Perez-Guerrero Trust Fund for Economic and

Technical Cooperation among Developing countries,

Members of the Group of 77,

Government of People's Republic of China

Bamboo Development Assessment for Asia and Africa under China's "One Belt and One Road Initiative"

Final Report

Submitted by

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Project Final Report

Introduction

The project —Bamboo Development Assessment for Asia and Africa under China's One Belt and One Road Initiative, submitted by China National Bamboo Research Center (CBRC) and endorsed by Perez-Guerrero Trust Fund for Economic and Technical Cooperation Among Developing countries, Members of the Group of 77, includes six major elements:

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001. Trainings for 3 countries

Through the network we established in the last past 25 years, and the training workshops organized for the developing countries, which has greatly facilitated our work to accumulate large amount of valuable first-hand information and the relevant policies and market information, and also thanks for the joint efforts of the cooperative partners in Thailand, Kenya and India and the related Chinese forestry bureaus, we have smoothly implemented this projects and the outputs generated by this project are described as below.

1. An investigation on bamboo development for Thailand, India and Kenya

1.1 Form an expert panel

An expert panel is formed by both the Chinese bamboo specialists and bamboo experts from the above-mentioned 3 countries. They normally have rich working experience in the bamboo areas and are quite familiar with the bamboo development in their own countries. Moreover, most of the experts in Thailand, India and Kenya have been trained in China through our bamboo workshops and have very strong awareness to develop bamboo industry in their countries as an approach to the social, economic and environment improvement. The below are the lists of the bamboo specialist team in the respective countries.

Table 1. Chinese bamboo specialist Team for —Bamboo Development Assessment for Asia and Africa under China's One Belt and One Road Initiative project funded by Perez-Guerrero Trust

Fund

No.	Name	Gender	Position/Title	Name of organization
1	Ma Naixun	M	Professor	Tropical Forestry Research Institute of CAF
2	Chen Yuhe	M	Professor	China National Bamboo Research Center (CBRC)
3	Ding Xingcui	M	Professor	CBRC
4	Zheng Youmiao	F	Senior Engineer	CBRC
5	Bai Ruihua	M	Associate professor	CBRC
6	Cai Hanjiang	F	Engineer	CBRC
7	Zhang Hongliang	M	Professor	Anji Forestry Bureau
8	Wu Guangwen	M	Engineer	Guangning Forestry Bureau

Table2. Thailand bamboo specialist Team for —Bamboo Development Assessment for Asia and Africa under China's One Belt and One Road Initiative project funded by Perez-Guerrero Trust Fund

No.	Name	Gender	Position/Title	Name of organization
1	Wilawan Wichiennoppa Rat	F	Director of Forest Economics Division	Royal Forest Department
2	Saruntorn Sukwatnijakul	F	Officer	Royal Forest Department
3	Warin Treemongkol	F	Forestry technical officer	Private reforestation division, Reforestation and Extension office, Royal forest department
4	Sunis Yodnam	F	Forestry technical officer	Private reforestation division, Reforestation and

				Extension office, Royal forest department
5	Nattakan Pattanasak	F	Forestry Techical Officer	Royal Forest Department
6	Nisabhat Tonwoot	F	Forestry Techical Officer	Royal Forest Department
7	Paitoon Kaewhom	M	Lecturer	Faculty of Agricultural Technology Burapha University,Sakaeo Campus
8	Waranyu Ratcharoen	F	Senior Forestry Technical Officer	Royal Forest Department

Table3. Indian bamboo specialist Team for —Bamboo Development Assessment for Asia and Africa under China's One Belt and One Road Initiative project funded by Perez-Guerrero Trust Fund

No.	Name	Gender	Position/Title	Name of organization
1	Pachuau Lianhming Thanga	M	Member & Secretary, State Planning Board	Government of Mizoram
2	Chalrosanga Ralte	M	Member Legislative Assembly	Government of Mizoram
3	Amenba Tsuknungmen Bayaden	M	Officer	Government of Nagaland
4	Krishan Kant Uniyal	M	Research assistant	Forest research institute Dehra Dun CBRC
5	Braja Narayan Mohanty	M	Research group coordinator	Institute of wood science & technology
6	Rajendra Kumar Meena	M	Research Officer	Advanced Research Center for Bamboo and

				Rattan,Aizawl,Mizoram
7	Amita Pandey	M	Scientist	Institute of Wood Science and Technology ,Bangalore
8	Ajitkumar Elangbam	M	Scientist	Manipur Cycle Club

Table4. Kenyan bamboo specialist Team for —Bamboo Development Assessment for Asia and Africa under China's One Belt and One Road Initiative project funded by Perez-Guerrero Trust Fund

No.	Name	Gender	Position/Title	Name of organization
1	Frouza Mwende Maingi	F	Laboratory Technician	Kenya Forestry Research Institute
2	Felix Orinda Akoko	M	Production Manager	Kenya Bamboo Center
3	Steve Ngonda Matiti	M	Principal agriculture officer	Ministry of Agriculture
4	James Juma Wekesa	M	District agricultural officer	Ministry of Agriculture
5	Josephine Kamene Musyoki	M	Research officer	Kenya Forestry Research Institute
6	Pauline Ngoli Dismas Ekaran	F	Senior forester	Ministry of Forestry and Wildlife-Kenya Forest Service
7	Dedan Ndiritu Gatiki	M	Head of Conservancy	Kenya Forest Service
8	Gabriel Marcharia Kariuki	M	Zonal forest manager	Kenya Forest Service

1.2 Mission to Thailand, India and Kenya for bamboo development survey

According to the original plan, investigation trip to Thailand, India and Kenya would have been arranged by the Chinese expert teams in Thailand and India, but the trip could not be fulfilled due to some reasons. However, bamboo development survey was carried out in each country by our working teams through various methodologies in the field of bamboo cultivation, processing, utilization, policies and its social-economic development environment. And that information has laid a solid foundation to the follow-up work.

The below is the bamboo development survey report in the 3 respective countries.

2. Domestic Survey of bamboo development in Thailand, India and Kenya

2.1 Thailand bamboo development survey report

2.1.1 Country profile:

Thailand is a country at the center of the Southeast Asian Indochinese peninsula composed of 76 provinces. At 513,120 km^2 (198,120 sq mi) and over 68 million people, Thailand is the world's 50th largest country by total area and the 21st-most-populous country. The capital and largest city is Bangkok. Politics belongs to the democratic monarchy.

2.1.2Geography:

Thailand comprises several distinct geographic regions, partly corresponding to the provincial groups. The north of the country is the mountainous area of the Thai highlands, with the highest point being Doi Inthanon in the Thanon Thong Chai Range at 2,565 metres (8,415 ft) above sea level. The northeast, Isan, consists of the Khorat Plateau, bordered to the east by the Mekong River. The center of the country is dominated by the predominantly flat Chao Phraya river valley, which runs into the Gulf of Thailand.

2.1.3 Climate:

Most of Thailand has a "tropical wet and dry or savanna climate" type. The first is the rainy or southwest monsoon season (mid–May to mid–October) which prevails over most of the country. Nonetheless, dry spells commonly occur for 1 to 2 weeks from June to early July. Winter or the northeast monsoon starts from mid–October until mid–February. Summer or the pre–monsoon season runs from mid–February until mid–May and is characterized by warmer weather.

2.1.4 Economy:

In 2016, Thailand was ranked 87th in Human Development

Index, and 70th in the inequality-adjusted HDI. In 2014, Credit Suisse reported that Thailand was the world's third most unequal country, behind Russia and India. In 2016, Thailand's 5.81 million people lived in poverty, or 11.6 million people (17.2% of population) if "near poor" is included. Forty-nine per cent of Thailand's labor force is employed in agriculture.

2.1.5 Forestry development

Historically, Thailand used to be one of the countries with abundant forest resources. At the beginning of the 20th century, Thailand's forest coverage rate was as high as 75%. It was reduced to 53% when the first national economic and social development plan was formulated in 1961, and fell to 27% in the late 1970s. By 1995, the forest coverage rate was only 22.8. %. Currently, Thailand has an area of 1.163 million hm^2 of forest, of which the natural forest area is 11.10 million hm^2. The per capita forest area is $0.2hm^2$. Due to the decline in forest resources, Thailand has changed from a timber exporter in the 1960s to a current timber importer. Moreover, imports of wood and other forest products are gradually increasing.

2.1.6 Bamboo Development

2.1.6.1 General Information

Thailand is one of the world major bamboo distribution areas. Currently, it has total bamboo area around 4.54 million ha, the stock volume is around 17.6 million m^3, the species richness up to 1.373. 72 bamboo species falling into 17 genres are recorded in Thailand, among which, 15 bamboo genres can be found in China. As one of the developing countries, Thailand is still in the initiative stage for bamboo cultivation, processing and utilization, however, the Thailand government has paid high attention to bamboo development. In 1965, the first bamboo research institute was established in Thailand, and bamboo plantation project by the year of 2002 covered 480 thousand ha in the whole country. In 2008, the Thailand Royal Forest Department allocated 250,000 bamboo seedlings for farmers to encourage them to develop bamboo plantation.

Thailand has a very long history in bamboo cultivation and utilization. The most common bamboo genera are *Dendrocalamus*, *Bambusa*, *Thrysostachys*, *Cephalostachyum* and *Gigantochloa*. The 5 above-mentioned genres are widely distributed in the whole country and all of them are big-sized bamboo with versatile utilization and, sharing many similarities with the species in Yunan province of China. *Dendrocalamus*, *Dendrocalamus membranaceus*, *Bambusa blumeana*, *Gigantochloa albociliata* and *Thrysostachys siamensis* are the most commonly utilized timber-oriented species.

2.1.6.2 Bamboo resources

Currently, 17 genera and 72 species of bamboo have been identified in Thailand. The total bamboo forest area is around 4.54 million ha, the stock volume around 17.6 million m^3, the species richness up to 1.373. The below is the list of indigenous bamboo species in Thailand:

Table 5. Native bamboo genera and species in Thailand

No.	Name of Genera	Number of Species
1.	*Bambusa*	15
2.	*Chimonocalamus*	1
3.	*Dendrocalamus*	10
4	*Dinochloa*	3
5	*Gigatochloa*	15
6	*Indosasa*	1
7	*Melocalamus*	1
8	*Melocanna*	2
9	*Neohouzeoua*	4
10	*Phuphanochloa*	1
11	*Phyllostachys*	1
12	*Pseudostachyum*	1
13	*Schizostachyum*	10
14	*Teinostachyum*	2
15	*Teimechloa*	1
16	*Thyrsostachys*	2
17	*Vietnamosasa*	2

Table 6. Newly-identified bamboo species in Thailand

New genera	New species	New record
Temochloa	*T. liliana S. dransf*	
	Neohouzeaua fimbriata	
	S. dransf., Pattan. & Sungkaew	
	N. kerriana S. Dransf., Pattan. &Sungkaew	
		Dendrocalamus Copalandii (Gamble ex Brandis) N. H. Xia & Stapleton
	Dendrocalamus khoonmengii Sungkaew, Teerawat. & Hodk.	
Phuphanochloa	*P. speciosa Sungkaew, Teerawat*	

2.1.6.3 Bamboo propagation

Both sexual and asexual methods are adopted in Thailand for bamboo propagation.

2.1.6.3.1 Sexual propagation

Seeds are collected when bamboo is flowering, although it rarely happens for most of the species and might lead to the death of the whole plantation. The following are the table of quantity of seeds for some local species.

Table 7. Quantity of seeds for some Thailand bamboo species

No.	Name of bamboo species	Quantity of seed (Average number of seed/kg)
1	*Bambusa bambos*	81,800
2	*D. brandisi*	66,300
3	*Thysostachys siamensis*	50,300
4	*D. strictus*	41,200
5	*Cephalostachyum pergracile*	37,000
6	*D. asper*	36,900
7	*Gigantochloa albociliata*	35,000
8	*D. membranaceus*	25,000

Bamboo seeds are very hard to obtain them as bamboo does not flower frequently. And it also takes long time for a seed to grow into a clum and even a plantation. The biggest advantage is that it is easy for carry and suitable for long distance transportation.

Pic 1. Bamboo flowering and seeds

Pic 2. Seeds collection by local farmers

2.1.6.3.2 Asexual propagation

Asexual propagation is more popular in Thailand as most of the countries. The common propagation materials are rhizome, root cutting/culm, branch, stump air laying etc..

Pic 3. Asexual propagation: by stumps

Pic.4 Bamboo seedlings after 2 months by the propagation method of stump

Pic. 5 Asexual propagation: by cuttings (Vertical)

Pic. 6 After 6-12 months by the cutting propagation way

Pic. 7. Asexual propagation: by culm segments

Pic.8 Asexual propagation: by branches

Pic. 9 Asexual propagation: air laying

2.1.6.4 New plantation establishment

Seedling bags are used for bamboo transplanting. It can be planted at any time, except in summer season when watering is required after transplanting

Pic. 10 Transplanting with seedling bags

2.1.6.5 Management

- Watering in Dry season.
- Add fertilizer in early raining season.
- Manure : Chicken manure 1.5 – 2 Ton/rai (25-30 kg./clump)

  Chemical fertilizer : 15 : 15 : 15

  (Approx. 30 – 40 kg/Rai - 0.5kg/clump)

- Shovel and cover with hay around clump

2.1.7 Bamboo utilization

Bamboo is widely utilized in the daily life of the Thailand people, in such areas as bamboo construction, bamboo daily utensils, bamboo shoot, bamboo musical instrument, bamboo for its culture development.

2.1.7.1 Bamboo construction

Among all the colorful Thailand ethnic culture, bamboo house is one of the typical representatives. As bamboo is easily accessible, and has very high properties of pressure resistance and tension resistance, bamboo is commonly utilized in the traditional construction. With the advance of science and technology and the requirement for environmental-friendly materials, bamboo house as a green construction is getting more popular in the current market.

2.1.7.2 Bamboo house

Bamboo house is big in space, and well ventilated, which has an ideal construction structure for humid climate like Thailand. Living in bamboo house is cool in summer season and warm in winter season. It is also resistant to moisture and earthquake. It can always been seen in some rural areas.

However, bamboo house usually occupies a large space of land, and psychologically, young people prefer to spend a large sum of money to buy a cement house in the city rather than to buy an informal house like bamboo house in rural areas. Therefore, bamboo houses and bamboo villas are mainly in some tourism spots. As folk house, it can only been seen in some of the ethnic communities.

Pic.10 Bamboo house in Thailand

Located in tropical region, Thailand has very hot climate. Additionally, Thailand people like enjoying life and bamboo pavilion in all styles can been seen commonly in the public places such as streets, schools and parks etc.. *Dendrocalamus* and *Bambusa*, due to their good timber quality and fine flexibility, are the most utilized genera for making the bamboo pavilion. Bamboo leaves and straws are covered on the top of the pavilion as the roof. Bamboo pavilion is a place for Thailand people to take a rest when they feel hot or tired. In the spring festival, bamboo pavilion is a social place for the local people to do the performance, celebrate the festival. Organizing parties, singing, dancing, playing guitar etc. in the bamboo pavilion is a usual activity for Thailand people.

2.1.7.2 Bamboo and food

Farmers in northern Thailand are heavily reliable to the forest resources and always harvest a large quantity of forest fruits and vegetable. Bamboo, thanks to its good taste and rich nutrient, is one of the traditional good for Thailand. Bamboo shoot with acid and spicy is one of the typical flavor in Thailand dishes. Bamboo shoot can is also very common in the supermarkets, quite marketable in Thailand. It is also an important export product, and the major export destination is EU and Australia etc.. The export trade value in 2016 is up to USD13,320,130.

Pic.11 Bamboo shoot in Thailand

2.1.7.3 Bamboo musical instrument

Thailand music is originated from China and India, therefore, it sounds similarities with the music of China and India. Bamboo musical instrument is a dispensable component in Thailand music system. *Cephalostachyum* and *Schizostachyum* are thin in the wall and long in internode distance, which are regarded as an excellent material for making musical instrument.

2.1.7.4 Bamboo crafts and handicrafts

Bamboo crafts and handicrafts have long history in Thailand. Bamboo handbags are delicately made.

Pic.12 Bamboo crafts and handicrafts

2.1.7.5 Bamboo furniture

Bamboo is also used for furniture use, including bamboo bed, bamboo sofa and bamboo chair. Most of them are using the whole culm and handmade, and no large-scaled commercialization has been realized.

Pic.12 Bamboo furniture in Thailand

2.1.7.6 Others

Bamboo is also used in other areas including agriculture utensils, bamboo cosmetics and bamboo for costal defense and bamboo for religious sacrifice etc..

2.1.8 Conclusion

(1)Bamboo has a long history utilization in Thailand and closely related to the people's daily life.

(2)Thailand has accumulated a series of technologies in bamboo cultivation, processing and utilization, but the techniques needs to be upgraded.

(3)Bamboo has very wide application areas in Thailand, including construction, food, agriculture, furniture, chemical use etc..

(4)With the awareness-rise of the environmental protection, bamboo has been gained more attention both by the government and the public. Bamboo is more commonly used in Thailand, esp. in the areas of construction.

(5) Bamboo products is mainly used domestically, however, preserved bamboo shoot is an important bamboo products for EU and Australia market.

2.2 Indian bamboo Development survey report

2.2.1 Basic information:

2.2.1.1 Country profile:

India is second most populous country in the largest world. About 60 percent of the population is still living close to, or below, the poverty line. Its history dates back to 2500 B.C. India is now one of the fastest growing economies in the world with a large skilled workforce. The country has a burgeoning urban middle class and has made great strides in fields such as information technology. Work force is estimated around 450 million. Agriculture is around 60% of the national economy; industry and commerce is 18% and services and government around 22%.

2.2.2 Forestry development

2.2.2.1 Forest resources

India is a large and diverse country. Its land area includes regions with some of the world's highest rainfall to very dry deserts, coast line to alpine regions, river deltas to tropical islands. There are 600 species of hardwoods, including *sal* (*Shorea robusta*).India is one of the 12 mega biodiverse regions of the world. Indian forests types include tropical evergreens, tropical deciduous, swamps, mangroves, sub-tropical, montane, scrub, sub-alpine and alpine forests.

2.2.2.2 Forestry Economy

Significant forest products of India include paper, plywood, sawn wood, timber, poles, pulp and matchwood, fuelwood, sal seeds, tendu leaves, gums and resins, cane and rattan, bamboo, grass and fodder, drugs, spices and condiments, herbs, cosmetics, tannins and other non-wood forest products.

India is a significant importer of forest products. Logs account for 67 percent of all wood and wood products imported into India due to local preference for unprocessed wood.

Indian market for unprocessed wood is mostly fulfilled with imports from Malaysia, Myanmar, Côte d'Ivoire, China and New Zealand.

India is growing market for partially finished and ready-to-assemble furniture. China and Malaysia account for 60 percent of this imported furniture market in India followed by Italy, Germany, Singapore, Sri Lanka, the United States, Hong Kong, and Taiwan.

India is the world's largest consumer of fuelwood. India's consumption of fuelwood is about five times higher than what can be sustainably removed from forests. However, a large percentage of this fuelwood is grown as biomass remaining from agriculture, and is managed outside forests. Fuelwood meets about 40 percent of the energy needs of the country. Around 80 percent of rural people and 48 percent of urban people use fuelwood.

Forestry in India is more than just about wood and fuel. India has a thriving non-wood forest products industry, which produces latex, gums, resins, essential oils, flavours, fragrances and aroma chemicals, incense sticks, handicrafts, thatching materials and medicinal plants.

About 60 percent of non-wood forest products production is consumed locally. About 50 percent of the total revenue from the forestry industry in India is in non-wood forest products category. In 2002, non-wood forest products were a source of significant supplemental income to over 100 million people in India.

2.2.2.3 Strategy to increase cover

India has a tendency of deforestation. In the 1970s, India declared its long-term strategy for forestry development to compose of three major objectives: to reduce soil erosion and flooding; to supply the growing needs of the domestic wood products industries; and to supply the needs of the rural population for fuelwood, fodder, small timber, and miscellaneous forest produce.

India's national forest policy expects to invest US$ 26.7 billion by 2020, to pursue nationwide afforestation coupled with forest conservation, with the goal of increasing India's forest cover from 20% to 33%.

2.2.3 Bamboo Development

2.2.3.1 General Information

In the Indian forestry sector, bamboo, which is referred as minor forest produce in classical forestry, is the most important sub-sector. Bamboo is one of the most abundant and renewable resources available .Bamboo, being a source of raw material to many industries such as pulp and paper, rayon, and fiberboard industry, has been critical in the forest-based industrial development in India.

2.2.3.2 Bamboo Resources

India is the second richest bamboo resource country in the world, next only to China. India has 136 bamboo species under 75 genera. About 89 bamboo species out of the species recorded in India fewer than 16 genera grow naturally in different forest areas or are cultivated. The annual bamboo production in India is estimated at 3.23 million tons.

India has about 30% of the world's bamboo resources with growing area of 8.9 million ha, but the country taps only one-tenth of its bamboo potential and contributes only 4% share of the global market mainly because of low productivity of around 2 tons/ha/annum.

It is found to grow practically all over the country, tropical, sub-tropical and temperate regions where the annual rainfall ranges between 1,200 mm to 4,000 mm and the temperature varies between 16^{o}C and 38^{o}C.

The most suitable conditions for the occurrence of bamboo are found in between 770-1,080 meter above sea level. Two-thirds of the growing stock of bamboo in the country is available in the north-eastern states.

Clump forming bamboo constitute over 67% of the total growing stock, of which *Dendrocalamus strictus* is 45%, *Bambusa bambos* 13%, *D. hamiltonii* 7%, *B. tulda* 5% and *B. pallida* 4%. All other species put together are 6%. *Melocanna baccifera*, a non-clump forming bamboo, accounts for 20% of the growing stock and is found in the north-eastern states.

Bamboo falls into two main categories according to growth pattern, (i) sympodial or clump forming, and (ii) monopodial or non-clump forming, runner bamboo.

The following are the list of indigenous bamboo species:

Table 8. Indigenous bamboo genera and species in India

No.	Species
1	*Ampelocalamus patellaris (Gamble)*
2	*Arundinaria simonii (Carr.)*
3	*Arundinaria racemosa Munro*
4	*Bambusa atra Lindl.*
5	*Bambusa auriculata Kurz*
6	*Bambusa balcooa Roxb.*
7	*Bambusa bambos (Linn.)*
8	*Bambusa burmanica Gamble*
9	*Bambusa cacharensis Majumdar*
10	*Bambusa copelandi Gamble*
11	*Bambusa griffithiana Munro*
12	*Bambusa jaintiana Majumdar*
13	*Bambusa khasiana Munro*
14	*Bambusa longispiculata Gamble ex Brandis*
15	*Bambusa mastersii Munro*
16	*Bambusa multiplex (Lour.) Raeusch. ex Schult.*
17	*Bambusa nutans Wall. ex Munro*
18	*Bambusa oliveriana Gamble*
19	*Bambusa pallida Munro*
20	*Bambusa polymorpha Munro*
21	*Bambusa pseudopallida Majumdar*
22	*Bambusa teres Buch.-Ham. ex Munro*
23	*Bambusa tulda Roxb*
24	*Bambusa vulgaris Schrad. ex Wendl.*

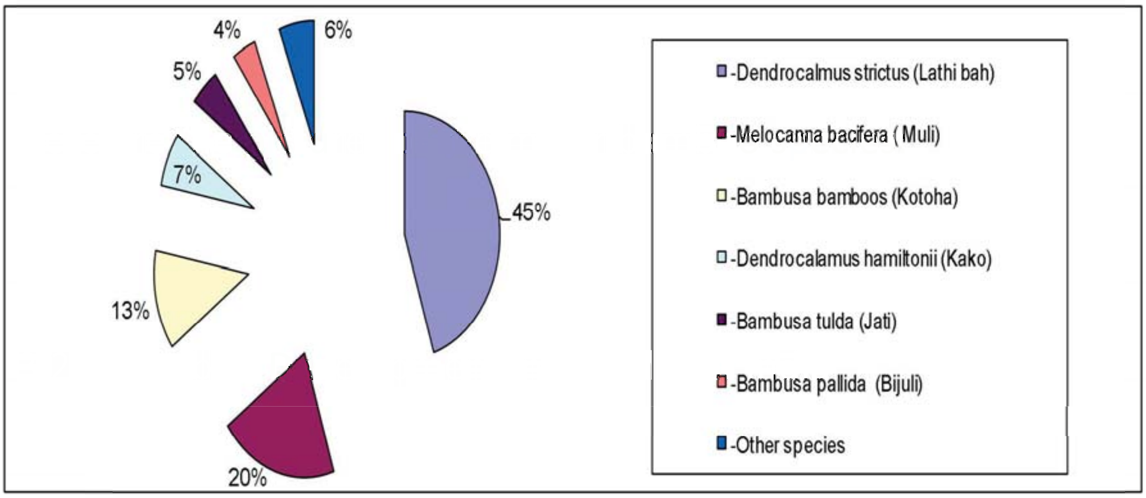
No.	Species
25	*Bambusa vulgaris var. striata (Lodd. ex Lindl.) Gamble*
26	*Bambusa vulgaris forma waminii (Brandis) Wen*
27	*Chimonobambusa callosa (Munro)*
28	*Dendrocalamus asper (Schult.f.) Back. ex Heyne*
29	*Dendrocalamus brandisii (Munro) Kurz*
30	*Dendrocalamus calostachys (Kurz) Kurz*
31	*Dendrocalamus giganteus Munro*
32	*Dendrocalamus hookeri Munro*
33	*Dendrocalamus hamiltonii Nees et Arn. ex Munro*
34	*Dendrocalamus longispathus Kurz*
35	*Dendrocalamus membranaceus Munro*
36	*Dendrocalamus parishii Munro*
37	*Dendrocalamus sahnii Naithani*
38	*Dendrocalamus somdevai Naithani*
39	*Dendrocalamus sikkimensis Gamble*
40	*Dendrocalamus strictus (Roxb.) Nees*
41	*Dendrocalamus strictus var. sericeus (Munro) Gamble*
42	*Dinochloa andamanica Kurz*
43	*Dinochloa maclellandii (Munro) Kurz*
44	*Dinochloa nicobarica Majumdar*
45	*Gigantochloa albociliata (Munro) Kurz*
46	*Gigantochloa apus (Bl. ex Schult.f.)*
47	*Gigantochloa atroviolacea Widjaja*
48	*Gigantochloa atter (Hassk.) Kurz*
49	*Gigantochloa macrostachya Kurz*

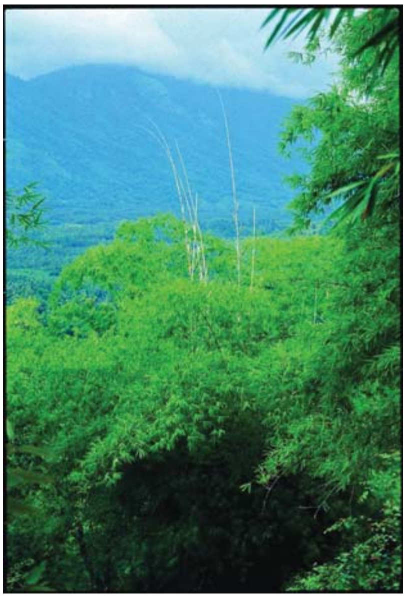
No.	Species
50	*Gigantochloa pseudoarundinacea (Steud.) Widjaja*
51	*Gigantochloa rostrata Wong*
52	*Melocalamus compactiflorus (Kurz) Benth.*
53	*Melocalamus indicus Majumdar*
54	*Melocanna arundina Parkinson (Melocanna humilis Kurz)*
55	*Melocanna baccifera (Roxb.) Kurz (Melocanna bambusoides Trin.)*
56	*Neomicrocalamus andropogonifolius (Griff.) Stapleton*
57	*Neomicrocalamus mannii (Gamble)*
58	*Neomicrocalamus prainii (Gamble)*
59	*Ochlandra beddomei Gamble*
60	*Ochlandra ebracteata Raizada & Chatterji*
61	*Ochlandra scriptoria (Dennst.) Fisch.*
62	*Ochlandra setigera Gamble*
63	*Ochlandra sivagiriana (Gamble) Camus*
64	*Ochlandra talbotii Brandis*
65	*Ochlandra travancorica Benth*
66	*Ochlandra travancorica var. hirsuta Gamble*
67	*Ochlandra wightii (Munro) Fischer*
68	*Pseudoxytenanthera bourdillonii (Gamble)*
69	*Pseudoxytenanthera monadelpha (Thw.)*
70	*Pseudoxytenanthera ritcheyi (Munro)*
71	*Pseudoxytenanthera stocksii (Munro)*
72	*Phyllostachys aurea Carr.*
73	*Phyllostachys bambusoides Sieb. & Zucc.*
74	*Phyllostachys mannii Gamble*

No.	Species
75	*Phyllostachys nigra (Lodd. ex Lindl.) Munro*
76	*Pseudosasa japonica (Sieb. & Zucc. ex Steud.)*
77	*Sasa palmata (Marl. ex Burb.) Camus*
78	*Schizostachyum arunachalensis Naithani*
79	*Schizostachyum beddomei (Fischer)*
80	*Schizostachyum capitatum (Munro)*
81	*Schizostachyum dullooa (Gamble)*
82	*Schizostachyum flavescens (Kurz)*
83	*Schizostachyum griffithii (Munro)*
84	*Schizostachyum helferi (Munro)*
85	*Schizostachyum kurzii (Munro)*
86	*Schizostachyum latifolium (Munro)*
87	*Schizostachyum mannii Majumdar*
88	*Schizostachyum pallidum (Munro)*
89	*Schizostachyum pergracile (Munro)*
90	*Schizostachyum polymorphum (Munro)*
91	*Schizostachyum rogersii Brandis*
92	*Schizostachyum seshagirianum Majumdar*
93	*Sinarundinaria anceps (Mitf.)*
94	*Sinarundinaria arunachalensis Naithani*
95	*Sinarundinaria densifolia (Munro)*
96	*Sinarundinaria elegans (Kurz)*
97	*Sinarundinaria falcata (Nees)*
98	*Sinarundinaria griffithiana (Munro)*
99	*Sinarundinaria hirsuta (Munro)*

No.	Species
100	*Sinarundinaria hookeriana (Munro)*
101	*Sinarundinaria intermedia (Munro)*
102	*Sinarundinaria longispiculata Chao & Renvoize*
103	*Sinarundinaria maling (Gamble)*
104	*Sinarundinaria microphylla (Munro)*
105	*Sinarundinaria naglandiana Naithani*
106	*Sinarundinaria pantlingii (Gamble)*
107	*Sinarundinaria polystachya (Kurz ex Gamble)*
108	*Sinarundinaria rolloana (Gamble)*
109	*Sinarundinaria walkeriana (Munro)*
110	*Sinarundinaria wightiana (Nees)*
111	*Thamnocalamus aristatus (Gamble)*
112	*Thamnocalamus falconeri Hk.f. ex Munro*
113	*Thamnocalamus spathiflorus (Trin.)*
114	*Thyrsostachys oliveri Gamble*
115	*Thyrsostachys regia (Munro)*

Fig.1 Species-wise distribution of bamboo in India

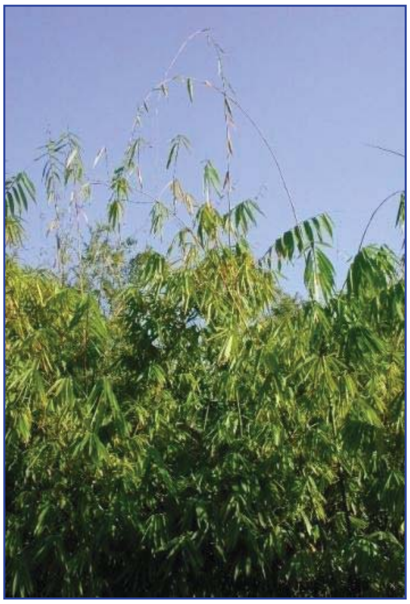




Pic.13 ***Dendrocalamus stictus***

Pic.14 ***Melocanna baccifera***

Pic.15 ***Bambusa bambos***



Pic.16 ***Dendrocalamus hamiltonii***

Pic.17 ***Bambusa tulda***

Pic.18 ***Bambusa pallida***

2.2.3.3Bamboo in North East India

Over 39% of the total area under Bamboo in India is available in the North East Region. Bamboo has immense potential in improving the rural economy, promoting industrial development and establishing a sound economic base for the states on sustainable basis.

Table 9 Status of bamboo area in North East India

States	Bamboo Growing Areas(Sq. Km)
Arunachal Pradesh	16,083
Assam	7,238
Manipur	9,303
Meghalaya	4,793
Mizoram	9,245
Nagaland	4,902
Tripura	3,246
Total	**54,810**

Bamboo is an important resource in the socio- economic-ecological-climatic- functional context for the North Eastern States and has traditionally been utilized for a variety of purpose. There has been a concerted effort by the Government of India to encourage development in the North Eastern States through development of its Bamboo resources

All states in NE have the Bamboo Development Agency which works towards development of bamboo as a resource as well as an Enterprise. Some of the strategies for development of bamboo by the bamboo development agencies involves: Inventory of current bamboo resources； creating massive and consistent awareness of the value of bamboo among the people, especially among major stakeholders； introduction of desirable species of commercial importance for cultivation ； establishment of infrastructure and mechanism for dissemination of bamboo production technologies to the common man.

Funding sources include:

For Resource Development: NBM Ministry of Agriculture & Co- operation Govt. of India

For Enterprise Development: ECTAR Ministry of Science & Technology Govt. of India

2.2.3.4 Bamboo market in India

India is one of the largest reserves of bamboo in the world today. The size of the domestic bamboo economy has been estimated at around 2000 crores by the Planning Commission. The market potential however is estimated at around 4500 crores. The average bamboo productivity is around 2 tons/acre. 85% bamboos are grown in wild condition, and only 20% are harvested. Plantation is not yet a culture. India only has around 5% of the international market share. The Indian government has come to regard bamboo as an easily manageable export item that provides high yields, has lots of uses and has the potential to provide employment for millions.

2.2.3.5 Usage of bamboo in India

Bamboos have been used by people in imaginative and widely varied ways wherever they are found. Bamboos in India are used for the following purposes.

Table 10 Consumption of bamboo in India

Uses	Consumption (Million tones)
Scaffolding	3.40
Handicraft sector	2.55
Paper Industries	2.5
Miscellaneous	1.97
Internal consumption	1.35
Illegal exports to BD & Myanmar	1.7

2.2.3.5.1 House Construction

More than 25% of Indians people live under poverty line, and can not afford for the brick built houses. Therefore, bamboo housing may become low cost alternative. Bamboo has been used for house construction in different ways as roofing, bamboo reinforced wall, light bamboo wall, bamboo flooring, doors and windows, scaffoldings.

Pic. 19 Bamboo house in India

Pic. 20 Bamboo house in India

2.2.3.5.2 Bamboo handcrafts

A large number of cottage industries like manufacturer of tablemats, bamboo wares, trays are dependent on bamboo as raw material. Many articles of common domestic use like mats, baskets, toys, nets, wall plates, trays etc. are made from bamboo. Bamboo articles with different sizes and shapes are made with bamboo strips for decorative arrangement of flowers and fruits, a common musical instrument in India is made out of bamboo.

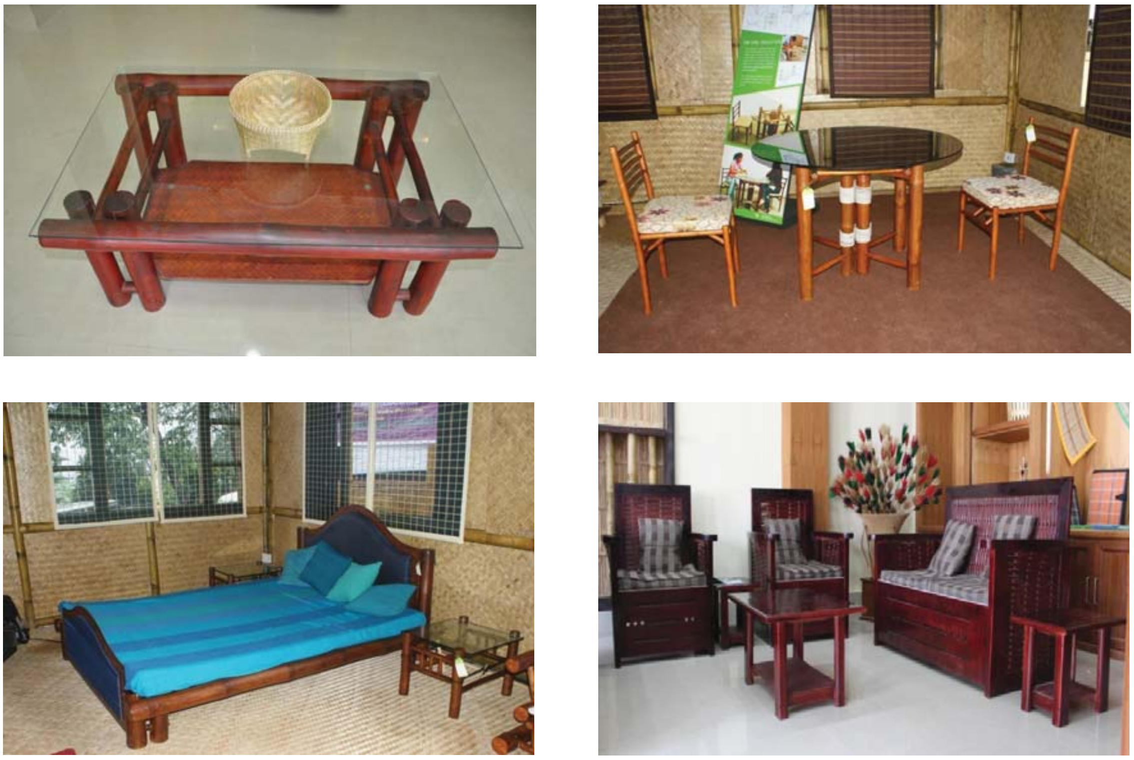
Pic. 21 Bamboo weavings in India

Pic. 22 Bamboo weavings in India

Pic. 23 Bamboo musical instruments in India

2.2.3.5.3 Furniture

Bamboo furniture is getting popular since it is cheap and lighter than timber cased furniture. Due to the sharp increase in the price of timber, bamboos are increasingly used for furniture. The bamboo based furniture, fancy basket-ware and high value decorative materials are increasing day by day in national and international market.



Pic. 24 Bamboo furniture in India

2.2.3.5.4 Bamboo Fuel and fodder

Another important use for bamboo is for fuel and fodder. Bamboos culms are an excellent source of fodder, while the leaves are palatable.

Pic. 25 Bamboo charcoal in India

2.2.3.5.5 Others

Besides, bamboos in India are also be used in farming, food, fishing utensils, cultural/religious items, ecological conservation and medicines etc..

2.2.3.6 Conclusion.

Similar to China, India is a big country withabundant bamboo resources, a long history of bamboo use and huge bamboo development potential. Esp. the North East Region of India has acknowledged as store house of bamboo having more than 2/3 of national bamboo resources. Bamboo has traditional roots with the people of this region and associated with the cultural and living habits. India is quite advanced in bamboo pulp and paper making. But in generally speaking, bamboo's utilization is mainly restricted in traditional, handcrafts and low-value-addition products. In recent years, some high value-added bamboo products have been successfully explored out, e.g. but still requires more efforts to make the application, industrialization and commercialization happen.

India has great potential in bamboo charcoal development for the fuel use which could alleviate the tendency of deforestation as well as meet the domestic demand. Bamboo plywood is also in an increasing demand due to the booming development of real estate. Besides, bamboo can also developed in medicine use.

2.3 Bamboo development survey report of Kenya:

2.3.1 Basic information:

2.3.1.1 Country profile:

The Republic of Kenya is located in East Africa, and lies between latitudes 5° N and 5° S and longitudes 34° and 42° E. It has a total area of 580, 367 Sq. Km, including over 11,000 Km^2 of water. Kenya has boundaries with Uganda in the east, Ethiopia and Sudan in the north, Tanzania in the south and Somalia in the west. The estimated current population of Kenya is about 48 million, with a growth rate of 3.0%. About 51% of the total population lives under the poverty line and about 79% lives in rural areas where they mainly depend on the agriculture to live. Nationwide, the unemployment rate is about 40% and the Human Development index is 0.55, which is considered as "low human development" (UNDP, 2017).

Kenya is a presidential representative democratic republic and has a multi-party system. The executive power is exercised by the executive branch of government (comprising of president, deputy president and cabinet secretaries of government), the legislative power is vested with the elected members of parliament (assembly and senate), Judiciary is independent of executive and legislature. Kenya is divided into 47 semi-autonomous counties that represent the first-order administrative divisions, followed by further sub-divisions into sub-county and locations (smallest administrative unit).

FAO (2015) estimates that forest lands accounts for 4 413000 hectares, representing the 7% of the total area. More than the 80% of the land area of Kenya consists of arid and semi-arid lands (ASALs), where population density is low and livelihoods are mainly based on livestock. Most of the rural population is concentrated on the remaining 20% where the rainfall is higher and soils are suited for agriculture. Only about 12% of the total national land is suitable for the closed canopy forest, and the current land covered by canopy forest accounts for only 2%.

2.3.2 Forestry development

2.3.2.1 Forest in Kenya

The contribution of the forestry sector to Kenya's GDP is about 3.6%, excluding charcoal and the direct subsistence uses. However, the forests provide ecosystem services and support other productive activities, such as agriculture, fishery, livestock, energy, wildlife, water, tourism, trade and industry, which accounts for between 33% and 39% of the national GDP. Private forestry sector is increasing by over 20 percent, and currently create an employment for over 27000 people. However, the 2030 is a serious problem for Kenya, with a deforestation rate of at least 50 000 hectares/year. The forestry resources are of special importance for the energy sector, where about 80% of all the energy used nationwide comes from the biomass

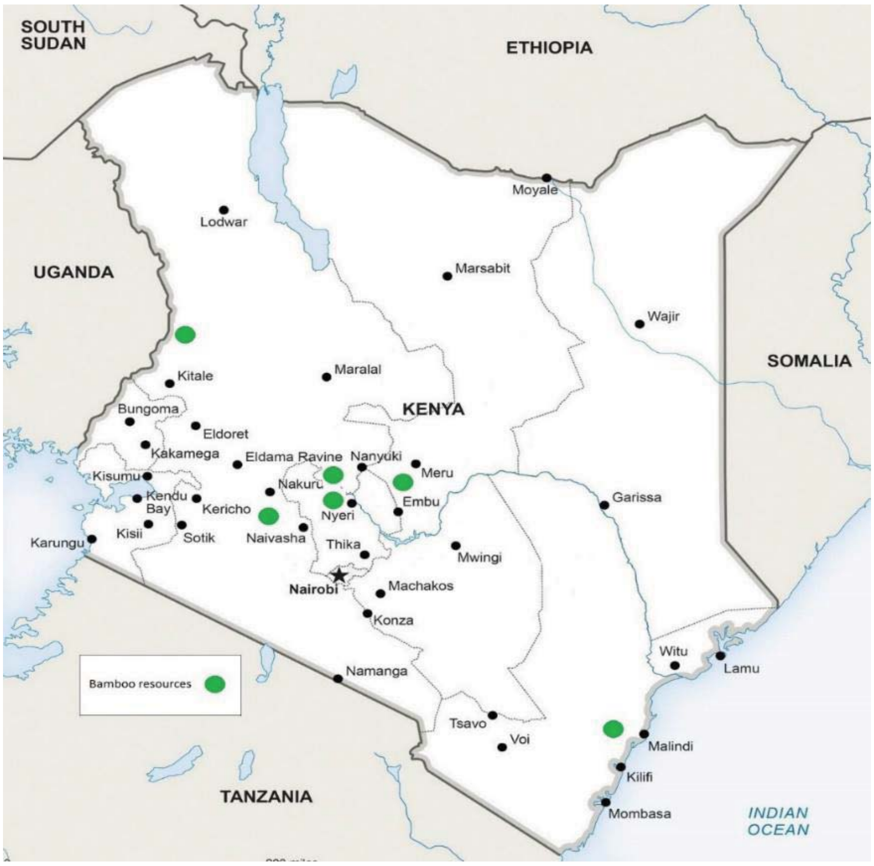
2.3.2.2 Bamboo Development

2.3.2.2.1 Bamboo resources

It is estimated that a total bamboo growing area is about 150,000 ha in Kenya, out of which 70,000 hectares is pure bamboo forests, and remaining is growing as mixed forests. The only indigenous species of bamboo in Kenya is *Yushania alpina*. However, FAO estimates the total bamboo growing area in Kenya is about 124,000 ha. The standing stock is bamboo forest is estimated at over 600,000 MT, with an average productivity of over 5 MT per hectare. According to the recent GIS based bamboo inventory conducted by INBAR and Tsinghua University (China), bamboo forest covers 140,000 ha land area in Kenya. The bamboo forest in Kenya is mostly found in an altitude between 2200 m and 3300 m Above Mean Sea Level (AMSL). The dominant species of bamboo is *Yushania alpina K. Schumach*, and it is found mainly in Mount Elgon, Mount Kenya, Cherang'any Hills, the Mau Forest and the Aberdare Range.

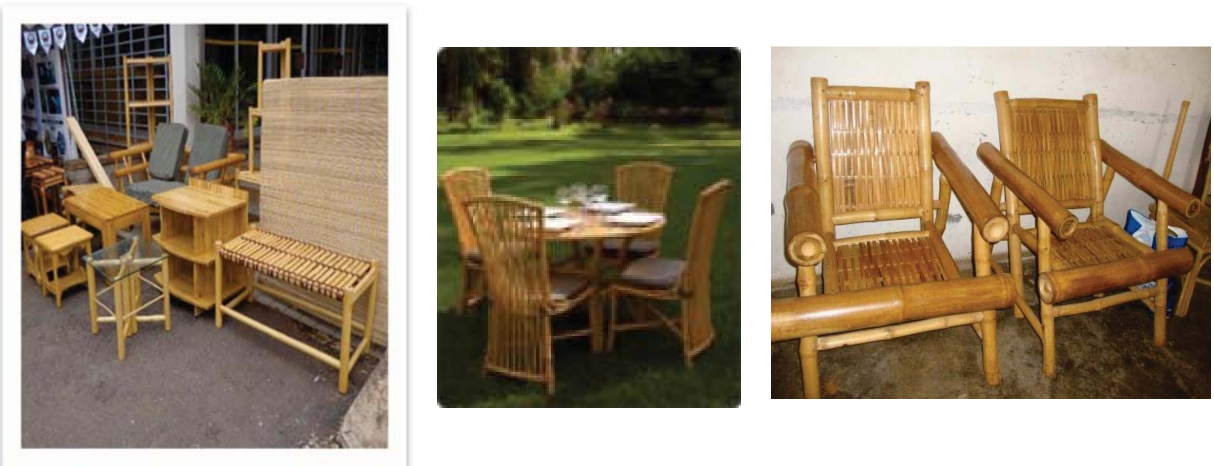
In addition, around 20 bamboo species from Asia were introduced into Kenya, which are mostly found in farmlands. The species include *Bambusa brandisii, Bambusa vulgaris var. striata, Bambusa bambos, Bambusa tulda, Dendrocalamus membranaceus, Dendrocalamus strictus, Gigantochloa aspera, Oxytenanthera abyssinica, Phyllostachys pubescens* and *Thyrsostachys siamensis*.

Pic. 26 Distribution of the bamboo resources in Kenya



2.3.2.2.2 Bamboo usage

Bamboo is a source of raw material for sustenance uses, and provides raw material to few industries, with different levels of processing and technology. The main products are baskets, toothpicks, incense sticks and bamboo shoots. Bamboo poles are also used for fencing, rural construction and as props/ tutors in horticulture and floriculture industry. It is estimated that the potential production and consumption of bamboo poles is around 25 million poles per year, mainly harvested from natural forests.



Pic.27 Bamboo furniture in Kenya

Pic.28 Bamboo handcrafts in Kenya

2.3.2.2.3 Bamboo economy

There is no information available on the contribution of the bamboo sector to national economy or to the forest sector. However, there are clear indicators on the role of bamboo for job creation and additional income generation to the family economies. Data of international trade (both export and imports of bamboo products) shows that Kenya is a negligible player in global bamboo sector. Kenya's import and export of bamboo products account for 0.06% and 0.02% respectively of the global trade.

Kenya's average value of bamboo and rattan products imports during 2009-13 was valued at USD 0.8 million; and exports during the same period is valued at USD 0.27 million. The major imported products are bamboo flooring, plywood and bamboo / rattan furniture. Annually, bamboo flooring, bamboo ply board, and bamboo / rattan furniture worth USD 209, 104, USD 355, 314 and 163, 346 respectively are imported.

2.3.2.3 Conclusion

Kenya is rich in bamboo resources and ripe for bamboo industry development as there is need to relieve pressure from wood timber. Bamboo products import and export are very small in the international bamboo trade. Local bamboo products are available in the market but still in a small quantity and low level. Reaping the benefits of investment in bamboo will require an integrated approach for sustainable rural development, linking environmental conservation with improvement of community livelihoods, access to business financing, skills and appropriate technologies, and an effective marketing system.

3. International market survey in some developed countries

3.1 International market survey in USA and Canada

There are only a few kinds of native bamboo resources in the USA. Expect *Arundinaria* and its two sub-species, thare are no indigenous bamboo species in USA. At the end of the 19th century, bamboo started to be introduced into USA. In the early 20th century, the Agriculture Ministry of USA conducted a research on bamboo pulp and paper-making and introduced quite a lot of bamboo species from all over the world. In the late 1970's, USA established the bamboo association to carry out the activities including bamboo education publicity and species introduction etc.. USA is also very active in bamboo processing and trading, around 40-50 bamboo companies exist in the USA, and majority of them are bamboo products distributors. The horticulture industry in USA developed very rapidly, there are about 150 bamboo nurseries for bamboo species trading, including 6 large-scale production and sales companies, 12 specialized bamboo nurseries and about 10 companies have the import rights for exotic species introduction. A relatively complete production, supply and marketing service system has been established in USA. There are several hundred of bamboo products in the USA market and most of them are imported. The biggest import partners are China, Japan, Indonesia, Thailand, Vietnam India etc.. As we can see from the table??, USA occupies 24.6% of the global import market share. Bamboo plywood, bamboo& rattan seats, bamboo basket work and bamboo & rattan furniture are the 4 top import categories, whose import values average USD59,351,616, USD55,502,711, USD53,649,719 and USD50,927,147 respectively of the year 2015-2017. It is also noted that bamboo shoot is largely consumed in USA, mainly because there are a large quantity of Asian immigrates.

Canada is not a suitable destination for bamboo's growth due to its cold weather in winter; however, it is a market can not be neglected. the import value of bamboo products averages USD21,535,198, accounting 1.8% of the global market share, and the main import categories are concentrated in bamboo & rattan furniture ,bamboo basket work and bamboo plywood.

3.2 International market survey in EU

There are no natural bamboo species in Europe, but due to the personal hobbies, the emphasis on environmental beautification and conservation of ecology, European countries such as Italy, Germany, France, the Netherlands, and the United Kingdom have introduced a large number of bamboo species from some bamboo producing countries in Asia, Africa and Latin America. In 2000, the "European Bamboo Association" was established, and a number of bamboo ornamental gardens and bamboo gardens for scientific research were established. In 2002, the European Commission funded the "Bamboo in Europe" project, planting some bamboo species in northern Germany, collecting different bamboo species and their genetic types and doing the evaluation. Though bamboo industry in Europe is still in fancy, whose scale is relatively small, its impact is noticeable. It has stimulated a lot of enthusiasm and interest in the development of the bamboo industry in EU, and its bamboo resource utilization level is relatively high. The EU has continuously funded some major projects such as "Bamboo Sustainable Management and Bamboo Quality Improvement" and "European Bamboo Action Plan" in Germany, Belgium, the Netherlands, France, Italy and Spain. Bamboo, as a new resource, has been widely applied in some emerging fields, esp. in the field of bamboo bio-performance development, bamboo deep processing, landscaping, bamboo horticulture and design in construction, fashion etc.

EU is the second largest bamboo product importer in the world, with an annual import average value of USD284,634,880 of the year 2015-2017. Bamboo and rattan furniture, bamboo raw materials and bamboo basket work are the 3 major import categories. While, EU is also one of the biggest bamboo shoot export destination, with an annual average import value amounting to USD25,823,064 of 2015-2017.

Table 11. International bamboo trade value of some developed regions

Product Code	Product	Trade Value (USD)										% Product Import	% Product Export
		USA		Canada		Spain		Total EU		Global			
		Import	Export	Import	Export	Import	Export	Import	Export	Import	Export		
140110	Bamboo	21438250	463054	1775886	15717	8908028	1116458	51663055	1334983	139887948	100351480	11.66%	7.03%
200591	Preserved Bamboo Shoot	29761727	248291	163796	6116	2424757	151378	25823069	2198714	226738495	320635691	18.90%	22.45%
460121	Bamboo Mats / Screens	3536826	269805	586185	131789	4016032	840367	17212399	1241191	62947088	84894996	5.25%	5.94%
460192	Bamboo Plaits and Plaiting material	3955370	396679	417530	3469	416226	37625	7207362	178589	24103923	52063621	2.01%	3.65%
460211	Bamboo Basket Work	53649719	1683733	3913893	686821	5841028	1148608	45956584	2350819	165670126	233540191	13.81%	16.35%
440210	Bamboo charcoal	3713193	347676	1059080	978887	475967	923797	1529459	303678	40403489	54454469	3.37%	3.81%
440921	Bamboo Flooring	3327343	3796223	2853905	157326	378799	9137	19870692	2055630	84823167	260622168	7.07%	18.25%
441210	Bamboo plywood	59351616	8131727	3537711	212781	251173	2226375	4624899	2110837	172390184	109262012	14.37%	7.65%
470630	Bamboo pulp	476264	67130	35741	0	174927	453	949014	370731	4709318	4404073	0.39%	0.31%
482361	Bamboo Paper based articles	4120144	1037183	587052	130596	444140	318412	5545815	1022822	36243895	30781449	3.02%	2.16%
940151	Bamboo and Rattan seats	55502711	2496630	1975692	607158	6523103	1760127	42750034	4212172.5	111491086	65683640	9.30%	4.60%
940381	Bamboo and rattan furniture	50927147	4048535	4628727	1084403	4411370	6518242.5	61502498	21577185	130012811	111492247	10.84%	7.81%
Total (USD)		289760309	22986667	21535198	4015061	34265548	15050979	284634880	38957352	1199421530	1428186037	100%	100.00%
Per cent per block (%)		**24.16%**	**1.61%**	**1.80%**	**0.28%**	**2.86%**	**1.05%**	**23.73%**	**2.73%**				

Note: **Global Trade Values are average of 2015-2017.**

4. National bamboo development policy and strategies recommendations for quick and sustainable development of bamboo industry for Thailand, India and Kenya

4.1 Research on China's bamboo development policies and strategies

China has the largest bamboo resources in the world in terms of both area and diversity, accounting for about 6 million ha belonging and 500 species. "Moso bamboo" (*Phyllostachys pubescens*) forests and plantations represent around 70% of the total bamboo resources in China, and is the most important bamboo species economically. The bamboo sector in China has seen a remarkable growth in the last 25 years, due to appropriate policies, strategies, planning and implementation.

4.1.1 China's bamboo sector reform

The bamboo sector in China had seen a remarkable growth in the last 25 years, due to appropriate policies, strategies, planning and implementation. Key policies and action include (a) research and development on bamboo plantation as well as high end value addition (b) land tenure; (c) development of supply-chain linkages.

A key aspect, which enabled the growth and transformation, is land tenure. In China, nearly 4.52 million ha of bamboo forests amounting to 93 percent of the total forest bamboo resource of the country were transferred to collective Forest (community and individuals). Collective Forest (CF) legitimize the rights of land users to manage and benefit from the forest. In the case of CF – land is owned by the government, bamboo / trees is owned by individual/ families / contractor. Within two decades, the annual yield per ha of bamboo forests had increased from four metric tons to over 20 metric tons per ha. The yield improvement happened due to the sustainable management and harvesting practices, and economic benefits from bamboo.

The bamboo revolution in China took part as the general change in the forestry sector experienced three stages of this change.

1) The first (between 1978 and 1984) focused in reforming the forest management system, establishing the "household responsibility system".
2) The second (from 1984 to 1991), changed the resource allocation system, liberalizing the market.
3) The third stage, started in 1992, improved the macroeconomic conditions and the market mechanisms.

b. Land Tenure: Forest Management System:

At the local level, the policies had to adapt to the specific conditions of the land distribution, local forest resources and economic conditions. Overall, the main benefits to farmers under the collective forest system is as follows:

a. Clear Land tenure: User Right title deeds for farmers / collectives / companies with clear land tenure. About 80 percent of the collective forests are under individual household management.

b. The increase of the duration of the leases and the possibility to have larger areas under contract. Currently 30 to 100 years' lease is possible.

c. The establishment, enforcement and standardization of the forest management activities.

d. Provision of financial incentives to encourage the farmers to reforest.

As for the commercialization and trade, the main changes and improvements were:

a. Removal of previous "quota system" and allowing growers to sell their products directly to the market

b. The facilitation of the agreements between farmers and factories

c. Infrastructure development – market for bamboo poles, shoots and products to facilitate marketing and trade.

Reform of Market System

Before 1980, agriculture and forest produce (including bamboo) had established quotas and had to be sold through the Supply and Marketing Cooperatives at fixed price. Since 1985, with policy change, farmers were allowed to sell the bamboo (and other agriculture and forest produce) without a fixed price in an open market resulting in an high increase of market price due to free negotiation.

Opening up of free market mechanism had enabled increasing local processing and value-addition; and developing supply-chain linkages with farmers. This can be illustrated from the below data. During 1978, 95.7% of the total local production of bamboo was sold to other counties and provinces in China. However, by 1994, the sales to other counties fall to 56.6 percent.

Open Door Policy: Macro-Economic Policy and free market

With the "Open door" policy, China allowed the foreign direct investment in China. The main effects were:

a. An increasing in investments, the import of machinery and technology.

b. A multiplier effect and the creation of family semi-processing units at rural areas

c. The use of new technology, especially for bamboo mats, flooring and shoots.

d. A more competitive market that encouraged farmers and companies to improve the quality standards

e. Product diversification and innovation

f. Foreign investment and markets triggered due to presence of foreign investors.

Technology innovation

a.Innovation of bamboo cultivation technology promoting the expansion of bamboo resources and improvement of bamboo timber quality, which laid a solid foundation for processing development.

Bamboo was naturally growing in China for several thousand years, however, before 1980s it was kept in natural growth and primitive use stage with very low value addition. From late 1970s to early 1980s, China started to implement the reform and opening-up policy and resorted to the Economic Development as the central national task. A campaign in many bamboo growing counties with the aims of improving low-yield and low-value bamboo forests and establishing more high-yielding and high-benefits bamboo forests were conducted; and a complete set of advanced bamboo forest management technologies including classification of bamboo forests, site preparation, balance fertilization, water irrigation, pest and disease prevention and control, age marking, selective harvest etc. were applied widely, which has remarkably improved the quantity and quality of bamboo resources. Meanwhile, a large number of high-yield and high-efficient bamboo demonstration sites, some of which are well established with mini-reservoir and irrigation system could generate production value were established.

b. Innovative processing technologies boost the bamboo enterprises and continuously upgrade the bamboo products, becoming the powerful engine for the development of the whole sector.

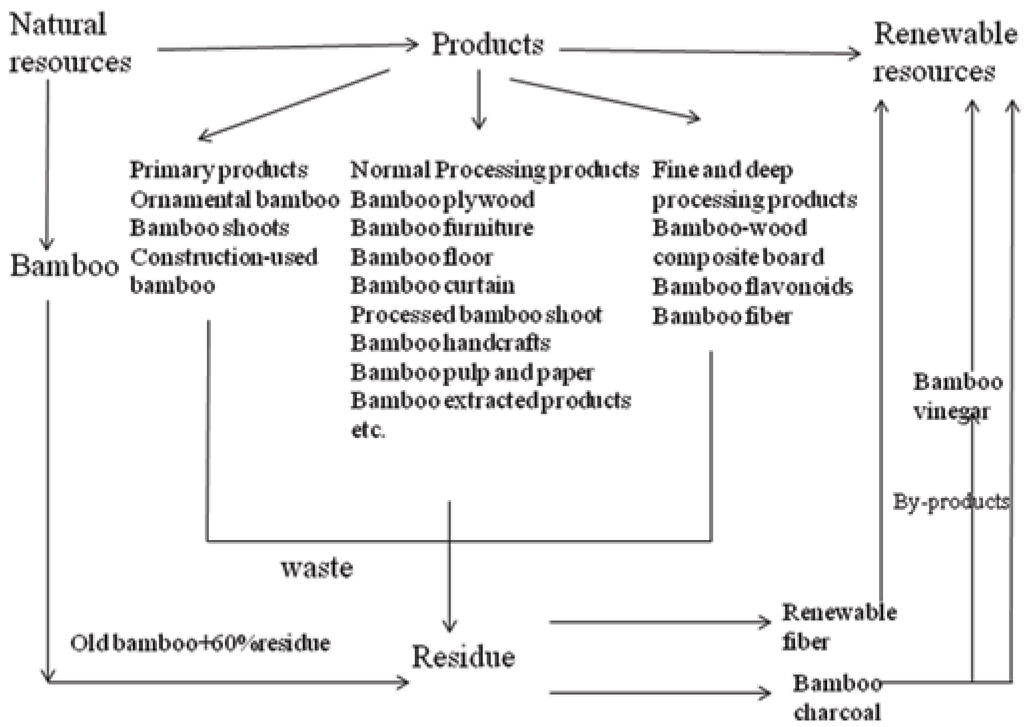
Collaborating with the R&D. Institute, universities and colleges and backed-up by the new processing technologies, a large quantity of new bamboo products including bamboo weaving plywood, bamboo mat, bamboo veneer plywood, bamboo chopsticks and so on were brought out and manufactured in certain big scales and some of the products have been exported to markets overseas.

It should be addressed that each leap in bamboo industry is driven by an important technological revolution. The following are the crucial bamboo processing technologies which have played key roles in making the bamboo industrialization from the traditional way to the modern industrial level: bamboo culm harvesting method, bamboo timber bleaching, preservation and drying, bamboo timber carbonization, manufacturing of bamboo floor (solid bamboo floor, bamboo and wood composite floor, bamboo veneer, bamboo construction plywood, reinforced bamboo floor) and bamboo mat, bamboo curtain and carpet, bamboo charcoal and vinegar, bamboo fiver and fabric, bamboo leave flavonoid-derived health-care products etc.

c. Technology innovation extended the bamboo supply chain, promoted the harmonious development of primary, secondary and tertiary industries and established the bamboo recycling economy

Bamboo is a precious green treasure, which can be comprehensively utilized from the top to the bottom, e.g. the base part of culm can be processed into bamboo charcoal, middle lower part for laminated floor and its derived furniture, middle upper part for bamboo mat /blind, chopsticks, middle upper part for weaving, top part for toothpicks and tips for twigs and branches. Bamboo charcoal, bamboo vinegar, produced from the leftover can be widely used in agriculture, cosmetics and health-care etc., meanwhile, bamboo can also be creatively processed into a new material-bamboo fiber for textile use with a distinct function in anti-bacteria and deodorization. The utilization rate of bamboo is over 95% and bamboo's value could be increased by over 40 times thanks to the constant upgrading of the processing technologies.

The expansion of bamboo plantation and booming bamboo processing also drive the rapid development of the tertiary industry. Take Anji, No.1 bamboo hometown in China for example, it has initially formed a bamboo industry recycling chain, which is symbolized with high-level forest management in the primary industry, a fine and deep processing in the second industry and quality derived service in the tertiary industry. In this cycling chain, bamboo natural resources have been maximized and the waste discharge minimized, whose operation process could be roughly explained in the below graphic.



Research and Development

Institutes & universities strongly back up the technology innovation. In China, there are several famous bamboo R&D institute, universities and organizations, e.g. Nanjing Forestry University, International Subtropical Forestry Institute of Chinese Academy of Forestry (CAF), CBRC, INBAR, Zhejiang Academy of Forestry, Zhejiang Agricultural and Forestry University etc..They are the most dynamic in R&D of bamboo in China and have brought about many contributions and benefits to bamboo development. In the last few years, many bamboo producing counties are closely collaborating with the above-mentioned institutes. Moreover, those R&D institutes also work with local enterprises, and have successfully explored over many new revolutionary products such as new-style bamboo curtain, outdoor bamboo floor, bamboo flavonoids and the derived products, bamboo leaves antioxidant, bamboo fibre and bamboo vinegar etc..

4.2 Bamboo development recommendations for related government departments for 3 countries

4.2.1 Common recommendations

4.2.1.1 Resources assessment: The 3 countries need to take the political decision to undertake the efforts to accurately estimate the extension of the bamboo resources. This effort implies budget, professionals, technicians and the cooperation of allies like CBRC etc.. Without this effort, considerable time and efforts will still being spent in discussions about the extension of the resources, instead of focusing how to use them better.

4.2.1.2 Develop a management plan: vast bamboo forest in the 3 countries are mostly unmanaged. There is an urgent need to develop guidelines for the sustainable management and harvesting. This guidelines must be based in local research and include specific methodologies to estimate the harvesting limits and the renewal rates.

4.2.1.3 National Bamboo Policy: Enact national bamboo policies accommodating the classification, land tenure and other incentives for communities and private sector. National forest act and policies and associated legislations and policies related to needed to be updated to include bamboo in their forest definitions. Bamboo should be included in development policies, strategies and action plan of relevant sub-sectors such as timber/wood, furniture, handicraft, construction and energy to leverage additional resources as well as market.

4.2.1.4 Develop bamboo development Strategy and Action Plan: The National Bamboo Policy should be take top-down to strategies and action plans. Being the bamboo species diverse, as well as their uses, the strategies and action plan should considers their different uses.

4.2.1.5 Land Tenure: State-owned bamboo forests, which encompass the majority of bamboo resources are unmanaged, resulting in poor growth, frequently occurring wild fires, and conversion to other land uses. For productive use, quality enhancement of the bamboo culms is necessary, as each application needs bamboo of a particular size and age. The government can consider long-term leasing the bamboo forests to private companies, individuals and associations who wish to sustainably manage the bamboo resources, under a set of guidelines. Bamboo grown in private lands with titles could plant, harvest, transport and sell bamboo without any legal limits or restrictions, although some benefits can be considered to be given to the owners/communities that voluntarily practice sustainable management activities.

4.2.1.6 Value addition through transformation: Establishment of bamboo plantations is only at a starting point. The real potential of the bamboo for employment and income generation can only be realized through SME enterprise development in the short term; and industrialization and large-scale conversion of bamboo into wood substitutes and composites, energy, food, charcoal and activated carbon. Sectors that could be immediately focused on are:

(a)Bamboo for furniture industry for the domestic market:

Bamboo has proven itself as a suitable material for furniture in various forms. To achieve this, the training and enterprises development strategy must be reviewed and the approach must be widened. The bamboo furniture should base its competitiveness in the quality and not in the price.

(b)Bamboo as substitute for wood and timber for the domestic market:

All the three countries have big demand in wood and its products, and the demand tends to increase driven by the development of real estate industry. Various proven technologies are available for conversion of bamboo into lumber, boards, panels, composites, etc.

(c)Bamboo for energy:

Firewood and charcoal is the main source of cooking fuel in Kenya and India. Bamboo is a suitable energy crop, could be alternated for use as biomass, charcoal, briquette and pellets; technologies of gasification for production of electrical energy, thermal energy; and bio-ethanol production are available. The support of the government on this sector is essential. In the form of special tax regime, preferential purchases or subsidies, the government should encourage the use of a more sustainable source of energy.

(d)Bamboo for construction sector:

The demand for house construction is growing at a rapid pace. Bamboo is a suitable construction material for rural housing, urban housing, and high-end structures for tourism industry. Bamboo is a disaster proof construction material when treated. For the inclusion of the bamboo in the housing programs is necessary to develop standards for construction, train the workforce and develop local house designs. The inclusion of the bamboo as a construction material should start with a review of the traditional building materials and go through the requirements, needs and aspirations of the families in each country. On this regard, also special efforts must be mad in order to break misconceptions related with the quality and durability of the material that in the case of the bamboo houses can represent a main constraint.

(e)Bamboo planting for food security:

Bamboo is a food, feed and fodder. The promotion of small agro-forestry systems to produce bamboo shoots for self-consumption or in a community-base can help to tackle the food security problem in the rural areas, especially in areas where the bamboo shoots are already part of the diet. In Thailand, where some fine sympodial bamboo species is not only good in taste, but also high in production, large plantation should be set up and high technologies should be adopted to realize its large-scale production.

4.2.1.7 Develop Bamboo Clusters

Develop bamboo activities in a close geographical cluster rather than all over the country. Bamboo resource generation, primary processing (preservation and treatment), intermediary processing, and final value addition into products should be done in a cluster approach. This will enable development of supply-chain, minimize wastages, simplify and reduce logistics costs.

4.2.1.8 Public-Private Partnership (PPP):

As in China, to create large-scale demand for bamboo, it is necessary to facilitate development of industries with private investment. The enable the development of PPP the government should:

(1)Engage companies already working in sectors were the bamboo can be used as a raw material. The companies working in the furniture, flooring, charcoal and timber knows the market, have the connections, a brand, trained personnel and the capital.

(2)The government, by giving preferential access to the national bamboo forests, training the personnel on the specifics of the bamboo, giving tax incentives for investments in research and development would encourage private companies to invest in bamboo ventures.

(3)Develop and widely spread local information about yields, regeneration rates, financial feasibility of the management and processing of bamboo and their products, to attract the private sector.

4.2.1.9 Market Development:

Since the bamboo has to deal with several constraints related with prejudges related with its quality and durability, it is necessary from the government to support the bamboo sector. This support can be done in two forms, both related. Through public purchases and the use of bamboo products in public offices, buildings, events and initiatives, the government will give visibility to the sector. This will help to build the public confidence in the material and its products. In parallel, the public purchases will invigorate the sector, providing a regular flow of incomes and promoting the competition within the bamboo sector. Initially, open up government markets – offices, education, hospital, housing, and similar markets to bamboo products such as furniture, biomass and charcoal, construction, bamboo timber products, etc. through appropriate policy initiatives.

In the long-term, the development of the bamboo sector needs special measures to improve the development conditions. These conditions should include:

- Develop commercial markets through appropriate policy initiatives such as special taxation regimes, tax deductions for investments in machinery, research and development, for hiring employees formally, for green products, especially bamboo.

- Provide business development services for enterprises through training and capacity building programs on new product designs, entrepreneurship development, input material supplies, preferential purchase agreements, etc.. Some useful measures should be taken to help enterprises to actively communicate the international market, improve the capacity building etc..
- Support local R & D institutions by providing specific budget. Long-term training to the professionals in bamboo technologies and transformation must be considered a priority. On this, the cooperation with China, through INBAR can play a key role
- Abolition of taxation systems for bamboo and its products; including bamboo processing machines to enable bamboo and its products compete with well-established alternatives.
- Enable availability of loans through banking institutions. To do this, it is first necessary to develop local financial information about the local bamboo sector, such as yields, conversion rates, processing costs, pricing, market assessment and financial viability.

5. Research on technology of bamboo cultivation and utilization and policy level strategic direction to be disseminated in Thailand, India and Kenya

5.1 Research on bamboo cultivation technology（Annex1）

5.2 Research on bamboo processing and utilization technolog （Annex2）

5.3 Research on China's bamboo development administration policies and strategies（Annex3）

6. Technical training of bamboo technologies for Thailand, India and Kenya

6.1 Trainings for 3 counties

6.1.1 The list of trainees from Kenya, Thailand and India

14 participants from Thailand (9), Kenya(3) and India(2) were trained in the workshop on bamboo technology/ forestry industry development organized by CBRC by the Ministry of Commerce, China during 2016-2018. Their training is funded both by G77 and the Ministry of Commerce, China.

The information of the participants is as below:

Table 12: Information of the trainees from Kenya, Thailand and India

No	Name	Gender	Country	Position/Title	Organization	Workshop	Time
1	Caroline Julia Njura Njeru	F	Kenya	Forest Station Manager	Kenya Forest Service	2016 Training Course on Sustainable Bamboo Management and Utilization for African Countries	July 25-Aug.14,2016
2	Tarus Robert Kiplagat	M	Kenya	Forester	Kenya Forest Service	2016 Training Course on Sustainable Bamboo Management and Utilization for African Countries	July 25-Aug.14,2016
3	Gache Jennifer Atieno	F	Kenya	Senior Industrial Engineer	East African Community	2018 Training Course on Bamboo Technologies for the Belt and Road countries	Apr. 23-June.17, 2018
4	Areeyapat Petcharat	F	Thailand	Forestry Technical Officer, Senior Professor level	Royal Forest Department, Forest Research and Development Office	2017 Seminar on High Value-added Forestry Industrial Development for ITTO Member Countries	Jul. 17-Aug. 6, 2017
5	Chanittha Chuntachot	F	Thailand	Forestry Technical Officer, Senior Professor level	Royal Forest Department, Forest Research and Development Office	2017 Seminar on High Value-added Forestry Industrial Development for ITTO Member Countries	Jul. 17-Aug. 6, 2017
6	Suebpradit Bunta	F	Thailand	Project Manager	Sustainable Development Foundation (SDF) - Northern branch	2018 Training Course on Bamboo Technologies for the Belt and Road countries	Apr. 23-June.17, 2018
7	Saman Kanthalak	M	Thailand	Policy and plan analyst officer	National Farmer Council, Thailand	2018 Training Course on Bamboo Technologies for the Belt and Road countries	Apr.23-June.17, 2018
8	Kamsai Bamrungphakdee	M	Thailand	Forestry Technical Officer	Royal Forest Department, Thailand	2018 Seminar on High Value-added Bamboo Use for ITTO Member Countries	Jun.24-Jul.14,2018

No	Name	Gender	Country	Position/Title	Organization	Workshop	Time
9	Thanaporn Trakuldit	F	Thailand	Forestry Technical Officer	Royal Forest Department, Thailand	2018 Seminar on High Value-added Bamboo Use for ITTO Member Countries	Jun.24-Jul.14,2018
10	Tarapol Pumdara	M	Thailand	Scientist	Burapha University, Chanthaburi Campus, Thailand	2018 Seminar on High Value-added Bamboo Use for ITTO Member Countries	Jun.24-Jul.14,2018
11	Saharath Dheerakomporn	M	Thailand	Deputy Director of Office of Innovation Development Burapha University	Burapha University, Thailand	2018 Ministerial Workshop on Forestry Industry for Developing Countries	Oct.30-Nov.5,2018
12	Yossapol Palapol	M	Thailand	Program Director of Agricultural Technology	Burapha University, Chanthaburi Campus	2018 Ministerial Workshop on Forestry Industry for Developing Countries	Oct.30~Nov.5,2018
13	Dhanapal Sujatha	M	India	Researcher	IPIPRTI Ministry of Environment Forests,Climate Change Goverment of India Bangalore	2018 Training Course on Bamboo Technologies for the Belt and Roa d countries	Apr.23-June.17, 2018
14	Nagammanavar Uday	M	India	Researcher	IPIPRTI Ministry of Environment Forests,Climate Change Goverment of India Bangalore	2018 Training Course on Bamboo Technologies for the Belt and Roa d countries	Apr.23-June.17, 2018

6.1.2 Training program for workshops on bamboo technologies:

Table13 2016 Training Program on Sustainable Bamboo Management and Utilization for African Countries(21 days)

Date	Day	Time	Activity	Speaker	Organization	Location
Jul. 24	Sun.	Whole day	Participant arrival and registration	Ding Xingcui	CBRC	CBRC headquarters
Jul. 25	Mon.	Morning	Rest	Cai Hanjiang	CBRC	
		Afternoon	Introduction of CBRC and the program	Cai Hanjiang	CBRC	
Jul. 26	Tues.	09:00-12:00	Opening ceremony	Wang Yukui	CBRC	
		14:00-17:00	Introduction of China	Cai Hanjiang	CBRC	
Jul. 27	Wed.	09:00-12:00	Bamboo biodiversity and conservation	Ma Naixun	Research Institute of Subtropical Forestry, CAF	
		14:00-17:00	Bamboo propagation and nursery construction	Ma Naixun	Research Institute of Subtropical Forestry, CAF	
Jul. 28	Thur.	09:00-12:00	Bamboo cellulose nano-materials	Zhou Chunhui	Zhejiang University of Technology	
		14:00-17:00	Short-rotation plantation in China	Wang Hong	Research Institute of Forest Resource Information Techniques, CAF	
Jul. 29	Fri.	Whole day	Tour in West Lake area	Cai Hanjiang	CBRC	
Jul. 30	Sat.	Whole day	Rest	Tian Xinli	CBRC	
Jul. 31	Sun.	Whole day	Rest	Zheng Youmiao	CBRC	Jinjiang Hotel
Aug. 1	Mon.	Morning	Leaving for Nanjing	Cai Hanjiang	Nanjing Forestry Univ.	
		14:00-17:00	Bamboo physiology	Ding Yulong	Nanjing Forestry Univ.	
Aug. 2	Tues.	09:00-12:00	Application of bamboo in landscaping	Lin Shuyan	Nanjing Forestry Univ.	
		Afternoon	Tour in Nanjing	Cai Hanjiang	Nanjing Forestry Univ.	
Aug. 3	Wed.	9:00-12:00	Returning to Hangzhou	Cai Hanjiang	CBRC	CBRC headquarters
		14:00-17:00	Bamboo shoot processing and preservation	Bai Ruihua	CBRC	

Date	Day	Time	Activity	Speaker	Organization	Location
Aug. 4	Thur.	9:00-12:00	Production and utilization of bamboo charcoal and bamboo vinegar	Zhang Wenbiao	Zhejiang Agriculture and Forestry Univ.	
		14:00-17:00	Bamboo pulp and paper-making	Fang Guigan	Institute of Chemical Industry of Forest Products, CAF	
Aug. 5	Fri.	9:00-12:00	Forest tenure reform in China	Chen Shaozhi	Research Institute of Forestry Policy and Information, CAF	
		14:00-17:00	Bamboo processing theory	Chen Yuhe	CBRC	
Aug. 6	Sat.	Whole day	Rest	Ding Xingcui	CBRC	
Aug. 7	Sun.	Whole day	Rest	Ding Xingcui	CBRC	
Aug. 8	Mon.	Whole day	Study tour in Haining agricultural base	Tian Xinli	CBRC	
Aug. 9	Tues.	Whole day	Study tour in Changxing experimental station of CBRC	Cai Hanjiang	CBRC	Changxing Senhuang Hotel
Aug. 10	Wed.	09:00-12:00	Introduction to bamboo industry in Anji county	Zhang Hongliang	Anji Forestry Bureau	Anji Jinfeng Hotel
		14:00-17:00	Visiting modern high-yield bamboo plantation	Wang Qin	Anji Forestry Bureau	
Aug. 11	Thur.	09:00-12:00	Visiting bamboo machinery factory, bamboo handicraft factory	Wang Qin	Anji Forestry Bureau	
		14:00-17:00	Visiting Anji Bamboo Expo Park and China Bamboo Museum	Wang Qin	Anji Forestry Bureau	
Aug. 12	Fri.	09:00-12:00	Visiting bamboo furniture factory, bamboo fiber factory	Wang Qin	Anji Forestry Bureau	
		14:00-17:00	Visiting bamboo floor factory, bamboo weaving factory	Wang Qin	Anji Forestry Bureau	
Aug. 13	Sat.	Whole day	Country report	Ding Xingcui	CBRC	CBRC headquarters
Aug. 14	Sun.	09:00-12:00	Exam and evaluation	Ding Xingcui	CBRC	
		14:00-16:00	Closing ceremony	Yu Hui	CBRC	
Aug. 15	Mon.	Whole day	Participant departure	Ding Xingcui	CBRC	

Table13 Program for 2017 Training Course on Bamboo Technologies for Developing Countries

Date		Time	Activities	Lecturer
Jun.11	Sun.	Whole day	Participant arrival, registration	
Jun.12	Mon.	10:30-11:30	Opening Ceremony	Yu Hui
		14:00-17:00	Project introduction	Cai Hanjiang
Jun.13	Tues.	09:00-12:00	Biodiversity and Utilization of Bamboo	Ma Naixun
		14:00-17:00	Construction of Bamboo Gardens and ex situ Conservation	Ma Naixun
Jun.14	Wed.	09:00-12:00	Directional cultivation technology for China's Monopodial bamboo	Zhai Zhizhong
		14:00-17:00	Bamboo species introduction and demo-site set-up--A Case study in Rwanda	Tian Xinli
Jun.15	Thur.	09:00-12:00	Properties and theories for utilization of bamboo	Chen Yuhe
		14:00-17:00	Comprehensive utilization of bamboo	Chen Yuhe
Jun.16	Fri.	09:00-12:00	Short-rotation plantation in China	Wang Hong
		14:00—17:00	FGHY Timber Plantation Programs Management in China	Wang Hong
Jun.17	Sat.	Whole day	Rest	
Jun.18	Sun.	Whole day	Rest	
Jun.19	Mon.	Morning	Depart for Nanjing	
		16:00-17:00	Introduction to Nanjing Forestry University	Zhu Jiangang
Jun.20	Tues.	8:30-9:30	Campus tour(Gallery of University History)	Zhang Ying
		9:30-11:30	Molecular biology of bamboo	Wei Qiang
		14:00-17:00	Diagnosis of plant nutrituion and fertilization	Zhang Huanchao
Jun.21	Wed.	09:00-12:00	Physiological studies on bamboo	Xie Yinfeng
		14:00-17:00	Forest genetics and tree breeding in China	Ji Kongshu
Jun.22	Thur.	09:00-12:00	Basic biological characters of bamboo	Ding Yulong
		14:00-17:00	Visiting laboratories	Zhang Ying
		18:00-21:00	Tour in Confucius Temple Market	
Jun.23	Fri.	09:00-12:00	Tour in Sun Yat-sen's Mausoleum	
		Afternoon	Return to Hangzhou	
Jun.24	Sat.	Whole day	Rest	
Jun.25	Sun.	Whole day	Rest	
Jun.26	Mon.	Morning	Depart for Changxing	Zhai Zhizhong
		14:00-17:00	Introduction to Changxing bamboo botanic garden	Zhai Zhizhong
Jun.27	Tues.	09:00-12:00	Visit Changxing acient tree garden and red plum plantation	Zhai Zhizhong
		Afternoon	Return to Hangzhou	Zhai Zhizhong
Jun.28	Wed.	Morning	Challenges and answers for quality and safety of agro-products in China	Wang Qiang
		Afternoon	Visit Yangdu base of Zhejiang Institute of Agricultural	Wang Qiang

Date		Time	Activities	Lecturer
			Sciences	
Jun.29	Thur.	Morning	Depart for Shanghai	
		Afternoon	Tour in the Bund and Lujiazui Area	
Jun.30	Fri.	Morning	Tour in Yu Garden and City God's Temple	
		Afternoon	Return to Hangzhou	
Jul.1	Sat.	Whole day	Rest	
Jul.2	Sun.	Whole day	Rest	
Jul.3	Mon.	Morning	Depart to Anji, introduction to Anji bamboo development mode	Wang Qin
		Afternoon	Visit Moso bamboo modern technological park	Wang Qin
Jul.4	Tues.	Morning	Visit Anji bamboo charcoal museum	Wang Qin
		Afternoon	Visit Anji bamboo handicraft factory	Wang Qin
Jul.5	Wed.	Morning	Visit Anji bamboo botanical garden and China bamboo museum	Wang Qin
		Afternoon	Visit Jitai Machinery Co., Jinma Bamboo Machinery Co., Yongyu Group	Wang Qin
Jul.6	Thur.	Morning	Visit Anji Cozy Home Co. Ltd., Zhuhong Bamboo Plyboard Factory, Hengshanwu Community	Wang Qin
		Afternoon	Visit bamboo beer and bamboo beverage company	Wang Qin
Jul.7	Fri.	Morning	Visit China bamboo market	Wang Qin
		Afternoon	Return to Hangzhou	
Jul.8	Sat.	Whole day	Rest	
Jul.9	Sun.	Whole day	Rest	
Jul.10	Mon.	9:00-12:00	Bamboo economy and market development	Zhu Zhen
		14:00-17:00	Bamboo cellulose nano-materials	Zhou Chunhui
Jul.11	Tues.	9:00-12:00	Desertification combat and desert industry in China	Wang Yukui
		14:00-17:00	Bamboo timber water-proof technology	Wu Zaixing
Jul.12	Wed.	9:00-12:00	Bamboo shoot processing and its nutrition	Bai Ruihua
		14:00-17:00	Studies on bamboo charcoal-based carbon fertilizer	Zhong Zheke
	Thur.	9:00-12:00	Bamboo pulping technology	Fang Guigan
		14:00-17:00	Bamboo pulping technology	Fang Guigan
Jul.14	Fri.	9:00-12:00	Production and utilization of bamboo charcoal and bamboo vinegar	Zhang Wenbiao
		14:00-17:00	Production and utilization of bamboo charcoal and bamboo vinegar	Zhang Wenbiao
Jul.15	Sat.	Whole day	Rest	
Jul.16	Sun.	Whole day	Rest	
Jul.17	Mon.	Whole day	Depart for Guangning, Guangdong Province	

Date		Time	Activities	Lecturer
Jul.18	Tues.	09:00-12:00	Introduction of Guangning bamboo industry	Deng Xiaoyan
		14:00-17:00	Visit Guangning forestry institute and sympodial bamboo propagation practice	Chen Xifang
Jul.19	Wed.	09:00-12:00	Visit Baodingshan bamboo museum and garden	Wu Guangmin
		14:00-17:00	Visit Guangning bamboo sea resort	Wu Guangmin
Jul.20	Thur.	09:00-12:00	Visit *Pseudosasa amabilis* plantation in Gushui township	Wu Guangmin
		14:00-17:00	Visit Huazi bamboo products company, Chengda bamboo products company	Wu Guangmin
Jul.21	Fri.	09:00-12:00	Visit Wanzhong bamboo and wood products factory,	Wu Guangmin
		14:00-17:00	Visit Dingfeng paper making Co. Ltd.	Wu Guangmin
Jul.22	Sat.	9:00-12:00	Introduction to Dinghu national researve	Wu Guangmin
		14:00-17:00	Visit Dinghu national researve and return to Guangning	Wu Guangmin
Jul.23	Sun.	Whole day	Rest	Wu Guangmin
Jul.24	Mon.	9:00-12:00	Visit Tiankang bamboo products company	Wu Guangmin
		14:00-17:00	Visit Xinyi bamboo machinery company, bamboo charcoal company, bamboo tea company	Wu Guangmin
Jul.25	Tues.	Whole day	Local sympodial bamboo species propagation practice in Huanji county	Wu Guangmin
Jul.26	Wed.	8;00-12:00	Depart for Guilin	
		14:00-17:00	Visit ornamental sympodial bamboo plantation	Tian Xinli
Jul.27	Thur.	09:00-12:00	Visit bamboo plantation for water and soil reservation	Tian Xinli
		14:00-17:00	Depart to Yangshuo	Tian Xinli
Jul.28	Fri.	Whole day	Visit sympodial bamboo plantaiton for ecological purpose	Tian Xinli
Jul.29	Sat.	Whole day	Return to Hanghzou	
Jul.30	Sun.	Whole day	Rest	
Jul.31	Mon.	09:00-12:00	Introduction and cultivation of wine bamboo species	Li Weicheng
		14:00-17:00	Current status and development trend for China's cash trees	Du Xuhua
Aug.1	Tues.	09:00-12:00	China National bamboo industry planning	Wu Liangru
		14:00-17:00	Bamboo bio-energy	Wu Zhizhuang
Aug.2	Wed.	09:00-12:00	Outline of world bamboo industry	Ding Xingcui
		14:00-17:00	World bamboo industry development direction and trend	Ding Xingcui
Aug.3	Thur.	Whole day	Country report	
Aug.4	Fri.	Whole day	Country report	
Aug.5	Sat.	09:00-12:00	Discussion on possible international bamboo cooperation	Ding Xingcui
		14:00-17:00	Exam and evaluation	
Aug.6	Sun.	10:00-11:30	Closing ceremony	Yu Hui
		14:00-17:00	Participants departure	

Table14 Program for 2018 Ministerial Workshop on Forestry Industry for Developing Countries

Registration	
Oct. 29 Whole day	Participant arrival & registration at Anji Junlan Resort Hotel
Opening ceremony & presentations	
Oct. 30 08:30-10:40	Opening ceremony (Venue: Conference Hall of Anji Junlan Resort Hotel) Facilitator: Director-general of Dept. of International Cooperation, China National Forestry and Grassland Administration (CNFGA)
08:30-09:00	Meeting with foreign ministers by leaders of CNFGA
09:00-09:05	Welcome speech by president of Chinese Academy of Forestry(CAF)
09:05-09:20	Speech by official of the People's Government of Zhejiang Province
09:20-09:35	Speech by participant representative
09:35-09:50	Speech by official of the Ministry of Commerce (MOFCOM) or the International Development Cooperation Agency
09:50-10:20	Keynote speech by Minister or vice Minister of CNFGA
10:20-10:40	Photo session & coffee break
10:40-12:00	**Presentation session I** Facilitator: Tian Yongchen, Director General of CBRC
10:40-11:20	Support of science and technology for China's forestry development by Zhang Shougong, academician of Chinese Academy of Engineering(CAE)
10:20-12:00	China's forestry international cooperation by Wu Zhiming, Director-general of Dept. of International Cooperation of CNFGA
12:00-13:15	Welcome banquet（Banquet Hall of Anji Junlan Resort Hotel） Facilitator: Wu Zhiming, Director-general of Dept. of International Cooperation, CNFGA
13:50-17:30	**Presentation session II** Facilitator: Wang Yukui, Deputy Director-general of CBRC
13:50-14:30	China's forestry industry by Director-general of Dept. of Development Planning & Assets Management, CNFGA
14:30-15:10	China forestry biomass energy by Jiang Jianchun, Academician of CAE
15:10-15:30	Coffee break
15:30-16:10	Remote sensing survey, assessment and planning of forest resources in China by Tang Xiaoping , President of Academy of Forest Inventory and Planning，CNFGA
16:10-16:50	Collective forest tenure reform in China by Chen Shaozhi, Secretary of Party Committee of China Green Times

16:50-17:30	Case study of China's forestry "Going out "strategy implementation----Industrial zone's development for timber comprehensive processing and utilization by Cui Xiaodong, Vice General Manager of China Foma (Group) Co., Ltd
Oct.31 09:00-12:00	**Presentation session III** Facilitator: Chen Yuhe, Deputy Director-general of CBRC
09:00-9:40	Harmonious development of Zhejiang's social economy and ecology under the guidance of "Two Mountain Theories" by Lan Jianping, President of Zhejiang Industry and Information Technology Institute
9:40-10:20	Regional economy development and ecological protection in Anji by official of the People's Government of Anji County
10:20-10:50	Experience of harmonious and sustainable development of the first, second and tertiary industry of Anji forestry under the guidance of "Two Mountains Theory" by Director-general of Anji Forestry Bureau
10:50-11:00	Coffee break
11:00-11:30	Review and prospect of Anji bamboo industry by Zhang Hongliang, Deputy Director-general of Anji Forestry Bureau
11:30-12:00	Construction of beautiful village and rural tourism in Anji by Director-general of Tourism Committee of Anji County
Study tour	
Oct. 31	Study tour in Anji
14:00-16:00	Visiting Zhejiang Yongyu Bamboo Floor and Furniture Company and China "Big bamboo sea"
16:00-19:00	Leaving for Yiwu city
Nov.1	Attending 2018 China (Yiwu) International Forest Products Expo.
09:00-10:30	Attending the opening ceremony of 2018 China (Yiwu) International Forest Products Expo.. Visiting the Exhibition Halls.
10:30-12:00	Visiting Yiwu International Small Commodity Markets
12:30-14:00	Lunch
14:00-	Back to Anji
Nov. 2	**Study tour in Anji**

09:00-12:00	Visiting Anji, birth land of "Two Mountain Theories"----Yucun village, local beautiful villages, bamboo pre-processing workshop and bamboo shoot factory
12:00-13:30	Lunch
13:30-15:00	Visiting Anji bamboo curtain and mat processing factory, and Anji rural tourism
15:30-	Leaving from Anji for Deqing
Nov. 3	**Study tour in Deqing**
09:00-12:00	Visiting Xiazhuhu National Wetland Park
12:00-13:30	Lunch
13:30-15:30	Visiting Zhejiang Dehua Wood Industry Co., discussions with entrepreneurs and government officials on wood industry international cooperation.
15:30-	Leaving Deqing for Hangzhou
17:00-18：00	Dinner
19:00-20:30	Viewing the art performance-- Impressions of the West Lake
Nov.4	**Study Tour in Hangzhou**
09:00-12:00	Visiting Hangzhou Xiasha Economic Development Zone, discussion with the local officials.
14:00-16:00	Study tour in CBRC
19:00-20:00	Sightseeing in Qianjiang Modern CBD
Nov.5	Closing ceremony（Venue: Conference Hall of Zhejiang International Jingmao Hotel） Facilitator: Tian Yongchen, Director General of CBRC
09:30-10:00	Speech by leader of CAF
10:00-11:00	Speech by participant representative and participants discussion
11:00-11:20	Speech by officials from MOFCOM or Dept. of Commerce, Zhejiang Province
11:20-11:50	Speech by Director-general of Dept. of International Cooperation, CNFGA
11:50-12:00	Photo session
12:00-13:30	Farewell banquet
Afternoon	Shopping
Nov.6	Participant departure

7. Annex: Breakdown of Expenditure

Item	PGTF Fund (USD)	CBRC & Chinese government fund(USD)	Total
Market Survey for 3 countries	**4000**	**2000**	**6000**
Travelling cost	2000	1000	3000
International consultant fee	2000	1000	3000
International market survey for developed countries	**2000**	**1000**	**3000**
International consultant fee	2000	1000	3000
Research for China's bamboo development policies and strategies	**1500**	**1500**	**3000**
Domestic travelling	1000	1000	2000
National consultant fee	500	500	100
Trainings for 14 participants from Kenya, Thailand and India	**23700**	**177200**	**200900**
Travelling cost in China	9200	9200	18400
Translation	500	20000	20500
Accommodation	6000	78000	84000
Allowance	8000	70000	78000
Equipment	**1000**	**1000**	**2000**
Laptop	1000	1000	2000
Subtotal	**32200**	**182700**	**214900**
Overhead	**800**	**2400**	**3200**
Total	**33000**	**185100**	**218100**

Contents

Chapter 1 the 20th Century in Retrospect for Bamboo Trade and Prospects for the 21st Century

1. Retrospect for Bamboo Trade in the World in the 20th Century

1.1 Bamboo Resources

As one of the forest resources, bamboos in the world are estimated to include about 1200 species belonging to over 70 genera whose area is about 22 million hm2 and the annual bamboo-wood is about 5 – 200 t. Bamboos are mainly distributed in the tropics and the sub-tropics where bamboos often form a mixed forest with other trees. Moreover, being below the main storey, it used to receive little attention in the past years. However, after removing the overtopping trees in these two regions (the tropics and the sub-tropics), bamboo has been regenerated as secondary bamboo stand with the characteristics of fast growing, rapid propagating and easy regenerating since the 20th century. Besides, when people realize its high economical value and continually widen use, the artificial bamboo stands have been formed by planting bamboos. Both the secondary stand and the artificial stand are spreading around by means of bamboos' powerful subterranean rhizomes. Most of bamboo stands are still out of cultivation and low yield with over-harvested and little attention paid to its conservation and management. By contrast, better management and more attention are paid to bamboo stands in China and Japan.

