of most of the materials is successful. While propagation of mature bamboo using tissue culture is relatively more difficult. Only a part of the varieties has produced plantlets. Buds from some of the materials, such as *Dendrocalamus hamiltonii* ex. and *Dendrocalamus brandisii*, die easily in Successive-Generation Cultivation. Tissue culture for these materials demands further research.

The critical techniques in tissue culture for the juvenile bamboo and mature bamboo will be summarized in detailed analyses.

2.1 Cultivation of maternal embryo

2.1.1 Sterilization of the explants

Mercuric chloride with a concentration of 0.1‰ ~0.2‰ or Javel water with a concentration of 1.67‰ ~2.5‰ is used for sterilizing the explants. They can either be used respectively or jointly. The result shows that it is better if the two medicaments are used jointly. However, embryo of the swollen seeds will be easily burned in Javel water. Therefore, Javel water can only be used before seed soaking and germination. While mercuric chloride is more moderate, so it can be used after seed soaking and germination. The steps of sterilization are as follows: (1) Select bright, lustrous and plump seeds without diseases and insect pests and shell them for later use. (2) Immerse the dry seeds for 10~15min in Javel water with a concentration of 1.67~2.5‰. (Add 4 drops of Tween). Then rinse them 3 times using sterile water. (3) Transfer the seeds to 35^0C sterile water and soak them for 30mins. Then transfer them to potassium permanganate liquor with a concentration of 20~50ppm and soak them for 6~20hs under room temperature. Rinse them twice using sterile water. (4) On a extra-clean worktable, transfer the seeds to mercuric chloride with a concentration of 0.1‰ ~0.2‰ (add 4 drops of Tween) and soak them for 15~30min. Then rinse them 5 times using sterile water. (5) Inoculation. To avoid across- infection, it is better to inoculate them one by one, each in a separate test tube. The seeds begin to bourgeon 2ds after inoculation, and germinate and 10ds afterwards, the rate of sterile maternal embryo of *Dendrocalamus latiflorus* reaches 64.3%, and that of *Dedrocalamus sinicus* reaches 90%.

2.1.2 Induction of clumping buds

The sterilized seeds germinate in the MS culture media containing BA0.2 mg.L^{-1}. Once the embryo reaches 1cm, transfer it to the MS culture media containing BA2~4 mg.L^{-1}. After 30ds' cultivation, each embryo will have 2~6 buds, a few will have more than 7 buds and one or two of them will have 18~35. Select those seedlings that have normal buds and a healthy form to carry out successive-generation cultivation, while those weak seedlings and those having too many buds should fall into disuse. Many years experiments prove that a better cloning will be achieved by those seedlings that have a middling level of buds, while those having a especially strong ability of multiplication will not necessarily achieved a good cloning result. For example, (*Dendrocalamus latiflorus*)$_{17}$, (*Dendrocalamus latiflorus*)$_{58,}$ (*Dendrocalamopsis oldhaml*)$_{5,}$ (*Dedrocalamus sinicus*)$_5$ and (*Dedrocalamus sinicus*)$_8$. All of these varieties of bamboo show a strong ability of multiplication at the early stage of the cloning, but this kind of cloning will blossom[10] easily in their test tubes. Their test-tube seedlings transferred to the nurseries have the following features: a big number of plants but short and small; the main stem is not distinct while the lateral branches are strong; a low commercial value. Having the above stated features, it is not proper to expand propagation of them. So they should be put into disuse.

2.1.3 Successive-Generation Cultivation

In order to select the proper culture media for the successive-generation cultivation of the clumping buds, we have respectively combined 1MS(m), 3/4MS(m), and 1/2MS(m) with CK of different concentration (BA0.5~6 mg.L^{-1}, KT0~0.5 mg.L^{-1}). The research shows that the macroelements only have a small influence on the growth of the test-tube seedlings of the juvenile bamboo, while the CK has a distinct influence on their growth. In the culture media containing CK of BA0.5~1mg•L^{-1}, the seedlings grow vigorously, while the multiplication of buds are relatively slow. In the culture media containing CK of BA3~6mg•L^{-1}, the multiplication of buds accelerates conspicuously, but the growth of the seedlings becomes worse and worse. Sometimes even the flower buds will differentiate. The time of flowering moves forward with the increase of the concentration of CK. A better combination is as follows: 3/4MS(m)+ BA2mg•L^{-1}+ KT0.5mg•L^{-1}+coconut milk 100ml•L^{-1}. Using this prescription, the authors have successively reproduced *Dendrocalamus latiflorus*, *Dendrocalamopsis oldhaml*, *Dedrocalamus sinicus* Chia and *Chimonocalamus dilicatus*. However, if continuous successive-generation cultivation is carried out, the multiplying ability of cloning and growing status of the seedlings has a gradual tendency of declining in kinds of media. To slow down this tendency of declining, the concentration of CK in the culture media should increase or reduce from time to time. In this way, not only a certain speed of multiplication can be maintained and the seedlings have a better growth, but also the multiplying ability of cloning will not be slowed down quickly.

2.1.4 Rooting of the test-tube seedlings

The macroelements in the culture media used in the rooting stage is 1/2MS(m), and the growth substances used are NAA or IBA with various concentration. They can either be used separately or jointly. The results prove that a combination of these two is better. For example, the root-taking rate of the cloning of (*Dendrocalamus latiflorus*)$_{17}$ in the culture media containing IBA3mg•L^{-1} is 70%, and the rate in the culture media containing NAA3mg•L^{-1} is 86.7%, and the rate reaches 93.3% in the culture media containing NAA1.5 mg•L^{-1}+ IBA1.5mg•L^{-1}. However, rooting of different cloning from different varieties of bamboo or even the same demands hormone of different concentration. For instance, the rooting rate of (*Dedrocalamus sinicus*)$_{10}$ reaches 100% in the culture media containing NAA4 mg•L^{-1}+ IBA4mg•L^{-1}, but the rate is only 93% in the culture media containing NAA3 mg•L^{-1}+ IBA3mg•L^{-1}. The rate of other cloning is as follows: 100% for (*Dedrocalamus sinicus*)$_8$, 81% for (*Dedrocalamus sinicus*)$_6$, and 25% for (*Dedrocalamus sinicus*)$_2$. Therefore, there is no universal prescription of the culture media used in the rooting of the seedlings. In mass breeding of seedlings in factories, experiments are to be carried out beforehand according to specific objects to decide the concentration and proportion of NAA and IBA so as to achieve a better rooting efficiency.

2.1.5 Transplantation of the test-tube seedlings

The survival ratio of the test-tube seedlings transplanting reaches to 90%. The technological essentials are as follows:

(1) The suitable temperature at transplanting is between $20^0C \sim 30^0C$. In Guangdong province, it is suitable to transplante the seedlings from March to June, and from September to December. From July to August, the survival ratio is lower because the temperature and the humidity is higher, and the seedlings are more easily effected. While during January and February, it is not proper to transplant the seedlings because the temperature is lower and it is more difficult for the seedlings to regrow.

(2) Use sand as the basic soil, or 3/4-sand+1/4 peat soils. The soil is to be sterilized before the transplantation, using 2‰ ~5‰ liquor of potassium permanganate.

(3) Before transplantation, open the lids and acclimatize the seedlings in natural light for 4~7 days. When transplantation, the culture media are to be washed clean first. Use liquor of Carbendazim with a concentration of 2.5‰ to drench the seedlings and solidify their roots so as to make their roots and the basic soil attached closely and wash away the remaining manganic ions in the soil. During the first week after transplantation, maintain the relative humidity in the microenvironment on the verge of saturation so the test-tube seedlings regrow relatively easily in the new environment. Uncover the lids every morning after one week to let the seedlings breathe freely, and gradually prolong the time each day until the seedlings adapt fully to the natural environment.

(4) Clear away the sick plantlets in time. Periodically spray Carbendazim with a concentration of 2.5‰ to avoid occurrence of diseases and pests.

(5) Transplant the seedlings cluster by cluster. Avoid transplanting them individually.

About one week after transplantation, the test-tube seedlings will regrow. In about 20 to 30ds new leaves will come out and in about 45ds, they can be transplanted to the nurseries.

2.2 Cultivation of stems from juvenile bamboo

2.2.1 Selection of the stems

Select those half-lignified branches. The way to recognize them is as follows: The branches stop growing, and there are three to seven leaves on it, and the sheaths on the base are withered and yellow or just start to flake off and there are no lateral buds or they just come out. If the branches seem to be soft and pliable and flexible, select them. Clumping buds will be easily induced from this kind of branches as explants. The tissue of the branches that have not stopped growing is too delicate and will be easily poisoned while being sterilized. The tissue of fully lignified branches is relatively hard. It is not easy to cleanse the bacteria and clumping buds come out very slowly. So these two kinds of branches are not ideal experimental materials. The branches being chosen, select those branches in the middle or in the front that nodes are wrapped tightly by sheaths, while those that nodes have exposed buds and dissilient sheaths and those insect-wounded branches should be cast into disuse.

2.2.2 Sterilization of the stems

The first barrier to overcome in cultivation of bamboo stems is to obtain germfree experimental materials. The bamboo internodes' being hollow brings about much difficulty in the sterilization of the stems. In the process of sterilization, dirty water and liquid medicine will enter the pith cavity. This will result in an incomplete sterilization or the stems will be poisoned. Therefore, selection of stems, control of the time of sterilization and the dosage of the sterilizing liquor must all take into a comprehensive consideration. A relatively ideal result will be achieved by repeated experiments. The steps of sterilization are as follows: clean the surface of the stems→ pretreatment for one day in a refrigerator→ scrub the stems twice using ethylalcohol with the concentration of 75‰→soak the stems for 15min in Javel water with a concentration of 2.5‰ (add four drops of Tween), then rinse them three times using sterilized water→ immerse the stems in mercuric chloride with a concentration of 2‰ (add 4 drops of Tween, the same below) and soak them for 15~30min. Then rinse them 5 times using sterile water→ immerse the stems in mercuric chloride with a concentration of 2‰ and soak them for 5min, then rinse them 5 times using sterilized water. Following the above steps of sterilization, a 60% rate of living sterilized explants will be obtained, sometimes the rate being 100%. Summarizing the successful experience, the authors think that in the process of sterilization, the following demands one's attention: (1) The branches chosen should not be too thick. The bigger they are, the more difficult to sterilize. (2) Avoid the entrance of the dirty water into the bamboo pith cavity and avoid direct buds away from the sterilizing liquid. Therefore, it is relatively easy to obtain sterilized explants from the stems with small pith cavity wrapped tightly by sheaths. (3) A suitable quantity of branches should be sterilized so as to fully immerse the surface in the liquid. (4) Using two medicaments alternately to sterilize or using a low dosage of one medicament to sterilize repeatedly is more reliable and safer than using a higher dosage. The germ-free explants can usually be obtained if attention is paid to the above.

2.2.3 **Induction of clumping buds**

Cut the two ends of the stems after sterilization. Leave the middle node with 1-2cm internode above and below. The macroelements in the culture media are usually 3/4MS(m), and the CK is BA3~6mg•L^{-1}, with or without KT with a concentration lower than 0.5mg•L^{-1}. 2~3 days after the stems are planted in the clumping buds culture media, they start to germinate and 45~60 days clumping buds will come out.