1.2 Bamboo Utilization

Bamboo has been used in building houses, making bamboo watercrafts and appliances for production, living and culture entertainment, wind break and improving residential environment and using its shoots for food by people of bamboo-producing countries such as Asia, Africa, and South American since as early as the beginning of mankind's activities. Mankind's food, clothes, house and means of transportation have close relation with bamboo. Liyose, a famous British scholar, once said a word: "East-Asia civilization is just bamboo civilization." There are only several large-sized bamboo species in South America where its major use is not in utilization. Bamboo utilization in Africa is far less than that in Asian countries.

[1] **Use in Countryside Production and People's Daily Life:** More than 70% of the annual bamboo wood produced in the world has been used for countryside buildings, agricultural production and people's daily life and less than 30% in modern industry raw-material that of timber.

[2] **Use in Paper-making:** The properties of bamboo wood such as long and thin fiber, good plasticity are ideal for making different kinds of high-quality paper pulp, artificial silk and glass paper. Bamboo has many advantages like fast growth, high yield, growing into full size in short time and highly renewable, therefore, it can be used sustainably. Bamboo culms generally contain higher and better fiber than many hardwoods. The annual fiber production per unit area of bamboo forest is 1 – 2 times higher than that of coniferous or hardwood forest. Bamboo fiber content is 40 – 60 %, with big density and without stripping, and its cooking quantity increases by 10 – 20 % than that of timber or grass. Now, the annual pulp is 146 million tons in the world, of which bamboo pulp is about 2 million tons. In India, among all raw-materials used in making paper, bamboo wood accounts for ⅔ of them; In Bangladesh there are 3 bamboo paper-mills; 4 bamboo paper-mills have been built in China since 1980s. Apart from being used in making paper, bamboo fiber still can be made into cellulose or nitrocellulose. Much research had been done on the techniques in saccharifying, fodderifying bamboo wood and producing active carbon in Japan Kyoto Timber Institute.

[3] **Bamboo Shoot Production:** Edible bamboo shoots contain sugar, protein, cellulose and a great variety of mineral nutrition elements, vitamin A, B, C, and so on; they are considered to be natural health food promoting digestion and excretion and reducing harmful substances and the occurring rate of toxic disease and bowel cancer. The people of bamboo-producing countries have the habit of eating bamboo shoots. But in the Southeast Asian countries, bamboo shoots are mainly produced as commodities. In Japan the annual bamboo shoots is 0.12 – 0.15 million tons, and its quantity increase year by year on consumption per person. For example: l.2, 2.47, 3.08 kg/person in 1955 – 1960, 1971 – 1980, 1981 – 1991 year respectively.

[4] **Bamboo Wood Processing:** In spite of its clear advantages in physical and mechanical properties, the use of bamboo has been largely limited due to its size, form and fistular culm. Bamboos are mainly used in building houses, making furniture, farm tools and daily necessities in bamboo-producing countries, of which the processing techniques are simple and the quality is low. China occupies first place in the world in the varieties, scale and output of bamboo artificial boards. Bamboo plain- sawn board has been manufactured in Japan, however, production of scale hasn't been formed. Bamboo mosaic board and laminated plywood have been manufactured in the Philippines.

[5] **Use in Making Bamboo Products and in Construction:** China occupies the first place in the world in fine bamboo weaving, bamboo carving, bamboo handicraft articles, rattan products and bamboo articles of daily use. Bamboo is also one of the oldest and most versatile building materials with many applications in the field of construction. Those bamboo buildings in Xishuangbanna, Yunnan province and those bamboo corridors in Taohuayuan, Hunan province impress people as being beautiful and imposing. Bamboo fine workmanship and bamboo products used in flower and tea culture are finely made in Japan. Some parks and temples are decorated with bamboo fence and bamboo doors. Bamboo fishing rod made in South Korea and bamboo musical instruments and bamboo weavings made in the countries of Southeast Asia sell well all over the world. In China, bamboo veneers (made from large, thick-walled culms) were once used to make tank attachment of military aircraft in the 1940s; bamboo woods have replaced concrete iron used in building houses in the 1950s. Now, in India and Thailand bamboo reinforced concrete is still used in construction.

[6] **Bamboo Introduction:** Maozhu (*Phyllostachys pubescens*) was introduced to Japan from China in 1736. Now the area of Maozhu bamboo stands accounts for 45% of Japan's bamboo forest total area. Many bamboo species have been introduced and planted in American South Introducing Plantation from China since the beginning of this century. Many bamboo species have been introduced to Britain, French, Germany, The Netherlands from Southeast – Asia. In China, the area of bamboo forest increased by O.01 million hm2 through introducing bamboo to the North from the South.

[7] **Bamboo Stands Play a Positive Role in Natural Environment:** Since bamboos are evergreen, beautiful tall and straight, cold resistant, simple, clear and dancing in branches and leaves, they receive people's likeness and are praised highly. In China, Mount Mogan located in Zhejiang, Mount Jinggang located in Jiangxi and Bamboo Sea of Sichuan are the best summer resorts. Many parks such as Beijing Zizhu Yuan Park, Chendu Wangjianglou Park, Guangzhou Xiaogang Park, Bamboo Species Garden in Huaan and Jianou of Fujian, Anji county and Ten Thousand Bamboo Plantation in Guanning county are all charactised with bamboo. The special important thing is that bamboo stands play a positive role in conserving soil and water and regulating and controlling the natural environment and climate. So bamboos can be planted at the upper reaches of or along the river, lake and reservoir in order to stabilize and protect bank or dyke against flooding. Good economic benefits can be derived by growing zhusun (a kind of mushroom only growing in bamboo stands, namely, *Dictyophora indusiata*), xianggu, Jew's-ear and medicinal plants such as tianma (*Gastrodia elata*) in bamboo stands with its fine ecological environment. Bamboo stands are also suitable habitat for those precious animals such as panda and golden monkey.

1.3 Achievements in Bamboo Research

[1] **Achievements Obtained in Production:** Bamboo afforestation has been received more attention in the tropical and the subtropical regions since the beginning of the 20th century. The bamboo forest area has been enlarged one times. The artificial bamboo forests have taken the place of 1/3 of primeval bamboo forests. The output of bamboo wood has increased 1 – 2 times. Bamboo used to be mainly used in making farm tools, however, it is now widely used in construction industry, paper- making industry and bamboo--wood processing industry. In Asia paper made from bamboo is 1.5 – 2.0 million tons every year. Bamboo shoots used to be supplied by peasant families and now it has been managed as a commodity. Special bamboo-shoot stands have been well and commercially managed. Bamboo culms have been made into various boards such as bamboo plywood, bamboo shaving board and ornamental bamboo board since the 1970s. Bamboo with its advantages takes the place of timber, for which the lack of timbers has solved.

[2] **In China, Japan and some bamboo-producing countries of Southeast Asia**, many studies have been done on the characteristics of some major economic bamboo species in their own countries like distribution, propagation, afforestation, structure of high-yield bamboo stand and cultivation. Some measures, especially in cultivating high- yield bamboo stands have been obtained from studies on maozhu *(Phyllostachys puhenscens)* in China and Japan, in India, on *Dendrocalamopsis oldhami* in Bangladesh. In China, much research also has been done on the characteristics of its flower and fruit from which some knowledge have been obtained. Success in afforestation with its seedlings has been obtained on the basis of the necessary knowledge obtained from researches. Some new-improved varieties have been cultivated by sexual hybridization. Studies on breeding and growing bamboo seedling with its vegetative tissue have been done in Germany, Belgium and other countries. There has been a good beginning in the research on the ecological benefit, stabilization of sands and wind-proof of bamboo forests.

[3] **In Taxonomy:** As early as the Jin Dynasty (A. D. 265 – 420) in China, a book of Bamboo Table written by Dai Kaizhi, in which there were some records about bamboo as follows: “there is a plant called as bamboo, who is neither grass nor tree, neither hardness nor softness, whose minor difference in hollow or solid and major similarity in being have nodes.” In this book he illuminated the morphological characteristics of bamboo correctly and also gave a description to the morphological characteristics, ecological habitats, distribution and the value of utilization of 61 bamboo species. In Song Dynasty (A.D. 960 –1279), a Buddhist monk called Zan Ning wrote a book of Bamboo-shoot Table, in which the morphological characteristics, ecological habitats, distribution and the value of utilization of 93 bamboo species were described in detail. In Qing Dynasty, the feature mentioned above of 110 bamboo species were described in details in the book of Guangqunfangpu, a book on plants. Natural classification of bamboo was carried out in 1753 when the binomial nomenclature was put forward by Linna, a Swedish scholar. At the beginning of the 20th century, only a few plant taxonomists have done much work on the preparative classification of several bamboo species, of which a few bamboo species and genera were described. Up to now, about 1200 bamboo species in 70 genera have been described in details for which preparative researches have been done on their ecological habitats and biology, however, there are more confusion, omissions and repetitions in many bamboo species.

[4] **Studies have been done on some major economical bamboo species in structure, physical, mechanical and chemical property and fiber’s form and the technology in making paper from bamboo in China, Japan and India.**

With the technology obtained from research and traditional experience increasing in making plywood, particle board, flooring board, section sheet and bamboo board by joining piece together into pattern and paper, the use of bamboo has been largely widened.

[5] **In Literature:** Over 8,000 theses on bamboo have been published in the 20th century, out of which the papers published after 1980 take 70 % or so. There are about 800 bamboo patents in China. There are many research reports on bamboo in Forestry Journals in India, Viet Nam, Japan, the Philippines and so on.

2. Prospects for Bamboo Trade in the 21st Century

2.1 Enlarging the area and output of bamboo forest

[1] **The area of bamboo forest in the 20th century is 2.2 million hm^2 occupying 1% of that of the forests in the world:** The annual output is 1.5~2.0 million tons. It is estimated that the total area of bamboo forests will be enlarged 2~3 times in the 21st century, about 55 ~ 65 million hm2, occupying 2 ~ 3% of that of forest in the world. The annual output will be increased 2.5~ 3.5 times, to about 55~65 million tons, taking 5% that of the timbers in the world. Of which there are 30, 20, 10, 1 and 1 million hm2 in area and 30, 20, 10, 1 and 1 million tons in the annual bamboo wood in Asia-pacific region; America (primarily South America, Africa, Australia and Europe respectively. About 1000 million hm2 of waste mountain and wasteland suitable for the growth of tree and many slashing, on which forest should be regenerated by the means of artificial afforestation or natural regeneration, especially bamboo forest. As a nice natural regeneration plant, bamboo can provide mankind society with more and finer bamboo products through increasing per unit area production. In order to reach the above aim, scientific cultivation should be applied to natural artificial bamboo forest on the slashing in tropical and subtropical regions.

[2] **Replacing Timber with Bamboo Wood with Better Quality:** A sustaining development policy should be adopted in managing and utilizing forest resources in the 21st century. As one of the sustaining resources, bamboo forest is not only of economic benefit with its bamboo wood but of ecological benefit with its evergreen. Therefore, bamboo forest should be paid more attention to and be developed. Replacing timber with bamboo with better quality will be a developing tendency in the 21st century. The deficiency in timber resulted from a large number of timber having been depleted in the paper-making industry. Bamboo forest used for making paper may be built with bamboo’s fast growth, high yield, long and thin fiber in tropical and subtropical regions to solve this problem. Bamboo wood, with its better quality and the techniques obtained in making denaturation materials and plywood, will replace timber. Bamboo stand on bank or slop protection and other protection forests should be advocated for to build with its good function in stabilizing soil, protecting bank and conserving soil and water.

2.2 *Broaden* Bamboo’s Use and Raise Its Increased Benefit

[1] **In Bamboo Wood Processing Trade:** Consumption in timber will reduce by machining, chemical processing and making all kinds of products with bamboo. There will be a more advancement in mechanical machining such as making bamboo pulp and paper, artificial silk and cellulose.

[2] **Making Full Use of the Whole Culm:** In the past years, much attention was only paid to bamboo wood rather than bamboo branch, shoot, leaf, rhizome and root, however, the whole culm will be made full of use in the 21st century. There will be a development in producing articles of everyday use, handicraft articles and food with bamboo branch, shoot, leaf, rhizome and root. Growth hormone and microelement can be extracted from bamboo’s organs to satisfy people’s necessity.

[3] **Making Use of the Environment in the Bamboo Stands:** Precious animals like panda, golden monkey and gorilla can be raised and bred in bamboo forest. Precious medicinal herbs and edible vegetables such as tianma (*Gastrodia elata*) and mushroom (*Dictyphora indusiata*, only growing in bamboo stands) can be grown in bamboo forest. Bamboo will be used in tourism, hotel and playfield in tropical region with the characteristics of cool and refreshing in bamboo stands.

3. Further Studies on Bamboo

[1] **Making an Inventory of Bamboo Resources:** In each bamboo-producing country and region, with the checking made in its distribution and the state of its utilization and development, scientific design in developing, using bamboo forest will be made according to their own specific conditions. The bamboo area will be enlarged in those regions without producing bamboo by introducing bamboo.

[2] **Research on the Ecological Effect and Application of Bamboo Stands:** Demands on ecological benefit will go beyond that of producing bamboo wood in the 21st century. Therefore, research on bamboo forest's ecological effect will be a key question. Tourism trade will be developed by building bamboo protection forest and scenery forest. Studies on the behavior, breeding and utilization of animal and plant, the effect of stabilizing soil and protecting against flooding/storm and conserving water of bamboo forest, on the ability of bamboo forest against natural disasters and the techniques in constructing shelter-forest, Besides, on the characteristics and law of bamboo economy.

[3] **Researches on Enlarging Bamboo Stand Area and *Increasing* per Unit Yield:** Researches on the biological and ecological habit of every bamboo species have been done. Researches on the technology in selecting and breeding good bamboo species adapted to all kinds of ecological conditions and uses; recreation and cultivation of secondary bamboo forest on the slashing in the tropical region; in afforestation on wastelands suitable for the growth of bamboo under all kinds of ecological conditions; in construction and high yield structure and cultivation of bamboo forest and prevention and control of bamboo diseases and elimination of pests.

[4] **Studies on Widening the Use of Bamboo Forest:** In order to replace timber with bamboo with better quality, further studies will be done on the properties of bamboo-wood. Studies will be also done on the technology in machining (bamboo artificial board) and chemical processing (making paper, bamboo pulp, bamboo charcoal) of bamboo-wood; in processing and the new use of bamboo shoot, branch, leaf, rhizome and root; in producing forage for livestock with bamboo's remainder; in chemical processing of bamboo-wood; and in producing artificial silk and glass paper which the demands for natural fiber will satisfy.

[5] **Breeding New-improved Bamboo Species by Taking Advantage of Bio-engineering:**
Various newly improved bamboos will be bred for producing timber, shoot and for viewing and admiring. Bamboo species with regular blossom and bearing fruit will be bred to produce bamboo seeds and satisfy mankind's demands.

[6] **Research on Bamboo Forest Bionics:** Bamboo forest, with knots in each long and thin bamboo culm, can resist the attacks of strong wind, through which the skyscraper should be followed in the structure of bamboo culm. Bamboo forest is likely to be the mode of skyscraper group in the future. The survival and development of mankind depends on the implementation of the policy of sustainable development in utilizing natural resources.

Bamboos with their renewable characteristics are the best sustainable resources. So we prospect with full confidence that the bamboo will spring up energetically and bamboo trade will be a popular one and bring new and greater contributions to mankind in the 21st century.

Chapter 2 the Reality of Production and Utilization of Bamboo Forest in the World

As one of the forest resources, bamboos are estimated to include about 1,200 species belonging to 70 genera. Bamboos are mainly distributed in the tropics and the subtropics, and a few bamboo species are distributed in Temperate Zone and Frigid Zone. Bamboo grows in tropical and subtropical zones and often forms a mixed forest with other trees. Being below the main story, it is apt to be neglected. Nevertheless after destructive cutting of forest in these two zones (the tropics and the subtropics) bamboo has been regenerated as secondary bamboo stand since it has the characteristics of fast growth, rapid propagation and easy regeneration. Besides, as bamboo is widely used and its high economical value, it is planted on the wasteland in the mountains and uncultivated land. The secondary stand and artificial stand are spreading around by means of their subterranean rhizomes. So the bamboo area on the surface of the earth is increasing year after year while the forest area is reducing. So far, it is estimated that the world's total area of bamboo forests is about 20 million hectares.

Environmental conditions for bamboo growth in the tropics are concerned with so many associated factors like latitude, altitude, temperature, sea level, soil, topography, rainfall, light, intensity and so on. Most of the bamboo species in the world naturally grow within 40 degree on either side of the equator, particularly in the area of the Tropic of Cancer and in the Tropic of Capricorn for the clump forming type of bamboo species are gregarious in two categories, namely, (i) bamboo forest in extensive areas, and (ii) in groups or colonies. Bamboos that grow together in the first category are more or less confined within 15 ~ 25 degrees of north side, especially tropical monsoon from Asia in where India, Bangladesh, Burma, Thailand, Laos, Viet Nam, etc. On the other hand, only colonies of bamboo forest occur in other Tropical America, Tropical Africa and the rest of above Tropical Asian countries including both sides of latitudes between Equator and 30 degrees. All of these tropical bamboo forests are natural pure forests or mixed with tree forests, however, bamboo forests located in the tropical rain forest are sandwiched between Equator and 15 degrees both sides of latitude are mainly mixed with tree forest. Tropical bamboo needs much rainfall than the bamboo which grows in temperate zone because there is close relationship between growth of shoots and rainfall. Generally speaking, the best growth condition for bamboo is to be maintained for six months with 100 ~ 200 mm monthly rainfall. Of course, if there are more than 1000rnm annual rainfall and duration of rainy season is continued about six to seven months, bamboo shoots sprout two or three times a year.

Geographically, bamboo distribution can be divided into three major regions in the world: 1. Asia-Pacific Bamboo Region; 2. America Bamboo Region; 3. Africa Bamboo Region (Fig. 2 – 1). Within each major region, some sub regions can be recognized on the basis of climatic differences and bamboo types.

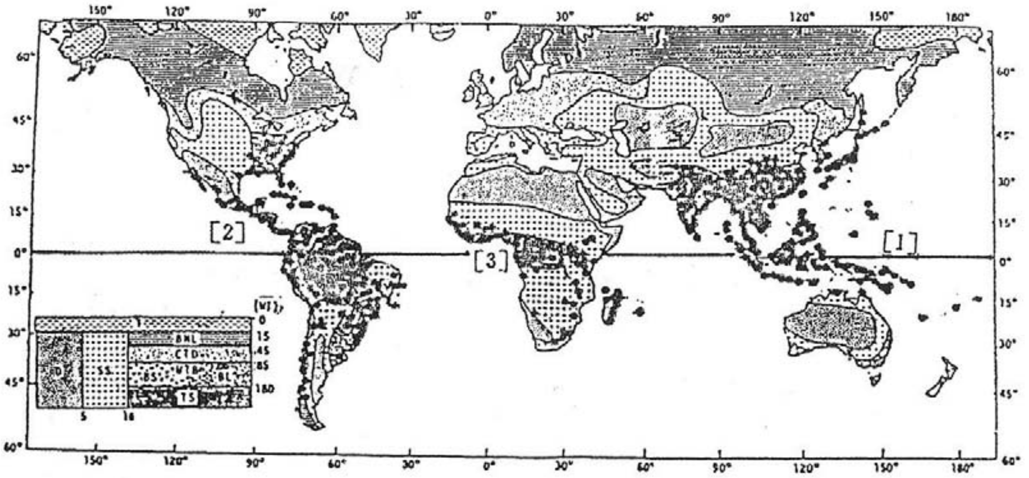


Fig. 2—1 Distribution of bamboos in the world

[1]—Asia—Pacific Bamboo Region [2]—American Bamboo Region [3]—African Bamboo Region
• —bamboo distribution T—tundra D—desert SS—steppe & savanna BNL—subpolar or conifer forest CTD—cool—temperate deciduous broad—leaved forest WTB—warm—temperate broad—leaved forest BS—broad—sclerophyll forest TS—broad—lucidophyll forest ,and Ts tropical & subtropical forests.
(This figure is quoted from Distribution of Bamboos in the World edited by Dr. M. Watanabe,《Bamboo Journal》No. 4,1987)

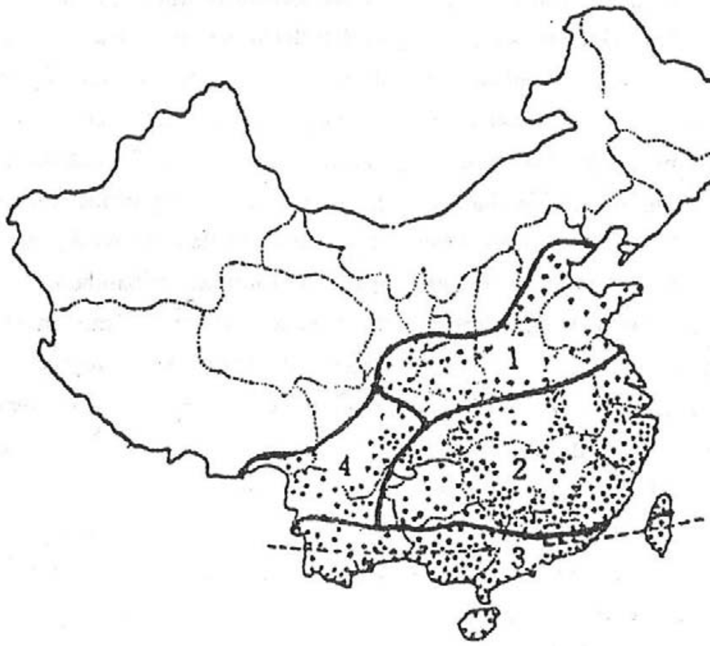


Fig. 2—2 Distribution of bamboos in China

1—Yellow River-Yangtze River bamboo area 2—Yangtze River-Nanling Range bamboo area
3—South China bamboo area 4—Alpine bamboo area of Southwest

Table 2—1 The areas of bamboo forests and bamboo species in the world

name of continent, country	area(million hm^2)	number of bamboo genera	number of bamboo species *
China	700(mixed forests is 300)	50	500
India	400(or 957)	19	136
Burma	2.170	—	90
Thailand	0.810	13	60
Bangladesh	0.600	13	30
Kampuchea	0.287	—	—
Viet Nam	0.141	16	92
Japan	0.138	13	230(660)
Indonesia	0.060	9	30
Malaysia	0.020	10	50
Philippines	0.020	1	55
South Korea	0.008	10	13
Sri Lanka	0.002	7	14
Oceania and islands of the Pacific	0.200 * *	6	10
America(South America, North America)	1.500 * *	17	270
Africa(including Madagascar)	1.500 * *	14	50

Bamboo has a wide range of distribution from the tropics to the temperate zones and from sea level to alpine elevations. Some species are even found in considerably high altitudes and elevations. *Sasa kurilensis* and *Chusquea culeou* occur in south Sakhalin (4 6°N) and South Argentina (47°) respectively. Certain species of *Sinarunfinaria* grow well at 3,400~3,500m in the Himalayan Mountains. While Neurolepis aperta forms irregular patches at 4,000m and impenetrable thickness at 5,000m in the East Andes. But most bamboo plants require warm, they are commonly distributed at low elevation in the tropic and subtropics of Asia, America, Africa and Australia where they grow either naturally in mixed forests or in plantations. Europe has no indigenous bamboo. But introduction has been made since the last century. It is estimated that the world total number of bamboo species and varieties is about 1,200 and the world total area of bamboo forests is about 20 million hectares, including bamboo forest which have formed mixed forest or alpine bamboo forest (Table 2 – 1).

1. Asia - Pacific Bamboo Region:

The Asia-Pacific bamboo region is the largest one, covering Japan, Korea, the southern half of China, Southeast Asia, Australia, New Zealand and the Pacific Islands. Within this region, there are 800 species and varieties belonging to 45 genera and 18 million hectares of bamboo lands in total. South China and Southeast Asia form the center of bamboo distribution in the world, with the greatest number of bamboo species and the greatest proportion of bamboo forests. More than 20 species have sizable culms with good quality, which can be used in production, culture and the daily life of local people. Away from this center their frequency of occurrence decreases considerably and they appear mostly in small patches. The Asia-Pacific bamboo region can be divided into two large subregions according to the bamboo rhizome type, monopodial and sympodial. Generally monopodial bamboos are characterized by relatively strong frost-resistance; they are distributed in higher latitudes such as Japan, Korea, the Yellow River Valley and the Yangtze Valley where winters are severe. Those with sympodial rhizomes occur mostly in areas between the Tropics of Cancer and Capricorn, with major components in the bamboo center and with an eastward spread to me Pacific Islands. Accordingly, one subregion can be recognized by dominance of monopodial and the other by sympodial forms (Table 2 – 2).

Table 2—2 per unit area yield of bamboo in main countries noted for bamboo(t/hm^2)

country	prefecture	bamboo species	area (hm^2)	average per unit area yield t/hm^2	average commercial bamboo culm number/hm^2
Japan	Kagoshima	*P. pubescens*	6,259	6.94	464
	Miyagi	*P. pubescens*	2,082	7.10	474
	Kumamoto	*P. pubescens*	3,620	4.92	327
	Fukuoka	*P. pubescens*	5,854	3.26	217
	Honshu	*P. pubescens*	3,308	2.62	174
China	Zhejiang Deqing	*P. pubescens*	8,903	3.78	252
	Zhejiang Anji	*P. pubescens*	42,667	2.50	166
	Jiangsu Yixing	*P. pubescens*	42,667	2.25	150
	Hunan Taojiang	*P. pubescens*	10,000	1.89	126
	Guangxi Lingchuan	*P. pubescens*	10,140	1.53	102
India	North State	*D. strictus*	—	0.173	—
	Central State	*D. strictus*	—	1.853	—
	Maholastela	*D. strictus*	—	2.520	—

1.1China

Ecologically, China covers two sub regions of bamboo distribution and shows close affinity with the bamboo flora of Japan and Korea in its north and that of Southeast Asia in its south (Fig. 2 – 2). *Phyllostachys, Pleioblastus, Sasa* and *Indocalamus* are monopodial; they are commonly distributed along the Yellow River, the Yangtze Valley and also in Japan and Korea. Similarly species of *Bambusa, Dendrocalamus, Oxytenanthera, Pseudostachyum, Gigantochloa, Schizostachyum, etc* are commonly encountered in South China and Southeast Asia where they form extensive vegetation with hardwoods spreading across the international borders.

China is a part of the world's bamboo center and has more than 500 species and varieties in 50 genera. The bamboo forest area in China is about 7 million hectares (including artificial bamboo forest and alpine bamboo forest). These bamboos are mainly distributed over our vast land in the south of latitude 40 north. It is the country with the richest bamboo flora and resources, and it has both monopodial and sympodial bamboos in roughly equal numbers. Please read "Bamboo Resources in China", it will give you details.

1.2 India

India has 113 species and varieties belonging to 19 genera. The bamboo forest area in India is about 4 million hectares. These bamboos mainly belong to the clumping type. Only in mountain area of the north, there are diffuse-form bamboos. In India, bamboo is chiefly distributed in the east such as Arunachal, Fradesh, Assam, Meghalaya, Mizoram, Nagaland, Sikkim, Fripura and West-Bangladesh, Andamans, Madhya, Pradesh, Bastar of Pradesh and mountain areas of the south-west.

The bamboo species that have been developed in India are: Drepanostachyum falcata, Thamnocalamus spathiflora, Arundinaria racemosa, Indocalamus wightianus, Bambusa anmdi-naria, B. balcooa, B. tulda, B. polymorpha, B. vulgaris, Cephalostachyum pergracile, Dendrocalamus giganteus, D. hamiltonii, D. stricyus, Gigantochloa macrostachya, Ochlandra travmicorica, O. scriptori, Oxytenanthera ritchevi, O. nigrociliata and Pseudoslachyum polymorphum, etc.

The management levels of bamboo stand is not high. The increment of those bamboos stands which have wide distribution and good growth in every year is as follows: *Dendrocalamus strictus* is 1.95t/hm^2, *Bambusa tulda* is 3.12t/hm^2, *Melocanna baccifera* is 4t/hm^2. The annual cut in India is about 400 X 10^4 t.

Those bamboo stands can be divided into four types in India:

[1] The pure bamboo stands: There are bamboo stands which have 125 clumps per hm^2. The yield is high. The average yield is 2.52t/hm^2. [2]The mixed stands dominated in bamboo: There are bamboo stands which have 50 ~125 clumps per hm^2. The yield is 1. 85t/hm^2. [3] The thinly scattered bamboo stands: There are

bamboo stands which have 25~50 per hm^2. The average yield is low, $0.17t/hm^2$. [4] The fragmentary bamboo stands: There are bamboo stands which have less than 25 clumps per hm^2. Their yield is very low.

1.3 Burma

There are more than 90 bamboo species.

The total bamboo area is 2.17 X $10^6 hm^2$. In general, the management is extensive. The main bamboo species are: Melocamza baccifera, Bambusa tulda, Bambusa arundinacea, B. polymorpha, Cephalostachum pergracile, Dendrocalamus membranaceus, D. brandii, D. longispathus, D. strictus, Dinochloa and amania, Pseudostachyum compactiflorus, Melocanna baccifera. It is estimated that the bamboo wood is 1.50 X 10^6t in every year.

1.4 Thailand

There are over 60 bamboo species in 13 genera. The bamboo area is about 8.1 X $10^5 hm^2$. The main bamboo species are: Dendrocalamus asper, D. aciculare, D. membranaceus, Bambusa arundinaceae, B. blumeana, B. nana. B. tulda. Thyr- sostachys siamensis, T. oliveri, Dendrocalamus brandisii, D. membranaceus. D. strictus, Gigantochloa albociliata, G. hasskeriana, G. ligulata, Oxytenanthera nigrociliata. O. houseusii, O. albociliata, Schizostachyum aciculare, S. humilis, S. ligulata, Thyrsostachys siamensis, Cephalostachyum virgatum, etc. In 1981~1984, the annual bamboo culms are 52 million (not including bamboo culms used in the country). There are two factories manufacturing bamboo plywoods in Kanchanaburiug province and Lampoon province. In 1936, Kanchanaburi Paper factory using bamboo as raw material was established. There are 22 bamboo-shoot processing factories in Prachinburi province. In 1984, the annual bamboo-shoot production was 37.975 t.

1.5 Bangladesh

There more than 30 bamboo species. The bamboo area is 6.0 X $10^5 hm^2$. Among them the area of pure bamboo stands, by all sides bamboo stands is 1.0 X 105hm2, 1.0 X 105hm2 respectively. The area of the mixed stands consisting of bamboo and trees is 4.0 X $105hm^2$. The main bamboo species are: *Melocanna baccifera* (popular name: Muli, Bajail, Nali), *Bambusa tulda* (popular name: Mirtinga), *B. arundinacea* (popular name: Betua), *B. arundinaceavar, B. spinosa. B. balcooa* (popular name: Balkn), *B. burmanica* (popular name: Tarala), *B. glaucescens, B. longispiculata* (popular name: Talia, Toru), *B. nutan* (popular name: Makal), *B. polymorpha* (popular name: Butua, Jama, Betua), *B. vulgaris* (popular name: Bariala, Baria, Bashini), *B. vulgarisvar. B. striata, Cephalostachyum pergracile, Dendrocalamus calostachyus, D. gigantens* (popular name: Budumbans), D. *hamiltonii* (popular name: Penchabans), *D. Longispathus* (popular name: Orah. Khang, Rupai), *D. membranous, D. strictus* (popular name: Lathibans, Rangoonbans), *Melocanna compaciflorus* (popular name: Latabans, Daral), *Neohouzeaua dullooa* (popular name: Dolubans), *Oxytenantera albociliata, O. nigrociliata* (popular name: Kalibans, Kalia), *Thyrostachys olivevi,* etc. There are two paper factories *using* bamboo as raw material in Bangladesh.

1.6 Viet Nam

The bamboo area is 2.3 X $10^5 hm^2$ or so.

Bamboo species belonging to clump is the main. There are 92 bamboo species belonging to 16 genera era. The main bamboo species are: *Bambusa spinosa* (popular name: Tregai), *B. arundinacea* (popular name: Locngoc), *B. tulda* (popular name: Maybong), *B. blumeana,* (popular name: Langa), *B. procera,* (popular name: Loo), *B. flexmosa,*(Tre Tau), *B. multiplex* (popular name: Trevaisod), *B. ventricosa* (popular name: Trucduiga), *Dendrocalamus patellaris* (popular name: Giang), *D. membranaceas* (popular name: Luong), *D. latflorus* (popular name: Mai), *D. flagellifer* (popular name: Tong), *D. sericens* (popular name:Maysang), *Arundinaria sat* (popular name Truccanceu), *A. pubescens* (popular name: Vaudang), *P. bambusoides* (popular name: Vaungot), *Neohoujeaua dulloa* (popular name: Nua), *Ginoalamus seribrerina* (popular name: Buang), *Sinocalamus latiflous* (popular name: Dientrug), Linganania sp (popular name: Lung). The management is generally extensive. The yield is low.

1.7 Laos

In the north of Laos, the giant bamboo giant species in rain forest are: *Dendrocalamus hamiltonii, D. brandisii,* etc. The diameter, height of those giant bamboos is 20cm, 30m. The bamboo species distributed in poor lands *is:Bambusa arundinaceae*. In the north of Laos, the bamboo species distributed in lithosol lands are: *Dendrocalamus membranaceus, Oxytenanthem albociliata* (popular name: Mailai), *Cephalostachyum pergmcile, Thyrsostachys siamensis*. The bamboo distributed 2,000 meters above sea level: *Chimonobamusa quadmngularis (Chimonobambusa griffithiana)*. In addition: *Arundinaria falcate* (popular name: Maiphek), *B. tulda, Cephalostachyum virgatum* (popular name: Maihia), *C. pergracile, dendrocalamus brandisii, D. membranaceus,* etc.

1.8 Japan

There are 227 bamboo species belonging 13 genera (1t has been reported there are 662 bamboo species. The total area of bamboo stands is 14. 10hm2.The diffuse-form bamboo species is the main. For example: *Phyllostachys bambusoides* is 42%, *Phyllostachys puhescensis* 40%. The total *area of bamboo* has been increasing since *Phylloatachys pubescens* was introduced from China in 1736. To the best *Phyllostachys pubescens* stands, the annual increment is 30~40t/hm^2. 97% bamboo stands belong to private. Those private bamboo stands are managed intensively. The annual bamboo-wood is totally 20~30 X 104t. The annual bamboo-shoot is 1.5 X 10^5t in total appendix II). The aim of bamboo management is bamboo-shoot used stands instead of bamboo-wood used stands in the 1950s, however, in the 1970s the aim of bamboo management is sightseeing stands instead of bamboo-shoot used stands.

1.9 Indonesia

There are 65 bamboo species in 9 genera. The bamboo area is about 60, 000 hm^2. The chiefly economic bamboo species are: Bambusa atra, Gigantochioa atter, G. maxima, G. verticillata, Nastus elegantissimus, Schizostachyum biflorum, S. blumei, S. Longispiculatum, Oreigostachys pullei, Oxytenanthera nigrociliata, etc.

1.10 Philippines

The bamboo area is more than 20,000 hm^2. There are 55 bamboo species belonging to 11 gen (popular era. The chiefly economic bamboo species are: *Bambusa blumeana* (popular name: Kawayan tinik), *B. cornuta, B. spinosa. B. vulgaris, Dendrocalamus merrilianus, D. latiflarus, Dinochloa scandens, Schizostachyum lumampao, S. Lima, Gigantochloa as- pera, G. levis,* etc. *B. blumeana* has wide distribution. The diameter and the height of G. *aspera* is 40cm, 30m.

1.11 Malaysia

There are 50 bamboo species belonging to 10 genera. The area is 20,000hm^2. The annual bamboo woods is 21, 000t. The chiefly economic bamboo species are: *Bambusa vulgaris, Dendrocalamus asper, D. pendulus, D. hirtellus, Dinochloa scandens, Gigantochloa scortechinii, Schizostachyum zollingeri, S. grande, Recemobambusa tessellata, Yushania yniita,* etc.

Besides, there are 13 bamboo species belonging to 10 genera in South Korea. The area is more than 8,000hm^2. There are 44 bamboo species belonging to 7 genera in Sri Lanka. The area is 2,000hm2. The bamboo area is 2.87 X 105hm2 in Kampuchea. Bamboo species belonging to clumping-form is chief. The management is extensive. There are 26 bamboo species distributed in Papua New Guinea. Bamboos are also distributed in Bhutan, Nepal, etc.

2. The American Bamboo Region

The America bamboo region consists of North and South America ranging from the eastern United States (40^0N) down to the southern part of Argentina (47^0S). There are more than 270 species and varieties in 17 genera. Except for a few species, most of them are small or even herbaceous and they do not have much economic value or a less closer relationship with production and the life activities of local people. *Arundinaria* is the only monopodial bamboo in the New World. *Arundinaria gigantea* and its three sub-species are the only indigenous bamboos in the United States where they occur scattered in mixed hardwood forests in the southeast part of the country. On the other hand, bamboo plants of sympodial type are sparsely scattered throughout extensive areas of Central and South America, a sub region of sympodial bamboos.

3. The African Bamboo Region

The African bamboo region is a relatively small one ranging from southern Senegal (16°N) down to southern Mozambique (22°S) and across the African tropics. The bamboo flora is very poor, less than 10 species on the continent, but about 40 species and 11 genera of indigenous and introduced bamboos occur in Madagascar. Several species of *Oreobambos, Oxytenanthera* and *Sinarundinaria (formerly misnamed as Arundinaria)* are sizable bamboos and form natural pure stands or mix with hardwoods. Bambusa and Sinanmdinaria are cosmopolitan genera. Their species are found over the world wherever the environment is favorable. *Bambusa vulgaris* is known as a pantropical bamboo growing widely in tropical countries. In view of flora affinity, the Asia-Pacific bamboo region is closely related to the African. *Bambusa, Cephalostachyum, Pseudocalamus, Ochlandra, Oxytenanthera and Schizostachyum* are common genera on both continents and their nearby islands.

Since bamboo plants are evergreen (only a few species shed their foliage during the dry season) and shallowly rooted, they are very sensitive to temperature and precipitation. Accordingly, heat and moisture distribution on the surface remarkably affects the geographical distribution of bamboo plants. Southeast Asia is a sink of ocean currents both from the Pacific and Indian Oceans, bringing in plentiful heat and rainfall and rainfall creating a most favorable environment for bamboo growth. A similar situation is also found in Central America and along the coastal areas facing ocean currents. Bamboo distribution is also related to topography, aspect, elevation and landscape through their local modification of heat and moisture. Furthermore, genetic make-up against frost and drought is also important factor affecting the adaptability of bamboo species and their distribution. Presumably, most bamboo plants do not grow well under climates with an annual mean temperature below 100C, a coldest monthly temperature below – 20C, or annual precipitation below 800mm. Above these lower limits, we may classify the bamboo distribution into the following three categories:

(1) temperate bamboo regions with annual mean temperature 10 C ~ 150C and annual precipitation 800 ~ 1,000mm; (2) subtropical bamboo regions with annual temperature 150C ~ 200C and annual precipitation 1,000 ~ 1,500mm; (3)tropical bamboo regions with annual mean temperature 200C and annual precipitation above 1,500mm.

In addition to the natural environment, human activities are also important in bamboo distribution. Bamboo is an important resource in Asia and closely related to production the culture and the living activities of local people. Some bamboo species have been introduced into areas where they are needed. *Bambusa vulgaris,* which possibly originated *from* Malaysia and Indonesia, now has become a cosmopolitan species widely grown in the tropics all over the world. *Oxytenanthera abysinica,* an indigenous species of Africa with high production and good fiber quality, has been introduced into India for the paper-making industry. *Phyllostachys pubescens,* a native of China, was introduced into Japan in 1738 and now has become the most important commercial bamboo there, where it covers 40% of the bamboo lands and produces 59% of culms.

In North America, only *Arundinaria gigantea* and its subspecies are indigenous. Since the last century, American botanists and horticulturists have introduced many different bamboo species and varieties from China, Japan and other Asiatic countries. The total number of introductions has amounted to 750 of which 200 were species of *Phyllostachys*. They grow in bamboo gardens in Puerto *Rico*, Florida, Georgia and Southern *Carlifornia.*

In Europe *Phyllostachys nigra* was the first bamboo introduced into England in 1827. Now there are 14 genera and 75 species, varieties and forms of cultivated bamboo in the United Kingdom which mostly came from China and Japan. The Bambuserate de Pratrance is a beautiful bamboo park with about 100 species and varieties of bamboo spreading over about 10 hectares in mysterious shades. Among them species of *Phyllostachys* are the most common. Some other European countries such as West Germany, Italy, Switzerland and even the Soviet Union have long introduced some hardy bamboos to plant in their appropriate favorable regions.

Recently, many bamboo enthusiasts in North America, Australia and Europe have been increasingly interested in bamboo introduction and cultivation. They have established the American Bamboo Society, the European Bamboo Society and the Australian Bamboo Network for communication and popularization of bamboo knowledge. For centuries people in Asia, Africa and Latin America are noted for bamboo use to build house, to make boat and other appliances for producing, life and culture entertainment. In a word, bamboo is widely used in food, clothing, lodging and transportation – basic necessities of life of people in the world. So, bamboo has close relationship with people. Now in the world, the bamboo forest area is about 20 million hectares and the annual bamboo wood is about 16 million tons. Among those bamboo woods, 70 % of them are used in building, agriculture production and daily necessities in the countryside,

Table 2—3 The utilization of bamboo wood in six countries of South—east Asia(%)

country	construction		used in countryside	used in package	used in pulp	used in others
	building	others				
Bangladesh	50	10	20	5	10	5
Burma	30	32	32	5	—	1
India	20	5	20	5	35	15
Japan	24	7	18	7	4	40
Philippine	80	—	15	2	—	3
Thailand	33	20	6	—	8	33

less than 30 % of them are used as raw materials in industry (Table 2 – 3).

In Asian countries noted for bamboo, bamboos use is comparable with that of trees. If it is calculated by the population, the biggest bamboo consuming countries are Burma and Indonesia. The bamboo consumption in Bangladesh is equivalent to 0.7 times that of them in India. The bamboo consumption in China and Japan is very high. That is, supply fails to meet demand. There are a few big bamboo species in Latin America. The utilization of bamboo is not chief in Latin America. The utilization of bamboo in Africa is not so much as that in Asia.

According to incomplete statistics in South-east Asia mainly noted for bamboo, the annual wood is more than 1. 3 million tons, among them, 30% ~ 40% of them are used in building, 15 % ~ 20 % of them are used in bamboo manufacture, 20 % ~ 25 % are used in paper pulp and 15% ~ 30 % of them are used in others.

3.1The common tendency is making paper bamboo in countries noted for bamboo

It is researched according to both inside and outside the country that the fiber of bamboo is thin and long and has good plasticity from which suited for making high quality paper pulp, artificial and glassine. Because bamboo has rapid growth, high yield and grows into useful timber in a few years, so it may ceaselessly supply industrial materials. Bamboo culms generally contain higher and better fiber than many hardwood species. Producing one ton of unbleached pulp requires four tons of fresh culms. The annual fiber per area of bamboo stands is 1~2 times than that of softwoods and hardwoods. The fiber content bamboo stand is 40 % ~ 60 %. They needn't peeling. Their density is big (0.7 – 0.8). The quantity of steamed bamboo is 10% ~ 20% more than that of wood and herb. So, bamboo is a good material for making paper. In addition, Acetic acid fiber and nitrificational fiber are made from bamboo fiber.

So far, the annual paper pulp is 1.46 billion tons in the world. Out of which, bamboo pulp is 1 million tons or so. The main countries that made paper pulp from bamboo are: India, China, Bangladesh, Burma, etc.

India The annual bamboo paper pulp is about 20,000 tons, 0.10~0.15 million tons, 0.4 ~ 0.5 million tons and 0.5 ~ 0.6 million in the 1930s, 1950s, 1970s and 1980s respectively. The annual bamboo-wood consumption is 2 million tons or so. There are 80 paper factories, out of which 30~35 paper factories use bamboo as raw materials. More than half of its 3.23 million tons total of culms is consumed by the paper industry (Table 2 – 4).

Table 2－4 Bamboo paper and bamboo board in India

year	the total product of paper and paper board (million t.)	bamboo paper and bamboo board (million t)	percentage of bamboo (%)	air－dried bamboo wood (million t)
1936	0.040	0.0496	49.1	0.0588
1952	0.130	0.0957	73.6	0.2871
1958	0.203	0.1505	74.1	0.4515
1970	0.758	0.4252	56.1	1.2756
1975	0.959	0.4559	47.5	1.3677
1980	2.001	0.5873	29.4	1.7619

Bangladesh There are two paper factories that used bamboo as raw materials. Their daily output is 100 tons. The artificial silk and glassine are sold to countries of the Middle East. The management of bamboo forest is not reasonable generally.

Burma There are two paper factories used bamboo as materials.

Thailand There are 0.7 million hectares bamboo forest. They may supply as bamboo paper materials.

Africa The World Tropical Forest Technology Center has studied the fiber and papermaking properties of *Bambusa vulgaris, Schrader* and *Oxytenanthera abyssinica* which grow in Cameroon, Congo the Ivory Coast, Gabon, Madagascar and Senegal.

3.2 Bamboo-shoot processing

Edible bamboo-shoot contains 2% ~ 4% sugar, 0.2% ~ 0.3% fat, 2.5% ~ 3.0% protein and 16 ~ 18 amino acids and other elements; they are considered to be nutritional vegetables. Edible bamboo-shoot is also considered to be a health-food. It can aid in digestion, promote to excrete and reduce accumulated harmful substance. But taking bamboo-shoot as commodity for production, there are some countries in South-east Asia, like China, Japan, Thailand, Viet Nam, Philippine and South Korea that must be mentioned.

Japan The annual bamboo-shoot is 0.12 ~ 0.15 million tons or so. The annual bamboo-shoot per hectare is 2.6~3.37 tons. The annual bamboo-shoot consumption according to the population is: 1.2kg per person in 1955 ~1960, 2.47kg per person in 1971 ~ 1980, 3.08kg per person in 1981~1991. But the annual bamboo-shoot consumption is about 0.3 million tons of which 50%~ 60% delete is imported from China, Thailand. In the 1970s, they have invested funds to establish bamboo-shoot factories in The Philippin*es* for bamboo-shoot supplying to Japan. (Table 2-5)

Thailand Apart from the bamboo-shoots supplying to the demand of Thailand's people, they are exported to Japan. The annual exported bamboo-shoot is more than 7,000 tons.

3.3 Processing of bamboo-wood

Any country noted for bamboo is mostly short of timber. Bamboo wood is chiefly used in buildings, furniture and daily necessities. These productions are also simply processed and their quality is not excellent. Although bamboo wood has excellent physical and mechanical characteristics, its size, shape and hollow inside limit its use. In Japan, the yields of bamboo forest and bamboo wood industries are decreasing day after day. The reason is that the area of bamboo stand is decreasing and the lack of bamboo materials. The Japanese have manufactured bamboo plain sawn board, however, production of scale hasn't been formed. In The Philippines, they have produced bamboo mosaic board and bamboo laminate and obtained patent. In India and Thailand, bamboo concrete is still in use. In some countries noted for bamboo in Latin America and Africa, bamboo experts of China and Japan have been invited to give directions for bamboo yielding, processing and utilization.

3.4 Bamboo Manufactures and Bamboo Buildings

In any country producing bamboo, there are their tradiational bamboo manufactures and buildings. The properties of bamboo culms such as straightness, lightness, strength, hardness, fiber content, flexibility and easy workability are ideal for different technological purposes. In China, there are bamboo weavings, bamboo carvings, bamboo mats, bamboo handicraft articles and bamboo daily necessities. China has a long history in making exquisite bamboo wares, is ahead of other countries. Besides, there are many bamboo buildings, like bamboo bridge, bamboo fence, bamboo pavilion, etc., populared with people of the world. For example, a three-storied bamboo pavilion in Yiyang county, Hunan; a three-storied bamboo building in Sweden and a bamboo bridge which is named the first bamboo bridge in Europe in Germany designed by Yunan Architectural Design Institute. In Japan, a five-li bamboo corridor in Taoyuan county, Hunan; there are fine bamboo workmanship, exquisite bamboo articles which are used in flower arts and tea culture. In addition, most fences and doors of parks are ornamented with bamboo. In Korea, there is bamboo fishing rod. In some countries of Southeast Asia, there are bamboo musical instruments and bamboo weavings which have a best sell all over the world. In The Philippines in 1818, there is a Catholic father, who made a bamboo organ which consists of 950 bamboo culms. Of course, the preservation from decay, the insect protection and the cracking protection for these products still need further study.

Table 2—5 The bamboo area, the yield of bamboo shoot and wood, the importation and exportation of bamboo shoot in Japan

year	yield of bamboo wood		yield of bamboo shoot		consuming of bamboo shoot (t)			
	hm^2	t	hm^2	t(A)	import (B)	export (C)	A+B −C	kg per person
1957	168.406	—	—	85.985	23.580	1.973	107.592	1.2
1967	146.221	385.540	—	77.617	35.450	685	112.322	1.2
1977	115.197	265.296	88.868	145.258	194.453	676	339.035	3.0
1978	122.702	274.467	76.930	145.717	189.416	818	334.315	3.0
1979	121.355	258.705	69.350	145.819	147.519	678	292.660	2.5
1981	120.934	252.837	50.179	156.674	138.027	1.844	292.857	2.5
1982	117.984	244.044	48.444	153.886	157.828	833	310.881	2.7
1984	111.791	238.980	44.513	146.929	84.647	788	230.788	2.0
1985	104.779	261.762	51.103	161.123	170,020	730	330.513	2.8
1986	101.174	249.753	51.362	146.773	194.020	630	340.163	2.9
1987	94,362	248.920	35,660	137.216	260,912	573	397.555	3.4
1988	93.342	210.729	33.428	150.349	412.919	—	563.268	4.8
1989	88.190	205.848	53.181	138.276	239.319	—	377.595	3.4
1990	88.171	238.770	53.128	137.616	244.537	—	382.153	3.4
1991	84.440	229.894	54.324	112.460	216.691	—	329.151	2.9
1992	79.633	202.961	48.994	100,060	305,263	—	405.323	3.4
1993	65.848	177.296	46.162	90.164	320.878	—	411.042	3.3
1994	71.116	157.871	43.741	74.617	339.115	—	382.856	3.2
1995	58.088	187.921	43.326	57.083	362.580	—	419.663	3.5
1996	62.990	119.840	41.975	53.083	378.011	—	431.094	3.6
1997	60,045	94,024	40.336	48.593	166,002	—	214.596	1.7

Notes: yield of bamboo wood is calculated according to : one bundle = 35kg.

[1] In this table, the weight of bamboo-shoot imports and exports have been converted into fresh weight per kilogram dried bamboo-soot is converted into 20 kilogram fresh bamboo-shoot per one kilogram bamboo-shoot can is converted into 2.5 kilogram fresh bamboo-shoot.

[2]The bamboo area in 1957 is the largest (l6.8406hm2). During 1957~1992, the area reduced by 0.52% every year.

[3]The yield of bamboo wood in 1965 is the highest (385.380t). During 1965~1992, the yielding of wood reduced by 1.55% every year. The average yield of per unit area is 2.07~2.72t/hm2.

[4]During 1955~1991, the yield of bamboo increases by O.86 % every year. The average yield of per is 2.6~3.37t/hm2.

[5]The average annual bamboo-shoot consumption of per person is: 1.20kg fresh bamboo shoots in 1950~1960; 1.35kg fresh bamboo shoots in 1961~1970; 2.47kg fresh bamboo shoot in 1971~1980; 3.08kg fresh bamboo shoot in 1981~1991.

Chapter 3 the Production and Utilization of Bamboo Forest in China

With economic development of human society, the primeval forests on the surface of the Earth have been deteriorated, especially in the tropical and subtropical zones, where the forest cover is rapidly reduced, water and soil loss is increasing with each passing day, climate becomes abnormal and air gets polluted. The living environment of human beings has been seriously threatened. How to preserve forests on earth, how to reforest in the tropical and subtropical zones have become common concern of all mankind. Bamboo grows in tropical and subtropical zones and often forms a mixed forest with other trees. Being below the main storey it is apt to be neglected. Nevertheless after destructive cutting of forest in these two zones bamboo has been regenerated as secondary bamboo stand since it has the characteristics of growing fast, propagating with rapidity and easy regenerating. Besides, as bamboo is widely used and is of high economical value, it is planted on the wasteland in the mountains, uncultivated land and some open spaces behind or in front of houses, thus artificial bamboo stand is formed. The secondary stand and artificial stand are spreading around by means of their subterranean shoots. So the bamboo area on the surface of the earth is increasing year after year. Take China for example, before 1950, pure bamboo area was about 1,650,000 hectares, while in 1980 it came up to 3,410,000 hectares. In the last thirty years bamboo forest area has increased by 2.45% annually. In terms of this speed, by now the pure bamboo forest area in China would have been 4 million hectares.

In addition to this, there are about 3 million hectares of bamboo forest which have formed mixed forest or alpine bamboo forest. Pandas live right in the alpine bamboo forest. In some countries in the tropical and subtropical zones, more or less, the forest area is reduced while the bamboo forest is extending. However in some other places bamboo forest is not reasonably made use of, as the destruction of bamboo forests can be found.

With the extending of the bamboo forest area on the surface of the earth bamboo is playing a more and more important role in people's life. How to develop the production of bamboo forest and raise its yield has become a remarkable problem in forestry production of the world. In the 17th Session of IUFRO held in Japan in 1981, for the first time a group in charge of production and utilization of bamboo was formed under IUFRO. It is obviously right to do so.

China has a long history in the production and uses of bamboo. Since 1949 the Chinese government has laid enough emphasis on the production and uses of bamboo, including its sales, etc, and has developed into a new trade – Chinese bamboo trade. Bamboo Association of China (CBA) was established in 1984. CBA is a nationwide unofficial organization of science and technology. It has its branches in the provinces which are noted for bamboo production. CBA, by now, consists of more than 5,000 members, including 8 honorary members from Japan, the Federal Republic of Germany, Thailand and the Philippines. In 1992, CBA was renamed Chinese Bamboo Industry Association and was directly led by Forestry Ministry.

Approved by the Chinese government, for the first time a bamboo research institute-the Bamboo Research Institute of Nanjing Forestry University (NFUBRO was established. The institute consists of such research offices as bamboo forest culture, utilization of bamboo forest, popularization of technology, including an editing and publishing office. Besides the institute has a culm processing laboratory, a bamboo experimental station and an administration office under it. In ten provinces of south China 24 fixed experimental stations have been set up.

The institute is made up of more than sixty researchers-including full-time and part-time research workers, six of them are professors, the fifteen of them associate professors. The institute has edited and published two periodicals "Bamboo Research" and "Bamboo Information". NFUBRI takes on research tasks both form the government and non-government units and has been in correspondence with the workers in the bamboo area in over 20 countries. CBA and NFUBRI are ready to cooperate with bamboo researchers and staff in all countries.

Table 3-1 Distribution of bamoos in China (in 1990~1995)

order	province city prefecture	*P. pubescens*			other bamboo species		total	
		Million (hm^2)	million (culm)	million (t)	million (hm^2)	million (t)	million (hm^2)	million (t)
1	Hunan	0.6353	1293.81	19.407	0.0482	0.705	0.6835	20.112
2	Fujian	0.6326	943.80	14.157	0.0150	0.924	0.6408	15.081
3	Jiangxi	0.6253	1030.00	15.450	0.0840	0.991	0.7093	16.441
4	Zhejiang	0.5281	911.62	13.674	0.0964	1.227	0.6245	14.901
5	Anhui	0.1529	411.00	6.165	0.0505	1.299	0.2034	7.464
6	Guangdong	0.1081	310.00	4.650	0.2099	5.000	0.3180	9.650
7	Guangxi	0.0951	240.00	3.600	0.0681	1.752	0.1632	5.352
8	HUbei	0.0622	147.43	2.211	0.0253	0.471	0.0875	2.682
9	Ninggbo	0.0504	142.00	2.130	0.0065	0.167	0.0569	2.297
10	Guizhou	0.0200	43.17	0.648	0.0243	0.692	0.0443	1.340
11	Jiangsu	0.0200	43.16	0.647	0.0200	0.515	0.0400	1.162
12	Sichuan	0.0190	47.54	0.713	0.7210	15.998	0.7400	16.711
13	Chomgqing	0.00033	7.85	0.118	0.0508	2.073	0.0541	2.193
14	Taiwan	0.0033	10.96	0.164	0.1723	4.434	0.1756	4.598
15	Henan	0.0020	3.60	0.054	0.0147	0.378	0.0167	0.432
16	Shanxi	0.03	0.55	0.0008	0.1342	2.652	0.1345	2.660
17	Yunnan	0.0003	0.55	0.0008	0.1017	2.617	0.1020	2.625
18	Hainan	—	—	—	0.0538	1.392	0.0539	1.392
19	Shandong	0.0001	0.10	0.001	0.0017	0.044	0.0018	0.045
20	Shanxi	—	—	—	0.0002	0.005	0.0002	0.005
total		2.9583	5587.14	83.805	1.8986	43.336	4.8902	127.143

Table 3—2 The area of bamboo forest in key counties noted for bamboo in China.

No.	county	hm²	million culms	No.	county	hm²	million culms	No.	county	hm²	million culms
—	Hunan	—	—	27	Dehua	73.40	11.08	27	Guangfeng	72.67	11.14
1	Taojiang	399.82	398.66	28	Luoyuan	72.47	12.88	28	Yiyang	69.33	12.20
2	Anhua	323.60	323.60	29	Wuyishan	64.73	15.39	29	Fenyi	66.67	12.57
3	Liuyang	303.56	303.08	30	Taining	50.04	12.08	30	Liangfu	66.67	13.35
4	Taoyuan	283.55	262.18	31	Gutian	58.07	8.72	—	Zhejiang	—	—
5	Suining	245.68	245.68	32	Pingnan	56.20	7.47	1	Anji	57.334	445.34
6	Xinhua	215.10	215.10	33	Ningde	54.40	11.77	2	Linan	468.76	179.33
7	Huitong	184.85	184.14	34	Minqing	51.53	9.14	3	QUxian	272.67	266.67
8	Xinning	183.85	183.84	35	Yongchun	47.33	7.37	4	Fuyang	259.33	228.00
9	Dongan	167.04	159.66	36	Yongtai	46.47	4.88	5	Longquan	246.00	245.33
10	Longhui	164.67	164.67	37	Wuping	41.27	8.51	6	Zhuji	185.33	182.00
11	Chengbu	154.54	154.25	38	Putian	0.4160	5.56	7	QInyuan	180.67	180.00
12	Pingjiang	152.13	151.67	39	Fuzhou	0.3880	6.72	8	Yuhang	178.67	125.33
13	Xinzhao	145.67	145.67	40	Anxi	0.3840	7.76	9	Longyou	175.33	174.67
14	Dongkou	142.85	142.84	41	Zhouning	0.3480	8.32	10	Fengxin	164.67	122.67
15	Shuangpai	127.17	122.60	42	Fuding	0.3453	9.98	11	Deqing	160.00	108.67
16	Qianyang	125.10	117.97	43	Xiapu	0.2967	67.5	12	Yuyao	152.00	145.33
17	Youxian	121.73	121.73	44	Zhaoan	0.2873	2.00	13	Chengxian	143.33	118.67
18	Zixing	120.53	119.35	45	Fuan	0.2687	7.24	14	Changxing	140.00	130.00
19	Rucheng	117.86	114.89	46	Shouan	0.2680	5.43	15	Jingning	118.00	116.00
20	Yanling	116.88	115.60	47	Pinghe	0.2653	5.59	16	Suichang	112.67	112.67
21	Haoshanqu	110.21	109.90	48	Longhai	0.2480	4.73	17	Shaoxing	112.00	94.67
22	Shuangfeng	109.54	109.50	49	Mingxi	22.87	5.54	18	Ninghai	108.67	107.33
23	Laiyang	108.90	108.65	50	Datian	22.20	4.26	19	Jinxian	104.67	94.67
24	Zhishanqu	107.29	106.43	51	Lianjiang	20.07	2.03	20	Taishun	103.33	99.33
25	Lingxiang	95.79	95.79	52	Qingliu	19.07	2.69	21	Wuyi	95.33	94.00
26	Lanshan	91.76	89.64	53	Huaan	16.80	2.69	22	Huzhou	94.00	68.67
27	Chaling	91.22	91.22	54	Zherong	10.93	3.13	23	Jinyun	91.33	91.33
28	Dingchengqu	91.10	91.04	55	Zhangpu	7.73	0.80	24	Chunan	87.33	82.67
29	Changning	87.49	87.40	56	Yunxiao	6.53	0.16	25	Jiangshan	85.33	84.67
30	Hengshan	82.76	82.76	57	Fuqing	4.60	0.46	26	Linhai	85.33	78.67
31	Rongxing	79.20	77.36	58	Zhangzhou	3.67	0.76	27	Songyang	82.00	81.33
32	Lianyuan	74.53	74.51	59	Nanan	2.73	0.24	28	Tiantai	73.33	71.33
33	Yueyang	70.07	70.07	60	Changtai	2.00	0.52	29	Xianju	72.67	69.33
—	Fujian	—	—	—	Jiangxi	—	—	30	Xinchang	70.00	62.67
1	Jianou	686.00	44.87	1	Yifeng	480.00	81.11	31	Jinhua	68.67	68.00
2	Yongan	330.13	50.54	2	Fengxin	372.00	53.18	32	Jiande	68.00	61.33
3	Pucheng	291.80	48.18	3	Chongyi	276.00	62.05	33	Huangyan	66.67	64.00
4	Shunchang	320.80	57.29	4	Qianshan	272.67	41.10	34	Shangyu	66.67	61.33
5	Chongan	249.80	37.31	5	Wanzai	234.67	38.94	—	Anhui	—	—
6	Shaowu	241.93	44.95	6	Yichun	222.00	32.48	1	Guangde	300.50	80.32
7	Changding	227.20	30.87	7	Tonggu	220.00	42.21	2	Ningguo	200.00	44.96
8	Nanping	218.93	39.97	8	Guixi	208.67	32.51	3	Jingxian	120.00	35.78
9	Liancheng	202.60	28.16	9	Anfu	192.67	25.05	4	Xiuning	127.00	30.73
10	Longyan	193.47	32.80	10	Shangrao	182.67	23.83	5	Huoshan	106.00	26.00
11	Youxi	185.27	30.10	11	Yihuang	182.00	28.98	6	Taiping	81.00	14.96
12	Shaxian	184.13	32.85	12	Suichuan	168.67	31.64	7	Jinzhai	75.62	—
13	Sanming	167.60	30.03	13	Lichuan	162.00	26.16	—	Guangxiqu	—	—
14	Jianyang	162.33	40.19	14	Jingan	156.00	26.82	1	Lingchuan	154.33	23.44
15	Shanghang	159.60	21.90	15	Zixi	152.00	32.17	2	Xingan	137.00	20.11
16	Guangze	133.87	43.15	16	Lean	120.00	17.43	3	Lingui	89.13	11.90
17	Jiangle	130.87	26.78	17	Chongren	108.00	16.03	4	Ziyuan	53.47	9.93
18	Ninghua	128.73	17.51	18	Wanan	105.33	20.72	5	Rongshui	52.00	7.50
19	Zhenghe	124.80	14.81	19	Luxi	104.00	17.32	6	Zhaoping	52.00	7.60
20	Minhou	113.33	10.51	20	Dexing	102.67	13.75	7	Rongan	42.67	6.40
21	Nanjing	93.87	16.14	21	Dayu	98.67	16.18	8	Sanjiang	37.33	5.40
22	Zhangping	93.47	18.73	22	Taihe	88.67	19.08	9	Yongfu	32.33	5.54
23	Songxi	92.93	10.88	23	Maoyuan	83.33	13.64	10	Longsheng	29.80	6.54
24	Yongding	89.40	13.17	24	Shangyou	82.00	18.49	—	Hubei	—	—
25	Jianning	89.13	19.72	25	Wuning	78.00	17.55	1	tongshan	131.60	14.62
26	Xianyou	78.47	14.58	26	Yongfeng	75.33	8.77	2	Chongyang	109.46	15.80

(continuation)

No.	county	hm²	million culms	No.	county	hm²	million culms	No.	county	hm²	million culms
3	Puqin		14.21	3	Yongchuan	11.72	—	1	Zhenba	125.33	696.80
4	xianning		10.04	—	others	—	—	1	Taibei city	9.60	—
—	Guangdong		—	1	Dazhu	131.33	30.19	2	Gaoxion	29.69	—
1	Nanxiong		—	2	Jiangan	76.76	5.85	3	Taibei	2.96	—
2	Renhua		25.00	3	Naxi	140.00	42.68	4	Yilan	3.97	—
3	Heping		—	4	Daxian	53.33	14.33	5	Taoyuan	4.44	—
4	Shixing	100.00	—	5	Guangan	51.20	42.00	6	Xinzhu	1.31	—
5	Dapu	78.33	—	6	Xuanhan	43.27	15.00	7	Miaoli	9.79	—
6	Jiaoling	—	—	7	Fuling	41.33	4.93	8	Taizhong	4.88	—
7	Lechang	212.00	—	8	Dali	40.37	1.10	9	Zhanghua	40.86	—
8	Qujiang	116.6	—	9	Hejiang	39.40	5.62	10	Nantou	51.31	—
9	Guangning	409.00	—	10	Chuannan	34.00	2.56	11	Yunlin	26.59	—
—	others	24.87	—	11	Liangping	34.67	4.52	12	Jiayi	24.34	—
1	Guangzhou	806.40	—	—	Guizhou	—	—	13	Tainan	1.42	—
2	Shaoguan	363.33	—	1	Chishui	182.67	30.39	14	Pingdong	7.22	—
3	Shaoguanqu	32.00	—	—	Yunnan	—	—	15	Taidong	8.17	—
4	Shantouqu	—	—	1	Baoshanqu	8.30	8.13	16	Hualian	2.99	—
5	Foshanqu	114.00	—	2	Dehongqu	54.94	64.43	17	Jilong	2.10	—
6	Zhaoqingqu	266.67	—	3	Linlunqu	130.73	293.45	18	Xinzhu	0.18	—
7	Zhanjiangqu	—	—	4	Simaoqu	63.03	15.69	19	Taizhong	10.18	—
8	automous	41.20	—	5	Xishuang-banna	548.35	422.19	20	Jiayi	0.39	—
—	Jiansu	17.06	—	6	Honghequ	116.39	9.78	—	Henan	167.00	—
1	Yixing		22.23	7	Wenshanqu	51.78	4.35	—	Shandong	20.00	—
2	others		—	8	Qujingqu	2.28	0.19	—	Gansu	26.67	—
—	Sichuan		—	9	Zhaotongqu	44.15	3.72	—	Shanxi	3.33	—
1	Changning		7.80	10	Kunming	3.13	0.26	—	Shanghai	6.67	—
2	Hejiang		3.00	—	Shanxi	—	—	—	Hainan	539.00	—

1. Bamboo Resources in China

1. Bamboo species and their distribution

China lies in the east of Asia, on the west coast of the Pacific. It occupies an area of more than 10 million square kilometers. China has a varied topography, which consists of plains, hills and mountains and its climate contains those of Tropical and Sub-Tropical Zones, Temperate Zone and Frigid Zone. It has rich resources in bamboo including clump bamboo of sympodial type fit for tropical regions and diffuse-form bamboo of monopodial type fit for subtropical regions, and intermediate-form bamboo of polypodial type and clump of sympodial type which are highly cold-resistant fit for the regions on the high elevation and at high latitude. According to incomplete statistics, in China there are 50 genera of bamboo consisting of over 500 species. These bamboos are distributed over our vast land-in the south of 40^0 northern latitude. Among 30 provinces (municipalities or minority regions) 24 of them are distributed with bamboo (Table 3–1, 3–2). As climate, soil and topography are varied and biological characteristics are different the distribution of bamboo in China is obviously zoned and regional. Roughly there are four regions.

(1) Yellow River-Yangtze River bamboo area. It is located between 30^0 and 40^0 of North latitude with average temperature annually 12^0C to 17^0C; the average temperature in January is 2^0C to 4^0C. Annual rainfall is 600 to 1200 mm. The main genera of bamboo in this area are: *Arudinaria, Fargesia; Phyllostachys, leioblastus*.

(2) Yangtze River-Nanling Range bamboo area. It is located between 25° to 30^0 of north latitude, the average temperature annually is 15^0C to 20^0C the average temperature in January is 4^0C to 8^0. The annual precipitation is 1,000 to 2,000 mm. It is China's largest bamboo area, which is the richest in bamboo resources. Among other bamboo forest the area of *Phyllostachys, and Pubescens* forest occupies 2,400,000 hectares. In this area the main genera of bamboo are: *Brachystachyum, Indosasa, Indocalamus, Phyllostachys, Pleioblastus*.

(3) South China bamboo area. It is located between lotto 25^{0}C of north latitude. The average temperature annually is 20^{0}C to 22^{0}C. The average temperature in January is above 8^{0}C. The annual precipitation is 1,200 to 2,000 mm or more. It tops the rest of the bamboo areas for its numerous species of Chinese bamboo. The main genera are: *Acidosasa, Bambusa, Chimonobambusa, Dendrocalamus, Dinochloa, Gigantochloa, Indosasa, Lingnania, Melocalamus, Melocanna, Oxytenanthera, Psudosasa, Schizostachyum, Thyrsostachys*.

(4) Alpine bamboo area of Southwest of China. It is located in the high mountainous ranges of west China, with an elevation of 1,000 to 3,000 meters. The average temperature of a year is 8^{0}C to 12^{0}C and the average temperature in January is –6^{0}C to 0^{0}C. The annual precipitation is 800 to 1,000 mm or more.

This area is of primeval bamboo forest where precious animals like panda, golden monkey are living. The main genera of bamboo here are: *Chimonobambusa, Fargesia, Qeongzhuea, Yushania*.

For hundreds of years different *bamboo species* have been introduced from one place to another, especially during the 1960s and 1970s. South bamboo species were transplanted to the North. Nearly 40,000 hectares of bamboo forest has been newly cultivated in the Yellow River Valley. Moreover in the last decades China has introduced some varieties of bamboo from some Southeast *Asian* countries and Japan, so that China has been enriched with more bamboo resources (Table 3 – 3).

2. The production of bamboo in China

2.1 The production of timber-used bamboo stand.

China now has an area of 7 million hectares of bamboo forest; 4 million hectares is pure bamboo forest, 3 million hectares of them is primeval mixed bamboo forest and alpine bamboo forest.

Out of the 4 million hectares of pure bamboo forest 2,800,000 hectares is *Phyllostachys pubescens,* occupying 70%. Annual allowable cut of bamboo is approximately 10 million tons, about 5 million tons of which is commercial culm. Artificial pure bamboo stand can be divided into three classes according to the management level:

The first class of bamboo forest: Soil-conditioning and fertilizing and properly cutting so as to keep the reasonable structure for its high yield. This class of bamboo forest occupies approximately 400,000 hectares, 10% of the total area of the pure bamboo stand. Each year each hectare produces 7 to 10 tons of bamboo culms, some of the stands with small area and high yield can reach 35 tons per hectare annually.

The second class of bamboo stand: Get rid of the bushes in the bamboo stand and weed it, conduct proper felling and keep there a reasonable structure of the stand. This kind of bamboo stand occupies approximately 2,000,000 hectares of the area, 50% of the total area of the pure bamboo stand. It produces 3.5 to 7 tons of bamboo culms per hectare annually.

The third class of bamboo stand: Usually this class of stand is not systematically and scientifically managed or is not properly treated, or it is felled too much. It occupies approximately 1,600,000 hectares of the area, 40% of the total area of the pure bamboo stand. It produces 3.5 tons of bamboo culms per hectare annually.

China’s task of bamboo production is to raise the third class of bamboo stand to the second class and the second class to the first class.

If the plan should be carried out, China’s yield capacity of bamboo culm would be three or four times as much as it is now.

2.2 Production of shoot-used bamboo stand

Bamboo shoot is regarded as a traditional dish by Chinese people. There are about fifty species of edible bamboo shoots. Among them are the bamboo of better qualities, growing on large scales and with high yield are these: *Phyllostachys pubescens, Phyllostachys praecox, Phyllostachys vivax, Phyllostachys ridenscens, Phyllostachys dulis, Phyllostachys glauca, Phyllostachys nuda, Phyllostachys viridis, Chimonobambusa utilis, Chimonobambusa quadrangularis, Dendrocalamus latiflorus, Dendrocalamus oldhami, Dendrocalamus giganteus, Bambusa rigida, Lingnania venchousis*.

In China there are two kinds of bamboo forest for growing bamboo shoots: One is to produce bamboo shoots by making use of timber-used bamboo stand. It is called culm and shoots bamboo stand. Since in timber-used bamboo stand 50% to 60% of the bamboo shoots can't grow into bamboo or can only grow into bamboo of poor quality, they should be dug out before they cease to grow and used as food. This kind of bamboo stands grows on large scales, and the bamboo shoot spring up as food for the people in the mountainous regions or are processed into dry shoots for market.

The other kind of bamboo stand specializes in producing bamboo shoots therefore it is named shoot-used bamboo stand, which should be carefully cultivated, its soil needs to be loosened and fertilized every year. In some places the bamboo stands are irrigated in dry season. Management of the stand requires fine work especially in digging out bamboo shoots. The shoot-used stand usually produces 10 to 20 tons per hectare a year, and some of the high-yield stands 30 to 35 tons per hectare yearly.

Nowadays China has 4 million hectares of the bamboo stand producing shoots. Among them are some stands specializing in producing shoots occupy 100,000 hectares, 500,000 to a million tons of bamboo shoots produced all over the country every year are for commercial use besides those required by the mountainous people for food (Table 3 – 4).

2.3 Bamboo stand for paper pulp

It is more than 1,700 years since China has made bamboo into paper. However in the past as paper was made by hand, its quality was poor with low efficiency in production. In these last thirty years China has set up a dozen of paper mills using bamboo as raw material; every year about a million tons of bamboo is used for paper making. In recent years China has been building three bamboo paper factories with the output of 100,000 tons of paper.