2.2.4 Successive-generation cultivation and propagation

After the clumping buds are induced, to avoid declining growth caused by too fast multiplication, the concentration of the CK in the culture media should be reduced. The concentration of BA is usually reduced to 3mg•L^{-1} below. In the culture media containing 3/4MS(m)+ BA2mg•L^{-1}+ KT0.5mg•L^{-1}, the authors have successively reproduced *Dendrocalamus latiflorus*, *Dedrocalamus sp*. and *Dedrocalamus sp*.. Based on these culture media, the dosage of BA is either increased or reduced according to the growing status of the seedlings so as to maintain a high speed of multiplication and a better growing status.

2.2.5 Rooting

The culture media used in the rooting stage is usually1/2MS(m) plus a proper quantity of the hormone NAA, IBA, and the quantity of saccharide should be reduced. The two kinds of hormone are used jointly with the concentration of 1.0~4.0 mg•L^{-1}. When the new buds reach 0.2~1cm, transfer them into the rooting media. Its rooting rate can reach 90% or more. However as the number of successive-generation cultivation increases, the rooting rate will decrease.

2.2.6 Transplantation of the test-tube seedlings

Transplantation can be carried out 20~30 days after rooting cultivation when the roots come out. The best time for transplantation is the last ten days of March to the first ten days of June. It is relatively difficult for the seedlings to survive if the temperature is above 30^0C or below 10^0C while transplantation is carried out. Before transplantation, the soil is to be sterilized. A week after transplantation, cover the seedlings with a cloak of membrane to maintain the original humid. A week after that, uncover the cloak every morning to let the seedlings breathe freely and gradually prolong the time until the seedlings adapt fully to the natural environment. Clear away the sick plantlets in time and periodically spray Carbendazim to avoid occurrence of diseases and pests. (For detailed handling, refer to the transplantation of maternal embryo). If the above measures are followed, the average survival ratio of the seedlings can reach 70%, some of the seedlings can reach above 90%.

2.3 Cultivation of stems from mature bamboo

2.3.1 Selection and sterilization of the stems

For details about the selection and sterilization of the explants, refer to the cultivation of stems from juvenile bamboo.

2.3.2 Induction of clumping buds

Experiments prove that reducing the dosage of macroelements in the culture media and increasing the concentration of CK is advantageous to the formation of clumping buds. Therefore, the macroelements used are usually 1/2MS(m) or 3/4MS(m), and CK is BA4~6mg•L^{-1}. To improve the growth of the buds, a proper dosage of KT0.5~1.0 mg•L^{-1} is added to the culture media.

2.3.3 Successive-Generation Cultivation and propagation

At the stage of multiplication, what is the most important in cultivation of mature bamboo is to ensure that the seedlings have a good way of growing. Continuous multiplication is possible only when the seedlings have a good growth. This is the key to the successful cultivation of mature bamboo. The measures to improve the growth of the test-tube seedlings are as follows: (1) Adjust the concentration of BA, KT and their proportion. Experiments prove that the rate of growth of the seedlings in the culture media containing KT differs from that in KT-free culture media by 10~100%, usually about 20%. This shows that KT has the function of regulating the growth rate. When the concentration of both BA and KT is low, the growth and multiplication of the seedlings are slow. When the concentration of BA is high and that of KT is low, new buds grow thickly, and the seedlings is shorter. The rate of growth is low and the flower buds differentiate easily. When the concentration of KT is inclined to the high point, the seedlings grow relatively fast, internodes lengthen, leaves are narrow with a light color and fragile quality and they wither easily. Only when the concentration of BA and KT is adjusted to a proper proportion, the multiplying seedlings have a normal form and a good growth. Bamboo of different varieties and of different age requires different concentration of BA and KT. For example, in our experiments, the seedlings of *B. pervariabilis* x *D latiflorus* No.7 have a good growth in the culture media containing BA2mg•L^{-1}+ KT1.5 mg•L^{-1}. In the culture media containing BA3mg•L^{-1}+ KT1.5 mg•L^{-1}, *Dendrocalamus minor* var. amoenus can undergo continuous successive-generation multiplication while *Dedrocalamus asper* has a normal growth in the culture media containing BA2.5mg•L^{-1}+ KT1.8 mg•L^{-1}. Therefore, repeated experiments are required to ensure the proper dosage of BA and KT used for different experimental objects. (2) Reduce the dosage of macroelements and the osmotic pressure of the culture media. For instance, when the macroelements is 1/2MS(m), the growth of the test-tube seedlings is improved to some extent. (3) Add active substances. For example, add coconut milk with the concentration of 100~150ml•L^{-1} to the culture media, the seedlings grow better. The more the age of the bamboo increases, the more the dosage of active substances.

2.3.4 Rooting

Root taking of mature bamboo is relatively more difficult than that of juvenile bamboo. The average problem is that a large number of the seedlings perish while rooting. The authors think that to increase the rate of rooting, the following demands one's attention: (1) Pay close attention to the growing status of the seedlings. The seedlings take roots easily at the time when new buds start to come out. When the new buds grow to more than 1cm, rooting is relatively difficult. To make sure that the seedlings sprout synchronously, the twice-root-taking method is adopted. First, root-taking cultivate the seedlings for 20~30 days, (pre-root taking). Then transfer the seedlings to multiplying cultivation for 5~7 days. This time, the seedlings will have many new buds synchronously. (This process is termed as regulating the growing status of the seedlings). After that, transfer immediately the seedlings to rooting cultivation for 20~30 days. The root-taking rate will be greatly increased if the twice-root-taking method is adopted. For example, in the same culture media, the pre-root-taking rate of *Dendrocalamus minor* var. amoenus is 4.3%, while the twice-root-taking rate reaches 58.7%. (2) If a low dosage of CK and active substances is added to the culture media, the death rate of the seedlings at root-taking stage will be reduced. For example, KT0.5 mg•L^{-1} and coconut milk 50ml•L^{-1} is added to the culture media when *Dendrocalamus minor var. amoenus* took roots, and a better result was obtained. (3) Select a better prescription of the culture media. For example, when NAA2 mg•L^{-1} and IBA2 mg•L^{-1} are combined, the root-taking rate of *B. pervariabilis* x *D latiflorus* No.7 reaches 78.2%~90%. Bamboo of different varieties and of different age requires different prescription, and experimentalists should try and adjust the prescription carefully according to specific objects.

2.3.5 Transplantation of the test-tube seedlings

The information of the transplantation of the seedlings of mature bamboo, refer to the transplantation of maternal embryo and juvenile bamboo. The cultivation of mature bamboo is very difficult and the rate of multiplication is low, so the seedlings are more precious. Therefore, survival will be guaranteed if the time of adaptation is prolonged so as to let the seedlings have a higher level of lignification and have a better ability to adapt to the external environment.

2.4 Frequently encountered questions in bamboo cultivation and their solutions.

2.4.1 The tissue changes into brown.

During the process of cultivation, bamboo will secrete one certain kind of oxide of polyphenols. This substance will cause the incision to become brown. Normally, the seedling will regrow if successive-generation transfer is carried out timely. Cut off the brown parts when the seedlings are transferred each time. However, if the transfer is not carried out timely, the tissue will become seriously brown, and the seedlings will be harmed and even perish. What's more, the next successive-generation cultivation will be endangered and the seedlings will become weaker and weaker. This will render the cultivation a failure. To keep the tissues from becoming seriously brown, the authors have tried adding vitamin C with a concentration of 30~50 mg•L^{-1} into the culture media. The culture media are renewed 3 to 4 times, once 7~10 days. In this way, the growth of the seedlings will be improved.

2.4.2 The growth of the test-tube seedlings declines

The seedlings grow vigorously and the rate of multiplication is high when they are just transferred into the test tubes. However, as the number of successive-generation cultivation increases, their growth has a declining tendency. For example, when *B. pervariabilis* x *D latiflorus* No.7 was just transferred into the test tube, its rate of buds multiplication is 300%. It slowed down to 229% half a year later. The rate was 171% after a year and that after one and half a years is only 150%. The length of the seedling was 10cm when it was just transferred into the test tube and it was only 2cm one and a half years later. The authors have tried the following method to slow down the declining tendency. Transfer the seedlings to rooting cultivation. After the seedlings root and grow high, the leaves being green, and the seedlings have stored enough nourishment, then transfer them to multiplying cultivation. The partly recovered seedlings that have taken roots obviously have a better growing status than those that have not rooted and their multiplying rate is increased accordingly. However, after 6~8 successive-generation cultivation, the growing status of the seedlings again declines gradually. Therefore, it is better to regularly transfer new branches into the test-tube. By the time when new cloning is multiplying rapidly, the old cloning that has multiplied for a long time should be cast into disuse.

2.4.3 The test-tube seedlings flower

Under natural environment, the cycle of bamboo flowering is very long, from a few decades to more than a century. Therefore, it is rare to see bamboo flowering. But it is no rare case to see bamboo flowering in test tubes. There are several reasons why bamboo flowers. (1) The genotype of the plants. Cloning buds of some of the varieties of bamboo differentiate the flower buds in less than half a year after their seeds are transferred into the test tube. The cloning that flowers easily is characterized by a strong bud-reproducing ability. In the forestland, they show the following features: they are numerous and small in form. Cloning of this kind of bamboo is not a good one and they should be cast into disuse as soon as possible. (2) The use of CK. It is discovered that BA will enhance the differentiation of the flower buds. Some good cloning will flower sporadically if exposed to BA for a long time. The higher concentration of BA is, the more easily it flowers. When this happens, the flowered seedlings should be cut off and the rest are left in the test tube to continue propagation. If the buds still differentiate, then the concentration of BA in the culture media should be reduced. Addition of KT, NAA and coconut milk into the culture media can improve the nourishment of the test-tube seedlings and decrease the occurrence of flowering.

3. DISCUSSION

The tissue-culture techniques of bamboo make it possible to grow seedlings in factories. In Guangdong the first factory that promotes tissue culture of bamboo produced about one million clumps of bamboo seedlings. The rapid mass reproduction of bamboo in factories draws people's attention to the quality of the products (seedlings of bamboo). It is known to all that bamboo is a perennial plant. Once it grows into a forest, it often will not be renewed for a few decades or even a century. Bamboo forests integrate economic, ecological, and social effects into one union. The quality of bamboo seedlings has further influence. Forestation using good cloning can bring treasure and a good environment to the society, while bad cloning might render forestation a failure, and cause a great waste of social resources. Therefore, in in-vitro rapid propagation of bamboo, the following demands attention:

3.1 Explants must come from those maternal plants that have a good generic quality.

This is to ensure that the cloned seedlings have a better economic property and growing property. This accords with the basic interest of forestation. It is not difficult to achieve this goal to the tissue culture of mature bamboo, because most of the bamboo forests in existence have undergone long-term natural selection and artificial selection, so they have a relatively better generic quality. What's more, fine varieties and fine cloning are not rare and they are worthy of our exploration and study. However, at present, the tissue culture of mature bamboo is difficult and the cultivation of maternal embryo is easier. If seeds are available, many people prefer to use seeds as explants to carry out tissue culture. It should be indicated that the generic quality of seeds is not clear and the seedlings sprouted differentiate greatly. According to Li Weixing's observation, when the seedlings of *Phyllostachys pubescens* are one year old, the highest growing rate is 6 times of the lowest growing rate and 1.56 times of the average rate. The seedlings whose growing rate is one Standard Deviation above the average rate accounts for 20% of all the seedlings and those whose growing rate is two Standard Deviations above the average rate only account for 1%. The growing rate of one third of the seedlings is lower than the average level. The observation of *Dendrocalamus latiflorus* has produced similar results. These facts show that tissue-cultivation of seeds has the risk that buds having a bad generic quality multiply numerously. The seedlings cultivated at the earlier stage cannot be used to expand reproduction. They should undergo field observation for a period of time. Then select the good cloning to expand reproduction while the bad cloning should be cast into disuse. This point is very important and should not neglect. A safer method is: sow the seeds, and observe them for 1~2 years, then select the seedlings that grow best as explants to be used in the cultivation of juvenile bamboo. This can avoid the mass multiplication of the seedlings that have a bad generic quality.

3.2 Introduce more varieties and cloning into test tubes and put them into production synchronously.

Mass multiplication of a single cloning is not advantageous to the protection of the generic diversity and will weaken the forests' ability to resist natural disasters. Therefore, every varieties has to have several cloned seedlings to be introduced into test tubes and at the same time, the mass of people should be encouraged to use various varieties and cloning in forestation. At present, some tissue-culture factories take a shortcut. They blindly mass-reproduce one certain variety and one certain cloning. In the province of Guangdong and Hainan, there appeared 5~6 factories that produce the same cloning at the same time. This kind of disorderly commerce-only behavior causes much anxiety. If it is indulged, what the new techniques bring to the society might not be benefits but disaster.

3.3 Bamboo in-vitro propagation should be combined with the conventional propagation techniques.

The reasons are: (1) The cost of bamboo in-vitro propagation is relatively high. If the propagated seedlings are divided after they are transplanted to the nurseries, one division will increase the number of seedlings to 2~3 times that of the original. Several divisions will increase the number to a few tens times that of the original. What's more, the risk is small and the survival rate is high. This will reduce the cost of cultivation effectively. (2) All bamboo in-vitro rapid propagation methods are new. Some problems remain to be work out. For example, under the influence of synthetical CK, BA, the test-tube seedlings flower easily. Then will forests made of in-vitro propagated seedlings encounter premature senility (bamboo flowering)? There is still no experimental evidence. To be on the safer side, we advocate that in-vitro propagation techniques be used to enlarge the number of seedlings. When a certain number of seedlings are obtained, conventional seedling-dividing techniques is to be used to reproduce seedlings from the former ones. Reduce the number of propagation in the laboratory so as to avoid potential problems. We do not advocate that mass reproduction of seedlings depend on in-vitro techniques wholly.

To conclude, we sum up bamboo in-vitro rapid propagation techniques by the follow flow diagram.

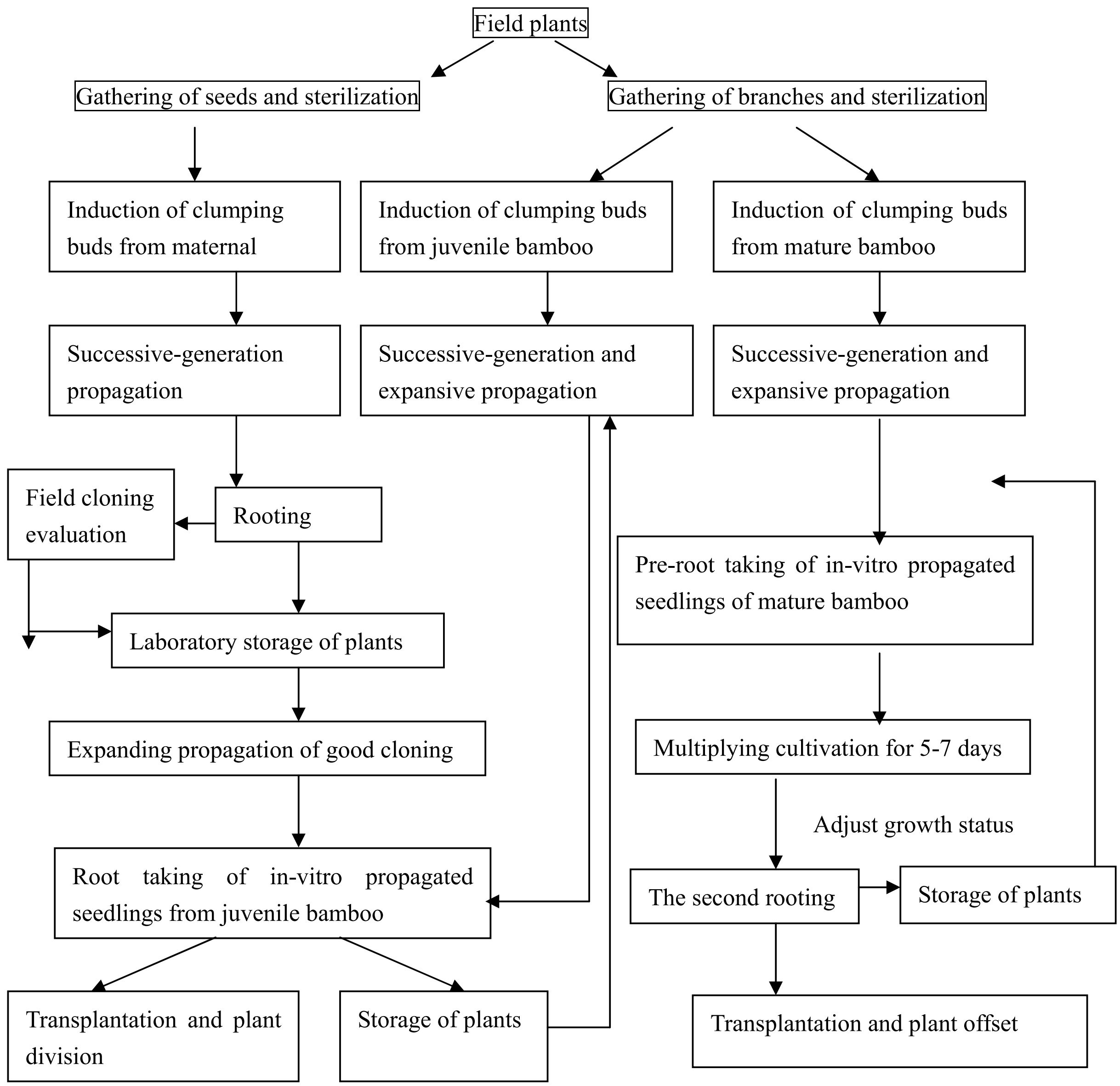


Figure 2 Flow diagram for clumping bamboo in-vitro rapid propagation

The in-vitro technique appears certain discrepancy because of the different physiological age of the stems . The propagation of maternal embryo has the process of field cloning evaluation while the propagation of mature bamboo has the process of pre-root taking. However, whether it is maternal embryo, juvenile bamboo or mature bamboo, it has to undergo plant-dividing process after their in-vitro seedlings are transferred to the nurseries. Then they can be used for forestation. This point is different from the in-vitro propagation of other trees.

References

(1) adgi. A L. Phadke C. H. Gupta P K. et al. *Rapid multiplication of bamboo by tissue Culture*. Silvae Genetica 1984. 22(6)219-223

(2) K. SuNpaibulwattana and P. Prutpongse, *In vitro culture of some commercial bamboo,* IV International Bamboo Workshop, Chiangmai Thauand 27-30 November 1991, 137-138

(3) Chen Zhenghua, *Rapid multiplication of woody plants by tissue culture an its application*. Higher Education Press 1986. 1-110

(4) M. Bonga D. J Duyzan *Multiplication of trees by tissue culture*. Translated by Yan Guoning Guo DaChu Li Jintian

China Forestry Press 1988

(5) Zhang Guangchu, Chen Fushu, Wang Yuxia, *Study on the in-vitro rapid propagation by tissue culture for Dendrocalamus latiflorus.* Journal of Studies on Bamboo, 1993, 12(4), 7-15

(6) Zhang GuangChu, Wang Yuxia *Studies on the in-vitro rapid propagation by tissue culture for hybrid B. pervariabilis XD latiflorus No.7* Study on Forestry, 2003, 16(3), 245-253

(7) Zhang GuangChu, Wang Yuxia *The present and future of bamboo breeding* Journal of Studies on Bamboo,1998 17(4), 6-9

(8) Tan Yuanjie *Preliminary study on the cultivation of Denrocalamus hamiltonii.* Journal of Studies on Bamboo 1994 13(2), 16-21

(9) Wang Yuxia, Zhang Guangchu *In-vitro propagation by tissue culture of Dendrocalamus latiflorus and its growth.* Guangdong Forestry Science. 2000 (3)

(10) Zhang Guangchu, Wang Yuxia, *Preliminary study on the flowering of test-tube bamboo seedlings* Journal of Studies on Bamboo, 2001, (1) 1-4

(11) Nadgauda, RS. VA Parsharami and AF Mascarenhsa, *Precious flowering and seeding behavior in tissue-cultureed bamboo*, Nature 344, 335-336

(12) Jon H. R. Heuch, Lautoka *Bamboo flowering in the test tube-----its future and its goal.* Collected works from the International Forum on Bamboo 1992, Beijing

Why giant panda became extinct in Central China: An appraisal of mountain bamboos in Shennongjia

Zhaohua Li PhD

University of Bonn. Centre for Development Research (ZEF). Walter-Flex-Str. 3, D-53113 Bonn. Germany. E-mail: zli9@hotmail.com
Current address: Hubei University. Institute of Regional Planning. Wuhan 430062. P. R. China. E-mail: zli9@hotmail.com

Manfred Denich PhD

University of Bonn. Centre for Development Research (ZEF). Walter-Flex-Str. 3, D-53113 Bonn. Germany. E-mail: m.denich@uni-bonn.de

Thomas Borsch PhD

University of Bonn. Institute of Botany. Meckenheimer Allee 170. D-53115 Bonn. Germany. E-mail: borsch@uni-bonn.de

SUMMARY

The giant panda was to be found on Mount Shennongjia in Central China for thousands of years but vanished in the late 19th century. The possibility for reintroducing the giant panda in Shennongjia is discussed in terms of food availability, carrying capacity, and predicted bamboo flowering. Based on the comparison of the bamboo species recorded in Shennongjia with what is known to be the panda's diet, three species (*F. spathacea, F. murielae*, and *Y. confusa*) are considered as the preferred forage bamboos. Based on aerial photos, these three species currently cover 12 %, 8 %, and 3 % of the land area of Shennongjia, respectively. On a seasonal basis, *F. spathacea* may provide the panda with fresh shoots from early April to June. When shoots of *F. spathacea* become fibrous, the panda can move to upper mountains to feed on new shoots from *F. murielae*, which produces suitable shoots from June to July. The carrying capacity is estimated based on the distribution and area coverage of the preferred forage bamboos (23 % of the land area in Shennongjia) and the panda density in bamboo-covered habitats (3.3-3.8 km^2 $panda^{-1}$). Estimations show that the preferred forage bamboos in Shennongjia could feed 194-223 giant pandas. However, simultaneous flowering of the forage bamboos may lead to a reduction in food supply. The flowering habits of bamboos in Shennongjia imply that in 1879-1888, three preferred food species, i.e., *F. spathacea, F. murielae,* and *Y. confusa*, simultaneously flowered and died back, which resulted in a shortage of food. In the past, such shortages usually forced the panda to migrate to a new habitat where forage bamboos were available. But in the late 19th century, Shennongjia had become separated from other panda habitats by densely populated agricultural zones. Such a habitat isolation and simultaneous flowering of the different forage bamboo species might have been the reason for the extinction of the giant panda in Shennongjia. Given the possibility of simultaneous flowering of the different forage bamboo species, reintroducing the giant panda to this isolated habitat is not without risks.