Main Bamboo Species for paper pulp are as follows: *Pyllostachys pubescens, Pyllostachys makinoi, Bambusa pervariablis, Bambusa sinospinosa, Bambusa rigida, Bambusa textilis, Lingnania chungii, Sinocanamus affinis, Sinocanamus farinosus, Sinocanamus oldhami*.

The management levels of bamboo stand for paper pulp are various with different places. Those with efficient management each hectare of bamboo may produce 5 tons yearly of paper or paper pulp. Those with soil-conditioning management may produce one to three tons of paper or paper pulp. Chinese traditional handmade paper can only be made from young bamboo. Felling young bamboo in the bamboo stand will do great harm to the bamboo. But now paper produced by machines is made from old bamboo having grown for three or four years, so that we can keep a balanced structure of the stand. Only in this way can the paper-making material be supplied steadily.

2.4 The development of ornamental bamboo

Chinese people like bamboo very much for it keeps green all the year round, remains unyielding in winter and stands tall and lofty, yet keeps modest. Chinese often take bamboo as a standard image, after which they conduct themselves in society. That is why people like to plant bamboo around the house, in the garden and park. There are more than two decades of bamboo parks and bamboo gardens in the whole country. Horticulture lovers make bamboo into potted landscape. Moreover some scenery spots have been built in bamboo forests, which have attracted a great number of visitors and tourists.

2.5 The development of protective bamboo stand

Bamboo has a strong subterranean shoots and rhizome system, which is capable of conserving water and soil and strengthening the riverbank, so in some parts of China where there is water loss and soil erosion, or where the banks of rivers, lakes and reservoirs are easy to be washed away, bamboo is planted to protect them from water loss and soil erosion. In so doing a good result has been achieved. Take Dayin river, Yunnan province for example, a project to protect its bank with stones had failed, and later to succeed by planting bamboo on the bank instead. As it is known to all, in China the water quality of Yangtze River is better than that of Yellow River. One of the important reasons for this is that the upper reach of Yangtze River and the source of its branches are covered with al pine bamboo forests. The Chinese government considers it an important measure to conserve water through afforestation including bamboo afforestation.

3. Utilization of bamboo forest

3.1 The bamboo used in the rural area and for agriculture

In China the agricultural population occupies 80% of the total. Many of their farm tools and articles for daily use are made of bamboo. Especially in the South, farmers have to rely mainly on bamboo for their clothing, food, lodging and transportation - basic necessities of life. Therefore about 70%~80% of the bamboo material produced all over the country is consumed on the countryside and for agricultural production.

3.2 Bamboo for handicraft

Bamboo ware by handicraft has a long history in China. Bamboo can be made into various articles with different designs and fine craftsmanship, such as figures and animal image woven with bamboo skin, wind and stringed instruments, hat and carpet woven with bamboo sheath and figures carved on the bamboo stock. The Chinese handicraft production relies mainly on skillful hands. Now machines have done the peeling of bamboo skin and weaving. Besides meeting the need in domestic market China's bamboo ware is exported to decades of foreign countries.

3.3 Bamboo used for building industry

It used to be popular for the people in mountainous regions in South China to build their houses with bamboo, however with the improvement of the living conditions of the people most houses are built with bricks and tiles instead, so the bamboo for that use has greatly reduced. Nevertheless quite a lot of bamboo is used as scaffolding and scaffold board for architecture in towns and cities. In the 1950s we once made use of bamboo into bamboo concrete. Later with the development of iron and steel industry steel-concrete structure is more reasonable than bamboo-concrete structure in price and more durable. That is why bamboo concrete is no longer used. Nonetheless in the mountainous regions where there are no transport facilities bamboo concrete is still of use in building cottage by farmers.

3.4 Culm for handmade broad of bamboo

Handmade board of bamboo consists of bamboo plywood, bamboo-woven plywood, bamboo fiber board, bamboo chip board, culm shavings board denatured culm etc. In recent years bamboo artificial board has been developing rapidly. There are more than two hundred bamboo handmade board factories of medium size and small size, which can produce several dozens of types of bamboo artificial board. Bamboo wearable. Bamboo plywood is fit for making into the deck plate of an automobile or the form panel in architecture.

3.5 Bamboo paper industry

Paper made from bamboo in China has a long history but a slow development. It is in the last thirty years that bamboo paper made by machines has been able to develop rapidly. Now in the whole country there are over a dozen of paper mills using bamboo as raw material. The recent years the government has paid enough attention to make paper from bamboo. Three new paper mills of bamboo material have been built up, their annual output is 100,000 tons of paper.

3.6 The utilization of bamboo shoots after processing

China is rich in the resources of bamboo shoot. In the past bamboo shoots were only processed to make into dried shoots. These last few years canned shoots industry has developed rapidly; more than a hundred *canned* bamboo shoots factories have been set up. The annual output of the canned shoots is over 100,000 tons, which sells in markers both at home and abroad.

3.7 Making use of the environment in the bamboo stand

In recent years edible fungi, medicinal herbs and flowers have been cultivated in the natural environment of the bamboo forest. The economic benefits of these side products surpassed by far that of bamboo production.

3.8 Utilization of sheath, leaves and branches of bamboo

Bamboo sheath can be used as wrapping, paper-making material and be woven into carpet. Bamboo leaf consists of rich protein and 17 varieties of amino acids. Bamboo leaf can be used as feed and bamboo protein can be extracted from it as food for mankind. Bamboo branch is a good material for making the broom.

4. The scientific research of bamboo in China

China has a contingent of bamboo research workers made up of several hundreds of senior and medium technicians. They are working respectively in colleges, research institutions and production units of different provinces which are notable for bamboo production. Research workers are engaged in their research concerning bamboo production in terms of the needs of local people as well as the government. Besides NFUBRI, a national institution of bamboo, bamboo research offices are set under some forestry research institutions and forestry colleges; Some bamboo institutions are also set in certain regions. There are about a dozen of bamboo research institutions (or research offices) in the country. China has edited and published three periodicals specialized in bamboo. They issue altogether more than a hundred papers and research report every year. And every year national academic conferences on bamboo research are held once or twice, technical training class is open once or twice. Nanjing Forestry University is in charge of bringing up research students of doctorate's degree and master's degree and master's degree on bamboo forest ecology. China's main achievements on bamboo research in these last thirty yeas and more areas are as follows:

4.1 On enlarging the area of bamboo forest

The biological and ecological characteristics of leading bamboo afforestation have been made so to suit bamboo species to local conditions. We have studied the technique of seed breeding of *Phyllostachys, pubescens* as well as the methods of slip for clump, and the seedling propagation of secondary branches so that the cost of afforestation is greatly reduced. More than a hundred of bamboo varieties have been transplanted interchangeably for experiments on a nation-wide scale. In the 1970s "bamboo transplantation from South to North" was greatly carried out, bamboo has been newly afforested in the Yellow River Valley.

4.2 On raising per unit area yield

On the basis of experience summarized by the broad masses of people, we have conducted a fixed-position trial on high yield structure and yield measures so that the breeding technique of high yield measures so that the breeding technique of high yield has been studied of bamboo forest growing out Chinese leading bamboo species. NFUBRI has put forward a theory on high yield structure of bamboo stand and made a mathematical model for high yield structure of *Phyllostachys pubescens* stand. Now it has been made possible that the technical design of breeding of *Phyllostachy pubescens* stand, yield anticipation with use of computer, and financial result can be calculated.

4.3 On the bamboo stand and its prevention and elimination

We have made study of principle laws governing the growth and development of plant diseases and pests as well as preventive measures against them in the bamboo stand. Serious bamboo diseases and pests have mainly been controlled. Bamboo culm and bamboo articles have been effectively prevented from being rotten and bored.

4.4 On the classification of bamboo

Chinese bamboo has been systematically classified and more than a hundred new species have been found. The vegetative and propagating organs have been systematically studied through morphological phytotomy.

4.5 On bamboo blossoming and sexual hybridization and its changes in physiology and biochemistry.

Since bamboo blossoms we have conducted breeding by means of sexual hybridization, and bred and selected some fine hybrid to be cultivated and introduced into bamboo production. We also made study of bamboo rejuvenation in its florescence and put forward some technical measures to make bamboo blossom and rejuvenate.

4.6 On the qualities of bamboo

We have made the test of the culm of Chinese leading bamboo species on their qualities of physics, mechanics and chemistry, so as to provide the scientific grounds for the mechanical processing of culm and chemical processing and use. We have made analysis of 50 to 60 species of Chinese bamboo used for paper making to find out how much cellulose and wood-cellulose are contained on them. We have calculated calorific values, when burning, of over 60 species of Chinese bamboo.

4.7 On bamboo shoot production and its use

We have analyzed the nutrition of Chinese leading bamboo shoots and made experiment on how to cultivate shoot-used bamboo stand with high yield. We have mastered techniques of cultivating bamboo shoot with high yield as well as its processing and keening.

4.8 Handmade board of bamboo

We have made study of productive technology of plywood and fiber board and shavings board of bamboo so that the technical problems have been solved in setting up the factory of handmade board of bamboo.

4.9 On medicinal value and drink made from bamboo

4.10 On utilization of the ecological environment of bamboo stand.

We have studied hydrological effect, the effect of water and soil conservation and the effect of beautifying the environment. Bamboo trade in China is under a favorable situation and rapid development. This should be attributed to the attention paid by the Chinese government and its support for the bamboo trade as well as to hard work devoted by workers of the bamboo circle. The Chinese workers of bamboo trade attach great importance to the successful results and experience of colleagues from various countries in the world.

4.11 On the ecological effect of bamboo stands.

4.12 On bamboo culture in China.

We would like to share our experience with all the developing countries without any preserve. May the bamboo trade all over the world be successful and flourishing so as to bring benefit to mankind.

Table 3－3 Change of bamboo resources in China

year	*Phyllostachys pubescens*			Other bamboo species		Total	
	10^3 hm^2	10^4 culms	10^3 t	10^3 hm^2	10^3 t	10^3 hm^2	10^3 t
1950	1,200.0	193,431	29,013	481.0	7,200	1,681.0	36,213
1957	1,499.5	237,553	35,633	700.0	10,500	2,200.5	46,133
1965	1,619.6	292,148	43,822	745.9	11,180	2,365.5	55,011
1975	2,001.2	354,274	53,141	703.5	10,552	2,704.7	63,693
1989	2,418.7	379,589	56,938	983.1	14,750	3,401.8	71,688
1990	2,685.4	491,730	73,410	1,733.7	41,512	4,419.3	114,923
1995	2,962.5	549,314	82,397	1,872.3	42,670	4,834.8	125,067
1998	3,229.9	633,175	94,972	2,272.7	56,258	5,502.6	151,229

Table 3－4 Production of bamboo shoot in China （10^3 t/year）

Year	Zhejiang	Fujian	Jiangxi	Hunan	Othe	Total
1981	110.3	60.0	103.0	103.0	80.0	456.3
1990	250.0	260.0	200.0	300.0	240.0	1,250.0

Chapter 4 Studies on Growth of Bamboo Shoot-culms

The growth of plants is the basis of their shape and formation. For a long time, botanists have paid attention to the studies on the phenomenon of the growth of plants and have given some definitions to the growth of plants: the growth of plants is the increment of their weight, reproduction of protoplasm, the proliferation of cells, and the permanent increment of their volume, etc. In the 19th century J. Sachs made a survey of the growth of plants. The curve he made to show the relationship between the volume and the time of growth was a curve of “s” type. The growth of bamboo shoot-culms includes the number of individual increase in a bamboo colony and the growth of organs such as culms, branches, leaves, rhizomes, roots and shoots. The growth of both a bamboo colony and an individual bamboo finds its expression in the increase of volume (such as the number of individuals, length, thickness) and the increase of weight. In 1958 and 1965, the author made a survey of the growth of the height and weight of culms of *Phyllostachys pubescens*. The result showed that the relationship between the height of culms of *Phyllostachys pubescens* (H) and time (t) was expressed in a curve of “S” type: the relationship between the weight of culms (W) and logarithmic value (Lnt) could also be expressed in a curve of “S” type. We can call the growth of height and thickness the growth of culms (the growth of volume); and we can call the increment of the weight of dry substance of bamboo shoot-culms the growth of material, that is, the growth of weight. The proliferation of cells and the reproduction of protoplasm is the basis of volume growth and weight growth. Generally speaking, the growth of culms of bamboo shoot-culms (volume growth), can be obviously seen, which takes a shorter time; whilst the growth of material (weight growth) can’t be obviously seen, which takes a longer time. The process of volume growth of bamboo shoot-culms goes together with the increment of weight. When volume growth stops the weight growth is still going on. This article is written on the basis of the analysis and summary of the data surveyed on the growth of 33 varieties of bamboo shoot-culms. The data of the growth of *Phyllostachys pubescens* is the result of the survey of the number of bamboo shoots and the growth of bamboo shoot in Yixing (l981, 1982), Xiashu (1960, 1961) of Jiangsu Province, Moganshan (1981) of Zhejiang Province, altogether 34 standard plots, with total area which amounts to 26, 667m^2. The data of the of growth of other varieties is the result of the survey of bamboo shoot-culms in the experimental plot for the introduction of fine varieties in this college. In addition to this, we also made use of the growth data of 12 varieties in Red Flag Forestry Center, Anji County, Zhejiang Province for our reference. In order to know the effect of the weather on the growth of bamboo shoot-culms, we made analysis of humidity, temperature, precipitation during their growing period (Table 4–1). The number of bamboo shoots in bamboo colony was surveyed once every 5 the first at 8 a.m.; the second at 6 p.m. The survey of the length growth of *Phyllostachys pubescens* between bamboo joints was marked with numbers from bottom upwards. The length growth was measured one by one 1~2 times a day. The weight growth is the result of the measurement of basic total volume of samples of bamboo culms of bamboo shoots – – young bamboo of different period of growth.

Table 4—1a Monthly Average Temperature, Rainfall, Relative humidity (%)
(1980~1982) In Nanjing

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average Amount
T(℃)	1.83	4.05	8.63	14.37	21.00	26.13	26.93	26.23	20.60	14.37	8.23	3.33	14.64
R(mn)	40.8	37.4	73.3	72.8	39.1	103.1	342.5	139.3	37.7	102.4	48.4	3.10	1039.9
R.H(%)	73.3	74.7	79.0	73.7	68.7	75.3	84.3	84.7	79.3	79.3	77.3	70.0	76.6

Table 4—1b Daily Change of Temperature During The Growing Period of bamboo Shoot—culms
(Average Temperature of the previous ten days on every month)

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T(℃) February	−0.2	1.1	1.6	1.3	−0.1	1.0	0.2	1.7	2.3	1.9	3.2 1.1	5.8 1.4	5.0 1.9	4.7 2.2	4.6 2.6
T(℃) March	5.1 5.8	4.2 5.6	6.9 5.4	7.4 5.6	7.2 5.6	6.5 5.7	7.4 5.7	8.2 5.8	6.6 6.2	6.8 6.5	8.6 6.6	9.4 7.0	9.3 7.5	9.8 7.7	9.1 8.0
T(℃) April	13.3 10.2	13.2 10.5	11.2 10.9	12.6 11.2	11.6 11.5	10.6 11.5	12.4 11.8	12.5 12.0	11.7 12.0	12.8 12.1	15.8 12.4	15.7 12.7	12.4 12.8	12.3 12.8	14.4 13.1
T(℃) May	19.1 16.3	19.5 16.6	18.6 16.8	19.5 17.3	19.8 17.9	18.4 18.2	18.8 18.5	20.8 18.8	32.2 19.4	27.3 20.5	20.9 20.7	20.8 20.8	18.7 20.8	18.5 20.7	18.2 20.6
T(℃) June	21.6 23.4	20.5 23.2	21.8 22.8	23.2 22.6	25.0 22.7	24.5 22.9	24.0 22.9	25.3 23.2	25.8 23.4	22.4 23.4	22.5 23.5	22.2 23.7	23.0 23.8	23.9 23.9	25.5 23.9

(continue)

Date	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
T(℃) February	3.6 3.0	4.2 3.3	5.9 3.7	5.1 4.1	5.3 4.4	5.0 4.7	7.2 4.9	6.8 5.1	6.7 5.2	5.7 5.6	4.2 5.6	3.9 5.6	5.6 5.6			
T(℃)March	9.7 8.2	9.4 8.5	8.8 8.7	10.6 8.8	10.7 9.2	8.6 9.5	9.5 9.5	10.1 9.6	7.9 9.6	9.0 9.4	9.3 9.4	9.8 9.4	10.1 9.6	10.2 9.5	11.7 9.6	10.9 9.9
T(℃) April	15.1 13.5	14.8 13.7	15.4 14.0	16.3 14.5	15.8 14.9	15.9 14.8	16.8 14.9	16.8 15.4	14.6 15.6	13.7 15.5	14.5 15.5	16.6 15.6	17.7 15.9	16.8 15.9	16.4 16.0	
T(℃) May	19.0 20.6	19.6 20.7	20.4 20.7	19.3 20.3	19.5 19.5	20.5 19.5	22.1 19.6	23.0 20.0	25.5 20.7	25.8 21.5	23.3 21.9	23.0 22.2	23.3 22.5	23.0 22.9	23.3 23.3	22.5 23.5
T(℃) June	26.6 24.1	25.9 24.1	26.4 24.2	26.7 24.3	27.0 24.7	25.8 25.2	25.4 25.5	25.2 25.8	26.0 25.9	25.3 26.1	25.4 26.1	24.9 26.0	24.1 25.8	26.0 25.6	25.2 25.5	

1 The Mathematical Model of the Growth of Bamboo Shoot-culms

There is growth of both volume and weight for bamboo shoot-culm colony (bamboo grove) and the various organs (culms, branches, leaves, rhizomes, roots and shoot) of each individual. The relationship between the growth of volume and weight and time can be expressed by the "slow – quick – slow" process, which is a curve of "S" type (Fig. 4 – 1, Fig. 4 – 2). The curve expressing the growth of both volume and weight is very similar to that of an automatic catalytic reaction. During the catalyst reaction the products can catalyze the formation of themselves, so the increasing speed of the slope of the first part of the curve is the index, then, the more basic material available, the more products formed. But a period of time after that, the basic material becomes limited, products thus can't be formed very quickly. In the end the basic material is used up, the growing rate is reduced to zero. The process of the growth of bamboo shoot-culms is very similar to the automatic catalytic reaction. The growth of bamboo shoot-culms takes the material stored inside them as the base, which is called the basic material (S). When the growth started, the number of new cells, protoplasm and growth element increase, the absorption of supplementary material (m) outside the bamboo shoot-culms also increases and the amount of growth (G) increase, too. After a period of time, the basic material becomes less, the rate of growth slows down gradually. At last, when the basic material is used up, the growth itself stops accordingly. From this we can see the relationship between the growth rate of bamboo shoot-culms ($\frac{dG}{dt}$), basic material (s) and the amount of growth (G) is direct proportion.

Reaction Reaction speed

$$S - \frac{G}{M} - G \qquad \frac{dG}{kSG} \cdots\cdots (4\text{-}1)$$

In formula (4 – 1): S – basic material, G – amount of growth, K – constant, $\frac{dG}{dt}$ growth rate, m – supplementary material absorbed externally during the growth period.

Suppose m and s enter the plant in certain proportion and form the amount of growth (G). Suppose r is the constant of the proportion, then:

M=rs……………………………………………(4-2)

At any time, the growth amount of the plant (G) is equal to basic material for growing (s) plus supplementary material absorbed externally (m) at the moment.

That is:G=S+M ……………(4-3)

In formula (4 – 2), m = rs, replace m in formula (4 – 3) with rs, then: G = S + rs = (1+ r)s

S = G/(1+ r) (4 – 4)

At any time, basic material (S) is equal to the maximum growth amount (Gmax) minus the growth amount formed (G) at that moment.

That is: $S = (G_{max} – G)/(1 + r)$ .... (4 – 5)

Replace Sin formula (4 – 1) with (Gmax – G)/(1+ r) in formula (4 – 5) then:

$$\frac{dG}{dt} = KG(G_{max} - G)/(1+r)$$

$$\frac{dG}{dt} = [K/(1+r)]G(G_{max} - G) \cdots\cdots (4\text{-}6)$$

Because in formula (4 – 6) K and (r ?) are constants, let's suppose:

b = K/(1+ r) then formula (4 – 6) will be:

$$\frac{dG}{dt} = bG(G_{max} - G) \cdots\cdots (4\text{-}7)$$

Formula 7 is a differential equation, so:

$$\int dG / G(G_{\max} - G) = \int bdt$$

$$\int dG / G + \int dG /(G_{\max} - G) = \int bG_{\max} dt$$

$Ln[G/(G_{max}-G)]-L_nG=bG_{max}t$

∴ $G/(G_{max}-C)=G_{exp}(bG_{max}t)$

∵ When t ⇒ 0，G ⇒ Go

Let both sides of equation go the limit, then: $C=G_o/(G_{max}-G_o)$

∴ $G/(G_{max}/-G)=[G_0/(G_{max}-Go)]exp(bG_{max}t)G$

$=[G_oG_{max}/(G_{max}-Go)]exp(bG_{max}t)$

∴ $G= \dfrac{[(G_o G_{\max})/(G_{\max} - G_o)]\exp(bG_{\max}t)}{[1+[G_o / G_{\max} - G_o)]\exp(bG_{\max}t)]}$

Then: $G=G_{max}/[1+(G_{max}-G_0)/G_0]exp(-bG_{max}t)$ ……………………………………………… (4-8)

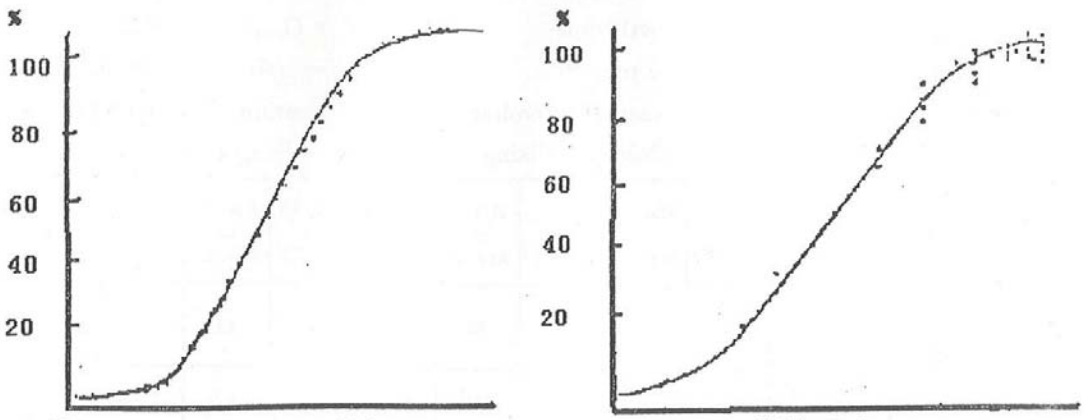
If the growth amount is expressed by relative value (RG), that is, when Gmax => 1, then

$RG = [1+ ((1 – Go)/Go)exp(–bt)]^{–1}$ ……………………… (4 – 9)

Let: $a=Ln[(G_{max}-G_o)G_o]=Ln[]1-G_o)/G_o]$

Then: $RG = [1+exp(a – bt)]^{–1}$……………………………………… (4-10)

The relative growth rate means the rate of the relative growth amount changing with the time of growth. It can be worked out according to formula (4 – 10).



$RGR = (dRG/dt) = bexp (a – bt)/[1 + exp (a – bt)]^2$ ……………………….(4 – 11)

The time of growth of bamboo shoot-culms (T_g) means the time from the beginning to the end of the growth. Suppose the time of the beginning of growth is to, the growth amount at the moment Go, the time of the end of growth tm and the growth amount at the moment Gmax, then the growth period will be:

$T_g=t_m-t_o$……………………………………………………………………………(4-12)

Let: $G_o=[1+exp(a-bt_o)]^{-1}$

Then: $t_o=[a-Ln(1/G_o)-1]b$ ……………………………………………………(4-13)

Let: $G_{max}=[1+\exp(a-bt_m)]^{-1}$

Then: $T_m=[a-Ln((1/G_{max})-1)]/b$ ……………………………………………………(4-14)

Replace to and tm in formula (12) with (Formula) in formula (13) and (Formula) in formula (14), $T_g=t_m-t_o=[a-Ln(1/G_{max})-1]]-[a-Ln((1/G_o)-1)]/b$

$Tg=[Ln((1/G_{max})-1)+Ln((1/G_o)-1)]/b$ ……………………………………………………(4-15)

Half-period of the growth of bamboo of shoot-culms (th) means half of the growth time needed for bamboo shoot-culms to grow to their maximum growth amount.

Let: $G=G_{max}/2=1+\exp(a-bth)^{-1}$

Then: $t_h=a/b$ ……………………………………………………………………(4-16)

Table 4—2 The relationship Between the Coming—out, Deteriorating of Bamboo Shoots of *Phyllostachys Pubescens* Colonyin Yixing Forest Center, Jiangsu Province

	the time of the coming—out of bamboo shoots	Before Mar. 25	Mar. 25 to Mar. 31	Apr. 1 to Apr. 5	Apr. 6 to Apr. 10	Apr. 11 to Apr. 15	Apr. 16 to Apr. 20	Apr. 21 to Apr. 25	Total number	Remarks
	The days of the coming—out of bamboo shoots	5	10	15	20	25	30	35		
1981	The number of bamboo shoots		3251	1176	819	601	252	92	5291	The area surveyed 7667M² All in on year
	Grand total		2351	3527	4346	4947	5199	5291	5291	
	The number of the bamboo shoots which grew into bamboo culms		869	277	140	45	6	0	1337	
	%		37.0	23.6	17.1	7.5	2.4	0.0	25.27	
	The number of deterioration of bamboo shoots		1482	899	679	556	246	92	3954	
	%		63.0	76.4	82.9	92.5	97.6	100.0	74.73	
	diameter		8.06	8.00	7.54	7.47	7.19		7.969	
1982	The number of bamboo shoots	1608		1378		835		178	3999	The area surveyed 13200M² (out of which 3867M² in on year)
	Grand total	1608		2986		3821		3999	3999	
	The number of the bamboo shoots which grew into bamboo culms	492		327		96		0	915	
	%	30.6		23.7		11.5		0	22.88	
	The number of deterioration of bamboo shoots	1116		1051		739		178	3084	
	%	69.4		76.3		88.5		100.0	77.12	

Growth Model of Bamboo Colony

The coming up of the bamboo shoots, the growing of bamboo culms, the branching and leafing out, the speeding of rhizomes, the budding and rooting in the bamboo colony result in greater number of bamboo individuals, the volume and weight. This phenomenon is called the growth of bamboo colony.

1.1 The relationship between the number of bamboo shoots coming out, the quality of grown bamboo and the time of their coming up.

In 1958 and 1965 the author divided the time the bamboo shoots' coming out in a bamboo colony into three periods. The number of the coming out of the bamboo shoots is small in the early period, great in the middle period and small again in the late period. The data from research work (Table 4 – 2) shows that the number of coming out of bamboo shoots in a bamboo colony is the function of the time of the coming out of bamboo shoots, and can be expressed by formulas (4 – 10) and (4 -11).

The way to calculate parameter a and parameter b in formula (4 – 10) and (4 – 11) is:

According to formula (4 -10)

$$RGN = (1+\exp(a-bt))^{-1}$$

$$(1/RGN) = 1+\exp(a-bt)$$

$$(1/RGN) - 1 = \exp(a-bt)$$

$$Ln[(1/RGN)-1] = a-bt \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (4\text{-}17)$$

$$RGN = G/G_{\max}$$

$$Ln[(1/RGN)-1] = Ln[(G_{\max}/G)-1], \text{Re } place$$

$$Ln[(1/RGN)-1] with \quad Ln[(G_{\max}/G)-1], then$$

$$Ln[(G_{\max}/G)-1] = a-bt$$

$$Let: \qquad Ln[(G_{\max}/G)-1] = y$$

Then: y = a – bt is a linear equation.

Using the method of least squares work out a, b parameters with the grand total of bamboo shoots in Table 3 – 2 (actual value gained from the survey):

In the years of 1981:

$$a = 4.123 \qquad b = -0.315$$

In the years of 1982:

A=4.32 b=-0.309

$$So, let \quad a = Ln[(G_{\max}-G_0)/G_0] = Ln[(1-G_0)/G_0]$$

The number of bamboo shoots in each bamboo colony or the growth amount of each bamboo shoot-culm, finally will reach a set value, that is, the maximum growth amount (Gmax). If it is expressed by the relative growth at the beginning, which has something to do with the time when the survey begins. For the convenience of comparison, we take the number of bamboo shoots in a bamboo colony (that is the growth amount), which reaches 0. 01 of the total amount of bamboo shoots as the growth amount at the beginning.

That is:

$$G_0 = 0.01G_{\max}$$

Then:

$$a = Ln[(G_{\max}-G_0)/G_0] = Ln[(G_{\max}-0.01G_{\max})/0.01G_{\max}]$$

$$a = 4.5951 = 4.6$$

In this article, parameter a in all model equations is expressed by a = 4.6. We express "value a" worked out with actual value gained in survey by 4.6, which only adjusts the time when the growth begins (t_o), and does not effect the change of growth rate. That is because:

$t_o = \{a - Ln[(1/G_o) - 1]\}/b$

$t_o = (a - 4.6)/b \quad (4-18)$

Replace a and b in formula (4 – 18) with the figures worked out with the actual – measured values. If $t_o = 0$, then the formula shows that the time when the survey begins is in accordance with the beginning time in theory; if t_o is a negative figure, then the day when the survey begins is later than the day when the bamboo shoots begin to come out in theory. The number of days when the survey begins should be shifted to an earlier date by t_o (days). If t_o is a positive figure, then the day when the survey begins is earlier than the day when bamboo shoots begin to come out in theory. The number of days when the survey begins should be postponed to a later date by t_o (days).

For example, in 1981, the date when the survey *began* in *phyllostachys pubescens* colony in Yixing was March 20th, (Table 4 – 2).

We worked out that a=4. 213, b= –0.315 according to the actual date. Put the above fig-

ures into formula (18) :

$t_o = (4.213 - 4.6)/0.315$: = 1.2 (days).

So, the date when the bamboos began to come out in theory should be 1. 2 days earlier than March 20th, that is, March 19th was the date when the bamboo shoots in the bamboo colony began to come out in theory.

After the adjustment of value a the relationship between the number of the coming out of the bamboo shoots and the time in *Phyllostachys puhescens* colony at Yixing Forest Center in Jiangsu in 1981 and 1982 is as follows:

(Bamboo shoots began to come out on Mar.19th, 1981})

$RGN(81) = [1 + \exp(4.6 - 0.315t]^{-1}$ .... (4 – 9)

(Bamboo shoots began to come out on Mar. 19th, 1982)

$RGN(82) = [1 + \exp(4.6 - n0.309t)]^{-1}$ .... (4 – 20)

Work out the time the bamboo shoots began to come out (t_o), the time when the bamboo shoots ceased to come out (t_o) and the semi-cycle (t_g) of the coming out of the bamboo shoots in the *Phyllostachys pubescens* colony according to the formula of (4 – 13), (4 – 14) and (4 – 16).

The results are shown in Table 4 – 13.

The Beginning and Ceasing of the Coming Out of Bamboo Shoots, the Semi-cycle and the period of time of the Coming Out of Bamboo Shoots in *Phyllostachys pubescens* Colony in Yixing Forest Center, Jiangsu Province.

Table 4—3

the year	the beginning time(t_0)	the ceasing time(t_m)	semicycle (t_n)	the period of time of the coming out of bamboo shoots(T_G)
1981	Mar. 19th	Apri. 19th	Apr. 4th	30
1982	Mar. 19th	Apri. 19th	Apr. 4th	30

From Table 3 we can see in the *Phyllostachys pubescens* colony in Yixing Forest Center, the beginning time of the coming out bamboo shoots is usually on Mar. 19. the ceasing time Apr. 19, the period of time of the corning out of bamboo shoots is around 30 days, and the semi-cycle is on Apr. 4, that is around Pure Brightness (Apr. 5)

1.2. The rate of the bamboo shoots which grew into bamboo culms and the rate of deterioration of bamboo shoots in the bamboo colony.

In the *Phyllostachys pubescens* colony part of the bamboo shoots grow into new bamboo culms; the rest deteriorate which is called deterioration of bamboo shoots. The percentage of the totality of bamboo shoots which can grow into bamboo culms is called the survival rate of bamboo shoots. The percentage of the totality of bamboo shoots which deteriorate is called the rate of deterioration of bamboo shoots.

The survival rate of bamboo shoots which come out *at* different period of time is various. Generally speaking the survival rate of the bamboo shoots coming out in the early period is high and the rate of deterioration low while the survival rate of the bamboo shoots coming out in the late period is low and the rate of deterioration high (Fig. 4 – 3, Fig. 4 – 4).

$RGNR = 0.312\exp(4.6 - 0.312^{t})$

$RGN = [H\exp(4.6 - 0.312)]^{-1}[1 + \exp(4.6 - 0.312^{t}]^{-2}$

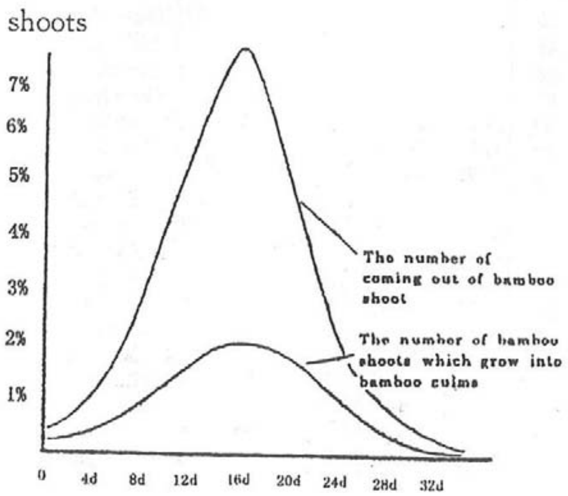
According to the data in Table 4 – 3, the relationship between the survival rate (RV) of bamboo shoots and the time of their coming out (t) in *Phyllostachys pubescens* colony in Yixing Forest Center, Jiangsu Province:

In the year of 1981: $PV(81) = 48 - 1.5^{t}$ ………………………….. (4 – 21)

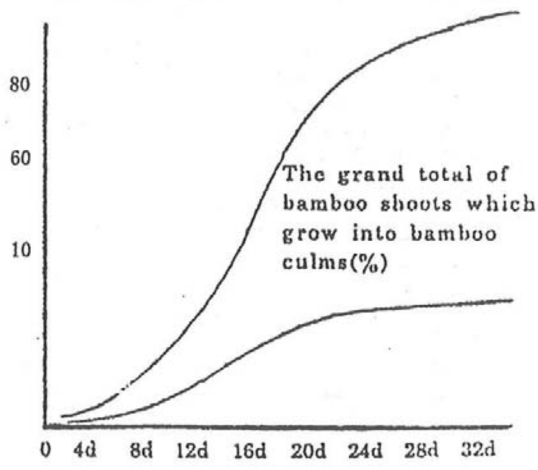
In the year of 1982: $PV(82) = 45 - 12^{t}$ …………………………... (4 – 22)

1.3. The relationship between the average diameter of new bamboo culms and the time of the coming out of the bamboo shoots

Fig. 4 – 3. The relationship between the coming out and the survival of bamboo-shoots of *Phyllostachys pubescens* colony and time



$D_{81} = 8.6 - 0.05^{t}$ …………… (4—23)



1.4. The time and speed of the coming out of the bamboo shoots for different bamboo species

During the time from 1980 to 1982 we surveyed the time and *rate* of the coming out of bamboo shoots of 35 different species (Table 4 – 4).The surveyed area of each species was 35m^2. The relationship between the relative growing number (RGN) of the coming out of bamboo shoots, the *rate* of the coming out of bamboo shoots (RGNR) and time of each bamboo colony different bamboo species:

$RGN = [1 + \exp(a_1 - b_1 t)]^{-1}$ ………………………….. (4 – 24)

$$RGNR = b_1 \exp(a_1 - b_1 t)[1 + \exp(a_1 - b_1 t)]^{-2} \cdots\cdots\cdots (4\text{-}25)$$

Generally speaking, for bamboo shoots coming out in the early period, they have greater average diameter when they grow up, while for bamboo shoots coming out in the late period, they have smaller diameter when they grow up. The relationship between the average diameter (D) and the time (t) of the coming out of bamboo shoots:

In the year of 1981:

$D_{81} = 8.6 - 0.05^t$ …………………………………………….. (4 – 23)

Fig. 4 – 4. The percentage of the grand total of bamboo shoots and the shoots which grow into bamboo culms in *Phyllostachys pubescens*

Work out a and b, using the method of least squares with actual – measured value of each bamboo species according to formulas (4 – 24) and (4 – 25). The parameters are listed in Table 4 – 4. For the convenience of comparison let $a_1 = 4.6$.

Work out the beginning time (t_o) or the coming out of the bamboo shoots of each bamboo species, the ceasing time (t_m) the period of time of coming out of bamboo shoots (T_G) and semi-cycle (th). etc. according to formulas (4 – 13), (4 – 14), (4 – 15) and (4 – 16).16). (see Table 4 – 4).

The number of coming out of bamboo shoots and their rate of bamboo colonies of each bamboo species can be worked out by using the parameter b_1 and parameter a_1=4.6 according to Table 4 – 4, in formulas (4 – 24) and (4 – 25).

Table 4 – 4 The Relative Growing Number of the Coming Out of Bamboo Shoots of Different Bamboo Species Colonies [RGN = $(1 + \exp(4.6 - b_1 t))^{-1}$] and the parameters b_1 and b_2 of the Relative

bamboo species	the coming out of bamboo shoots				height growth of culms				growing area
	b_1	date of coming out the shoots	days	r_1	b_2	date of growth	days	r_2	
1. *Arundinaria amabilis*	.242	5/5	38	.98	.210	8/5	44	.97	Gu–do.
2. *A. fargesii*	.199	1/3	46	.93	.222	5/3	41	.97	Sh–xi.
3. *Brachyschyum densiflorum*	.324	19/4	28	.98	.332	19/4	27	.96	Ji–Su.
4. *Indocalamus barbatus*	.144	25/2	67	.96	.139	2/3	66	.92	Gu–Xi.
5. *Indosasa crassiflora*	.229	30/4	40	.98	.282	30/4	32	.98	Gu–Xi.
6. *Inosasa patans*	.197	24/4	47	.98	.246	24/4	37	.97	Gu–Xi.
7. *Phyllostachys august* (1)	.409	5/4	22	.99	.349	5/4	26	.98	Ji–Su.
Ph. august (2)					.322	22/4	28	.97	Gu–Xi.
8. *Ph. bambisoides* (1)					.255	3/5	36	.98	He–Na.
Ph. bambysoides (2) *					.259	17/5	35	.98	Zh–Ji.
Ph. bambusoides (3) *					.301	20/5	30	.99	Zh–Ji.
9. *Ph. bambusoides f. tanakae*	.351	28/4	26	.96	.339	28/4	27	.97	He–Na.
10. *Ph. bambusoides var. youngii*	.323	27/5	28	.98	.348	27/5	26	.98	Ji–Su.
11. *Ph. bissetii*	.265	1/4	35	.97	.317	1/4	29	.98	Si–Ch.
12. *Ph. decora*	.417	18/5	22	.98	.379	18/5	24	.96	Zh–Ji.
13. *Ph. flexuosa*					.395	16/4	23	.95	He–Na.
14. *Ph. glauca* (1)	.319	14/4	29	.99	.294	14/4	31	.98	Sh–Do.
Ph. glauca (2) *	.204	15/4	45	.98	.272	15/4	33	.99	Ji–Su.
Ph. glauca (3) *					.232	23/4	40	.99	Ji–Su.
Ph. glauca (4) *					.256	28/4	36	.99	Zh–Ji.
15. *Ph. glauca f. yunzhu*	.308	18/4	30	.99	.327	18/4	28	.99	He–Na.
Ph. glauca f. yunzhu	.424	16/4	22	.99	.395	16/4	23	.97	He–Na.
16. *Ph. parvifolio*	.289	24/4	32	.99	.305	24/4	30	.98	Zh–Ji.
Ph. parvifolia *					.235	3/5	39	.99	Zh–Ji.
17. *Ph. praecox*	.315	17/3	29	.96	.321	25/3	28	.98	Ji–Su.
18. *Ph. propinqua* *					.241	15/4	38	.99	Zh–Ji.
19. *Ph. meyeri*	.173	13/4	53	.98	.244	13/4	36	.90	Zh–Ji.
20. *Ph. mirabilis*					.244	25	37	.97	Zh–Ji.
21. *Ph. nidularia* *					.275	28/4	33	.99	Zh. –Ji
22. *Ph. nigra*	.345	11/4	30	.99	.359	11/4	25	.96	Ji–Su.
23. *Ph. nigra var. henonis*	.356	16/4	26	.98	.338	16/4	27	.98	Ji–Su.
24. *Ph. nuda*	.323	3/4	28	.98	.281	3/4	33	.99	Ji–Su.
25. *Ph. pubescens*	.312	20/3	30	.98	.230	5/4	40	.97	Zh–Ji.
Ph. pubescens * *	.251	9/3	37	.99	.244	9/3	38	.98	Ji–Su.
26. *Ph. pubescens f. grammica*	.250	28/3	37	.98	.294	28/3	31	.96	Zh–Ji.
27. *Ph. rubela*	.241	6/4	38	.94	.251	6/4	37	.95	Zh–Ji.
Ph. rubela *					.217	19/4	32	.97	Zh–Ji.
28. *Ph. setosa*					.322	12/4	28	.98	Zh–Ji.
Ph. setosa *					.251	28/4	37	.96	Zh. –Ji
29. *Ph. spextabilis*	.352	1/4	26	.99	.315	4/4	29	.99	Ji–Su.
30. *Ph. viriridis*					.224	3/5	41	.99	Zh–Ji.
31. *Ph. viridis f. houzeauana*	.320	6/5	29	.98	.328	6/5	28	.97	Ji–Su.
32. *Ph. vivax*	.333	12/4	28	.98	.322	12/4	28	.98	Ji–Su.
33. *Sinobambusa laeta*	.169	7/4	54	.97	.184	7/4	50	.96	Gu–Do.

Height Growth RGH = $[1 + \exp(4.6 - b_2 t)^{-1}]$

For example, the relative growing number of the coming out of bamboo shoots (RGN) and their rate (RGNR) in *Arundinaria amabilis* bamboo colony are as follows:

$$RGN=[1+\exp(4.6-0.2417t)]^{-1}$$

RGNR = 0.2417exp (4. 6 – 0.2417t) (1 + exp(4. 6 –

0.2417t))$^{-2}$.

1.5. The effect of temperature on the coming out of bamboo shoots

In spring, with the increase in temperature, the bamboo shoots emerge from the underground, grow slowly and become larger in size gradually. During this period, the growth rate is rather slow. With the continuous increase in temperature, the growth rate quickens. The bamboo shoots come out of the earth one after another. With different bamboo species, the time of coming out of their shoots is different. The bamboo species whose shoots can grow under comparatively low temperature have their shoots come out earlier, while those whose shoots need higher temperature for their growth have their shoots come out later. For the convenience of comparison, we take the average temperature of the 10 days before the beginning of the coming out of bamboo shoots as the required temperature for species that can be catalogued into three according to the required temperature and the seasons in which their bamboo shoots come out early spring bamboo, spring bamboo and summer – autumn bamboo. (Table 4 – 5).

Table 4—5 The Date, Temperature (T). and Accumulated Temperature (T_t) for the Coming Out of Bamboo Shoots in Bamboo Colonies of Different Bamboo Species

Type	Species	Date	T.C	T.t C
Early Spring Type	*Indocalamus barbatus*	25/2	5.6	389
	Arundinaria fargesii	1/3	5.6	471
	Phyllostachys pubescens	9/3	6.5	402
	Ph. Praecox	17/3	8.7	330
	Ph. pubescens f. grammica	28/3	9.6	539
Spring Type	*Ph. bissetii*	1/4	10.2	531
	Ph. nuda	3/4	10.9	411
	Ph. spectabilis	4/4	11.2	465
	Ph. rubela	5/4	11.5	641
	Ph. augusta	5/4	11.5	317
	Sinobambusa laeta	7/4	11.8	1.022
	Ph. nigra	11/4	12.4	518
	Ph. vivax	12/4	12.7	481
	Ph. meyeri	13/4	12.8	1,080
	Ph. glauca(1)	14/4	12.8	517
	Ph. glauva(2)	15/4	13.1	914
	Ph. nigra var. henonis	16/4	13.5	524
	Ph. glauca f. yunzhu	16/4	13.5	553
	Brachystachyum densiflorum	19/4	14.5	516
	Indosasa patans	24/4	15.6	919
	Ph. parcifolia	24/4	15.6	636
	Ph. bambusoides f. tanakae	28/4	15.9	524
	Indosasa crassiflora	30/4	16.0	866
Summer Type	*Arundinaria amabilis*	5/5	17.9	838
	Ph. viridis f. houzeauana	6/5	18.2	677
	Ph. decora	18/5	20.7	506
	Ph. bambusoides var. youngii	27/5	22.2	704

(1) Early spring bamboo type: The temperature required for the coming out of bamboo shoots in a bamboo colony is below 10 ^{0}C. In Nanjing area, before late March, bamboo shoots in the bamboo colony begin to come out. Among the bamboo species there are: *Indocalamus barbatus, Aiundinaria fargesji. Phyllostachys Ph. pubescens* f. *grammica*.

(2) Spring bamboo type: The temperature required for the coming out of bamboo shoots in a bamboo colony is 10 ^{0}C ~16^{0}C. In Nanjing area from early April to early May, bamboo shoots in the bamboo colony begin to come out. Among the bamboo species there are: *Ph. bissetii, Ph. nuda, Ph. spectabilis. Ph. rubela, Ph. augusta, Sinobamutsa laeta, Ph. nigra, Ph. vivax, Ph. eyeri, Ph. glauca* (1), *Ph. glauca* (2), *Ph. nigra* var. *henonis, Ph. glauca* f. *Yunzhu, Brachystachyum densflorwn, Indosada patans, Ph. bambusoides* f. *tanakae, Indosasa crassiflora*.

(3) Summer – Autumn bamboo type: The temperature required for the coming out of bamboo shoots in a bamboo colony is above 16 ^{0}C. In Nanjing area from the middle of May to late October, bamboo shoots in a bamboo colony begin to come out. Among the bamboo species there are: *Ph. decora, Arundinaiia amabilis, Ph. Vividis, houzeauana, Ph. bambusoides var. Youngji*.

Bamboo colonies of different bamboo species require different temperature for their shoot to come out. That's one of the biological characteristics of bamboo shoot-culms, and the result of their adaptation to environments over a long period. Generally speaking, bamboo species originated in the northern area require a comparatively low temperature for the coming out of bamboo shoots in a bamboo colony, and their shoots come out *at* an earlier date. Those originated in the southern area require a comparatively high temperature for the coming out of bamboo shoots in a bamboo colony, and their shoots come out *at* a later date. For example, *Arundinaria fargesii* is originated in Zhengba, Shanxi Province (l,500~2,400m, above sea level), after its being introduced to Nanjing area, begin to shoot on March 1st. *Arundinaria amabilis* originated in Guangning County, Guangdong Province, after its being introduced to Nanjing area, begins to shoot on May 5th.

For bamboo shoot-culms of the same species, the coming out of their bamboo shoots can be earlier or later because of their different distribution. Those distributed in the northern area, where temperature is comparatively low, have their shoots coming out late. For example, Taian *Ph. glanca* originated in Taian County Shangdong Province, after begging introduced to Nanjing, have their shoots come out on April 14th, while Zhejiang *Ph. glanca,* originated in Anji county, after being introduced to Nanjing, have their shoots come out on April 23rd.

It must be pointed out that the coming out of bamboo shoots in bamboo colony is affected not only by the temperature but also by environmental factors such as rainfall etc. However, in the seasons for the bamboo shoots to come out, if its moisture content is insufficient the coming out of bamboo shoots will be delayed even if the temperature meets the requirement.

2. The growth model of barn boo culms

2.1. The relationship between the height growth of bamboo shoot – culms – young culms and time.

The height growth of bamboo shoots – young culms is an important component of volume growth of bamboo shoot-culms. The relationship between the amount of height growth (H) of bamboo shoots and time (t) can be expressed in the pattern "slow – quick – slow" that is, a curve of "S" type. We once divided the process of the height growth of *Phyllostachys pubescens* shoots – young bamboo into four stages: the early stage, the rising stage, the prime stage and the final stage. The relationship between the relative height growth amount of bamboo shoots – young culms (RGH), growth rate (RGHR) and time (t):

$$RGH = [1+\exp(a_2 - b_2 t)] - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4-26)$$

$$RGHR=b_2\exp(a_2-b_2t)[1+\exp(a_2-b_2t)]^{-2} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (4\text{-}27)$$

Work out a_2 and b_2, using the method of least squares with actual – measured value of each bamboo species according to formulas (4 – 26) and (4 – 27). The parameters are listed in Table 4 – 4. For the convenience of comparison, let a_2 = 4.6.

Work out the beginning time of the coming out of the bamboo shoots of each bamboo species, the ceasing time, the period of the time of the coming out bamboo shoots semi-cycle, etc. according to formulas (4 – 13), (4 – 14), (4 — 15) and (4 – 16). (See Table 4 – 4).

The relationship between the relative height growth amount of bamboo shoots – young culms of each bamboo species and time and the *rate* of height growth can be worked out by using parameter b_2 and parameter $a_2 = 4.6$ according to table 4 – 4, in formulas (4 – 26) and (4 – 27). For example, the relative, height growth amount (RGH) and height growth speed (RGHR) of *Arundinaria* are as follows: amabilis

$$RGH = [1 + \exp(4.6 - 0.210t)]^{-1}$$

$$RGHR = 0.210\exp(4.6 - 0.210t)[1 + \exp(4.6 - 0.210t]^{-2}$$

2.2 The relationship between Culm growth and the time of the coming out of bamboo shoots.

The value of parameter b_2 of the height growth of bamboo shoots – young culms of various bamboo species listed in Table 4 – 4, is not stable. The value of b_2 of the same bamboo species is variable in different year under different weather conditions. Generally speaking, the lower the temperature, the slower the growth, the smaller the value of parameter b_2; on the other hand, the higher the temperature, the greater the value of parameter b_2. For, the same bamboo species in the same year and the same colony, bamboo culm of early – date shoots grow slowly because of the low temperature and the value of b_2 is smaller; on the other hand, bamboo culms of late – date shoots grow fast because of the high temperature, and the value of b_2 is greater. For example, in the height growth equation of *Phyllostachys pubscens* shoots – young culms which came out of the earth on March 25th, b_2 equals 0.21; in the height growth equation of *Phyllostachys pubescens* shoots – young which came out of the earth on April 5th b_2 equals 0.23; in the height growth equation of *Phyllostachys pubescens* shoots – young culms which came out of the earth on April 15th be (b_2) equals 0.25. From this we can see, in the height growth equations, the value of parameter b_2 for the bamboo shoot – young culms of early date is smaller than that for the bamboo shoot – young culms of late date. That is to say, the longer the growth period, the slower the growth *rate*. If we take March 20th as the fifth day after the beginning of the coming out of barn booboo shoots, then April 5th will be the fifteenth day after the coming out the shoots, and April 15th will be the 25th day after that. Suppose the days of the coming out of bamboo shoots are expressed by Da, then the relationship between b_2 and Da will be Table (4 – 6).

$b_2 = 0.2 + 0.002 + Da$ ……………………………………. (4 – 28)

If we use the value b_2 in formulas (4 – 26) and (4 – 27), we can express the relationship between the relative value of height growth (RGH) of *Phylloatachys pubescens* shoot – young culm coming out of the earth at different time and the height growth rate (RGHR) and the number of the coming out of bamboo shoots (Da) and growth time (T):

Table 4 – 6 The Relationship between the Number of Days of the Coming Out of Bamboo Shoots in a bamboo Colony and Parameter b_2

The number of days of shooting	5(March 25)	15(Apr.5)	25(Apri.15)
b_2	0.21	0.23	0.25

$$RGH = [1 + \exp C4.6 - 0.2 + 0.002Da)t]^{-1}$$

$$RGH = [(0.2 + 0.002Da)\exp(4.6 - (0.2 - 0.002Da)\,t)\,]/[\,(1 + \exp(4.6 - (0.2 + 0.2Da)t)^2$$

2.3. The relationship between the rate of the coming out of bamboo shoots in bamboo colony and the height growth rate.

From the formulas (4 – 24), (4 – 25) ,and (4 – 26) , (4 – 27) we can see the rate of the coming out of bamboo shoots in a bamboo colony (dRGN/dt) and height growth rate (dRGH/dt) are the function of b1 and b2. That is:

$$\frac{dRGN}{dt} = (b_1) \cdots\cdots (4\text{-}29)$$

$$\frac{dRGH}{dt} = (b_2) \cdots\cdots (4\text{-}30)$$

Therefore, the relationship between the rate of the coming out of bamboo shoots in bamboo colony and the rate of height growth can be expressed by the relationship between parameter b_1 and b_2. The data in Table 4 – 5 indicates that b_1 is in proportion to b_2, that is, the value of b_2 increases with the increase of the parameter b_l. The lineal regression of b_1 and b_2 of different bamboo species is as follows:

$b_2 = 0.74b_1^{0.75}$ ……………………………………….. (4 – 31)

$b_2 = 1.49b_2^{1.333}$ ……………………………………… (4 – 32)

From formula (4 – 3) we can see the rate of the coming out the bamboo shoots is in proportion to the height growth rate. That is, the greater the rate of the coming out of the bamboo shoots, the greater the height growth rate. Conversely the smaller the rate of the coming out of the bamboo shoots, the smaller the height growth speed (rate). According to the relationship between parameter b_1 and parameter b_2 formula (4 – 31) or formula (4 – 32), as long as we know either parameter b_1 or parameter b_2 we can estimate the other parameter. Therefore we can work out the results of formulas (4 – 24), (4 – 25) and formulas (4 – 26), (4 – 27), as long as we know either parameter b_1 or parameter b_2. For example, if the parameter b_1 of the rate of the coining out of the bamboo shoots in a bamboo colony is known, the parameter b_2 of the height growth rate of bamboo shoots – young bamboos can be reckoned, then $b_2 = 0.74b_1^{0.74}$. If the parameter b_2 of the height growth rate of the bamboo shoots – young bamboos is known, the parameter b_1 of the rate of the coming out of bamboo shoots in a bamboo colony can be reckoned, then $b_1=1.494b_2^{1.333}$.

2.4. The coming out of bamboo shoots and the growing condition of bamboo culms of different species.

The parameter b_1 and parameter b_2 can be regarded as the indication of the rate of the coming out of the bamboo shoots in a bamboo colony (b_1) and the rate of bamboo shoots – young culms b_2. Therefore, according to the values of parameter b_1, and parameter b_2 in Table 6, bamboo types can be divided into: bamboo type of slow growth speed (rate), $(b_1, b_2) < 0.2$; bamboo type of medium growth speed, $0.2 < (b_1, b_2) < 0.3$; bamboo type of quick growth speed, $(b_1, b_2) < 0.3$.

Among bamboo type of slow growth rate, there are bamboo species of *Indocalamus* and *Sinobambusa*; among bamboo type of medium growth rate, there are bamboo species of *Arundinaria*; among bamboo type of quick growth rate, there are bamboo species of *Phylloslachys and Brahystachyum*. The growth rate of some bamboo species of slow – growth – speed type, medium – growth –rate type and quick – - growth –rate type will be shown clearly by using Fig. 4 – 5.

Table 4－7 The Parameters of the Coming out of Bamboo Shoots and the Growth of Bamboo Culms of Species of Different Genera.

Family Names	Number of bamboo shoots	b_1	σ	The days of shooting	b_2	σ	The days of growth	Accumulated temperature (℃)	
								Shooting	Growth
1. *Indocalamus*	1	0. 144	0. 000	64. 0	1. 39	0. 000	65. 9	789	823
2. *Sinobambusa*	1	0. 169	0. 000	54. 4	1. 84	0. 000	49. 8	1022	908
Average		0. 157		59. 2	0. 162		57. 9	906	866
3. *Indosasa*	2	0. 213	0. 023	43. 2	0. 264	0. 025	34. 8	889	714
4. *Arundinaria*	2	0. 220	0. 031	41. 7	0. 216	0. 009	42. 6	655	730
Average		0. 217		42. 5	0. 240		38. 7	772	717
5. *Phyllostachys*	24	0. 307	0. 062	30. 4	0. 314	0. 038	29. 4	560	507
6. *Brachystachyum*	1	0. 324	0. 000	28. 3	0. 331	0. 000	27. 7	516	497
Average		0. 316		29. 4	0. 323		28. 6	538	502

3. The model of growth of bamboo internodes.

When the sprouts on the rhizomes develop into bamboo shoots, nodes and internodes are formed. Each internode has its own division tissue. During the process of the growth of bamboo shoots – young culms, new cells are derived from each division tissue of internodes and form new tissues. The growth of internodes of bamboo culms the derivation and development of the cells in the internode. The growth of internodes of bamboo culms develops from the bottom gradually upwards. For the convenience of calculation. We marked 1, 2, 3 ... n, from bottom to top, on each internode of a bamboo shoot – young culms, and measure the growth amount of the internode twice a day: 6 a.m. and 6 p.m, And the result showed the *commencing* and ceasing time of the growth of each internode *is* not the same. The pattern of the growth *rate* of the internodes is also “slow – quick – slow”. Therefore, it is proper to express the pattern with formulas (4 – 10) and (4 – 11).

$RGD= [1+\exp(a_o – b_o t)]^{-1}$

3.1. The time of the growth of Internodes

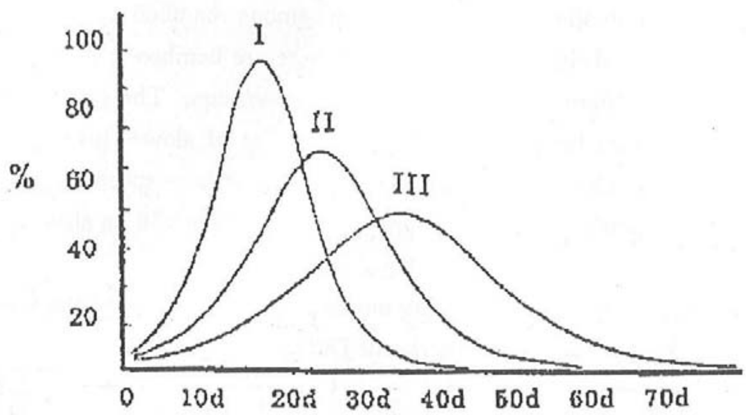
The result of survey showed that the relationship between the commencing time (t_o), ceasing time (t_m) of each internode from bottom to top of *Phyllostachys pubescens* bamboo shoots – young culms and the time of the growth of internodes (T_g) and the node position (n.)

$T_o = 0.76n$ ………………………………………. (4 – 33)

$T_m = 12.56 + 0.59n$ ……………………………... (4 – 34)

$T_g = t_m – t_o = 12.56 – 0.08$ ……………………... (4 – 35)

Fig. 4 – 5 The Change of the Growth Rate of Three Bamboo Types



Bamboo type of quick – growth speed; II. Bamboo type of medium – growth speed

III. Bamboo type of slow –growth speed;

Table 4—8 The values of parameters a and b in Yixing

$[RGD=(1+\exp(a_0-b_0t))^{-1}]$

N	a_0	a_t	$-b_0$	$-b_t$	N	a_0	a_t	$-b_0$	$-b_t$
14	15.188	9.264	0.271	0.248	34	26.605	24.444	0.336	0.364
15	15.974	10.023	0.276	0.254	35	29.023	25.203	0.370	0.370
16	16.165	10.782	0.268	0.260	36	29.207	25.962	0.365	0.376
17	17.307	11.541	0.287	0.266	37	30.711	26.721	0.382	0.382
18	17.332	12.300	0.276	0.271	38	28.952	27.480	0.352	0.387
19	17.421	13.059	0.265	0.277	39	29.341	28.239	0.347	0.393
20	19.358	13.818	0.303	0.283	40	31.323	28.998	0.373	0.399
21	20/529	14.577	0.319	0.289	41	28.760	29.757	0.330	0.405
22	20.412	15.336	0.306	0.295	42	29.670	30.516	0.345	0.411
23	21.147	16.095	0.322	0.300	43	36.992	31.275	0.377	0.416
24	20.144	16.854	0.283	0.306	44	31.034	32.034	0.358	0.422
25	21.138	17.613	0.295	0.312	45	33.910	32.793	0.390	0.428
26	22.714	18.372	0.321	0.318	46	32.505	33.552	0.361	0.434
27	22.965	19.131	0.319	0.324	47	35.194	34.311	0.397	0.440
28	23.930	19.890	0.329	0.329	48	40.609	35.070	0.467	0.445
29	24.749	20.649	0.335	0.335	49	45.198	35.829	0.535	0.451
30	25.374	21.408	0.339	0.341	50	46.469	36.588	0.537	0.457
31	28.307	22.167	0.386	0.347	51	43.485	37.347	0.488	0.463
32	28.423	22.926	0.382	0.353	52	52.781	38.106	0.598	0.469
33	27.222	23.685	0.353	0.358	53	48.329	38.865	0.528	0.474

From formulas (4 33), (4 – 34) and (4 – 35), we learn, for bamboo shoots – young culms, every 0.67 day (about 16 hours) there is a node beginning to grow. The growth time of the first internode is 12.48 days (about 300 Hours). The from the bottom upwards, with each node increased, the duration of growth of internode will be 0.08 days less (about 1.92 hours).

3.2. The process of the growth of internodes

According to the data obtained in Yixing, the relationship between the growth amount of internodes of *Phyllostachys pubescens* and the time can be expressed with formulas (4 – 10) and (4 – 11). Parameter a_o and parameter b_o in the formulas have been worked out according to each internode and are listed in Table

4 – 5. From Table 4 – 5, we can see parameters a_o and b_o increased with the increment of each node position (n). The relationship between them is:

a = 3.62+0. 76n ....(4 – 36)

b = 0.33+0. 012n ....(4 – 37)

a_t= 3.62+0.76N b_t = 0.33+0. 012N

Put the values of parameters a and b into formulas (4 – 10) and (4 – 11), we can get the model equation of the relative growth amount (RGD) and the relative growth rate (RGDR) of each internode of each *Phyllostachys puhescens*.

$RGD = [1+\exp(3.62+0.76n-(0.33+0.012n)t]^{-1}$ ……………… (4 – 38)

$RGDG = (0.33+0.012n)\exp[3.62+76n - (0.33+0.012n)t]/[1+\exp(3.62+0.76n - (0.33+0.012n)t]^2$

………………………. (4 – 39)

3.3. The absolute growth amount of internodes of *Phyllostachys pubescens*

Formula (4 – 34) is the equation for the calculation of the relative growth amount of internodes of *Phyllostachys pubescens*. In order to calculate the absolute growth amount of each internode, the absolute height of each bamboo culm is needed. The absolute growth amount of each internode can be worked out by multiplying the absolute height and the relative growth amount of each internode (RGD). According to our survey the distribution equation of the height of the internodes of Phyllostachys *pubescens* is:

$h(n) = 0.1D^{0.5513}[\exp - 2((n/15.8D^{0.9933}) - 1)]^2$ ………………….. (4 – 40)

In the equation h (n) is the height of the internode of the nth. node (Cm) D is e diameter (Cm), n is the number marked on the node.

According to formulas (34), (35) and 4 – 36) the accumulated amount of absolute growth (GDR)and growth rate (dGDh/dt) of each internode (n) of bamboo shoot – young culms:

$GDh=h(n)RGD=0.1D^{0.5513}\exp(-2((n/15.8D^{0.2933})-1)]^2/1+\exp[3.62+0.73n-(0.33+0.012n)t]$……(4-41)

$dGDhdt=h(n)RGDR=0.1D^{0.5513}\exp(-2((n/15.8D^{0.2933})-1))^2$

$\times(0.33+0.012n)\exp[3.62+0.76n-(0.33+0.012n)t]/[1+\exp(3.62+0.76n-(0.33+0.012n)t]^2$……(4-42)

According to formulas (4 – 41), (4 – 42), we can work out the absolute growth and growth rate of *Phyllostachys pubescens* of the diameter (D) at any time (t) in the growth period and any internode (n). When D = 10Cm. the changes with time of the relative growth amount (A), relative growth rate (B) and the absolute growth amount are expressed in Fig. 4 – 6).

4. The model of weight growth of bamboo culms

4.1. The process of the coming out of bamboo shoots and the process of volume (height) growth of bamboo shoots – young culms of a bamboo colony go with the growth of the bamboo colony or the weight growth of the bamboo culms.

After the ceasing of volume growth bamboo culms, the weight growth still goes on until their natural death. The weight growth of bamboo culms take the increase of the bamboo individuals in a bamboo colony, the volume growth of the bamboo culm and the growth of volume weight in a bamboo colony as its basis. If "RGV" stands for the relative value of the volume growth of bamboo culms; "RGVW" stands for relative value of volume weight of a bamboo colony, "RGN" stands for relative volume of the coming onto of bamboo shoots in a bamboo colony, then the relative value (RGW) of the weight growth of bamboo culms is:

RGW = RGV. RGVW …………………………… (4 – 43)

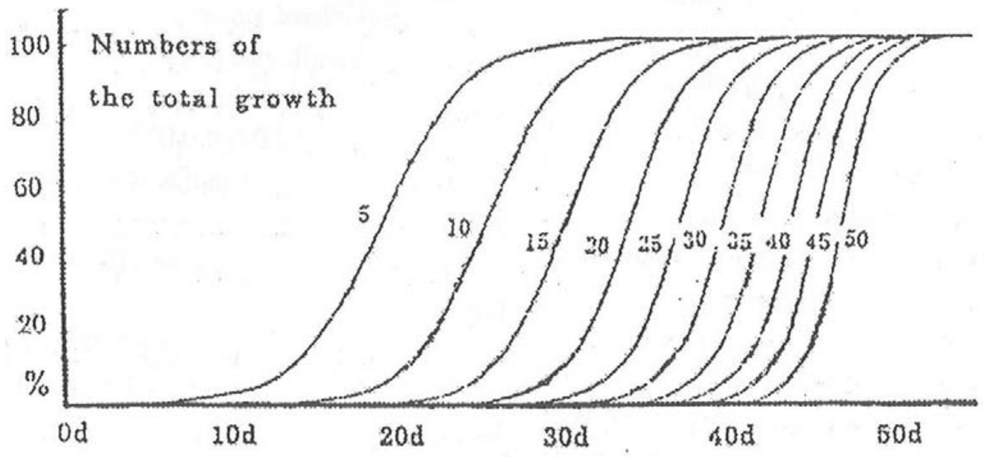


Fig. 4—6—1 Numbers of Total Growth of *Phyllostachys pubescens*

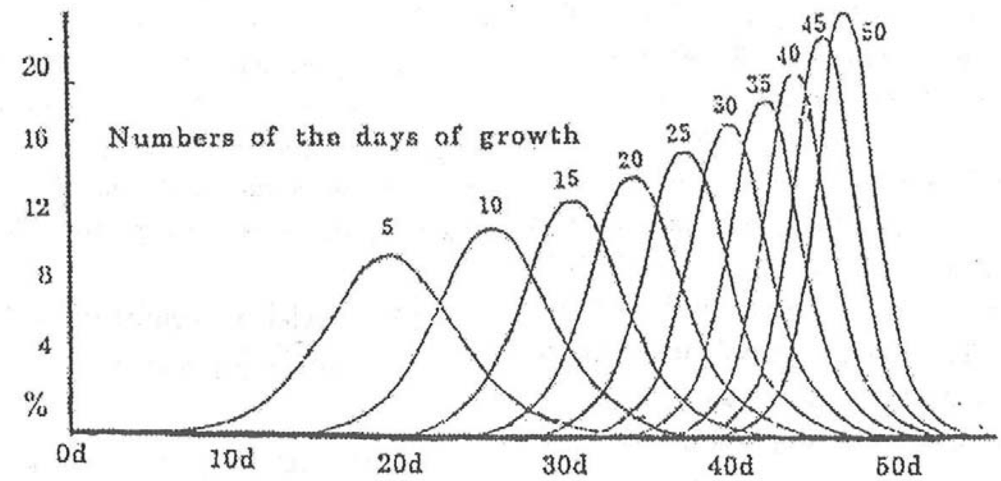


Fig. 4—6—2 Numbers of the days of Growth of *Phyllostachys pubescens*

The relative value of weight growth of a bamboo colony (RGTW) is:

RGTW = RGV. RGVW. RGV ……………………… (4 – 44)

Fig. 4 - 6, [A] The growth of internodes of *Phyllostachys pubescens*

RGD= 0+exp[3. 62+0.76n – 00. 33+0.012n)t]}$^{-1}$

RGDR = (0.33 + 0.012n)exp[3.62 + 0.76n – (0.33 + 0.012n)t]}^{2}

(A – the process of the growth of the internodes

B – the speed of the growth of the internodes

C – growth amount of the internodes)

dGDh/dt = h(n)RGDR= 0.1D$^{0.5513}$exp{- 2[(n/15.8D$^{0.2933}$) $^{-1}$]}^{2}

x{(0.33+0.012n)exp[3.62+0.76n–(0.33+0.012n)t]}/{l+exp[3.62+0.76n–(0.33 +0.012n)t]}2

(D=10cm)

4.2. The change in the growth of basic volume weight of bamboos

The data in Table 4 – 10 shows the change of basic volume weight of *Phyllostachys pubescens* and *Phyllostachys glauca* with the time of growth. If we express basic volume weight with ordinate and express the logarithmic value of the time of growth with abscissa, the diagram will be curves of "S" type which are related with each other. Therefore the relationship between the relative value of the basic volume weight of bamboos (RGVW) and the logarithmic value of the time of growth (Lnt) is as follows:

$RGVW = [l+\exp(A - BLnt)]^{-1}$ ………………………… (4 – 45)

$RGVWR = B\exp(A - BLnt)[1+\exp(A - bLnt)] - 2$ ……… (4 – 46)

According to the data in Table 4 – 9, using the regression of (4 – 45), (4 – 46), the parameters of the relationship between basic volume weight and the time of growth of *Phyllostachys pubescens* can be worked out:

$A = 7.0558$, $B = -1.3854$,

The equation of the relationship between the relative value of basic volume weight of *Phyllostachys pubescens* and the time of grow can be formed by putting the parameters A, B of *Phyllostachys pubescens* into formulas (4 – 45) , (4 – 46).

$RGVW = [1 + \exp(7.0558 - l.385Lnt)]^{-1}$ ………………… (4 – 47)

$RGVWR = 1.3854\exp(7.0558 - l.3854Lnt)[1+\exp(7.0558 - 1.385Lnt)^{-2}$……. (4 – 48)

Table 4—9 The Relationship Between volume Weight and Bamboo Age *Phyllostachys pubescens* Bamboos

Bamboo age	Year	0.1	0.2	1	2	4	6	8	10
	Days	37	72	365	730	1460	2190	2920	3650
Volume weight	g/cm³	0.050	0.243	0.425	0.531	0.596	0.626	0.629	0.606
	%	7.9	38.6	67.6	84.4	94.8	99.5	100	96.3

4.3. The changes in weight growth of bamboo culms

The volume growth and height growth of bamboo culms are going on simultaneously. When the weight growth stops, the volume growth stops too. Therefore the relative value of the volume growth (RGV) of bamboo culms is close to their relative value of height growth (RGH). So formula (4 – 43) can be approximately expressed with the following equation:

$RGW = RGH.\ RGVW$ ………………………….. (4 - 49)

Put RGH in formula (4 – 26) and RGVW in formula (4 – 45) in formula (47), then:

$RGW = (l+\exp(a_2 - b_2t) - 1\ (1+\exp)A - BLnt)\ ]^{-1}$ …………………. (4 – 50)

Formula (4 – 48) is the growth model of the relative value of bamboo weight. For any bamboo species, if parameters a_2 , b_2, A, B are worked out and put into formula (4 – 48) we can express the relationship between relative value of the weight of bamboo culms of this species and time of growth. For example: The relationship between the relative value of the weight of *Phyllostachys pubescens* culms and time is as follows:

$a_1 = a_2 = 4.6$, $b_1 = 0.312$, $b_2 = 0.23$

4.4. The change in weight growth of bamboo colony

According to the reasons mentioned above, RGV can be replaced by RGH in formula (4 – 44). Then, the relative value of weight of bamboo colony (RGTW) will be:

$RGTW=RGH.\ RGVW.\ RGN$ ………………………… (4 – 51)

Put RGH in formula (26), RGVW in formula (45) and RGN in formula (4 – 10) into formula (4-52), then:

RGHW= $[1 + \exp(a_1 - b_1 t)]^{-1} [1+\exp(a_2+b_2 t)]^{-1} [1 + \exp(A - BLnt)^{-1}$ (53) ……… (4 – 52)

Formula (4 – 53) is the growth model of the relative value of weight in the bamboo colony, for any bamboo species, if parameters a_1, b_1, A, B are worked out and put into formula (4 – 53) we can express the relationship between the relative value of the weight of bamboo culms of this species and time of growth. For example: The relationship between the relative value of the weight of *Phyllostachys pubescens* colony and time is as follows:

RGTW = $[1 + \exp(4.6 - 0.23t)]^{-1}[1+ \exp(7.056 - 1.385Lnt)]^{-1}[1 + \exp(4.6 - 0.312t)]^{-1}$……(4-53)

From formulas (4 – 49) and (4 – 52) we can see when bamboo shoots are coming out and bamboo culms are growing in the bamboo colony, the value of RGN and RGH in this formula changes with the time of growth; when the coming out of the bamboo shoots and the height growth in a bamboo colony stop ($t > 60$ days), RGH and RGN in the formula tend to be 1. Then the growth of the relative value of weight of bamboo culms can mainly be expressed by the change in the growth of the relative value of basic volume weight of bamboos (RGVW). Therefore, the growth of the relative value of weight of bamboos and of bamboos and of bamboo colony can be directly expressed with the growth of relative value of basic volume weight of bamboos. So formulas (4 – 49) and (4 – 52) can be simplified as formula (4 – 54):

RGW = $[1+\exp(A - BLnt)]^{-1}$ ……………………………(4 – 54)

For example, the relationship between the relative value for weight of *Phyllostachys pubescens* and time of growth is as follows:

RGW = $[1+\exp(7.056 - 1.385Lnt)^{-1}$ ………………………….. (4 – 55)

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Chapter 5 On Bamboo Flower

1. Bamboo is a seed plant

So its flowering and yielding seeds is its inevitable phenomenon. Any bamboo species has this natural property. But they have different flowering periods. Generally speaking, the flowering period is 50 ~ 60 years, some bamboo species can reach more than 100 years.

2. The presage before flowering

(1) Bamboo shoots reduce obviously or even stop shooting in the preceding year before fl owering;

(2) Short and small abnormal leaves and spikelets appear on the branches sprouted in the winter of the previous year, these spikelets begin to flower in the spring (March – April) of the next year when it begins shooting. If some new shoots sprout, they will blossom when they grow into new bamboos.

3. Generally speaking, bamboo being in flower will last 3~5 years.

Bamboo will keep on blossoming during this stage.

4. On bamboo species of *Phyllostachys* genus

(*Ph. fleuosa, Ph. albovariegata, Ph. aecox,* etc.), there are two possibilities on their growth:

(1) All bamboos in the whole stand have been dead. Its flowering distinguishing feature is:
All bamboos in the whole stand are in flower. Their seeds are full.

(2) Part of the bamboos in the stand has been dead. Its flowering distinguishing feature is: Part of the bamboos are in flower, their seeds are full; those bamboos that have flowered have been dead, those bamboos that haven't flowered will still be able to renew to a new bamboo stand.

5. In those bamboo stands being in flower:

Some new thin bamboos sprout from rhizome still can grow and flower. These thin new bamboos are called renewing bamboos, they should be protected. New bamboos sprout from the base of the renewing bamboos, new rhizomes will sprout from the base of these new bamboos. Then, those bamboos grow from these new rhizomes will stop flowering and recover a new bamboo stand gradually. This is called asexual renewal.

6. To those whole stands being in flower and with full seeds:

Their seeds should be gathered immediately. Sow them immediately after seed gathering to cultivate seedlings. Plant these seedlings to renew, this is called sexual renewal.

7. Measures

(1) Cut away the whole flowered bamboo;

(2) Only prune off those flowered branches, keep those branches that have not flowered;

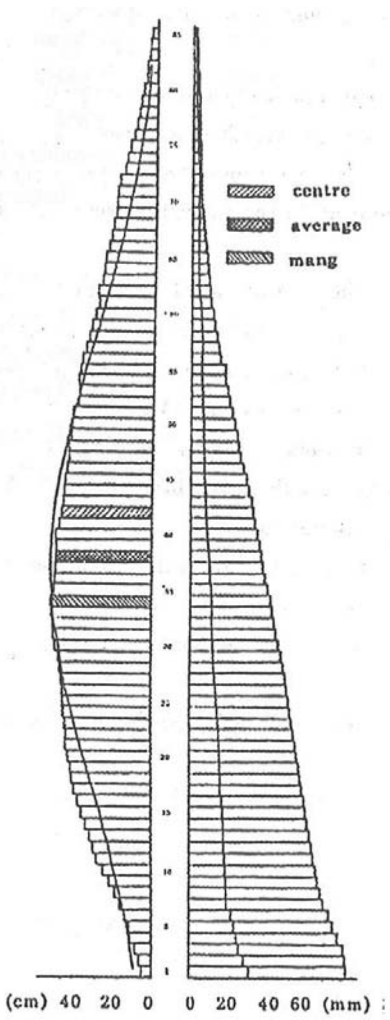
(3) Loosen soil, dig up those old rhizomes;

(4) Apply nitrogenous fertilizer;

(5) Protect those renewing bamboo.

Fargesia genus chiefly distributed in the high mountain of the south-west in China is the chief bamboo foods of Panda. It enormously flowered in 1980 and threatened the survival of Panda. The seed of *Fargesia sp*. fell down to the ground and germinated very easily and grew into new bamboo. Now all flowered bamboo stands have been completely renewed.

Chapter 6 the Structure of Culm Structure of Culm Form of *Phyllostachys pubescens*



Based on 3567 culms from 13 districts located in China and Japan, fourteen mathematical models have been worked out by statistical procedures. They are

1. The distribution of internode length of culms

$$h = (\frac{H}{1.25\overline{\overline{N}}})EXP - 2[\frac{N}{\overline{\overline{N}}} - 1]^2$$

$$H(p) = (\frac{H}{1.25\overline{\overline{N}}})\int_1^N \quad EXP - 2[\frac{N}{\overline{\overline{N}}} - 1]$$

2. The distribution of internode circumference of culms:

$$L = A(1 - \frac{N}{2\overline{\overline{N}}})$$

3. The distribution of internode wall-thickness of culms

$$Z = B(1 - \frac{N}{2\overline{\overline{N}})}$$

4. The distribution of internode volume of culms

$$V = (\frac{HB}{1.25\overline{\overline{N}}})(1 - \frac{N}{2\overline{\overline{N}}})^2 (A - \frac{\pi B}{2})^2 EXP - 2$$

$$V = (\frac{HB}{1.25\overline{\overline{N}}})(A - \frac{\pi B}{2})\int_1^N (1 - \frac{N}{2\overline{\overline{N}}})^2 EXP - 2[(\frac{N}{\overline{\overline{N}}}) - 1]dN$$

5. The structural model of the relative diameter of culms ($D_{\%}$)

$D_{\%} = 122[1 - (0.lH_x)^3] - 18.5H_x(1 - 0.\ 1H_x$

6. The structural model of the relative wall thickness of culms ($Z_{\%}$)

$Z_{\%} = 107.5 - 10.52H_x + 0.295H_x^2 - 0.0118H_x^3$.

7. The structural model of relative fresh weight of culms ($W_{\%}$)

$W_{\%} = 27H_x - 2.5H_x + 0.08H_x^3$

8. The relationship between the culm breast-height diameter (D) and the culm length (H) which is dependent *on the annual* mean temperature (t) and rainfall (R):

$$H = (0.1t + 0.0216\frac{R}{t} - 1.1)\,D^{(10223-28.6\frac{R}{t})10^{-4}}$$

9. The relationship between the breast-height diameter (D) and the fresh weight (W) which also depends on the annual mean temperature (t), D (insert formula)

10. The relationship between the breast-height diameter (D) and *the clear* length (H_{cl}) which is dependent on the annual mean temperature (t) and rainfall (R)

$H_{cl} = (0.667Rt^2 * 10^{-6} + 0.433)D - 1$

11. The relationship between the breast-height diameter (D) and the total fresh weight of branches with leaves (W_{bl}) which also result from the annual mean temperature (t) and rainfall (R)

$$W_{bl} = [0.188\frac{R^2}{t}10^{-5} + 0.5]D - 1.6$$

12. The relationship between the diameter (D) at breast-height and the diameter (D_x) at any height:

$D_x = (109.4 - 9.5H_x + 0.14H^2 - 0.028H_x^3)\ D/(81.14+2.85D - 0.085D^2)$

13. The relationship between the breast-height diameter (D) and the wall thickness (Z_x) at any height

$Zx = (007.5 - 10.52H_x + 0.296H_x^2 - 0.0118H_x^3)D(2.14D+81.44)$

$(0.72 - 1.85Rt10^{-5} + 0.086D)$

14. The relationship between the breast-height diameter (D), the length (H) and the total fresh weight (W) in connection with the influence of annual mean temperature (t) and rainfall (R)

$$W = [(2t + \frac{R}{t} + 8)/(100t + 20\frac{R}{t} - 920)]HD(150825 - 564.8t + 98.6\frac{R}{t})10^{-5}$$

Table 6—1 Natural conditions of sampled districts

Locations	N. Lat.	E. Long	An. m. temp. (c)	An. ppt. (mm)	R/t	Plots	Culms
Chaoping	24°15′	110°45′	19. 97°	2142	107. 3	14	20
Zhungyi	25°50′	114°10′	19. 20°	1484	77. 3	4	65
Huankeng	27°34′	117°40′	17. 75°	1880	105. 9	1	45
Zhanning	28°19′	105°00′	16. 50°	1350	81. 8	7	449
Chisui	28°35′	105°42′	18. 10°	1350	73. 0	5	73
Fuxing	28°42′	105°23′	17. 40°	1844	106. 0	6	109
Taimaoshan	28°45′	117°48′	17. 60°	1800	102. 3	65	575
Shimen	29°37′	121°16′	5. 98°	1512	94. 6	28	53
Yuchiashan	30°00′	118°00′	15. 60°	1615	103. 5	6	54
Tienmoshan	30°25′	119°25′	14. 40°	1800	125. 0	11	82
Yixing	31°22′	119°51′	15. 60°	1320	84. 6	92	1126
Xiashui	31°55′	119°00′	15. 80°	970	61. 4	2	647
Kyoto	35°00′	135°04′	16. 31°	1537	94. 2	—	289
Total						244	3567

An attempt is made to analyse the structure of culmform of *Phyllostachys pubescens* including diameter, height, wall thickness and weight with special reference to the climatic conditions.

Phyllostachys pubescens is the most important timber bamboo in China and naturally distributed in the region between 23°~33°N and 104°~122°E with an elevation of less than 1,200 metres. In this region annual mean temperature varied from 12^0C to 22^0C and annual precipitation from 800mm to

2,200 mm. During the period of 1958~1980, we investigated 3,298 culms of 244 plots from 13 districts located in China and coupled with the data of 289 culms from Japanese literature as listed in Table 6 – 1.

1 Node Distribution of Culms

Nodes of individual culms of *Phyllostachys pubescens* vary greatly. Generally, a large culm may have 80~90 nodes, while a small one only have 50 nodes. The position of nodes is indicated by 1, 2, 3…N from the base to the top of a culm. The length, circumference and wall-thickness of individual internodes can be diagrammed accordingly to show a general pattern of their distribution (Fig. 6 – 1).

1.1. Distribution of internodal length

As seen from Fig. 6 – 1, the internodal length usually reaches its maximum around the central nodal position and then gradually decreases toward both ends in a more or less symmetrical form. Thus, the distribution of internodal length can be expressed by the following equation,

$$y = (\frac{1}{c}\sqrt{2\pi})EXP - \frac{(X - X)^2}{2\sigma^2} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(6-1)}$$

In equation (6 – 1), y indicates the length rate (p) of individual internodes, x the number of individual nodal position N, X the average number of nodal position N calculated according to equation (6 – 2) () the standard deviation of average nodal position calculated according equation (6 – 3).

$$\overline{N} = \sum_1^N Nh / \sum_1^N h \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(6-2)}$$

$$\sigma = \sqrt{\sum_1^N h(N - a\overline{N})^2 / \sum_1^N h} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(6-3)}$$

$$\therefore \quad h(p) = \frac{1}{\sigma\sqrt{2\pi}} EXP - \frac{(N - \overline{N})^2}{2\delta^2} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(6-4)}$$

On the basis of equation (6 – 4), we select five culms of different size and calculate N, () of distribution of their internodal length (Table 6 – 2).

Table 6 – 2 Distribution of intermodal length

As indicated in Table 6 – 2, the average node position (N) is located between the longest internode (N) and the central node (Nc) as generally expressed in $N_1 \leq N \leq Nc$. For the practical purpose, N should be taken from 0 ~ 50 only. Thus, N of equation (4) can be calculated by

N = (N1 – Nc)/2 …………………….. (6 – 5)

From Table 6 – 2, the deviation coefficient of five sampled culms varies between 0.46 and 0.49. Such a difference is so small that can it) be neglected. Thus, an assumed constant = 0.5 is used in the practical calculation. The equation (6 – 4) can be written as follows:

$$h(p) = (\frac{1}{0.5\overline{N}\sqrt{2\pi}})EXP - \frac{(N - \overline{N})^2}{2(0.5\overline{N})^2} = \frac{1}{1.25\overline{N}} EXP - 2(\frac{N}{\overline{N}} - 1)^2 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(6-6)}$$

Equation (6) is an expression of the internodal length rate of culms and can be used to calculate the actual length (h) of individual internodes by multiplying the internodal length rate by the total height (H) of the culm. Consequently the distribution of internodal length of the culm also can be calculated accordingly.

$$h = h(p) * H = (\frac{H}{1.25\overline{N}})EXP[-2(\frac{N}{\overline{N}} - 1)^2] \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6\text{-}7)$$

$$H(p) = \int_1^N (\frac{H}{1.25\overline{N}})EXP - 2[(\frac{N}{\overline{N}} - 1]^2 dN \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6\text{-}8)$$

Table 6—2 Distribution if internodal length

Locations	D. B. H. (cm)	Ht (cm)	Node Position							
			Total $\sum N$	Long (NI)	Cent. (Nc)	Ave. (N)	$\sigma\pm$	$\sigma\sqrt{}N$	A	B
Xiashui	5.35	772	56	24	28	26.03	12.22	0.47	22.4	0.93
Xiashui	6.50	1060	60	28	30	29.30	13.55	0.46	28.2	1.30
Yixing	8.00	1096	56	28	28	27.28	12.56	0.46	31.4	1.49
yixing	11.14	1446	66	27	33	30.32	14.93	0.49	43.1	—
Huankeng	17.50	2448	85	36	42	38.29	18.34	0.48	67.0	1.90

1.2. Distribution of internodal circumference

The internodes of bamboo culms are generally cylindrical. Their girth is their circumference (L). The relationship between internodal circumference and two internodal diameter is L = d. The intermodal circumference decreases acrosspetally and is also related to the node position as expressed by

$$L = A(1 - \frac{N}{2\overline{N}}) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6\text{-}9)$$

A is the circumference of the basal internodes and can be expressed by the average circumference of 1~5 internodes, i.e. A= the given node position; N the mean node position; either of them should be taken as a unit for the practical purpose.

1.3. Distribution of internodal wall-thickness

The wall-thickness of individual internodes decreases acrosspetally and is related to the node position as expressed by

$$Z = B(1 - \frac{N}{2\overline{N}}) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6\text{-}10)$$

B is the wall-thickness of the basal mternodes and can be expressed by the average wallthickness of 1 ~ 5 internodes, i.e.

$$B = \frac{1}{5}\sum Z.$$

1.4. Distribution of internodal volume

On the basis of length (h), circumference (L) and wall-thickness (Z) of an internode, its volume (V) can be calculated, i.e. V = h.Z.L

If L1 is the outer circumference of the internode, L, the inner circumference, D_1 the outer diameter, and D_o the inner diameter, then

$$L = \frac{(L + L_o)}{2};\quad L_1 = \pi D_1;\quad L_o = \pi D_0; D_0 = D_1 - Z$$

$$L = \frac{(\frac{\pi}{2})}{(D_1 + D_0)} and\quad L = (\frac{\pi}{2})(D_1 + D_1 - Z) = \pi D_1 - (\frac{\pi Z}{2}) = L_1 - \frac{\pi Z}{2}$$

thus $V. = hZ(L_1 - \frac{\pi Z}{2})$ ··(6-11)

If h from (6 – 7), L from (9) and Z from (10) are given to (6 – 11), we obtain

$$V = (\frac{H}{1.25\overline{N}})EXP - 2[(\frac{N}{\overline{N}} - 1]^2\, XB(1 - \frac{N}{2\overline{N}})[A(1 - \frac{N}{2\overline{N}}) - (\frac{\pi B}{2})(1 - \frac{N}{2\overline{N}})]$$

$$V = (\frac{H}{1.25\overline{N}})EXP - 2[(\frac{N}{\overline{N}} - 1]^2 [AB(1 - \frac{N}{2\overline{N}})2 - (\frac{\pi B^2}{2})(1 - \frac{N}{2\overline{N}})^2]$$

$$= (\frac{HB}{1.25\overline{N}})(1 - \frac{N}{2\overline{N}})^2 (A - \frac{\pi B^2}{2})(1 - \frac{N}{2\overline{N}})^2]$$

···(6-12)

Equation (6 – 12) is the distribution of internodal volume of culms and equation (13) is the accumulative distribution of internodal volume of culms. The number 1, 2, 3, ... N of (5 – 13) should be unit for practical calculation.

$$V = \int_1^N VdN = \int_1^N (\frac{HB}{1.15\overline{N}})(A - \frac{B\pi}{2})(1 - \frac{N}{2\overline{N}})^2 EXP - 2(\frac{N}{\overline{N}})^2 EXP - 2(\frac{N}{\overline{N}} - 1)^2 dN$$

$$= (\frac{HB}{1.25\overline{N}})(A - \frac{\pi}{2})B \int_1^N (1 - \frac{N}{2\overline{N}})^2 EXP - 2(\frac{N}{\overline{N}} - 1)^2 dN$$

··(6-13)

2 Structural Model of Culm Form

The culms of *Phyllostachys pubescens* display a general model of their structural form, though they vary greatly in diameter, height and wall-thickness.

2.1. Variation of relative diameter of culms

A culm can be divided into 10 parts which are called the relative height and can be numbered by 0, 1, 2, … 9 from the base to the top. The ratio of a given diameter ($D_{\%}$) to that (D) at 1/10 height is the relative diameter $D_{\%}$ as expressed by $D_x/D_{0.1}$ X 100%. As indicated in Table 6 – 3 the relative diameter at a same relative height of culms is very similar regardless of their *location*, stand condition and size. In general, with 1/10 increase in relative height of culms upward, the relative diameter decreases about 10% (Fig. 6 – 3).

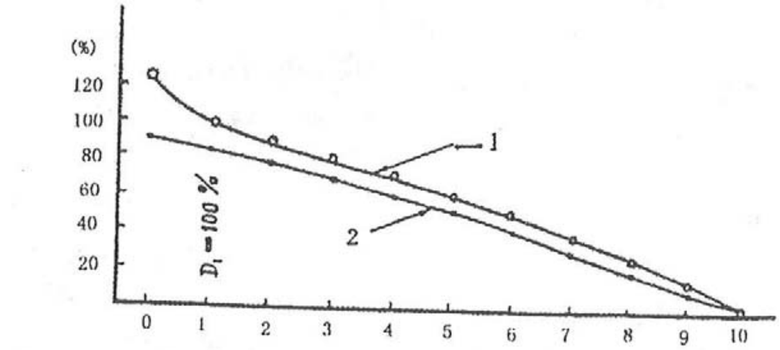


Fig. 6—3 Relative culm form rate(1. Outerdiameter; 2. Inner diameter)

In order to simulate the relationship between $D_{\%}$ and H_x, the theoretical value, standard deviation () and correlation coefficient (r) can be calculated according to equation (6 – 14) and (*as*) listed in Table 6 – 3.

$D_{\%} = 122[1 - 0.1H_x)^3] - 18.5H_x(1 - 0.1H_x)$ .... (6 – 14)

In polynomial simulation of $D_{\%}$ and H_x, the more the nomials, the *smaller standard* deviation. But for general practice, a cubic curvilinear *regression is* enough. According to equation (6 – 14), a relative diameter and then an actual diameter at any relative height can be calculated.

Table 6—3 Relative diameter of relative height of culms (D_x/D_i, %)

Locations	Culms	Relative height (total height=10)									
		0	1	2	3	4	5	6	7	8	9
Jiangsi	407	124.16	100	90.79	81.65	72.14	62.15	51.76	40.41	28.56	16.22
Jiansu	148	129.10	100	91.50	82.28	72.22	61.84	50.34	38.98	27.43	15.01
Anhui	54	121.59	100	89.39	81.64	71.70	61.06	50.34	38.64	26.65	14.57
Zhejing	15	127.46	100	89.07	80.75	70.13	59.80	50.75	40.67	28.69	16.64
Kuizhou	14	120.83	100	89.99	80.25	70.83	61.09	50.64	39.39	26.40	14.99
Av. or. Tot	638	125.10	100	90.80	81.74	72.04	61.91	51.26	39.91	28.09	15.78
±σ		2.42	0	0.61	0.40	0.41	0.54	0.78	0.78	0.77	0.77
Cal. valus		122.00	105.2	91.40	79.90	69.80	60.50	51.20	41.30	29.90	16.40

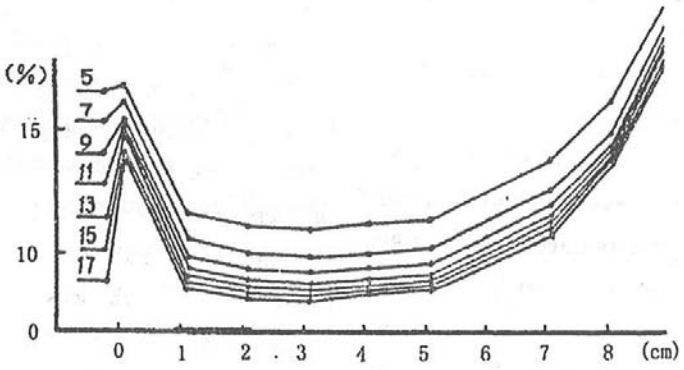


Fig. 6—4. Wall—thickness rate (%) at relative height of culms
(d.c. Diameter class Taimaoshan 1980)

The ratio of the breast-height diameter (D) to $D_{0.1}$ with increase in diameter at breast-height, and the relation is

$$\frac{D}{D_{0.1}} = 81.14 + 2.85D - 0.085D^2 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(6\text{-}15)$$

From (6 – 15)

$$D_{0.1} = \frac{D}{(81.14 + 2.85D - 0.085D^2)} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(6\text{-}16)$$

then multiplying (6 – 14) by (6 – 16)

$D_x = [122[1 - (0.1H_x)^3] - 18.5H_x(1 - 0.1H_x)]/(81.14 + 2.85D - 0.85D^2)$ .... (6 – 17)

If D and H_x are known, D_x can be calculated from (6 – 17).

2.2. Variation of wall-thickness rate of culms

The *percentage* of wall-thickness in outer diameter of culms, known as wall-thickness rate, is closely related to their size and parts. As seen in Fig. 6 – 4, the wall-thickness rate decreases with increase in the breast-height diameter. In individual culms, the wall-thickness rate is always greater in their lower and upper parts than that in the middle.

The wall-thickness rate of culms varies considerably in different districts (Table 6 – 4).

In general, the warm, humid climate promotes the height growth of culms, while the low temperature and low humidity *favors* the increase of the culm wall-thickness. In an area, the bigger diameter of culms, the thicker culm wall-thickness. The relationship between breast-height diameter (D) and wall-thickness (Z) at breast-height is:

Z = a + bD …………………………… (6 – 18)

According to equation (18), the following formulas can be derived.

Taimaoshan, (121 culms):

Z = 0.07 + 0.092D ………………… (6 – 19)

Table 6 – 4 Wall-thickness rate of relative height of culms (Z/D)

Table 6—4 Wall—thickness rate of relative height of culms (Z/D)

Relativ	0	1	2	3	4	5	6	7	8	9	Ave.
Yixing	17.77	11.88	10.92	10.73	10.30	9.83	11.09	13.03	14.44	21.36	13.14
Damaoshan	15.50	9.99	9.51	9.33	9.58	9.66	10.81	12.28	14.34	18.93	11.98
Chishui	13.60	9.34	8.99	8.83	8.94	8.81	9.59	10.45	12.74	14.83	10.61

Tienmnshan (82 culms):

Z = 0.25 + 0.086D …………………….. (6 – 20)

Funxing (109 culms):

Z = 0.27 + 0.84D ……………………… (6 – 21)

Yixing (55 culms):

Z = 0.33 + 0.86D ……………………… (6 – 22)

In the formulas mentioned above, b is relatively stable and can be estimated to br 0.086, while a varies *considerably in different* areas and is related to the annual mean temperature (t) and annual precipitation (R): a = 0.72 – 1.85 Rt10^{-5} …. (6 – 23)

Thus, the relationship between Z and D in different districts can be obtained by substituting 0.72 – 1.85Rt X 10 and 0.086 for a, b *in* equation (6 – 19) respectively.

Z = 0.72 – 1.85 Rt10^{-5}+ 0.086D . …………….. (6 – 24)

2.3. Variation of relative wall- thickness of culms

The ratio of a given wall-thickness (Z_x) to the wall-thickness at 1/10 height ($Z_{0.1}$) is known as relative wall-thickness ($Z_{\%}$) and can be expressed by:

$$Z_{\%} = \frac{Z_x}{Z_{0.1}} \times 100\%$$

As seen in Table 6 – 2, the relative *wall* thickness at a relative *height of* culms is very similar regardless of their *provenance*, stand condition and size. On the basis of 251 culms from five districts, the relationship between relative wall-thickness ($Z_{\%}$) and relative height (H_x) of culms can (*be*) calculated by the least square fitting,

$Z_{\%}$= 107.5 – 10.52H_x + 0.296H_x^2 – 0.118H_x^3 ………………… (6 – 25)

According to (6 – 25), a relative wall-thickness and an actual wall-thickness at any relative height of a culm can be calculated if its wall-thickness at a given relative height is known. The relative wall-thickness at breast-height [(Z/$Z_{0.1}$) 100%] increases with increase in diameter at breast-height. Their relationship is:

$$(\frac{Z}{Z_{0.1}})100\% = 2.14D + 81.44 \cdots\cdots\cdots\cdots (6\text{-}26)$$

$$\therefore Z_{0.1} = \frac{Z}{(2.14D + 81.44)} \cdots\cdots\cdots\cdots (6\text{-}27)$$

From (6 – 24):

$$Z_{0.1} = \frac{(0.72 - 1.85Rt10^{-5} + 0.086D)}{(2.14D + 81.44)} \cdots\cdots\cdots\cdots (6\text{-}28)$$

$$\because \quad Z_{\%} = \frac{Z_x}{Z_{0.1}} \therefore Z_x = \frac{Z}{Z_{0.1}} \cdots\cdots\cdots\cdots (6\text{-}29)$$

Then $Z_{\%}$ from (6 – 25) and $Z_{0.1}$ from (28),

Z_x = (0.72–1.85Rt10^{-5}+0.86D) (107.5–10.52Hx+0.295H_x^2–0.0118H_x^3)/(2.14D+ 81.44)

…………………… (6 – 30)

Consequently, the wall-thickness at different relative height of *different culms* from different areas can be calculated, if t, R and d values are given.

Table 6—5 Relative wall—thickness at relative height of culms ($\frac{Z_x}{Z_{0.1}}$, %)

Locations	Relative height (total ht = 10) of Culms									
	1.3m	0	2	3	4	5	6	7	8	9
Taimaoshan	131	188.02	85.13	76.23	68.22	61.37	53.36	46.01	37.23	26.20
Yuchisshan	54	173.67	85.84	74.63	66.15	57.79	51.61	43.94	35.51	26.87
Xiasu	37	191.64	85.46	77.54	69.71	60.28	53.50	45.36	34.99	25.15
Shimen	15	187.37	82.95	78.37	68.93	60.57	54.01	47.91	39.31	31.97
Chishui	14	178.33	85.36	75.96	67.49	57.47	51.87	43.41	36.13	23.44
Ave. total	251	184.88	85.22	76.20	67.91	60.17	52.96	45.44	36.59	26.38
Theoretic value			87.55	78.29	69.40	60.83	52.49	44.32	36.24	28.19

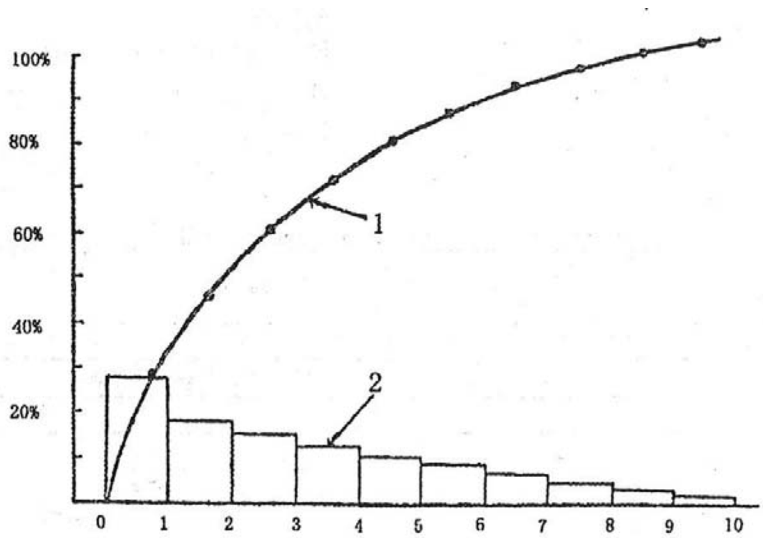


Fig. 6 – 5 Weight percent of relative sections of culms

Structural Model of Fresh Weight of Culms

As indicated in table 6 – 6, the section at *the* same relative height of culms have similar *percentage* of the total weight (Fig. 6 – 5).

The relationship between relative height (H_x) and relative weight ($W_{\%}$) can be obtained by least square fitting,

$$W_{\%} = 27H_x - 2.5H_x^2 + 0.08H_x^3 \quad \text{……………………} \quad (6-31)$$

According to (6 – 31), the relative weight or actual weight of culm sections at any relative

Table 6—6 Weight percent of relative section of culms

Locations	Section weight of culm										
	Culms	1	2	3	4	5	6	7	8	9	10
Jiangxi	24	26.74	18.56	14.63	11.85	9.44	7.40	5.34	3.50	1.82	0.72
Jiangsu	28	26.88	18.94	15.08	12.23	9.58	7.26	5.05	2.98	1.48	0.52
Zhejiang	14	27.74	18.27	13.94	11.51	9.51	7.27	5.24	3.63	2.03	0.86
Kuizhou	14	26.99	19.16	15.01	12.05	9.39	7.18	5.21	3.04	1.58	0.39
Tot. or Ave.	80	27.01	18.75	14.73	11.96	9.49	7.29	5.20	3.25	1.70	0.62

3. Relation of Breast-height Diameter to Total Height and Clear Length of Culms

3.1. Breast height diameter and total height of culms

A. In order to determine the correlation of breast- *height diameter* (D) and total length (H) of culms, data collected from Damaoshan, Shimen and Yixing are fitted by least square into

$H = a+bD$, $H = a + D^b$, and

$H = a + bD + cD^2$,

Damaoshan (575culmshm)

$H = 2.4574 + 1.1665D$ …………… (6 – 32)

$H = 2.775D^{0.7179}$ ………………...... (6 – 33)

$H = 0.2002 + 1.7694D – 0.038D^2$ …….. (6 – 34)

Shimen (53 culms):

$H = 3.9042 + 0.9662D$ ………………. (6 – 35)

$H = 2.469D^{0.7416}$ …………………... (6 – 36)

$H = 1.3109 + 1.4551D – 0.0218D^2$ …… (6 – 37)

Yixing (300 culms):

$H = 2.4574 + 1.1665D$ ………………… (6 – 38)

$H = 2.289D^{0.7905}$ …………………….. (6 – 39)

$H = 0.2002 + 1.7694D – 0.038D^2$ …… (6 – 40)

Table 6—7a Relation of annual mean temperature and rainfall to culm height ($H=aD^b$)

Locations		Chao ping	Zhung yi	Huan keng	Zhan shui	Chi shui	Fun xing	Daimao shan	Shimen	Yuchia shan	Tianmu shan	Yi xing	Xie shui	Kyoto *
An. m. tem.		19.97°	19.20°	17.75°	16.50°	18.10°	17.40°	17.60°	15.98°	15.60°	14.40°	15.60°	15.80°	16.31°
An. ppt. mm		2142	1484	1880	1350	1322	1844	1800	1512	1615	1800	1320	970	1537
R/t		107.3	77.3	105.9	81.8	73.0	106.0	102.3	94.6	103.5	125.0	84.6	61.4	94.2
Expt.	a	3.035	2.519	3.109	2.291	2.524	3.042	2.775	2.469	2.975	3.109	2.289	1.892	2.250
	b	.7659	.7398	.6766	.8071	.7824	.6648	.7179	.7416	.6900	.6648	.7905	.8469	.7753
	r	0.994	0.915	0.969	0.998	0.950	0.877	0.982	0.976	0.963	0.976	0.990	0.993	0.986
Theor.	a	3.215	2.490	2.962	2.317	2.287	2.763	2.870	2.541	2.696	3.040	2.287	1.806	2.566
	b	.7154	.8012	.7194	.7933	.8135	.7386	.7297	.7517	.7263	.6648	.7803	.8467	.7529
	r	0.927	0.868	0.848	0.981	0.871	0.440	0.890	0.899	0.935	0.996	0.976	0.922	0.936

Table 6—7b Relation of annual mean temperature and clear length

Locations		Chao ping	Zhung yi	Huan keng	Zhan shui	Chi shui	Fun xing	Daimao shan	Shimen	Yuchia shan	Tianmu shan	Yi xing	Xie shui	Kyoto *
Expt.	a_0'	−1.10	−1.00	0.000	−1.50	−1.12	−0.50	÷0.50	−4.36	+0.62	−1.00	−1.11	−0.95	—
	b_0'	1.11	0.80	0.70	0.85	0.80	0.70	0.67	1.00	0.59	0.68	0.67	0.60	—
Theor.	a_t'	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00	−1.00
	b_t'	1.0028	.7979	.8281	.6781	.7219	.8054	.8049	.6905	.6951	.6820	.6473	.5945	.7057

Table 6—7c Relation of annual mean temperature and rainfall to weight of branches and leaves ($W_{bl}=c_1+d_1D$)

Locations		Chao ping	Zhung yi	Huan keng	Zhan shui	Chi shui	Fun xing	Daimao shan	Shimen	Yuchia shan	Tianmu shan	Yi xing	Xie shui	Kyoto *
Expt.	c_0'	−1.10	−1.80	2.000	−1.87	−1.14	−1.80	−1.60	−1.53	—	−2.40	−1.38	−1.30	—
	d_0'	0.94	0.73	0.85	0.78	0.65	0.74	0.72	0.83	—	0.98	0.86	0.62	—
Theor.	c_t'	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60	−1.60
	d_t'	.9319	.7156	.8743	.7077	.6815	.8674	.8461	.7690	.8140	.9230	.7100	.6120	.7723

Table 6—7d Relation of annual mean temperature and rainfall to weight of culms($W=cD^d$)

Locations		Chao ping	Zhung yi	Huan keng	Zhan shui	Chi shui	Fun xing	Daimao shan	Shimen	Yuchia shan	Tianmu shan	Yi xing	Xie shui	Kyoto *
Expt.	a_0	.1538	.1513	.1849	.1386	.1008	.1594	.1566	.0959	.1467	.1614	.1527	.1000	.0906
	b_0	0.94	0.73	0.85	0.78	0.6	0.74	0.72	0.83	—	0.98	0.86	0.62	—
	r_0	.9319	.7156	.8743	.7077	.6815	.8674	.8461	.7690	.8140	.9230	.7100	.6120	.7723
Theor.	a_t	.1545	.1258	.1486	.1242	.1197	.1488	.1450	.1346	.1420	.1589	.1250	.1045	.1351
	b_t	2.2165	2.2772	2.2318	2.2864	2.2915	2.2336	2.2394	2.2629	2.2485	2.2150	2.2839	2.3262	2.2619
	r_t	0.946	0.957	0.983	0.979	0.991	0.974	0.950	0.971	0.856	0.978	0.982	0.999	0.939

Table 6—7e Relation of annual mean temperature and rainfall to weight of culms ($W=eD^f\cdot H$)

Locations		Chao ping	Zhung yi	Huan keng	Zhan shui	Chi shui	Fun xing	Daimao shan	Shimen	Yuchia shan	Tianmu shan	Yi xing	Xie shui	Kyoto *
Expt.	e_0	.0507	.0600	.0595	.0605	.0399	.0524	.0564	.0388	.0493	.0519	.0667	.0528	.0403
	f_0	1.4970	1.5034	1.4615	1.4571	1.5853	1.5212	1.4564	1.6222	1.5624	1.5431	1.3857	1.4841	1.5885
Theor.	e_t	.0482	.0505	.0502	.0519	.0523	.0506	.0518	.0524	.0527	.0536	.0531	.0535	.0520
	f_t	1.5038	1.4760	1.5124	1.4931	1.4780	1.5169	1.5120	1.5134	1.5222	1.5527	1.5055	1.4812	1.5090

Then, we calculate their standard deviation ( ). The *quadri-* curve is the best with least error and height correlation, the power function the next, and the straight line the last. But for the (delete) *practical* purpose, the power function equation is desirable, because it has two parameters and *results in* much less error than the straight line, though slightly greater than the *quadri-* curve.

According to $H = aD^b$, we calculate a, b of regression equation for breast-height diameter and total height of culms from 13 locations and their correlation coefficient (r) as listed in table 6 – 7.

B. Climatic factors and height culms

In Table 6 – 7, a_0 and b_0 vary with annual mean temperature (t) and precipitation (R). Their relationship is

$$ao = 0.1t + 0.216\frac{R}{t} - 1.1 \quad \ldots\ldots (6-41)$$

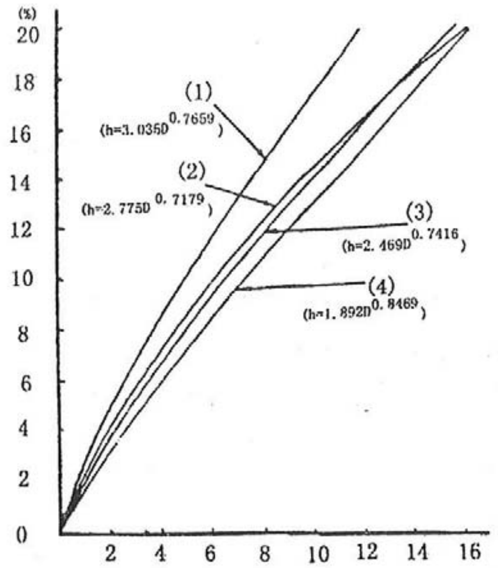
$$bo = 1.0223 - 0.00286\frac{R}{t} \quad \ldots\ldots (6-42)$$

Then from $H = a_0Db_o$, we obtain

$$H = [0.1t + (0.0.216\frac{R}{t}) - 1.1]\, D^{(1.0223 - 0.00286 \underline{R})} \cdots\cdots\cdots\cdots (6-43)$$

In the total annual mean temperature and rainfall of an area are given to *formulas* (42), at and bt can be calculated (Table 6 – 7) and the correlation coefficient (r) obtained shows that *formulas* 43 is feasible.

Fig. 6 – 6 Breast-height diameter and height of culms



C. Stand density and height of culms

Stand density (N) influences the culm height (H). The relationship is

$H = 0.8549N^{0.1745}D^{0.78}$ …… (6 – 44)

Apparently, a denser stand always promotes height growth of culms, and a lower stand density results in a smaller height of culms.

Table 6 – 7 shows that the density of bamboo stands in 12 locations (except Kyoto, *Japan*) is about 200 culms per mu, i.e. N =200/mu, which can be recognized as a standard, the stand parameter

$K_N = 1,$ and be calculated,

$$K_N = \frac{(0.8459N^{0.1745}D^{0.78})}{(0.8459 \times 2000.1745D^{0.78})} = 0.3967N^{0.1745} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
(6-45)

D. Breast-height diameter and total height of culms in different climate and different stand density.

In studying the relationship between breast-height diameter and total height of culms, it is necessary to consider the influence from the climatic conditions (t, R). Such *an* influence can be expressed in a mathematical model by (6 – 43) X (6 – 45),

$$H = 0.3967N^{0.1745}(0.1t + 0.0216\frac{R}{t} - 1.1)D^{(1.0223-0.00286\frac{R}{t})}$$

$$H = (3967t + 857\frac{R}{t} - 43637)10^{-5}N^{0.1745}D^{(1.0223-0.00286\frac{R}{t})10^{-4}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(6-}$$

46)

3.2. Breast-height diameter and clear length of culms

A. The correlation of breast-height diameter and clear length of culms is a straight line (Fig. 6 – 8)

H_{c1} = a' + b'D .... (6 – 47)

Based on the data collected from 12 locations, a' and b' can calculated and listed in Table 6 – 7.

B. Climatic factors and clear length of culms

From Table 6 – 7, a' values, except –4.36 for Shimen, are about –1, is related to the annual mean temperature and *precipitation*, b' = 0.66Rt2. Giving a' and b' values to (6 – 47) we obtain

$$H_{cl} = (0.667Rt^2 10^{-6} + 0.433)D - 1 \cdots\cdots\cdots\cdots (6\text{-}48)$$

According to (6 – 48), a' and b' of these *locations* are *given*. Results obtained from such an equation is only slightly different as compared with the actual values.

C. Stand density and clear length of culms

In an area, the denser the stand, the longer the clear length of culms. Their *relationship* is

$H_{c1} = 0.0398N^{0.4668}$ …………………… (6 – 49)

As seen in Table 6 – 7, the stand density of 12 districts is about 200 culms per mu. We take N = 200 culms/mu as a standard stand, i.e. $K_N = 1$, and calculate K_N as follows:

$$K_N = (0.0398N^{0.4668}D)/(0.0398 \times 200^{0.4668}D = 0.0843N^{0.4668} \cdots\cdots\cdots (6\text{-}50)$$

D. *Breast*-height diameter and clear length of culms in different climate and stand density.

The mathematical model for *breast*-height diameter and clear length of culms can be constructed in relation to the *climatic* conditions:

$$\begin{aligned} H_{cl} &= 0.0843N^{0.4668}(0.667Rt^2 10^{-6} + 0.433)D - 1 \\ &= (562Rt^2 10^{-10} + 365 \times 10^{-4})N^{0.4668}D - 1 \end{aligned} \cdots\cdots\cdots (6\text{-}51)$$

As expressed in (6 – 51), the greater the stand density, the larger the *breast*-height diameter and the longer is the clear length of culms. This fact indicates that with fair increase in the density of bamboo stands, not only the culm production increases, but the *quality* of culms is greatly improved.

4.Reaction of Brest-height Diameter to Fresh Weight of Culms and Branch-leaves

4.1.Breast-height diameter and culm weight

A. The fresh weight of culms is *correlated* to the *breast*-height, that is the greater the diameter, the heavier the weight (Fig. 6 – 7).

According to equations of W = a + bD, w = cD^d and W = a + bD =cD^2, we calculate the data collected from *Daimaoshan*, Shimen and Yixing as follows.

Daimaoshan (575 culms):

W = 5.1193D – 25.809 ……………………….. (6 – 52)

W = $0.1566D^{2.1745}$ …………………………… (6 – 53)

W = $0.2706D^2$ – 0.7074D + 14.4193 ………… (6 – 54)

Shimen (53 culms):

W = 6.2079D – 37.957 ………………… (6 – 55)

$W = 0.0959D^{2.3638}$……………………. (6 – 56)

W = 0.4468D2 – 3.7074D + 14.4193 ………. (6 – 57)

Yixing (300 culms):

W = 3.8493D – 15.6926 …………………. (6 – 58)

W = 0.1527D2.1756 ……………………… (6 – 59)

W = 0.2825D2 – 0.6312D + 1.0815 ……… (6 – 60)

The standard deviations obtained show that the quadric curve is the best with the least error, the power function the next, and the straight line the last. But for practical purpose, $W = cD^d$ is desirable. It has only two parameters and results in much less error than the straight line, though slightly greater than the quadric curve.

According to $W = cD^d$, we calculate c, d for breast-height diameter and total weight of culms of 13 locations and correlation (r) as listed in Table 6 – 7 and Appendix.

B. As indicated in Table 6 – 8, the parameter c increases with increase in annual mean temperature (t) and rainfall index (R/t). Their relationship is:

$$c = 0.0163 + 0.00208t + 0.000901\frac{R}{t} = (163 + 20.8t + 9.01\frac{R}{t})10^{-4} \cdots\cdots\cdots\cdots\cdots\cdots$$

(6-61)

But the parameter d decreases with increase in annual mean temperature (t) and rainfall index (R/t). Their relationship is:

$$d = 2.53055 - 0.005648t - 0.001874\frac{R}{t} = (253005 - 564.8 - 187.4\frac{R}{t})10^{-5} \cdots\cdots (6\text{-}62)$$

From (6 – 61) and (6 – 62), the *relationship* of culm weight (w) to annual mean temperature (t) and rainfall index (R/t) can be obtained.

$$W = (163 + 20.8t + 9.01\frac{R}{t})10^{-4} D^{(253055 - 564.8t - 187.4\frac{R}{t})10^{-5}} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6\text{-}63)$$

Accordingly on the basis of t and R/t, ct, dt and r can be calculated and listed in Table 6 – 7. As indicated in r values, the difference is not significant. Consequently (6 – 63) is feasible to calculate the *relationship* of breast-height diameter to culm weight in connection with the *climatic factors* (t, R).

4.2. Brest-height diameter and fresh weight of branches and leaves

A. In general, weight of branches is relatively stable, but the weight of leaves varies considerably with season and leaf age. Thus the weight of branches and *leaves appear* to change greatly in accordance with seasons, leaf age and on or off year.

Apparently the weight of branches and leaves increases with increase in *breast*-height diameter of culms.

The relationship is expressed by:

Wb1 = c' + d'D

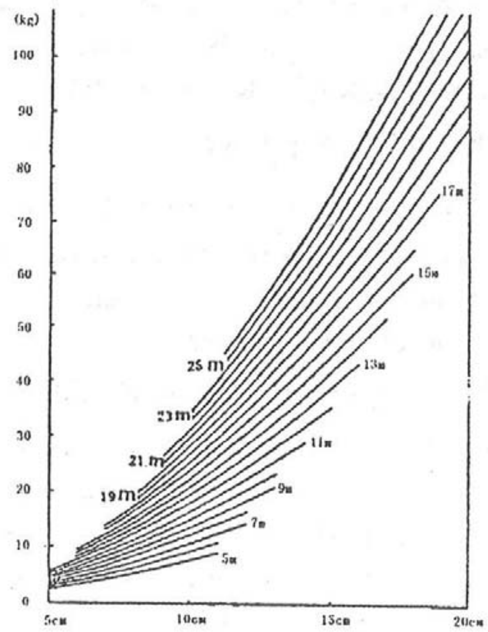
and c' and b' (*d*') can be calculated and listed in Table 6 – 7.

B. Climatic factors and branch-leaf weight of culms

As indicated in Table 6 – 7c is about –1.6 in average, d' is related to t and R and can be written as follows:

$$d' = 0.188X10^{-5}\frac{R^2}{t} + 0.5 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6-65)$$

Fig. 6 – 7 *Breast*-height diameter and weight of culms



If c', d' values are given to (6 – 64), the *relationship* of branch-leaf weight of to annual mean temperature and rainfall index (R/t) can be obtained.

$$W_{bl} = (0.188X10^{-5}\frac{R^2}{t} + 0.5)D - 1.6 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6-66)$$

C. Stand density and branch-leaf weight

Generally, the greater the density, the smaller the branch-leaf weight of individual culms. Their relationship is:

$$W_{bl} = 2.5998N^{0.403}D^{1.25} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6-67)$$

In Table 6 – 7, the stand density in 12 locations is about 200 culms per mu. We use N=200 culms/mu as a standard density to calculate K_N,

$$K_N = \frac{(2.5998N^{-0.4030}D^{1.25}}{(2.5998 \times 200 - 0.4030D^{1.25})} = 6.759N^{-0.4030} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6-68)$$

D. Under different climatic conditions a mathematical model can be constructed to express the relationship between *breast*-height diameter and branch-leaf weight in different stand density.

$$W_{bl} = 6.759N^{-0.4030}(0.188X10^{-5}\frac{R^2}{t} + 0.5)D - 1.6$$

$$W_{bl} = (1.2707X10^{-5}\frac{R^2}{t} + 3.3795)N^{-0.4030}D - 1.6 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (6-$$

69)

4.3. Breast-height diameter, height and weight of culms

The weight of culms always increases with increase in their breast-height diameter and height. If the culms are same in diameter at breast-height, their weight increases proportionally with their height. In the case of same height, however, the increase of culm weight is not proportional to the breast-height diameter, but follows a power function curve. Thus their relationship can be expressed by:

$$W = eD^f H \cdots\cdots\cdots\cdots\cdots\cdots (6-70)$$

From W = cDd and W = cDb, e, f can be calculated.

$$\because W = eD^f H, W = cD^d, H = aD^b$$

$$\therefore W = eD^f H = cD^d, eD^f XaD^b = cD^d$$

$$eD^f = cD^d / aD^b = cD^{(d-b)} / a$$

$$\therefore e = c/a, f = d - c$$

$$\because a = 0.1t + 0.0216R/t - 1.1, b = 1.0223 - 0.00286R/t,$$

$$c = 0.0163 + 0.00208t + 0.000901R/t$$

$$d = 2.53055 - 0.005648t - 0.0001874R/t$$

$$\therefore e = (0.0163 + 0.00208 + 0.000901R/t)/(0.1t + 0.0216R/t - 1.1)$$

$$= (2t + R/t + 8)/(100t + 20R/t - 920 \cdots\cdots\cdots (6-71)$$

$$f = (2.53055 - 0.005648t - 0.001874R/t) - (1.0223 - 0.00286R/t)$$

$$= (150825 - 564.8t + 98.6R/t)10^{-5} \cdots\cdots (6\text{-}72)$$

Giving e, f values to W = eD^fH, we obtain the *relationship* of culm weight to breast-height diameter (D) and height (H) with reference to annual mean temperature (t) and rainfall index (R/t):

$$W = [(2t + R/t + 8)/(100t + 20R/t - 920)]HD^{(150825 - 564.8t + 98.6R/t)10^{-5}} \cdots\cdots (6-73)$$

Accordingly giving t and R/t of different districts to (6 – 73), e, f of their theoretical regression equation can be calculated and listed as in Table 6 – 7.

From the standard deviation and standard error between the theoretical value and actual value, the difference is not significant generally. Thus, the (6 – 73) is feasible to express the *relationship* of culm weight to breast-height diameter and height in connection with the influence of annual mean temperature and precipitation.

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Appendix:

Appendix:

Reation of Brest—height diameter to Fresh Weight on Types I of Bamboo stand

Breast—height diameter (cm)		5	6	7	8	9	10	11	12	13	14	15
Fresh Weight (kg)	0.0	4.31	6.66	9.54	13.08	17.27	22.16	27.76	34.06	41.19	49.09	57.80
	0.2	4.71	7.16	10.19	13.86	18.20	23.23	28.96	35.49	42.72	50.76	59.61
	0.4	5.17	7.72	10.88	14.68	19.14	24.31	30.21	36.85	44.27	52.48	61.49
	0.6	5.47	8.30	11.58	15.52	20.23	25.43	31.48	38.27	45.84	54.23	63.39
	0.8	6.11	8.91	12.31	16.39	21.13	26.58	32.78	39.72	47.46	56.01	65.37

Reation of Breast—height diameter to Fresh weight on Types II, III of Bamboo stand

Brest—height diameter (cm)		5	6	7	8	9	10	11	12	13	14	15
Fresh Weight (kg)	0.0	5.12	7.62	10.65	14.24	18.40	23.13	28.47	34.46	40.93	48.10	55.89
	0.2	5.58	8.18	11.32	15.02	19.30	24.00	29.60	35.66	42.33	49.61	57.50
	0.4	6.06	8.77	12.02	15.84	20.22	25.20	30.76	36.94	43.72	51.15	59.17
	0.6	6.56	9.37	12.72	16.66	21.17	26.26	31.96	38.25	45.15	52.71	60.86
	0.8	7.07	10.00	13.48	17.52	22.14	27.35	33.17	39.58	46.62	54.29	62.59

Relationship of *Breast*-height diameter to Fresh Weight on Types I of Bamboo stand

Reation (*Relationship*) of Breast-height diameter to Fresh weight on Types II, III of Bamboo stand

Chapter 7 Propagation and Afforestation of Bamboo

1. Breeding bamboo seedling

When bamboo is afforested in an area, offset planting method can be used. However, bamboo afforesting in a large area must be conducted by planting bamboo seedlings when they are bred up to the standard.

The ways of breeding bamboo seedlings in China are as follows:

1.1. Seed breeding

Bamboo seeds are able to germinate, so they can be cultivated into seedlings. Bamboo seeds when they are ripe, can germinate as long as they are sown under appropriate temperature, moisture and air, since they have no after ripening. In the tropical zone, where the contrast between rainy seasons and dry seasons is remarkable, it is best to sow bamboo seeds when a rainy season is just beginning, while in the subtropical zone or temperate zone spring is the best season for bamboo seeds to sow. Bamboo seeds can be sown in a green house at anytime of the year.

The time between the collecting and sowing of the bamboo seeds is a stage for store. This stage generally should not be too long, otherwise it is apt to germinate. Most of the seeds which are cryopsis-shaped or nut-shaped need to be stored in dry and low-temperature place; a few of them which are berry-fruit-shaped need to dressed with moist sand and kept in cold storage. Before the bamboo seeds are put in store they must be disinfected with insecticide and germicide so as to protect the seeds from being eaten by pests or becoming rotten and going bad.

The plot for growing bamboo seedlings from seeds requires good drainage, convenient irrigation, loose and fertile and acid soil, which needs to be carefully ploughed and leveled, and formed into seedbeds in rectangle 1.2m. to 1.5m broad; at the same time ditches for drainage should be cut ready.

Before being sown the bamboo seeds should be examined on their quality and tested whether they germinate. The quantity of bamboo seeds for sowing is decided according to the results of the examination and the test mentioned above. Small-sized seeds are fit for broadcasting, the medium-sized and large- sized are fit for drilling or dibbling. After sowing, the seeds are to be covered with the soil 2~3 times as the thick as the diameter of the seed. Then let the seedbeds be covered with hay so as to keep the soil moist.

After germination of the seeds, the hay covering the seeded is to be taken away without delay while a shed is to be put up to protect young seedlings from the burning sunlight. Young seedling management:

(1) Weed the seedbed;

(2) Water the seedbed to keep its soil moist;

(3) Condition the soil to prevent it from being fixed and tight;

(4) Apply manure to make the soil fertile and help the bamboo seedlings grow;

(5) Prevent and eliminate plant diseases and pests to guarantee healthy growth of the seedlings.

Generally, in the growing season of a year, bamboo seedlings tiller 4 to 6 times. The young seedlings are growing thicker and thicker with each tillering and they crowd together and form a “bamboo clump” or “seedling cluster”. Yearly “seedling cluster” of the running type and intermediate type is very similar to clump of cluster type. But only after the growth for a year, when rhizome of seedling cluster of the running type intermediate type come up out of land, will the feature of the diffuse or intermediate bamboo seedlings gradually present.

In tropical zone yearly bamboo seedlings can be used for afforestation. In the subtropical and temperate zones some varieties of bamboo seedlings should be bred for two years before they can be used for afforestation.

1.2. Breeding by layering of culms or nodes

This method is fit for clump seedling of the sympodial type. Such bamboo species as *Bambusa, Dendrocalamas, Sinocalamus, Lingnania, Schizostachyum* etc. can be bred by this method.

The rainy season or spring is the best time for seedling breeding by these two methods.

Selection of breeding material: Breeding material is selected from those bamboo culms having grown for two or three years, well-cultivated and healthily-developed, and without insect pest and plant diseases. Cut down the selected bamboo culms, get rid of their tops and branches, and reserve the bud on the first one or two nodes of the base of the branches as well as those on the culm. The culm can be used as the material for layering of culms when it is cut off 2/3 deeper of its diameter with a saw on either side of the neighboring nodes. In some places the sawn culms are soaked in water. After water enters bamboo internodes, the cut is to be sealed with clay. Thus the internodes full of water inside *is* used as breeding material.

The selection of the breeding plot, preparation for the land and seedbed demand the same requirements as those in bamboo propagation from seeds. Vertical ditches are cut on the seedbed with the span of 0.3m to 0.4m. Then lay the breeding material at the bottom of the ditch, cover it with soil from 3 to 6mm, level the seedbed, cover it with a layer of hay so as to keep the soil moist. In one week or two weeks young seedlings will be growing out of the shoots on the internode of the buried culm.

The management of seedlings is the same as that of seed breeding. Young seedlings tiller 4 to 6 times a year. Tillering shoots are getting larger and larger and forming altogether a seedlings cluster.

Breeding by layering of internodes means selecting proper culms for breeding, cutting each one node or two nodes off before burying them respectively into the soil for breeding. The rest of the process of management is as exactly the same as that of layering of culms method used for breeding.

1.3. Breeding by planting-of-slip

Most of the varieties of bamboo which are fit for breeding by layering-of-node method can be bred by planting of slip.

The golden time for breeding by planting of slip is rainy seasons or spring, 10 to 20 days before bamboo shoots.

Internodes applied in the layering-of-internode method can be used as slips for planting; and the secondary branches growing out of the branch on the base culms or young culms growing from seeds can also be used as slips. A few of the branches and leaves may be reserved on the slips.

The selection of the breeding plot, preparation for the land and seedbed demand the same requirements as those for bamboo breeding from seeds. When a slip is planted in the seedbed, the node and the base of its secondary branch should be inserted into soil, leaving only a few of its branches and leaves exposed. Water the slip as soon as it is planted, to keep the soil moist, and spray water on the exposed bamboo leaves so as to prevent then from being drying and withering. A shed is needed over the seedbed. Breeding in this way young seedlings will come up approximately in 5 to10 days. Each year young seedlings seedling is able to tiller 5 to 7 times, growing into bamboo culm used for afforestation.

1.4. Breeding by layering

This breeding method is basically the same as the layering-of-culm method. The chief difference between them is that in this method the bamboo culm for breeding are not to be cut off from bamboo clump, but to be cut half at the culm. Prune away some of the branches with a part of them reserved, then bend down, bury it in soil, leaving a part of branches and leaves exposed out of the land. In about 2 or 3 months the bud on the base of the secondary branch from the nodes will be growing into seedlings. After undergoing tillering for several times they will form seedling cluster themselves, used for afforestation.

There are many ways to breed bamboo, nevertheless the basic principles governing the methods are mainly alike. Therefore no further breeding method is to be introduced here.

1.5. Breeding by tissue cultivation

In adopting this method, culture media should be prepared and applied in the laboratory. A bamboo seedling is bred out of monocotyledon in the tube then transplant it into soil and further cultivate into seedling cluster, which can be used as material for afforestation. However this method requires careful work and expensive equipment, it is not yet adopted in production.

2. Bamboo afforestation

When bamboo is afforested choice of area and selection of *seeds should* be completed. In China afforestation usually involves a large area and natural conditions are complicated, and bamboo species are numerous with different characteristics in nature, so any blind selection of area or seeds will lead to failure in afforestation. There have been a lot of experiences, both positive and negative, concerning this in the last thirty years. Now there are divisions of region for bamboo afforestation in different parts of our country and afforestation work is under guidance.

The locality for bamboo afforestation generally requires warm weather, fertile and acid land with good drainage. Bamboo is not fit to afforest in saline and alkaline soil, or low- lying land, or heavy- clayey soil or very stony soil.

Spring or autumn is the best season for bamboo afforestation. It is best, in the place where rainy season is remarkable, to afforest at the beginning of the rainy season. Chief methods of afforestation of Chinese bamboo

2.1. Offset planting

Offset planting means to afforest by selection of healthy-cultivated, normally-developed culms having grown for 2 or 3 years without pest and plant diseases and by transplantation of the “mother culm” together with their rhizomes.

When rooting out and transplanting mother bamboo, its rhizomes and root system should be reserved, but the bamboo top is to be cut off with 5 or 6 branches and their leaves reserved. Keep as much soil around the rhizomes and root system as much as possible so as to protect the shoots and root ball of the mother bamboo. To achieve this mother bamboo should be wrapped in straw bag or plastic bag and kept humid.

Density of plantation is managed according to what variety it is. For example, *Phyllostachys pubescens*, 300 to 450 seedlings per hectare; *Bambusa textilis*, 750 to 900 seedlings per hectare.

When planting mother culm, soil should be filled firmly without leaving any big holes in it. When plant hole is filled, the soil should stick out of the ground and preparation should be made for drainage.

If bamboo is planted in dry weather, it should be watered without delay so as to prevent mother bamboo from being withered because of shortage of water.

2.2. Afforestation by stock planting

This method is fit for bamboo seedlings of sympodial type, such as *Bambusa, Dendrocalamus, Sinocalamus, Lingnanea* etc.

Select mother culm in terms of requirements needed in offset planting. Root out the stock of the mother bamboo with a bit of root reserved. Keep the culm about a metre long with its top cut off.

This kind of culm with its base culms can be used for afforestation. This method is similar to that of afforestation by offset planting.

2.3. Afforestation by bamboo seedling

When seedling cluster is used for afforestation, it is called afforestation by bamboo seedling whether the seedling cluster is produced by seedling shoots, or by layering of culm, layering of node, transplanting or by cuttage layering.

Bamboo seedling afforestation demands the same technical conditions as offset planting. Afforesting bamboo in this way results. in more seedlings, lower cost and higher survival rate and it is fit for afforesting on a large scale, therefore it is widely applied throughout China.

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Chapter 8 A Study on the Classification of Bamboo Stands

Bamboos are widely distributed in China. Owing to the complexity of habitats and the great variety of bamboo management, any attempt to extend an area's experiences without specification would bring about undesirable consequence. It is important to test the technique extension and the stand prescription on the basis of bamboo stand which are classified according to their natural and historical conditions.

To recognize a bamboo stand, some questions are naturally raised. How the bamboos grow? What about habitat appears to be? What the state of management is? These questions must be answered as far as the classification of bamboo stands is concerned.

At first, it is necessary to understand bamboo growth by measuring the size of culms and the production of stand, then to recognize the site quality, the topographical features and soil properties is needed in relation to the bamboo growth, and finally the state of management should be learnt from the silvicultural treatments and their effects on stands at present and in the past.

1 Growth classes of bamboo stands

Average stand at breast height can be used to evaluate the bamboo stand growth. The better the bamboo stand grows, the larger the average stand diameter is. Hence, on the basis of average stand diameter we grouped bamboo stands into five growth classes (G) (Table 9 – 1).

Class 1-stands with an average diameter above 12 cm; Class 2-stands with average diameter 10~12 cm; Class 3-stands with average diameter 8~1 0 cm; Class 4-stands with average diameter 6~8 cm; Class 5-stands with average diameter less than 6 cm.

Table 9 – 2 shows the average height and weight of individual culms in different growth classes.

Grateful acknowledgment is due to Professor Wenyue Hsiung under whose direction this study was made to fulfill the requirement for graduate work.

If the growth class of culms is determined separately in a stand according to their age class (two years for each age class), it is known as growth class of age.

The growth structure of a bamboo stand consists of the growth classes and the total weight of individual age classes. There are altogether 12 principal growth structural types of bamboo stands.

Table 9 – 1 Growth class and average diameter

Table 9—2 Average height and weight of culms in different growth

Growth class	1	2	3	4	5
Total height(m)	17.14	15.12	13.01	10.77	8.37
Clear height(m)	8.33	6.77	5.12	3.65	2.35
Total weight (kg)	49.97	35.57	23.78	14.42	7.56
culm weight(kg)	41.03	28.24	18.78	10.30	5.05
Branch and leaf weight(kg)	8.94	7.33	5.73	4.12	2.51

Table 9—3 Culm weight and growth class.

Growth class		1	2	3	4	5
Average weight of individual culms(kg)	0.0	40.93	28.47	18.40	10.65	5.12
	0.2	38.25	26.26	16.66	9.37	4.27
	0.4	35.66	24.00	15.02	8.18	3.15
	0.6	33.17	22.14	13.48	7.07	2.82
	0.8	30.76	20.22	12.02	6.06	2.21

The average weight of individual culms can be estimated according to following equation.

$W = 0.1547(15 – 2G)$

Where G is the growth class.

In order to simplify the calculation, we listed the values of average weight of individual culms (W) in Table 9 – 3, they were computed for each growth class.

If the growth class (G) is known, the average weight of individualculms (W) can be obtained from

Table 9 – 3. Then the culm weight of the stand can be estimated from

$W = NXW$

Where N is the density of stand.

For example, if a bamboo stand is of growth class 3 with a density of 1,800 culms/hm^2, the culm weight per hectare thereby can be estimated from

W 1,800 X 18.4 = 33.12(t/hm^2)

By the similar process, if the growth class of age and the number of culms in this age class are known, the culm weight of this age class can also be estimated.

2. Site type and site class of bamboo stands

2.1. Site type

The combination of ecological factors as climate, topography, soil and biota is called the habitat (site) of bamboo stands with alike site condition are considered to be of same site type, within a climatic region, the topography-soil conditions are the main factors affecting on bamboo growth. The topography-soil conditions can be grouped into 12 types (Table 9 – 4).

Humus rich loam is black and sometimes dark brown in colour, rich in organic matter, loose, well structured, well drained with better aeration and less gravel content. Soils of this group are most favorable to bamboo growth. They occur in the valley, piedmont, the middle and upper parts of low hills. Moderate humus loam is yellow or red in colour, loosely textured, well drained, with good aeration, less gravel content and thin-layered A-horizon. The bamboo growth is about average. Soils of this kind occur in the middle and lower parts of low hills.

Table 9—4 Topography and soils

Topog—raphy	Humus rich loam	Humus moderate loam	Clay ransoil	Gravel doils
Valley	Deep humus rich loam	Deep humus moderte loam	Deepclay pansoil	Deep gravel soil
Slope	Medium deep humus rich	Medium deep humus deep	Medium deep clay pan	Medium deep gvavel soil
Table Labd	Loam Shallow humus rech loam	Shallow humus moderate loam	Soil Shallow clay pan soil	Shallow gravel soil

Clay pan soil is yellow or red, heavy clay, poorly textured, easy to be water-logged, with heavy clay and very thin A-horizon, and unfavorable to bamboo growth. They mainly occur in tableland.

Gravel soils are characterized by having a large proportion of gravels and distributed along valleys and on piedmont with satisfactory water condition and fertile alluvial soil in the gaps of gravels.

The growth of bamboo is about average. But on the hill-top they are shallow, droughty and sterile, and the bamboo growth is very poor.

In order to understand the relation between topography and the growth class, we investigated 182 sample plots and estimated the relative frequency of each growth class on various topographies. The valley-land is best for the bamboo growth due to its deep and fertile soil, satisfactory water condition and less wind destruction.

Along the valley, growth class I and II may amount to 70 %. On hill ridge where soils are shallow, sterile and droughty and bamboos are easy to be uprooted by wind, the relative frequency of growth class IV and V is up to 73%. Both the soil and microclimatic conditions of slopes are less favorable than those in valley, but much better than those on hill-top to bamboo growth. Accordingly, the bamboo growth on slope is intermediate.

Since the site type is constituted of topography-soil type and the microclimates, it can be named by heading the topography-soil type with its locality, such as “Yexing shallow-humus rich loam.”

Table 9—5 Topography and growth class

Topography	Numbers of plots	Growthn class					
		1	2	3	4	5	Total
Tableland	11		9.1	54.5		36.4	100
Valley Lower	40	25.0	45.0	22.5	2.5	5.0	100
moderate slope	50	8.0	40.0	28.0	22.0	2.0	100
Upper steep	66	6.0	24.3	30.3	27.3	12.1	100
slope Ridge	15		6.7	20.0	26.7	46.6	100

2.2. Site classes of bamboo stands

The growth of bamboos and the production of bamboo stands vary with different site types. We grouped the 12 different site types into 5 site classes according to their favorableness to bamboo growth. They indicate the potential productivity of bamboo stands (Table 9 – 6).

Site class I: “Deep-humus rich loam” in valley, most favorable to bamboo growth average stand diameter 10~12 cm, bamboo of growth class I.

Site class II: "Medium deep-humus rich loam" on tableland, "medium deep-humus moderate loam" on slops, "deep-clay pan soil" and "deep-gravel soil" in valley, favorable to bamboo growth, average stand diameter 10~12 cm, bamboo of growth class II.

Site class III: Including "shallow-humus moderate loam" on tableland, "medium deep-humus moderate loam" on slops, "deep-clay pan soil" and "deep-gravel soil" in valley, favorable to bamboo growth, average stand diameter 8~10 cm, bamboo of growth class III.

Site class IV: "Shallow-humus moderate loam" on ridge, "medium deep clay pan soil" and "medium deep-gravel soil" on slopes, less favorable to bamboo growth, average stand diameter 6~ 8 cm. Bamboos of growth class IV.

Site class V: "Shallow-clay pan soil" and "Shallow-gravel soil" on tableland, unfavorable to bamboo growth, average stand diameter less than 6 cm, bamboos of growth class V.

In general, site class can be used to predicate the potential productivity of bamboo stands. But the actual increment results from both the site quality and the management activity. Therefore, only under similar management conditions the growth of bamboo stand can truly indicate the quality of site.

Table 9—6 Topography and site class

Topography	Humus rich loam	moderate loam	Clay pan soil	Gravel soil
Valley—land Slope Tableland	I(>12cm) II(10~12) III(8~10)	II(10~12) III(8~10) IV(6~8)	III(8~10) IV(6~8) V(<6)	III(8~10) IV(6~8) V(<6)

3 Management types of bamboo stands

3.1. The classification of silvicultural treatment of bamboo stands.

For a long time Chinese peasants have accumulated much silvicultural experiences specially dealing with the management of bamboo stands. They are commonly known as weeding, soil conditioning, organic matter mulching, fertilization, shoot-culm protection, pest and disease controlling, rational cutting and water soil conservation, etc. These treatments are aimed to regulate and improve the bamboo-environment relationship in order to promote the production of bamboo stands.

Based on the intensity of management, silvicultural treatments of bamboo stands, can be grouped into three grades and eight sub-grades (Table 9 – 7).

Grade I includes all the treatments needed to improve the productive conditions of bamboo stands such as weeding, soil conditioning, organic mulching, fertilization, water and soil conservation. Besides, shoot and culm protection, disease and pest control and rational cutting should be taken into consideration.

Grade II includes the treatments operated to suppress the undergrowth or ground cover. Except soil conditioning and fertilization, all treatments are same to those in grade I.

Grade III is of extensive management in which only selective cutting is practiced to adjust the composition, density and age of bamboo stand.

Table 9—7 Silvicultural treatments and management grades

Grades	I		II			III		
Subgrades	A	B	A	B	C	A	B	C
Major	Fertilization mulching	Soil conditioning	Weeding yearly	Weeding very two years	Weeding irregularly	Rational havesting	Irregular cutting	Lack of managment

These grades mentioned above are general categories arranged for silvicultural treatments. With increase in the intensity of management each grade may have additional treatments. All the grades are interrelated. Good results can be expected if intensive measures are taken on the basis of extensive management, for example, in addition to weeding soil conditioning always brings about desirable production of bamboo stands.

The intensive management differs from the management. Obviously the intensive management means the intensity of management that does not necessarily yield agreeable economic results. While the rational management may be less intensive, but could bring about desirable consequences. As results of rational management, the production and quality of culms can be improved correspondingly and yield more economic benefits. Therefore, any silvicultural practice should be based on economic consideration.

3.2. Management type of bamboo stands

A management type of bamboo stands can be realized by applying a series of silviculural treatments repeatedly to a number of bamboo stands long period. If this series of treatments is replaced or modified, the management type could change from one to the other. But such a change usually takes 6 ~ 8 years to become stabilized. For example, if the treatments of grade I are continually practiced in a stand for more than 6 years, this stand could fully exert the correspondent productivity and thus can be grouped into management type I

The major features of management types are described as following:

Type I: Bamboo stands of this type are commonly located in valley-land and lower moderate slope with rich humus loam or moderate humus loam soils of site classes I, II, III, and are continually practiced with intensive measures of grade I. Accordingly the stands are pure, moderately dense and highly productive. The culms are uniformly large-sized and relatively even-spaced. Generally, this management system is often practiced in areas, with convenient transportation, urgent needs of bamboos and abundant labour supply.

Type II: Bamboo stands located in areas with convenient transportation and sufficient labour are selected and continually treated with measures of grade II, the site quality varies greatly with site classes I ~ V. The stands are pure, occasionally mixed with other tree species, moderately dense and productive. Ground cover exists.

Type III: Bamboo stands of this management type are either distributed in remote mountains where transportation is poor and labour supply is short or located in areas where transportation is convenient, but bamboo supply is short. In the former case, bamboo stands remain in natural condition, no silvicultural treatments are practiced but regular cuttings, the stands are often mixed with other tree species and under-growth. In the latter case, over- cutting is the most important factor causing the deterioration of stands, undergrowth is luxuriant, the stand density is low, culms are small. The site quality varies greatly with site classes I~V and their production is changeable accordingly.

The determination of bamboo stand type

A bamboo stand type is a group of bamboo stands with same management type, same site class and same growth class and can be expressed by three numerals. The first indicates the management type, the second the site class and the third the growth class of bamboo. For example, the "234 bamboo stand" shows that this bamboo stand belongs to management type II, site class III, and growth class IV.

Theoretically a site class should correspond to a growth class, the better site quality, the better bamboo growth. If the growth class of a stand is higher than its site class (for example "132 bamboo stand"), this stand is rationally managed. On the contrary, if the growth class is lower than its site class (for example "234 bamboo stand"), the management of this stand is undesirable. Obviously its potential productivity is not fully exerted. It should be pointed out that the management type, site class and growth class are closely related to each other. They are the three aspects of bamboo stands. Site class is the material basis of production; management type indicates the silvicultural activities and the growth of bamboo stand is influenced by site quality and management activities. Growth class, therefore, can be used for evaluating site and management qualities.

Bamboo stand types and the management activities

The yield and quality of bamboo stands are linked with their type. As shown in Table 9 – 3, the higher the growth class, the larger the average diameter and the heavier the average culm weight, accordingly a higher yield can be expected. In higher site class, however, the culm size increases, the volume weight decreases and the mechanical properties become degraded consequently. Apparently the stand prescription must be based on the stand type.

In China, the total area of *Phyllostachys pubescens* stands is about 2.3 million hectares of which 70 % ~75% of are of management type III. For promoting bamboo production, attention should be paid to the bamboo stand of management type III. On the basis of their habitat and growth, the bamboo stands can be properly treated with appropriate silvicultural measures and gradually be transferred to the management type II. The unit production will increase greatly.

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Chapter 9 on the Cultivation of Ornamental Bamboo Forest

1. Histories and stories of bamboos used for ornament in China.

As early as Zhou Dynasty in China, in the book of “Mu Emperor”, there are records about bamboo like “the son of heaven goes on an expedition west; arrive at the beside of deep pond, along which there are trees called bamboo forest”. In the book of “Making Good Omissions”, there are such records about bamboo such as First Emperor of Qin Dynasty (Qin Shi Huang) collect a large amount of treasures in the whole country and obtain “Bamboo of Yun-Gang”. It is obvious that Qin Shi Huang planted Bamboo of YunGang regarded as a jewel of the great value in palace, Yianyang city. In Han Dynasty bamboo palace was established in Royal Sweet Spring Water Palace. Millions of arrows were made of bamboo cut in Zhan Garden, which was demanded by CouXun, a minister. In Liangxiao Prince’s area which has a circumference of 300 li in the east is called as Tu Garden where there are many bamboos. “Supervisive Department of Bamboo” was established in Western Han Dynasty. In Wei and Jin Dynasties there are seven men called as “bamboo forest 7 virtuous persons”. They love bamboo; respect bamboo; entertain and gather among bamboo forest; implied their feelings in bamboos. In the book of Luoyang Jialan Notes” there are records about bamboo planted in the private garden of high officials such as “needless to say peaches and plums green in summer; bamboo, cypress and Chinese ilex green in winter. In Jing Ming Temple there are bamboos and pines along the side of roads and steps; In Yong Ming Temple there are slender bamboos, stroking pine and eave; In Northern Wei, there are bamboos in the yard of Gaoyang Prince. The records about bamboo are as followes: “allow no person to his bamboo forest and fish pool so that fragrant grasses amass and rare trees gather together with each other and shield off sunlight”. In the book of “Stories of All Palace” there are records about bamboo. The Second Emperor of Liang Dynasty built flower grad en in which establish bamboo garden in the west of Jiangling. In Tang Dynasty, there is a famous, natural landscape garden among which was established a bamboorium along the river, which lying at the south foot of Mount Zhonnan and designed and built person ally by Wangwei who was a great poet. Dupu, an eminent poet in Tang Dynasty, has the habit of planting some bamboo around his house.

When Bai Juyi was an official in Jianzhou county, he ornament his yard with bamboo. There is a poem to prove it. In Song Dynasty, there was a Buddhist monk. He wrote a book of “Bamboo-shoot Table”. Mount Shou and Mount Ken engineered by Zhaoji, an Emperor of the Song Dynasty, is a representative of mountains – and –waters garden among which there are many bamboo sceneries. Huizong Emperor wrote a book of “Mount Ken Notes”, in which there are such descriptions as “there are countless bamboos in the north shielding off sunlight". There are decades of sceneries noted for bamboo named after bamboo in the book of "Loyang Famous Garden".

GuiRen Garden was noted for collecting and planting all kinds of ornamental plants, among which there were several thousand mu bamboos; In Song Dynasty ruled by Shenzong Emperor, Miao Shou, a minister, whose private garden was described as follows: there are ten thousand bamboos whose diameter is 2 ~ 3 cm, look like rafter. There are many beautiful bamboos in Sima Guang's Garden whose beautiful scene was composed of bamboos completely and whose scenery areas were divided by bamboo and natural scenery only. There are some written records/documents to prove it. The description is as follows: There are so many beautiful bamboos in the garden that it is a pleasant place keeping from hot and humid in summer. There are some records about bamboo in the book of "Wujia Garden Notes" written by Zhoumi, which describe 34 private gardens in Wuxing county, among which the most attractive scenery is Yeshi Garden noted for bamboo. Description about it is as follows: there is a most famous and attractive garden in the east of Wuxing county. Ye Mengde once described bamboo in the book of "Keeping From Sunstroke", in which the written accounts/records/documents are as follows: bamboo are planted wherever there is a room. In Song Dynasty, the artistic conception of plum orchid bamboo chrysanthemum – 4 gentlemen and pine bamboo plum – 3 durable plants of winter was taking shape. In South Dynasty, there are many bamboos in Xin Qiji's Yard. The written accounts are as follows: thinning hedge to protect bamboo and avoid obstructing the pleasant sight of plum. Autumn chrysanthemum may be imagined as meal, spring orchid makes itself respected. The description written by Lin Jingxi is as follows: there are various of plums grow with tall trees and bamboos, with the above 3 plants being called durable plants of winter. In Ming Dynasty, there are sceneries of bamboo in 36 Gardens of Jinling written by Wang Shilu of which there are many bamboos in Xuda's Gardens. For example, in West Gardens there are ten thousands of slender bamboos. In Ten thousands (Thousands) Bamboo Gardens there are over 2 ~ 3 hectares. In Tong Chun Garden there are thousands of bamboos outside a fountain below the pavilion. Sound sent out when spring water in-swept sounds like music". Besides, there are large numbers of sceneries made of bamboo in many gardens. For example, Zhuozheng Garden in Suzhou city, Jichang Garden in Wuxi city, Yu Garden in Shanghai city and other private gardens like Xieshang Garden, in which the compound of bamboo and brimstone, pavilion, water, is a marvelous creation excelling nature.

In Beijing Gardens bamboo was also used to form into scenery. QuShui Garden was noted for bamboo. In the book of Scenery in Emperor's Palace Notes written by LiuTong there are records about bamboos. The description about the bamboo in Wofu Temple is as follows: bamboos cover the south bank of river. At the end of Ming Dynasty, an artistic conception about garden was summarized in the book of Garden's Design written by Jicheng like "creating quiet place among bamboo forest". In Qing Dynasty, the famous gardens noted for bamboo are as follows: Ge Garden in

Yangzhou city, Shui Garden and Jiezi Garden in Nanjing city, Liu Garden and Lion Garden in Suzhou city. No matter how the garden was designed with bamboo as main scene, scenery area divided by bamboo, bamboo path, or mixed grove with other plants, bamboo's elegant appearance took on before the eyes of every visitors. The description about the bamboo in Bamboo Plantation established in Qinghui Garden in Shunde county, Guangdong province, one of the famous gardens in the south of Mount Nanling-Back written on the front door is as follows: Bamboo's music can be heard when wind blows. Zheng Banqiao described bamboo in the book of "Bamboo Stone" in which he set a high value on the artistic conception appeared from those scene built by bamboo.

2. Classifications of Ornamental Bamboo Species Applied to Gardens

1. Classified according to its form. According to rhizome, please see "bamboo rhizome type".
2. According to bamboo's size.
   (1) Big bamboo species: *P. pubescens, L. chungii, S. affinis, S. oldhami, B. textilis, P. glauca, B. textilis, B. vulgaris* cv *vitata, P. pubescens* f. *bicotor, S. farinosus*.
   (2) Medium-sized bamboo species: *Psu. amabilis, B. multiplex* var. *lutea, B. textilis, P. heterocycla* cv. *Luteosu Icat, P. spectabilis, P. bambusoides* f. *tanakae, P. glauca* f. *youzhu, P. nigra, Pl. gramineus* f. *monstarispirali, Q. tumidinoda, S. tootsik*.
   (3) Small-sized bamboo species: *B. multiplex* var *nana, S. chiangshanensis, S. pygmaea, S. fortune, B. vulgaris* f. *waminii, S. auricoma, S. veitchii, S. chinensis, I. latiflorus, S. japoneca, P. japoneca* var. *tsutsumiana, S. sinica*.
3. According to culm.
   (1) According to the stem's form: *Pl. gramineus f. monstarispirali, B. vulgaris* cv. *wamin, B. vulgaris* f. *waminii, Q. tumidinoda, P. pubescens* var. *heterocycls, S. japoneca, Pl. oedogonatus, Pl. aedogonatus*.
   (2) According to stem's colour:
   [1] Purple: *P. nigra, C. neopurpurea, Q. tumidinoda, S. fastuosa*;
   [2]Yellow: *P. bambusoides var. sulphurea, P. aureosulcata* f. *aureocaulis, P. bambusoides, P. sulphurea, P. sulphurea*;
   [3] White: *L. chungi, D. pulverulentus, S. farinosus*;
   [4] Green: There are yellow stripes on internode or in furrow. *P. aureosculata, S. oldhami P. bambusoides* f. *mixta, P. bamb.* var. *castilloni*;
   [5] Yellow: There are green stripes on internode or in furrow: *S. affinis,* f. *flavidorivens, B. vulgaris* cv. *vitata, P. spectabilis, P. pubescens, P. bambusoides* var. *castillon, P. sulphurea, P. vivax* f. *aureocaulis, P. vivax, S. affinis*;
   [6] There are other colorful stripes or mottled spots on the stem. *P. bambusoides* f. *tanakae, P. glauca* f. *youzhu, P. nuda* f. *localis, B. textilis, B. pervariabilis, P. rubella*.

4. According to bamboo leaf
   (1) According to the form of leaf, broad leaf: *I. herklotsii, S. sinica*;
   (2) Long and narrow leaf: *Pl. gramineus.*
   (3) Leaf's color
   [1] Green leaf with white stripe: *C. marmorea, S. fortune, S. argenteostriatus f. albo – st, H. tranquillans* f. *shiroshima, Pl. chino* f. *angustifolius*;
   [2] There are other colorful stripes on the leaf, for example, *P. bambusodes, S. auricoma, S. veitchii.*
5. According to gardens' use
   (1) Large tracts of land of bamboo forest: big bamboo such as *P. pubescens, P. glauca, P. bambusoides, P. amabilis, P. pubescens, L. chungii, S. affinis, S. oldhami, B. textilis, B. textilis, B. pervariabilis, B. sinospinosa, L. chungii, D. latiflorus*.
   (2) Piece planting, ornamenting: medium-sized or big bamboo species, especially those of *striking* culm or leaf.
   (3) Green fence: The best is clumping-form bamboo or inter-grown bamboo.
   (4) Used in ground cover, *slope* protection and edging like *Sa. Argenteostriatus* f. *albo – st, In. herklotsii, S. fortune, S. chinensis, Sa. longiligulata, S. chiangshanensis, Sasa pygmaea, S. aurieoma, S. japoneca, P. bambusoides, etc*.
   (5) Single-bamboo planting: The best is clumping bamboo. For example: *B. multiplex* var. *lutea, B. glaueeseens* f. *alphonsokarri, B. multiplex* var. *nana, B. vulgaris* f. *waminii, S. affinis, B. textilis, B. textilis, S. affinis* f. *flavidorivens* etc.
   (6) Bamboo species used in potted landscape: The best is small-sized, medium- sized bamboo with striking culm or leaf such as *B. vulgaris* f. *waminii, B. multiplex* var. *nana, S. fortunei, S. aurieoma, C. quadrangularis, Q. tumidinoda, Pl. aedogonatus, Q. tumidinoda, P. heterocycla* cv. *Luteosu leat, P. spectabilis, Pl. gramineus* f. *monstarispirali, P. bambusoides* f. *tanakae, P. nigra, S. chinensis, S. chiangshanensis, S. pygmaea, S. japoneca, H. tranquillans* f. *shiroshima, etc*.
   (7) Used in barrier scenery: the best is dense-growing like *P. amabilis, Pl. amarus, B. multiplex* var. *lutea, B. glaueescens* f. *alphonsokarri*, *S. japoneca, Pl. amarus* var. *pendolifolius*.

6. Bamboo species used in gardens for ornament: According to property, *limitation* and form, gardens are classified as bamboo forest, special bamboo plantation, flower garden, potted landscape and bamboo building, etc.

(1) Bamboo forest: This is a sort of large tracts of land's bamboo afforestation, like bamboo mountain, bamboo sloping, bamboo forest round the reservoir.

(2) Special bamboo plantation: There are chiefly three types such as Bamboo Park, bamboo garden and private bamboo plantation.

(3) Flower garden: bamboos make the chief section of scenery. Disposing forms have several kinds:

[l] Creating all kinds of bamboo forest landscape with bamboos prior to other trees;

[2] Bamboo, gardens building, road scenery, landscape and rock constitute group scenery.

(4) Potted landscape: potted landscape requires short and small bamboo species. The

methods of stunting bamboo are: shelling sheath, coped with medicine, culturing in poor soil, controlling water and fertility, seeding, stunted with rhizome reproducing.

(5) Bamboo building: Bamboo was used in building by the ancient as far back as the New Stone Age. Bamboo building in the Northern and Southern Dynasties was called as "dry hurdle". In Northern Song Dynasty, there was a book called "Construction standard", of which there was a section concerned with bamboo used in construction including bamboo's function and technical standard in the process of construction. "Yellow hillock bamboo building" has been well-known up to now. The "bamboo buildings" built by the Dai nationality and Jingpo nationality people living in the south of Yunnan, China are of distinctive national features very much. Because of striking stem and color and lustre different from other building materials, bamboo has (a) special lasting appeal. In recent years, a new upsurge in bamboo construction conforming to good taste like bamboo pavilion, bamboo house and bamboo porch is in the making. Three durable plants of winter – pine, bamboo, plum; plum, orchid, bamboo, chrysanthemum – 4 gentleman, this kind at mixed plant is a characteristic of Chinese gardens.

3. Propagation and Management of Ornamental Bamboo used in Gardens.

3.1. Propagation of ornamental bamboo

classified as two types: sexual multiplication and vegetative propagation. The main reproduction methods suitable for scattered bamboo are planting bamboo individually, planting bamboo rhizome, planting culm section or bamboo stock. One of the effective means is to solve less enough mother bamboo sources and to enlarge forest areas, which is economical and quick. There are two main reproduction methods for clumping-form bamboo afforestation: planting bamboo individually and covering up stem. The latter includes three types: covering layer, culm-length and node. The method for covering node includes three types: flat, slanting and vertical covering. Of these the survival rate of slanting covering is the highest. In general, to grow seedlings with two internodes, flat covering should be adopted; while to grow seedlings with one internode, slanting or vertical covering should be adopted. Because inter-grown bamboo has bamboo stock and rhizome, its character of growth and propagation is between that of scattering and clumping bamboo.

Therefore, to inter-grown bamboo, the reproduction methods of clumping and scattering bamboo can be adopted. The best season for transplanting bamboo should be 1~2 months before the coming out of its shoot. In fact, the best season depends on three factors: the time and period of bamboo-shoot coming out, winter resistance and climate. In the south of the Changjiang River area of China, for P. genus (*P. pubescens, P. praecox, P. glauca*, etc), transplanting should be between January and February; for Pl. genus, *Sinobambusa* genus, transplanting should be between February and March; for clumping-form bamboo, transplanting should be between March and May; for *Chimonobambusa* genus transplanting should be between May and June. Adopting 1~3-year-old rhizome and 1~2-year-old mother culm bamboo used for transplanting is the best. The volume of planting pit should be 1.5 times larger than that of mother bamboo's original soil and roots. Cover planting soil on the bottom of pit. About 10cm thickness soil on bottom stock. Lay 1~ 2cm thickness straw on the covering soil after having finished planting. Water 1~2 times a day within two weeks after having been planted.

3.2. Management of Ornamental Bamboo Forest.

(1) Inter-till and weeding: to large land of bamboo amenity forests, inter-till and weeding should be carried on 1 ~ 2 times per year, moreover, the two above should be carried out simultaneously. Inter-till should be carried on between June and July; the depth is 8 – 10cm. The ventilating of soil porosity will be increased and the evaporating of soil moisture will be prevented. Keep those weeds after having been weeded out in the forest and decay them into manure.

(2) Fertilize and earth up: because the distribution of bamboo subterranean stem is shallow, earthing up should be carried out immediately after weeding, which make those weeds having been weeded out decay and will be good for being absorbed by bamboo. If manure is not enough, bamboo will be in unhealthy growth. In order to keep many healthy and strong bamboos in flower garden every year, nitrogen fertilizer, potassium fertilizer, phosphorus fertilizer and silicon fertilizer should be carried out, especially organic fertilizer.

(3) Irrigate and drain flooded fields: bamboo favors mild climate, much less bamboo-shoot; so "bamboo shoots after a spring rain" is generally accepted. For bamboo on low-lying land which is easily flooded in rainy season, draining should be carried out in time lest bamboo rhizome will be decayed.

(4) Pruning: the best is keeping bamboo's natural figure; avoid pruning as much as possible; so that the sight of her inartificial appearance will be enjoyed by people. But in actual application, pruning is necessary. For example, for those bamboos around the garden road obstructing traffic, pruning is necessary. For those bamboos being of striking stem which should be kept appear through cutting away branches against stem within 1m over-ground, in order for their striking appearance/outlook can be enjoyed easily, the suitable season for pruning should be between June and July.

(5) Intermediate cutting: the time, intensity and other steps depend on its purpose (repair scenery, obscure, wind-proof and others), felling age, species and the space between two stems.

[1] the suitable period for intermediate cutting: if bamboo culm is to be used, should be carried out during the period of dormancy when nutrient and moisture flow is slow and low (i.e. December – January in next year); if bamboo stem is not to be used, intermediate cutting should be carried out after bamboo-shoot grow to young bamboo;

[2] intermediate cutting intensity: according to purpose, bamboo species' feature. For obscuring, wind-proof purpose, intensity should be kept higher; for scenery purpose, intensity should be kept lower. Intermediate cut 5~6 -year-old bamboos in order to form into dense bamboo bunch, however, the bright green color of culm will disappear with aging; so, those bamboo culms fading away should be intermediate cut in time without consideration of bamboo age for holding on to bamboo's feature, especially those bamboos without feature and expressive force (e. g. deformity, color, brindled).

4. Classification of Japanese Ornamental Bamboo Species.

In the book of "Japan Horticultural Bamboo Species" written by Hata Okamura, Yukio Tanaka 1986, horticultural bamboo species was classified into 4 kinds.

1. Bamboo species being of certain height and suitable for growing easily with other trees are as follows:

(1) bamboo species being of over 5m height and suitable for planting on the sides of the avenue or all around of the tall buildings and great mansions are as follows: *B. vulgaris, P. pubescens, P. heterocycla* f. *bicotor, P. pubescens* var. *heterocycla,* etc.

(2) bamboo species being of 3 ~ 4m height and suitable for planting in corners and all around of big flower garden like: *B. glaucescens* f. *alphonsokarr, P. bambusoides* f. *holochrysa, P. bambusoides* f. *holochrysa, Pl. hindsii, Pl. graminrus,* and so on.

(3) bamboo species being of 2 ~ 4m height and suitable for planting in middle- sized flower garden mixed with other trees such as *P. aurea* f. *holochrysa, P. aurea* f. *flavescens – inversa, P. aurea, P. nigra, P. bambusoides* f. *holochrysa, P. bambusoides* f. *holochrysa, T. quadrangularis, T. qu f. suow*, etc.

(4) bamboo species being of 2 ~ 3m height and suitable for planting in flower garden for ornamenting like: B. glaucescens f. elegans, B. glaucescens f. albostrata, B. glaucescens f. elegans, S. nitida, P. aurea f. albo-variegata, P. nigra, P. bambusoides f. holochrysa, P. bamb. f. holochrysa, T. quadrangularis, T. quadrangularia, T. qu, f. suow, S. tootsik, S. tootsik f. albopstriata, S. japoneca, Ps. jap. var. tsutsumiana, S. japoneca, and the like.

(5) bamboo species being of 1.5 ~ 2m height and suitable for planting with main trees in small-sized flower garden are: *P. aurea* f. *holochrysa, P. aurea* f. *flavescens – inversa, P. aurea, P. nigra, P. bambusoides* f. *holochrysa, P. bamb.* f. *holochrysa,* and what not.

(6) bamboo species being of 1.5 ~ 2m height and suitable for planting in small- sized flower garden acting as secondary sprinkle are as follows: *B. glaucescens* f. *elegans, B. glaucescens* f. *elegans, B. gla.* f. *albostrata, B. gla.* f. *solida, Si. nitida, C. marmoreal, T. quadrangularis, T. qu*

f. *suow, S. tootsik, S. tootsik* f. *albopstriata, S. japoneca, Ps. jap*. var. *tsutsumiana, S. japoneca,* etc.

(7) bamboo species being of 1.5~3m height and suitable for planting at outer-ring as natural hedgerow are: *S. tootsik, Pl. hindsii,* etc.

(8) bamboo species being of 1.5~2m height and suitable for planting at outer-ring as naturally ornamental green hedgerow like: *B. glaucescens* var. *elegans, P. bambusoides, P. bamb*. f. *kasirodake, P. aurea, S. kumasasa,* etc.

(9) bamboo species being of 0.5~1m height and suitable for internal hedgerow such as: *B. glaucenscens* f. *solida, C. marmoreal*, and the like.

(10) bamboo species being of 1.5~2m height and suitable for planting in the corners of residential areas are as follows: *S. tootsik, S. to*. f. *albopstriata, S. japoneca,* etc. 2. the bamboo species suitable for ground coverings and ring – shaped oasis under arbores are as follows:

(11) Bamboo species being of 0.7 ~1m height, large – leaf, used for cultivation: for example, *S. megalophylla* f. *nobilis, S. asahinae, S. kurilensis* f. *shiroakeebono, S. kur*. f. *kiakebono, I. herklotsii*, and so on.

(12) bamboo species being of 0.3~0.5m *height*, medium-sized leaf, used for cultivation: *Pl. argenteo – striatus* f. *aureo – striata*, and the like.

(13) bamboo species being of 0.3m height, small – leaf, used for cultivation: S. kumasasa, Pl. fortune, Pl. viridistriatus, Pl. chino f. murakamianus, Pl. distichus, Sa. Kongosensis var. gracillin, and what not.

3. the bamboo species suitable for making harmony with ground surface, embellishing rockery or other tall bamboos are as follows:

(14) bamboo species being of 0.7~1m *height,* large – leaf, used for cultivation: *S. megallophylla* f. *nobilis, Sa. asahinae, S. kurilensis* f. *chabonkoshima*, etc.

4. the bamboo species suitable for pot planting are as follows:

(17) bamboo species being of 1.5 ~ 2m *height*, suitable for planting in over 40cm – diameter pot by 3 ~ 5 individuals, for instance, *B. vulgaris, P. heterocyela* f. *bicotor, P. pubescens* var. *heterocycla,* and so on.