1. INTRODUCTION

The giant panda (*Ailurropoda melanoleuca*) is a highly specialized carnivore whose diet consists almost entirely of various species of bamboo (Schaller et al. 1985; Fong and Li 2001). Fossil evidence has demonstrated that the giant panda was once widespread in southern and eastern China and in neighboring Myanmar and North Vietnam (Taylor et al. 1991; O'Brien et al. 1994; Reid and Gong 1998; Loucks et al. 2001; Liu et al. 2001). By 1800 the giant panda was likely occurred only in two isolated mountain regions (Figure 1): on the east slope of the Tibetan plateau in central Sichuan and southern Gansu, stretching east to the Qinling Mountains of south-central Shaanxi; and in the hilly country in southern Shaanxi, eastern Sichuan, western Hubei, and north western Hunan provinces, with Shennongjia as the distribution canter (Fong and Li 2001). However, by 1900, pandas were apparently extinct over the eastern region including Shennongjia (Schaller et al. 1985; Reid and Gong 1998).

Bamboo availability has long been considered as a key factor to affect the survival of the giant panda (O'Brien and Knight 1987; Taylor et al. 1991; Fong and Li 2001). In the mid-1970s, three *Fargesia* species flowered and died within a few years in the Min Mountains. Consequently, a total of 138 giant pandas were found dead, mainly due to starvation (Schaller et al. 1985; Taylor et al. 1991). In the early 1980s, *Bashania fangiana*, the preferred sub-alpine bamboo in the Qionglai Mountains, synchronously flowered (Reid et al. 1989). Another 141 pandas were found dead (Fong and Li 2001). In fact, wild pandas rapidly declined from about 2,000 animals in the 1960s to less than 1,200 in the 1990s (Li and Denich 2001). Considering the serious problems of bamboo flowering and environment degradation in the panda habitats in Sichuan, the Chinese government proposed to remove some of the starving pandas to Shennongjia in Central China, because there is a plentiful bamboo supply and less human impact (Cui 1996). This proposal has not put into practice, due to many reasons. One of the reasons is lack of knowledge/information why pandas became extinct from the Shennongjia, despite the presence of bamboo in plenty.

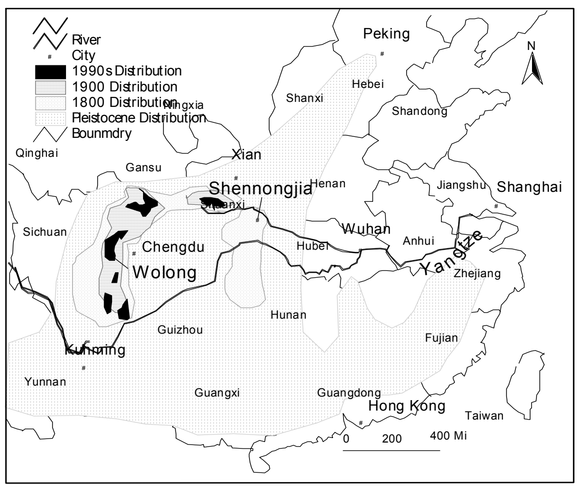


Figure 1 Distribution of the giant panda in China during Pleistocene (50,000 years ago), 1800, 1900, and 1990s.

2. METHODS

Shennongjia (31º18'-31º52'N, 109º58'-110º58'E), located at the western terminus of the Daba mountain range in western Hubei of Central China (Figure 1), comprises 3,200 km^2 of steep rugged mountains and elevations that range from 400 to 3,100 m asl. The extreme topographic relief coupled with the elevational range provides habitats for 2,762 species of vascular plants and 75 species of mammals, and climatic conditions that extend from warm temperate through boreal (Zhu and Song 1999). From the mountain feet (Songpei, 930 m) to the summit (Observation tower, 2,930 m), the mean annual temperature decreases from 12.1 to 2.2 ºC and the annual frost-free period from 223 to 83 days, meanwhile the average annual precipitation increases from 965.5 to 2780 mm. Here bamboos thrive over the mountain ranges and feed the giant pandas for thousands of years until the late 19th century.

Bamboo species and distribution were intermittently surveyed between June 2000 and August 2001 in Shennongjia. Investigation was focused on wild bamboos, but cultivated bamboos were also sampled wherever encountered. Nomenclature was following Keng and Wang (1996). Distribution of each species was expressed in two terms: the altitudinal range and the land coverage. Land coverage was estimated on the aerial-photos by interpreting the species with field records. Flowering intervals of the bamboo species were estimated by integrating the anecdotal evidence and field observation.

Monitory of bamboo sprouting was given to five forage species listed on the panda diet following Yi (1985): *Fargesia spathacea, F. murielae, Yushania confusa, Phyllostachys heteroclada* and *Ph. nigra* var. *henonis*. A total of 14 plots were set up to observe the shoot sprouting of these species. From late March to mid-July in 2001, shoot emergence was inspected every two days. Shoots were considered sprouted when they were higher than 3 cm. Phenological observations then were conversed as a sprouting phase for each species in terms of starting day, end day and duration of the phase.

3. RESULTS

3.1 Bamboo species

The species inventory recorded 4 genera and 11 species of mountain bamboos in Shennongjia. Of these, 4 species (*Phyllostachys nigra* var. *henonis*, *Ph. heteroclada*, *Ph. nidularia* and *Ph. bambusoides*) were large bamboos with monopodial rhizomes; 3 species (*Fargesia spathacea, F. murielae* and *Yushania confusa*) were medium-sized bamboos with sympodial rhizomes; and 4 species (*Indocalamus latifolius, I. longiauritus, I. wilsoni* and *I. tessellatus*) were small bamboos with amphipodial rhizomes. According to panda diet list (Yi 1985a), *F. spathacea, F. murielae,* and *Y. confusa* are the preferred food, while *Ph. heteroclada* and *Ph. heteroclada* are acceptable food of the panda. *Fargesia spathacea* covers about 12 % of the mountain ranges. It is a lover of low altitudes, being found between 1,200 and 2,600 m on the slopes and stripped plains of the mountains. *Fargesia murielae* grows in dense clumps which cover around 8 % of the mountain ranges. It occurs from 2,400 m to the mountaintop of 3,100 m. The altitudinal range and land coverage for each species are showed in Table 1.

3.2 Bamboo flowering

Shennongjia is the sole home of *F. murielae* and all individuals in the Western countries were the offspring starting with one clone from Shennongjia (Keng and Wang 1996; Eberts 1996; Gielis et al. 1999). From 1993 to 1998, millions of *F. murielae* plants gregariously flowered and then died all over the world (Gielis et al. 1999). In Shennongjia, *F. murielae* started to gregariously flower in 1996 at low elevations, later extending to the higher mountains. Until 2000, over 95 % of the bamboo clumps of *F. murielae* flowered and died back in Shennongjia. This is the first synchronous flowering of this species since Ernest Wilson recorded and introduced it to the West in 1907. Considering *F. murielae* was in a fully vegetative stage in 1907 (Sargent 1913) and *Fargesia* bamboos usually need about 20 years for rebuilding the bamboo stands after flowering death (Taylor and Qin 1993), it is assumed that the flowering interval of *F. murielae* may be as long as 110 years (1886-1996). *Y. confusa* flowered in around 1888 (sample *Henry 6832* in Kew). After that it flowered again in 1976-79, which indicates that the flowering interval of this bamboo is about 88 years. Latest flowering of *F. spathacea* occurred in 1984-88 and the flowering prior to this time was around 1949. Therefore, the flowering interval of *F. spathacea* is of 35 years. The flowering intervals rather than these three species were just the anecdotal records without field confirmations (Table 1).

Table 1 Summary of mountain bamboos in Shennongjia. ** Species preferred by the giant panda, * species accepted by the giant panda.

Species	Elevation range (m)	Land coverage	Flowering type	Last flowering	Flowering interval (year)
Indocalamus langiauritus	500-1,200	< 1 %	Unknown	Unknown	Unknown
Indocalamus wilsoni	1,700-2,400	1-2 %	Sporadica	1997-98	Unknown
Indocalamus latifolius	500-1,300	1-2 %	Unknown	Unknown	Unknown
Indocalamus tessellatus	500-1000	< 1 %	Unknown	Unknown	Unknown
*Phyllostachys nigra henonis**	500-1,800	1-2 %	Gregarious	1993	40-50
Phyllostachys bambusoides	500-1,300	< 1 %	Unknown	Unknown	40-50
Phyllostachys nidularia	500-1,200	< 1 %	Sporadic	Frequently	NA
*Phyllostachys heteroclada**	500-1,400	< 1 %	Gregarious	1958	50-60
*Fargesia spathacea***	1,200-2,600	12 %	Gregarious	1984-88	110
*Fargesia murielae***	2,400-3,100	8 %	Gregarious	1996-2000	35
*Yushania confusa***	1,200-2,300	3 %	Gregarious	1976-79	88

Table 2 Sprouting phases of five bamboo species in Shennongjia.

Species	Starting day	End day	Duration (days)	Shoot density (shoots m^{-2})
Phyllostachys heteroclada	11 May	7 June	27	2.4
Phyllostachys nigra var. *henonis*	9 May	17 May	19	2.7
Fargesia spathacea	29 March	26 May	63	9.9
Fargesia murielae	12 June	20 July	39	7.0
Yushania confusa	10 May	24 June	46	4.7

3.3 Bamboo sprouting

Every year, new shoots are produced from the rhizomes. In the low mountains (1,200 m), *F. spathacea* started to produce new shoots at the end of March, coinciding with the onset of the wet season. This sprouting successively run through, along the altitude, to late May in high mountains (2,600 m), with a sprouting phase of 63 days. *F. murielae* occurs in the frigid temperate zone (2,400-3,100 m). In a living clump (2,930 m), the first shoot emerged on 12 June and the final one on 20 July, with a sprouting phase of 38 days. *Y. confusa* occurs under the forests on the south slopes between 1,200-2,300 m. Its new shoots came out between 10 May and 24 June, about 2-4 weeks later than that of *F. spathacea* in the same altitude. *Phyllostachys* bamboos usually have a short sprouting phase, i.e. new shoots of *Ph. nigra* var. *henonis* sprouted in May, reaching a density of 2.7 shoots m^{-2} within 19 days, while *Ph. heteroclada* sprouted from mid-May to early June, reaching a density of 2.4 shoots m^{-2} within 27 days (Table 2).

4. DISUSSION

4.1 Food availability

In Shennongjia, three species (*F. spathacea, F. murielae*, and *Y. confusa*) are the most preferred bamboos of the panda. Pandas select certain bamboo species on a seasonal basis, and consequently undergo altitudinal migration in certain seasons. Key factors inducing these movements are availability of bamboo shoots, and severity of winter weather. For example, in Wolong Reserve, giant pandas spend most of the year feeding on leaves and stems of *Bashania fangiana* bamboo, from 2600 to 3400 m in the sub-alpine conifer forest. In May most pandas move down-slope to feed almost exclusively on emerging shoots of *Fargesia robusta*, which only grows below 2600 m under a mixed canopy forest. By late June, when shoots are fully grown and fibrous, the pandas move back upslope to feed on *Bashania* again (Campbell and Qin 1983; Schaller et al. 1985; Reid et al. 1989). Apart from during the sprouting phase, pandas feed on *F. robusta* when winter snow makes foraging more difficult in the conifer forests (Schaller et al. 1985), or soon after a die-back of the dominant *B. fangiana* (Reid and Hu 1991).

In Shennongjia, altitudinal distribution of two major food species, *F. spathacea* (1200-2600 m) and *F. murielae* (2400-3100 m), follows the same pattern of *F. robusta* (1800-2600 m) and *B. fangiana* (2600-3400 m) in Wolong. *Fargesia spathacea* starts to sprout new shoots in late March in the low elevations and the sprouting phase lasts until late May in upper mountains, providing the panda with fresh shoots from early April to June. When shoots of *F. spathacea* become fibrous, the panda can move to upper mountains to feed on newly growing shoots from *F. murielae*, which produces available shoots from late June to July. Beside these two staple food species, *Y. confusa* and *Ph. heteroclada* may provide an additional choice. So the species availability and distribution are not the factor that trigged the extinction of the giant panda in Shennongjia.