(18) bamboo species being of 1. 5 ~ 2m high, suitable for planting in over 40cm – diameter pot by 5~7 individuals, for example, *P. nigra, P. aurea, P. bambusoides* f. *holochrysa, T. quadrangularis, S. tootsik, S. to*. f. *albopstriata,* etc.

(19) bamboo species being of 1.5m *height*, suitable for planting in over 40cm – diameter pot by 5~10 individuals, such as *B. glaucescens* f. *elegans, B. glau.* f. *albostrata, B. glaucescens* f. *albovariegat, H. tranquillans* f. *shiroshima, Pl. chino* f. *angustifolius, P. japoneca* var. *tsutsumiana, S. japoneca, S. japoneca*, etc.

(20) bamboo species being of *suitable* to plant through thick growing individuals are as follows: *S. nitida, B. glaucescens* f. *elegans, B. glau.* f. *alphansokarr,* and the like.

(21) bamboo species being of 0.5~lm height, suitable for planting in 30cm – diameter pot by 5 ~ 10 individuals, against exterior wall are as follows: *S. nitida, B. glaucescens* f. *elegans, B. glaucescens* f. *elegans, B. vulgaris f. waminii, C. marmorea, P. aurea,* etc.

(22) bamboo species suitable for planting in less than 20cm – diameter pot, used for indoor decoration like *S. kumasasa, Pl. distichus, Pl. chino* f. *murakamianus, S. glabra* f. *alba-striata, Sa. glabra f. albo – striata,* and so on.

(23) bamboo species suitable to plant in 30cm – diameter circular, rectangle, shallow pot, for example, *P. nigra*, *P. humilis, P. aurea* , *Pl. fortune,* C. *marmorea, T. quadrangularis*, *S. japoneca*, etc.

(24) bamboo species suitable to plant in less than 30cm-diameter. shallow pot bamboo are as follows: *P . allrea,P. humilis,P. aurea* f. *albo-variegata,P. nigra, Pl. fortwlei,* C. *marmorea, T. quadrangll-laris,PI. distiehus,S. japoneea,and* what not.

(25) bamboo species being of be suit to plant in flower garden, all around of rockery, beside of the path like *Pl. fortunei, P. owa,* f. *pygmaea, S. glabra,* etc.

Contents

Chapter 1 Structure and Properties of Bamboo Timber

1 Characteristics of Bamboo

Bamboo is one of the most primitive subfamilies of gramineal plants with the most bio-diversities. It differs from other plants by having woody culms, compound branches, developed root system and very rare flowering phenomena etc. Bamboo looks both like grass and wood trees, and is a special population of the plant family. Bamboo is very adaptable and widely distributed. It is easy to propagate, plant, process and utilize bamboo with lower investment while a higher return. There are comparatively less pests and diseases in bamboo forest and its products are widely used in many areas with a big market demand and lower risk in investment. Bamboo is combined of ecological, economic and social benefits.

Bamboo is very fast in propagation. There are some new bamboo culms in one rhizome, which will grow into full size and can be used for some purposes each year. One cluster of bamboos can produce around 15 km (with the diameter of 30 cm) usable bamboo culms. Bamboo is the fastest growing plant in the world. It can grow from 20-30 cm to 150-200 cm within 24 hours. Moso bamboo can grow up to 15-18 m within 30-40 days. Dendrocalamus sinicus can grow up to 40-45 m within 100 – 120 days. For a bamboo plantation, the 1st year it will grow stably and if well managed, in the 2nd and 3rd year, people can be ready to harvest shoots, and up to the 4th or 5th year, the timber is ready to be used. The annual output value of bamboo plantation can reach around RMB15,000 to 45,000 yuan per ha. For some intensively managed plantations, its value can reach RMB75,000 yuan/ha. per year. And farmers can benefit from this plantation for over 60 years.

2 Structure of bamboo timber

2.1 Macrostructure

2.1.1 Bamboo Culm

Bamboo culm is a main trunk of bamboo stem above ground, namely a trunk has been removed all lateral branches after being cut down. It usually shapes as a cylinder with nodes. Bamboo culm, with a hollow center and conical shape, is consisted of several tens of nodes and internodes. Its outside portion is called bamboo wall, which is a major part of bamboo timber. Bamboo wall has three layers, middle layer and internal layer. The number of nodes and the length of internode vary significantly among species, for example, about 70 nodes for Moso, only a dozen nodes for some other species. The length of internodes can reach over one meter, but the short one is only several centimeters. The diameter of internode and thickness of bamboo wall vary among species. Its diameter ranges from over 20 cm. to a few millimeters. Some bamboos are nearly solid. Bamboo nodes have two rings, the other called sheath ring. The internal potion of the node is a wood septum called bamboo septum, which separates the culm into cavities. Inside the cavity there are pithy tissues, which appear to be membrane-shaped (called flute membrane), slice-shaped and crumble-shaped etc.

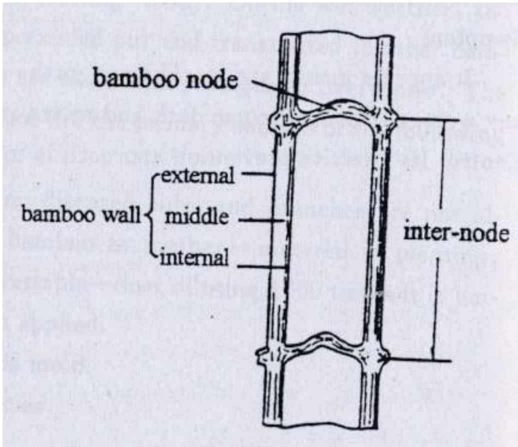


Fig.. 1 Structure of bamboo culm

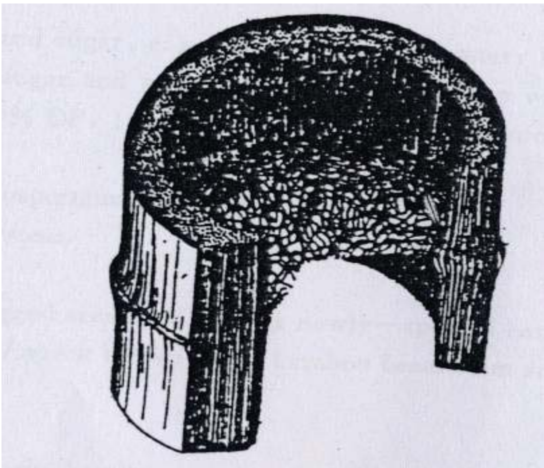


Fig.. 2 Distribution of Moso vascular at the node

2.1.2 Bamboo node

Arrangements of vascular bundles in internodes are parallel and regular with a straight grain. However, as passed through nodes, they deflect their distribution, except for those vascular bundles distributed in the outmost layer break off and one part continues distributing vertically and parallel in sheath ring. Some of the vascular bundles at the inner layer bend towards the outside; on the contrary, those at the outer one bend towards the inside. In addition, some vascular bundles at node bend from one side of the culm to another side through the septum, as a result, in a networked form (Fig.. 2). The vascular bundles in the bending parts usually become thicker, so bamboo wall in the node is much thicker than those in the adjacent internodes. Such behavior of bending and interlocking of vascular bundles in the nodes is conducive to strengthening culm's erect property and ability of transverse conducting of water and nutrients, but is one of the flaws in utilizing the bamboo timber.

2.1.3 Bamboo Wall

The bamboo wall can be divided into three parts: bamboo cyan, bamboo wood and bamboo yellow (concretio silicea bambusae).

Bamboo cyan is the external layer, which features closed tissues, smooth surface, and wax contained. Chlorophyll was contained in the surface cells, so the young bamboo is green; the old bamboo culms and harvested ones for a long time become yellow because the chlorophyll have been changed or ruined.

Bamboo yellow is the internal layer of bamboo wall, which features loosen and frail tissues.

Bamboo wood, the middle portion, in other words, between bamboo cyan and bamboo yellow, is consisted of fiber, vascular bundles and basic tissues.

Besides, there is a film inside the bamboo yellow which called bamboo clothes.

Tab. 1 Relationship between diameter and thickness of Moso culm

Diameter (D)	Thickness (δ)	Weighted Average X=δ/D (%)
55-70	5.5-6.4	9.5
71-80	9.0-11.8	10.5
81-90	9.0-12.7	11.5
91-110	11.5-13.0	12.5
>120	---	14

Bamboo wall is thicker at the base, but thinner at the apex. The thickness of bamboo wall varies according to its diameter. (Table 1)

The thickness of external and internal layers ranges from 0.6mm to 0.8mm respectively. Bamboo wall mainly consists of vertical fiber, which can be divided into two parts, vascular bundles and basic tissues. Through naked eyes and microscope, transverse section of the culm, the distribution pattern of vascular bundles and basic tissues are visible. There are smaller, tenderer vascular bundles and basic tissues. So, the density and mechanic strength of the outside of wall are much higher than the inside one.

2.2 Microstructure

Observing the cross section under microscope, the external cortex of bamboo wall is made up of three types of cells in different forms, which are external epidermis, internal epidermis and internal cortex. The internodes' structure is divided into epidermis, sub-cortex, basic tissues, vascular bundles, pithy ring and pith from the outer part to the inner part.

2.2.1 Vascular bundles

Fiber cells and vessel cells are the major composition of vascular bundles. The size and density of vascular bundles relate to bamboo culm's position, thickness and bamboo's species. The number of vascular bundles is the same, but its size is smaller, and density is higher from the base to the top.

Tab. 2 Density variation of vascular bundles from the 2nd to the 34th node of Moso

NN	2	6	10	14	18	22	26	30	34	Average
DT	172.6	210.8	240.4	275.0	300.1	321.0	357.0	375.9	396.4	294.4

Notes : NN= No. of nodes; DT=density

Tab. 3 density and size of vascular bundles in bamboo timber of various species

Species	Density(No. /cm^{-2}			Length(μ)			Width(μ)			DOV(μ)		
	O	M	I	O	M	I	O	M	I	O	M	I
Ⅰ Arundinaria P. japonica	13	5	3	510	440	250	340	390	360	28	67	67
Ⅱ Bambusa Multiplex	9	3	3	170	440	290	120	360	480	16	66	110
B. multiplex cv. femleaf	29	8	4	140	180	—	110	230	—	19	63	41
Ⅲ Brachystachyum densiflorum	13	6	3	360	410	250	270	400	260	41	110	78
Ⅳ Chimonobambusa quadrangularis	10	3	2	300	310	250	190	280	280	28	72	72
Ⅴ Indocalamus latifolius	11	6	3	340	370	240	250	280	290	22	57	57
Ⅵ Phyllostachys bambusoides	7	2	2	510	620	480	320	500	630	44	132	153
glacuca	10	4	3	480	510	360	240	360	450	28	91	116
pubescens	6	2	1	510	540	460	320	510	630	25	122	147
Ⅶ Pleioblastus amarus	9	3	2	390	510	360	290	470	520	41	99	103
Ⅷ Sinicalamus oldhami	18	2	1	230	650	390	180	530	770	19	113	172
Ⅸ Shibataea chinensis	33	13	8	150	150	130	140	150	19	48	51	
Average	14	4. 8	2. 9	380	420	320	230	370	440	28	87	98

Notes: DOV=Diameter of vessel; O=outer, M=middle; I=inner

In general, the cross-area of a single vascular bundle is about 0.1 mm^2 to 0.5mm^2. It is indicated that the area gets smaller from the base to the top, but larger from the external layer to internal layer. However, the total area of vascular bundles per unit bamboo timber is gradually smaller from external layer to internal layer. The density of vascular bundle of thick culm is less than that of slender culm among the same species (Fig. 3, Fig. 4). The form and density of vascular bundles are different among species. Fiber cells of bamboo timber are in shuttle shape and thick-walled. Vessel cells are cylinder-shaped in vertical arrangement. Their distribution and law of change in bamboo timber are the same with those of the vascular bundles because they are main constituents of vascular bundle tissues.

2.2.2 Basic tissues

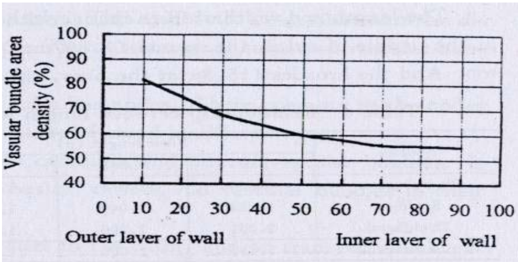


Fig.. 3 Percentage of vascular bundles to total area of transverse section of S. affinis

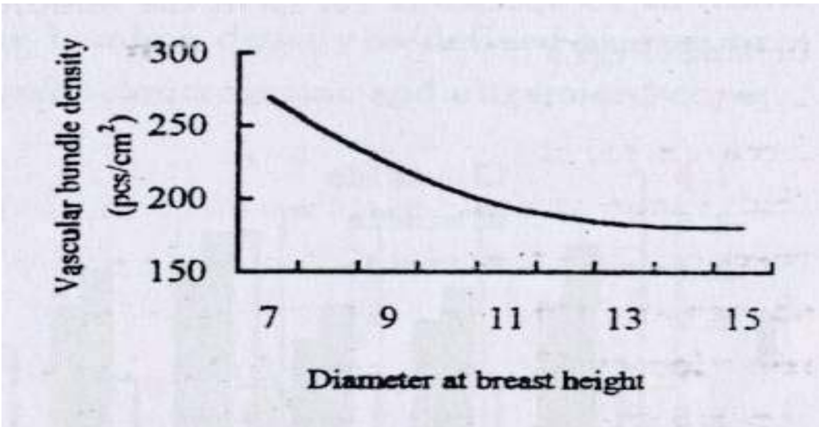


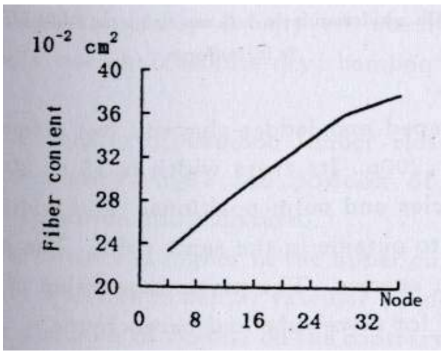
Fig.. 4 Moso diameter and vascular bundle

Parenchyma is the basic tissue and occupies higher percentage of bamboo timber, about 40 to 60%. They encircle vascular bundles, but some pass through vascular bundles. On the transverse section of bamboo wall, they are shaped like circle and multi-angle. The cross thickness of parenchyma tissues is 30 to 60µm. on the vertical section, parenchyma are irregular cells, whose length vary from 50µm to 300µm. in addition, there are small pits on cellular wall.

In one bamboo culm, the percentage of parenchyma at the base is about 60%, and less in the top, about 40%. Parenchyma increases gradually from external layer to inner layer. The function of parenchyma is to store nutrients and water. The moisture content of parenchyma decreases gradually year by year, with cellular wall being thicker, and cellular cavity being smaller due to bamboo aging. Therefore, the dry shrinkage rate of old bamboo is small.

2.2.3 Fiber

There are close relationships among the changes of content, length, width of fiber, diameter and thickness of cellular cavity, and species and position of bamboo culms (Fig.5, Fig.6). It is shown that the area of fiber tissues on the transverse section is different among species. The content of fiber per unit area rises gradually from base to top.



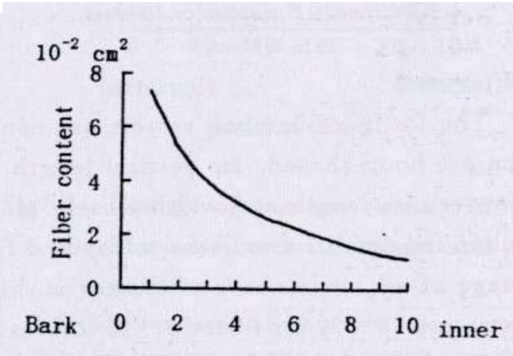


Fig.. 5 Fiber content and culm height   Fig.. 6 Fiber content and wall position

The length and width of fiber change with culm height. The longest fiber (2. 095mm.) is in the middle of the culm, the second (1.897mm) at the base, and the third (1.833mm) at the top. The broadest (15.30μ) and the second (14.5μ and 13.8μ) are in the middle.

Tab. 4 Relationship between fiber dimension and species

Species	Fiber length (μ)			Fiber width (μ)		
	Base	Middle	Tip	Base	Middle	Tip
Ph. Pubescens	1.850	2.035	1.980	10.0	15.0	15.4
S. affinis	1.823	2.040	1.940	14.8	13.5	14.5
D. oldhami	2.001	2.290	1.580	15.2	13.2	13.0
Average	1.897	2.005	1.833	15.3	13.8	14.5

In addition, its length and width change with the position of bamboo wall. The longest fiber, 2141.0μ is in the middle, 2049.1μ inside and 1960.0μ outside. The average fiber with a width of 13.7μ is in the exterior side (Fig.. 7).

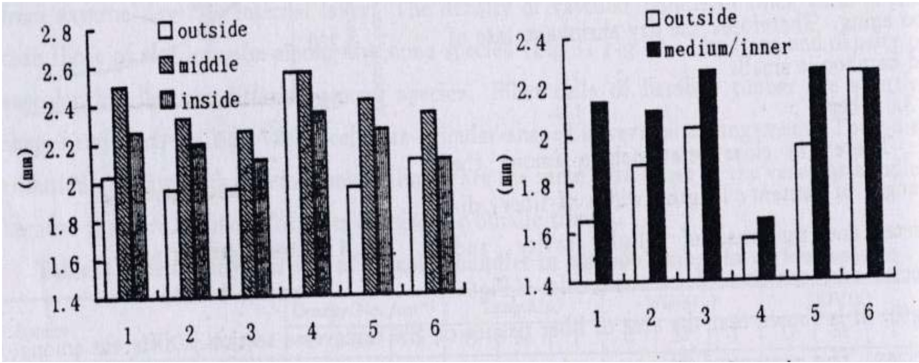


Fig.. 7 Comparison of fiber length in different portions and species

Right: 1 Ph.Pubescens. 2. Ph. viridid. 3. Ph.. glauca. 1. Shibataea.

4. B. Oldhami. 5. B. multilex cv. Fernleaf. 6. In. latiforus

Left: 1 Shibataea. 2 P. japonica 3.B.densiflorum. 4. Ch. quadrangularis.

5. B. multiplex cv. Fernleaf 6. In. lariforus

2.2.4 Vessel

Bamboo vessels are usually net-shaped and ladder-shaped, but a few of them are hoop-shaped. Its vertical length is 300 to 1,200μ. Its cross width is 15 to 200μ. However, its length and width closely relate to species and culm positions. The width is smaller from base to top and from inside to outside in the same culm. The percentage of all kinds of the above tissues is different with species. The percentage value of 33 species is 40.8% for fiber, 6.1%for vessel, 52.8% for sieve tube and parenchyma.

The differences in structure between bamboo and wood will be introduced briefly as follows.

Bamboo timber is rounded by epidermis and middle column is the basic tissue, among which many vascular bundles are distributed irregularly. The epidermis of gymnosperm or dicotyledon is only limited in young stems' growth. Then rough skin will replace vascular bundles in young stems' tissue.

Bamboo timber has no wood rays, but its culm has nodes. There is emptiness in the nodes and diaphragm between the nodes, but the structure of wood is different.

Bamboo belongs to monocotyledon, having no cambium and limited vascular bundles. It can't form secondary xylem or phloem, but its capacity of basic tissues and vascular bundles in increases when they are young.

All kinds of cells in bamboo wood are parallel to the culm, without any transverse arrangement. Compared with wood, it has simple structure and regular arrangement.

2.3 Characteristics of Bamboo Structure

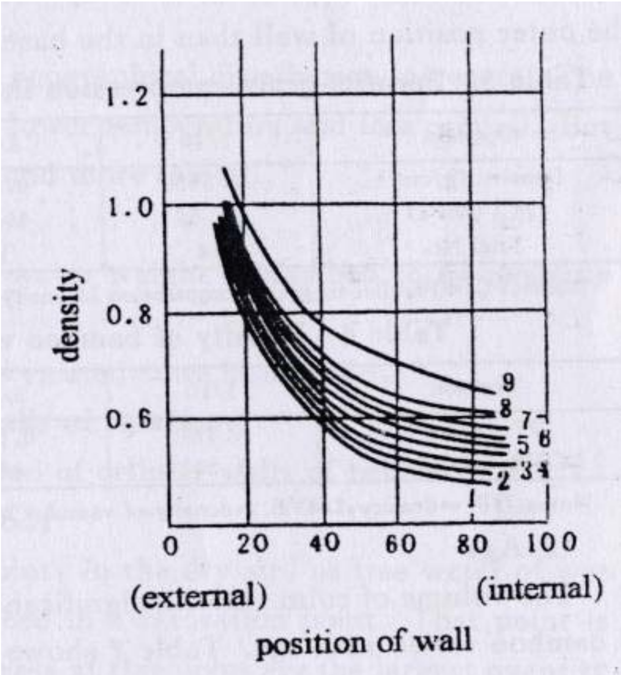


Fig. 8 Change of bamboo density of Moso timber with height and position

1. 1~2 m from base; 2. 2~3 m from base;
3. 3~4 m from base; 4. 4~5 m from base;
5. 5~6 m from base; 6. 6~7 m from base;
7. 7~8 m from base; 8. 8~9 m from base;
9. 9~10 m from base;

Uneven/anisotropic——the most remarkable characteristic of the bamboo structure. Lengthwise，it’s different between the nodes and inter-nodes. The former features straight vascular bundles, even distribution, while the latter winding and uneven.

Widthwise, the outer side differs significantly from the inner side of bamboo. The outer part is featured with closed tissues, small vascular bundles, and little basic tissues; while the inner part is opposite to the outer part precisely.

Therefore, density and mechanical strength of the outer of bamboo wall are far better than those of the inner part.

3 Physical properties of bamboo timber

3.1 Density

3.1.1 Definition of Density

Bamboo timber is a kind of porous material. Bamboo density is defined as weight per unit volume, which includes materials of cellular walls, microscopic and ultramicroscopic holes.

There are four kinds of density, basic density, fresh density, air-dried density, and absolute dry density. Among them, basic density and air-dried density are commonly used.

In a certain atmospheric condition, the moisture content reaches Equilibrium Moisture Content (EMC); the weight of per volume is called air-dried density. And, g/cm3 is always adopted as the unit of density, the same below.

Basic Density = absolute dry bamboo's weight/fresh bamboo's volume;

Fresh Density = fresh bamboo's weight/fresh bamboo's volume;

Air-dried Density = air-dried bamboo's weight/air-dried bamboo's volume;

Absolute-dried Density = absolute-dried bamboo's weight/ absolute-dried bamboo's volume.

The density of bamboo has a close relationship with its mechanical properties. The higher the density of bamboo timber is, the more strength it has in the same culm. Therefore, the density of bamboo is significantly reflecting mechanical properties.

3.1.2 Factors Influence Bamboo Density

The density of bamboo timber closely relates to species, age, and position of culm, growth condition and moisture.

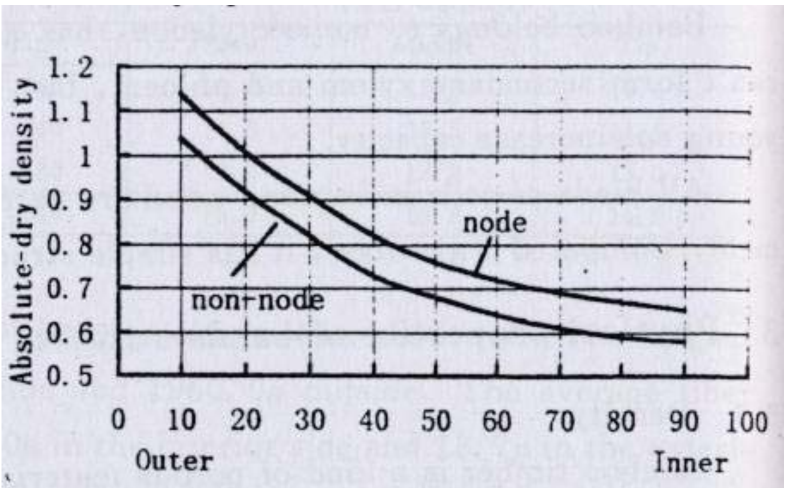


Fig.. 8 Influence of nodes on density of S. affinis

Position in the culm

The density of bamboo increases from the base to the top in the same culm. The density of external layer of bamboo wall is more than that of the internal one in the same height of the culm (Fig.. 8). In the nodal position, the density is also higher than that in non-nodal position (Fig.. 9), because there are closer vascular bundles and smaller-diameter vessels in the top and the outer position of the wall than in the base and the inner position.

Table 5 Parallel-grain compression intensity and density of moso in various positions

Position	1/10	3/10	5/10	7/10	9/10
Density (g/cm^3)	0.593	0.633	0.649	0.702	0.740
PCI (MPa)	61.56	69.79	71.95	79.89	83.10
Trial No.	14	14	14	14	14

Notes: PCI=Parallel-to-grain Compression Intensity

Table 6 Density of bamboo wall and vascular bundles of S. affinis

Position	1/10	3/10	5/10	7/10	9/10
DT. (g/cm^3)	0.814	0.600	0.487	0.443	0.422
DOVB. (No. $/cm^2$)	1,200	400	254	215	—

Notes: DT. =density; DOVB. =density of vascular bundle

Age

Table 7 Relationship between age and density of bamboo wood

Age	1	2	3	4	5	6	7	8	9	10
Ph. Pubescens	0.43	0.56	0.61	0.63	0.62	0.63	0.62	0.66	0.61	0.61
S. affinis	0.49	0.49	0.55	0.51	0.61	0.64	0.63			

The volume of culm varies insignificantly after bamboo has grown up; however, the density of bamboo varies with age. Table 7 shows that the density of Moso and S. affinis is lower for immature culm. It increases gradually from 1 to 6 years old. They are more stable from 5 to 8 years old, but decreases slightly after the age of 8 . The main reason is that bamboo cellular wall and its content vary and get richer gradually with aging. So, a research on those patterns is one of theoretical bases to make rational cutting age for bamboo.

Conditions of bamboo stand

In general, in a fertile soil, and warm, damp climate, the bamboo is bigger, but smaller in density of vascular bundles and looser in tissues; therefore, the density of bamboo timber also is smaller. However, in a barren site together with low temperature and dry climate, bamboo is slender, so there are denser vascular bundles and tissues. The density of bamboo timber is higher (Fig..8). Consequently, the better stand condition, the looser tissues of bamboo timber, and the lower density of bamboo. But the worse stand conditions, the tighter tissues and the higher density of bamboo.

Table 8 Relationship of soil site condition with density of bamboo timber and vascular bundles

SC.	1	2	3	4	Average
Dt.(0g/cm^3)	0.591	0.597	0.603	0.602	0.603
DOVB(No./cm^2)	187	196	240		211

Note: SC. = site condition; DT. =density; DOVB= density of vascular bundles

Species

The variation of bamboo density relates to its geographical distribution in genera. The bamboo density is higher in the northern areas with lower temperature and less rainfall while lower in the southern areas with warm climate and more rainfall.

3.2 Moisture content

3.2.1 Water in Bamboo

Moisture content was defined as a percentage of water weight in bamboo to its absolute dry weight.

Water, according to its existence state in bamboo, can be divided as follows:

Absorbed water: Binding water in cellular walls of bamboo;

Chemical water: Water in chemical composition of cellular walls of bamboo;

Free water: Water in cellular cavity of bamboo;

Fiber Saturation Point (FSP) of Bamboo

When bamboo timber is drying in the air, the free water will be evaporating first, when all the free water has turned into gas and the held water is saturated, this situation is called Fiber Saturation Point (FSP), the content in this situation is called moisture content of FSP.

FSP has a great influence on the physical and mechanical properties of bamboo timber.

The moisture content of FSP is about 30%. And, different direction, different moisture content of FSP. For example, the yellow bamboo, chordwise 24.64% and radial direction 29.65%.

3.2.2 Factors Influence Moisture Content

The moisture content of fresh bamboo timber has a close relationship with age, position of culm and season of bamboo cutting. In general, the old culm has low moisture content, and young culm has high moisture content. For example, the moisture content of fresh Moso is 135% for 1 age-grade (one-year), 91% for 2 (two to three years), 82% for 3 (four to five years), and 77% for 4 (six to seven years). The moisture content decreases gradually from bottom to top (Table 9).

Table 9 Moisture content in various portions of fresh Moso culm (%)

Position	0/10	1/10	2/10	3/10	4/10	5/10	6/10	7/10	8/10	9/10
M.C	97.1	77.8	74.2	70.5	66.0	61.5	56.6	52.8	48.8	45.7

Note: M.C. = moisture content

The moisture content of the outer wall is lower than that of the middle and the inner, for example, it is 36% to 74% for the outer wall of fresh Moso culm, 102.83% for the middle, and 105.35% for the inner.

The moisture contents of cut-down wood are in the order of 70.41% for summer, 66.54% for autumn, 60.11% for spring and 59.31% for winter. The moisture content of green bamboo is usually over 70%, the highest is up to 145%, and an average value is about 80 to 100%.

3.3 Coefficient of Shrinkage

3.3.1 Shrinkage of Bamboo

It is called shrinkage phenomenon when green bamboo timber is gradually losing its water in natural or artificial seasoning, it shrinks in three directions of radial, vertical, and height and in volume as a whole.

The shrinkage rate of bamboo timber is usually less than that of wood. But, there are remarkable differences in directions of bamboo (Fig.. 10). The shrinkage of bamboo can be expressed by percentage of shrink (s), and shrinkage coefficient (k).

$$S = \frac{(A - B)}{A} \times 100 \quad \%$$

$$K = \frac{S}{W}$$

Note: S: Shrinkage percentage;

B: Absolute dry timber size;

K: Dry shrinkage coefficient;

W: Water content at fiber saturation point

3.3.2 Factors Influencing Coefficient of Shrinkage

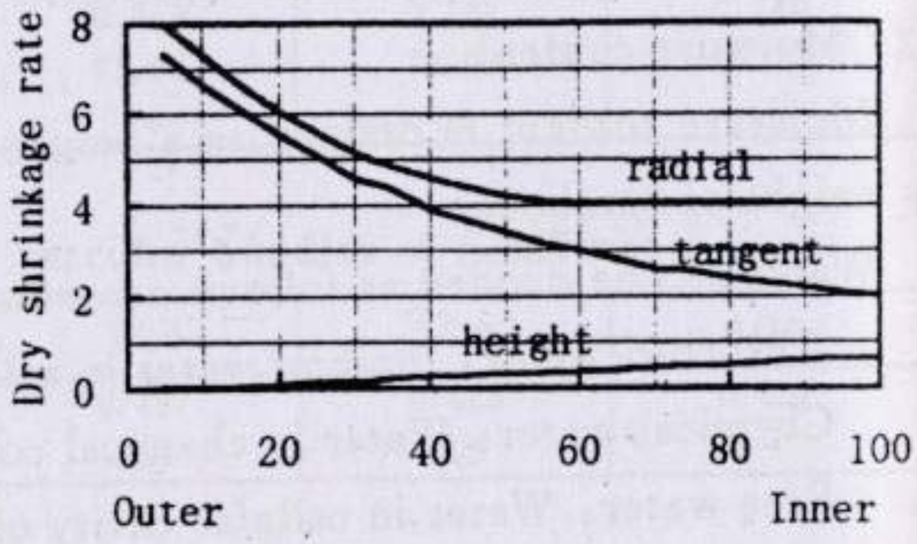


Fig. 10 Relationship between shrinkage and positions of bamboo wood

According to the studies by Tongji University, the extent of shrinkage for four-year old Moso wood is in order tangential, radial and vertical direction. Tangential shrinkage is in the order outer layer, middle layer and inner layer of bamboo. Vertical shrinkage is in order inner layer, middle layer and outer layer.

The information by Tsinghua University indicates that shrinkage coefficient of Moso wood for 4 to 6 years is different with its moisture content. When moisture content is below 25%, the shrinkage coefficient varies significantly. Whereas, when the moisture content is over 25%, it varies insignificantly.

The shrinkage volume of bamboo is more than the linear shrinkage. The highest shrinkage is for tangential direction of the outer wall, the second for radial and tangential directions of the inner, the least for vertical direction, esp. for vertical shrinkage of the outer-lateral wall.

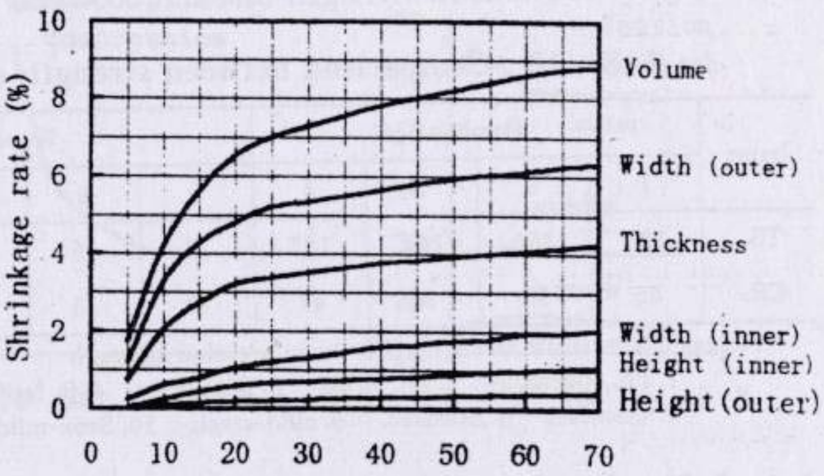


Fig. 11 Relationship between moisture content and shrinkage of moso

The younger Moso culm is of higher tangential and radial shrinkage such as, 7.45% for the two-year-old culm, 4.46% for the four-year-old, and 3.53% for the six-year-old. Vertical shrinkage doesn't relate to culm age. Its average value is about 0.1% (from green to air-dried wood).

The main reason for shrinkage of bamboo wood is that the vessels in vascular bundles lose the water. Consequently, the shrinkage is higher in the position with the denser vascular bundles. On the contrary, lower in the position with sparser vascular bundles. Bamboo wall usually splits during the drying process because the shrinkage of the outer wall (green skin) is more than that of the inner.

3.4 Absorption of water

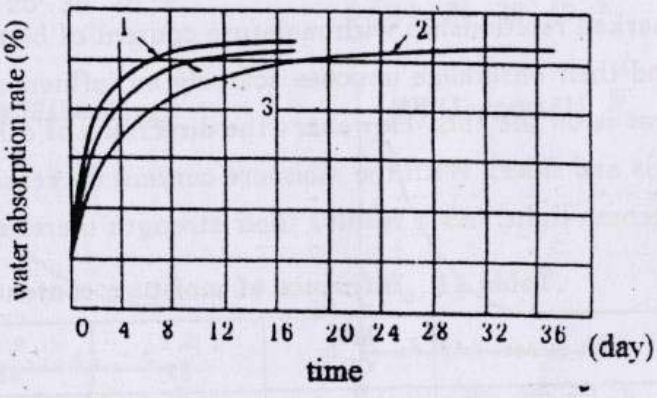


Fig. 12 Relationship between length and absorption rate of bamboo

Water absorption and evaporation of bamboo wood are reverse processes. Dried bamboo wood has strong absorption. The velocity of absorption is inversely to the length of bamboo wood. Namely, the longer the bamboo wood is, the slower the velocity is. However, the absorption speed is scarcely related to the width of wood. Fig. 12 shows the relationship between velocity and length. The result indicates both the processes of absorption and evaporation are the same, processing is mainly through transverse section. Like wood, bamboo wood becomes large in all directions and their strength decreases after water absorption.

4 Mechanical properties of bamboo timber

4.1 Mechanical properties of bamboo timber

Bamboo timber, with strong mechanics and good adaptability, is easy to be processed; therefore, it has a wide range of usage for architecture, handicraft industry, agriculture and fishery. Table 10 shows that the tensile strength of bamboo wood is about double that of wood, and the compression strength is about 10% higher than that of wood. Although the tensile strength of steel is 2.5 to 3.0 times higher than that of bamboo, the specific gravity of steel is 6 to 8, and the density of bamboo is 0.6 to 0.8. Therefore, by counting their strength per unit weight, the tensile strength of bamboo wood is 3 or 4 times as high as steel.

Table 10 Comparison between strength of bamboo, wood and steel (MPa)

Items	Bamboo				Wood				Steel			
	1	2	3	4	5	6	7	8	9	10	11	12
TS.	197	286	284	197	78	99	145	111	382~	444~	520~	>730
CR.	65	55	36	42	40	33	58	47	430	500	600	

Notes: TS. = tensile strength; CR. = compression strength
1. Ph. pubescens 2. Ph. viridis 3. Ph. glauca 4. D. latiforus 5. Chinese pine 6. Red pine
7. Quercus. 8. Sasafras. 9. mild-steel. 10. Semi-mild steel, 11. Semi-hard steel, 12. Hard steel

4.2 Factors Influence Mechanical Properties of Bamboo Timber

4.2.1 Structure of Bamboo

Bamboo nodes influence the strengths greatly. The tensile strength of node is 25%lower than that of inter-nodes while other strengths are higher. The reason for a lower tensile strength of nodes is that the unevenly distributed vascular bundles cannot resist the external force and will be easily destroyed.

The strengths parallel to grain are as much as 10 or more times than those of perpendicular to grain.

4.2.2 Moisture Content

Like wood, within the fiber saturation water point, bamboo wood strength is reduced for its being brittle. On the other hand, the strength has an insignificant change with moisture content when it is over the fiber saturation water point. Fig. 13 indicates that compression strength, parallel-to-grain tensile strength, shearing strength, static bending strength and modulus of elasticity are always decreased with rises of moisture contents. Whereas its transverse tensile strength, tangential static bending strength do not have a marked relationship with moisture content of bamboo wood, because the vessels are vertical, and their shrinkage scarcely imposes an influence on radial compression when moisture content is on the ebb. However, the directions of other compression strengths are parallel to vessels and fiber. As a result, their strength increases.

Table 11 Influence of moisture content on parallel-to-grain compression

Ph. glanca	MC. CR.	5.1 89	9.6 68	17.1 63	23.0 63	51.8 61
D. Minor	MC. CR.	4.8 111	9.1 100	15.6 94	25.6 90	62.6 88
Ph. Angusta	MC. CR.	5.7 77	9.2 69	18.8 64	33.8 60	84.4 46
Pl. Amarus	MC. CR.	4.4 90	8.7 85	17.4 74	27.3 72	52.1 67

Notes: MC. = moisture content; CR = compression strength

4.2.3 Position of culm

The mechanical strength varies much with the positions of culm. In general, it is higher in the upper position than in the lower, outer layer of bamboo wall than inner layer of bamboo wall. All kinds of strengths of Moso wood increase gradually with the height of position. They vary significantly within the height of 1m to 3m of culm, but slightly within 3m to 7m (Table 12). The influence value is about 15% to 30%.

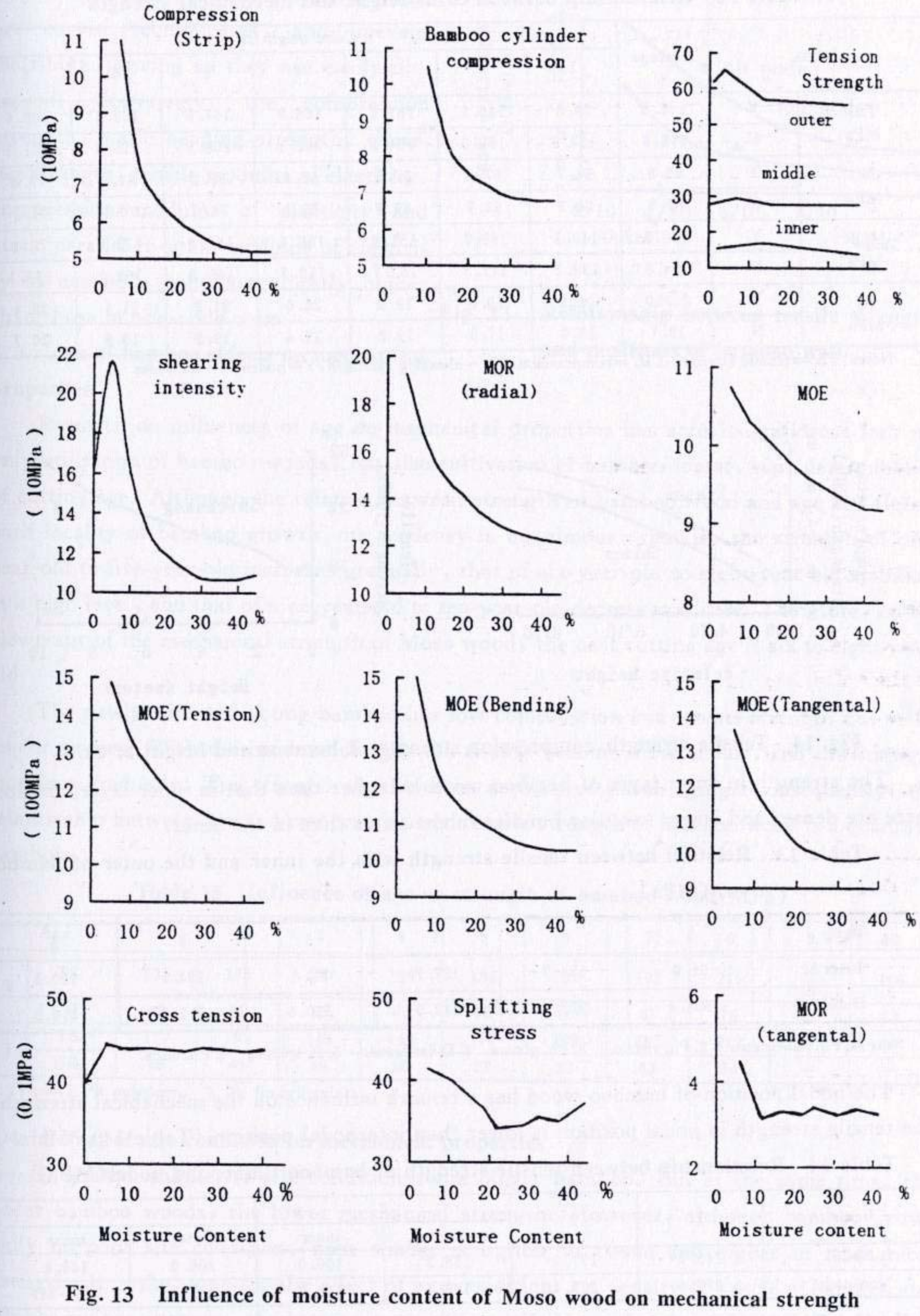


Fig. 13 Influence of moisture content of Moso wood on mechanical strength

Table 12 Relationship between culm beight and mechanical strength

Items		Average	Culm height(m)						
			1	2	3	4	5	6	7
TS. MPa	Y	144. 8	26. 8	146. 1	167. 3	166. 9	167. 5	169. 8	169. 4
	N	198. 6	157. 9	190. 9	194. 2	202. 1	208. 9	215. 3	221. 1
CR. MPa	Y	68. 9	64. 7	67. 2	67. 8	68. 4	69. 2	71. 6	73. 6
	N	67. 8	60. 9	63. 9	69. 9	68. 1	70. 0	70. 5	71. 1
MOR MPa	Y	158. 0	140. 3	149. 7	151. 8	156. 1	162. 8	173. 2	72. 4
	N	154. 8	138. 7	147. 3	152. 1	152. 7	160. 8	162. 0	170. 1
SS MPa	Y	20. 50	18. 9	19. 0	19. 8	20. 0	21. 3	21. 1	23. 4
	N	19. 1	16. 7	17. 6	19. 2	19. 4	19. 9	19. 9	20. 7

Notes: TS. = tensile strength; CR. = compression; SS. —shearing strength; Y=nodes; N=no nodes

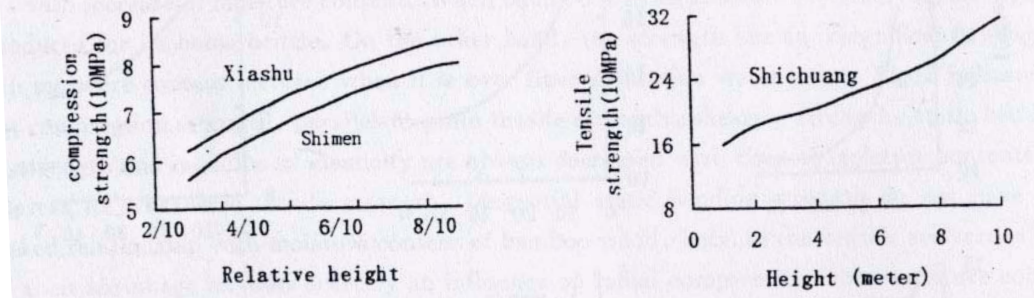


Fig. .14 Tensile strength, compression strength of bamboo and height of culm

The strength in outer layer of bamboo wood is higher than that in the inner layers because there are denser and larger vascular bundles in the outer than in the inner.

Table 13 Relation between tensile strength with the inner and the outer of the bamboo wall (MPa)

Items	1	2	3	4	5	6
Inner	91.0	184.7	127.7	87.4	194.1	150.1
Outer	304.4	393.4	242.9	310.6	312.8	316.5

Note: 1. Ph. pubescens. 2. Ph. Viridis. 3. Ph. Glauca 4. lariforus. 5.B. spinosa 6. Ph. Nuda

The nodal position of bamboo wood has a remarkable influence on the mechanical strength. The tensile strength in nodal position is lower than that in internodal position (Table 14).

Table 14 Relationship between tensile strength of bamboo timber and nodes (MPa)

Items	1	2	3		4	
			Out	Inner	Out	Inner
Node	245.7	177.9	158.3	100.0	206.0	149.4
Non-node	272.4	268.4	198.8	119.3	233.8	332-347

Note: 1. Ph. Bambusonides 2. D. spinosa 3.Ph. pubescens 4. Ph. Viridis.

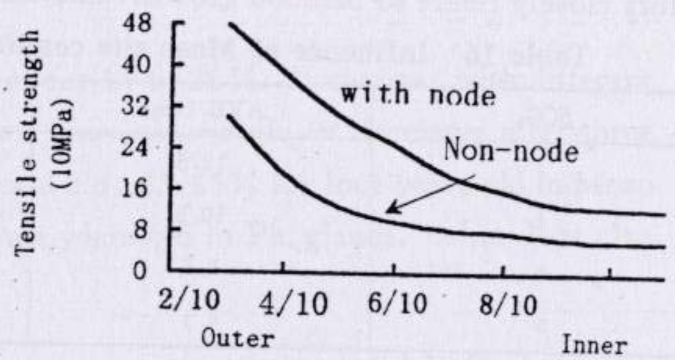


Fig. 13 Relationship between tensile strength and positions of bamboo wall

Main reasons are that vascular bundles in the node are curved, complicated, and unevenly distributed so they are easily destroyed. Conversely, the compression strength, shearing strength, tensile modulus of elasticity, compression modulus of elasticity and static parallel-to-grain modulus of elasticity in non-node culm are slightly higher than those in non-node culm.

4.2.4 Harvest Season

Take Moso Bamboo Timber as an Example:

The most suitable season for the harvest of Moso bamboo is the end of autumn and winter when the nutrients are stored in the roots, and the water, sugar and protein are less in the culm. Then the bamboo timber has a closed tissue, higher strength and is not easy to be ruined by pests or fungi.

Oppositely, spring is not suitable for bamboo harvesting because the water and nutrient are rich and strengths are low.

4.2.5 Age of bamboo

Research on influences of age on mechanical properties has a real significance, for not only utilization of bamboo woods, but also cultivation of bamboo forest, esp. determination of cutting age. Although the relation between strength of bamboo wood and age is different with locality of bamboo growth, its tendency is unanimous, that of six-year-old to eight-year-old stabilizes on a high level, and that of nine-year-old to ten-year-old decreases a little. Therefore, on the viewpoint of the mechanical strength of Moso wood, the best cutting age is six to eight years old.

Table 15 Influence of age on strength of bamboo wood(MPa)

	Age	1	2	3	4	5	6	7	8	9	10
1	TS.	135	175	200	186	184	181	192	215	18 5	186
	CR.	49	61	65	69	68	70	67	76	65	63
1	TS.	117	133	149	163	177	189	201	212	—	—
	CR.	46	48	49	50	52	52	53	54	—	—

Note: 1. Ph. pubescens 2. Ph. fimbriligula.

The newly sprouted young bamboo has low compression and tensile strength due to its tender tissues. With the increase of age, the tissues become more senior, and the strength increases gradually. The strength decreases on account of tissue aging. Consequently, the relationship between age and compression and tensile strength of bamboo wood is a quadratic parabola.

4.2.6 Site condition

Generally, the better site conditions, the bigger bamboo. But at the same time, the looser bamboo woods, the lower mechanical strength. However, although bamboo grows badly in poor site condition, their timber is tighter in tissue and tigher in mechanical strength. It is the same for the effect of site conditions on density of vascular bundles and bamboo timber, namely, the better site condition, the bigger bamboo. In addition, climatic factors closely relate to bamboo growth, and also influence on properties of bamboo wood.

Table 16 Influence of Moso site conditions on mechanical strength (MPa)

SCG.	AVB. (cm)	PCS	PTS.
I	12.5	63.02	180.76
II	10.5	66.04	184.69
III	9.8	64.50	185.03
IV	8.1	67.12	198.86

Notes: SCG: site condition grade; AVB: mean diameter at breast height;

PCS: parallel-tograin compression strength; PTS: parallel-to-grain tensile strength

Table 17 Influence of climate conditions on mechanical strength of Moso wood

Place	EL	NL	AMT ℃	AR mm	TS	CS
Yixing	119°51′	30°00′	1560	1,020.6	199.98	71.94
Siming	121°16′	29°37′	1598	1,819.6	185.60	61.15
Damousan	117°45′	28°45′	1760	1,739.9	177.41	61.13

Note: EL: Eastern congitnde, NL: Northern latitude, AMT: annual Average temperature,

AR: annual rainfall, TS: tensile strength, CS: compression strength.

4.2.7 Bamboo species

Bamboo mechanical strengths vary with different species due to different structural features.

Table 18 Mechanical properties of several kinds of bamboo

	1	2	3	4	5
TS.	188.77	227.55	199.10	185.89	289.13
MOR	163.90	-	-	213.36	194.08

Note : 1. Ph. Pubescens, 2. S. affinis, 3. D. latiforus, 4. Ph. Viridis.

5 Chemical properties of bamboo

5.1 Chemical compositions

The chemical compositions of bamboo are very complicated. They vary with different species, ages, localities, growth situations, cutting seasons, and moisture contents.

Bamboo is made up of cellulose, hemi-cellulose and lignin, the three components account for 80%. Besides, oil, volatile oil, tannin, pectin, pigment, protein, ash and so on are contained in cell wall, mostly in cell lumen or other special tissues and relate to the physiological action of bamboo.

The chemical constituent of bamboo is similar to that of hardwood. Ash and silicon are richer in bamboo than in wood, but substances extracted with alkali.

Different bamboo species, different chemical constituents; and in the same family, heredity and environment influence the chemical constituent; in the same bamboo, different positions, different chemical constituents.

Table 19 Chemical compositions of bamboo wood

Name	Cellulose	Pentose	Lignin	Cold water extraction	Hot water extraction	Alcohol & ether extraction
Con. (%)	(10~60) 50.38	(14~25) 20.86	(16~34) 25.45	(2.5~5.0) 3.92	(5.0~12.5) 7.72	(3.5~5.5) 4.55
Name	Alcohol & benz extraction	1%NaOH extraction	Protein	Fat, wax	Starch	Reduced sugar
Con. (%)	(2~9) 5.45	(21~31) 27.26	(1.5~6) 2.55	(2~4) 2.87	(2~6) 3.60	2.0 2.0
Name	Nitrogen	P_2O_5	K_2O	SiO_2	Others	Total
Con. (%)	(0.21~0.26) 0.24	(0.11~0.24) 0.16	(0.5~1.2) 0.82	(0.1~0.5) 1.30	(0.3~1.3) 0.72	(1.0~3.5) 2.04

5.1.1 Cellulose

Cellulose is a kind of straight-chain macromolecular compound made up of D-glucose and a special bond. Formula for cellulose is ($C6H10O5$).

Cellulose is the structure material which forms the cellular wall of bamboo, esp. for fiber cells. In general, the cellulose content of bamboo is about 40%～60%, among which α－cellulose accounts for about 70%～80%，β－cellulose 25%～35%，γ－cellulose 1%～5%.

The cellulose content will change with the age of bamboo, it decreases while bamboo grows. For example, the contents of cellulose in Moso culm are 75% for the young, 66% for the one-year-old, 58% for the three-year-old respectively.

Cellulose content distribution is more at the top, medium in the middle, and less at the bottom.

In the rhizome, there is more cellulose in the outer layer of bamboo wall than in the inner one.

5.1.2 Hemi-cellulose

Hemi-cellulose is a kind of carbohydrate which is part of cell wall and can be hydrolyzed to xylose and galactose.

Hemi-cellulose always runs parallel to cellulose, and is a bonding between the cellulose and lignin.

Bamboo hemi-cellulose content occupies usually about 14%~25%. It changes with age. Generally, it is higher for culm of one to two years old, while, it decreases after three years, for instance, it contains 24.9% for two years old, 23.65% for four years old in Moso and 19.88% for one year old and 18.12% for three years old in Ph. Glauca. culm. It is also subject to bamboo species.

5.1.3 Lignin

Lignin is a complex macromolecular compound of aromatic series. The elements of bamboo lignin: carbon accounts for 61~65%, hydrogen 4.9~6.4%, and oxygen 28.6~34.1%.

The lignin content in bamboo is about 16~34%. It changes with aging, for example, in Moso culm, 44.1% for two years old, and 45.60% for four years old.

The lignin contents of bamboo timber are more stable than those of wood. Therefore, their abilities of acid and alkaline resistance are stronger. It is also different in different species.

In all kinds of bamboos, the cellulose and hemi-cellulose contents in culm decrease gradually year by year with aging, but the lignin content increases. Generally, up to six years, they have a stable tendency. Therefore, the physical and mechanical properties also tend to stability. It is reasonable that culms of over six years old are usually adopted in industrial use.

Bamboo's biological properties indicate that bamboo's cutting age is below six years, or the remaining culm age is over ten years is harmful to shooting, growth and high yield of bamboo forest.

5.1.4 Extractions

They refer to those matters extracted from bamboo timber after soaked by solvents such as cold water, hot water, ether, benzene and 1% sodium hydroxide.

Generally, the extractions are 2.5~5% by cold water which includes tannin, pigment, alkaloid, dissoluble minerals and sugars; 5~12.5% by hot water which includes starch and pectin besides cold water extractions; 3.5~9% by ether or alcohol; by 21~31% by 1% sodium hydroxide including protein, amino acids, some hemi-cellulose, some lignin, a little bit of oil and floral attar beside more hot water extractions. And benzene-ethyl alcohol is always used as a solvent to degrease sodium hydroxide. The extractions have a tendency of decreasing with aging.

In addition, there are 1.5 to 6.0% protein, 2% sugar, 2.0% to 4.0% fat and wax, 2.0% to 6.0% starch, and 1.0% to 3.5% total content of ash elements. Among which, there are contents of P_2O_5, K_2O, SiO_2. In summary, the chemical compositions of bamboo wood are shown in Table 19.

5.2 Effect of Chemical Constituent on Physical and Mechanical Properties

Generally, Chemical constituent influences physical and mechanical properties very much.

Cellulose and its distribution is the main factor for the high tensile strength parallel to grain, and hemi-cellulose and lignin combine the celluloses together and support them, then bamboo gets an ideal flexibility and compressive strength.

Hygroscopicity of bamboo comes from the dissociative hydroxy group in the cellulose chains, pigments and hemi-cellulose. The swelling and shrinkage of bamboo timber are anisotropic, in general, less changes of scale in the lengthwise while more in the widthwise.

5.2.1 Cellulose

Degree of crystalloid also plays an important role in the quality of bamboo timber; and the ratio of crystal region to the unformed region is closely related to many properties of bamboo timber, fiber and paper such as bending strength, ductility, shrinkage and swelling, bonding, dyeing, and resistance to chemicals.

5.2.2 Hemi-cellulose

Removing most lignin and hemi-cellulose, the strengths of bamboo decrease rapidly in wetting condition.

5.2.3 Lignin

It gives birth to the stability of bamboo timber in some extent because lignin occupies the space between cell walls which may absorb water.

The shrinkage of un-lignified cell walls is bigger than that of the lignified ones.

5.2.4 Extractions

Extractions exist in the cell lumen mostly, and some in the pits which prevent penetrating. This is the reason for the difficulty of penetration of chemicals for anti-mildew and preservation treatment.

High content of silicon dioxide has a bad effect on the bonding.

High content of starch has a bad effect on the durability.

High content of hemi-cellulose has a bad effect on bleaching of bamboo timber.

6 Defects and Countermeasure

6.1 Defects of Bamboo Timber

Bamboo is easy to be damaged by worms and fungi because some nutrition such as cellulose, hemi-cellulose, lignin and sugar exist in bamboo timber.

Newly harvested, half-dried bamboo timber and bamboo timber used in wet condition are very easy to mildew and erosion, which pollutes the surface and decreases the quality of products.

Erosion decreases the strength of bamboo, even disables its utility. Generally, bamboo timber can be used only for 1~2 years in wet condition or outdoors, which result in a huge waste of resource and economic loss.

There are many species of fungi, and vary with geographic climate and nature condition.

However, bamboo is very high in MOR, but low in rigidity, so it is easy to be bent and deformed.

6.2 Preservation and Mildew-proof of Bamboo

Treatments by using borate and santobrite were forbidden in some countries because the medicals are poisonous. It is an urgent task to develop some effective and low-poisonous medicine to boom the bamboo industry.

A technology named sealed fumigation is in use and being improved. The process is described as follows: fumigate the bamboo timber in a sealed container with sulfur dioxide for 24 hours, then wash, rinse and bake in the sun. Attention: sulfur dioxide is poisonous, should be prevented from danger.

6.3 Moisture Absorption, Cracking and Bending

Much more attention should be paid to the moisture absorption, cracking, bending and anisotropy of bamboo timber which should be researched and solved because they bring bad effect on the process of bamboo timber.

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Chapter 2 Processes &Equipments for Bamboo Daily Products

Bamboo is widely used in people's daily life for a long history; bamboo daily products were all made by hand before the 1930s, after this, the first mechanical production by motor appeared in Japan. And hand making was replaced by machine gradually. Many township enterprises are penetrating bamboo products market since China's reform and opening up policy and stimulating bamboo industry by importing advanced production machines for manufacturing in large scale. Currently, the following main products are done by mechanization or semi-mechanization: (1) Chopstick (2) Mat (3) Stick. This chapter will give you the primary idea on bamboo production, mechanic equipment and working theory.

1 Bamboo Chopstick

Raw bamboo cutting→ Splitting → Shaping → Sharpening round → Bleaching→ Drying → Polishing → Inspecting →packing

Columniformed sanitary bamboo chopstick (single):

Raw bamboo cutting— Stripping— Slicing (Φ5.5) — Bleaching— Drying— Small cutting— Polishing— Inspecting—Packing

1.1 Raw bamboo cutting

Bamboo material: shall be 3 grades (older than 6 years) or above, which can be identified from:

Color: Grade 1: green wholly; grade 2: green partially; grade3: yellow mostly. Most bamboo is being marked due to the improved bamboo management.

Chopstick staple: bamboo cliff shall be over 7mm thick, 18~26cm for length, and 5mm, 7mm for diameter respectively. Length of 18cm is for children. Common chopsticks can have knots, but non for better one. So the length between knots for better shall be 20~27cm, see drawing in detail and pay attention to the bamboo cliff thickness when cutting. Most leftovers during chopstick processing can be reused as flooring (cliff thicker one) and stake (cliff thinner one).

Round Saw Cutting (Sharp Tooth) 2.Running Belt 3.Motor 4.Controlling shank

Main technical parameter:

Production diameter maximum (mm): Φ150

Main spindle speed (r/min): 2800

Motor powder (kw): 0.75

Machine outside sizes (length *width * height) (mm): 914x508x914

Net weight for machine (kg):50

1.2 Splitting

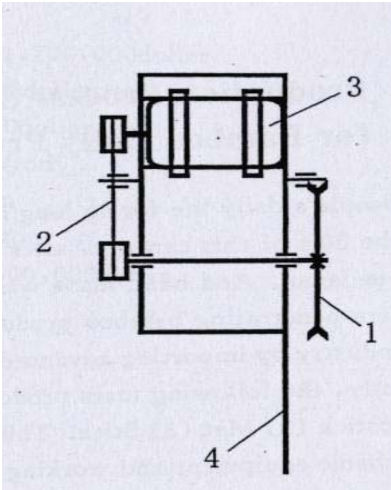

Fig.1 Round Cutting Machine

Method: machine production and raw cutting can be done simultaneously; splitting is normally made by hand. Material usage efficiency can be improved if splitting from bamboo chime due to its thickness. If length between knots is as long as required, splitting from top of knot shall be maintained to avoid chime defects.

Shaping

Punch shall be square-shaped and sizes shall be 6mmx6mm for 5mm chopstick manufacturing and 8mmx8mm for 7mm, green and yellow sides on bamboo shall be punched simultaneously, one piece for each punching so as to form single square-shaped chopstick. If punch is round, the round chopstick can be made. (Fig. 2)

1. Motor 2.Running belt 3.Structure for bracing and rolling 4.Punch slipping device 5.Toools and adjustment structures

Main technical parameter:

Motor power (kw):1.1

Machine outside sizes (length x width x height)(mm): 1450x700x1070

Machine Net Weight (kg): 180

Production efficiency (piece/min): 50~60

1.3 Sharpening round (partial edge)

Each chopstick may be produced into columniform or coniform shape, the specific length will be based on the order and different sized production requires different tools. Whole piece chopstick round sharpening is showing as picture 3.

1. Motor 2.Running Belt 3.Shaping roll

Main technical parameter:

Motor power (kw): 0.75

Machine outside sizes (length x width x height) (mm): 500x400x600

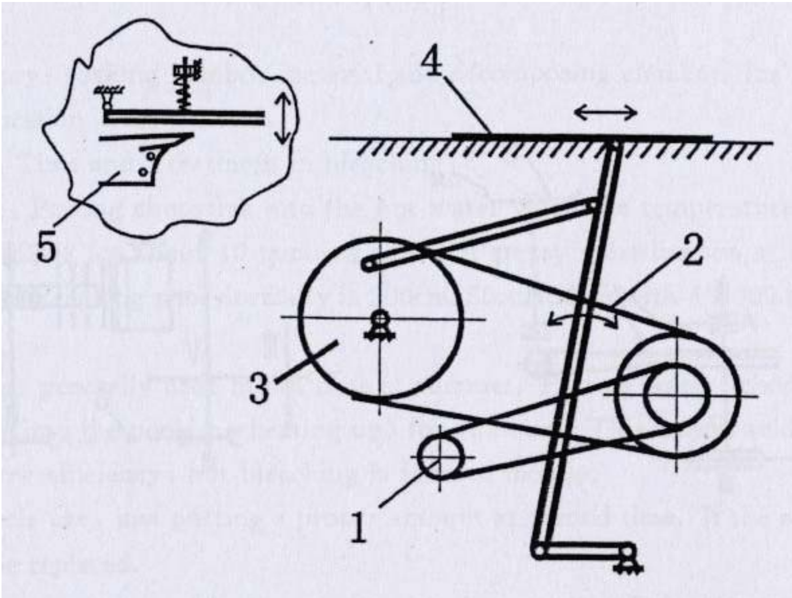

Fig. 2 Shaping machine for bamboo chopstick

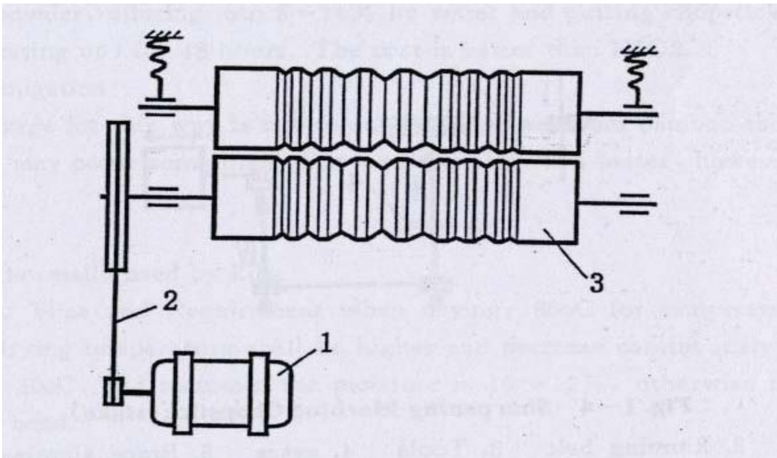

Fig.3 Round sharpening machine for chopstick

Machine Net Weight (kg): 40

Production capacity (pair/min): 10

1.4 Sharpening spiky

Sharpening each single chopstick one edge into spiky shape (see Fig.. 4) and manufacture the other into round chopstick (stake), machine can do it automatically. The spiky degree can be adjusted. 50,000 pieces can be produced out in 8 hours for one machine.

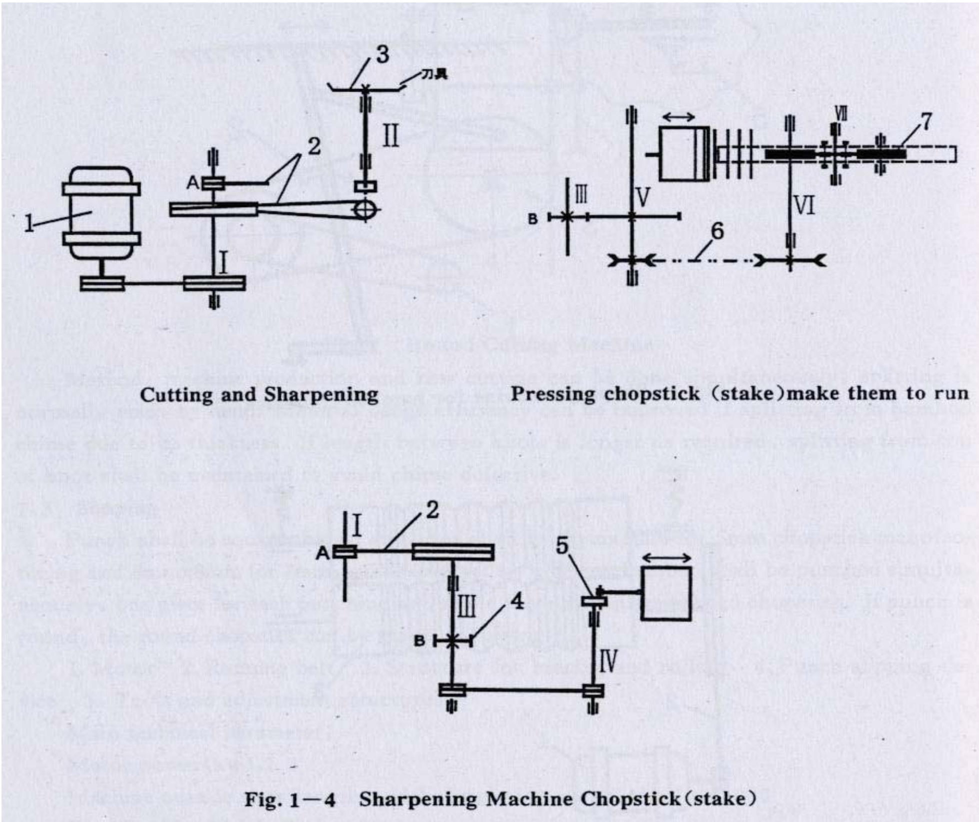

Fig. 4 sharpening machine

1. Motor 2.Runing belt 3.Tools 4.gears 5.Brace slipping part (feeding)

6. Links running 7.Devices for pressing and running

Main technical parameter:

Production capacity (piece/min): 250~320

Motor power (kw): 0.75

Machine outside sizes (length x width x height) (mm): 1500x710x990

Machine Net Weight (kg): 217

Main problems in sharpening spiky: Chopstick (stake) has natural bending character due to its length, it will be locked when feeding and irregular shapes come out, which is deemed as defective or waste product.

1.5 Bleaching

The bleaching shall be maintained in the process for preventing the insect & mildew on the bamboo products.

Bleaching dosage: Normally is H_2O_2, concentration is 27%~30%, 9%~13% for use after diluting.

Bleaching theory: soak bamboo material and decompose elements for killing insect and mildew deterioration is maintained.

Temperature, Time and Treatment in bleaching:

Hot bleaching: Put the chopsticks into the hot water when the temperature is appropriate, and then flow H_2O_2 for about 40 minutes due to its easy volatilization in a hot condition. The bleaching pool normally is 200cm x 50cm x 50cm with 60,000 treatment capacity.

Cool bleaching (generally summer): Put water, chopsticks (stakes) and H_2O_2 together into the pool (no heating up) for 48 hours. This way is seldom used due to long time and low efficiency, hot bleaching is favored mostly.

H_2O_2 can be recycled: just put a proper amount at the second time. If the solution turns into red, it shall be replaced.

Other bleaching:

$Na_2S_2O_7$ solution

$Na_2S_2O_7$ is powder, make the dilution into 8~14% with water and put the chopsticks (stakes) into the solution (no heating up) for 48 hours. The cost is lower than that of H_2O_2。

Sulfur fumigation

The disadvantage of this way is disability to extract elements from bamboo thoroughly and mildew and insect may occur sometimes. The result for H_2O_2 is better; however the cost is slightly high.

1.6 Drying

Drying method: normally by kiln. Temperature: 80℃;time: 12hours. Drying temperature at the beginning shall be higher and decrease continuously but shall be controlled around 80℃, and the moisture is maintained within 10~12%, otherwise the chopsticks (stakes) are easy to bend.

1.7 Polishing

The rolling polishing machine is used to polish the double sides of the chopstick, (see Fig. 5). The capacity is 30,000 pairs of chopsticks one time and the polishing time is kept for above 1 hour.

1. Motor 2.Belt 3.Reducer 4.Rolling parts

1.8 Inspecting

Manual work

Requirement for the finished product: slippery, no notch, similar color, length is as required and body is straight. The product can be sold out after quality inspection in the factory.

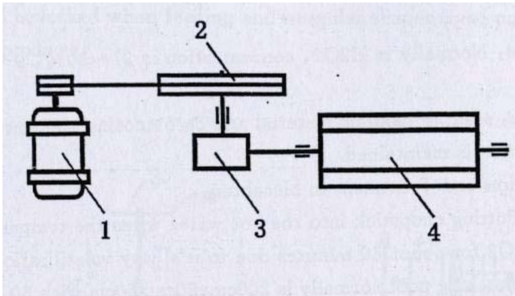

Fig. 5 Rolling polishing machine

1.9 Packing

It can be done by hand or machine.

2 Bamboo Mat

Production Process & Equipment for long Strip Mat

Process for long strip mat:

Raw cutting—Punching strip (vertical direction) —Splitting strip (horizontal direction)—Slicing—Bleaching—Drying—Selection—Weaving—Pressing and Coating—Edge sealing—Inspection -packing

2.1 Raw cutting

Raw bamboo: over 4 years' growing and the cliff thickness is over 5mm, 5mm is much better for the use of two parts, 8mm for three parts. Raw bamboo cannot be too bent, the bottom material is generally used for plywood (production waste is too much for 10mm cliff thickness even for the use of the three parts).

Length requirement: based on the dimension of the finished product, it shall be 10cm longer than the finished products during cutting.

Punching strip (vertical direction) (Fig. 6)

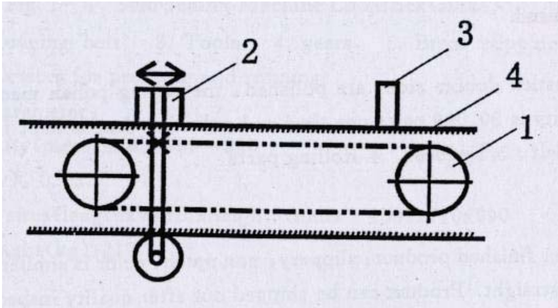

Fig. 6 Punching strip machine

1. Running motor & links 2.Pallet & Top pressing equipment 3.Tools 4.Track (bracket attached)

Proper tools shall be selected based on punching strip sizes and confirmation shall be made on the quantity for splitting strips. Otherwise, lots of material will be wasted. In the operation, select appropriate sized tool to judge bamboo diameter.

Locate width and separate strips interval (Fig. 7)

If we separate strips by machine, firstly locate the width, cut knots and make interval, separate strip finally. Bamboo yellow surface shall be on the up side when feeding; quantity of the separating strips is just based on cliff thickness. Normally thinner green body and thicker yellow body shall be separated, and then cut. Slicing process cannot be continued if cliff is not up to two pieces.

1. Four sets of driving roll 2.Width—locating tool 3.Knot—eliminating tool 4.Interval—eliminating tool 5.Partial tools

Main technical parameter:

Feeding speed (m/min):67~97.5

Motor power (kw): 2.2x4

Machine outside sizes (Length x Width x Height) (mm): 2100 x 725 x 940

Machine net weight (kg): 1800

2.2 Shaping bamboo mat slice (Fig.8)

Bamboo strip is rough on one side after splitting. Set one tool for trimming before vertical cutting, then do shaping and cutting. Before cutting make sure that all the tools' installation is perfect in order to maintain that the qualified cutting is engaged. The green color shall be planed when slice the green strips, so the slicing for yellow strip is very different from yellow strips slicing (trimming tool is replaced by green eliminating tool, the blade is like an arc).

1.Driving wheel 2.Flattening tool 3.Milling tool

Main technical parameter:

Feeding speed (m/min):70~104

Motor power (kw): 2.0, 3.0, 1.1

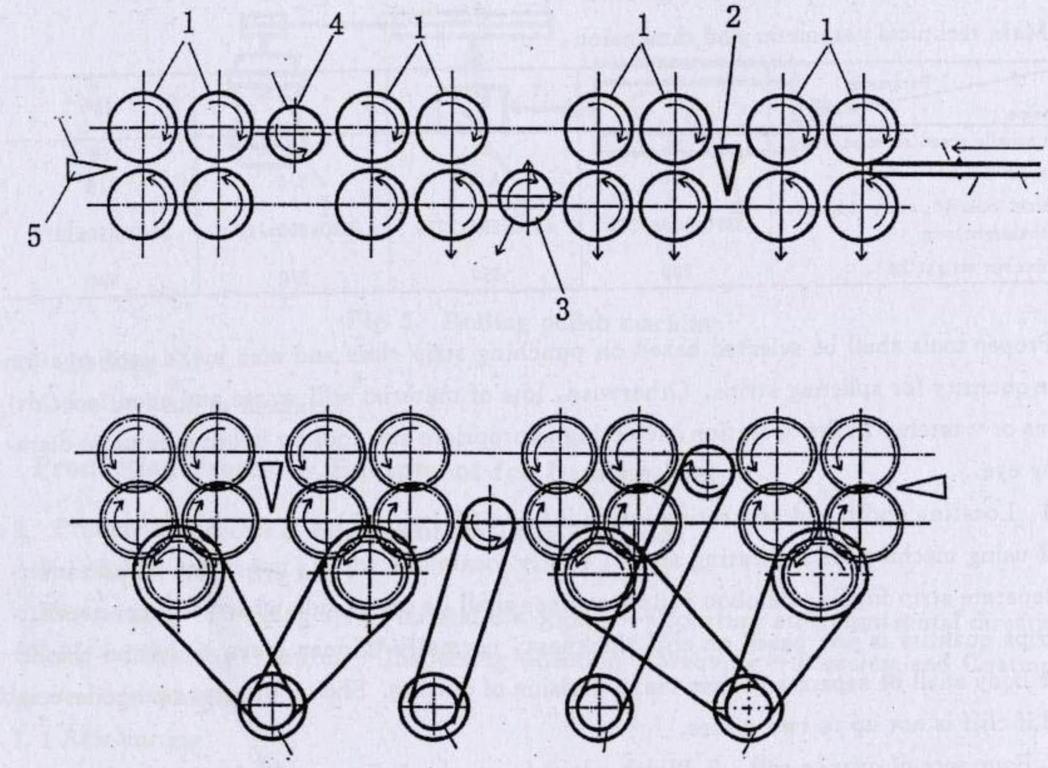

Fig. 7 Machine for locating and separating strips interval

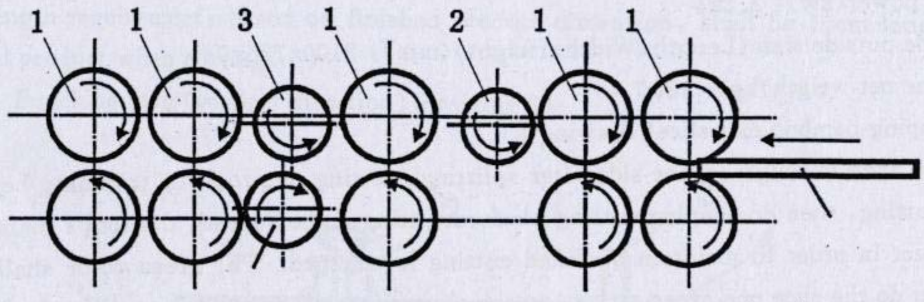

Fig. 8 Shaping machine for bamboo mat strip

Machine outside sizes (Length x Width x Height) (mm): 1092x800x850

Machine net weight (kg)：500

2.3 Bleaching

Bleaching dosage: Normally is H_2O_2, concentration is 27~30%, 10% as use after diluting.

Temperature, Time and Treatment in bleaching:

Put the bamboo mat slices into the hot water when the temperature is appropriate, then flow H_2O_2 for about 2 hours.

H_2O_2 can be recycled, so only proper amount will be needed for the second time. If the solution turns into red, the solution should be replaced.

Coffee-color slice is usually done by carbonization, i.e., fumigation in a big tank by supplying high pressure hot steam at 0.4Mpa (3~4kg/cm2) for around 2 hours.

2.4 Drying

Mat slice drying is normally done by kiln, which takes the left material as fuel. Temperature, Time and Requirement when drying: 80℃ for temperature, 5 hours for time. Temperature of starting drying shall be higher and decrease continuously but shall be controlled around 80℃, and the moisture shall be maintained 10~12%, otherwise the mat slice is easy to bend.

Inspecting selection

This is done by hand.

Requirement: length should be perfect and thickness is as desired without defectives, etc. the qualified ones can be used for weaving after selection.

2.5 Weaving (drawing)

Weaved by machine, 170meters (or longer) can be made for one machine in 8 hours.

1.Motor 2.Rotation belt 3.Gear

A. Brace B.Thread lifting rotation C. Mat lifting thread

D. Interval feeding E. Recycle pressing

Main technical parameter:

Production efficiency (m/min):0.37~0.42

Motor power (kw): 0.75, 0.19

Machine outside sizes (Length x Width x Height) (mm): 2388x2515x1753

Machine net weight (kg):1500

2.6 Pressing and coating

This is done by heating pressing. Firstly coat the mat back (rolling coating system), then add clothing which will be stuck with mat by heating pressing system. The glue is urethane and heating pressure is 0.5~0.8Mpa, Heating pressing temperature is around 110℃, pressing time is 5~8 seconds.

2.7 Edge sealing

This is done by hand or sewing machine.

2.8 Packing

Requirement for checking up: the mat shall be flat and slice is regularly woven, clothing shall attach the mat tightly, then for the final shipment.

Total 18 Employees (including management and operator) for slice mat production from

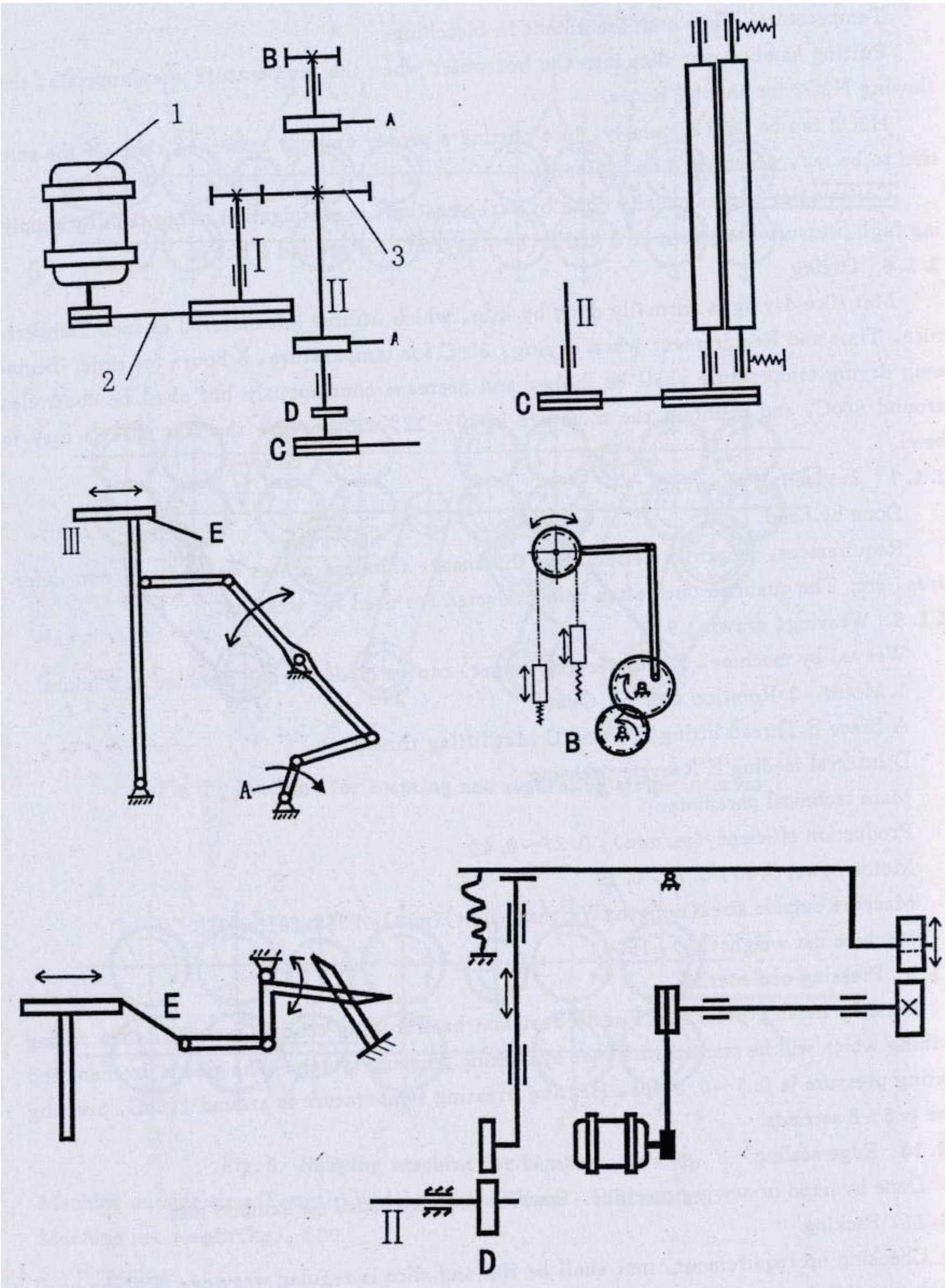

Fig. 9 Weaving machine

the material to be processed in the factory to the finished products. 150,000 RMB for investment and occupies an area of 300m^2 (excluding raw material cutting place and warehouse). Clothing attachment is normally a separated process. 3~5 production locations (over 2000 m/shift) need one pressing machine (also one small boiler), about 5operators (3 for pressing, 1 for boiler, 1for forklift), with an investment of about 250,000 RMB and the area for this is approximately 100m^2, a warehouse is of need for bamboo plywood production in slack seasons.

3 Bamboo Mah-Jong Mat

Raw bamboo cutting—splitting—stripping—small cutting—drilling—wet grinding—bleaching—drying—polishing—selecting—stringing (by hand)

3.1 Raw bamboo cutting (see drawing 1)

Bamboo material of over 6 years: only grain parts used between knots, whole cutting (normally used as fuel), top bamboo cliff cannot be used for it is too thin but can be used for toothpick or scaffolding.

3.2 Splitting (usually done by hand)

Split the bamboo into tile shape along the bamboo growing line from the existing grain cutting part.

3.3 Stripping

Make semi-round bamboo tile into three-side flat parts, no work on the bamboo green side. The sizes for production parts shall be based on the sizes of the finished products. Normally three types are attached: 7mm, 6 mm, 5.5mm, bamboo cliff can be thinner if the bamboo parts are smaller, but stringing is time-consuming. To make part cutting perfect, set two tools on the three sides, first set rough cutting, second precious production so that the better production can be engaged.

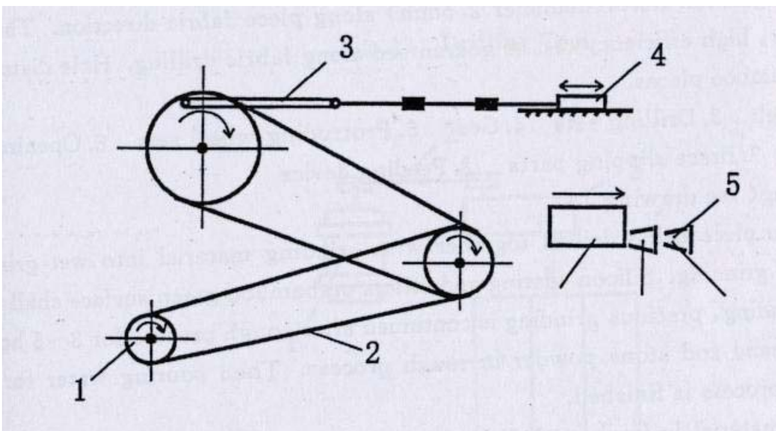

Fig.10 Punching and Cutting machine

1.Motor 2.Belt 3.Brace slipping parts 4.Punching head 5.Cutting and Sharpening tools (two sets, fixed)

3.4 Small cutting (see Fig. 11)

3.5 Punching bamboo parts into Mah-Jong pieces.

The sharp saw is favored for getting flat cutting pieces; usually rotation speed for saw is faster than that of feeding rolling system. Cutting side is normally on the same level with feeding roll, we need to try to reduce the cutting knots to improve the usage efficiency.

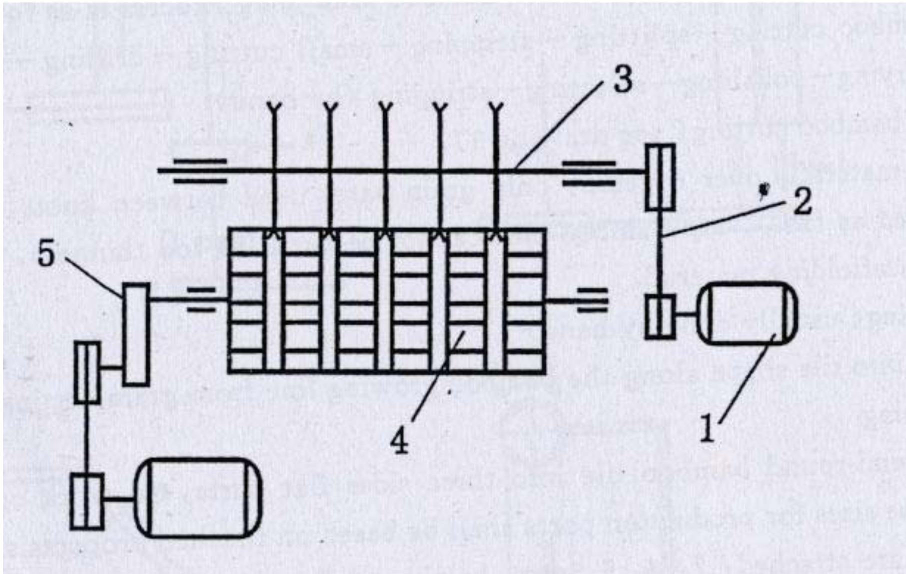

Fig. 11 Cutting saw

1.Motor 2.Belt 3.Sawing sets 4.Feeding roll 5.Reducer

3.7 Drilling (see drawing)

Drill two horizontal holes (diameter 2.5mm) along piece fabric. The quality, slippery, high efficiency of the hole can be guaranteed along fabric drilling. The hole distance is based on the sizes of bamboo pieces.

3.8 Wet grinding (see Fig 13)

Put the drilled bamboo pieces together with grinding material into wet grinding roller for grinding. Silicon coating and others on bamboo green surface shall be eliminated before grinding, fine grinding is continued after rough process for 3~5 hours, then add some small sand and stone powder in rough process. Then pour water for wet grinding when first process is finished.

If the bamboo material is fresh, grinding time can be decreased and surface glabrous performance can be better. But for semi-drying bamboo material, it takes a long time to get such performance and quality will also be decreased. So attention needs to be paid to moisture content in the production.

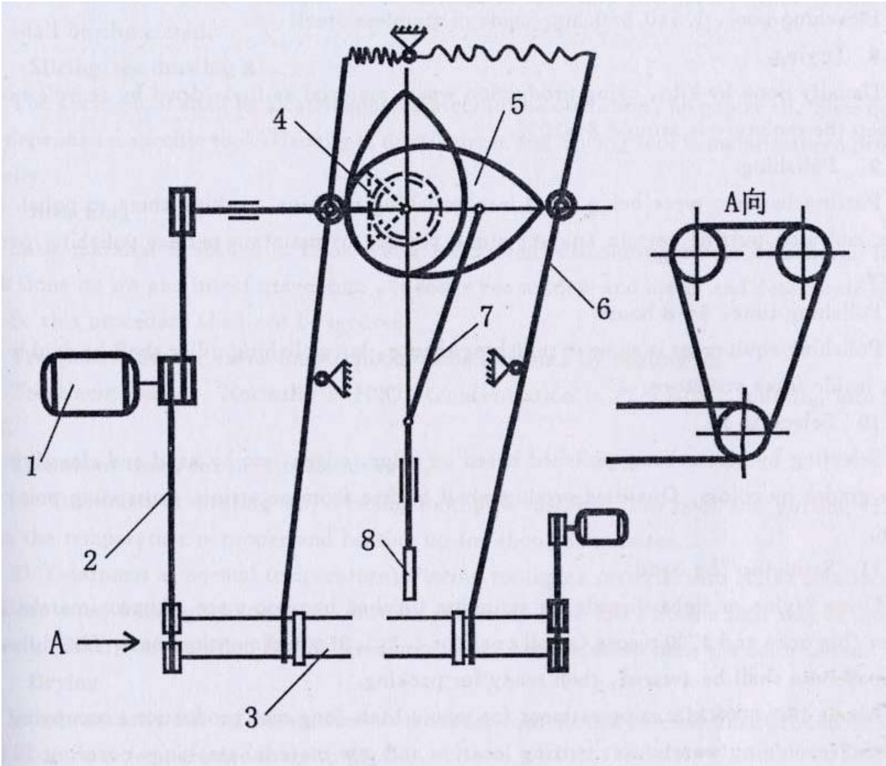

Fig. 12 Drilling Tool

1. Motor 2.Belt 3.Drilling sets 4.Gear 5.Protruding wheel sets 6.Opening and shutting controller 7.Brace slipping parts 8.Feeing device

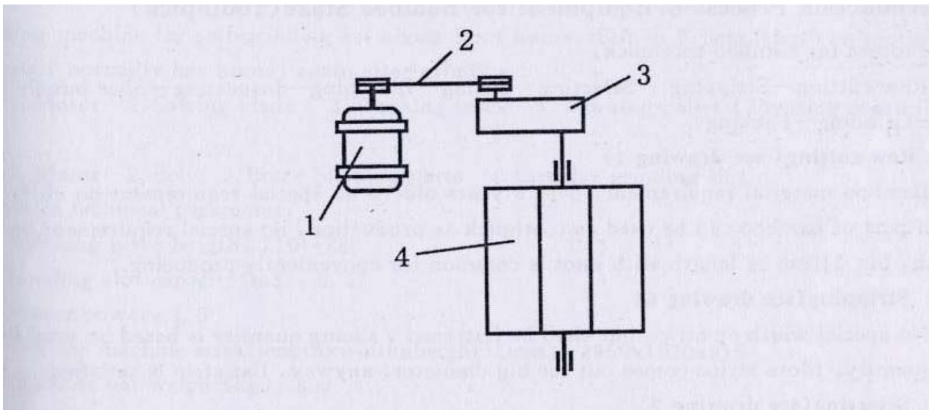

Fig. 13 Wet grinding machine

1.Motor 2.Belt 3.Reducer 4.Wet grinding roller

3.9 Bleaching

The process is the same as that of the bamboo mat slice

Bleaching poll: 1.5x0.5x0.5m made of stainless steel

3.10 Drying

Usually done by kiln, by using production waste material as fuel, dried by recycling the hot air and keep the moisture around 8~10%.

3.11 Polishing

Put the dried bamboo pieces in the polishing machine, making them polish each other; also put certain amount of stone powder to maintain perfect polishing performance.

Polishing time: 6~8 hours

Polishing equipment is the same as the polishing theory, but polishing roller shall be of double layers, inside filter structure.

3.12 Selecting

Selection is based on color, edges, etc by hand and the pieces can be classified into three grades by colors. Qualified products shall be free from stripe, protruding point and so on.

3.13 Stringing (by hand)

Use Nylon or tight threads to string the finished bamboo pieces. Approximately 2200 pieces (big one) and 4700 pieces (small one) for the mat in size of 1.5mx1.95m. Special attention shall be paid to the tightness and looseness.

About 150,000RMB as investment for whole Mah-Jong mat production, occupying 200~250m^2 (excluding stringing workers)

4 Bamboo Stakes (Toothpicks)

Process for bamboo toothpicks:

Rawcutting—Stripping—Selecting—Slicing—Bleaching—Drying-Inspecting—Slic e bundle cutting—Grinding—Inspecting-Packing

4.1 Raw cutting (see Fig. 1)

Requirement of the bamboo material: over 6 years older, no special requirement on cliff, the top part of bamboo can be used for toothpick production, no special requirement on the length, but length of 140cm with knot is common for the convenience in production.

4.2 Stripping (see Fig. 6)

No special requirement on the width of the strips, but they shall be flattened, the slicing quantity is based on the whole bamboo quantity. More strips are from the bamboo of big diameter, only the flat strip is satisfactory.

4.3 Selecting (see Fig. 7)

This is done by machine and the strip thickness is required to be 2.8~3mm. Strip quantity depends on bamboo cliff thickness. Normally pick green surface strips out firstly for direct manufacturing. Basic material for toothpick: from the left thicker part of the yellow surface, thick cliff can be split into two parts, the inner yellow surface shall be eliminated.

4.4 Slicing (see drawing 8)

The slicing tool with no gap shall be located appropriately in the operation. Slicing quantity depends on the specific tool.

4.5 Bleaching

Basic material is soaked in clean water for discoloring prevention before bleaching. If nothing done on rot and insect prevention, it will easily have mildew and insect and the quality will be deteriorated.

Treatment theory: extract the inside bamboo elements by heating it up.

Treatment dosage: Normally is H_2O_2 solution (concentration is 27~30%).

Treatment time, temperature and ways:

1) Treatment at heating up: Place toothpick material into the pool and put in H_2O_2 when the temperature is proper and heating up for about 20minutes.

2) Treatment at normal temperature: Place toothpick material into H_2O_2 solution for 30 hours without heating up, but the efficiency is very low. So the former method is mostly favored. Treatment solution can be recycled.

4.6 Drying

Dried naturally due to too smallness, moisture content can be controlled around 10%~12% if the outdoor temperature is up to 30℃.

4.7 Basic material cutting and grinding for the toothpicks (see Fig. 14&15)

Cut the bundled toothpick material after drying into strips of 42cm, then place it to the grinding machine for self-grinding for about 3~4 hours. Cut the material into strips of 6.5cm for producing toothpicks (normally with knots) again after grinding

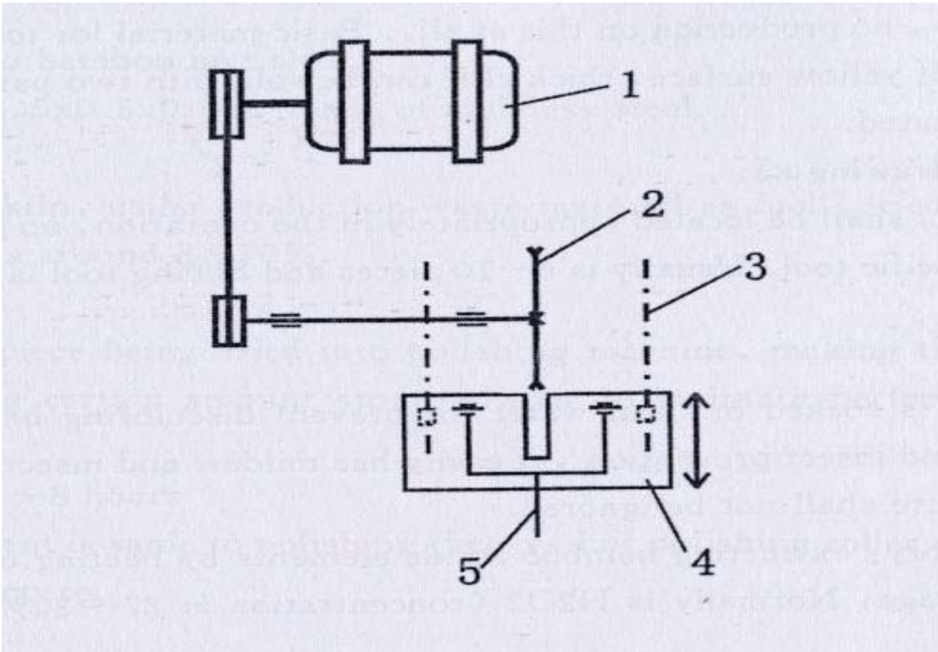

Fig. 14 Sawing machine

1.Motor 2.Sawing blade 3.Working track 4.Woring pallet 4 Pressing controlling pole

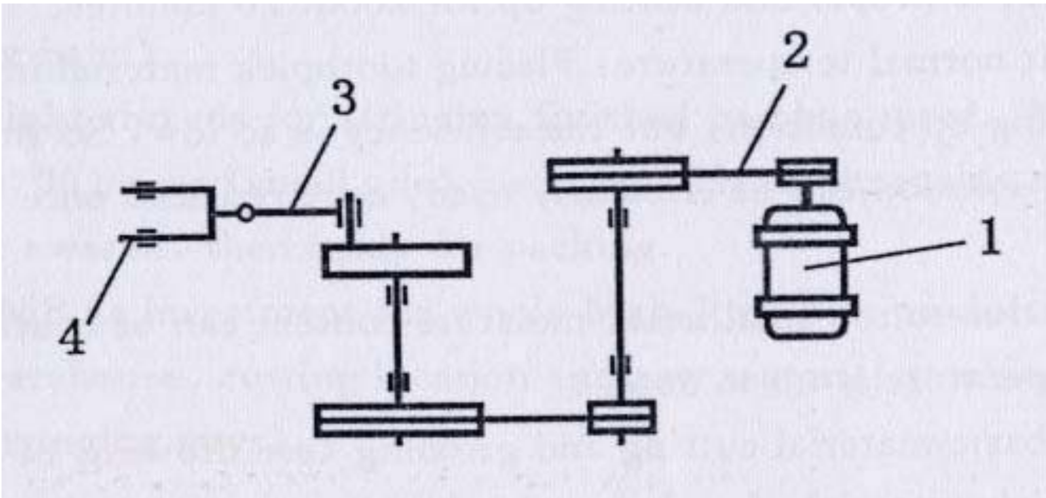

Fig. 15 Slot type grinding machine

1.Motor 2.Belt 3.Brace Slipping parts 4.Circular grinding slot

Main technical parameter:

Working piece length: 210~780

Loading slot capacity (m3): 0.37

Motor power: 1.5

Outside machine sizes (length x width x height) (mm): 2950x1020x915

Machine net weight (kg): 300

4.8 Sharpening (Fig. 16)

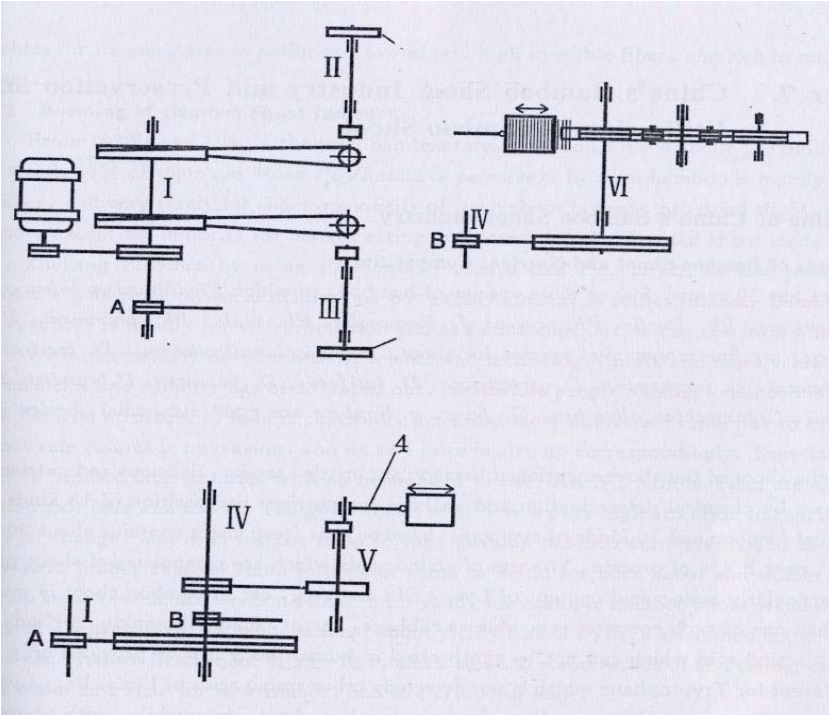

Fig. 16 Sharpening machine for toothpick 1 Motor

1. Vibration Feeding 2.Belt 3.Sanding sharpening cutting 4.Brace slipping parts

Main technical parameter:

Production capacity (piece/min): 520~625

Production diameter (mm):1.5~2.3

Production length (mm):65

Motor power (kw): 0.75

Outside machine sizes (length x width x height) (mm): 1245x 864 990

Machine net weight (kg): 225

This is done by sanding sharpening machine (two edges sharpening once). One machine can do 120,000 pieces for 8 hours.

Tightly pressing and toothpick rotation

Cutting movement

4.9 Inspecting

Inspection is done by hand. Two edges of the toothpick shall be appropriately sharpened; the length and circular degree are strictly required. No special requirement on the bending condition and knots for toothpick. After checking up the goods can be shipped out.

4.10 packing

Packing is done by hand or machine.

Chapter 3 Status and Prospect of Small and Daily Bamboo Products

China is the country richest in bamboo resources in the world, with over 40 genera and over 500 kinds of bamboo, the bamboo area is the largest in the world, and China is often renowned as “Kingdom of Bamboo”. Since the reform and opening up policy carried out over 20 years ago, there has been a fast development in China’s bamboo industry, and a new industry from resource cultivation and processing utilization to exportation has been formed. Moso bamboo, with the largest area is the bamboo most widely distributed and used. Moso bamboo can be processed into ply bamboo, construction model, bamboo floor, bamboo wood compound floor, bamboo furniture and other daily domestic and decorative products.

I have been engaged in processing small and daily bamboo products for 12 years, and the company I am work for is Shaoxing Huanyin Bamboo & Wood Manufacturing Co., Ltd. a Sino-Japan joint venture, mainly producing disposable bamboo slips, bamboo chopsticks, bamboo iron chain, even chain, fish chain etc. The annual production amount is 1800 t, 90% of the products is exported to Japan, Republic of Korea and Holland etc. It is listed as No.1 in Zhejiang province. According to the arrangement of the conference, I’d like to say something about the development for small and daily bamboo products according to my personal experience.

1 Uses of small and daily bamboo products

The uses are very wide, especially the bamboo slips which could be divided into: bamboo chain, fruit chain, fish chain, eel chain, flower chain, knife chain, skewers etc. The most widely used is bamboo slips. The largest consumer of the bamboo slips for food is Japan. The Japanese people select bamboo slips as the assisting material, through vacuum wrapping, the bamboo slips are finally sold as goods. Secondly, the chain slips are used in roasting and baking. In accordance with the incomplete statistics, the annual sale amount of bamboo slips in Japan is around 12000 t, i.e.15 billion sticks. The Republic of Korea is one of the main countries in using the chain slips. Arabic and European countries use bamboo chain slips for food and in restaurants. Small and daily bamboo products are really widely used and they have a bright prospect for development.

2 Technology and related equipments

The small and daily bamboo products seem simple in technology. In fact it is not so. Take bamboo slip technology as an example, it includes 12 steps: material selection, breaking, shaping, pulling round, disinfections, whiting, drying, polishing, cutting even, re-polishing, sharpening, sorting, wrapping and sterilization. The quality requirement and hygienic standards of the chain bamboo slips are very strict. Be even, straight with no bending, smooth with no veins or needling, lustrous with no tarnish, and the bamboo should be 5 years old at least. In the early 1980s in China, the bamboo slips were produced mainly manually, there were a lot of skin needles, unevenness in length, sharpening degree and unsatisfactory color. So, the products were at low level while of high cost. The foreigners were afraid to order and most clients issued orders from providers from Taiwan province, China. Since the mid 1980s, some enterprises started to import complete sets of equipments for bamboo production from Taiwan or Japan, including semi-automatic bamboo cutters, bamboo breakers, bamboo chopsticks shapers, automatic bamboo chopsticks sharpeners. Bamboo slips machines include: puncher, even-cutter, automatic sharpener, bamboo polisher, and the enterprises in China stepped into the mechanization. Due to the changes of production technology, the cost was greatly reduced and quality increased.

Clients both at home and abroad ordered disposable chopsticks and bamboo slips. China is rich in bamboo resources and low in labor cost, therefore, the competitive power of China's bamboo products increases. The Japanese clients order bamboo products from Mainland China instead of Taiwan. Meanwhile, many Taiwan bamboo product manufacturers went to mainland China to set up cooperation by establishing joint ventures to run bamboo factories in mainland China. For example, the biggest Taiwan manufacturer of daily bamboo products went to Fujian province to open the independent business and in 1993 its amount of export reached 20 million USD. Much progress has been made in recent years in bamboo machinery developed by mainland China and most of it has realized nationalization. There is increase of bamboo manufacturers in China and the quality of the products has also increased year by year. The export amount of bamboo products in Taiwan decreases yearly, but Taiwan's position as the leader in this area has not been changed yet.

3 Prospect of daily bamboo products in China is bright

With the improvement of people's living standard and concern for the environment, inevitably the bamboo will replace the wood. The daily disposable bamboo products such as disposable bamboo chopsticks, bamboo slips, medical cotton slips etc are all safe, hygienic and green, welcome by more and more clients.

Internationally, the bamboo products of the biggest sale amount are bamboo floor and ply bamboo floor; the second are bamboo slips and its series and the country which consumes most is Japan, the second is the Republic of Korea, then Greece and Arabic countries. The annual export volume of bamboo slips in China amounts to about 150 million USD. The consumption market of bamboo slips in northeastern China has just started to thrive, some large chicken processing manufacturers in particular use the bamboo slips wholly, and after chaining they are exported. In north China, around 200 million sticks of bamboo slips are in need, the selling amount reaches 80 mil Yuan. Further more, throughout the country roasting and baking all need bamboo slips which could uniquely gender sale amount around 150 million Yuan at least.

4 The magnitude of the domestic bamboo manufacturers

The domestic bamboo manufacturers for disposable bamboo products are mainly distributed in Zhejiang, Fujian, Hunan, Jiangxi, Hubei, Anhui, Sichuan provinces. There are around 100 domestic bamboo manufacturers for disposable and daily bamboo products with the registered capital of over 1 mil Yuan. There are fewer than 50 such manufacturers which are authorized the right to import and export. There are lots of family factories or bamboo processing plants with registered capital less than 1 million Yuan.

The sale amount of bamboo slip series exported from the Mainland China could account for around 150 million USD and it is increasing every year. But we are faced with new difficulties and problems: The first is the competition without order, hampering the increase of benefit. Many enterprises and trade companies send improper quotations or decrease the prices irrationally just for the immediate profit. For example, within 1992-1995, the price for each box (3000 pairs) of disposable twin bamboo chopsticks to Japan was 27 USD and the sharpened chopsticks 32 USD. After 1995, the prices dropped to 21 USD and 24 USD per box respectively. The price of bamboo slips also dropped from 1450 USD in 1992-1995 to 1250 USD at present. The benefit of the enterprises has been worsened. Secondly, the quality of the products is uneven, influencing the reputation of the companies. The enterprises of small daily bamboo products in mainland China have developed into two extremities: The bigger ones are quite competitive whether in production magnitude or quality. Whereas the numerous small bamboo enterprises, due to their own limitations: unscientific technology, unsatisfactory management and unstable quality, they become uncompetitive. The products were rough, breaching power exceeded the limit, and products become moldy or hurt by insects. Although it occurred in some individual enterprises, it caused bad reputation to the small daily bamboo products in mainland China. I received a Japanese client who was one of the five big merchants producing daily bamboo and slip products in Japan. Before 1996, he regarded the quality of the products in mainland China was bad while that in Taiwan was good. We failed to make them believe despite the repeated explanations. Afterwards through years of contact and communication, he gradually put confidence in the bamboo products produced by our company. In recent years, he ordered from the bamboo company the small and daily bamboo products with a worth of 2 million USD and ended the purchase agreements with Taiwan. But his expected price was still lower than that of Taiwan.

5 Social and economic benefit.

The development of small and daily bamboo products is appropriate to the developing countries and significant in promoting the rural economy, increasing the income of the rural hilly farmers. The social and economic benefit is very obvious. First, there could bring increment of the bamboo resources. Through the development of small and daily bamboo products, the original value could increase four folds. Second, there is sharp increase of the hilly farmers' income. Attribute to the production of the small and daily bamboo products which belong to the labor intensive industry, it could attract and settle a large number of rural labor force. Take the company as an example, the annual payment for the rural manpower was over 700,000 Yuan. Third, there has been a big increase of the state revenue. Processing of the small and daily bamboo products has become the main financial income of many areas. Take the company as an example, the annual tax to the state reaches 1 mil Yuan. Fourth, there has been evident environmental benefit. Through the development of small and daily bamboo products, the forest is protected, bamboo replaces the wood, improving the ecological environment. Fifth, the enterprise achieves its financial benefit considerably. The enterprise of certain magnitude for small and daily bamboo products has generally obtained the profit of 10-30% and is competitive in the market with great potential for further development. Our company is a good example for this, since its establishment in 1993, the fixed asset now reaches 13.08 million Yuan, the sale amount last year reached 15.6 million Yuan and the profit plus tax 3 million Yuan.

6 Experience and recommendations

The full and steady development of the bamboo production industry is closely associated with the firm support of various sectors at various levels and the efforts of the enterprise. Looking back on the history from the low period to the high time of the enterprise, three experiences have been drawn: First, stress on the development of the products. There is no market without no change. Product with no change could hardly meet the need of the clients. Closely trace the market is the everlasting objective of the enterprise. With the increasingly intensive market competition, you have to stick to the long term development of the enterprise. The enterprise will aim at multi-series and multi-varieties development. So far, our enterprise has developed with success 8 series and over 30 kinds of products. Over 90% of the products have been exported abroad, meeting the need of the clients in a maximum way. Second, pay attention to the quality. Our enterprise strictly implements the quality standards for the products and scientific management. All the products are checked strictly and we pursue the green, safe and hygienic products, ensuring that unqualified products should never go out of the factory. For many years, there has been no product which has been returned by the clients. Recently, the enterprise has spent a big sum of money purchasing newly developed high efficient sterilization equipment for killing the bacteria in the bamboo so as to make all the bamboo products sterilized. The level of the products has been lifted and the sale increased. Third, develop more markets. Based on sincerity, the enterprise keeps good relation with the old clients, making new friends steadily. The products go not only to Japan, but also to Korea, Holland, Italy as well. The fourth is the joint development. Our enterprise has set up a group of sites for bamboo processing, practicing “four unifications” and “one decentralization”. The “four unifications” refers to: 1.Unifying technical coaching; 2. Unifying installation and equipment testing; 3. Unifying returning of the used bamboo; 4.Unifying bamboo sale. The “One decentralization” refers to decentralized marketing by the individuals so as to bring the initiative into full play and to make more people rich.

Our suggestions: from the status of processing bamboo and to ensuring the sustainable development of our bamboo processing industry, governments and sector management organizations should study earnestly to solve the problems existing in the bamboo product processing industry in China.

First, the governments should continue to assist those leading bamboo enterprises to strengthen the competition.

Second, government should put the bamboo product processing enterprises as the priority for development, make strategic arrangement and work out related supporting policies.

Third, the industry association should be stressed in management, unifying product standards and coordinating the product price, optimizing the various resources, eliminating the disorder and vicious competition. The bamboo product processing should be led onto a healthy track.

I firmly believe that under the joint efforts of governments at various levels, the bamboo product processing industry in China will surely have a bright tomorrow.

Chapter 4 Recent Situation of Bamboo Curtain Production, Market and Prospective in china

1 General situation of bamboo curtain

According to the feedbacks from our sales department, it is analyzed that there are some factories in Japan, the U.S. and Southeast Asian countries which are producing the bamboo curtains. However, in these areas there is a serious shortage of raw materials, and the price is relatively high, so every year abundant raw materials and finished products are imported from China to meet the demands of their processing industries and their local people for daily use. Japan is one of the best countries which keeps yielding and using the natural bamboo curtains, and there is a huge domestic demand for bamboo products. The Japanese are extremely favoring bamboo weaving, and most of the households can easily show you several daily necessities made of bamboo, and some become indispensable to their living. In the 1950s and 1960s Americans started to use bamboo curtains, and now there is a large demand from the market, and furthermore, there is still a big potential for the increase in demand. With more and more people love to use bamboo curtains, the market for this product would expand more and more.

2 History, output, scales of factories and the economic benefits

In China there is a long history of producing bamboo curtains, and thousands of years ago our ancestors began to make (absolutely by hand) and use bamboo curtains. In modern society, the production of bamboo curtains was initiated from Taiwan province, with its products sold to the world markets, and from the 1990s this production was shifted to the mainland China. Over a decade later, presently there are hundreds of factories in China committed to processing bamboo curtains, among which there are nearly 100 factories with the annual output up to millions of U.S. dollars, scores of factories up to tens of millions of U.S. dollars, and the total production value amounts to billions of dollars or so, and an enormous economic profit of about hundreds of millions of U.S. dollars can be achieved. Since the processing of bamboo curtains is involved with an intensive labor force, there is a large demand for manpower, which can alleviate the society from its jobless pressure to a full extent, especially for women employees. In a factory with the annual output of over a mullion U.S. dollars, 200-500 employees will be needed, and 1000-3000 workers are needed for a factory with the annual output over ten million dollars. This will also promote the development of other auxiliary processing industries.

The natural bamboo curtain is widely applied in households, office buildings and hotels etc., and it is a kind of environmentally friendly daily necessity, so it is globally acceptable. In the years to come, its styles shall be continuously innovated according to the habits and requirements of different countries or regions, so as to create a wide variety of bamboo curtains for a further promotion.

3 Prospect of domestic and foreign markets

There is a brilliant future for the bamboo curtain on the market. In a word, it is a kind of seasonal product acceptable to each household. As far as the Chinese market is concerned, at present the demand for this product is mainly from the families and is increasing definitely in those metropolises. So we take an optimistic view about its brisk future market. In the developing countries the bamboo curtain is basically one-off use (refers to the common bamboo curtain), and some of them will be changed for a new style after 2 or 3 years.

Chapter 5 China Bamboo Mat

China is the country using and manufacturing bamboo earliest in the world. Bamboo mat is one of the Bamboo products with a long history. There are thousands of factories in China, mainly distributed in ZHEJIANG、FUJIAN、JIANGXI and HUNAN provinces. In China, the bamboo mats are not only used in domestic market, but also exported to southeast Asia、Europe、North America and other regions.

1 Development of China Bamboo Mat

Bamboo mat is a mat is made of thin bamboo strips, processed with bamboo. This is the original China bamboo mat which has been used in some areas in china till now. With development of modern science and technology, great progress has been made in bamboo in the1980s. People researched and produced new varieties of bamboo mats, such as bamboo chip mat, mahjong mat、fiber mat. The function has been changed from daily utilization to health care and decoration.

2. Bamboo Mat's Feature

2.1 Technical Feature

The technology of bamboo mat has the features of less investment, simple equipment, easy operation and high benefits. Compared with traditional method, modern technique has advantage of high rate of bamboo utilization, mechanical operation, time saving and high efficiency (ten times more than before).

Tab. 1 The feature chart of comparing the traditional technique with the modern technique

Feature / Category	The rate of bamboo utilization	Operation	Advantage or disadvantage
Traditional technique	30%	By hand	High cost 、low efficiency 、easy damage
Modern technique	90%	Mechanical	Low cost、high efficiency、long time use、better air

2.2 Products feature

2.2.1 Green and environmental protection. Bamboo replaces wood for it has the advantages of protecting the forest resources, and giving people the feeling of returning to the nature.

2.2.2 Practical. With good ventilation and radiation, it's convenient for daily use.

2.2.3 Medicine treatment. It can remove fatigue, promote blood circulation and accelerate metabolism.

3 Technological Processing of Bamboo Mat

Generally, bamboo mat manufacturing has ten working steps of splitting, cutting, drilling, polishing, bleaching, insect treatment/carbonization, drying, fine selecting, weaving, checking and packing.

3.1 Bamboo selecting

There are more than four hundred categories of bamboos in china, but only about ten categories have been used and benefited. Among these, Moso bamboo occupies 69% of the bamboo resources; it's the main material for bamboo mat making. Four to six years old and undamaged epidermis bamboo is the best choice. Meanwhile, longer bamboo stick will better the rate of bamboo utilization.

3.2 Manufacturing

3.2.1 Splitting. Cut the bamboo into regular narrow and long pieces.

3.2.2Cutting. Cut the material to thin pieces.

3.2.3 Drilling. According to the requirement, drilling should be on the proper place at thin piece for weaving.

3.2.4 Polishing. Draw in the edges, corner and surface by machine, make the thin pieces smooth.

3.2.5 Bleaching/insect treatment/carbonization. Make the same color; protect the moth and mildew by medicine treatment. The color of products after carbonization will keep steady and can be permanently unfading.

3.2.6 Drying. Control the humidity of the bamboo pieces, make color well-proportioned by photochemical action, restoring sweet-smelling to the former state.

3.2.7 Selecting. Pick out the unqualified products.

3.2.8 Weaving. Bamboo mat is woven in yarn according to different specifications and requirements.

3.2.9 Checking and Packing. Bamboo mat reaches the standard: smooth and durable weaving; even mat edge; brightness, no spot; moderate weight.

3.3 Matters Requiring Attention

The two key links in manufacturing are carbonization and insect prevention, control the ratio of compound medicines, meeting the requirement of environment protection.

4 Products and Structure

4.1 Series Products

At present, the bamboo mat has over ten series products, for example, ordinary mat, mahjong mat, plum blossom mat, weave flower mat, carved designs mat, magnetization mat which have been widely used in families and hotels.

4.2 Structure.

According to the different ways of weaving, bamboo mat can be classified into threadlike bamboo, block bamboo, strip bamboo.

4.2.1 Threadlike bamboo

4.2.2 Block bamboo. It is divided into pattern variety and plain.

4.2.3 Strip bamboo

5 Economic and Social Benefits Analysis

5.1 Economic Benefits

Bamboo mat products have high added value. A bamboo of one dollar will be of six dollars after being processed with high economic benefits. On the other hand, Moso bamboo always grows at mountainous and forest regions, the farmers living in these areas have relatively low income. So bamboo mat improves bamboo utilization value, and also add peasants' income.

5.2 Social Benefits.

Bamboo is the fastest flora growing in the world. It propagates 30% every year, i.e. its growth must be under reasonable fell. Bamboo mat manufacturing can make better use of the bamboo resources and take advantage of ecological balance, water and soil conservation, vegetation protection. It also creates jobs for people in mountainous region. That's important to keep society steady and develop country and local economy.

6 Research and Development Direction of Bamboo Mat

On researching and developing bamboo mat, first, advance technique, improve efficiency and develop new products depend on science and technology. At the same time, research the recovery and utilization technique of surplus bamboo materials, multipurpose use the bamboo resources. Second, explore management ways suitable for industrial development, perfect production way of “company +base + farmers” further, improve enterprise benefits, increase farmers’ income.

At last, great thanks for United Nations Industrial Development Organization who gives me a chance for the international exchange, also my great gratitude to everyone here, I’d like to try my best to head china bamboo mat to the world. I am looking forward to the opportunity to work with you more.

Chapter 6 Bamboo Flooring

1 Properties of Bamboo Flooring

Bamboo flooring, which is made by over twenty procedures such as sawing, splitting, rough-planing, chemical treating, drying, precious planing, strip selecting, glue applying, laminating, and lacquering etc., is a decorative floor. According to its surface structure, it can be divided into two classes, the horizontal lamination flooring and vertical lamination flooring. This decorative floor is characterized with high strength, good tenacity and abrasion-resistance, dim and elegant color, artistic appearance and unique and novelty structure, so it has perfect decorative effects, which is not only durable but also caters for people’s desire for returning to the nature. Therefore, it has a big potential market.

Fig. 1 Physical Mechanics Properties of Bamboo Flooring Item

Item		Uinit	Target value
Moisture Content		%	8. 0～13. 0 must survey
Static strength	Thickness≤5	Mpa	≥98. 0
	Thickness>15mm		≥90. 0
Macerating and striping test		Mm	The striping length of each glued layer≤25 must survey
Gluing strength		Mpa	≥0. 90
Hardness		Mpa	≥50. 0
Surface lacqure film wear-resistance	Revolution of wear and tear	R	400
	Surface situation		Leaving 50% lacquer film on the surface
	Wear and tear value	9/100r	≤0. 08 must survey
Surface lacquer film pollution-resistance			No pollution
Surface lacquer film acherence			Smooth cutting line, no lacquer film peeling off
Degree of surface Lacquer film's luster	Brightness	%	≥85
	Less brightness		80～40
	Least brightness		10～30
Amount of formaldenhyde release		Mg/100g	≤30 must survey

It can be divided into the natural and carbonized flooring according to different treatment to the raw bamboo strips. The former keeps the original color of bamboo; but the latter makes bamboo strips undergo carbonized treatment under high temperature and pressure, which deepens the color of bamboo strips and spreads color evenly. Physical mechanics properties of bamboo flooring are as follows in Fig.1.

2 Processing Technology

Flow chart of bamboo flooring processing

Raw bamboo→Sawing→Splitting→Rough planing→Boiling (treatment for antiseptic, anti-distort, and anti-mould)→ Drying→ Strip selection→ Gluing→ Sanding→ lacquering→ Quality testing and grading→ Packing and storing

The above processes can be adjusted according to the actual production.

Material Preparation

The bamboo must be 5~6 years old and the diameter at eyebrow's height is more than 10cm. The distance for sawing should be over 10cm than the actual production length. The sawed bamboo part should be processed by using strip saw on the working table but not bamboo splitter, which works quickly; but if by splitter the edges of bamboo strips will not be straight, reducing material's utilization ratio.

After rough-planing and parts of the green surface and yellow inner layer have been trimmed, this will be better for boiling and precious planing. The green surface and yellow inner layers are waterproofed. Water can easily penetrate the bamboo timber during boiling after rough planing to guarantee the quality of treatment for antiseptic, anti-distort, and anti-mould. Rough planing decreases the amount of precious planing but is convenient for piling during the dry period, hence the drying efficiency will be raised.

The aim of boiling is to remove the nutrients in bamboo as much as possible. In order to enhance whiteness and brightness of bamboo timber and size stabilization, we can add certain amount of solution of pest proof and mould inhibitor or bleach liquid into the boiling pool to treat bamboo.

After boiling, bamboo strips will have high moisture content, and they must be dried. Moisture content for strips after drying should be 9% in so as to guarantee the gluing performance. After drying, precious planing can eliminate the left green surface and yellow inner layers clearly. After that, the common difference of the thickness of strips should be controlled within ±0.2mm.

Heat-pressure lamination

Before gluing, it is necessary to select strips so that the similar color strips can be laminated on the same floor. Unqualified strips shall be picked out. Urea formaldehyde resin is usually used as glue, and 200g/m^2 is taken as gluing unit. During vertical lamination flooring production, the glue should be put on for a long time, then bamboo strips should be arranged along gluing side according to yellow inner layer towards yellow layer while green layers towards green layers. In producing the horizontal flooring, it is better to use two shaping technologies to avoid the gap line among layers. The first shaping is to glue and press bamboo strips in one horizontal direction veneer as the single-layer board, then glue and press the single-layer board according to the required floor thickness. Generally, two-way pressing machine heated by the steam is normally used for producing flooring. Thermal conductivity of bamboo timber is a little smaller than that of wood , so the time for bamboo flooring hot pressing is a little longer than that of wood.

Further production

After sawing, semi-finished glued flooring will be further processed into finished products: cut at a definite length, four-side planed to have tongue and groove, sanding, lacquering.

The bamboo strips should be made of the same width in sawing. The controlled width = product surface width + protruding groove + processing margin (about 2cm). If it is sawn in the cross direction, the sawing surface should be vertical to the direction of bamboo strips length side. The sawing length = the required board length + horizontal protruding groove length + processing margin (about 8mm). Longitudinal four-side planer with tongue and groove should be of 45-degree angle and the chamfering width is under 0.8~1mm. Make sure the groove direction is parallel to the width side of the floor, and coincide with its geometry center side to ensure the quality of the floor with tight joint in installation. Wide-belt sanding machine is used for sanding. The procedure is as follows: firstly, rough-sanded by belt 80~100#, then preciously sanded by belt 180~240#. Sanding margin is 0.6~0.8mm. Photosensitive paint can be used for coating. At first, paint the base varnish, then sanded until lacquer is solidified. After that, paint the surface varnish. The back of bamboo flooring may not be painted. Specific lacquer types or brightness is based on the customers.

The above-mentioned is the basic process for bamboo flooring production; the specific product is produced by applying different procedures (such as natural flooring or carbonized flooring).

3 The Latest Progress of Bamboo Flooring

Bamboo floor is bamboo based panel in small size used as a kind of decorative material for indoor ground for the simple and elegant color, luster and solidity and wear-proof. At present, the structure of bamboo floor is mostly the 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 series have been developed successfully by Central-south Forestry University.

3.1 Bamboo Composite floor

Pure solid bamboo floor was produced firstly upon various solid bamboo floors with structure form: One is multilayer tangential section glued bamboo floor, the other is single layer side jointed radiation section bamboo floor. These bamboo-wood compound floors have been developed to make good use of fast-growing wood.

One is three-layer bamboo-fir composite floor, bamboo plate as surface layer, and fir veneer as core layer. This kind of 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 is used 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 uneasy deformation. Patent number of long-strip bamboo-wood composite floor is ZL952373157. Among all the kinds of solid bamboo floors, multilayer chordwise section glued bamboo floor has the maximum producers, the most output and the widest utilization.

3.2 Hollow bamboo floor

Hollow bamboo floor consists of core layer, a kind of grid structure and poor quality bamboo plate together with surface layer which is made of good quality bamboo plate by side joint. They are bonded together. There are three kinds of floor strips due to differences in edge structure in installation: 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 connecting method is the same as that for solid bamboo floor. Loose tongue joint is to make bamboo plate be inserted into the groove which has 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 shorter, two floors are connected through inserting extended bamboo plates of one floor into the other. Hollow bamboo floor series can not only save stuff, having good sound and thermal insulation but are not 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 household floor.

3.3 Reconstituted Bamboo Flooring

Under the situation of making full use of bamboo timber, reconstituted bamboo flooring then has been developed. The whole process can be divided into two parts. The first part is just similar to reconstituted wood manufacturing, and the second part is like manufacturing of wood flooring with square timber.

Chapter 7 Bamboo Floor-A Perfect Combination of Science-Technology and the Nature

Yapu Bamboo Co., Ltd. in Anhui is a joint venture, specializing in producing compound floor, bamboo floor and a series of products. Its total asset is 70 mil RMB Yuan, with the annual production over 600,000 m^2. Some 80% of its products have been exported to Germany, France, US, Canada, Italy, Japan and other countries. The company adopts the world advanced floor production line from Germany and Italy, incorporating the modern science technology for producing the international first rate products. General Director Li has pointed out that macro environment, resources and management are the key factors to the production of excellent Yapu bamboo floor.

1 Macro environment

1. People's concern for the environment increases day by day. As the industrial civilization of the human race develops, the forest resources suffer from severe sabotage and the global environment where we inhabit is worsening, floods go rampant, land becomes desert, the global climate becomes warmer. All these disasters are linked with the over-felling. It is a trend to replace the timber floor originated from the valuable primitive forest even led to sabotage to the environment with grass plant --- bamboo as the material together with the fast growing tree like cedar and poplar, combining modern high science and technology, mass producing the natural green floor with stable structure, and resistance of formation, high temperature, humidity, but of high intensity without pollution or harm.

2. Comparison between the timber floor and the bamboo floor. The timber floor is decoration material suitable for home, office and recreation environment. But growing valuable trees needed for producing the timber floor is generally longer. The production is a big waste of the forest resources.

3. The need for fine decoration. With the popularity of fine decoration in the housing development, Yapu Co., Ltd. will popularize in domestic market the products by cooperating with the foreign companies to cope with the commercialized living. Bamboo timber floor is the third new generation floor. With the progress of science and technology, it has a bright "sale" future. Some experts predict that the bamboo timber floor could occupy 30% of the total floor sale within 10 years. Modern life needs the bamboo timber floor and that is the "macro environment".

2 Resources

The bamboo resources are an important part of the forest resources in China. Bamboo area in China is listed as the second largest but the bamboo production is the first in the world. Yapu Bamboo Co., Ltd. in Anhui is located at the foot of picturesque Mt. Huangshan which is rich in bamboo resources with very advantageous conditions. Through the market investigation and research by some experts, bamboo is found to have good physical features: small shrinking amount, good cutting and friction feature, elasticity and tenacity, etc. It has much better capacity of pressure resistance than the timber. Bamboo products are now widely used in China. So, once the bamboo floor is introduced to the market as the new decoration material, it will gain quick welcome from the consumers, for it not only keeps the natural stripes or grains, but also is hard, fine and smooth, with the plain and ancient decorating effect, giving one a feeling of being close to the nature. As the areas rich in bamboo resources are located in the economically under developed areas, the development of bamboo could stimulate the local economy. The investment in bamboo floor usually does not require too much but the benefit is high and that is the “resource”.

3 Management

1. Take the talented persons as the first priority, stress the rational collocation of talents and bring the initiative of the staff into full play. We set quota of position and number of staffing for each post on the production line and arrange the key technical staff at the important positions so as to form the good atmosphere of marching forward jointly.

2. Exportation is our main work of trade business. So, we must be modest and diligent, learning from the advanced countries.

3. Each individual capacity is limited but the “joint force” is great. We need to take joint efforts together with the related research institutes in China for joint material supply to do better work in the national industry so that the Chinese products could win honor in the international market. We consider that “management” is the core to the success.

4 High standard of technical requirement

Production should be as earnest as embroidery. “Take science & technology as the base, strive for the perfect, take the clients as god and provide all-round service” is our new objective of marketing. We adopt the bamboo and valuable timber as the surface plate, cedar and poplar and other valuable trees as the core plate with the bottom plate being rotary-cut single plate. The thickness is 15 mm, surface plate 4 mm, core plate 9 mm, bottom plate 2 mm. We make the stable structure, keeping hard and straight timber, while overcoming the deformation after the floor becomes wet. It is featured with stable dimension, moderate elasticity, durability and convenience in installation. In production world's most advanced equipment, the harmless adhesive of high intensity and the most advanced painting material have been adopted. Thus, the intensity, durability, tenacity, anti-inflammability, water-proof, safety and other indexes are all in agreement with the E1 grade standards of Europe, belonging to the environmentally friendly green construction material. The tolerance of the fine manufactured “Yapu” floor is strictly controlled within 0.03 mm. The surface of the product is smooth and even, reducing the dust coming into the crevice of the floor, and is beneficial for health. The grains are clear, graceful and noble. The high-quality “Yapu” bamboo timber floor has hard intensity, high accuracy, small color difference, no deformation, humidity resistance, no harm, easy installation and maintenance; therefore it is warmly welcomed by the clients. The products are tested as qualified by China Man-made Plate Inspection Center and other Japanese and German inspection centers. So adoption of the high standard technology requirement could make it possible for the company to produce the products of high quality. General Manager Li pointed out: The history of bamboo floor in China is short, only 8 or 9 years from the market orientation period. It is only 4 or 5 years if dated back to the time of mass entry into the market. The man of letters Mr. Su Dongpu once said that “prefer a living with bamboo to having meat for food”. Everyone knows that Mr. Zheng Banqiao loved and painted bamboo. It still takes some time for people to fully accept in concept the bamboo timber floor as a kind of new construction material. So, the market position for the bamboo timber floor is of middle and high level presently. Meanwhile，many customers do not know how to select bamboo timber floor, and also the price of the product is higher than the ordinary timber floor or other compound floor. So, you have to compare and select the best. Some recommendations for the buyers: The surface of fine floor is lustrous, pleasant to the eye. Take the floor to the sunlight and see whether there are some air bubbles, spots or wrinkles. Then observe the processing quality at the bottom and sides. You should also know whether the adhesives and paints used are environmentally friendly or not. General Manager Li told the journalists: “It is a big trend from the timber floor to the bamboo timber compound floor. The consumers will not be satisfied until we are responsible for every piece of floor with high standard and strict requirement. Not only YAPU bamboo timber compound floor of environmental protection will have a bright future，but also the families of the consumers will be filled with warmth.”

YAPU bamboo timber compound floor of environmental protection--- a perfect combination of science-technology and the nature will contribute to your happy life, making you enjoy the freshness and the nature.

5 Selection and maintenance for bamboo floor

Bamboo floor selection:

The surface of fine good-quality floor should be lustrous, pleasant to the eye. Take the floor to the sunlight and see whether there are some air bubbles, spots or wrinkles. Then, observe the processing quality at the bottom and sides. You should also know whether the adhesives and paints used are environmentally friendly or not. The maintenance for bamboo timber compound floor is simple: ventilate the room often and keep the room dry, avoid direct sunshine or rain. Be modest when mopping the floor. Timely maintenance to the floor could keep it fresh and new.

Fresh and natural bamboo wood floor of environmental protection could bring you a green home for a happier life.

Chapter 8 Bamboo Concrete Form

Bamboo concrete form, also called bamboo cement form or bamboo module board sometimes, is made by such processes as splitting bamboo into bamboo strips 0f about 1~2mm wide, weaving bamboo curtain or bamboo mat, drying, applying glue and heat-pressure assembling, it is a kind of structure material.

In this chapter, we mainly study the processing technology of overlaid bamboo-mat-curtain concrete form.

1 Properties

Bamboo concrete form is featured with broad width, good size stabilization and high strength. Its physical mechanics properties are as follows in Fig.2.

Fig. 2 Physical Mechanics Properties of Bamboo-Glued BoardItem

Item			Unit	Quality target
Absolute moisture content			%	5~14
Static strength	Dry state	Vertical	Mpa	⩾80
		Horizontal		55
	Wet state	Vertical		⩾65
		Horizontal		⩾45
Modulus of elasticity	Dry state	Vertical	Mpa	$\geqslant 6.5\times10^3$
		Horizontal		$\geqslant 4.5\times10^3$
	Wet state	Vertical		5.0×10^3
		Horizontal		$\geqslant 3.5\times10^3$
Gluing properyt				No peeling off
Expansion rate of absorbing water thickness			%	⩽5
Surface wear-resistance			Abrasion value (mg/100T)	⩽80
Surface chap-resistance				grade 0~1

2 Processing Technology

The detailed processing is as follows:

2.1 Bamboo Strips Processing

Bamboo strips, basic raw material in producing bamboo module board, its processing contains cutting roots, cutting tops, cutting off, cutting nodes, splitting bamboo strips etc. When cutting off bamboo, the length of every section cut of bamboo mainly depends on length of strips. The basic unit of board forming consists of three forms, vertical bamboo curtain (long bamboo curtain), horizontal bamboo curtain (short bamboo curtain) and bamboo mat. The sizes of bamboo strips are quite different among these three kinds. The first one should leave processing margin of about 120~150mm, while the second 90~100mm. When sawing, make rational arrangement for material used for long and short bamboo curtain in the whole length of bamboo timber to make full use. To avoid the difficulty in passing the nodes during splitting strips, generally, the place for sawing should be about 100mm in front of the nodes. Splitting is to split bamboo into strips in certain width. The common width for weaving bamboo curtain is 10~20mm, but that of weaving bamboo mat is 10~15mm. The split strips should be identical in width as much as possible. After that, remove the inner nodes of the inner yellow layer for easy splitting.

There are two ways to split strips, vertical splitting and horizontal splitting. The first is no split bamboo in vertical direction. The specific strip thickness is controlled by people, but the width is based on the thickness of bamboo wall. Since bamboo timber has degree of sharpness, the width is different in the direction of strips. The nearer to the top, the smaller the width is. Especially in processing vertical bamboo strips, trouble comes in bamboo curtain weaving, because the length is quite long and the difference between the widths is quite obvious. Therefore, when weaving bamboo curtains, bamboo strips edges should be processed alternatively between the two ends to make the wide end and the narrow end to remedy each other to ensure the regularity of the width of bamboo curtains.

The latter one is to split sawn bamboo strips horizontally, then split to strips one by one according to the width required. It is necessary to remove the green surface layer and yellow inner layer. Bamboo strips can be split in equal thickness and unequal thickness. Using the former way, the quality of bamboo strips is quite good and the thickness is nearly equal in the whole length. Hot pressing makes fine contact between layers, high gluing strength, little deviation difference in thickness and great stability quality. The thickness of non equal-thickness strips changes with the thickness of bamboo wall, and the thickness differs in the length direction. The bottom is much thicker than that of the top. In order to reduce deviation in thickness, in weaving and assembling, strips with uneven thickness need to be arranged regularly and high heat pressure is required to ensure gluing strength.

Length and width horizontal bamboo strips are decided by that of bamboo strips. The width of strips is generally 10~20mm. If the bamboo is of small diameter, the strip width shall be small, vice versa, that is to raise utilization ratio. The thickness of strips is 1.2~1.5mm. In pressing the thick board, the thickness of the center layer of strips can be 1.5~2.0mm. In producing bamboo curtains, the distortion of the bamboo strips can be reduced in drying. If the bamboo curtain veneer is quite regular, the amount of glue can be saved to save the cost.

The thickness of horizontal strips for bamboo mat should be small, commonly 0.6~0.7mm, so the bamboo mat can have quite good plasticity and elasticity with very smooth surface.

2.2 Bamboo Curtain and Mat Weaving

The width of strips is only 10~20mm due to the limitation of special properties, such as the hollow core and small diameter grades. In order to make up the board base, the strips should be joined with narrow width to form “single board”. At present, in some ways, the connection can be made by cotton thread, linen thread or blended thread to meet the demands. In accordance with the different fiber directions in the board base, bamboo curtains can be divided into vertical and horizontal bamboo curtains. The former is woven with strips opposite to the length direction: the fiber is parallel to each other and the same as the length direction. The width of weaving is decided by width of product, 60~80mm is left as processing margin. On the other hand, the fiber direction of horizontal bamboo curtains among thin strips is not only parallel to each other but also in the same direction as the width. The weaving length is decided by width of product, 100~120mm is left as processing margin.

There exists crevices between strips in both vertical and horizontal ones. If the product is used as the board surface, the influence caused by the crevice will lead to unsmooth surface even can't meet the requirement of concrete construction. Presently, the surface material of board is bamboo mat woven with strips. The surface bamboo mat is woven crisscross with thin bamboo strips of 0.5~0.7mm thick. Though it can't reach the smoothness of wood board, after high-pressure hot pressing, it can basically reach certain smoothness to meet the project requirement.

Bamboo mat is woven with strips in certain connecting way. The vertical strip is perpendicular to the horizontal strip in weaving and bamboo mat is formed by "up" and "down" interweaving, which can be divided into "up and down one by one", "up two and down two" etc. The former one is that horizontal strip is down contact to vertical strip, making the bamboo mat grain fine and closer. There should be a back strip and twisted side of about 20cm near every corner of four edges to prevent bamboo mat from loosening and maintain the close structure. The width of thin bamboo strips used for weaving bamboo mat is 10~15mm. After weaving, drying is necessary to prevent the mat and curtain from getting moldy.

2.3 Bamboo Curtain and Mat Drying

There are a lot of crevices in bamboo timber. The pipe made up by innumerable cell cavities linking up to each other, forming big a capillary system of bamboo timber. When divided steam voltage on the water surface among big capillary approaches or equals to that on the surface of free water, this part of water can be evaporated as the water on the surface of free water. The water which can hardly be controlled by the big capillary system is called free water. Part of water lying in small capillary system is made up by gaps within the cell wall. The diameter of small capillary is small, while the controlling strength is strong. The water which can be evaporated into the air when the temperature is reduced to certain degree or the outside is heated is called combing water or absorbing water. The amount of water in bamboo timber is the sum of free water and absorbing water.

Drying bamboo timber includes conducting heat energy from the surface to the inside to cause the inner water to move to the surface which then evaporates in the air. At the beginning of drying, heat medium conducts heat energy to bamboo timber to heat the surface of bamboo timber, where water evaporates because of heating, so water reduces gradually and forms moisture content gradient in the width direction and relevantly steams pressure gradient. Under the comprehensive effects of moisture content gradient, steam pressure gradient and heat energy passed to the inner part of bamboo, water moves to the surface and evaporates continuously in the air to decrease moisture content.

The main factors influencing the speed of drying bamboo curtain and mat are drying temperature, relative humidity of drying medium, speed of airflow and first moisture content of thin bamboo strips etc. Drying temperature refers to the temperature of heat medium during drying, the major factor affecting drying speed. In weaving bamboo curtain, thin bamboo strips are quite thin in thickness and quite narrow in width, but does not easily cause drawbacks such as distortion and cracking etc., therefore high-pressure and quick-speed drying technology are utilized. Drying is started in the way of heat convection changing. In drying, heat medium conducts heat to bamboo curtain and mat. On the other hand, water evaporated from the surface of bamboo strips should be taken away. The quick-speed airflow can promote heat medium conducting heat energy to bamboo strips and take away water evaporated from bamboo strips to accelerate the airflow speed. In addition, it helps conducting heat and evaporating to raise the drying speed.

Nowadays drying equipments in producing board are periodicity drying room and continuity net band drying machine. The former is mainly used for drying wet bamboo curtain and mat, the latter for immersed glued bamboo curtain and mat. These two can adjust drying technology to ensure the drying quality.

2.4 Glue Spreading

Bamboo board lies in the open air for longtime use, so it should suit all kinds of abominable weather. And it requests more for physical mechanics properties such as water tolerance and size stabilization. The glue used for bamboo-glued board should have good water tolerance to keep its gluing property in utilization.

To improve the surface quality and the physical properties of bamboo board, glue should be spread on the board surface to form resin coating paper to enhance the smoothness, brightness and wear-resistance etc. The original paper of coating paper is the bleached or non-bleached sulfate wood pulp, with amount of 80~120g/m^2. The original paper is regarded as glue carrier on the bamboo board surface, making certain amount of glue being applied to the board surface evenly through the original paper to form continuous and even gluing coating. This can increase the brightness and cleanness, wear-resistance and physical and chemical property of the surface. Integrated glue drying technology is utilized continuously in the immersing drying machine. At present, the scale of production line is quite small and the demand of the gluing coating paper is not much, so vertical immersing drying machine can satisfy the requirement of processing. After immersed in glue, great amount of glue permeates into the crevices and fiber inside the original paper, as a result, the gap broadens, fiber expands, but tensile strength of the original paper decreases greatly, the original paper surface is stuck by glue completely. The next is drying in the drying room. Drying room of vertical drying machine is composed of 2~3 separated drying rooms. The temperature in the drying room from higher to lower can be divided into three states: the lower part is 60~80℃; the middle part is 80~100℃; the higher part is 100~130℃. The temperature distribution is determined by drying technology of gluing paper. Before drying, heat the air in drying room first, then heat the immersed glue paper to get rid of the volatilization element. Since drying room of vertical drying machine is quite tall, the height of whole machine can reach 6~10m and air convection can basically discharge the volatilization element from the immersed glue paper. After drying, the amount of resin absorption in immersing glue paper occupies 40%~60% of the weight of the original paper. The volatilization content is controlled within 15%~20%. Apart from that, control the change rate (within 10%~20%) from first resin to the middle one, that is, middle resin covers a small portion of all, most resin is still kept in the first state to ensure good mobility and high gluing strength in hot pressing.

2.5 Assembling and Hot-pressing

Assembling refers to glue coating paper and bamboo curtain and mat, after immersing drying, compose board base with certain layers and width according to certain principles. Bamboo timber, the same as wood, is a kind of material of anisotropy. In assembling, make sure layers of board base and width should meet the demands of the customers. The raw material of bamboo timber is mainly in three forms: long bamboo curtain, short bamboo curtain and bamboo mat. The long and short bamboo curtains have the same weaving form, but the different sizes of bamboo strips, the arrangement direction of which inside the board is mostly alike. In order to guarantee high static strength in both the length and width directions, the layers of long and short bamboo curtains should be arranged rationally. In assembling, follow the symmetry rule and odd number layer rule. The former one requests that all kinds of bamboo curtains and mats, the width and layers of thin bamboo strips at the both sides of symmetry center should be exactly the same; this is the basic requirement to ensure size stabilization of product. The different structures of product’s symmetry side will lead to difference in board base’s strength-endurance, conducting heat and water evaporation situation etc., during hot pressing. If the board is taken away from the hot pressing machine, it will distort and bend quickly. In using the product, due to water-absorption, moisture-absorption and drying etc., the direction of dry-shrinkage and wet-expansion inside bamboo curtain and mat will bring about differences, causing quite great internal stress; therefore, glued bamboo board will distort and bend. The odd number layer rule is that the number of the board base layer is odd in assembling to make the board base symmetry center on the middle bamboo curtain, so as to endure the strong cutting strength.

There are mainly three forms of board: rough board, single side coating board and double-side coating board. The first one is made up of bamboo mat, long and short bamboo curtains. Bamboo mat lies in the upper and lower surface of board base. Without glue coating paper, brightness and cleanness, smoothness and wear-resistance on the surface are inferior. One surface of single side coating board and rough board is covered with glue coating paper, but the other side will still keep naked. This structure destroys the symmetry of board.

Double-side coating board is produced in the following steps: Cover one or two layers of glue coating paper on the upper and lower surfaces of glued bamboo board, this is mainly the product of this structure in processing glued bamboo board. After hot pressing, glue coating paper forms continuous layers of glue coating with certain thickness on the two surfaces of the board. The layers of glue coating close two surfaces of bamboo-glued board completely to smooth two surfaces of board and keep good water-resistance, wear-resistance and mold-resistance to ensure fine usage property of the product.

The board base after assembling should have pre-pressing to make it shrink to certain degree. Since bamboo curtain and mat distort unavoidably after being immersed in glue and drying, this contorted thin bamboo strips can support each other to strengthen the board base. For example, in producing glued bamboo board of 110~120mm thick, the thickness of board base commonly can reach over 100mm and the great thickness of board base and rough surface bring difficulties in feeding board into the machine. The board base in feeding the board can be destroyed easily, but after pre-pressing, the originally loose board base becomes close. The pre-pressing can be done in the way of cold pressing, and the interval height of pre-pressing machine is 1~1.5m, the maximum unit pressure is 1.5~2.0Mpa, the time is 10 minutes.

Hot pressing is the most important process in producing board. In hot pressing, under the combined effects of high temperature and pressure, water, glue and bamboo timber within the board base will lead to a series of physical and chemical changes, making the loose board base turn into firm glued bamboo board with certain surface quality and physical chemical properties. To guarantee the product quality, technology of “cold in and cold out” is applied in hot pressing, that is, when board base is fed into heat pressure machine, the temperature of hot pressing board is about 50℃, then heated by steam. The pressure of pressure machine reaches the highest as requested when board is completely fed. At the same time, when heating is continued, time needs to be counted for heat preservation when the temperature reaches that as demanded. The temperature of hot pressing is generally 130~150℃ and length of heat preservation is related to the width of product.

The more the width is, the longer the temperature of heat and pressure preservation is. Then, the pressure of hot pressing should maintain stable. Next shut the in-come steam valve in the pressure machine, get rid of steam within hot pressing board and feed cold water into hot pressing board to force it to be cold. When the temperature of hot pressing board is reduced to about 50℃, the pressure decreases.

Bamboo timber is a kind of elastic material. In heat pressing, under the simultaneous influences of heating power and pressure, moisture content of strips in the board base is still 15%~25%, twice after being immersed in glue and twice drying. Under high temperature, certain plasticity distortion will occur to the strips, but with the heat pressure, the bamboo strips are closely connected and their gluing and raise gluing strength will be strengthened.

The time for hot pressing refers to the time when the temperature of hot pressing board reaches the temperature preservation requested to the end of pressure preservation. The time is decided by glue properties, hot pressing temperature, width of product and moisture content of product. The more the width of product is, the longer the time of hot pressing is required. Due to weak heat conduction of bamboo timber, the heat conducting speed is slow in the board base. The more the width is, the slower the speed is. In hot pressing, the major factor influencing its process and quality of product is the heat pressure, temperature and time, which influence and restrict each other. Rational determination of heat pressure ensures the gluing strength of board.

2.6 Product Finishing

It includes edge cutting, edge sealing, testing and grading, and storing etc.

Temperature difference exists in rough-edged boards unloaded from heat pressure machine. In order to ensure board stabilization in the shape and size, pile the rough-edged boards unloaded from the heat pressure machine for certain time to make the temperature inside and outside the board same, then cut the edge till the size and shape tend to be stable. Edge cutting can be done in edging machine. Because of the hardness of bamboo timber, saw blade must be alloy and the saw teeth should be sharp. After sawing, two nearby edges should be perpendicular, with regular and smooth edges. To enhance water-resistance of board, urac resin shall be applied to seal the edge of the board.

3 Application and Problems

3.1 Application

As a new kind of construction formwork replacement of wood and steel, bamboo concrete form has been developed into such three series as the plain bamboo plywood form, the middle-grade coating form and the high-grade double-coating plain bamboo-plywood form after almost 20 years' research, with the development and large-scale production, the bamboo concrete forms are widely applied in the building industry and have been unanimously accepted by the professionals. Bamboo plywood formworks are extensively adopted in many national key projects such as Beijing Oriental Square, the Capital Airport, China Millennium Monument, Yangpu Bridge in Sanghai, Tianhuangping Pumped Storage Power Plant in Anji County etc. The Ministry of Construction has listed bamboo concrete form as one of those 10 new technologies for popularization, and the State Development Planning Commission also encouraged the development and investment on the bamboo-oriented building materials to its utmost.

3.2 Problems

Quality

The product qualities are various and unstable. Though the Ministry of Construction promulgated the professional standard, not all the factories are seriously sticking to these regulations. In some enterprises the poor management and quality have impeded the healthy development of the bamboo concrete form.

In processing the bamboo concrete form, the raw materials shall be treated once by hot-pressing to have a fixed shape and structure, so its surface evenness and thickness tolerance are much different. After it has been processed to be the formwork with steel frame, there would be some joints and split levels between the steel frame and the plate surface, and between the steel frames, it shall affect negatively the quality of concrete surface, and that’s why the export is restricted.

Cost

With the fast development of bamboo industry and the increase of petrol price, the raw materials for manufacturing bamboo concrete form such as bamboo timber and glue are becoming more and more expensive; meanwhile, the product price has only increased slightly.

Nailing

Because of the hardness of bamboo concrete form, it can be used repeatedly, but it will also bring some trouble, one main trouble is difficulty to nail.

Chapter 9 Bamboo-based Panels

Bamboo-based panel is a kind of pressed and glued plank material taking bamboo as the material by mechanical and chemical processing under a proper temperature and pressure.

Bamboo timber is featured with many advantages such as rapid growth, high yield, early maturing, fine property and versatile usage meanwhile compared with wood, it is of high strength, flexibility, and abrasion-resistance. Big-sized bamboo board made of such kind of bamboo, not only inherits characteristics of bamboo timber itself, but also improves its defects, such as small diameter, central hollowness, high tapering grade, good uneven structure, and directional properties. Bamboo-based board with merits as big size, high rigidity, strong abrasion-resistance, its size and structure can be easily adjusted according to usage demand, is a desirable engineering structure material. Its exploitation has enhanced utilization value of bamboo to certain extent.

1 Characteristics of Bamboo

Like wood, bamboo is a natural organic substance, and falls into the category of heterogeneous and directional material. Because of some differences in its outlook, structure, chemical composition with wood, it has the characteristics of high strength, big flexibility, good rigidity and easily processed etc. Bamboo's fundamental traits can be concluded as follows.

(1)Easily cut and processed, versatile usage

Bamboo has straight grain, and can be split into strips by simple tool as thin as several microns and can be woven into various implements for art, furniture, farming, and daily use. Meanwhile, fresh bamboo can be bent into various unique bamboo products, besides, bamboo has light color, and it can be bleached and dyed.

(2)Small diameter, thin wall, hollowness, high tapering grade

It can not be sawed into board, plank like wood. Bamboo diameter grade is smaller, even Moso (Phyllostachys pubescens)which has high economic value in China, its diameter at breast height is mostly 7 to 12 cm. Bamboo has thin wall and hollow center and taped from bottom to top in diameter and wall thickness, e.g. tapering grade for Moso is 7.2 to 8.

(3)Uneven structure

Three-layer structural difference of bamboo results in their distinctive variations in density, moisture content, dry shrinkage rate, intensity, gluing property, etc., which influence bamboo processing and utilization negatively.

(4)Directional properties

Due to the only vertical and parallel orientation distribution of bamboo vascular bundles without any transverse linkage, bamboo intensity is high in latitudinal direction, but low in longitudinal one. What's more bamboo is prone to crack, into cleavage. In general, the intensity ratio of the latitudinal to longitudinal is 20:1 for wood, but 30:1 for bamboo. Furthermore, physical, mechanical properties and chemical compositions of bamboo timber vary so much with different positions and directions; all those altogether render many unstable factors in processing and utilization of bamboo.

(5)Susceptibility to attack by moth, mold, and fungus

Bamboo contains richer nutrients than those in the wood, which are also nutrients for some insects, microorganisms, among which protein is 1.5 to 6.0%, sugar about 2%, starch 2.0 to 6.0%, fat and wax 2.0 to 4.0%, so bamboo is vary prone to be attacked by moth, mildew and fungus during transportation, storage, in case of unfavorable temperature and moisture.

(6)High transportation costs and difficult long-term storage

Bamboo has thin wall and hollow center, so outlook volume is much bigger than the real one, so truck's loading capacity is low while the transportation costs are high, so it is not suitable for long-distance transportation. Bamboo timber is susceptible to attacks by insect, mildew, fungus and crack, so it does not have a long span of storage indoor and bamboo cutting is season-limited. Form March to April, cutting is banned.

To sum up, bamboo morphological and structural features are major bases for technical analysis of bamboo industrial processing and utilization. And bamboo inherited defects greatly restrain bamboo usage in weaving, raw bamboo pole, or preliminary products by simple processing, as a result, industrial exploitation and utilization of bamboo has not been formed.

2 Properties of bamboo-based panel

For thousands of years, raw bamboo timber or simply processed bamboo timber have been used in agriculture, fishery, construction, living utensil weaving, farm implements and traditional handicrafts. Now the so-called bamboo-based boards have both some similarities and differences from wood-based panel, but compared with wood-based panels it has some special properties as follows:

Big width, small deformation, stable size;

High strength, fine rigidity, strong abrasion-resistance;

Size and structure can be changed and adjusted according to usage demands;

Rather preservation;

Some improvement of bamboo directional properties;

Surface finishing and coating are available to meet different requirements.

2.1 Physical properties of bamboo-based panel

Moisture content

Moisture content of bamboo plywood is indicated by the value of absolute moisture rate. It is measured by temperature and moisture adjustment after bamboo plywood is stored for a period of time in room temperature since they are taken off from the hot-presser. It can be calculated by the formula below:

$$H = \frac{M_H - M_0}{M_0} * 100$$

H: Absolute moisture rate of sample (%);

M_H: Sample weight once sampled (g);

M_O: Dry weight of sample once dried into an absolute dry state (g).

As usual, it should be lower than 10% for phenol formaldehyde resin bamboo plywood, and 12% for urea formaldehyde resin one.

Density

Density is defined as weight per volume, and can be calculated by the following formula:

$$\gamma = \frac{W}{V}$$

γ : Sample density (g/cm^3);

W: Sample weight once sampled (g);

V: Sample volume once sampled (cm^3);

Dry shrinkage or swelling rate (%)

$$H = \frac{h_2 - h_1}{h_1}$$

H: Sample dry shrinkage or swelling rate (%);

h_1: Sample length before wet or dry (mm);

h_2: Sample length after wet or dry (mm).

Specific heat and heat conduct coefficient

The density of bamboo is higher than that of wood. Hence, specific heat and heat conduct coefficient are higher than those of wood plywood in the same category.

2.2 Mechanical properties of bamboo-based panel

Static bending strength: MOR

It refers to materials' endurance capability of bending force, and can be measured by the formula below:

$$Mor = \frac{3 \cdot P \cdot L}{2 \cdot b \cdot h^2}$$

MOR: Sample static strength (Mpa);

P: Sample destruction loading weight (N);

L: Distance (mm);

B: Sample width (mm);

H: Sample thickness (mm).

Gluing strength/shear strength

It expresses bonding intensity of glued material, and is indicated by loaded shear force on its glue surface.

$$\tau = \frac{P}{A \times B}$$

τ : Sample gluing strength (Mpa);

P: Maximum loading breaking weight of sample (N);

A: Sheared surface width of sample (mm);

B: Sheared surface length of sample (mm).

Impact flexibility

It is the absorbed energy of material per area when the sample is broken down from impact load. It can be calculated as follows:

$$T = \frac{A}{b \cdot h}$$

T: Impact flexibility (J/cm2);

A: Sample absorbed energy (J);

B: Sample width;

H: Sample height (cm).

Modulus of elasticity: MOE

It measures material rigidity, and stands for:

$$MOE = \frac{1}{4} \cdot \frac{\Delta P \cdot L^3}{\Delta f \cdot b \cdot h^3}$$

MOE: Material modulus (Mpa);

L: Distance (mm);

B: Sample width (mm);

H: Sample thickness (mm);

$\frac{\Delta P}{\Delta f}$: Acclivity rate of loading-deforming curve within a proportional limit.

3 Structure Principles of Bamboo-based Panels

Symmetric structure principle

This principle must be complied with the production of various artificial boards. It means that components of each side such as species, grain direction, and moisture content along the center layer of cross-section of the board must coordinate each other. Only under such conditions, the stresses located at two sides of the center layer are equal during processing and utilization. Although the moisture content in the board gives birth to change, it cannot result in deformation and cleavage of board owing to this symmetric structure. For bamboo plywood, the thickness of bamboo strips, layers, ratio of parallel and perpendicular layers at two sides of center layer should be coordinate (Fig. 2).

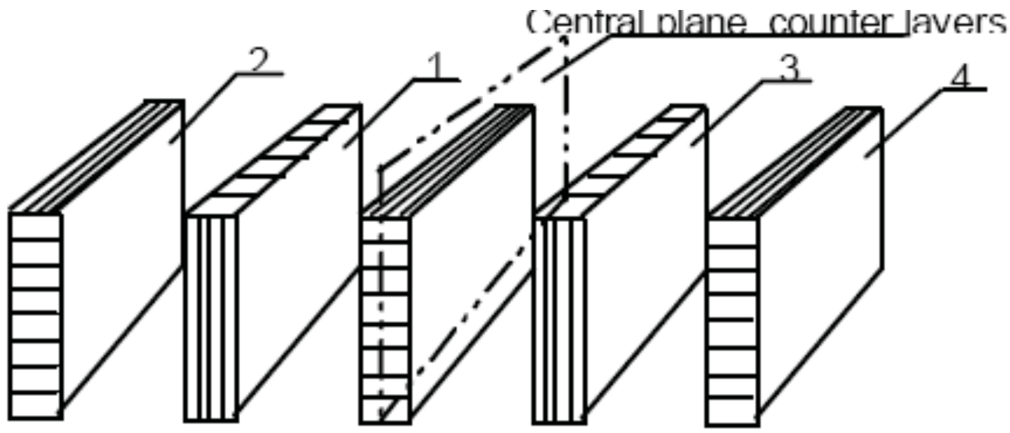

Fig.2 Central plane and counter layers of five-layer plybamboo

(1 and 3 symmetry, and 2 and 4 symmetry)

The plywood is a board shaped product based on bamboo timber, which has experienced a series of mechanical and chemical processing and pressing together under certain temperature and pressure by adhesive binding. It has such characteristics as broad width, good rigidity and stable size etc. In addition, the structure and size can be adjusted based on requirements and it is deemed as ideal engineering construction material.

Surface forming method

Since the strength of bamboo wall gradually decreases from the outer layer to the inner layer, the outer portion of the wall is used on board surface to enhance the strength and abrasive resistance such as bamboo plywood, bamboo curtain board and bamboo flooring. Bamboo based-panel is usually used as engineering material, thus the largest stress appears at the surfaces when it is loaded.

Structuring principle of equalization stress

This principle is mainly used to design composite board of bamboo and wood. Usually, when a board is loaded, the dominating bending stress occurs on its surfaces, and the maximum shear stress exists in the central layer of inner material. To enhance the integrated strength of a board, with the stress distribution, we should select parallel bamboo strips as the surface material and wood board or veneer as the inside material that is placed across each other or paralleled. Meantime, we should lay thin wood boards or veneers near the central layer, or make a full superposition of central layer and wood so as to strengthen the shearing resistance. In this way the composite board of bamboo and wood is almost equal to bamboo boards in strength and abrasive resistance. Furthermore, this composite board is lower in cost and density than that of bamboo-based panels, and also easy to nail as well (Sun 1999).

4 Component Unit and Classification

4.1 Component Unit

Bamboo strips

Two kinds of strips are often used in gluing, lying up, and hot pressing. In addition, its parallel production of bamboo-based panel (Fig.1) has perpendicular strength and property and can be assigned with the arc strips with certain length softened in high temperature. After the bamboo strips are flattened, they are then planed at both outer and inner parts. Through 20 years' development, in China the bamboo-based panel has been increased not only in types of surfaces to form a strip of 60-80 mm in width and of products but also in productivity. 3.0-7.0 mm in thickness with cracks on its surfaces, particularly on the inner surface. The other is called saw-planed strip which is obtained by sawing a culm into many strips of 20-30 mm in width which then are planed.

Bamboo sliver

Since bamboo is easy to split along longitudinal direction, a narrow strip is split into several layers according to the thickness of bamboo wall to produce bamboo slivers (width 10-20 mm, thickness 0.8-2.0).

Bamboo particle

Small-diameter culms, irregular culms, and various residuals of bamboo processing can be roller-pressed, cut, and planed to form needle-shaped particles.

4.2 Classification

In chapter four and five, bamboo flooring and bamboo concrete form named according to application have been studied. In order to study the processing technology of bamboo-based panels, classification of the products according to the component unit and processing methods will be very reasonable.

4.2.1 Bamboo Plywood

This is about the special property of bamboo which is being easily chipped along the direction of bamboo fibers into several layers of the generally fixed thickness. These layers are thin bamboo chips with fairly small width. The main products from these bamboo chips (strips and slivers) include:

(1) Bamboo mat plywood

Split bamboo culms into strips of 1~2mm in thickness to be woven into bamboo mats, then apply adhesive after the mats are dried.

Bamboo mat plywood is usually glued from 2~5 bamboo mats. Most of the products are thin boards. Ordinary bamboo mat plywood is mostly glued and processed from rather thick and wide coarse bamboo mats. Thin bamboo boards are mainly used as packaging materials for the ceiling of railway vans, while the thick boards can be used as structure materials, e.g. cement moldboards and carriage floorings, etc.

Skin splitting and mat weaving in producing bamboo mat plywood can all be decentralized and scattered as household side-line industry in the rural areas. No complex mechanical equipment is necessary. However, small diameter bamboo culms of Phyllostachys heterocycla cv pubescens and other bamboo species can be utilized. In other word, the sources of raw materials are rather multiple and diverse.

Bamboo mat plywood producing is most appropriate in areas that are still economically underdeveloped and where the bamboo species are mostly of small diameter culms (e.g. Neosincalamus affinis). In China, there are quite a number of bamboo mat plywood factories in Sichuan, Hubei and Zhejiang provinces. But in particular in Sichuan province, the total yearly production is about 20,000~30,000m^3.

(2) Bamboo laminated plywood (or bamboo skin-laminated plywood)

For this product, bamboo is split into skins which, without weaving but direct application of adhesives instead, are dried to a certain ratio of water content, and then it can be woven into the mat. With application of thermal compression on the mat, the boards processed in this way are called bamboo laminated plywood. Most of the skins in bamboo-laminated plywood are matted in vertical arrays and phenolic adhesives are used as glue. The products are mainly thick boards used for structure timber/materials.

All the bamboo skins used in bamboo-laminated plywood must be soaked in the glue. During hot pressing, with the high requirements for the unit pressures, therefore, the density of the products can be above 1.0. As the skins are matted latitudinally, the longitudinal MOR is equal or greater than 100 MPa, whereas the MOR in the latitudinal direction is rather low.

Presently, such laminated plywood is mainly used as strip boards needed on the bottom of Dongfeng 141 trucks and as bottom boards and caul plate in the railway vans. The processing of bamboo skins needed for the laminated plywood is scattered in many farmer households as a kind of family sideline industry, however there are no specific requirements for the bamboo culm diameter. Presently, there are several dozens of bamboo laminated skin factories in Zhejiang, Jiangxi, Sichuan，Hunan and Hubei provinces etc. with an annual production capacity of 20,000~30,000 tons.

(3)Bamboo curtain plywood

As a means to simplify the processing of bamboo weaving, bamboo skins can be placed in parallel arrays and woven into a whole bamboo curtain with strings. Then the bamboo curtain is dried and applied with adhesives (either spreading or soaking), matted and pressed to get the final bamboo curtain plywood. When the surface processing and weaving have been both delicately done, after hot pressing, gluing and polishing, the final product can be nice-looking, intensive and strong bamboo curtain laminated plywood. Due to the requirements for specific uses, the thickness of bamboo skins can be reduced, the matting pattern varied, so that the bamboo curtain laminated plywood produced can cater multiple uses.

(4) Bamboo plywood (composite plywood of bamboo mats and curtains)

Bamboo mats (spread or soaked in glue) are taken as the surface and bottom layer and bamboo curtain as the core layers (also spread or soaked with glue). These layers are matted in perpendicularity one with another and then hot-pressed. Due to the needs, a layer of (melamine-phenolic resin) melamine-impregnated paper can be added to the bamboo mats to get the final product-bamboo plastic weaving and curtain plywood. This product is mainly used as cement moldboards in construction.

Special staff can be designated for collection and purchasing of the mats which then will be sent to the factories for the rest of the processing: drying, glue soaking, matting, hot pressing and residual cutting off etc. Only simple equipment is needed and the products can suffice the requirements of construction moldboard. There have already been several dozens of such factories mainly distributed in Hunan, Hubei, Jiangxi, Zhejiang and Jiangsu provinces, etc. Generally called glued bamboo moldboard, it is the dominant product of the cement moldboards in the construction market in China whose total annual production is projected at about 300,000m^3.

4.2.2 Bamboo Particleboard

(1) Bamboo particleboard

In accordance with the production principles of timber particle boards and the purpose of raising the utilization rate of bamboo timber, the raw materials such as small diameter bamboo species, miscellaneous bamboo species and sheath of Phyllostachys heterocycla cv pubescens and the residuals from various types of bamboo products can be roller-pressed, chopped and sliced, and then dried and spread with glue and loaded into molded shapes. After hot pressing, the final product is the bamboo particleboards.

The sources of raw materials for bamboo particle boards is extensive: not only various types of small diameter miscellaneous bamboo species, but also the residuals from bamboo logging and processing of other bamboo products all can be utilized at a high utilization ratio. In most cases, 1 m^3 of bamboo particleboards can be produced from 1.3 tons of raw materials. The workmanship and processing techniques are similar to those of the (timber) particleboards. This is virtually one of the products worthwhile for raising the comprehensive utilization of bamboo materials as well as raising the economic efficiencies of enterprises specialized in bamboo products production.

Bamboo particleboards applied with phenol adhesives possess high intensity, high modulus of rupture (MOR) and minimal water absorbing inflating rate. If necessary, bamboo curtain or mats can be reinforced onto the internal layers or surfaces of the bamboo particleboards to meet the diversified requirements and there are broad prospects for utilization.

(2) Reinforced bamboo particle board

In order to reinforce the intensity of bamboo particle boards, bamboo curtains can be added in the particle boards (an equivalent of bamboo consolidation) to improve its physical properties.

(3) Plastic bamboo particle board

To increase the surface polish and brightness of templates of bamboo particle boards and to reduce the water absorbing rate, a layer of melamine/or phenol adhesive impregnated paper can be laminated on both of the surfaces of bamboo particle boards.

Reinforced plastic bamboo particle board

Cover the two surfaces of bamboo particle board with melamine/or phenol adhesive impregnated paper for decoration.