4.2 Carrying capacity

An adult giant panda consumes 12-15 kg of food per day when feeding on bamboo leaves and stems. However, when feeding on new bamboo shoots, they are capable of eating up to 38 kg per day, which is about 40 % of their average body weight (Schaller et al. 1985). On average, within the 6000 km^{-2} panda habitats in China, an area of 9.3-10.7 km^2 can support a panda. But in the bamboo-covered stands, an area of 3.3-3.8 km^2 is sufficient to feed a panda (Schaller et al. 1985). In extreme cases, i.e. bamboo flowering, the living bamboos may carry more pandas. In Wolong, the maximum carrying capacity of the bamboo stands could reach 3.03 pandas km^{-2} (Schaller et al. 1985; Fong and Li. 2001).

Table 3 Panda carry capacity of three preferred bamboo species in Shennongjia.

Species	Coverage	Covered area (km^2)	Carrying capacities		
			(3.8 km^2 $panda^{-1}$)	(3.3 km^2 $panda^{-1}$)	(0.33 km^2 $panda^{-1}$)
Fargesia spathacea	12 %	384	101	116	1163
Fargesia murielae	8 %	256	67	76	775
Yushania confusa	3 %	96	25	29	290
Total	23 %	736	193	223	2230

Shennongjia has an area of 3200 km^2, in which 736 km^2 is covered with preferred forage bamboos (Table 3). This habitat area, on the average level, could support 300-344 pandas. On the other hand, preferred bamboos could feed 193-223 pandas. Nevertheless, such preferred bamboos may potentially support 2428 pandas, as the maximum carrying capacity in particular case. It is accepted that 30 individuals can form a viable effective panda population (Hu 1998). So the carrying capacity of both the mountain ranges and staple food was large enough to support an effective panda population. Therefore, the carrying capacity should be not responsible for the demise of the panda population in Shennongjia.

4.3 Bamboo flowering risk

Historically, panda populations have obviously survived thousands of flowering events without any help from humans. When one species had flowered, pandas would normally switch to other species, or expand their home ranges to access areas where bamboo had not flowered. However, the panda habitat has been fragmented into isolated areas by human activities in recent centuries, and migration to other areas where bamboo is still plentiful, is thus obstructed. During the flowering death of bamboo species, bamboo species richness may reduce the panda mortality. When bamboo species flowered in the Min Mountains in 1970s, in the area with only one bamboo species, between 30 and 80 % of the pandas died, while in the area with two or more bamboos, few animals died (Schaller et al. 1985). So that when a substantial standing crop of at least one alternative bamboo is available, the threat to the giant panda is greatly reduced.

Normally, forage bamboos in Shennongjia could support a panda population of 193-233 animals, however, the maximum carrying capacity of *F. spathacea, F. murielae* and *Y. confusa* is as high as 1163, 775, and 290 pandas, respectively. This indicates that when one or even two species die back, other bamboo species may support the underlying population through the hard time. Such food shifting is a common strategy of the giant panda to survive the bamboo flowering, e.g., when *B. fangiana* flowered in the Qionglai in the1980s, for a short period pandas cropped more culms from the remaining un-flowered clones than these clones replaced with new shoots (Reid et al. 1989). After a few years they changed their winter food habits, and began to eat more of the alternative lower elevation bamboo (Reid et al. 1989).

However, this may be desirable when multi-species flowerings are nearly synchronous. In Shennongjia, three staple-food species, *F. murielae*, *F. spathacea,* and *Y. confusa* have their own flowering intervals, i.e., 110, 35, and 88 years, respectively. Under the assumption that the intervals are genetically fixed, in the past four centuries (1600-2000), *F. murielae* flowered 4 times (1666, 1776, 1886, and 1996), *F. spathacea* 11 times (1634, 1669, 1704, 1739, 1774, 1809, 1844, 1879, 1914, 1949, 1984), and *Y. confusa* 5 times (1616, 1704, 1792, 1880, 1888, 1976). Two staple food species, *F. murielae* and *F. spathacea* might have synchronously flowered twice in the past four hundred years: 1666 (*murielae*) - 1669 (*spathacea*) and 1774 (*spathacea*) - 1776 (*murielae*), but *Y. confusa* might have carried the pandas over this hard time. However, an extensive flowering occurred in 1879-1888: in less than ten years, three species synchronously flowered one after another. In this case, the pandas had to migrate to other habitats where suitable bamboos were available.

Historically, this migration was a normal way to maintain the panda population, even a method to eliminate the weaker and sicker individuals. Geographically, Shennongjia is separated from the northern panda habitats of Qinling by the Hanshui River and from the southern panda habitats in north-western Hunan by the Yangtze River. In the east, Shennongjia faces an intensive lowland: Jianhan Plain, one of the most famous agricultural regions in China. This plain has an agricultural history going back 3,700 years ago and as early as the Song Dynasty (960-1279), it had been completely occupied by humans (Cheng et al. 1995). So when the bamboos died back in Shennongjia, the underlying giant pandas mostly moved to western habitats, i.e., panda habitats in central and western Sichuan. However, since the Qing Dynasty (1616-1912), millions of people, called by the government, had migrated from central and eastern China to the

Sichuan basin, a region between Shennongjia and western Sichuan. Consequently, Shennongjia was successively separated from the western panda habitats by this well-populated Sichuan basin. When all preferred bamboos flowered synchronously in 1879-1888, the panda population in Shennongjia had already been isolated. Starvation might have caused the die-off of the underlying pandas in this habitat. Giving this background of habitat isolation and bamboo flowering, introducing the giant panda backing to Shennongjia is a risky task.

ACKNOWLEDGMENTS

The authors thank the Center for Development Research (ZEF), University of Bonn, for financing this project. Deep thanks are extended to the Shennongjia National Nature Reserve for providing logistic supports throughout the fieldwork, and to our field assistants Mr. Zhao Benyuan (from the Shennongjia Reserve) and Mr. Liu Bao (from Hubei University).

REFERENCES

J.J.N. Campbell and Z.S. Qin. 1983. Interaction of giant panda, bamboo and people. *J Am Bamb Soc*, Vol. 4, pp. 1-35.

J. Cheng, H.Y. Fang and Y.J. Zhang. 1995. *History of agricultural development in Hubei*. Hubei Publishing House of Science and Technology, Wuhan.

J.S. Cui. 1996. *History of the Shennongjia Forest Region.* Hubei Publishing House of Science and Technology, Wuhan.

W. Eberts. 1996. *Fargesia murielae*: Ein Gartenbambus blüht und stirbt. *Florist,* 11, pp. 10-12.

W.H. Fong and G.H. Li. 2001. *The saving of giant panda.* Sichuan Publishing House of Science and Technology, Chengdu.

J. Gielis, P. Goetghebeur and P. Debergh. 1999. Physiological aspects of development and experimental reversion of flowering in *Fargesia murieliae* (Poaceae: Bambusoideae). *Syst Geog Pl,* Vol. 68, pp. 147-158.

J.C. Hu. 1998. Re-introduction and conservation of giant panda. In: Mainka S, Lü Z (eds) *International workshop on the feasibility of giant panda re-introduction, Wolong Reserve, Sichuan, China, September 25-29, 1997*. China Forestry Press, Peking, pp 169-172.

B.J. Keng and Z.P. Wang. 1996. *Flora republicae popularis Sinicae, Tomus 9(1)*. Science Press, Peking.

Z. Li and M. Denich. 2001. Survival of giant panda in the wild. *Tigerpaper*, Vol. 28, pp. 9-14

J.G. Liu, M. Linderman, Z.Y. Ouyang, L. An, J. Yang and H.M. Zhang. 2001. Ecological degradation in protected areas: the case of Wolong Nature Reserve for giant pandas. *Science*, Vol. 292, pp. 98-101.

C.J. Loucks, Z. Lü, E. Dinerstein, H. Wang, D.M. Olson, C. Zhu and D.Y. Wang. 2001. Giant panda in a changing landscape. *Science*, Vol. 294, pp.1465.

S.J. O'Brein and J.A. Knight. 1987. The future of the giant panda. *Nature*, Vol. 325, pp. 758-759.

S.J. O'Brein, W. Pan and Z. Lü. 1994. Panda, people and policy. *Nature*, Vol. 369, pp. 179-180.

D.G. Reid, J.C. Hu, S. Dong, W. Wang and Y. Huang. 1989. Giant panda *Ailuropoda melanoleuca* behavior and carrying capacity following a bamboo die-off. *Biol Conserv*, Vol. 49, pp. 85-104.

D.G. Reid and J.C. Hu. 1991. Giant panda selection between *Bashania fangiana* bamboo habitats in Wolong reserve, Sichuan, China. *J App Ecol*, Vol. 28, pp. 228-243.

D.G. Reid and J. Gong. 1998. Giant panda conservation plan. In: C. Servheen, H. Herrero and B. Beyton (eds) *Status survey and conservation action plan: Bear.* IUCN Publications Service Unit, Cambridge, pp. 241-254.

C.S. Sargent. 1913. *Plantae wilsonianae* (Vol. I). The University Press, Cambridge.

G.B. Schaller, J.C. Hu, W.S. Pan and Zhu J. 1985. *The giant panda of Wolong.* University of Chicago Press, Chicago.

G.B. Schaller. 1987. Bamboo shortage not the only cause of panda decline. *Nature*, Vol. 327, pp. 562.

A.H. Taylor, Z.S. Qin and J.C. Hu. 1991. Bamboo dieback: an opportunity to restore panda habitat. *Environ Conserv,* Vol.18, pp. 166-168.

A.H. Taylor and Z.S. Qin. 1993. Bamboo regeneration after flowering in the Wolong giant panda reserve, China. *Biol Conserv,* Vol. 63, pp. 231-234.

T.P. Yi. 1985. Classification and distribution of food bamboos of giant panda. *J Bamb Res* Vol. 4, no. 1, pp. 1-27.

Z.Q. Zhu and Z.S. Song. 1999. *Scientific survey of the Shennongjia Nature Reserve.* China Forestry Press, Peking.

A Study on the Conservation and Development of *Dendrocalamus sinicus*, A Giant Bamboo From Yunnan

Hui Chaomao, Chen Fang, Zhang Guoxue, Yang Yuming

Bamboo Institute of Southwest Forestry university, Kunming, China, 650224. Phone:+86-871-128 39211.

Abstract: *Dendrocalamus sinicus* is an endemic species in southwestern Yunnan, China, and it is the largest bamboo in the world. It can grow to more than 30m tall with 30cm in diameter. Its culms yield per unit area is 5-8 times as that of *Phyllostachys pubscens* that is now popularized as a major economic bamboo species in China. So it is one of the most excellent economic bamboo species in south China and in the tropical and subtropical areas of the world. Based On the investigation of the biological characteristics and present seed resources situation of *Dendrocalamus sinicus,* the paper discusses the limitations of its natural population distribution, its fragile growth and propagation, and its rich meaning in culture. The authors suggest that this species be included in the list of wild plants for priority protection in China, nature reserve of *Dendrocalamus sinicus* (ecological and cultural) be established in its main distribution areas and that its scientific protection and industrial development be carried out as soon as possible.