4.2.3 Bamboo-based composite

Although China is a mega-bamboo country and its bamboo yield, equivalent to that of 6.5 million m^3 of timber, ranks the first in the world. This figure, however, is merely 6~10% of the annual timber consumption in China. The absolute quantity owned is still rather limited. Along with the constant industrialized utilization of bamboo timber, the contradiction between the supply and demand of bamboo timber is looming large in manifold magnitudes and the prices have also been rising in large margins. The present prices have been raised 5 times compared with those in the beginning of the 1980s, whereas the prices of steel and timber in the same period presented a declining tendency, posing direct negative impacts on the market competition of the bamboo-based industrial products. On the other hand, when used as structure materials, the surface materials carry the major external forces; therefore, the surface materials for either structure or decoration materials are both the dominant determining factors of the product performances and qualities. Out of the considerations of sciences underlying the processing techniques and structures, composite structures of bamboo and timber should be used to replace the pure bamboo structures. Based on this scientific justification, some products, e.g. container flooring of bamboo and timber composite panels, floor panels and bamboo-wood laminated boards, etc. have been developed.

(1)Bamboo-wood composite

To have the bamboo-wood composite, phenol impregnated paper, bamboo mats and two bamboo curtains are taken as the surface and backside materials and several timber laminates are filled as the core. Have matting and hot pressing to produce bamboo and timber composite container floor panel meeting the specific requirements in durability, intensity and rigidity. The density of this product is lower than 85, and MOR>80MPa, and MOR>1000MPa (No indication of which is the latitudinal or longitudinal MOR)

(2) Bamboo-wood laminated composite board

Bamboo curtain plywood is taken as the surface and backside materials while several layers of sawn lumber of 10~15 mm in thickness are used as the core laminated mat to become core plywood. This product is now being tested as floor panel on railway freight carriages. With the intensity and durability of bamboo timber, this product also possess high nail-grasping power but at low production cost.

(3) Bamboo-wood laminated board with hollow structure

In order to reduce the weight of bamboo-wood laminated composite boards while maintain adequate rigidity, hollow structure is introduced into the production. Presently experimentation is underway on the construction scaffold boards.

(4) Bamboo and spruce composite floor panel

Thin bamboo chips are taken as surface and backside materials and spruce mosaic boards, after matting and gluing, the composite boards produced have both the exterior textures of bamboo timber and the physical properties of the wood.

High intensity bamboo gluing templates

Polished, bamboo-wood plywood or bamboo curtain plywood with fixed thickness are taken as the base materials, and wood laminates and impregnated paper as the backside and surface layers. Adhesives should be applied in matting and hot-pressing. This produces bamboo gluing templates with high intensity, brightness surface feel, is an elite product in templates in China.

5 Processing Technology of Bamboo plywood

5.1 Processing with Soften-flatten Technology

5.1.1 Flow chart

The process of manufacturing bamboo plywood with soften-flatten technology is as follows:

Bamboo selection →cutting → removing outer nodes→ splitting→ removing inner nodes →water boiling → softening under high temperature →spreading flat→ roller pressing →planning yellow inner layer →planning green surface layer→ pre-drying → drying and shaping → sawing edge →applying glue→ combining → pre-pressing → hot pressing →longitudinal and crosswise edging →inspecting→ storing

This technology can gain bamboo strips with maximum width to reduce the quantity of adhesive using and the bamboo plywood with high strength and small errors in thickness, which can be regarded as ideal construction timber.

5.1.2 Material preparation

Strip board needs to have bamboo with diameter of over 9cm and others of big diameter (such as dragon bamboo, hemp bamboo) as the raw material, bamboo is widely distributed and also with rich storage, thick diameter and bamboo wall. Bamboos are regarded as the main material for bamboo plywood.

The growth of bamboo can be divided into three periods: the enhancing period, the stable period and the dropping period. The enhancing period is generally about the young and strong bamboo of 4 to 5 years old. In this period, the density of bamboo increases quickly, water content reduces and mechanical strength rises; in the next period, the density and mechanical strength are stabilized at the highest level, and bamboo is of 5 to 8 years old, the last period is the aging period, when the growth declines, the density of bamboo timber and mechanical strength drop gradually, during this period, bamboo is of 9 to 10 years old. According to this growth rule, bamboo cutting not only benefits the cultivation of bamboo forest, but also the growth of the bamboo timber with high quality. So harvest shall be carried out in the stable period. The quality of the young bamboo is worse than that of wood while the physical, mechanical properties are poor, so it is difficult to guarantee the quality of bamboo plywood. But, for the older bamboo, it not only extends the cutting cycle, but also decreases the utilization rate of bamboo, the tenacity and elasticity fall down for the older bamboo, which will affect the quality of bamboo plywood if used as the basic material.

The cutting season closely relates to the growth and quality of bamboo. In the growing season, the physiological metabolic movement is exuberant and bamboo cutting at this time will cause great harm, influence to the growth of bamboo without any benefit to the renewing and development of bamboo, so it is unsuitable to cut bamboo in the growth season. Due to the seasonal phenomenon, the factory should preserve certain amount of raw material to guarantee the balanced production.

5.1.3 Processing of bamboo strips

The processing of bamboo strips generally contains cutting, removing the nodes, splitting, softening, spreading flat, planing and drying.

a. Cutting bamboo culm

It refers to cutting the long bamboo into small bamboo of certain length according to the size requirements. In cutting, it is necessary to determine the cutting position properly according to the tapering degree and bending degree of raw bamboo to make full use of the bamboo.

Cutting should begin from the roots to the top in turn. At first, cut the bamboo into crooked shape. Because from roots to about 1.5m in height, the bamboo diameter is big, so to raise the utilization rate of bamboo, generally, the first section of raw bamboo should be cut into short ones, but the second and third cuttings should be into long parts, leaving enough processing margin for production.

b. Removing nodes and splitting

To raise the processing quality of spreading flat and planing, it needs to remove the protruding part in the knots. Outer knots can be eliminated by machine, which will be greatly decided by the knife tools on the machine. The arrangement of the vascular bundles is in good order, crosswise combining strength is small, so the splitting is quite convenient. In addition, according to the diameter of raw bamboo and requirement of producing technology, bamboo cutting machine is used to cut different pieces. Removing the inner knots can keep the inner wall smooth, and satisfying spreading effects can be reached.

c. Softening bamboo pieces

The bamboo diameter is generally small, but the curvature is quite big. To spread the semicircular thick bamboo tube, the pressure to the outer surface and inner dragging strength to the inner surface are quite big, generally, the former is big while the latter is poor. When being spread flat, the extending strength is much more than the crosswise strength, so the piece surface is apt to causing crevice and crack. To reduce the width and depth of that, new method, i.e. bamboo pieces softening should be adapted.

Bamboo timber is the substance with hot bending. With present technology, raising moisture content and temperature for bamboo is very effective to reduce the dragging strength in spreading.

Bamboo timber is usually kept soaking in hot water at 70~80℃ for 2~3 hours consequently, its moisture content will increase and the initial temperature will be procured. During the course of immersion, many substances will be extracted which can build up bamboo's capability of anti-corrosion and anti-pest.

Bamboo timber has amount of fibers inside, after being macerated in hot water at 140~150℃, the bamboo wood will be made more ductile.

d. Flattening bamboo splints

It is to flatten those semi-circular bamboo tubes under pressure after their being boiled and macerated in hot water. We can put these tubes into a single-layer or multi-layer pressing machine and finish flattening once by pressing in order to continue the following production procedures.

e. Chipping and planing

The green surface layer and yellow inner layer have moisture to adhesive. But chipping and planing can be of much help. In addition, two edges of bamboo are irregular, error gap in thickness becomes worse if the bamboo is longer, and plane them to be equally thick will guarantee minor thickness defect and better bonding strength.

f. Drying bamboo strips

The bamboo moisture content is much higher after being boiled in the hot water. After being flattened and chipped, moisture content is still around 35%~50%. For the sake of bonding strength, bamboo strips should be dried to the required moisture content. Usually synvaren for bamboo plywood adhesive, moisture content less than 8% is required and shall be less than 12% if urac is used.

Due to bamboo parts' crack in cutting and the uneven shrinkage during drying, the two sides of the dried bamboo parts also appear uneven. In order to make good appearance of the bamboo plywood, all the bamboo pieces shall have edging processing.

5.1.4 Assembling & hot pressing

a. Gluing

A bamboo piece is the smallest unit of bamboo plywood. It is normally 3.0mm~8.0mm thick. The gluing equipment is a 4-rolly coater and the coating amount is 300~350g/m^2. To reduce the amount of glue, we can mix it with 1%~3% flour or bean powder as packing materials.

The addition of small amount of packing material can help to form a coating or surface to the bamboo piece, minimizing the loss of the squeezed and split glue in the course of hot pressing, so that the fragility of the glue can be reduced.

b. Assembling

It is a stage combining all the veneers or sheets together.

Take the bamboo plywood as a construction material requires longitudinally a high mechanical strength. Thickness of plywood back together with that in the back fabric direction shall make up to 55%~70% among the total thickness.

The core veneers and fiber of back veneers shall be in vertical direction. The assembly of the surface veneers and the back veneers requires green surface layer to be facing outward, yellow inner layer inward. But during assembling, the long border shall be of mutual verticality with short border as the basic board for the following production.

c. Pre-pressing

In order to improve the quality of bamboo plywood, to reduce hot pressing time, and to prevent such defects as overlapping cores and fissure due to the deflection at the time when board is put into the hot pressing machine, it is necessary to pre-press the board after its being assembled to pre-crosslink them as a whole. At last, they should be put into the hot pressing machine again to receive hot-pressing gluing. Synvaren is a good adhesive, which can make an ideal pre-pressing. But urac will be better to mix with such packing materials as some vinyl, flour or bean powder.

The unit pressure of pre-pressing is usually 0.1~1.0Mpa. And because of the great rigidity of bamboo strip, the pre-pressing should go on for a long time, 90~120 minutes is commonly accepted. Anyhow, the longer the time, the better the effect.

d. Hot-pressing and gluing

In the course of hot pressing, the pre-pressed board will undergo a series of chemical and physical changes under the thermal power and pressure. For instance, the adhesive will be solidified to make bamboo plywood of certain intensity. Usually, the process goes through 3 stages.

The first stage is called free heating. It begins with the first veneer being put into the heat pressing and ends with both the shutting of the heating platen and the obtaining of the required unit pressure.

The second stage is called pressure maintenance. It lasts from the obtaining of the required unit pressure to the compression relief.

The third stage is called compression relief. It is from pressure relief to board opening.

In the first stage, the lower side of the board is firstly heated by contacting the heating board. Before these boards are pressed, the bamboo strips will have some air shrinkage in different degree. Accordingly, the adhesive might be solidified to some extent. Furthermore, the upper side of the board, heated only by hot air, will undergo a slow heat transfer, hence, the unevenly distributed heat of the upper part and the lower part will take an effect on gluing. So we should endeavor to reduce the time of the free heating in the production. Anyhow, the most complex change in the board occurs in the second stage, which includes the change of moisture and temperature and internal changes of bamboo timber, the reaction and solidification of the adhesive polycondensation. In the first stage, part contact heat and radiant heat make little evaporation. But in the second stage, the temperature in the slabs is seen soaring with the rising temperature and pressure, thus the movement of the water particles in the slabs accelerates. Therefore, some of the water begins to be evaporated. Generally, vapor has a better diffusion capacity than water. In addition, the volume of the heated air in the slabs is becoming bigger and bigger. As a result, the co-action of the vapor and the heated air makes increasingly high pressure, which, in turn, accelerates the differing speed of the vapor. As the hot pressing proceeds, the bamboo wood in the slabs can be seen being compressed and tightened gradually, the comedian being solidified slowly and the moisture flow and vapor becoming obstacle, so does the vapor

Pressure in the slabs is rocketing and the temperature in the slabs is also creeping. The water around the slabs is liable to be evaporating which absorbs the evaporation heat and at the same time, is influenced by the cooled air around. In this way, temperature of the circumferential part of the slabs stays at 100℃ or so for a certain time, but the core of the slabs will experience gradual temperature rise to that of the heating platen.

With the hot pressing time lasts and the temperature rises, the internal part and the external part will witness an obvious temperature gradient. The circumferential part is the low temperature region whose coverage is restricted by the water absorption; the low temperature region covers about 75~150mm around. The central part of the slabs, with the temperature rising and the diffusing vapor obstacle, will produce increasing vapor pressure which in turn raises the central temperature. The comedian on the bamboo splints will be melted then solidified slowly and at last becomes an insoluble and undeletable substance because the temperature of the central part exceeds that of the outer part. Thus, the hot pressing time and temperature for the slabs will be based on the temperature in the outer part.

In the stage of compression relief, with the pressure being reduced, the vapor in the slab will diffuse quickly. Simultaneously, the overheated water will become vapor as soon as possible. The pressure between the internal part and the external part will be out of balance. The more speedily the pressure is relieved, the more serious the imbalance will be, even resulting in the breakaway of the glue line at worst. So compression relief usually requires a relative balance between the internal part and the external part, thus the water in the slabs will be eliminated with the pressure decreases. Generally, the compression relief goes through 3 steps.

First, reduce the operation pressure to the “balance pressure”. The so-called balance pressure, about 0.3~0.1Mpa, refers to the external pressure which keeps a balance with the internal vapor pressure. It lasts for about 10~15 seconds.

Second, reduce the balance pressure to zero. Now, the decreasing external pressure gives rise to a pressure difference between the internal part and the external part of the boards. The slabs contain a large amount of vapor, including both the original and the additional form the overheated water. If the pressure is reduced too fast, the huge pressure difference will cause the vapor in the board to diffuse at a high speed which will generate “air drums”. So the speed for compression relief will be adjusted to that of vapor being exhausted from the boards. As a rule, the 3-layer bamboo plywood requires 30~50 seconds, and the multi-layer ones more.

Third, to fully open the heating board after the pressure is reduced to zero. And we can open it at a relatively high speed.

In the course of hot pressing, the main factors that influence the gluing effect are the temperature, the pressure besides the quality of bamboo strips and the adhesive. In order to contact the bamboo splints and the comedian thoroughly, a certain pressure on the board is needed and the unit pressure depends on such factors such as adhesive types, the surface smoothness, the hardness, and the working accuracy of the plywood materials. In order to guarantee a good gluing strength, 3.0~3.5Mpa pressure can be used and board shrinkage shall be 13%~16%.

When adhesive and bamboo pieces contact each other completely, temperature becomes an important condition for solidifying the adhesive. If the temperature for hot pressing is raised, the time can be shortened. But the higher the temperature is, the bigger the compressing rate of board base will become. Synvaren resin is used as adhesive for bamboo plywood and the temperature for hot pressing is 135~140℃ at best. However for urac resin, the temperature is 115~120.C at best. When making thick board by pressing, the temperature should be reduced correspondingly, but the unit pressure should be increased. During the gluing process under hot pressure, the time for all the gluing layers to solidify is called hot pressing time. If it is too long, the solidification of adhesive will be excessive and the gluing layers will become fragile, so the strength of bamboo plywood reduces. On the contrary, if the time is too short, the gluing layers will not be solidified totally, so the gluing property, water-resistance will be poor. According to the thickness per millimeter, 11minutes is at best for hot pressing.

5.1.5 Finishing

When the bamboo plywood is taken from the hot pressing machine, the temperature is high and it needs to be piled in order. After that, the remaining heat is used to continue solidifying adhesive to raise solidification level of the gluing layers. Because of orderly and closely piling, bamboo plywood cools down slowly and the inner temperature is well-distributed to eliminate the inner strength and prevent deformation. The time for piling can not be less than 24 hours.

Sawing edges requests that the edges should be smooth without obvious sawing track, two edges nearby should be in the right angle; the deviation should conform to the requested standard, and the scorched edges should be reduced etc.

5.2 Processing with planing technology

Put thick bamboo strips and mat all in one direction and apply adhesive and compression from both sides. The specific work process is:
Bamboo culm →slog cutting →strip splitting →coarse planing→ steaming & boiling (treatment for borer-proof, dehiscence-proof, dehiscence-proof and coloring maintenance) and drying fine planning →adhesive application →matting →dual compression → lumbering → cross cutting/residual cut-off four-side planning (including fluting/grooving) crosswise grooving →polishing →painting →grading →packaging→ storing.

Bamboo flooring is mostly rectangular strips.

The technical requirements for bamboo flooring panels are very strict. The exterior of the products must be nice-looking, delicate with even brightness and color, which implies high difficulties in processing and also high requirements for bamboo timber (large DBH classes and fresh bamboo timber). It is also one of the products that have been developed in recent years. The timber utilization ratio of this product is rather low (merely 15~20%), whereas the prices are rather high with a large margin of added value. Presently, there are about more than 100 factories in the bamboo production areas throughout China with the total production volume of above 10 million m^3.

6 Bamboo particleboard

Bamboo particleboard uses small-diameter bamboo and remainder of bamboo processing as its raw materials. And particle is therefore produced through drying, glue application, forming and hot-pressing. Bamboo particleboard is a good product which can make good use of small diameter bamboo and improve bamboo utilization. Nowadays, ordinary bamboo particleboard becomes the main production and its property and function is similar to wood particleboard.

At present, few factories produce bamboo particleboard, because if this product is used for furniture and indoor decoration to get good decorative effect, this kind of stuff must be overlaid with unideal ordinary painting effect. If the bamboo particleboard is used as structural material, its mechanical capability can not satisfy the 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. The processing is still one-time formation technology. First, one or two layers of strengthening stuff should be put on the caul plate, then l bamboo particle should be spread, and later one or two layers of strengthening stuff, finally they are formed by hot-pressing. There are two kinds of particle sandwich composite boards with different structures and uses. In the first structure, dipping paper is served as the surface layer, bamboo curtain with adhesive dipping is served as the inside layer and bamboo particle is used as the core layer. Panel with this structure, whose property is closer to multi-plastic 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 it is mainly used as bottom board of container.

7 Market，Challenges and Opportunities

7.1 Market

Since bamboo has the advantages of straight grain, beautiful color, high strength and toughness, and excellent abrasion resistance, bamboo-based panels have been widely used in the fields of vehicle, construction, ship building, furniture, and decoration to partly replace wood, steel, plastic etc.

7.1.1 Structural Material

Bamboo-based panel can be widely used as structure material such as platform floor of trucks and buses, concrete form, scaffold for ship building, etc., because its strength is higher than that of wood, toughness is better than that of steel, and aging resistance is superior to that of plastic. In addition, it is easy to process with an acceptable price.

Bamboo plywood for vehicle platform floor

It is mainly used as the platform floor of trucks, buses, rail box wagons, and platform wagons. Many measures and investigations have proved that bamboo plywood is much better in strength, shock resistance, and durability than that of wood. For example, the thicknesses of wood platform floor for light truck, middle truck, box wagon and platform wagon are 25, 35, 50 and 70 mm respectively, while using bamboo plywood as platform floor, the thicknesses of those products are reduced to 15, 22, 30 and 45 mm respectively. Compared with wood platform floor, bamboo plywood platform floor has the advantages of lower price, richer raw material resources, more convenience in assembly and more durability. More than 50 truck and bus factories have been using bamboo plywood as platform floor, and 10 railway factories use ply bamboo as the platform floor of box wagon and platform wagon. The total amount of bamboo plywood demanded in China approximates to 100 000 m^3 yearly.

Bamboo mat-woven board for inner top board of box wagon

State Rail Department plans to build several thousand box-wagons each year, so the demand for this product reaches approximately 5 000 m^3 one year.

Bamboo - wood composite for container floor

Traditional container floor is made of a sort of thick plywood made from tropic hard wood. The property of bamboo plywood is similar to that of the hard wood. A few companies in China had tracked for a long time in utilizing bamboo plywood to replace tropic hard wood; however the bamboo plywood cannot meet the requirements of the property of container floor, particularly in MOE. The composite container floor of bamboo-wood, developed by Bamboo Engineering Research Center of Nanjing Forestry University, is made up of bamboo laid on surfaces and wood veneer that is used as the core layers of the board. It is a kind of composite board through lying up, hot pressing, and finishing processing, and meets the need of container floor. At present, the container productivity in China is more than 1,000,000 TEU of standard container one year, and the demand of container floor is estimated at 300,000 m^3 yearly.

Concrete form

It is a basic shaping board in construction. As more and more concrete engineering such as skyscrapers, cross bridges and highway etc. are being constructed, the demand of concrete form is large in China. Traditional concrete form was made of wood board. The steel form and wooden plywood were developed from the 1960s to the 1980s. Since 1990, various sorts of bamboo-based panels have been widely applied in construction for the advantages of large size and good stiffness. In particular, the overlaid bamboo-based panel is easy to be separated from concrete. Now bamboo-based panel concrete forms occupy one third in the construction market. Approximately 100 factories produce various bamboo concrete forms with the sum of productivity and sale of 500 000 to 600 000 m^3 one year.

7.1.2 Decorative Material

Besides the similar physical and mechanical properties with the hard wood, bamboo has the advantages of straight grain, white color, easy to bleach and dye etc. and can be regarded as an important decorative material.

Bamboo flooring

There are various kinds of floorings such as wood flooring, intensive composite flooring, and bamboo flooring etc. in the market of China, and the yearly demand is more than 100 million m^2. Bamboo flooring, a new product, has been in China for 10 years. The process of bamboo flooring is more complex than that of wood flooring, and its technical requirement is stricter than that of wood flooring. This product had more or less quality problems in most of the factories in the early 1990s. During the past several years, the process and equipment of bamboo flooring have been improved, and product quality keeps steady. It has been well accepted by foreign and domestic markets. It is counted that the productivity of bamboo flooring in 1999 reached 3,000,000 m^2, of which 60%-70% were exported to Japan and Europe. It is estimated that the output of bamboo flooring will reach 10 million m^2 in 2002.

Laminated bamboo lumber

Laminated bamboo lumber is a kind of large-size board that is made up of bamboo strips of certain width and thickness. It has various thick products by changing the layers of strips laid up. Thick laminated bamboo lumber can be used as the post elements of bamboo furniture or decorative material, and the thinner ones can be used as the boards of bamboo furniture or decorative boards or lining material. The laminated bamboo strip lumber is a new product and has been produced on scale; most of the products are exported to the foreign countries.

7.2 Challenges

In recent years, due to deflation, the prices of timber, steel and plastic products have been sluggish; lots of the bamboo-based industrial products are also confronted with many new challenges, which are mainly derived from the following aspects:

(1) Product replacements and alternatives, shrinking markets and fierce market competition. The bamboo plywood and cement template plywood used in passenger buses and freight lorries in highway transport have been confronted with the challenges from timber plywood and carriage bottom boards made of steel, wood/bamboo plywood in recent years. Presently, template boards of steel, timber plywood and carriage bottom boards made of steel, wood/bamboo plywood have all been used in the same filed, the mutual replacement and competition between and among these products have never been less intensified.

(2) Low product prices: Most of the products that are supplementary to mainstream industries experiencing high pressures of price reduction. At present, the prices of both the bottom boards and templates for carriages are at the lowest level in the past several years and the profits wherefrom have also dropped significantly.

(3) Enterprises are shouldering too heavy a burden. Most of the bamboo processing enterprises are located in counties and townships and they are the major sources of taxation income for the local county and township governments. The present prices of bamboo raw materials have already covered a number of forestry taxes and fees, while the enterprises still have to defray the tax for special agriculture and forestry produces. The taxation rate value of the added taxes (VAT) is 17%, whereas the discounts of bamboo timber as the raw materials are merely 10%, therefore, the actual taxation rate is higher than the products from other sectors of the industries. The VAT of bamboo timber products has now in generally reached 10~12% of the total sales income, nearly doubled compared with that of other products. Most of the enterprises have a very small margin of profits, and some enterprises are even experiencing operational or survival difficulties, a fact implying the impossibilities in investment for developing new products and expanded reproduction.

7.3 Opportunities

Up until now, the wood-based panel industry in China has developed into a considerable scale, the output of plywood and medium density fiberboard (MDF) ranks the second in the world, second only to the United States. Although there are differences and discrepancies in various regions and among various enterprises in terms of technology, equipment and product quality, the starting point in general is rather high. In particular, after China's entry into the World Trade Organization (WTO), market competition, both at home and abroad, will become increasingly fierce day by day. In this context, when we come to discuss again the development of bamboo-based industry, the issues of concern will be no more no matter we have or do not have the products as in previous discussions, rather, the consideration should be given to such issues as whether we have the advantages in technology, quality and performance of products, pieces and marketing, etc. When there are no these advantages, the ending moment of an enterprise comes, hence it should be the paramount issue in consideration. We therefore, conclude the following essential conditions to the development of bamboo-based industry:

7.2.1 Rich resources and available conditions for sustainable development

Resources advantages must be available. It should never be the case that various types of products are exploited from the same resources. In constructing the plants, planning is rather isolated to individual enterprises whose overall planning is also lacking. When the plants are put into operation, the individual enterprises will contend for resources and chaotically up the prices.

7.2.2 Select or develop those products with advantages in resources, technology and marketing channels as the mainstream products of an enterprise

The success of an enterprise lies in selecting or developing bamboo-based products with advantages in resources for technology. The present products form wood-based panels in China and the world are basically the products developed with mature technology, economically profitable quantities and market acceptance. For bamboo-based panel we intended to develop, comparisons must be made in terms of the performance, prices and uses. When the advantages in these aspects are not promising, then the markets will accept only those products with low prices, better performances and quality, meeting the requirements for intended uses. The market will not, wishfully, consider merely the ecologic benefits but neglect the economic benefits.

7.2.3 Technology and equipment should be at a nationally advanced level and product quality reaches the standards of similar domestic products

As the production of wood-based panels had already reached a rather high standard in China and the market demand and supply have reached a balance. The past economic situation of product shortage no more avails, therefore, the entry into markets for new bamboo-based panels has been rather high and, accordingly, the starting point should also be high.

7.2.4 An adequate investment intensity and corresponding technology and equipment

Along with the raising of the industrial standards for wood-based panels in China, the starting pint for developing bamboo-based panels should also be based on the same level with that of the wood-based panels, it is therefore not adequate to build small new factories with mainly manual labor. Only when mature technology, modern equipment with required processing precision and specialized processing equipment for bamboo timber are applied, can high quality products of bamboo-based panels be produced. However, due to the difficulties in the transport and storage of bamboo timber, the labor production efficiency is rather low, it is therefore advisable that the adequate capacity of one single production line in an enterprise should be between 3,000~5,000 m^3, and should not be higher than this limit. In addition to those specialized processing equipments, the commonly used equipments include those for drying, plywood thermal pressing, specifications (highly precise saws and cutters) and thickness trimming (highly precise polishing machinery), with the total equipment investment between RMB 4~6 million yuan. Often, the products from plywood panel require some manual labor, causing low streamlining level, and consequently low investment. Particle boards and MDF require rather high automation and streamlining, and therefore, higher investments. Bamboo floor panels require high processing precision, surface polishing and decoration, the necessary equipment investment is between RMB 4~5 million yuan for a production streamline with the annual capacity of 60,000 m^2.

8 Development Orientation

8.1 Development Orientation of Technology

Improvement of craft and technology include two ways below: first, craft and technology themselves; second, machinery instruments with the exploitation and utilization 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 producing bamboo-based panel. Meanwhile, as for high-grade block board, one time hot-pressing craft will be replaced by double processing craft.

8.2 Mechanization and Continuous Processing

Processing of the semi-finished products of bamboo-based panel, such as cutting strips, weaving curtain, weaving mat and so on, was almost processed manually and inefficiently in the 1980s. Because of the exploitation of instrument for a special processing including bamboo cutting machine, knot cutting machine, bamboo strips cutting machine, length feed weaving curtain machine, cross-feed curtain weaving machine, mat weaving machine and so on, nowadays it presents the state of semi-manual 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 spreading of unify of light, machine and electricity will be improved.

8.3 Modification of Adhesive

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

The other aim of modification of phenol-formaldehyde resin adhesive is to reduce curing temperature and promote curing speed, which requires the curing temperature (115±5℃) and curing time (below100s) that urea-formaldehyde adhesive needs under the situation of not reducing its function without cost increase. In this way, 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 the pressure is reduced. At present phenol-formaldehyde resin adhesive’s modification work has been carried on in many ways. For example, the method 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. There is a large potential and there is still lots of work to do.

8.4 Diversification of bamboo materials

Nowadays, bamboo-based panels all belong to the structural stuff. With high strength, good toughness, large rigidity of bamboo, they are mainly used as templates for concrete forms and bottom boards of trains, buses and containers. 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 supply of wood 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, choose fine and large diameter bamboo, in bamboo peeling machine and make the width of bamboo veneer 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 panels by cutting and matching to get good decorative effect. Zhejiang Forestry University used bamboo floor strips for material, utilized pressed impregnation 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 into 0.2~1.2mm micro-bamboos for decoration. Rotary-cutting bamboo veneer and slicing micro-bamboo both have fine bamboo texture and better decorative effect. They both have large profit margin. It is 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 requires more attention, and bamboo-based panel used as decorative packaging stuff will have broad future in exploitation.

8.5 Trend of green industry

Bamboo is green natural stuff, but in the production of bamboo-based panels a lot of pollution having worse effect on human and the environment will appear. First is air-pollution, which is caused by adhesive, because adhesives of bamboo-based panel are mainly phenol and especially formaldehyde that are heavily poisonous and easily volatile. After they are in the air, human and environment will be threatened. The second is water-pollution, for example, people wash the kettle and installation of glue application and so on in the water. And the third is noise pollution, which is created by the bamboo machine. Some noise is so high that almost makes one deaf. The last is dust-pollution, which mainly includes boiler coal dust, smoke dust, sawdust, etc.

With the increasing consciousness of environment protection, the improving power of government in protecting the environment and the advancement in technology, these pollution problems caused by bamboo-based panel production will be solved. Some measures, such as the use of natural poisonous resin, the application of supervising system on noise and dust, banning releasing the polluted water and so on will promote the green development of the bamboo-based panel. The development of environment-protection industry will make bamboo-based panels green products.

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Chapter 10 Process and Properties of Bamboo Charcoal

Bamboo charcoal is a solid product by using bamboo timber as the raw material and processing through carbonization under high temperature.

1 Classification of Bamboo Charcoal

Bamboo charcoal can be categorized as the follows:

According to its shape: canister charcoal, slice charcoal, particle charcoal and powder charcoal etc;

According to its usage: water purifying charcoal, air purifying charcoal, humidity adjusting charcoal, healthcare charcoal, freshness-keeping charcoal, soil improving charcoal, deodorizing charcoal, micro-wave protection charcoal and fodder charcoal etc;

According to carbonization temperature: low-temperature charcoal, middle-temperature charcoal and high-temperature charcoal;

According to electricity resistance: electric charcoal and non-electric charcoal.

Tab.1 Definition of charcoals

Term	Definition
Cylinder charcoal	Cylindrate bamboo charcoal
Slice charcoal	Sheet bamboo charcoal
Particle charcoal	Cracked bamboo charcoal with anomalous shapes
Granular charcoal	Granular bamboo charcoal
Powder charcoal	Dusty bamboo charcoal
Charcoal for water decontamination	Charcoal used to filtrate water
Charcoal for air decontamination	Charcoal used to adsorb formaldehyde and benzene in the air.
Charcoal for humidity accommodation	Charcoal used to accommodate the humidity in the room, under the floor and bed.
Charcoal for health protection	Charcoal used to fill mattress, cushions and pillows.

Term	**Definition**
Charcoal for keeping fresh	Charcoal used to keep the fruit, vegetables and flowers fresh.
Charcoal for meliorating soil	Charcoal used to meliorate the acidity, alkalescency and loose degree of soil.
Charcoal for eliminating smell	Charcoal used to eliminate smell in the bathrooms and refrigerators.
Charcoal for shielding Hertzian waves	Charcoal used to shield Hertzian waves of electrical appliances.
Charcoal for feedstuff	Charcoal as feedstuff for livestock and fish.
Low-temperature charcoal	Carbonizing temperature≤500℃
Medial-temperature charcoal	Carbonizing temperature is 600~800℃
High-temperature charcoal	Carbonizing temperature≥800℃
Electric charcoal	Resistance rate＜0.1Ω•cm
Nonelectric charcoal	Resistance rate ≥0.1Ω•cm

2 Process of Bamboo Charcoal

Fig.1 sketch of bamboo to charcoal

Raw bamboo

Without air or with little air

Dry, pre-carbonize, carbonize, calcine and cool in kiln

Duration is around 20 days

2.1 Raw material selection

Density: Closely related to bamboo species, age, site and culm section. 4-year-old bamboo which is growing in ordinary site is recommended.

Moisture content: Closely related to bamboo age, culm section or harvest season. 6-year-old bamboo is the best concerning MC.

Site: depend on the heavy metal in the soil which is related to fertilizer management.

In all, we should select 4-year-old bamboo growing in the ordinary site with low MC.

2.2 Pyrolysis facilities

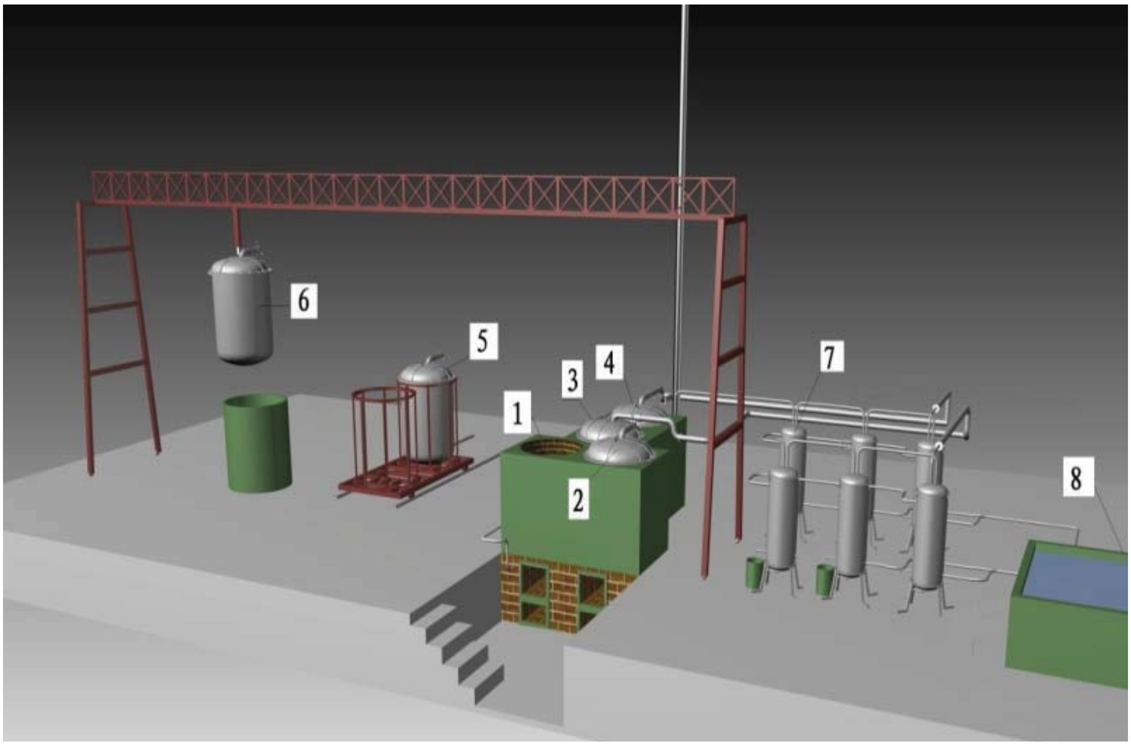


Fig.2 Succession modern kiln machinery and facilities

1,2 Heating room； 3,4-Pre-heating room； 5,6-Carbonizer；7Cooling system；
8-Water pool

Brick kiln (vertical and horizontal

Improved brick kiln (temperature monitor system)

Distillation pyrogenic decomposition facilities (vertical and horizontal)

Successional vertical kiln

2.3 Process of Carbonization

Tab.2 Five periods of the carbonization of bamboo timber

Name	Temperature	Main characteristics	Outputs
Drying	Room temperature ~150℃	Decalescence reaction, moisture evaporation, basically no changes in chemical components	Water
Pre-carbonization	150~275℃	Decalescence reaction, instable contents decompose, chemical components begin to change	CO_2 、 CO 、 acetic acid, etc.
Carbonization	275~450℃	exothermic reaction, the chemical components decompose dramatically, the charcoal begins to take place	Large amount of liquids and gases
Calcine	450~500℃	Decalescence reaction , fixed carbon content increases	Liquids and gases reduce
Cooling	High~60℃	exothermic reaction , the inner structure of charcoal changes	Producing of liquids and gases stop

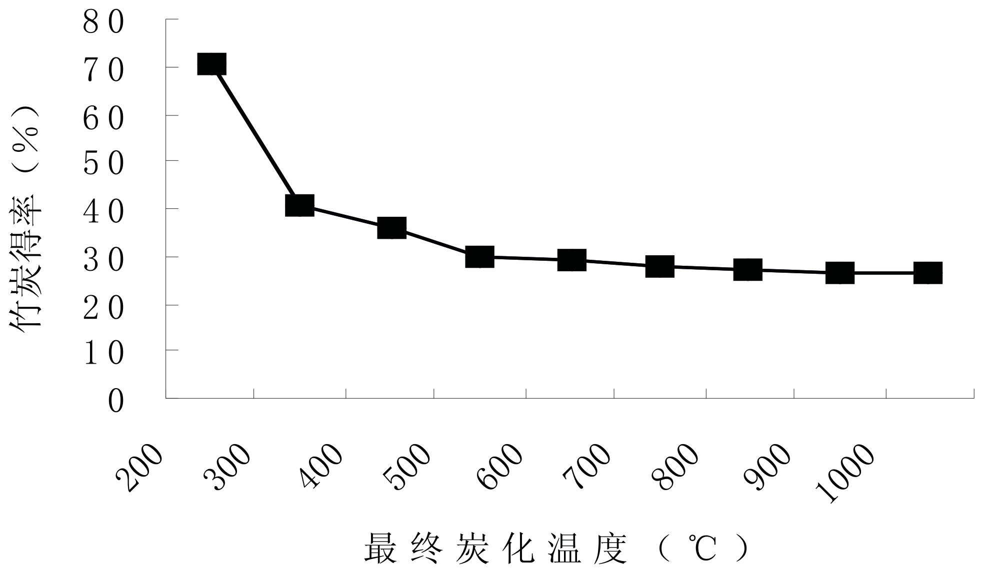


Fig. 3 Relationship between carbonizing temperature and ratio from bamboo to charcoal

Ratio from bamboo to charcoal

Ratio from bamboo to charcoal can be defined in two ways: gas ratio and dry ratio. Gas ratio is smaller than dry ratio and more commonly used in practice.

Gas ratio is a percentage between dry charcoal weight and raw bamboo weight. Dry ratio is a percentage between dry charcoal weight and dry bamboo weight.

Influencing factors for the ratio from bamboo to charcoal

Carbonization temperature

Carbonization speed: the higher the speed, the lower the ratio

Heat temperature time: the longer the time, the lower the ratio

Bamboo age: the smaller the age, the lower the ratio

Bamboo section: the higher the section, higher the ratio

3 Properties of Bamboo Charcoal

3.1 Elements in Bamboo Charcoal

Elements in bamboo charcoal: carbon, hydrogen, oxygen and ash etc. The substance composition is determined by the max temperature of carbonization. With the increase of max temperature of carbonization, there is an increase of carbon, but a decrease of hydrogen and oxygen. The contents of carbon, hydrogen, oxygen and carbon vary with different species.

Tab. 3 Elements content of different carbonization temperatures and bamboo species

Charcoal type	Carbonization temperature	C	H	O	N
Moso charcoal	300	69.03	3.69	22.9	0.23
Moso charcoal	500	81.85	2.46	14.9	0.43
Moso charcoal	700	84.77	0.98	6.84	0.55
Moso charcoal	900	85.85	0.31	4.93	0.69
Moso charcoal	1000	85.42	0.25	4.83	0.68
Charcoal of Sinocalmus affinis (Rendle) Mcclure	500	75.99	0.78	13.39	0.604
Charcoal of D.latiflorus Munro	500	86.98	0.57	12.68	0.012
kiln charcoal	-	85.34	0.56	4.86	0.06

3.2 Chemical components of bamboo charcoal

The main chemical components are charcoal, ash and some volatile substance.

Ash

Relatively high content of ash, which is composed of many elements including phosphor(P), kalium (K), silicon (Si), aluminum(Al), magnesium (Mg), Iron(Fe), sodium(Na)etc. The content slightly increases with the carbonization temperature. And the ash content varies with the different parts of bamboo.

Volatile substance

Bamboo charcoal will release volatile substance including CO^2, CO(carbon dioxide, carbonic oxide), methane, hydrogen when it is burnt under the high temperature of 850℃. The volatile substance content generally decreases with the carbonization ultimate temperature. The higher the temperature, the more completed bamboo is carbonated. CO^2, CO, methane, hydrogen will be fully volatized or take part in the second reaction, resulting in decline of the volatile substance left in the bamboo charcoal.

Fixed Carbon

Fixed carbon is the percentage of valid carbon in bamboo charcoal. In China, we calculate it as below:

$$\text{Fixed carbon (C)} = 100-(A+V)$$

A——ash portion in mass, %;

V——volatile substance portion in mass, %.

Fixed Carbon is an important index to identify bamboo charcoal quality as well as a symbol of charcoal's burning level. Fixed carbon content increases obviously with the carbonization temperature. But when the temperature reaches a certain level, the increase of fixed carbon becomes very slight, which indicates that selection and control of the max temperature during burning plays a very important role in improving charcoal quality.

3.3 Bamboo charcoal's density

Bamboo charcoal density is a quality in unit volume.

There are three ways for real density.

3.3.1 Packing Density

Packing density means charcoal weight in unit volume under provided condition, including the charcoal holes and particle holes.

$$P_B = \frac{m}{V堆} = \frac{m}{V隙 + V孔 + V真}$$

m：Charcoal weight (g)

V：Charcoal's accumulation volume(cm^3)

V：Volume of charcoal particle's hole(cm^3)

V：volume of interior holes in charcoals(cm^3)

V：Charcoal's volume(cm^3)

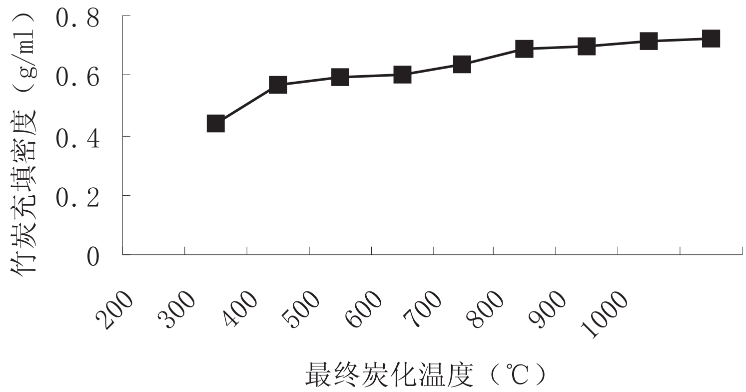


Fig. 4 Relationship between ultimate carbonization temperature and its accumulation density

3.3.2 Particle density（PP）

Particle density means charcoal weight in unit volume in the provided condition, including particle interior hole's volume not the hole volume between particles.

Particle density can be calculated by the method of mercury replacement.

3.3.3 Real density（Pτ）

Real density is the same as absolute density,（Pτ）meaning charcoal weight in unit volume in the provided condition, exclusive of particle interior hole's volume and the hole volume between particles.

Real density can be calculated either by helium as it can well penetrate in tiny holes in charcoal or X-ray.

3.4 Ph value of bamboo charcoal

Bamboo charcoal Ph value can be categorized as surface Ph and solution Ph.

Bamboo charcoal's surface Ph is determined by the carbonization temperature as it is getting higher with the increase of ultimate temperature. 600℃ is a 600℃ demarcation point, which means ≤600℃ is showing acid while ＞600℃ is alkali. Therefore, the higher carbonization temperature is, the less acid organs in the charcoal surface and more alkali there will be, therefore, the ph value is showing a higher level.

Bamboo charcoal's solution Ph is the substance dissolved in the water, mainly the ash. The increase of some substances like silicate, chlorine , phosphate containing soluble potassium(K), and sodium(Na) leads to an increase of Ph value.

3.5 Humidity absorption

Bamboo charcoal whose ultimate temperature is 700℃ and 1000℃ has the best performance in humidity absorption. Under the condition of relative humidity of 95%, its humidity absorption can amount 14%. While bamboo charcoal with the ultimate temperature of 500℃ and 600℃ have a similar humidity absorption capability, which are 8.6% and 8.8% respectively.

3.6 Electronic resistivity

Bamboo charcoal's electronic resistivity increases with the increase of the ultimate carbonization temperature. When the carbonization temperature is 700℃, the electronic resistivity has become very small, only 5.40×10-3Ω·cm and shows a very good electric conductivity. When the temperature is over 700℃, the decrease speed of charcoal's electric resistivity slows down. This means volume fraction reaches a critical point.

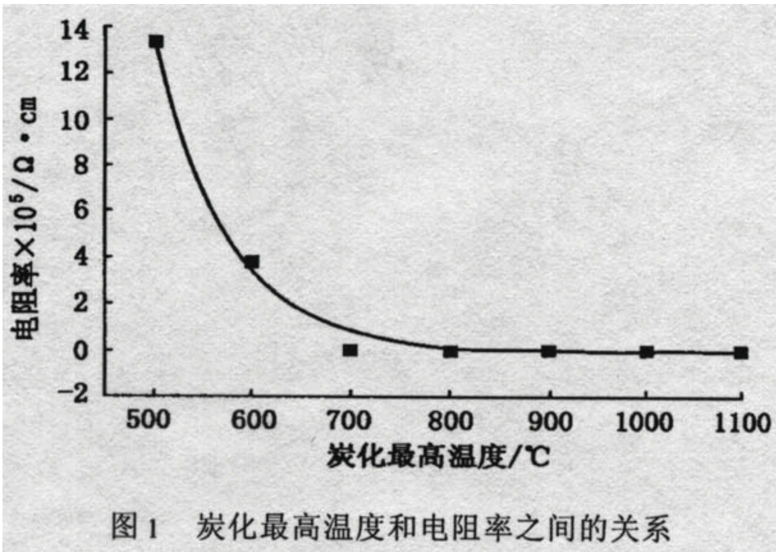


Fig.5 relationship between carbonization temperature and electronic resistivity

3.7 Specific Surface Area of Charcoal

When charcoal reaches carbonization temperature of 700℃, it has the largest specific surface area of 385m^2/g,and when the temperature is low(＜500℃),because the carbonization is not complete, and there are not so many holes, the specific surface area is small. When carbonization temperature is high（＞800℃）, the holes are decreasing or lost on the surface by burning out the holes, and when the temperature reaches 1000℃,the specific surface area is also very small.

3.8 Microstructure

3.9 The far infrared ray feature

Infrared ray is one part of the electronic spectrum with wavelength of 0.76 0.76~1000 μm. It can be divided into near infrared ray (0.76-1.5 μm), mid infrared ray(1.5-5.6 μm), far infrared ray (8-14 μm)and super far infrared ray (15-1000 μm). Mid infrared ray and far infrared ray are the reason that object can produce thermal inductance ,so it is also called thermal infrared , of which the wave band of 4-14μm are easily for human being to absorb, and can bring about resonance effect with histiocyte, which is good for human beings, so it is also called the light of life.

Efficacy

(1) Far infrared ray has the features of refraction, reflection and penetrability. Far infrared ray has very good penetrability and can be as deep as 1mm below the skin, and then it can go to the deep part of human structure through medium transmissions and blood circulation. Under the condition that it doesn't give burden to the heart, it can expand periphery vein and promote blood circulation.

(2) The 4—14μm far infrared ray has the same frequency with the water molecules in the cells of the living things. They are easy for our body to absorb and can activate the cells, therefore, charcoal can keep warm, accelerate metabolism, prevent and cure some diseases such as arthritis and insomnia.

Tab. 4 Radiation ratio of different charcoal samples

Radiation ratio	ε1	ε2	ε3	ε4	ε5	ε6	ε7	ε8
Suichang	0.90	0.90	0.91	0.90	0.90	0.90	0.91	0.90
Quzhou	0.90	0.90	0.90	0.90	0.91	0.90	0.90	0.91
Fujian	0.88	0.88	0.88	0.88	0.88	0.88	0.87	0.88

Note: ε1 is integral radiation ratio of whole wavelength; ε2 is（8-25）μm integral radiation ratio; ε3 is 8.45μm; ε4 is 9.50μm，ε5 is 10.6μm; ε6 is12.0μm; ε7 is 13.5μm; ε8 is（14-25）μm integral radiation ratio ε1

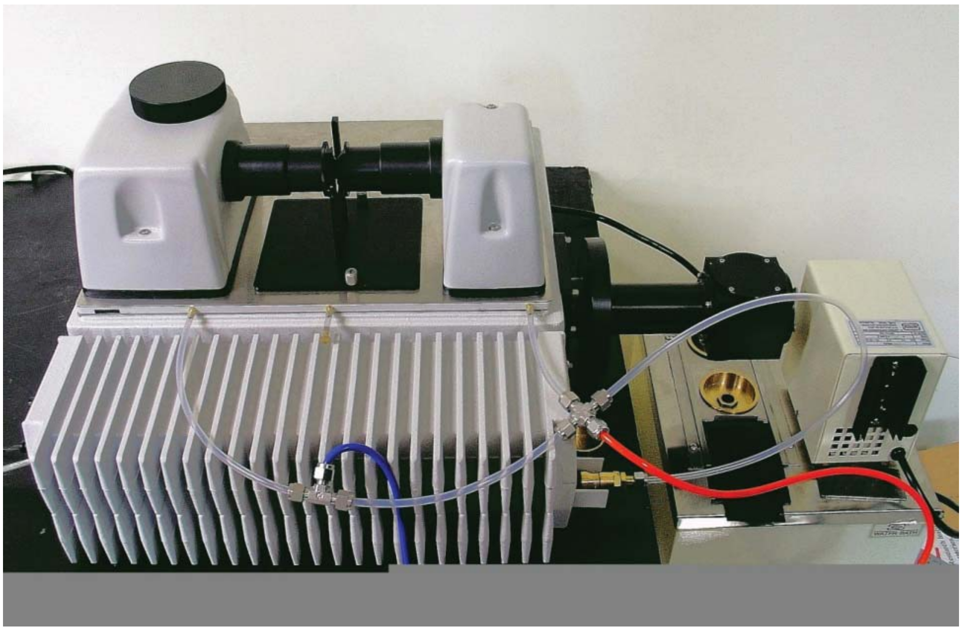


Fig. 6 FTIR for Emissivity Measurement

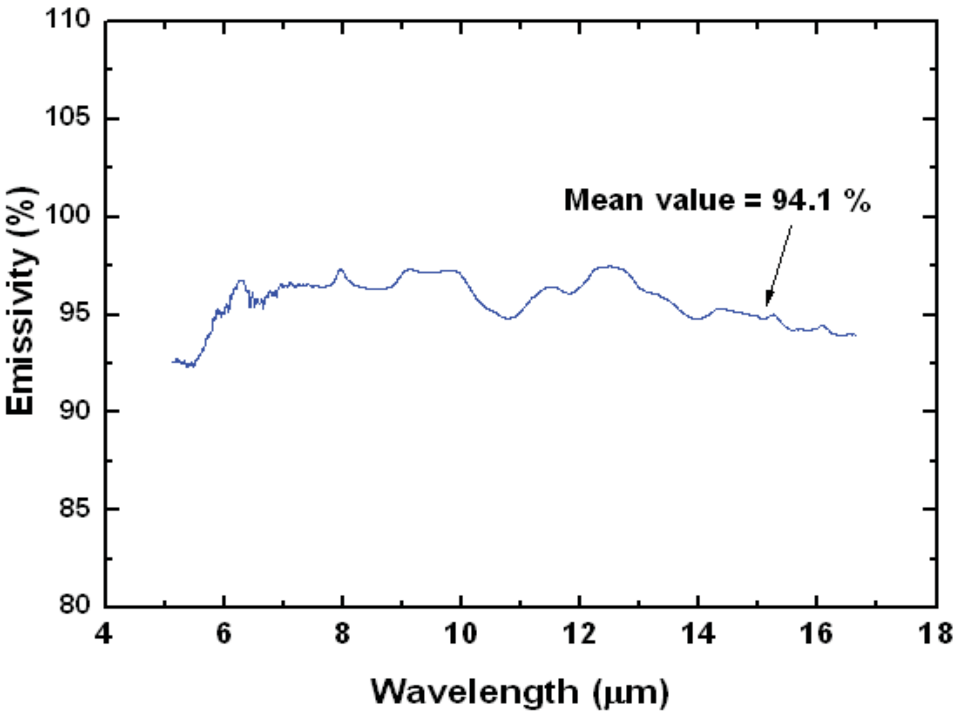


Fig.7 Relationship between emissivity and wavelength

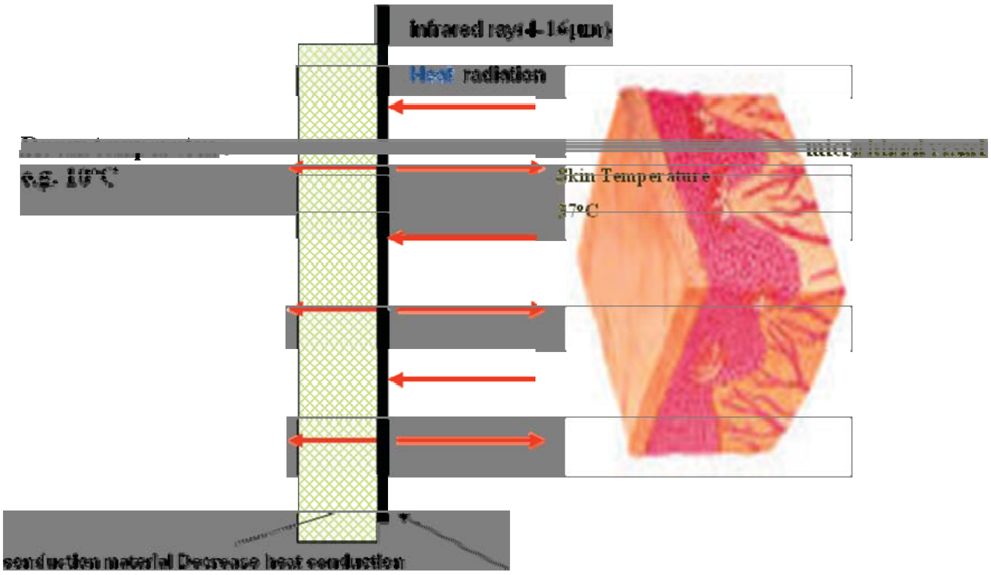


Fig. 8 Charcoal gauze for heat preservation

3.10 Negative Ion Functions

Air is a mixture of oxygen, nitrogen, steam and carbon dioxide etc. In most of normal conditions, gas molecule is neutral. However, under the functions of all kinds of rays (universe rays, radioactive substances, ultraviolet radiation, etc), strong electric field and kinetic energy, gas molecule will be ionized and lose some electrons. These free electrons will combine with other neutral molecules and become the negative ions, which are also named electronegative ions. Most of positive ions in the air are mineral ions and nitrogen ions etc. while the main negative ions are oxygen ions and OH^-.

Reasons

With the characters of cellularity, group substances on the surface and dissymmetry of crystal lattice, charcoal can produce negative ions. When the water molecules in the air meet the charcoal, they will electrolyze and produce negative ions. As water molecules always exist in the air, they will electrolyze constantly.

Functions

The quantity of negative ions in the air has relationship with our health and we need a certain number of negative ions to keep fresh and calm. Therefore, negative ion is named as "vitamin in the air". According to the research, charcoal can produce as many negative ions as the sea can. Charcoal in the room and office can increase the quantity of negative ions in the air, and it is beneficial to our health.

(1)O^{2-}in the air can accommodate the estate of nerve center in our head. It can improve the function of lung and accelerate metabolism.

(2)Negative ion is good for sleep, appetite and can ease pain and stop coughing.

(3)To a certain extent, it can cure high blood pressure, asthma, flu, arthritis etc.

If we space charcoal samples in an airproof storehouse (1 m^3) for 12hours, there will be 170 negative ions per cm^3 increasing. That is to say, charcoal can produce negative ions.

Chapter 11 The Application of Bamboo Charcoal, Bamboo Active Charcoal and Bamboo Vinegar Liquor in Production

Friendship brings friends apart here together. Today, we get together here to discuss about the common topic on bamboo cultivation, processing and production technologies, its administration and tools & small machines. On behalf of Sanshan Charcoal Co. Ltd. of Changxing, Zhejiang Province, I'd like to take this opportunity to make a report to the senior and specialists within this profession, on the development, utilization, and processing technological flow of bamboo charcoal, bamboo active charcoal and bamboo vinegar, as well as the future products' research and development tendency. Advice and comments will be appreciated.

Sanshan Charcoal Co. Ltd. of Changxing, Zhejiang Province, is situated in Wu Shandu in Heping Town, Changxing County, Zhejiang Province, covering an area of over 8,000 square meters. We have eight active charcoal producing water vapour kilns, as well as a set of multi-functional active charcoal kiln whose patent number is ZL01259217X. The annual output of active charcoal in our company is up to 1000 tons. We use bamboo particles, bamboo branches, bamboo slices, etc (which are termed as 'the three leftovers' in the following parts) as raw materials to produce active charcoal with the physical method without any chemicals (namely water vapour method). Equipped with advanced manufacturing facilities and with high scientific and technological value in its manufacturing method, our company is a large-scale manufacturing enterprise mainly concentrating on active charcoal production in this industry in current China.

As we all know, active charcoal has relatively stable chemical natures. It can revive many chemicals and is widely utilized in petroleum, pharmacology, chemical, food, national defense and environmental protection. With the upraising of social awareness about environmental protection and the state's formal bans on excessive cutting and felling trees to protect forest resources, the raw materials for wood active charcoal have become lacking and it has been an urgent task to search for substitutive raw materials to produce active charcoal. The scientific research staffs in our company have undergone a series of experiments and practices to develop the following method to produce active charcoal: to use bamboo particles, bamboo branches and bamboo slices, etc, as raw materials and use the physical method for the production after the charring by the high-temperature kiln. And the by-product bamboo vinegar derived from the pyrolysis of the 'three leftovers' during the high-temperature charring can also be widely used. We recycle the bamboo vinegar and have applied together with China national Bamboo research Center for an invention patent. The patent number is 02129534.4.

According to a longtime survey, it is indicated that in the enterprises specialized in bamboo chopsticks, the utilization ratio of a Moso bamboo culm is only 40% ,and the left 60% all belongs to ‘three leftovers’. There are 40% ‘three leftovers’ in bamboo handcrafts enterprises and 10% in bamboo-flooring enterprises. Supposed radiated from our company, there are over 500 tons of ‘three leftovers’ within 100 kilometers every day, what’s more, it is a big problem in environment protection. As a result, to produce bamboo active charcoal, bamboo vinegar ,etc. though ‘three leftovers’ plays a very positive role not only in bringing economic profits to a company but also in keeping ecological balance and environment protection.

Now I’d like to introduce the various uses of bamboo charcoal, bamboo active charcoal and bamboo vinegar.

In agriculture, as the carrier of soil microbes and organic nutrition constituents, bamboo charcoal can strengthen soil’s vitality. It is a good soil modifier.

In chemical industry, bamboo charcoal can be used as the raw material for active charcoal. Thanks to bamboo’s special micro-hole structure, it has strong absorptivity after its charring. This ability can be strengthened after the activation, resulting in the very good absorptivity of the well-produced bamboo active charcoal.

Bamboo charcoal also has many uses in medicine and health care. Pillows and bed mattress made of bamboo charcoal have effects on relieving people’s tension and mind and eliminating backache. At the same time, they can be used as deodorant, drying agent and antibacterial agent. It will be a must for family living, house decoration and public places in the future.

In environmental protection, because of its good absorptivity, it can be used as water purifier, protection to electromagnetic wave and absorption agent to poisonous gas.

The uses of the bamboo active charcoal are much wider: it can be used as absorption agent in air purifying. The bamboo active charcoal can expel the harmful gas during the process of producing semiconductors. It can be used to highly purify the water. It is also widely used in food industry, brewing and refined sugar making, and in many other fields it can be used as catalyzer or catalyzing carrier.

Bamboo active charcoal also plays quite a part in medicine. The cigarette filter tips made of it can absorb a good deal of poisonous materials like nicotine for people’s physical and psychological health.

Bamboo active charcoal is the invention patent of our company, the patent number is 01131145.2. It is made from Moso bamboo and made by high-temperature steaming method and other high-tech. The bamboo active charcoal capsule is researched and developed by Yi on Co., Ltd. of Japan and our company together, and it has been on sale in the Japanese market.

The active charcoal can strengthen children’s resistance to diseases. Some Russian countries use the active charcoal in the regular health care for children in spring and autumn. The active charcoal is good at reducing cholesterol. It can be used as the health care materials for the heart and vasculum. The expellant ratio of active charcoal to uric acid etc. in body fluid is not lower than 80% of much referential value in curing gout and uremia. It also has obvious effect on curing parasitic disease and intestinal infection. The large surficial area of the active charcoal leads to its strong absorptivity. As the improvement of people’s life, the excessive-nutrition has become a more and more obvious problem; thus the active charcoal plays a significant role in removing harmful materials and maintaining people's youth.

Because of its simple raw materials and the high-tech producing method, the bamboo active charcoal capsule is absolutely without any toxin or side effects. Reasonable taking will be of great help to our health.

Bamboo vinegar is the by-product from bamboo's pyrolysis. It's mainly composed of moisture (about 80%), organic acid, phenol, alcohol. It can be used as the soil germicide, plants' growing accelerator and eliminator of peculiar smell. It can also be used in facial and skin beautification, as well as in healthy drinks. As in the medical care, it plays a certain part in curing diabetes.

The Main Facilities for Producing Active Charcoals in Sanshan Company:

1. Eight high-temperature activating kilns: The charred materials are put into these stoves to activate after adding water. The temperature for activation is within 800℃ -1000℃, and the condition is the existence of micro-oxygen.

2. A set of multi-function active charcoal converter. Put into the converter, the materials are charred and activated there. As soon as a process is finished, the activating materials are immediately wrapped tightly with plastic bags.

3. Airtight crusher: it will put the crushed materials into package automatically.

4. Airtight vibration sifter will send the sifted materials to the package automatically.

Now I'd like to introduce you part of the producing technology and technological formula of Sanshan Charcoal Co. Ltd. Advice and guidance will be appreciated.

1 Processing steps

Bamboo charcoal production: From years' producing practice, we found that the requirements for raw materials are not so high in bamboo charcoal making, but the quality and characteristics of the bamboo charcoal are closely related to the technology of burning. Generally speaking, it goes through four stages from preparation, drying, charring and refining to developing the raw materials to charcoal.

In preparation, adjustment to bamboo's structure organization is carried out. The quality of this step is directly related to the product ratio of the bamboo charcoal and their quality. In drying, the moisture in the raw materials is expelled. This step is related to the appearance of the bamboo charcoal, because bamboo's bubble and layer separation will be seen here. The reasonable temperature for this step is around 150℃. From 180℃, the bamboo begin to be sectionally charred. When it comes to 450℃, the charring is basically finished. In this step, resolvents with a large quantity of bamboo tar spill out from the raw materials, so the temperature upraising should not be too hasty. The balance between the spilling speed of bamboo tar and the charring speed should be kept. Refining actually is bamboo charcoal contraction, mainly stressing upon upraising the quality of bamboo charcoal as well as its hardness. In this step, the temperature upraising can be faster, but a certain time should be guaranteed for the full contraction of the bamboo charcoal.

Traditional earthen kilns as well as the concentrative computer-controlled mechanical stoves can be used as processing facilities for bamboo charcoal.

There are two ways to produce bamboo active charcoal: water vapour method (physical method) and the chemical method.

Our company adopts the first method, namely the physical method to produce active charcoal and we also recycle the water in cleansing. What should be underlined is that we don't add any chemical agent during cleansing.

2 Processing Technology

The processing technology and formula are mainly derived from the new high-tech with which we have obtained patent with the patent number 01131145.2. And our company is in tight ties with Zhejiang Academy of Forestry and China National Bamboo Research Center.

3 Production Formula

The formula of the active charcoal production in our company is as follows: char the bamboo particles in the converter, and then mix the charred materials with water in a ratio of 1 to 2. Then put the proportioned charred materials into the activating stove and carry out the activation.

Bamboo vinegar is the by-product derived from the pyrolysis of raw bamboo during its charring. Usually we use simple refining method, namely the disposity and the distillation method.

Experiments have proved that there are no significant changes in the odor and density of the bamboo vinegar with different types of charcoal powder, but obvious changes can be seen in its color, absorbance and PH value. The bamboo vinegar with active charcoal in it has lighter color, thinner smell and slightly higher PH value than that with bamboo charcoal. It indicates that the absorptivity of activated charcoal powder is stronger than that of bamboo charcoal powder.

The refined bamboo vinegar: for the sake of convenient transportation, storage and utilization, as well as the advanced purity of the bamboo vinegar components, our company together with China National Bamboo Research Center has applied an invention patent whose number is 02129534.4 and used this invention to refine the bamboo vinegar. The final product of the refinement is the bamboo vinegar powder.

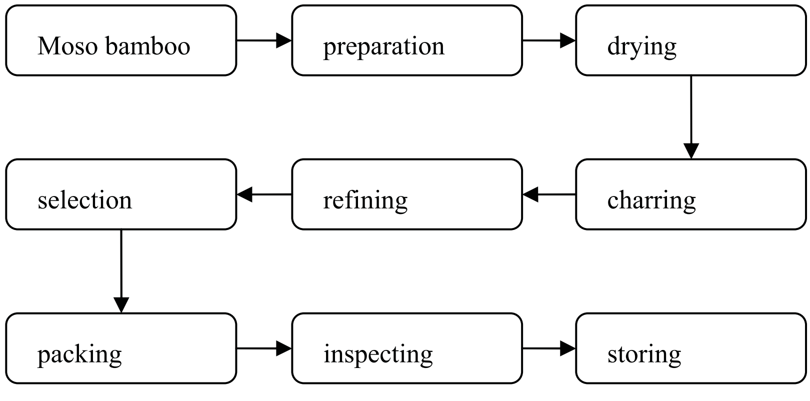
The research and development tendency of the products in the future: In the future ten years, with the development of the world's economy, China's entry into WTO, the advancement of the global economic integration process, the increase of people's awareness about environmental protection, as well as the diversity of protected species, there is an increasingly higher claim to the protection of forest ecological system. Therefore the enterprises producing active charcoal, raw materials become particularly important. Under such circumstances, the development of bamboo resources has risen as a new industry, mainly because the productive period of bamboo is very short, usually it only three to five years for a bamboo to grow into use. Besides, China is the main bamboo producing country with over 500 species of bamboo plants, covering a half of the world's total. What's more, with the second place in bamboo forest area but first place both in output and its value, Zhejiang's bamboo industry occupies the leading status in China's bamboo industry.

Opportunities always coexist with challenges. In this situation, our company has laid much effort on the research and development of bamboo charcoal, bamboo active charcoal and bamboo vinegar. This act has not only created benefits for our company, but also added the bamboo farmers' income. We will go on to take the combined advantages of the favorable climatic, geographical and human conditions to carry out the further processing towards the bamboo charcoal, bamboo active charcoal and bamboo vinegar, aiming at their overall development on air-conditioning and humidity-conditioning in living places, on harmful gas absorption, water purifying, health caring for man, on food, fruit and vegetable preservation, on soil improvement and in the medical field. We will focus our efforts on realizing the full utilization of bamboo charcoal, bamboo active charcoal and bamboo vinegar in environmental protection, and it is believed that this new industry will have very broad prospects.

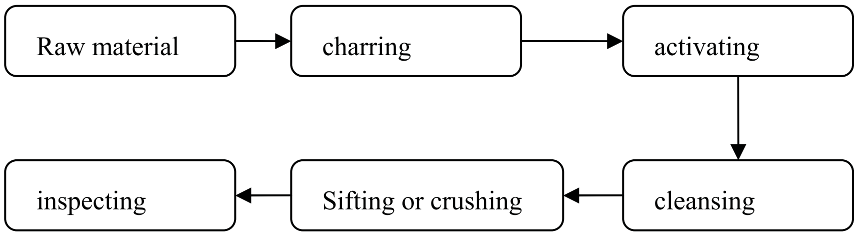
All leaders and friends and colleagues, it's very hot in Hangzhou recently, but the united hearts of Sanshan Company are much hotter. In this flourishing country and in this fervent summer, the whole staff of Sanshan Company will join you to witness the development and to create a brighter future together. Paradise above, Su Hang on the earth. I sincerely wish all of you have a pleasant trip here in this beautiful paradise on the earth which will give you cheerful memory.

4 Technology Flow Chart

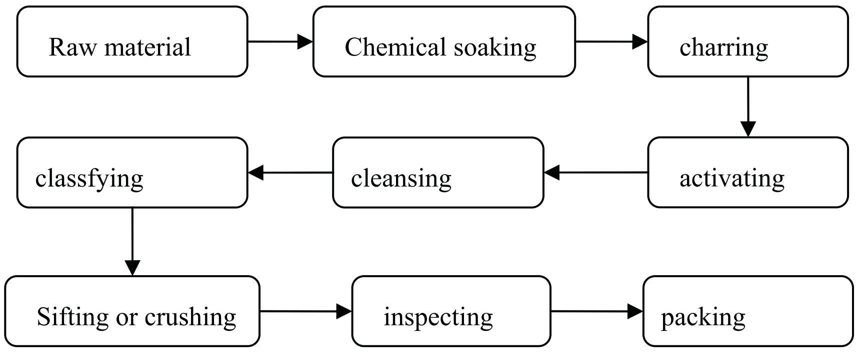
4.1. Flow Chart for Producing Bamboo Charcoal:



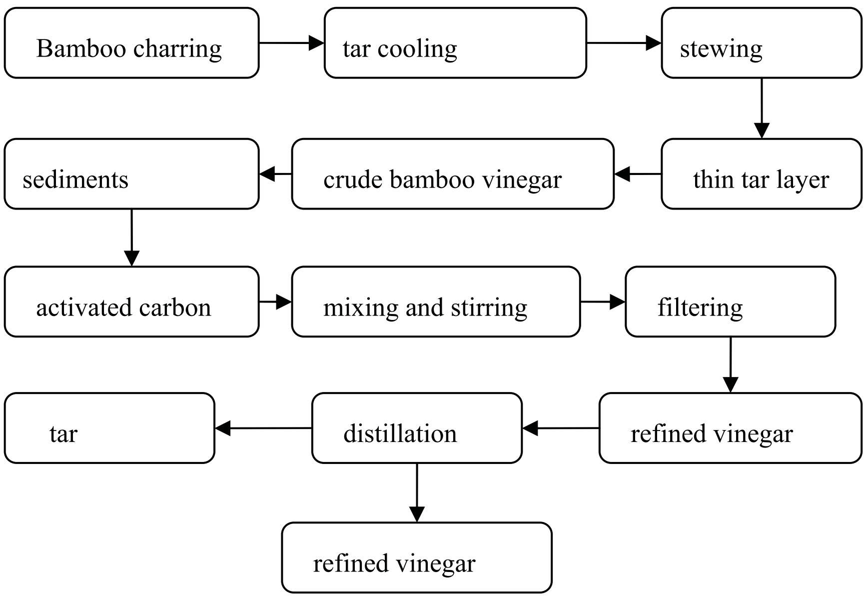
4.2 Flow Chart for Producing Bamboo Active Charcoal (Physical Method):



4.3 Flow Chart for Producing Bamboo Active Charcoal (Chemical Method)



4.4 Flow Chart for Producing Bamboo Vinegar Liquor:



Chapter 12 Processing and Utilization of Bamboo Vinegar

1 General Introduction

Raw bamboo vinegar is an acid liquid obtained by cooling the volatile substance in carbonizing and pyrogenating the bamboo.

The transparent and yellow brownish solid liquid obtained after settling still raw bamboo vinegar for 3 to 6 months is called bamboo vinegar.

1.1 Classification of bamboo vinegar

It could be classified as traditional-kiln bamboo vinegar and machine-made bamboo vinegar according to the different production techniques.

Traditional-kiln bamboo vinegar is processed in the traditional kilns and based on the white charcoal kiln technique.

1.2 Components of bamboo vinegar

Water: 80%-90%

Organic acid：acetic acid is about 6%, fomic acid, butyric acid, methylacetic acid etc. will be introduced next.

Hydroxybenzene：mainly are some phenol and its ramifications, such as 2-cymene phenol, 2-methoxyl pheol, 2,6-methoxyl phenok,3-three methoxyl phenok and malt hydroxybenzene etc.

Ketone£ºmainly are acetone, 2-butanone and its ramifications etc.

Aldehyde：Mainly are formaldehyde, furfural, vanillin etc.

Alcohol: Mainly are Propylene Glycol, methyl alcohol, etc.

Lipid：Mainly are butyrolactone, 2-ethyl butyrateetc, etc.

Others: such as Pyridine, ethyl silicane, etc.

2 Bamboo vinegar processing

2.1 Bamboo vinegar production methods

Raw bamboo vinegar is an acid liquid obtained by cooling the volatile substance when carbonizing and pyrogenating bamboo.

Presently, the raw bamboo vinegar production method could be divided into two categories: traditional kiln way and machine way.

2.1Production technique of raw bamboo vinegar

2.1.1 Traditional kiln technique

Bamboo vinegar obtained in this way is a by-product of bamboo charcoal. By directly burning the bamboo charcoal in the kiln with fuel-like wood timber, we can collect the raw bamboo vinegar from its condensation facilities installed in the chimney, it takes around 22-25 and the valid vinegar ratio is about 10%.

Technique flow for traditional-kiln bamboo vinegar:

Raw material preparation →cutting into segments or strips →natural or man-made drying →putting into kiln → kiln sealing and burning →bamboo vinegar collection → cooling→ out of kiln.

Characteristics of traditional kiln technique: clear, discontinuous

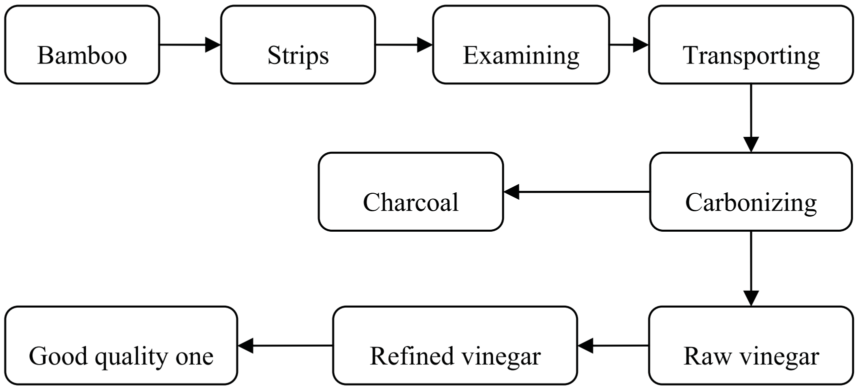
Advantage: light investment and long duration

Disadvantage: unstable in component and low in yield percentage

2.1.2 Machine-burning technique

It is based on the traditional technique and combined with modern industrialized production technique by using the electronic carbonizor, drying distillation kettle, vertical-pipe-like carbonizor and self-igniting carbonizor etc. Bamboo vinegar produced in this way is very stable in component and has low requirement for raw material. All the bamboo and its waste could be fully utilized. It also has a very short production cycle and is easy for operation with a very high yield percentage of over 30%.

Machine-made bamboo vinegar production technique flow:



Characteristics of Chinese clearance potable stove:

Successive and mechanical

Advantage: stable in component and high yield percentage and good quality

Disadvantage: heavy investment and high technique requirement

Tab.1 Differences of bamboo vinegar produced by different techniques

Index	From traditional kiln	From Machine
PH	3.1-2.5	2.3-2.8
Density（g/ml）	over 1.00	over 1.01
Content of organic acid%	4-5	5-8
refraction（%）	4-5	over 7.0
Color and luster	light yellow and transparent	brown and transparent
Chromatogram analysis	80—200	200—280

2.2 Bamboo Vinegar Extraction

Raw bamboo vinegar is a mixture containing many chemical compounds, some of which is easy to be oxygenated and some of which are inclined to be polymerized or changed in the color. Further refinement is necessary as it also contains some tar etc. The transparent and yellow or brown color liquid is called bamboo vinegar. The most popular method to refine bamboo vinegar is layering method.

Layering method:

Pour raw bamboo vinegar into the container, and layer for 3-6 months. During the layering period, the instable component will oxidate, converge and deposit, and we choose the middle clear part as the bamboo vinegar. This method is the best and most effective for separating and refining bamboo vinegar. The disadvantage is that it takes a long time.

Fig.1 sketch of layering method

Bamboo charcoal or active carbon method:

Mix the grain or powder of the charcoal or active carbon with the original product, churn up and filtrate, the filtrate is therefore the refined bamboo vinegar.The put away method is simple and low-cost, the main contents are not disturbed or changed, but the quality is not favorable; the bamboo charcoal or active carbon absorption method costs more, some valid content such as hydroxybenzenes is also absorbed, the refined liquid is almost achromatic, after some time it finally turns into buff.

2.3 Bamboo vinegar distillation

Distillation makes use of the different boiling point of components in the bamboo vinegar. Generally we use common still to distill, but this is only for rough classification of compound, and it is easy to operate, inexpensive but energy consuming. While rectifying tower is expensive with complicated operation, the advantage is that it saves steam, guarantees the quality, and has a higher rate of separation.

The bamboo vinegar obtained from distillation is called distillated bamboo vinegar.

Fig.2 Normal Atmosphere Distillation Device

Tab. 2 Technical Index of Distillation Bamboo Vinegar

Index Name	distillated bamboo vinegar
appearance	primrose yellow, transparent, no suspended substance
Total Acid Content%	≥2.5
density g/ml	1.005～1.020
pH value	2.2～2.8
Refraction rate（Brix）	3.0～5.0
Dissolved Tar %	≤0.1

3 Bamboo Vinegar Standard

Nowadays, there is no unified national standard and only the enterprise's standard is available. Zhejiang Fulaisen Zhongzhong Science and Technology Co., Ltd.(ZFZSTC) cooperated with Zhejiang Forestry Science Research Institute(ZFSRI) is embarking to draw a national industry standard with the support of the Ministry of Forestry and International Bamboo and Rattan Network Center(INBAR).

Based on the enterprises standard made in March, 2006, ZFZSCTC and ZFSRI revised and promulgated the new one. The abstract is as below:

◆Technique requirement:

● Appearance:

* Refined bamboo vinegar made by machine

Orange or brown, transparent liquid without suspending substance

* Bamboo vinegar made by traditional kiln

Orange or brown, transparent liquid without suspending substance

* Distilled bamboo vinegar

Light yellow, transparent liquid without suspending substance

●Physical and chemical indexes

Tab.3 Physical and chemical indexes of bamboo vinegar

Items	Refined bamboo vinegar made by machine	Bamboo vinegar made by traditional kiln	Distilled bamboo vinegar
Total Acid %	5.0-10.0	3.0-5.0	≥2.5
Density g/ml	1.010～1.050	1.005～1.030	1.005～1.020
pH value	2.3～2.8	2.3～3.0	2.2～2.8
Refraction ratio	6.0～8.0	4.0～6.0	3.0～5.0
Tar dissolution	≤2.0％	≤1.0％	≤0.1％

4 Applications of Bamboo Vinegar

Bamboo vinegar is multi-functional as it contains various ingredients. Currently, the main application of bamboo vinegar is as follows:

- ◆Food and health-care juice
- ◆Hygiene
- ◆Agriculture
- ◆Daily-use
- ◆Others

4.1 Health-care food

With strong acid-resistance, bamboo vinegar is an ideal chemical for pest-proof, freshness-keeping and fumigation. Food added with bamboo vinegar is strong in anti-acid and high in SOD activation content, which is able to remove the active acid in our body caused by fatigue and smoking etc.

Refined bamboo vinegar is pure and natural free from any harmful substances. Apart from vinegar, it contains over 280 useful substances including K, Ca, and Na etc. and over 20 mineral substances and trance elements necessary for the human beings. All the elements in bamboo vinegar are in good balance because it well absorbs the nature's essence easily soluble in bamboo vinegar, consequently, bamboo is a health-care juice and its function is over 30 times than the common edible vinegar.

Some experiments show that bamboo vinegar can improve stomach and intestines' function, activate cells, remove fat and prolong life, alleviate some diseases like skin problems, liver disease and diabetes etc. Beside, due to the phenol inside, bamboo vinegar can lubricate blood vessel and prevent arteriosclerosis and cerebrovascular disease.

4.2 Hygiene

Bamboo vinegar is 100% natural without any by-effect. Added into cosmetic scream and hand skin cream, the phenol in bamboo vinegar can penetrate into the deep lay of the skin and provide more nutrients. Acetic can soften skin keratode. Alcohol can clean and sterilize the skin. Therefore, bamboo vinegar plays a very important role not only in skin maintenance, but also in curing skin diseases like acne and dermatophytosis.

4.3 Agriculture use

Soil modifier

Bi-functional organic fertilizer

Fertilizer exclusive for berry

Fertilizer exclusive for tea

Fertilizer exclusive for grape

Fertilizer exclusive for strawberry

As efficiency improver

●Mixed with the pesticide, it can reduce 30-50% pesticide or improve 50% of its effect.

●Mixed with the fertilizer, it can reduce 30% of the fertilizer amount or improve 30%-50% of its effect.

●Drive pest and prevent disease. It can increase the yield of the crop and improve the quality of the fruits and vegetables.

Tab.4 Improvement of water with bamboo vinegar

Water	Bamboo vinegar	frequency
100ML	——	134HZ
100ML	40up	113HZ
100ML	80up	94HZ
100ML	160up	70HZ

From the table, we can find that bamboo vinegar can shrink the water molecule. After the effective elements of the fertilizer combine with bamboo vinegar, its penetrability will increase. Therefore, it can quickly penetrate into the plants, so that the amount of pesticide and fertilizer will be reduced and the effects can be improved.

Improve its ability to absorb effective P. Organic acid and increase crop roots vigor.

Crops roots can excrete some organic acid to dissolve and absorb P. Organic acid in bamboo, the efficiency chemical can also dissolve P. Organic acid and accelerate the roots to absorb effective P. Organic acid, which will activate the root vigor and develop its root system. Therefore, mixed bamboo efficiency chemical with organic fertilizer and compound fertilizer can improve the fertilizer efficiency.

Bamboo Vinegar has some substances which can help pesticide dissolution

Bamboo vinegar efficiency chemical contains several trance elements like alcohol, phenol and aldehyde, which can accelerate pesticide's solution and dispersion so as to enable the leaves well accept its effective ingredients.

Anti-bacteria function

Phenol in bamboo vinegar can sterilize bacteria, fungi and virus. Bamboo Vinegar in low solution is a good disinfector. It functions better if used together with other antiseptics especially some pesticide for killing of blast, anthracnose etc.

Efficacy of drive pests:

With the special smell, bamboo vinegar can drive pests, especially little leafhopper, red spider, aphid, snail etc. It also can prevent those pests to produce eggs in the plants.

4.4 Daily-used ware

Bamboo vinegar can be sprinkled in the bathroom to eliminate the smell, so as to keep fresh air. We can sprinkle bamboo vinegar in the bathroom every 3-5 days.

23-30ml bamboo vinegar in the bath water can make your skin smooth, as well as to promote blood cycle, removing fatigue, keeping moisture and curing skin disease.

Sprinkling bamboo vinegar diluted with cold water (10-50times) on chopping block or some other places, it can sterilize in the kitchen. We can put bamboo vinegar in small bottles. Sprinkle bamboo vinegar on the hands and legs can effectively prevent the mosquitoes.

A spoon of bamboo vinegar with a cup of water or lemon juice can kill large intestine bacilli.

In addition, with washing powder, bamboo vinegar can be used as scour.

4.5 Others

Bamboo vinegar is also applied in fodder additives and edible mushroom additives etc. For instance, if we put 0.5%-1% bamboo vinegar in chick and duck fodder, it can not only improve their immunity but also the egg quantity and quality and lessen odor from the manure. Bamboo vinegar can function well in bacteria pollution and mycelium development in edible mushroom production.

Chapter 13 Bamboo Shoots' Utilization and Industry in China

1 Outline of China's Bamboo Shoot Industry

1.1 Kinds of Bamboo Shoots and Nutrients

In China there are 39 genus, 500 or more species of bamboo, in which Phyllostachys pubescens, Ph. iridenscens, Ph. Duclis, Ph. Praecox f. Pervenalis, Ph. nuda, Ph. prominens, Ph. proecox etc. are fine monopodial species for shoot, Dendrocalamsis oldhami, D. beechyana var. pubescens, D. beecheyana, D. variostriata, D. latiforus, D. yunaicus, D. brandisi, D. hamilitonii, Gigantochloa albocilita, G. levis, g. ligulata are good sympodial species for shoot.