Key Words: *Dendrocalamus sinicus,* biological characteristics, population ecology and culture, fragile growth and propagation, conservation and development

Yunnan is an area with the richest bamboo resources in the world. Yunnan is one of the origin and modern distribution center of bamboos in the world. There are 28 genera and 220 species of bamboo in Yunnan, with the diversity of rare bamboos, the diversity of tropical bamboo forest scenery, the diversity of natural bamboo population, and the diversity of bamboo cultures of the nationalities. Whether we can use the diversities are the key, the special foundation and the important symbol in the sustainable development of bamboo industry. In the varieties of bamboo plants in Yunnan, *Dendrocalamus sinicus* is the largest bamboo in the world and a worldly rare bamboo species. It is very important to systematically study its germplasm, conservation and development.

Dendrocalamus sinicus China et J. L. Sun is called big bamboo by the locals. Day people call it Maibo, and in the south of Xishuangbanna, “waijiao longzhu” (it is meaming “askew footed dragon bamboo”). It can grow to more than 30m tall with 30cm in diameter, and it is the biggest bamboo that can be found in literature.

1. BIOLOGICAL CHARACTERISTICS

Dendrocalamus sinicus was originated between the altitude 500~1870 m, with yearly average temperature between 15.2～21.7℃, the lowest monthly average temperature between 10.2～15.6℃, yearly average frost days between 0～12, yearly rain fall between 1 200～2 813mm, and sum of temperature great than 18 ℃ between 319.5～6 378.3℃. It often forms populations constituted of scattered several or dozens of clumps. The pole is straight and high with high branches. The separation of the clumps is distinct. The size of the clumps varies. Usually, a small clump has 5－10 poles，a medium clump10－15 poles and a big clump more than 15 poles. The largest seen in investigation was 100 poles. The diameter of a clump can reach more than 10 m. when there are too much stumps in a clump, the base of the poles is exposed, causing the increase of the number of deteriorated shoot and the decrease of grown up bamboo poles.

`

※ Funded as a major project （1999C0006Z）by Yunnan Natural Science Foundation and the Soft-science Research Program （02RKX20）of Yunnan Science and Technology Bureau.

According to the analysis of the data from fixed investigation plots, the bamboo in low altitude areas usually began to shoot between the end of May and the beginning of June（19 May ~27 June）and finished shooting in the end of August (4 August ~15 September). The period of shooting was about 65~70 days and shooting peak time about 55 days (4 June ~29 July). Most of the shoots were produced between the middle of June to the middle of July. The bamboo shoot earlier on sunny slops than on shaded slops and earlier in low elevation areas than in high elevation areas.

2. THE LIMITATIONS OF ITS NATURAL DISTRIBUTION

Dendrocalamus sinicus is a new species that had just been found in Xishuanbangna in early 1980s (Jia Liangzhi and Sun Jilian, 1982). However, According to the investigation by Southwest Forestry College, its origin and modern distribution center is not Xishuanbangna, but some subtropical medium hilly areas in the remote southwest areas of Yunnan with elevations between 600-1800m. Most of the bamboo is distributed in low hill areas, flat areas and valleys. The range is about 98° 50′ ~101° 40′ E and 21° -23° 40′ N, basically to the south of the Tropic of Cancer and only across the line in some special valleys.

Dendrocalamus sinicus grows best to the south of the Tropic of Cancer under elevation 1200m. The characteristics are thickest and highest bamboo poles. These areas coincide with the tropical seasonal rain forest and seasonal rain forest areas in Yunnan. The lowest monthly average temperature is greater than 13℃, yearly lowest temperature greater than -1℃, no frost all the year around and the days with temperature under 0℃are not more than 1. In these areas the biggest *Dendrocalamus sinicus* found was more than 27 m high and 28 cm thick.

Above 1200 m, or across the Tropic of Cancer too much, the temperature drops gradually. The lowest monthly average temperature is greater than 10℃, yearly lowest temperature greater than -5℃, frost days in a year less than 12, and the days with temperature under 0℃are not more than 5. In the winter of some extremely cold years, for example, in the end of 1999, some *Dendrocalamus sinicus* bamboos were damaged by low temperature. In areas like this, though the bamboo can grow the thickness decreases, and the better ones can reach 22 cm in diameter.

3. THE FRAGILE DEVELOPMENT

3.1 Seed Scarcity and Narrow Distribution

Dendrocalamus sinicus is only distributed in some mountainous areas in some counties and townships in southwestern Yunnan and the seed is scarce. This may be caused by the combined effects of social, history and cultural factors, but the limitations of the ecological conditions should be the main cause. No a single ecological limitation factor has been discovered. According to the integrated analysis of the ecological factors from the fixed investigation plots, the main environmental limitations are: elevation≤1600 m, annual rain fall≥1200 mm, yearly average temperature≥16℃，lowest temperature≥-1℃, days with temperature≤0℃are not more than 5, the average temperature of the coldest month≥10℃, average frost days in a year≤12, and the sum of degree days above 18℃>320℃. Presently, the lowest elevation of the *Dendrocalamus sinicus* distributed area is 500m and the highest 1870m.

3.2 Pollination Difficulties and Low Seed Bearing

Dendrocalamus sinicus is seldom found flowering. It was seen the first time in 1986 when the authors went to Cangyuan County for investigation for the master degree theses. A clump of *Dendrocalamus sinicus* bamboo was found blossoming at lower Nadi Village of Nanla Township. The bamboo was bought and all the branches with flowers were cut, but only 3 seeds were got. In recent years scattered flowering *Dendrocalamus sinicus* bamboos are sometimes found. The flowering branched bearing less or no leaves. It flowers all clump or only some poles in a clump and the flowered part dies after flowering. As the male and female do not mature at the same time pollination is very difficult, seed bearing is very low and seed collection very hard. In order to do the study of tissue culture and non-sexual propagation, the authors collected 21 seeds (fortunate enough!). Based on this, tube culture was carried out and 2 non-sexual breeds with good performance have bee got.

3.3 Low Surviving Rate in Propagation

According to the saying of the locals, compared with other bamboos, *Dendrocalamus sinicus* has low surviving rate when propagated by separating clumps and low shooting rate. In testing propagation, we used the methods of planting the underground stem and cuttage more than 20000 times and compared different methods. There were no roots grew out or only very few roots. We are now working hard using limited quantity of good seeds separated and selected from its origin areas and industrialized fast propagation method to meet the needs of breeding good *Dendrocalamus sinicus* resources and studying systematic resource conservation methods.

3.4 Species Change and Variation

When published, *Dendrocalamus sinicus* was called Waijiaolongzhu (askew footed dragon bamboo) because the base of the pole of the type specimen had shorted and askew knob interval looking liked askew foot. Investigation showed that the shape of the pole varying in different areas. There are the types of straight, crooked, askew footed (shortened), and turtle back. This is a special phenomenon in species change and has some potential influence in its industrial development, especially in breeding good varieties in designed direction. The straight type is high and straight and suit for construction. It is also the main source for breeding good varieties in designed direction. The turtle back type has high art and ornamental value and is also good for breeding good varieties in designed direction.

4. The Varieties in Cultural Meaning

The natural distribution of *Dendrocalamus sinicus* is limited in small areas inhabited by Wa people and these areas are usually called as Wa Mountains. This is a interesting biological and cultural phenomenon and worth to be studied in human ecology, and the history and culture of the minority nationalities. In the Wa Mountains distributed with *Dendrocalamus sinicus*, biodiversity and cultural diversity are expressed by the planting, propagation, extension and utilization of the bamboo. Since 1995, with the investigation of *Dendrocalamus sinicus*, we have found that the bamboo plays an important role in the production, living, and ecological protection of the local minority nationalities.

The vigorous *Dendrocalamus sinicus* bamboo scenery and the Wa villages retaining their primitives make the Wa Mountains mysterious. In the most grand festival of Wa people, Duisha festival, a big *Dendrocalamus sinicus* bamboo pole is erected in the center of the meeting place with a banner on the top. This symbolizes the hope of the Wa people for bumper harvest, prosperous, happiness and avoiding bad things.

Dendrocalamus sinicus is one of the important material used in production and living of the local minority nationalities. In the practice in the long history of Wa people, *Dendrocalamus sinicus* bamboo is widely used in wearing, food, shelter, and transportation. The bamboo is closely linked with the living and production of the people. As the bamboo is very big, it is often used for fetching water, and store rice and other things. It can be used with only one knob interval or two or more intervals cut through. A single interval is widely used as a stool, a basin, or a pig trough.

After so many generations there are few houses all made of bamboo, but people still cal them bamboo house. This is not only a tradition but also expresses the love for bamboo houses of the minority nationalities. The bamboo houses spreaded in the green bamboo forests form special scenery of bamboo culture. How to use bamboo to rebuild, improve and develop the traditional houses is not only for architecture, but also for protecting nationalities' culture and developing special tourism.

5. URGENCY IN CONSERVATION AND DEVELOPING

Dendrocalamus sinicus is one of the bamboo species with excellent characteristics and great potential for developing and extension. It is also a worldly rare species and precious natural heritage. The study of this bamboo is still primitive, especially in its biology, population ecology, intensive culture and industrial utilization. In the paper "The study of the establishment of the Yunnan rare bamboo gene pool garden", the authors have suggested include the bamboo in the list of protected rare plants. The systematic research is now carrying out and funded by the Natural Science Foundation of Yunnan Science and Technology Bureau as a major project.

The forest resources crisis and wood shortage is worldwide and it is called for using bamboo to replace wood. There is a great market potential to use *Dendrocalamus sinicus* bamboo for building residential houses, suburban villas, and special buildings in tourism spots. The bamboo poles can support weight and maintain the buildings. It is significant to use industrialized modular bamboo houses to replace the residential houses in the poor minority nationalities' mountainous areas, to save wood and protect forest resources, and to restore the bamboo houses and conserve the minority nationalities' culture. There is also a great expectation in developing big whole pole bamboo handicraft articles, building *Dendrocalamus sinicus* bamboo ecological and cultural scenery, and creating Wa mountain tourism.

Its culm yield of *Dendrocalamus sinicus* is 5-8 times as that of *Phyllostachys pubscens* that is now popularized as a major economic bamboo species in China. So it is one of the most excellent economic bamboo species with great development potential in south China and in the tropical and subtropical areas of the world. It is very significant to conserve, study, and industrially develop the rare *Dendrocalamus sinicus* resources, to optimize the bamboo industry and the combination of good bamboo species, and to extend the plantation of *Dendrocalamus sinicus*.

6. Establish Natural Reserve for *Dendrocalamus sinicus*

The authors suggest that nature reserve of *Dendrocalamus sinicus* population (ecological and cultural) must be established.

The excellent characteristics of *Dendrocalamus sinicus* have drawn great attention of the research organizations and scientists both in China and abroad. Some international research organizations and specialists have come to China for investigation, data collection and discussion for co-research and species introduction. Three clumps of *Dendrocalamus sinicus* have been introduced into the bamboo garden in 1999 International Horticultural Exposition in Kunming, China and the authors were the main builders of the bamboo garden. This amazed the guests from China and abroad and has drawn the attention of the specialists in and outside China. There are continuous correspondences coming for this bamboo.

To establish *Dendrocalamus sinicus* nature reserve is to design a special area of typical *Dendrocalamus sinicus* population ecological system, set a special organization to manage it, and use it as an important base for natural resources protection and scientific research. To establish *Dendrocalamus sinicus* nature reserve is for better conservation and developing of the rare *Dendrocalamus sinicus* resources and finding ways for rational and scientific use of it. To establish *Dendrocalamus sinicus* nature reserve is also an important strategy and measure for protecting and developing *Dendrocalamus sinicus* resources, for protecting the worldly rare and endangered bamboo species and preventing its gene from lost abroad, and for providing scientific methods to industrialize its utilization and to mass produce big clumped bamboos.

To establish nature reserve for *Dendrocalamus sinicus* population (ecological and cultural) as soon as possible is very important for reinforcing the ecological construction of the Wa mountains, for developing tourism as new economic growth, for enhance the popularity of Wa mountains in the world, for attracting investment abroad for the conservation and developing of the *Dendrocalamus sinicus* resources, and for promoting ecological tourism and minority nationalities' cultural tourism in Wa mountain to alleviate poverty and make the locals rich.

References

1. Jia Liangzhi & Sun Jiliang.1982.*Dendrocalamus sinicus* discovered in China. Bamboo Rsearch. 1(1) 10
2. Du Fan et all. The Study of the Varieties of *Dendrocalamus sinicus* and Its Introduction Area Planning. A Collection of Bamboo Study. 20(1)
3. Hui Chaomao. The Flora of Yunnan Bamboo and Its Study Progress. A Collection of Bamboo Study. 18(1)
4. Hui Chaomao. A Discussion about the Industrialized Development of Big Clumped Bamboos in Yunnan. Forestry Science and Technology Development.
5. Hui Chaomao. Bamboo Resources used for Culms and Its Industrial Utilization. Yunnan Science and Technology Press. 1999
6. Hui Chaomao. The Study of Some Issues of the General Planning for the development of Yunnan Bamboo Industry. A Collection of Bamboo Study. 1999
7. Hui Chaomao. A study of the Diversity of Yunnan Bamboo and Their Conservation and Development. Forestry Science. 2003, 39(1)
8. Hui Chaomao. A Hand Book for Culture and Utilization of Bamboo in China. The Forestry Press of China. 2002. 05

The Retrospective and Prospective of China's Bamboo Industry

Wang Shudong

China National Bamboo Research center, No.138, Wenyi Road, Hangzhou 310012, Zhejiang Province, P. R. China. Phone: +86-571-8860945. Fax: +86-571-8860944. E-mail: Cbrc@public.hz.zj.cn

1. THE REVIEW OF PAST CHINA BAMBOO INDUSTRY

1.1 The Development Processes and Phases of China's Bamboo Industry

1.1.1 Natural development and primitive usage stage.

China has the earliest history of bamboo usage in the world. There are some unearthed 5000-6000 year-old bamboo weavings, which have been discovered at the Banpo village, Xian City, and of the Neolithic Stone Age in Zhejiang. Bamboo was used for arrows, books, warring in Shang Dynasty, for building palaces in the Han Dynasty, for pulping and papermaking in the Jin Dynasty. A rather comprehensive description was made on bamboo cultivation and usage during the later Wei Dynasty. Some "Bamboo Hotels" were specially set up for bamboo businessmen coming from all directions to Boai, Hunan in Ming and Qing Dynasties, which accelerated the production and circulation of bamboo there. "Chinese bamboo culture, a long history of over 5000 years, bamboo can be found where-ever it is , clothing, eating, housing, walking, usage", that famous poem is just a very condensation of bamboo historical role and position.

1.1.2 Orderly development and general usage stage.

Since the founding of the People's Republic of China in 1949, the Chinese government has paid great attention to push bamboo forward in a big effort as a means of accelerating prosperity, enriching peoples' material livelihood. Bamboo was listed as one of the main planting tree species in the first National Notice of "Instructions on Planting in spring" issued by the Ministry of Forestry and Reclamation in March, 1952. all levels of government were requested to take effective measures to protect and develop bamboo forest in the Notice on the Protection and Development of Bamboo Forest issued by the State Council in Jun., 1956. A national conference on bamboo was held in Jiangsu province in 1962. A conference on bamboo forest management in the 12 southern bamboo-growing provinces/ autonomous region was held by the Ministry of Forestry in Beijing in July, 1982. In this stage, big success has been achieved in such areas as introduction and cultivation of crop bamboo, planting of southern bamboo in the north, control of harmful bamboo pests, bamboo weaving arts and handicrafts, etc; also experiments have been done in orientation cultivation and management for shoots. In other words, bamboo industry development was put on a normal and well-circulated track.

1.1.3 High-speed development and extensively used stage.

Since 90's, China's bamboo industry growth has entered a high-speed phase thanks to the implementation of a series of policies and measures taken by the Chinese government, esp. since the National Bamboo Conference held in Hangzhou in 1991, in which guidelines for bamboo industry development in China have been put forward, i.e. "all-inclusive planning, reasonable lay-out, improving administrative management, exploiting bamboo resources; tapping all potentials for bamboo processing and utilization, opening up markets for raising economic benefits, invigorating bamboo industry through science and technology". Guided by this policy, and after many years' efforts, China's bamboo industry has made some encouraging changes: on bamboo silviculture, a transfer from singular pursuing of area expansion to a combination of new planting and low-yield bamboo stand improvement; from extensive to intensive management, from management of singular bamboo species to that of multiple ones, from timber bamboo forest alone to timber and shoot ones; from bamboo forest alone to mixed ones. Therefore, a bamboo cultivation system has been established with Chinese characteristics and China bamboo's leadership is recognized worldwide; on bamboo processing and utilization, a gradual transfer from traditional utilization to modernized ones, from singular utilization to comprehensive ones, from hand making and semi-mechanization to mechanization ones, from extensive processing to intensive one, from singular products to multiple ones, from low-added value to high-added values. Through this way a bamboo processing industry of proper scale and economic efficiency was set up.

10 bamboo-growing counties/ cities have been nominated as "China Bamboo Towns", 10 demo bases of harvest bamboo forests nationwide have been established; new bamboo species are being developed by the China National Bamboo Research Center (CBRC) in Hangzhou since 1989, and by the China Bamboo Industry Association (CBIA) in Beijing since 1993, the "eighth-five", "ninth-five" national key bamboo projects have been implemented and successfully finished, the implementation of the "tenth-five" national key bamboo project, the establishment of International Bamboo and Rattan Network (INBAR) with its headquarter in Beijing, and China Bamboo Culture Festival organized every two years since 1997, all these have further ushered China's bamboo industry into an advanced development stage.

In the international and national context, environment protection and sustainable development have become the permanent topics, which attract most people's eyes. In China, several favorable policies have come out as a result of the holding of two international environment and development seminars and our party and leaders' increasing attention paid to the environment protection and sustainable development. Recently, vice-premier Wen Jiabao has pointed out definitely "Forestry should be placed in an important position in environment protection, and in the top important position in land ecology establishment". This has put forestry into an unprecedented height and it no doubted has given our bamboo industry which is taken as an important component of forestry and a combination a ecological, economic and social benefit a rare opportunity of development. Meanwhile, it is also a challenge. The key point is that we who are working with bamboo have to catch it both in mentality and real action through our super judgment and fastest speed to make breakthrough from many aspects such as bamboo industry's policy R. & D., management, investment etc., in order to realize the leap-jump development of bamboo industry.

1.2 Achievements of China Bamboo Industry

1.2.1 Bamboo forest area increases quickly and its quality has been much raised

There are over 39 genera and more than 500 species of bamboo resources in China, which mainly distributes in the 13 provinces' mountainous region of South China. There are over 130 counties with a bamboo forest area up above 10,000 hects, most are economy lag-behind mountain areas. According to statistics, our bamboo forest area has reached 66 million mu with an increase of over 18 million mu compared with the junior stage of reform and opening's 48 million mu, and the number is increasing at a speed of 1 million mu per year. Three "bamboo high-yielding " provinces Fujian, Zhejiang and Jiangxi' s bamboo forest area increased more than 6 million mu during the "ninth-five" period, which occupied 60% of the whole country. Besides, all provinces' average bamboo forest area has surpassed 10 million mu. Bamboo forest has become the main component of forest resources. The average culm volume of Moso per mu has reached 138 while in late 70's it was less than 90, and its harvesting volume per year has been raised from 79 million to 0.5 billion. Besides, the exploration of bamboo species resources tends to be multiform; the structure is more optimized and rational. The small-diameter bamboo such as Leizhu, Bujizhu, Kuzhu etc. which had been called "small hybrid bamboo" in the past have become high value bamboos through big-area's introduction, cultivation, exploration and utilization.

1.2.2 Great achievements in scientific and technical research and its wide application

According to an general statistics, there are about 45 scientific and technical achievements of national bamboo research work after 80's. Among them, 5 achievements got national scientific and technical progress prize, 16 got provincial- and ministerial- prize. The achievements ranging form bamboo forest cultivation, bamboo timber processing and value-added bamboo products exploration etc. have been widely used in practice and received a good economic benefit. Fro example, Linan county of Zhejiang province has greatly promoted "Lei bamboo high-yielding technology" since 90's and raised its value from 1000 Yuan to 10, 000 Yuan per mu! Some super high-yielding forest even reached 30,000-50,000 Yuan per mu! This action has really enriched the local people. Scientific technology has become "a ready source of money" of the local people.

1.2.3 Great progress on bamboo's comprehensive utilization and the expendsion of its application field.

Presently, bamboo's processing and utilization have been changed deeply. People utilize to use the bamboo culm and its branch and shoot, but now its utilization has been extended to construction, paper-making, food, furniture, artist, packing, transportation, medicine, health-care, tourism and environment etc. It has formed a new-rising industry from cultivation, processing to exporting. Among its above utilizations, bamboo shoot processing, construction and decoration, environmental protection and health-care medicine etc. have got great breakthroughs and show a brilliant prospect, particularly in bamboo charcoal and active charcoal, bamboo vinegar and bamboo fiber's refined and deep processing etc. Bamboo charcoal production develops quickly and has formed a preliminary industry scale. statistically, Zhejiang province's bamboo charcoal yielding is about 20,000 Ton and its total value is 160 million Yuan with a net profit of 32 million Yuan in 2001. Bamboo active charcoal is now at the starting line since CBRC allied some entities to do research work for several years and successfully produce active charcoal by using the leftovers of Moso processing, such as bamboo particle, bamboo node, bamboo rhizome etc. We have applied to National Intelligence Right Bureau for an invention patent (patent No. 01131145.2). So the precondition of bamboo active charcoal's industrialization development's precondition is now available.

Meanwhile, we have applied to Ministry of Science and Technology for agricultural scientific and technical achievements' transferring to productivity project "external heating of multifunctional active charcoal rotating furnace". It has been approved and now has passed the inspection. All these will further promote the development of bamboo industry. Besides, great achievements have been made on bamboo (wood) vinegar deep exploration research, and two invention patents on very practical and high-value-added products have been applied.

1.2.4 Circulation channel being improved, and market being widened

After years' effort, our bamboo shoot products have finally changed the situation of "able to sell only in South China". Now it is warmly welcomed in North China, and has been selling to the oversea markets, ranging from Japan, southeast countries to Europe and North America. Bamboo handicrafts have become national-classed gifts, appreciation bamboo seedling's exporting to European countries has formed a scale. We have resource and technology double advantages in bamboo industry, so the prospect of both products exploration and market should be very brilliant.

1.2.5 Expanding of Industry scale and co-existing of multiple benefits

Bamboo industry's economic benefit is increasing continuously through technology dissemination, restructuring and new production exploration. According to statistics, bamboo industry boasts 20 billion Yuan in 2001, among them processing value is 10.5 billion Yuan, exporting is USD 0.5 billion, this is over 4 times of the early 90's. Recently, China's bamboo industry shows a high-speed developing tendency. Its annul value increases 1.5—2 billion Yuan, particularly in Zhejiang province, the bamboo industry value reached 10 billion in 2001, which is 30% over 1998's. Linan and Anji are two of the ten "China bamboo towns". Bamboo industry has become the pillar one of the local economy's development and farmers' income sources. In Linan, Lei bamboo plantation's value reached 0.4 billion Yuan, and its derivative value is up to over 2 billion Yuan. Among the average income of Lin an county's farmers' 4200 Yuan, almost half of it is from Lei bamboo. Anji County's bamboo industry's value is over 2 billion, too. 1/3 of its financial income is from bamboo. Nanping county of Fujian province's bamboo industry reached 2.05 billion. Bamboo industry not only has an obvious economic benefit, but also has social benefit and ecological benefit. The dissemination of intensive management technology and establishment of processing factories have attracted lots of laborers to plant bamboo and work in the factories, which has a good effect to maintain the society's stability.

Bamboo's unique biology and ecology characteristics and its special management mode determine that it should have extensive ecological environment and appreciation benefit and effects:

As an excellent appreciation plant, bamboo maintains high value. In China, wherever in Suzhou city or Shanghai city, many gardens use bamboo as a decoration plant, such as Zhuozheng Garden, Xi Garden, Liu Garden, Yu Garden, etc. Besides, we can use many small-sized appreciation bamboos to make bonsi, such as Fodu Bamboo, Cui Bamboo, Fengwei Bamboo, etc. Combining by beautifying city's environments and intensifying city's virescence, we should do our best to exert bamboo's function in the cities.

Bamboo is not only beautiful, but also has a deep cultural connotation. it has a high appreciation value. Bamboo's ecological and environmental functions are catching people's eyes daily with more and more attentions being paid to the global environment quality. Eco-tourism based on bamboo forest and bamboo culture is rising to be the tourism hotspot. Taojiang hongshan Bamboo Sea, Anji bamboo species garden, Chishui Bamboo Sea, Shunan Bamboo Sea all have form unique tourism advantages and promote the local economy's stable development. Meanwhile, it has protected the ecological environment. Now we are planning to set up a "China Hangzhou Bamboo Sea" together with Hangzhou bamboo resource Exploration Company in Yuhang district is just based on the thinking of eco-tourism.

2. EXISTING PROBLEMS

Despite gigantic achievements by China's bamboo industry, however, we should acknowledge that from a macroscopic view, bamboo development level is still low and has many problems as stated below:

2.1 Low financial input of science and technology in bamboo industry, and always remain the same mode.

China is a developing country with a large population and lag-behind infrastructure, so the financing of bamboo science and technology has been cut short and lagged behind the needs of the bamboo industry to a large extent. And the finance is mainly from the national budget with the same mode. The bamboo technology development can not fit for the bamboo industry's development, particularly in the basic theory's research; bamboo processing products can not form a fist product which has distinct market advantages; less progress in hi-tech, high-value-added products research; even for some promising products, we can't implement due to the lack of R. & D. fund; the chemical utilization is far behind Japan and South Korea.

2.2 Small industrial scale, bad managerial systems, low economic benefits and serious waste in resources.

Statistically, there were 260 bamboo plywood processing factories in 1998, and more in other bamboo products processing factories. In Huanhua county of Guangdong, there were bamboo products factories over 400, this had greatly promoted the local economy and encouraged the farmers' enthusiasm in that time. But the situation is not fit for the present market with the formation and development of market economy. The overwhelming majority of bamboo processing enterprises are small in scale, out of date, and with low economic benefits; even some of them had to be closed due to lack of capital. At the same time, out of order and blinded production leads to vicious competition, bad quality and low prices and serious waste in resources. Some factories even sell at a price lower that the cost in order to get the orders. Over cutting is another problem, those less than 3 years old bamboos have been cut, too! All these actions not only waste our bamboo resources, but also gave bad impressions to the customers, and thus influenced the progress of the whole bamboo industry.

2.3 Inconsistent regulation of the bamboo industry and market building's lagged behind.

The majority of then are scattered in remote mountainous areas. There is a lack of information and technology, ineffective macroscopic administration by the government and bamboo industry. At the same time, some regions add high tax to bamboo, the highest even reaches 0% of the sale price, some region protectionism even protects poverty and lagging behind. All these no doubted limited bamboo industry's development and farmers' enthusiasm; hence, it is hard to cope with daily changing market.

3. THE PROSPECTIVE OF CHINA'S BAMBOO INDUSTRY

Bamboo is one of vital and unique components of forestry, and plays a very important role in improving ecological environment, sustainable development, and poverty alleviation. China has scarce forest resources, a very fragile ecology, and shortage of timber supply. Bamboo, with features such as a very strong root system, evergreen, sustainable management once planted, not only effectively conserves water and soil, improves ecological environments, but also provides a great deal of bamboo timber for "replacing wood with bamboo", and protect "wood with bamboo", so it is very typical of "the shorter cycle of the longer ones", and "the faster growing of the slower ones". Through developing bamboo industry and maintaining and upgrading our leading position in bamboo industry so to enhance our forestry's whole situation.

Presently, China's bamboo industry is still in a bad condition, but is facing excellent opportunities. What attitudes should we take to meet that challenge? The main opportunity is global focus on environmental protection and sustainable development (the Chinese government pays greater attention) to develop bamboo industry and do well in bamboo cultivation and comprehensive utilization; meanwhile, we should understand that we are still encountering problems and difficulties. It is difficult to realize bamboo industry's sustainable development if without foreseeing thinking and long-term planning. Now I'd like to address its prospective:

3.1 Guidelines for bamboo industry development

On the precondition of ensuring sustainability of bamboo, by following socialist market, taking bamboo cultivation as a base, low-yield bamboo stand improvement as a breakthrough, science and technology as a "dragon-head", raising comprehensive economic benefit as a target, trying to open up domestic and overseas markets in order to gradually set up a modern bamboo industry streamlined with bamboo cultivation, processing, trade, as well as production, supply and sale which can adapt to national economic and social development needs.

3.2 Tasks and targets of bamboo industry development.

To intensify the strength of cultivating new resources and implementing "Two restructuring and one breakthrough" on the base of protection the present bamboo resources. One restructuring is bamboo processing. To implement uniting and amalgamating, to upgrade the enterprises' quality and scale, to organize multinational and multi province bamboo industry group. The government should catch the big ones while let the small ones develop by itself. Second is research institute. We should restructure the existing university lab, researching institute to make re-assignment based on the market and production to solve the problems such as new products exploration and so on. The third one is to make breakthrough on comprehensive utilization. A) To solve the problem of glue, dry, anti-rotten, anti-mould, coating and the use of its leftovers. B) To solve the key problems in chemical utilization (e.g. bamboo vinegar's deep processing, bamboo green-keeping, and bamboo timber's soften etc.) to explore new hi-techs. C) Applicable research of Nano technology in bamboo industry. (e.g. bamboo charcoal and active charcoal's nano-materials).

3.3. Main measures of bamboo Industry development

3.3.1 Setting up macroscopic guidelines and streamlining management administration.

One is bamboo forest's cultivation, protection, rebuilding, utilization, and updating, to implement macro control and micro intensified management and supervision, to set up bamboo industry development planning, policy and laws, to execute license system on cutting, transportation and participating bamboo shoot's market management; to change the collection, management and use of bamboo forest products cultivation fund in order to bring bamboo industry's development into standardization. Second is to stipulate kinds of standards and set up quality inspection and supervision system.

3.3.2 To set up the enterprises' leading position and support dragon-head companies.

To upgrade the whole bamboo industry's level, we have to establish the enterprises' leading position in market economy. It is gratified to see that some bamboo processing enterprises with middle or large scale and good quality and reputation have appeared, such as Shuangqiang company, Dazhuang company and Jianan company. Bamboo industry should also narrow its gaps with other industries and introduce new management concepts such as brand-making, patent and technology, standard and designing, etc.

3.3.3 To intensify the supporting input of china's bamboo industry and establish a completed research institutes.

Scientific technology is the first productivity and its progress is the basic characteristic of modernization. A certain amount of capital input and high effective R. & D. institutes are the necessary guarantee of the realization of scientific and technical productivity.

Excepting the national budget inputs in bamboo research, we also should encourage enterprises themselves to make investment in R. & D. when encountering difficulties in real processing by allying or entrusting to the research and development institutes. Besides, it is also possible for them to apply to other countries' governments or some international organizations for fund.

China National Bamboo Research Center (CBRC) was established in 1988 in Hangzhou, a picturesque city in eastern China, which is located in one of the China's biggest bamboo grown centers, and well known for its West Lake. CBRC has three missions as enshrined by the Ministry of Science and Technology, the State Administration of Forestry: (a) to undertake, organize and coordinate major international and domestic bamboo projects of research and exploitation; (b) to undertake international technical and economic exchange and cooperation and personnel training in bamboo; and (c) to be managed and operated by modality of share-holding and gradually grow into a locomotive and backbone enterprise of China's bamboo sector so as to enhance China bamboo industry as a whole.

The total investment of CBRC is about 100million Yuan. The bamboo plaza is a comprehensive building of scientific research, training, lodging and boarding. Its construction area is 18000m^2. Up to now, the construction work is finished and the stress is now in R. & D. Our primary thinking is to base on information and invisual capital, focus on the settlement of key technical problems, center on the establishment of scientific and technical industry to set up our leading position in following aspects through international and national economic and technical cooperation:

a) Bamboo research center. Our aim is to become the dragon-head institute in bamboo timber, charcoal processing and other comprehensive utilization, bamboo seedling's fast propagation, bamboo gardening etc.
b) To become the information dealing center of bamboo resources, technology, achievements and person with ability

c) To become the international economic and technical exchange and trade center;
d) To become bamboo products' analysis, inspection, quality control and evaluation center;
e) To become China national bamboo project technology center

CBRC has made great achievements in many of the above fields. And now it is undertaking many bamboo projects and part of them are finished successfully. e.g. 948 project, bamboo shoot fresh-keeping, bamboo active charcoal, bamboo vinegar, bamboo forest base establishment. Besides, CBRC has hosted China International Bamboo Technology Training Course for 6 times. And has contributed a lot in sino-indian's projects such as setting up factories etc.

3.3.4 To intensify bilateral and multilateral cooperation

China is reputed as "Kingdom of bamboo resource" and has a favorable resource and technology advantage. International Bamboo and Rattan Network (INBAR) headquarters in Beijing. All these great facilitates China and other bamboo producing countries' bilateral and multilateral exchange and cooperation. It is also good for the promotion of other countries' bamboo industry since this can attract the governments' attention and support. This could be a combination of all people's intelligence globally. Through this way, it may be possible for us to use the developed countries' technology and capital and further more, we can introduce bamboo to the largest extend of the world and share the achievements, which will greatly help the early realization of bamboo intelligent economy. We are sure that through bilateral and multilateral cooperation, China and international bamboo industry will be greatly promoted.

3.3.5 Implementation of classified management and deep processing to open up two markets both at home and abroad.

To manage them according to the different requirements and technical standards of bamboo timber forest, shoot forest, timber and shoot forest, appreciation forest and paper-pulp forest. To upgrade bamboo products' quality and add its value. To develop the well-selling products based on the market changing. To open the two markets both at home and abroad.

3. 3.6 To upgrade the whole bamboo industry's level by S. & T.

a) To encourage R. & D. actively. This should be mainly focused on key problems of bamboo research, such as bamboo flowering, bamboo paper-pulp, bamboo timber's comprehensive utilization, bamboo chemical utilization etc.
b) To disseminate the newest technology;
c) To explore new systems which fits for the market economy.
d) To increase the input and develop bamboo forest.
e) To fully bring out the bamboo association and other bamboo research institutes' function.