All the shoots of the above-mentioned bamboos are brittle, tender, delicious and nutritious. It is shown by chemical determination and analysis for nutrient composition of 18 kinds of monopodial bamboos and 10 kinds of sympodial bamboos that fresh shoot contains about 90% water, over 2.4% protein, 17 sorts of amino acids which are composites of shoot protein, particularly amino acid content of Lys., Glu and Arg, etc. in bamboo shoot is much higher than one of such common vegetables as cabbage, carrot, onion, pumpkin. 8 Kinds of necessary amino acids which can not be synthesized in human body can be provided only by food. Except for Tryptophane which has not been detected, other amino acids of Lue. Ile., Lys., Met., Jhr., Phe., and Val. are all available in bamboo shoot. Meanwhile, His., which could not be produced in child body until it is 2 years old, therefore, it is sometimes called necessary amino acid for 1-or 2-year old child. Besides, Met., and Phe. can be transferred to Cys. and Tyr. respectively, but the latter is under research for its potential usage against starvation, black hair, cancer, etc. Lys of shoot is also lack in rice, flour, corn, and beneficial for children's growth and development, so it is regarded as one scarce amino acid. The total sugar content absorption capability by human body is 2.5%, fat is 0.05%, and edible fiber 0.6%～1.2%. There are over 10 other kinds of mineral elements such as Cr, Zn, Mn, Fe, Mg, Ni, Co, Cu, etc, in particular, bamboo shoot contains element of selenium which is called "Miraculous Life Element" because once without the supply of this element, there will appear over 40 sorts of diseases, even liver cancer. Content of selenium is varied with bamboo species and the growth positions. It has succeeded by our trial experiments that organic and unorganic selenium content in the shoot can be enhanced by external injection of unorganic selenium into bamboo cavity. Bamboo shoot has also the element of germaclinium. It is reported in Japanese patent that germaclinium extracted from shoot can activate human cell.

It can be concluded that from the above facts that bamboo shoot is one kind of ideal vegetable for its being free in pollution, low in fat, high in edible fiber, and rich in mineral elements.

1.2 Booming of Bamboo Shoot Industry

From the 1970s to the 1980s, the total bamboo forest area in China is about 1.8 million hectares in which 80% are Moso Phyllostachys pubescens, by then bamboo is mainly used for timber, and very rarely for shoot, majority of the fresh shoots are made into dried shoots, or salted shoots, except for the minority for instant eating and domestic sale. Braised shoot made in Ningbo, Zhejiang Province by using shoots of Phyllostachy glauca and Ph. viridis as raw material has earned a golden prize of world exhibition, but export amount is rather limited. Bamboo shoots of vast area are mainly for self-production and self-consumption, so the market is hard to be formed.

With increasing development of science and technology, more and more value of shoot in medicine and edibility has been exploited, meanwhile people's living standard is being improved, and demand structure of food is changing, more and more Chinese people like to eat shoots which leads to the increasing sale volume of shoots and the sale price correspondingly. Especially since the 1980s bamboo dice factories with an investment of over RMB 1 million Yuan have been appearing nationwide. The governments at all levels pay high attention to that opportunity of change, and call for the mass to fully develop bamboo cultivation, improving low-yield timber bamboo stand into shoot stand or stand for both shoot and timber, and to set up some new high-yield demonstration bases. For example bamboo shoot stand in Yuyan City of Zhejiang Province whose annual shoot yield is 37.5t/ha., a bamboo stand of 1 ha. can produce fresh shoots of 15～22t, and a bamboo stand for shoot and timber can annually produce 23t/ha. for new timber, and 2.4t/ha. for shoots.

According to statistics released by the State Administration of Forestry, P.R. China, the total bamboo forest in China in 1998 reached 4.5 million ha., and the production value RMB 17 billion Yuan, in which USD 500 million from export, farmer's annual income in bamboo production area occupies about 30～40% of their total yearly income.

A lot of bamboo dice factories have been sharply decreased even closed down since 1997 because of the acute reduction of export of 18 L shoot can into Japan.

In that context, governments at each level decide a rapid adjustment of industrial structure and operation mechanism, which have been turned into exploitation of new products such as preservation of shoot, instantly-polled shoot can, and tourist food, which altogether peaks to 2000 kinds. Shoot value is doubled by deep processing, and the domestic market is also opened up. For instance, annual shoot consumption per capita in Huzhou City with a population of 92,000 consumers is about 18 kg. Shanghai consumers totally over 1000 t of "winter shoot" (Phyllostachys pubescens) and "Thunder shoot" (Phyllostachys praecox) during the spring festival (from Jan. to

Feb.). So you can imagine how vast the China's shoot market capacity is. It is reported in 1999 that Fujian Province has a total bamboo forest area of 0.75 million ha., and an annual fresh shoot production of 80,000 tons with a production value of RMB 3 billion Yuan. Zhejiang Province has a total bamboo forest area of 0.63 million ha., and an annual fresh shoot production yield of 65,000 t with a production value of RMB 5.5 billion Yuan, there are over 2000 factories there. It can be seen clearly from county level. In Lin'an City of Zhejiang Province, the total bamboo forest area is 30,000 ha., its production value was RMB 5 million Yuan in 1984, but now 53,000 ha., and RMB 650 million Yuan, especially for Phyllostachys praecox whose area is only 200 ha., and shoot yield is 1,420 t with a production value of RMB 800,000 Yuan in 1984, but now 14,000 ha., 60,000 t, and RMB 230 million Yuan respectively. There are more there over 40 factories, and 10 special fairs, and over 4000 farmers have become a full-time dealer of shoot, so it has come into a rural pillar industry there. Deqing has an area of Phyllostachys praecox of 3,800 ha, and a production yield of 32,000 t with an annual production value of RMB 230 million Yuan. There is a bamboo forest area of 65,000 in Anji County, where Moso has 50,000 ha. or a rise of 8,000 ha. compared with that of the 1970s .So far bamboo processing enterprises in Anji have surpassed 1500, in which over 60 are township-or village-owned. Annual production volume of clear-water boiled shoot can is 25,000 t, they also produce instantly-polled shoot can, soft-packaging flavoured shoot. The total production value of shoot alone is RMB 350 million Yuan, and that of shoot and timber together is RMB 1.6 billion Yuan.

In short, a shoot industry oriented by market demand and propped by processing utilization, based on resource cultivation ,invigorated by science and technology with an integration of production, processing and sale and with a organic growth of economy, ecology and society is coming into formation. Further processing of shoot especially in the respect of medicine and industrial usage is looking forward to research and opening up. Explore new products, broaden domestic and international market are still faced with a lot of difficulties and problems, although grouping and industrialization is rather limited but has a bright prospect.

2 Comprehensive Utilization of Bamboo Shoot

As shown by survey in Zhejiang, the using percentage of Moso shoot purchased by factory in early April was about 44%, but only30% of that done after April 20 when shoot height was up to 35cm, despite the lower price then, the shoot factories stops purchasing raw shoot for producing shoot cans for export. In that case, a great deal of Moso shoots can not be treated on time, and have to be left over for decay, meanwhile, those shoots in factory or over the hills have to be treated as waste for its being attacked by flies and insects. On the other hand, shoot factories also take shoot sheath and old shoot bottom as a waste, as a consequence, leading to a big wasting.

According to nutrient composition analysis, basal shoot part, sheath, middle shoot part are rather rich in sugar, crude protein, free amino acid, and mineral element of Fe, Zn, so advice on shoot integrated usage is as follows:

(1) Old basal shoot part should not be discarded;

(A) Make into fodder by grinding and squeezing;

(B) Make into shoot powder as a food filling by long soaking, softening drying, grinding, etc.;

(C)Extract selenium or Tyr.;

(D)The remaining left over from the above processing of extraction and squeezing can be used for edible fungus cultivation medium.

(2) If not used properly, the sheath will pollute the environment, so now factories concerned in Hangzhou are trying to extract “Bamboo Medicine”. It can be also used for cultivation of edible fungus cultivation and pumpkin after treatment.

(3) Middle part of shoot can be made into soft-packaging leisure food by slicing, stripping and dicing with exception that is produced into round-shape bamboo strip which will be processed into instantly-polled flavoured shoot can or soft-packing chilli shoot.

Usage of shoot usually refers to the restricted dried or canned shoot; in fact, it still has value of medicine and industrial utilization. As recorded in the book titled “Food Nutrition and Therapy”, bamboo shoot is cold in property, functions well in removing sputum, enhancing the digestion, relieving toxicity and improving diuresis. Some bamboo shoots attacked by insects have a diuretic effect, and are often used for healing edema and ascites. Besides, shoot contains much saccharide which can resist against little white mouse tumour and tumour-180, If enjoy the shoot cooked with sea cucumber, human face skin becomes fine, tender, radiating. These facts indicate that bamboo shoot has multiple outlets of usage.

So far a lot of shoot composition is mysterious. What’s more, shoot nutrient composition varies with species, and with a big change range of amino acid content, which is different with different shoots collection time, shoot growth condition and shoot height. For example, D. oldhami shoot appears in the morning and is dug out, which can be instantly eaten by de-sheathing and washing ,but can not be directly eaten until by boiling and rinsing as bamboo shoot grows 10 cm over the ground. On the other hand, different storage methods will impose and effect on shoot nutrient.

It requires us to make an intensive research on each kind of the composition in bamboo shoot for full utilization. There are over 1200 species of bamboo in the world, many of them can not be directly eaten, but with further research, the edibility can be tapped out.

3 Main Methods of Preservation of Bamboo Shoot

The necessary requirements and objectives for storing and preservation of bamboo are as follows: First, it can keep its original characters; second, it can prevent it from rotting and can extend in intensive processing duration so as to raise its economic benefits.

Over 80% of China’s bamboo forest is Phyllostachys pubescens whose shooting season falls on from March to May, but is sold narrowly in the early April. In this context, majority of town-owned shoot processing factories have no strong capability of on-the-spot purchasing, trucking, and processing, and selling, therefore, some of them have to be left in the plantation or factory just for rotting. That, of course, will reduce bamboo farmers' income. At present, many methods, available both at home and abroad, for storing and preservation of other vegetables and fruits are not suitable to bamboo shoot, such as pitch storing, cave storing, liquid membrane, wax coating, air controlling preservation, radiation and quick freezing etc. Vacuum freezing will make the bamboo shoot tasteless and unbrittle. If we adopt the advanced vacuum freezing technique, the price of bamboo shoot could be too high to be accepted, because the cost of the equipment is rather expensive, which includes four parts, the refrigerator, reduced pressure device, storing depot and regulator. To find out a proper way for township-owned shoot processing factory, scale is a crux. After the bamboo shoot is dug out, it is still an active and living organic body, it still undergoes breathing, some nutrient components are on the way of inter-transforming, on the other hand, the external factors such as temperature, humility, microbe and storing conditions, impose an effect on storage span of bamboo shoot. Water is a necessary requirement to keep bamboo shoot physiologically active and fresh. Without water, the bamboo shoot will lose its fresh outlook, and its quality degrades. Meanwhile, enzymes in bamboo shoots become more active and sacchraises are prone to hydrolysis, as a result, it will be more subject to infection and rotting. The major sacchraises in bamboo shoots are glucose, fructose and sucrose. Sacchraises, basic substance of maintaining bamboo shoot respiration, will be torn down with storing.

The respiration if bamboo shoot is divided into oxygenous and deoxygenous ways .Under the extra oxygen atmosphere, the sacchraises will be completely oxidized into carbon dioxide and water, accompanied with a great deal of heat and energy. This respiration is called oxygenous respiration. The reaction equation is

$$C_6H_{12}0_6+6O_2 \rightarrow 6CO_2+6H_2O+674\ \text{Kcal}$$

Under less oxygen (usually the amount of oxygen is below 2 %), this respiration is called deoxygenous respiration. In this respiration, the reaction products are alcohol, acetic aldehyde, carbon monoxide, the heat releasing is less than the oxygenous reaction. The equation is

$$C_6H_{13}O_6 \rightarrow 2\ C_2H_5OH+2\ CO_2+28\ \text{Kcal}$$

During storing, the bamboo shoot respiration is strong, which will cause bamboo shoot to have higher temperature, or the bamboo shoot is more susceptible to decaying.

Therefore, a due low temperature condition is required to inhabit water transpiration and microbial activity. Any damage or breaking of bamboo shoot will speed up respiration reaction which leads to rotting caused by infection, multiplication of more microorganism.

Anyway, the water content, temperature, humility and enzymatic activity are all related to the respiration of bamboo shoot, and take an important role in keeping bamboo shoot fresh in storing, transportation, the shoot should be avoided from a direct sunshine, and be placed in a dim and low-temperature place.

Only in conformity with these rules, the shoot can be stored for a long time.

Now, some vital domestic and international methods /expertises /know-hows of preservation of bamboo shoot are profiled as and introduced as follows for due reference.

3.1 The Method for Preservation of the Fresh Bamboo Shoot

(1) Storing in cold depots. In Japan and China, the raw shoot is stored in cold depot, where the temperature is controlled at about 5℃ with an air humidity of about 86 %. The storing period reaches up to about 3 months. But, in this way, the cost of storing is very high because building up such a cold depot will cost RMB 1million Yuan or so.

(2) Salt method. This method is to control enzyme activity by saline water, the saline dosage ranges from 15 % to 25 %. The storing span is about 4 months. Its shortcoming is that more nutrient of shoot will escape.

(3) Alcohol coating. It is about coating the shoot cutting with alcohol. According to the Japanese report, in this way, the shoot can be kept for 4 days or so.

(4) Fruit preservation. With English fruit preservation, the shoot can be stored up to 4 days.

(5) Use $Na_2S_2O_5$ as the preservative. The shoot is kept in a sealed plastic bag with that preservative. The storing span is nearly half a year. This method is not only simple, convenient, operational, but also low in cost. However, the preservative of $Na_2S_2O_5$ is harmful to human, so it must be washed again and again until all the preservative is not left over for the hygienical safty. In this case, its original colour is bleached and lost, and more of nutrient runs away.

(6) Storing up with a sugar solution. Fresh shoots, whose injured and nasty basal parts have been removed away, but with intact sheath is soaked in a pail containing a 5 % sugar solution, with its tip being upward. The storing span is 5 or 7 days

(7) A know-how of freshness keeping for raw shoot. It is applied mainly for sympodial bamboo shoot. The preservative is $Na_2S_2O_3$ and benozic acid solution. The raw shoot treated in this way can be processed into a soft-packaging bag shoot. Be sure that that if washing of the preservative is not enough, it will still be harmful to human body.

(8) A short-cut preservation of raw fresh shoot. The advantage of this method is a longer period of storing, nearly about one year. The taste of shoot processed in this way is still delicious and the preservative can be entered into process of human metabolism. This method is safe, and simple, it is suitable for most shoot processing.

The main technological processes are below:

Peeling off sheath---Shaping (cutting the old, rotted and infected parts)---Adding edible salt and water---Immersing shoots with saline solution, stirring and placing for 2 or 3 days---Adding a pack of No. 3 preservative into each bag to reduce nutrition loss and keep shoot as it is ----Stirring ---Vacuum bag----Sealing bag----Storing in a dim room. Because cooked, the shoot should be rinsed for 1-3 hours, and then for boiling.

3.2 Preservation of Boiled Shoot

(1) The know-how for sour shoot making

In countryside, farmers often make a sour shoot, the steps are as follows:

Boiling shoots---Cooling----Putting and pressing them in a jar---Inserting jar with straw---Placing the jar downside in a basin full of water---Storing it in a dim place.

With the reaction of lactic acid bacteria, the PH value of the shoot solution is kept between 3.8 and storing period is up to 3 months or more.

(2) Saline pickled shoot

This method can be conveniently adopted by each family. The producing process is below:

Peeling off the sheath---Boiling---Immersing the shoot into a 25 % salt (NaCl) solution pressing the shoot with a few of stones to prevent them from floating up.

The storing period is about 1 or 2 months. Before cooking, the shoot should be washed with clear water for one day to remove the salt. The shortcoming of this way is loss of most nutrition of shoot.

This method is very simple. The device involved is a household water container. Another method of pickling shoot is to wash cooked shoot with clear water for one or two days. When the PH Value of shoot solution has changed between 4 and 5, the shoot can be packed into plastic bags. For each bag, add 1.5 kg salt with water, sealing bag. Shoot can be kept for 2 or 3 months.

(3) Water boiling shoots with soft packaging

The production process is below:

Boiling shoot---Peeling off sheath---Cutting old part---Rinsing----Shaping---Boiling in water---Cooling ---Putting them into bag made by PET/PE or PET/OPP in a size of 24 cm x 17 cm. The net weight for each bag is 350 or 500 g---Vacuum sealing----Sterilizing---Storing them in a cold and dim place.

This storing span is about half a year. The advantage of this method is convenient transportation.

(4) Preservation by S.M formula preservative

This storing method is invented by the Subtropical Forestry Research Institute, the Chinese Academy of Forestry, and has been granted with a patent by the Chinese Patent Administration.

The material is the raw shoot. The producing process is below:

Boiling shoot----Cooling----Cutting old part---Rinsing----Packing shoot into a plastic bag the net weight for each bag is 23 kg----Dissovling a bag of preservative S.M. preservative into water------Making shoot immerse with this solution, keeping the level of solution 5 cm far from the bag edge----Vacuuming and sealing the bag----Placing shoot in a dim place.

Before cooking, the shoots should be rinsed about 30 hours; the storing period is 3 or 10months. In this way, the original character of this shoot such as odor, color, flavour, etc., can be held back. The preservative is safe to human being.

After rinsing, the shoots can be, not only cooked as delicious dishes, but also made further into variously-flavoured can. This shoot processed in this way has reached the quality inspection standard imposed by the state food and hygiene departments. Attention, before cooking this shoots, they have to be rinsed about 30 minutes and boiled for 5 minutes.

(5)The method of semi-finished boiled shoots can (18 liters)

The 18-liter boiled shoot can is a most popular method for raw shoot temporary storing in the world. In this way, the shoot quality is still kept in a good condition and its storage term can be lasted up to 18 months.

The technological processes are in the below:

Boiling shoots –cooling—peeling off sheath—rinsing—shaping—classing—making soup—sterilizing—sealing—cooling—stocking

In mountainous areas with inconvenient traffic, the shoots can be boiled in a big iron pan (l meter in diameter) for over 2 hours, until the shoots are well done.

If the amount of shoots for processing is 100 tons or 1000tons, the equipment is needed as follows:

A 1.5-or-2 ton boiler, a ceramic tile-faced poll(capacity is 1000 or 1500 kg shoots),whose volume is 1 meter*1.5 meters*2 meters, a 1400 m^2 working building, a 400m^2 depot, a 200 m^2 sheath-peeling building and office building. The total investment is about RMB 1-1.8 million Yuan.

The quality inspection standard of boiled shoots is implemented by the state GB 77010---90. The products exported into regular grades and secondary grades. The regular grades are divided into A, B, and C.

(6)Finished boiled shoot can

For details, please see the Standard of ZB 77010-90 promulgated by the Light Industry Ministry of P.R. China. It is mainly used for the production of fresh shoot of Phylostachys pubescens and Dendracalamus latiforus.

The producing steps:

Processing—packing can—adding clear water—sealing—sterilizing classification

The canned shoots are divided into those grades: whole shoot loading, mixed loading, chip loading, slice loading, dice loading. The whole shoot loading are also divided into 3 classes of large, medium and small.

(a) Large whole shoot loading. Its net weight is 2950 g. It contains 3 or 6 pieces of bamboo shoots. The code or this product is 855 L;

(b) Medium size whole shoot loading. Its net weight is 2950g. Its loading capacity is from 7 to 10 pieces of whole shoots. Its code number is855M;

(c) Small whole shoot loading. The code number is 855 S;

(d) Mixed loading shoot can. This can is made of the shoot tip, broken shoot tip or modified shoot tip, the shoot is cut into half. They are loaded in mixture together. The code number of this shoot is 855.1;

(e) Chipper loading shoot can (including modified shoots). The shoots size is 4.5 cm x 2.5 cm x 0.45 cm. The code number is 855.2;

(f) Slice loading shoot can. The size of this shoot is 4.5 cm x 0.3 cm x 0.3 cm. The code number is 855.3;

(g) Dice loading shoot can. Its code number is 855.4.

4 Processing of Dried Bamboo Shoot

4.1 Tianmu (Small-Sized) Dried Shoots

It is produced nearly only in Anji and Lin'an counties, Zhejiang province. The raw material is Ph. nuda shoot. Its technological process is as follows:

Removing the old part—weighting—rinsing—adding water—adding salt—baking for 4 hours—boiling—filtrating and placing them on the bamboo mats—pressing—covering them with a plastic film—fermenting for 4 or 5 days—twisting the tip of shoots—making the shoots ball-shaped—taking them to nearly dried –taking out—hammering them—grading—packing

The dried Tianmu dried shoots are divided into curing, fatting tappet, bare tappet, little tappet and traditional tappet.

4.2 Big-sized Dried Shoot

Technological process:

Removing the sheath—immersing them in clear water for swelling for a few of hours—taking them out for another boiling for 2-3 hours to make colour turn from green into white or jade—rinsing, pricking node—cooling squeezing out water and tightening for about 3 or 6 months---flattening---taking them out for seasoning—scaling---packing

Device and tools involved:

(1) Building for boiling, fermenting and drying;

(2) Boiling stove including wood scoop, pot wood squeezer, etc.;

(3) A three-layer baling chamber for shoot baking;

Classification: the dried shoot is divided into such grades as Phoenix tail, Sheep's horn, Short tips, Auxiliary tips and so on.

4.3 Dried Mar Shoot (Dried Sliced Shoot)

Technological process:

Peeling off sheath---chipping shoot---slicing it into half----making it into flake-shape-----boiling for 1 hour---lacing them into a sealed pail for fermentation in 10 days----seasoning or baking---grading---packing

The elite shoot appears yellowish brown and lusterous.

5 Shoot Products of Fine processing

5.1 Braised Shoot Can

The products are divided into tow kinds: one is "Longyun" shoot Can, its product code is 811.1, the other is "Danzhou" shoot can, and its product code is 811.

Equipment :1.5 or 2 ton boiler, can sealing machine, horizontal high pressure sterilizing pot, stainless steel double-layer pot.

5.2 Soft-packaging Flavoured Shoot

The soft-packaging bag is made of PET /OPP or three-layer different material structure (the outer layer is polyester, the medium is aluminum plate, and the inner layer is coated with polyethylene) If the Pa is painted on the aluminum plate, the bag

can stand the temperature between 120℃ and 150 ℃. The equipment: Boiler,

stainless steel double -layer pot, high pressure sterilizing pot and vacuum sealing machine.

The technological process: Chipping shoot ----Boiling ---Rinsing---Weighting ---Saucing ---Sealing can----Sterilizing---Stocking.

In rural area with inconvenient traffic, this is a simple processing way for shoot, but anyway, the vacuum sealing machine has to be equipped.

5.3 Fine Instantly-pulling Shoot Can

Technological process:

Boiling shoot---Chipping---Rising with clear water---Weighting ---Pouring into double-layer pot----Adding water and sauces----Cooking ---Packing in can----Weighting ---Adding soup ----Sealing can ---Rinsing ---Sterilizing ---Cooling ----Storing in depot.

Equipment: 1-or-2-ton boiler, sealing machine, horizontal sterilizing pot (if they are exported to America, the pot should be equipped with recording graph for temperature, pressure and chronograph) and easy pouring stainless steel double-layer pot.

The product can be kept for 18 months. For the degraded shoots, and those which could not be processed on time in the factory, they can be firstly preserved temporarily, then intensively processed into various kinds of cans. In this way, the income will be raised nearly twice times, so the economic benefit is great.

Reference

Shi Quantai, "Processing and Utilization of Bamboo Shoot", Expert Crack on the Development of Cash Forest in Chinese Mountainous Areas", Chinese Forestry Publishing House, July 1998.

Zhao Zhangzhong, The Food Nutrition and Therapy, Shangahiai Scientific Publishing House, Jan. 1991

Table 1 Comparison of Amino Acid Content with Different Storage Methods for the Same Batch of Bamboo Shoot

shoot / g/100g / Amino Acid	A1 Preservation shoot by MS	W5 Clear-water shoot	N6 Salted shoot	D8 Preservation shoot by other preservatives
ASP	2.768	3.039	0.294	/
JHR	1.127	1.123	0.091	0.476
SER	1.110	1.031	0.118	0.474
GIU	3.222	3.282	0.399	1.134
GLY	1.280	1.248	0.141	0.484
ALA	1.946	1.703	0.398	0.632
VAL	1.612	1.667	0.270	0.110
MET	0.444	0.305	0.196	0.463
ILE	1.123	1.258	0.322	0.710
LEU	1.920	2.203	0.265	1.965

shoot / g/100g / Amino Acid	A1 Preservation shoot by MS	W5 Clear-water shoot	N6 Salted shoot	D8 Preservation shoot by other preservatives
TYR	1.040	2.435	0.265	0.254
PHE	0.543	1.1235	0.1645	0.518
HIS	0.658	0.883	0.214	1.675
LYS	2.408	2.074	0.309	0.459
ARG	3.898	2.051	/	0.751

Chapter 14 Research & Development of Extract of Bamboo Leaves (EBL)

Bamboo Leaves have been listed in the catalog of "*Natural plants can be used both as food and drug"* by the Ministry of Health, P.R. China since 1998. Bamboo leaf is a traditional Chinese herb, usually used to aid in clearing fever for its detoxification properties. The plant has also been used as a food source in many places of China as well as Southeast Asia.

1Effective Components in Ebl

C-glycosyl flavones, flavonoids glycones, coumarin lactones , trace elements amino acids & peptides.

2 Functionality of Ebl971

①It has excellent scavenging power for many kinds of active oxygen free radicals (AOR) and can prevent lipid peroxidation in both heart tissue and brain artery.

②Its effects on anti-aging, and anti-fatigue are equal to pure bee-pollen.

③Its functions to lower blood TG and elevate HDL-c are better than the extract of Ginkgo biloba (Egb761).

④ Additional activities including anti-bacteria, diminishing inflammation and anti-virus, which are similar to tea polyphenols.

⑤Its efficacy of codein, removing phlegm, clearing fever and detoxification is better than Zhu-Li, a traditional Chinese medicine made of bamboo juice.

⑥It has good immunity effects and may assist in enhancing human immune system.

Improve Technology & upgrade quality

Ebl971 ⟶ EOB-f01 ⟶ flavone monomer

TF 24~32% ³ 50 ³95%

Membrane Isolation (UF, NF, RO) Countercurrent Chromatograph And/or CO_2 Supercritical Extract and/or Preparative HPL

3 Expand Application Fields

Foregoing usages: Beverages, Wines, Healthy food (nutraceuticals);

Lately exploited fields: Chinese medicines, Food additives (natural antioxidant), Feed additives, Cosmetic, Preservatives

4 Strengthen Basic Research

Mechanism of TG/LDL-c lowering effect; cancer prevention action mechanism detoxification; skin physiological effect (1) Ebl exhibited an antioxidant property in a peroxyl radical induced liposome peroxidation

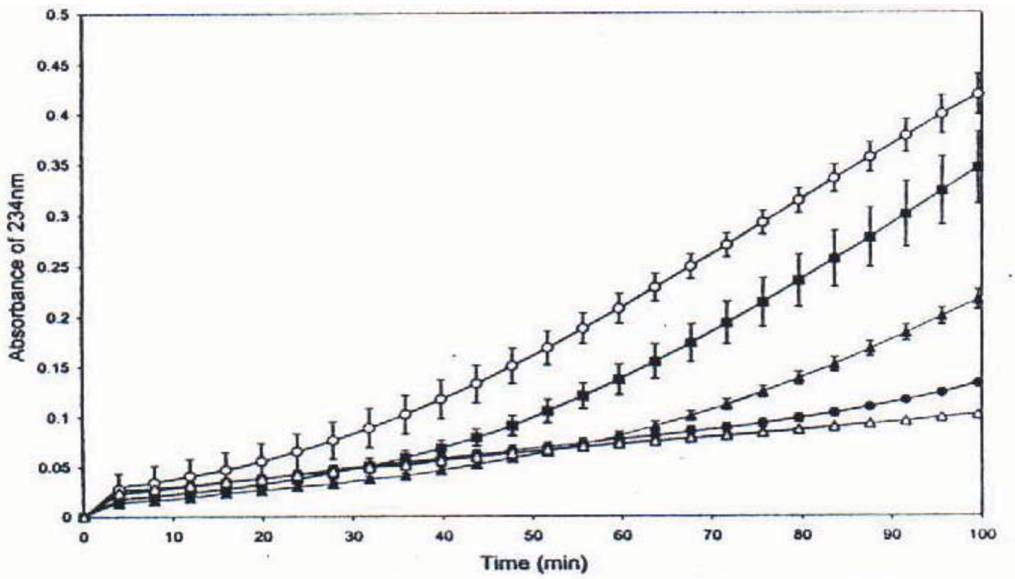


Figure 1. Time course of formation of conjugated diene in the oxidation of structured liposome mediated by peroxyl radical generated by thermal decomposition of AAPH at 37 °C: (○) control incubation; concentration of BLE (■) 0.5 μg/mL, (▲) 1 μg/mL, and (●) 2 μg/mL; concentration of Trolox (△) 1 μg/mL; mean ± SD, n = 3.

EBL971 exhibited an antioxidant property in a peroxyl radical induced liposome peroxidation at 37°C, which was characterized by both a concentration dependent prolongation of lag phase duration and a reduction of rate of propagation.

Compared to the control incubation, EBL971 increased lag phase by 24, 55 and 135%, and EBL971 exhibited an antioxidant property in a peroxyl radical induce liposome peroxidation at 37°C, which was characterized by both a concentration dependent prolongation of lag phase duration and a reduction of rate of propagation.

Compared with the control incubation, EBL971 increased lag phase by 24, 55 and 135%, and decreased the rate of propagation by 2, 36 and 71% at concentration varying from 0.5-2.0mg/ml, respectively.

Trolox in the similar condition exhibited higher antioxidant activity than EBL971 in both of lag phase and rate of propagation ($p<0.01$).

(2) A concentration-dependent protection of Ebl was observed in the human LDL-oxidation model

Agarose gel electrophoresis of human LDL incubated with cupric ion

L1=LDL incubated without Cu^{2+}(native)

2=LDL incubated with Cu^{2+}(oxidative)

3=LDL incubated with Cu^{2+} and 10mg/ml of Ebl

4=LDL incubated with Cu^{2+} and 25mg/ml of Ebl

5=LDL incubated with Cu^{2+} and 50mg/ml of Ebl

6=LDL incubated with Cu^{2+} and 100mg/ml of Ebl

7=LDL incubated with Cu^{2+} and 10mg/ml of BHT

8=LDL incubated with Cu^{2+} and 20mg/ml of Vc

9=LDL incubated with Cu^{2+} and 10mM of EDTA.

(3) Ebl protected supercoiled DNA strand against scission induced by AAPH-mediated peroxyl radical

The presence of reactive oxygen species, such as peroxyl radical, resulted in dramatic scission of pBR322 supercoiled DNA. The addition of Ebl provided a protective effect against peroxyl radical-induced DNA breakage. In the aqueous medium, Trolox concentrations of 1 and 2μg/ml added in vitro significantly ($p<0.001$) reduced DNA damage induced by peroxyl radical. High protection against DNA strand breakage observed with 2μg/ml of Trolox was also achieved by BLE at 20μg/ml.

	% protection
control	0
Ebl, 10 mg/ml	37.5±0.5***
Ebl, 20 mg/ml	82.1±5.9***
Trolox, 0.5 mg/ml	46.4±6.1***
Trolox, 2 mg/ml	92.6 ±2.6***

Contents

Chapter 1 Landscape Ecology Contributions to Forestry and Forest Management in China: Progresses and Research Needs

1 Introduction

Forest is a major component of terrestrial ecosystems and provides important ecosystem services such as ecological functions and wood and numerous other products that significantly contribute to human well-being. Forests, like many other types of vegetation, have faced great challenges of environmental changes, with human disturbances as a main driving force in the past centuries. Over the past 50 years, forests in China have experienced unprecedented rapid and extensive changes, due largely to rapidly growing demands for food, fresh water, timber, fiber, and fuel (Ma, 2005). Climate change, e.g., increasing frequency of extreme events of dry and hot periods, is expected to exert significant impacts on forests over the next 100 years or so (IPCC, 2007).

Climate change will cause geographical shifts in distributions of individual tree species and forest types by altering the spatial and temporal patterns of temperature and precipitation, two of the most fundamental factors that determine the distribution and productivity of trees and forests. These impacts are not limited to trees themselves, but also to the whole forest ecosystems and the associated biota. The changing climate will also affect the occurrence, timing, frequency, duration, extent, and intensity of disturbances such as fire, insect and disease, hurricane, drought, and wind storm, which shape forest ecosystems by influencing their composition, structure, and functional processes (Dale et al., 2001; Lynch, 2008). The forest sector needs to assess the short-term and long-term impacts of climate change on trees and forests, identify their adaptive potentials, and find ways to improve forest vitality and resilience to cope with global change. There is therefore a clear need to integrate adaptive strategies into current forest management, especially in fragile landscapes and forests under severe threats by both human activities and climate change.

Forest is a major stabilizing component of natural landscapes, protecting soil, water, and households, reducing hazard risks of floods and landslides, and mitigating global climate change by carbon sequestration. Forest ecosystem services depend critically on the area and spatial distribution of forests across landscapes. Many issues of global importance, such as climate change, land use and land cover change and water resource alteration, are of great relevance to forests; furthermore, the consequences of these factors to forests, forestry and human well-being manifest mainly at the landscape and regional scales. Seeking solutions and establishing scientific basis to tackle many of the forestry-related issues should therefore be based on enhanced knowledge of landscape ecology and associated application technologies in terms of GIS, remote sensing, and decision support systems (DSS).

Forest management in the context of global change has become more complex and cannot be approached only at stand level and by the forestry sector alone. Instead, forest management should be implemented with cross-sectoral cooperation at the landscape level. Embedded in the concept of forest landscape management is the recognition of interrelationships among land use, sustainability of landscape resources such as desired goods and services, and diversified adaptive options for different stakeholders to cope with global change and land use conflicts. Sustainable forest management (SFM), which is guided by explicit goals, executed by policies and protocols, and monitored and assessed by defined indicators and standards, has been widely advocated and become the mainstream of the world forestry development. In the last two decades and aided by the fast developing spatial information technology in terms of computer, GIS, and remote sensing, landscape ecology has been increasingly applied to SFM practices (Diaz and Apostol, 1992; Otto, 1996; Schlaepfer, 1997; Wilson and Baker, 1998). Faster and more extensive implementation of the SFM paradigm should greatly reduce anthropogenic impacts and minimize negative climate change threats.

The objectives of this chapter are two-fold: to provide an overview of forestry, forest management, and challenges under climate change in China, and to describe the contributions and future research needs of landscape ecology to achieve SFM. Section 2 focuses on historical and current status of China's forestry and forest management. In this section, we identify the past problems and illustrate the progresses made in China's forestry over time, along with different policies and needs from various periods of national economic development. Section 3 describes the major challenges that China faces today in forestry and forest management, especially those under the climate change conditions. Following a summary of landscape ecology research that has contributed to the solutions to these challenges in section 4, a number of future research needs is listed in section 5. Landscape ecology has a major role to play in coping with climate change and facilitating SFM by providing theories and management tools for forest restoration, biodiversity conservation, land and water resource management and forest landscape planning. Adaptive forest management through a participatory and cross-sectoral approach should be promoted to ensure landscape biodiversity, health and sustainability at multiple scales.

2 China's forestry and forest management

2.1 History of forestry and its mission

Historically, China had rich forest resources and biodiversity due to its vast geographical areas and highly diversified environmental conditions, which sustained various forest ecosystems ranging from boreal forests in the North to tropical rain forests in the South. Forests have been providing a large quantity and varieties of material resources for China's social and economic development, as well as China's civilization. However, natural forests in China had been greatly reduced over time, particularly in the past several centuries, due to agricultural development, over-exploration, and years of wars. For example, China's forest coverage was estimated to have decreased from 64% in 2000 BC to 10% in 1949 (Ma, 1997; Fan et al., 2008). Since the founding of P. R. China in 1949, the forestry development has experienced a zigzag process characterized by three distinct phases of reduction, rehabilitation and development of forest resources.

Phase I: Focusing on timber utilization. From the 1950s to the end of the 1970s China's forestry focused primarily on timber utilization. This phase was guided by the traditional forestry concepts and exemplified by extensive exploitation of forest resources. In order to meet the needs of national economic development, the priorities of forestry were to secure supply of timber and rehabilitate the country's timber-production capacity from war-induced damages. Under those circumstances, forests were regarded primarily as economic resources, forestry as a key industry of the national economy, and forestry sector as an industrial sector. Forest management in this period centered on increasing timber production and emphasized on enhancing human-aided stand regeneration after clear-cut.

Phase II: Balancing timber production and ecological improvement. From the end of the 1970s to the late 1990s, the rapid forestry development, especially the implementation of the Three-North Shelterbelt Development Program, ushered China’s forestry into a phase with equal emphases on timber production and ecological improvement. It was not a simple coincidence that this phase overlapped closely with the first two decades of China’s reform and opening-up during which profound economic and social changes took place. While promoting timber production, China gradually intensified its efforts in protecting forest resources, conducted large-scale afforestation and greening campaigns, and initiated ecology-based forestry programs to control soil and water erosion, to protect and improve environmental conditions, and to increase forest resources. The strategic forestry objective was to enhance both forest ecosystems and forest industry systems at the same time. In this period, forest management was mainly conducted at the forest stand level with emphasis on stand productivity, biodiversity conservation, and water and soil protection.

Phase III: Emphasizing ecological improvement. From the late 1990s up till now China’s forestry development has entered into a new period characterized by strong emphases on sustainable forestry development and ecological benefits. With rapid progress in economic reform and opening up of the country, the Chinese Government recognizes the importance of balancing the three dimensions of ecological, social and economic benefits in forestry development. In 2003 China released the Resolution on Accelerating Forestry Development, which defines the national strategy for forestry development that focuses on ecological improvement, ecological security and ecological culture. The ecological awareness of the whole society in China has been significantly enhanced, which leads to fundamental changes in the social demands for forestry. For example, a series of key forestry programs have been implemented, including the Natural Forest Protection Program (NFPP), the Conversion of Cropland to Forest Program (CCPF), the Sandification Control Program for Areas in the Vicinity of Beijing and Tianjin (SCP), the Key Shelterbelt Development Programs (SDP), the Wildlife Conservation and Nature Reserves Development Program, and the Forest Industrial Base Development Program (FIBDP). In this period, forest management is often conducted at landscape or region scales, highlighting the roles of forest in biodiversity conservation, carbon and hydrological cycling, and mitigation of global climate change. Landscape ecology and associated spatial technologies are increasingly used in forest management.

2.2 National Programs of Forestry Initiatives

Since the Rio Summit in 1992, the Chinese Government has been improving the policies, regulations and laws on sustainable forest development. It encourages people from all walks of life to get involved in forest ecological improvement through the implementation of the national key forestry programs. Following is a brief description about the scope and status of each program.

The Natural Forest Protection Program (NFPP): The NFPP program, started in 1998 and fully implemented in 2000, covers large areas of China: the upper reach of the Yangzi River (including the provinces of Yunnan, Sichuan, Guizhou, Chongqing, Hubei, and Tibet autonomous region), the upper and middle reaches of the Yellow River (including the provinces of Shanxi, Gansu, Qinghai, Ningxia autonomous region Inner Mongolia, Shaanxi, and Henan), the Northeastern China (including the provinces of Inner Mongolia, Jilin and Heilong Jiang), and the Xinjiang autonomous region of Western China. As a strong measure of the program, timber harvesting has been banned completely in the upper reaches of Yangzi River and Yellow River, and greatly reduced in the Northeastern China and the Xinjiang autonomous region. The targets of afforestation are 9.06×106 ha and 3.67×106 ha for the two regions of Yangzi River and Yellow River, primarily by means of logging moratorium to allow for natural regeneration. Nevertheless, a new policy is envisioned that would allow for some forest management operations such as thinning and limited commercial logging when appropriate.

The Conversion of Cropland to Forest Program (CCPF): The CCPF program is to deal with soil and water erosion on hilly areas by afforestation in these marginal agriculture lands. CCPF covers nearly 20 provinces. The program plans to restore 1.467×107 ha for forest management, of which 7.452×106 ha is in the Yangtze River tributaries and Southern China and 7.125×106 ha in the Yellow River tributaries and Northern China. The program also includes afforestation on 1.733×107 ha of barren mountains and lands suitable for forest vegetation, with 7.511×106 ha in the regions of the Yangtze River and southern China and 9.822×106 ha in the regions of the Yellow River and Beijing.

The Desertification Control Program (DCP): The DCP program is to reduce the frequency and intensity of sandstorms for areas adjacent to Beijing and Tianjin. The implementation of SCP began in 2000 with a total planned area of 4.58 ×107 ha in 75 counties of Beijing, Tianjin, Hebei, Shanxi, and Inner Mongolia. By 2007, a total area of 6.694 ×106 ha had been treated as potential sources of airborne particles; a total area of 5.684 ×106 ha had been protected from grazing; the numbers of the ecological migrants who moved from the area severely affected by desertification to the other area less affected by desertification was 116,000. During the period of 2001-2005, the coverage of forests and grasslands within the program area increased by 10-20.4%, while the dustfall declined by 15.8%. The large area of desertification control (ca. 960 million ha) should help mitigate the impact of climate change on ecosystems and the wellbeing of people in China.

Key Shelterbelt Development Programs (SDP): The SDP programs have been widely implemented in the Three-North regions and the middle and lower tributaries of the Yangtze River in China. SDP includes six sub-programs that cover all major river systems, costal lines, and vast mountain and plain areas in China (Table 1). With the full financial support and wide-range participation, these key shelterbelt programs have achieved great success. For example, the Three-North SDP, the largest shelterbelt program in China, has received world-wide recognitions. In 2007 and after 30 years of construction, the total area of reforestation has reached 23.74 million ha, the forest coverage has doubled and increased to 10.51%, the timber stock increased from 100 million m3 to 720 million m3, and the erosion-pro land areas in the Loess Plateau have been reduced by 40%.

Table 1 Brief descriptions of the China's Shelterbelt Development Programs (SDP)

Shelterbelt Program	**Areal Extent**	**Program Target**
The Fourth Phase of the Three-North Shelterbelt Program	Covering 590 counties in 13 provinces of Northwest, North, and Northeast of China	6.30×106 ha for tree planting; 1.26×106 ha for air-sowing; 1.94×106 ha for natural regeneration via hill closing
The Second Phase of the Yangtze River Shelterbelt Program	Covering 1,033 counties in 17 provinces	6.87×106 ha for tree planting; 6.29×106 ha for shelterbelt improvement
The Second Phase of Costal Shelterbelt Program	Covering 220 counties in 11 costal provinces	6.8×105 ha for tree planting; 6.2×105 ha for natural regeneration via hill closing; 6.0×104 ha for air-sowing
The Second Phase of the Zhujiang River Shelterbelt Program	Covering 188 counties of 6 provinces	2.28×106 ha for tree planting; 1.0×106 ha for shelterbelt improvement
The Second Phase of the Taihang Mountain Greening Program	Covering 112 counties of Hebei, Shanxi, Henan provinces and Beijing	1.46×106 ha for tree planting; 4.5×105 ha for shelterbelt improvement
The Second Phase of the National Plain Greening Program	Covering 944 counties of 26 provinces	4.2×105 ha for tree planting; 7.3×105 ha for shelterbelt improvement

The Wildlife Conservation and Nature Reserves Development Program: This conservation program is to protect biodiversity of genes, species and ecosystems by establishing 2,500 nature reserves. In addition, new conservation measures will be developed, such as hunting-free areas, reproduction bases, and wild plant cultivation bases. By the end of 2006, more than 2,000 nature reserves had been established, covering a total area of 1.21 million km2, which accounts for 14% of the total terrestrial area in the country. China has also established more than 400 centers for natural resource conservation of wild plants and genes, and more than 160 botanical gardens or arboretums. These measures preserved more than 60% of the China flora with more than 1,000 rare and endangered plants being effectively protected.

The Forest Industrial Base Development Program (FIBDP): The FIBDP program aims at enhancing timber production by planting fast-growing and high-yielding trees in most favorable areas of Southeastern and Northeastern China. FIBDP covers 886 counties in 18 provinces with a plan to afforest 6.18×106 ha and to improve 7.15×106 ha of low-productivity plantations. Forest plantations can complement natural forests and other land uses across the wider landscape. Thus, forest plantations as an important renewable resource will continue to grow in importance and to increase in area in China. However, forest plantations must be carefully distributed and properly managed in order to ensure positive economic and environmental effects on natural landscapes. For example, establishing forest plantations in areas previously occupied by natural or semi-natural forests in China should consider the possible significant loss of habitat for a wide range of species and potential increase in risks of biodiversity decline, soil degradation, pest and disease outbreaks and fire occurrence (Liu and Li, 1993; Liu et al., 1998a; Sheng, 2001; Whitmore, 2008)

The implementation of these six key forest programs nationwide has generated a great momentum for sustained growth of forest coverage and timber stock and for improvement of forest quality and stand structure. According to the 6th national forest resources inventory taken in 2003, China has 8.21% of forest coverage, with 175 million ha of forested lands (i.e., 4.5% of the world's total) and 12.456 billion m3 of timer (i.e., 3.2% of the world's total) (Fig. 1). Of these forest resources in China, plantations account for 53.257 million ha and 1.505 billion m3.

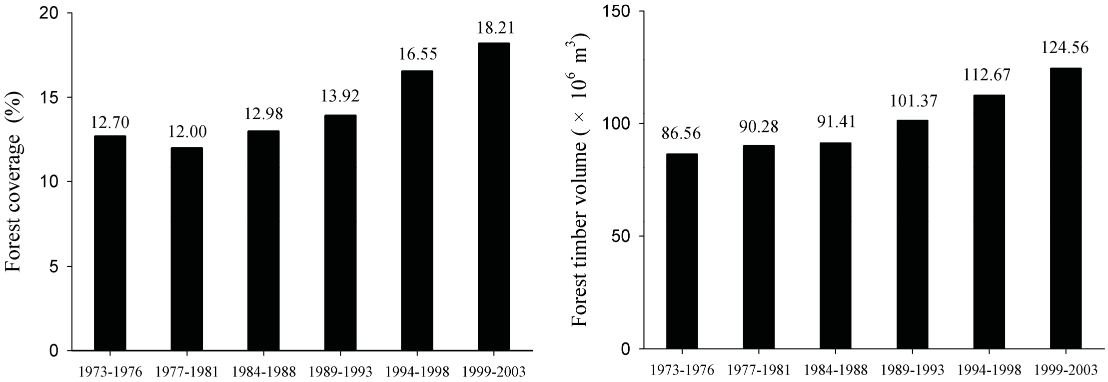


Fig.1 Changes in forest coverage and stock in China during 1973-2003 (Xiao et al., 2005).

Although outstanding achievements have been made in forestry development in recent years, China still faces great challenges of insufficient forest area and stock, and low productive forest resources because of the long-term severe disturbances and over-logging. The area ratios of coniferous to broad-leaved to mixed forests are 47:50:3. Monoculture is the predominant practice with poplar being the primary tree species in the North and the Chinese fir or Masson pine in the South. The forests are primarily young stands (67.85%) with low volume growth per unit area. The average canopy closure is 54% with an average diameter at the breast height (DBH) of 13.18 cm. The average annual growth rate is 3.55 m3/ha, and the average stock is 84.73 m3/ha (i.e., lower than the world average of 100 m3/ha).

Currently, China's forest resource cannot meet the national needs for wood and other forest products, which inevitably leads to the large amount of timber import. Given the annual timber consumption of 550 million m3, the available timber volume in China can last for only about 10 year without import. The gap between the timber supply and demand is estimated at 300 million m3. In 2005 China imported an equivalent of 73 million m3 of timber. The future forest resource used for timber production mainly come from forest plantations. Although China ranked first in the world in the existing plantation area (53.2573 million ha), its stock volume is low with only 1.5045 billion m3, which accounts for 12.44% of the entire forest stock volumes (stock per unit area at only 46.59 m3/ha). The reasons for such low values are the poor management and the low site index.

2.3 Key Issues for Forest Management in China

2.3.1 Deficiency in linking forest management with end usage

The main objective of forest management is to enhance forest productivity and ecosystem services to satisfy social, environmental, and economic needs for forest products. In this regard, clear and long-term vision for forest management is critical to the competitiveness and sustainability of forestry and associated industries. However, the interconnectedness of the forest production to the end uses of forest resources has often been overlooked in China. For example, plantations use only a few tree species, but their final utilization is not clearly defined. In addition to the traditional objective of using forest ecosystems as renewable resources (e.g., timber, biomass, water supply and quality), non-economic functions of forest, such as biodiversity, recreation, education, carbon sequestration and aesthetics, have become increasingly important. Such changes in societal perspectives have had profound implications for forest management (Spieker, 2002): sustainable forestry requires that forest management emphasize multi-functions of forests, such as production of timber, pulp for paper, bio-fuels, maintenance of wildlife habitat and watershed health, and carbon sinks to combat climate change. These desirable end-products and goals must be defined clearly and explicitly in future forest management plans to ensure sustainable forestry development. Technological innovations and scientific advancements should contribute to new, sustainable, ecological and competitive products for forestry-based industries and to enhancement of ecosystem services critically needed in the face of increasing anthropogenic effects on environment.

2.3.2. Inadequate forest health management

Due to past long-term and large-scale anthropogenic disturbances, the existing natural forests in China are largely distributed in the remote mountain areas, in fragmented landscape, and/or in degraded secondary successional stages (Chen et al., 1994). Much of the natural forests in China have been put under protection to restore productivity, biodiversity, and ecosystem stability; but, the time required may be long because of their low resilience to disturbances. At the same time, China has the largest acreages of plantations in the world, and these plantations are mostly composed of single tree species and simplified stand structure and are more vulnerable to disease and pest infection, forest fire, extreme climatic disasters and even soil degradation (Xu, 1992; Sheng, 2001; Zhou and Sheng, 2008). In general, most of China’s forests have low resilience in terms of low ecological stability and productivity to disturbances because of inadequate forest health management. Forest health management may need to consider manipulating forest composition, structure, and diversity to enhance ecological functions at genetic, species, ecosystem and landscape levels and to improve forest resilience to natural and anthropogenic disturbances.

2.3.3 Lack of integrated forest landscape management

For SFM according to ecosystem based management, forest management objectives should be clearly defined before the management takes place (Wintle and Lindenmayer, 2008). In China, the current forest landscape regardless of geographical regions is likely to be a mix of primary forest, managed forest plantation, secondary forest and degraded forest lands interspersed with extensive areas of other agricultural land and rangeland, non-forest land-uses, due to the rapid land use and land cover change that leads to deforestation, forest degradation and forest fragmentation. At the same time, there are many more people living in these landscapes than was previously the case. Therefore, there is clear need to address multifunctional forest landscapes management to attain a large number of beneficial functions and services to human beings, which go far beyond agri- and silvicultural production (Foley et al. 2005). However, forest managers rarely consider the impacts of forest management on fisheries and aquatic biodiversity and downstream wetlands due to lack of an integrated forest landscape management. In addition, non-commodity outputs as well as a wide array of ecosystem functions that are considered to be indispensable properties of forest landscapes have been poorly recognized. Forest managers are being challenged by the need to consider all relevant landscape functions in forest landscape management. Integrated forest landscape management should take account of many factors, including interests of key stakeholders, the nature of the physical landscape, the resources available, the existing institutional and land tenure arrangements, and the prevailing land-use policy framework. Decision supporting system for integrated forest landscape management are needed to be developed to facilitate sound forest landscape management decisions for ensuring forest landscape sustainability.

2.3.4 Unbalanced consideration on society, environment, and economics

Society has placed increasing demands for forest planners to balance diverse resource management objectives (Kneeshaw et al., 2000; Schulte et al., 2006). With adoption of SFM that emphasizes integrated land-use planning strategies with social, economic, and ecological dimensions (Lämås and Eriksson, 2003), China has invested heavily in the six key forestry programs (see discussions above) to expand forest resources and to improve eco-environmental conditions, especially in Western China over the last twenty years. However, these programs were designed separately and independently, and implemented on a sectoral basis and in accordance with the individual program's objectives and legal constraints of each agency in charge. This requires strong coordination and systematic integration in order to develop effective strategies of ecosystem management, identify land use patterns for multiple objectives of resource sustainability and ecosystem health, and explore solutions to location-specific environmental problems. At the moment, the expected overall synergic effects in terms of forest resource expansion and environmental improvement are yet to be fully achieved.

3 Challenges and emerging global issues in forestry

3.1 Coping with uncertainties under climate change

Forests in China are under threads of changing climate (Bu et al., 2007; Leng et al., 2008). Changes in temperature and precipitation regimes have the potential to gradually affect forests in terms of forest structure, spatial distribution, growth and productivity. Some effects from rising temperature and increasing precipitation may be positive for forest growth and productivity (Liu et al., 1998b; Fang, 2000), while others (e.g., increased fire occurrence and pest and disease outbreaks) may be negative (Tian et al., 2003; Zhang et al., 2005; Wang et al., 2007). In addition, changing climate can affect hydrological process and water yield of forested watersheds, as well as the downstream water availability for both people and wetland ecosystems (Minshal, 1988; Poff and ward, 1989; Poff, 1996; Sun et al., 2008). The climate extremes can be highly detrimental to forest ecosystems (e.g., 21 million ha of forests damaged by the ice-storm occurred during the early-spring of 2008 in Southern China). Therefore, forest management needs to consider the uncertainties of climatic change and its effects on forests and environments in order to enhance the positive effects while reduce the negative effects.

3.2 Developing desicion suport systems for SFM

Traditional forest management in China focused primarily on tree planting and harvesting (Qu and Zhou, 2000), without the help of management tools to plan for whole-system based silvicultural operations. The "new information technologies" are changing the way of how forest management is conceived and applied by allowing for easy access and effective use of information and knowledge and, thus, enhancing participation and collaboration in decision making based on multiple objectives and functions of forestry. The forest management today is knowledge-based and process-oriented. There is now increasing demand for web-based DSS's to deliver customized management options for sustainable forest management (Jose and Keith, 2006; Jiang, 2008). One example is REMSOFT (Li et al., 2008), which can generate options for multi-purpose management planning to facilitate SFM.

3.3 Managing forest ecosystems cross multiple scales

The traditional forestry focused on managing stand structure, growth process, and productivity at the stand level. With increasing understanding of the structure, functions and services of forest ecosystems, the forest management today aims at maintaining ecosystem integrity and stability while achieving multi-functions of forests, such as timber, biofuels, carbon sequestration, water, and biodiversity (Deng, 1998). Therefore, SFM should consider diversity and stability of forest ecosystems at genetic, tree, stand, ecosystem and landscape levels, and fulfill ecological, social, and economic functions at local, regional, country and global scales. Landscape planning and design to maintain regional landscape heterogeneity and diversity and to enhance landscape sustainability and resilience to disturbances must be at the core of SFM (Huang, 2004).

4 Contributions of landscape ecology to forest management and conservation

Landscape ecology plays a key role in facilitating the research development to address emerging issues of global forestry. Landscape ecology provides both theories and tools for forest management and planning, which enable land managers to assess the impacts of rapid and broad-scale changes in the environment (Turner et al., 2001). The concepts and theories of landscape ecology have helped change the traditional visions and ways of managing forest lands from stand level to landscape scale or even to regional scale. Forest management plans that combine the concepts of spatial heterogeneity, pattern-process, scale and spatial-temporal context of forest landscapes within a region are being developed and implemented by forest managers in China. The demands for sound adaptive management strategies should stimulate further development of theories and methods of landscape ecology, while the applications of landscape ecology in various forest landscape types under varying intensities of human disturbances should provide excellent experiment sites for landscape ecology research.

4.1 Ecological restoration

Forest restoration is to reestablish forest cover to produce economic products or restore ecological functions in areas where forests had been destroyed in the past (Choi, 2007). In many cases, forest restoration is synonymous to reforestation and afforestation. The paradigm of ecological restoration considers the changing environments, in particular, global change, and emphasizes the maintenance of ecosystem functions and processes, rather than simply re-assembling the past floras and faunas (Choi et al., 2008). Ecologica1 restoration has also shifted its focus from local degraded sites (or ecosystems) to landscapes, placing the emphasis on the roles of size and spatial configuration of forest patches in the targeted forest landscapes (Naveh, 1994; Be11 et a1., 1997; Aronson et a1., 1998; Schuller et a1., 2000). In addition, effective restoration of degraded ecosystems or landscapes requires the restoration of the natural disturbance regimes and the removal of artificial disturbances at the sites (Kuuluvainen and Aapala, 2005).

In recent years, ecological restoration in China has become a top management priority with increasing focus on ecosystem functions and biodiversity conservation as the national key forestry programs are being implemented (Liu et a1., 2003; Kong et a1., 2004). Many restoration projects are either completed, underway, or planned in China. For instance, Guan et a1. (2003) proposed the idea of constructing ecological safety strategically to promote restoration of degraded landscapes. Long et a1. (2001) established an index system composed of water and soil erosion rates, forest cover, biomass and other variables to assess landscape change and its ecological consequences. Guo and Zhang (2002) analyzed distribution patterns and dynamic changes of landscape elements during the forest landscape restoration process in Guandishan Mountain. Kong et al. (2004) investigated how slope and elevation affected forest landscape restoration in the burned areas of Daxing’anling in Northeast China. However, the new paradigm of ecologica1 restoration has not been incorporated fully into the forest management planning in general and into most of the restoration projects in particular.

4.2 Biodiversity conservation

China is one of the countries with the richest biodiversity in the world. For example, China has approximately 6,481 species of vertebrates, accounting for 10 percent of the world total, and over 30,000 species of vascular plants with 17,000 species being endemic plants, ranking as the third in the world (Zhang, 2002). However, massive deforestation (including timber harvest) during the 1950s and 1980s resulted in a huge loss of biodiversity associated with natural forests. Biodiversity is closely related to landscape change, such as patch dynamics and habitat fragmentation. Thus, species conservation should consider the integrity and diversity of ecosystems (habitat) and landscapes, with more emphasis on the landscape approach than the species approach, because species distribution pattern, ecologica1 processes, and their relationships operate at multiple scales and manifest at the landscape scale (Wu, 1992; Otte et al., 2007). It is likely to be the dynamics of patch mosaics per se that may hold the key to conservation of species diversity (Pickett and Rogers 1997). Biodiversity conservation should allow species to be adapted to variations in habitat types and patch configurations created by natural and anthropogenic disturbances to guarantee their survival in the changing forest landscapes.

Conserving large natural vegetation patches, protecting riparian zones and river corridors, and reducing habitat fragmentation by establishing stepping stones of suitable habitat are all the key landscape planning principles for biodiversity conservation (Forman, 1995). These principles are being used in China to create patch networks for biodiversity conservation in the context of global climate change. For example, Chen et al. (2000) and Lu et al. (2003) assessed the landscape suitability for giant panda conservation in the Wolong Nature Reserve. In addition, Liu et al. (2001) examined the impacts of establishing the Wolong Nature Reserve on giant panda conservation and found that habitat loss and fragmentation unexpectedly intensified within the reserve. All these case studies provide knowledge for identifying suitable habitats and designing future reserves for giant pandas. Future forest landscape management in China should use landscape ecological principles to address issues about biodiversity conservation and adaptive management under potential climatic changes.

4.3 Forest eco-hydrology

Forest can help maintain and regulate hydrological processes, one of the most important services provided by forest ecosystems. Vegetation dynamics and spatial distribution of forests are largely controlled by climate and soil characteristics, whereas vegetation may affect climate by modifying the radiation, momentum, and hydrologic balance of the land surface (Foley et al., 2000). There is increasing concern with fresh water supply from forested watersheds because of the potential effects of climate change on forest cover. However, the current watershed hydrology in China is concerned mainly with land use/cover change on hydrological processes. Research is greatly needed to integrate the complicated interactive relationships among climate change, forest vegetation dynamics and hydrological processes at large landscape and regional scales. The roles of landscape structure or pattern change in watershed hydrological processes are poorly understood (Lin et al., 2004; Suo et al., 2005; Li et al., 2006). Studies showed that the vegetation composition in terms of forest, shrub and alpine meadow could affect the amount of water yield in a watershed (Jiang et al., 2004; Liu et al., 2006) and that the annual mean runoff coefficient and evapotranspiration (ET) may be closely related to landscape structure of watersheds (Li et al., 2006; Jiang et al., 2004; Liu et al., 2006, 2008). Optimization of landscape structure could improve utilization of water resources especially in semi-arid and arid regions (Lin et al., 2004; Li et al., 2006). In addition, changing landscape patterns in upper-stream forests may have severe consequences to down-stream hydrology and, thus, the ecological integrity of downstream ecosystems. Optimizing spatial pattern of forest vegetation by means of combining hydrological models and habitat models may meet critical needs for addressing hydrological issues at large scales. In recent years, the effects of climate change on either hydrological processes (e.g., precipitation, snow cover, snow melting) or forest vegetation dynamics are increasingly manifested in the upper Mingjiang River, the south-eastern extension of the Tibet Plateau. An analysis of NDVI (Normalized Difference of Vegetation Index) indicated that vegetation activity showed great improvement over the period of 1982-2003, leading to the 40% increase in ET and consequently reduction in runoff (Sun et al., 2008). Sustaining and restoring watershed health (e.g., water supply and quality, stream integrity) must be a top priority of forest management because it is an integral part of hydrological processes.

5 Research needs for forest landscape management

5.1 Long-term forest ecosystem monitoring

Long-term monitoring must be the cornerstone of successful SFM. High quality ecological monitoring data, together with simulation modeling, provide the necessary knowledge of potential effects of climate change and forest management practices on forest ecosystems and various ecological services (Scheller and Mladenoff, 2005). It may be necessary to redesign monitoring systems in the context of climatic change in some cases. The monitoring of short-term carbon and green house gas (GHG) fluxes in forests should be incorporated into the long-term forest ecosystems studies. New monitoring indicators also need to be developed and included in the current monitoring systems to recognize the importance of climate change impacts on forest management. In addition, long-term data about natural disturbance regimes are the prerequisite for SFM in any attempts to enhance forest ecosystem resilience.

5.2 Cross-scale and multiple-purpose forest management

Paradigm change must take place at all levels of forest management hierarchies. Forest ecosystems are open systems operating through all the components linked in an interacting network of ecological processes (e.g., flows of energy, nutrient and water) cross scales (Jentsch et al., 2002). Therefore, forest management should aim at maintaining the complex biodiversity, healthy ecological processes, and reliable ecosystem services, and seeking the appropriate balance between biodiversity conservation and resource utilization. To achieve such integrated and comprehensive objectives, forest ecosystem management should use the concepts and principles of landscape ecology to develop appropriate spatial planning tools and DSS's to meet the long-term and multi-functional objectives, including biodiversity conservation, water and soil protection, carbon sequestration, ecotourism and ecosystem services.

5.3 Landscape decision support systems

Landscape dynamics models are necessary and useful to assess the effects of forest management and climate change scenarios on forest (He and Mladenoff, 1999; Scheller and Mladenoff, 2005, 2008). Many complicated issues and scenarios can only be evaluated with the help of comprehensive DSS's. However, most ecological models used in China were developed outside China, and such introduced DSS’s may be of limited values and applications (Liu et al., 2006). Therefore, it is necessary to modify the introduced models or develop new models specifically designed for China to meet the requirements of the specific landscape configurations and management objectives, especially those models for assessing effects of forest management and for carbon and GHG accounting.

5.4 Fragile forest ecosystem management and protection

The threat of climate change to fragile forest ecosystems is the most serious problem in managing forest resources. The sensitivity of forests in China to climate change varies with regions, ecosystems and climatic factors. For instance, Mangrove forests are highly sensitive to the sea-level rise that may be caused by climatic warming;

forests in semi-arid and arid regions are vulnerable to changes in pattern and amount of precipitation; forested wetlands are susceptible to variability in hydrological regimes in both wetland and upland forests. Recent studies have also found that the transitional zones between forest and other ecosystem types may be more vulnerable to climatic change (Neilson, 1993; Allen and Breshears, 1998; Loehle, 2000; Noss, 2001). Therefore, improving health, stability and resilience of fragile forest ecosystems should be a top priority in forest management planning and forest landscape restoration, in addition to preventing forest degradation, fragmentation, and alien species invasion to maintain biodiversity and ecosystem functions.

5.5 Adaptive forest management

As responses to climatic change, the distributions of some tree species in China may move northward and up in elevation and, as a result, new assemblages of species may emerge (Xu et al., 1997). At the same time, the extreme climate events (e.g., hot spot, severe drought) may have harmful impacts on forest ecosystems directly by damaging forests and trees or indirectly by altering patterns of pest and disease outbreaks and fire occurrence. Conventional forest management strategies in China are unlikely to be able to cope with the uncertainties associated with climate change and to meet growing needs for ecosystem services and forest products. It is crucial that adaptive forest management be developed for current and future forest landscapes under different climate change scenarios. Implementation of SFM through the adaptive management process can contribute to the reduction of negative environmental, social and economic impacts on forest and forestry caused by climatic change. Adaptive forest management must consider principles of landscape ecology and disturbance theory and integrate multiple objectives, including improving land productivity and ecosystem health, enhancing ecosystem services such as water and soil protection, biodiversity conservation, and carbon sequestration, facilitating and coordinating development of effective policies, programs, and actions, and ensuring sustainability of and social economic benefits from forest ecosystems. For example, since landscape fragmentation induced by human activities is likely to have more serious impacts under climate change on forest biodiversity conservation, establishing patch and corridor network is essential to facilitate migration of plant and animal species under potential future climatic conditions. Adaptive forest management must also assess the possible changes in natural disturbance regimes induced by climate change through simulations with spatially explicit and process-based landscape models. Thus, research is needed to develop a system of adaptive forest management strategies that suits unique characteristics and situations in China. One aspect of such research is to educate land managers and the public about the principles and process of adaptive forest management, such as getting all shareholders involved in the planning phase. Major changes in attitudes must take place before adaptive forest management can become the new paradigm in China.

6 Concluding remarks

China has made great achievements over the last 20 years in sustaining continuous growth of forest areas and volumes, improving biodiversity conservation, and developing effective strategies and policies of forestry and forest ecosystem management. One example of the achievements is the successful implementation of the national key forestry programs. The three-phase history of changing forest management focuses also exemplifies the great progress in China’s forestry. However, China's forestry is still insufficient with large areas of forests being of the poor quality and low productivity, which poses great challenges in meeting the increasing demands for desirable goods and services. Effective forest management may help resolve the problems. To be successful, new forest management strategies must be based on better understanding of emerging global challenges and issues and reorganization of climate change as the most severe threat to future forests and forest management.

Given the complexity and uncertainties of climate change, adaptive forest management must be developed to combat current and future implications of climate change to forest ecosystems. Adaptive forest management based SFM principles can help prevent or at least contain forest degradation, enhance forest resilience, and reduce negative environmental, social and economic impacts on forestry and forest ecosystems posed by climatic change. A key component of adaptive forest management is to define operational guidelines to carry out the goals and objectives, in which landscape ecology can play a major role. Landscape ecology provides theories and management tools for forest restoration, biodiversity conservation, land and water resource management, and forest management planning to help cope with climate change and facilitate SFM. For example, forest management should consider ecological patterns and processes, disturbance regimes, spatial heterogeneity, and forest landscape configurations at multiple spatial-temporal scales to achieve comprehensive ecological, social and economic benefits. Forest researchers and managers in China should advocate and adopt the adaptive management approach to ensure sustainability of landscape biodiversity, health, and functions and processes.

In addition to policies, guidelines, and strategic planning, forestry research must lead the way to sustainability of forest resources. To alleviate impacts of climate change and anthropogenic disturbances on forest ecosystems in the future, cross-disciplinary research activities are needed, including long-term forest ecosystem monitoring, improvement of forest productivity and ecosystem services, decision-support system development and applications, and adaptive forest management that integrate multiple objectives at multiple spatial and temporal scales. The emerging global issues also require strong international collaborations such that research can be advanced in broad scopes and at fast paces to help decision-makers and land managers cope with the rapidly changing environment and associated problems in forest management. It is critical that close relationships between science and policy (i.e., policies based on science while science used explicitly to address policy-related issues) can be established to assure and promote significant research contributions to SFM and climate change mitigation and adaptation.

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Chapter 2 Impacts of Climate Change on Forests in China and Adaptation Strategies

1 Introduction

The observational evidence demonstrates that atmospheric CO2 concentration has increased by almost 100ppmv since its pre-industrial level reaching 379ppmv in 2005, with mean annual growth rates in the 2000-2005 period higher than in the 1990s, as the results of anthropogenic activities in terms of combustion of fossil fuels, land use and land cover change (IPCC, 2007). The increased atmospheric concentration of CO2 along with other greenhouse gases has led to the observed changes in Earth´ surface temperature and precipitation. The global mean surface temperature has risen by 0.74±0.18℃ over the last 100 years, with the largest increases over the mid- and high latitude of the northern continent (IPCC, 2007). Precipitation during the 20th century has on average increased by 5 to 10 % over most mid- and high latitude of northern hemisphere continent, but in contrast decreased by 3% on average over much of the subtropical areas. Recent model projections suggest a global mean surface air temperature will rise by 1.8℃ to 4.0℃ till the year 2100. The projected global warming tends to be faster during 21 century than in 20th century, with the most notable areas of warming in the land surface of northern hemisphere (IPCC, 2001a and 2001b).

Climate is the major governing agent of the composition and distributive pattern of forests. Rising temperature may give rise to a latitudinal and altitudinal migration of tree species by shifting the thermal and precipitation regimes, and furthermore may alter forest structure and productivity by both speeding up ontogenetic development and increasing growing length. The impacts of climate change on forest, through increasing air temperature, changes in precipitation and subsequent changing the intensity and frequency of disturbances such as wildfire and pest outbreak, will also depend on the significant processes of habitat loss and fragmentation, and invasive species intrusion. One of the most important consequences for forests affected by rising air temperatures will be higher potential evaportranspiration, resulting in decrease in stream water and hence regional available water resource. Synergic effects of rising atmospheric CO2 concentration and air temperature will very likely affect forest growth, development and functioning.

2 Projected changes in climate in China

During the last 100 years, the general pattern of warming tendency in China is similar to that in the northern hemisphere, but with some significant differences in warming process and magnitudes. These differences induce (1) the peak temperature in China occurred in the 40's rather than after 80's; (2) since 1950's the cooling was observed in the southwest China while the warming mainly occurred in the northeast China and north China; (3) the two sudden changes in the surface temperature in China during the last 100 years were recorded, with the first one in1999 and the second in 1952; and (4) mean temperature is low in 80's than 40's in China, in contrast to global change. Climate is projected to be wetter in high latitudes, and drier in the middle of the global. The many of regions in China, however, will be dry, in particular, in north China and northwest China (Ding, et.al. 2001).

According to simulations of UK Hadley Center and downscaling approach, the climate projections indicate that the warming tendency in China is the similar as the global and East Asian conditions in future 100 years. Warming amplitude is very likely greater in China than global and East Asia if only greenhouse gas takes into account, but it may be not true and more complex if inclusion of the radiative effect of sulfate aerosol is considered.

Under the GHGs scenario, the annual mean precipitation is projected to increase over much of China in the next 50 years, mainly in western China, but decrease in all regions of China in 2099, mainly in Yangtze River. Precipitation is very likely to increase in coastal areas in southern and northern of Northeast China, while decrease by 7.5% in the Shandong peninsula, by 4.6% in the Xishuangbanna in southern Yunan, and by 2.5% in the west of Tibet. The seasonal pattern of projected precipitation in China will vary from -4.8% to 14.3%, in which more than 10% increase will occur in the northeast and northwest, 5% to 10% increase in the western and northern parts of China, but 5% decrease may occur in tropics and subtropics.

In any case, the temperature in China is projected to increase in 2050 by 0.5℃ ~ 1.0℃ and greater warming in the north than in the south. In addition to Northeast China, marked warming is projected to occur in most of Xinjiang regions and upper reaches of the Yangtze River in China.

3 Impacts of climate changes on forests in China

Theoretically, there is no realistic projection of the future ecosystems in response to climate change without taking account of human-induced change in land use patterns. Climate change associated forest shifts towards higher latitudes or higher elevations are expected based on the projection of ecosystem movement approach, which assumes that ecosystems will migrate relatively intact to new locations that are close analogues to their current climate and environment. In temperate forest tree species are likely to move polewards and boreal forest species projected to show large shifts (150-400 km) in the next 100 years.

In China, Hulme et al. (1992) predicted the impacts of climate change on vegetation change based on the average values of 7 GCMs models, they found that all vegetation types in China will move northwards about 500 km. The temperate grassland and tropical forest in China will expand, and some natural vegetation will migrate to a certain extent in response to the climate change. The cold temperate forest is projected to decrease dramatically due to the aggression of the temperate forest. The temperate forest will shift northwards and the warm-temperate forest will replace approximately a half of the temperate forest. The majority of the warm-temperate forest will be replaced by subtropical forest. The southern subtropics will be changed into tropics.

Based on the averaged model of five GCMs (GFDL, GISS, NCAR, OSU, UKMO) (Zhao, 1990) with the assumption of doubled atmospheric CO2 concentration by 2030, the distribution of major tree species in China were projected. Larch is projected to go across the Russia-China border, leading to the shrink in area by 8.5% in China (see

Fig.1). The projection of Korea Pine's distribution under the future climate change is northward shift, though it is not significant. The southern boundary of the current distribution region will move northward by 0.1° to 0.6° in latitude, and the northern boundary will move northward by 0.3° to 0.5°. The other parts of its distribution region remain roughly the same. The area of total potential distribution will increase by 3.4% in contrast to the area under the current climate condition (see Fig.2). The prediction based on HadCM2 model with the assumptions that the annual CO_2 concentrations increase by 0.5% and 0.1% until 2030, respectively, indicates sharp decreases in the distribution area of Korea Pine, especially for the case of 1% CO_2 increment.

For the scenario of 0.5% CO_2 increment, the distribution area of Korean pine will be decreased by 12.1%, whereas it is decreased by 44.9% of its original distribution area under the current climate condition for the scenario of 1% CO2 increment (Guo, et al., 1998; Xu, et al., 2001). Chinese pine and mason pine will decrease roughly by 9% in area while Chinese fir will decrease by about 2% (see Fig. 3 and Fig.4).

The prediction of net primary productivity of forest in China under the future climate change based on the averaged model of five GCMs (GFDL, GISS, NCAR, OSU, UKMO) with the assumption of doubled atmospheric CO2 concentration by 2030 indicates that the geographical distribution patterns of net productivity of forests in China is the same as that of the current actual distribution pattern, i.e. forest productivity decrease with increasing latitude and southeast to northeast. Amplitude of the projected increases in forest productivity varies with regions. Under the future climate change, the productivity of cold-temperate forests in high latitude is projected to increase by 8% to 10%, the temperate forest by 5% to 6%, and the warm-temperate forest by 4% to 5%, and the tropical and subtropical forests by 1% to 2% (see Fig.5). However, there are still larger increase in some parts of tropical and subtropical regions, such as 7% increase in the southern area of Yuannan and 10% in the western Sichuan. The projections of forest productivity in response to climate change are in good agreement with changing climate regime, i.e. larger increase in air temperature and precipitation in high latitudes than in low latitudes under climate change (Liu, et al., 1998).

There are great uncertainties in reality about the projections of forest ecosystems in response to climate change. The uncertainties in predictions have been attributed to the model structure of GCM, lower resolution of regional climate change, and simplified response processes of forest to climate change.

4 Adaptation strategies of forestry to climate change

Although there are many uncertainties in terms of climate change and associated impact projections on forest ecosystems, we have to take immediate action and to formulate forestry adaptation strategies to mitigate likely adverse impacts of climate change on forests and forestry development (Liu, et al., 1996). The following silvicultural approaches and forest conservation measurements should be schemed in advance.

Tree improvement: Various means of tree improvement need to be taken for enlarging genetic variations of tree species by which to increase selection opportunity for tree species to adapt to climate change. Besides several major commonly used planting tree species such as Chinese fir, Chinese pine and Masson pine and poplars, the optimum provenance trials of more different tree species should be carried out with more consideration of stronger resistance to drought and to pest and disease attack. Those selected provenance types will be planted and expanded deliberately in the southern boundary of their natural distribution in order to allow them to shift during the acclimation process in changing climate. In addition, seed resources and germplasm of forest tree species need to be well protected and expanded, and this effort will be conducive to conservation of genetic diversity therein. Ecological adaptability and genetic variation of tree species need to be identified and then genetic classification can be made according to genetic composition and structure. This knowledge will be used to determine appropriate population matching varying climate conditions under climate change.

Plantation strategy: The current silvicultural practices in terms of planting techniques and forest management should be adjusted accordingly due to high temperature in summer and severe drought resulting from water shortages under the climate change. An appropriate planning season will be advanced half a month or even more than the current climate scenario in order to use snow-melted water and enhance the survival rate of seedlings, escaping the period of drought and high temperature. In addition to spring season, autumn is also good choice to plant trees because seedlings can easily maintain their physiological functions under favorable conditions for root growth. Seedling-containers should be strongly encouraged in the semi-arid and arid areas of China in order to improve microenvironment of seedlings in early planting stage and to minimize negative effects in terms of high temperature and drought stress. Mixed stands should be also encouraged in silvicultural practice in order to increase the option probability of trees successfully adapting to diversified site conditions and climate regimes. In the same time, soil degradation after continuous cropping of same tree species can be avoided and damages resulting from forest fire, pests and disease induced by climate change can also be reduced.

Thinning and rotation management: As predicted that forest growth will be accelerated, and stand age structure and tree maturity will be altered under climate change, all these impacts should be taken into account in thinning management in terms of timing, frequency and intensity, as well as rotation. During thinning or harvesting, dead wood components with varying degree of decay should remain in forest ecosystem in order to maintain site nutrient balance, biodiversity and soil organic carbon therein, as well as seed sources for natural regeneration. Timing of thinning will be advanced and thinning intensity will be enhanced accordingly under climate change in contrast to the current climate situation. Rotation period of forests will be shortened accordingly, especially for larch or popular plantation in the northern parts of China, as the result of earlier tree maturity under climate change. Adopting short rotation under climate change will provide more opportunities to change tree species in order to ensure successful adaptability of forests to the changing climate. In addition, this can increase timber production in association with improvement of stand stability.

Forest biodiversity conservation: As known that climate change is very likely to have great impacts on species composition and distribution, and structure and function of a forest ecosystem, that either have been observed or projected. Adaptive measures should be taken to ensure conservation and maintenance of the existing forests, genetic resources, wilderness and habitats for wildlife. Protection and sustainable use of natural forests should be given high priority and logging should be strictly under control. Disturbed natural ecosystems in terms of degraded, damaged and fragmented forests will be properly restored and protected areas for natural forests in critical areas that are vulnerable or susceptible to climate change should be identified and designated. Such efforts have been realizing by the implementation of China Natural Forest Conservation Programme.

China national nature reserve network should be strengthened and improved. More nature reserves need to be established in some hot pot areas, in particular, transitional zones and susceptible zones where biodiversity is very likely to be affected by climate change. The establishment of new nature reserves should be given high priority to those acting as a corridor to connect individual nature and furthermore to create a sound distribution network of nature reserves in China. Such a corridor will play an important role in providing favorable conditions and transitional paths for species movement in response to climate change.

Invasive exotic species should be absolutely banned and under strict control. Inter-regional introduction of tree species within China should be carried out among different nature reserves, and this will create changing climate conditions for tree species to experience the future climate conditions and allow those species to adjust themselves in advance before future climate change occurs on original sites.

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Figure 1-4.

Fig 1. Changes of distribution areas of *Larix gmelini* under climate change.

Fig 2. Changes of distribution areas of *Pinus koraiensis* under climate change.

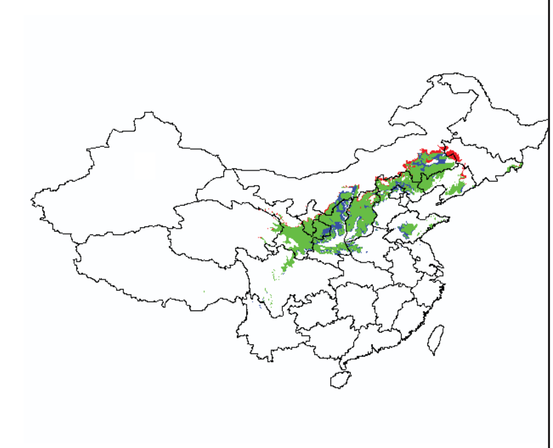
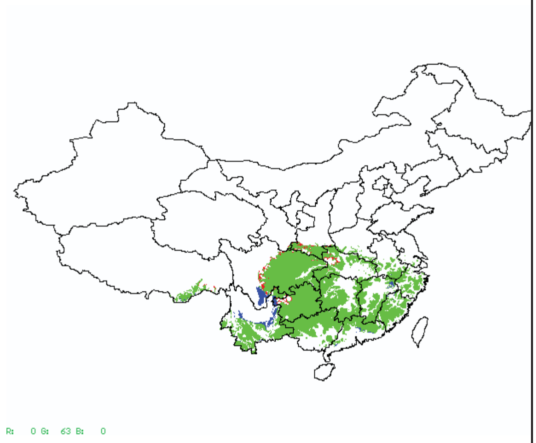
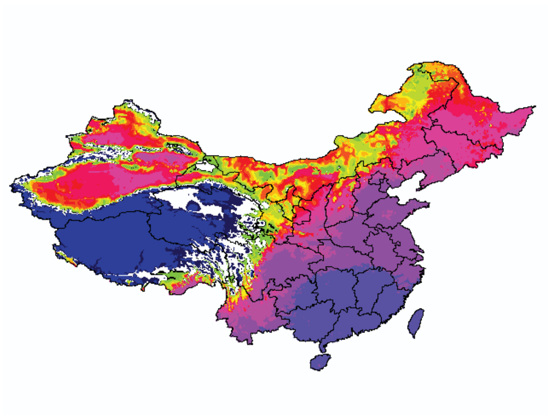


Fig 3. Changes of distribution areas of *Pinus tabulaeformis* under climate change.



Fig, 4 Changes of distribution areas of *Cunninghamia lanceolata* under climate change.

Figure 5.



Fig, 5. Change ratios of forest net productivity under climate change.

1% 2% 4% 5% 6% 6-7% 7-8% >10%

Chapter 3 Review and Prospect of China's Bamboo Industry

1 The Reviews of Past China's bamboo industry

1.1The Development Processes and Phases of China's Bamboo Industry

Natural Development and Primitive Utilization Stage

China has the longest history of bamboo utilization in the world. There are some unearthed 5000-6000 years old bamboo weavings, which have been discovered at the Banpo village, Xian City, in the Neolithic Stone Age in Zhejiang. Bamboo was used for arrows, books, warring in the 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 province in Ming and Qing Dynasties, which accelerated the production and circulation of bamboo there. "In the Chinese bamboo culture, which has a long history of over 5000 years, bamboo can be found wherever it is, clothing, eating, housing, walking, and usage", that famous poem is just a very epitome of bamboo historical role and position.

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 industry 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 according to 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. On 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.

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 the leadership role of China's bamboo industry 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's 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 ecological establishment”. This has put forestry into an unprecedented height and without a doubt it has given our bamboo industry, which is taken as an important component of forestry and a combination of 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 in 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's 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 are mainly distributed in the 13 provinces' mountainous region of South China. There are over 130 counties with a bamboo forest area up above 10,000 ha, most are backward mountainous 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-yield" 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 a 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 yielded a good economic benefit. For example, Lin'an 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 Expansion of Its Application Field

Presently, bamboo's processing and utilization have been changed greatly. People used to use the bamboo culms and their branches and shoots, but now its utilization has been extended to construction, paper-making, food, furniture, arts, 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 breakthrough 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 yields about 20,000 tons 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 produced 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 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 to.

1.2.4 The Circulation Channel is Improved, and Market is 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 welcome 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-class gifts, and ornamental bamboo seedling's exporting to European countries has formed a scale. We have both resource and technology 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 benefits are 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 by 1.5—2 billion Yuan, particularly in Zhejiang province, the bamboo industry value reached 10 billion in 2001, which is 30% more than that of 1998's. Lin'an and Anji are two of the ten "China bamboo towns". Bamboo industry has become the pillar industry of the local economic development and farmers' income sources. In Lin'an, 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, which is 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 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 in maintaining the society's stability.

Bamboo's unique biological and ecological characteristics and its special management mode determine that it should have extensive ecological environment and ornamental value and effects.

As an excellent ornamental plant, bamboo maintains high value. In China, wherever in Suzhou city or Shanghai city, many gardens use bamboo as a ornamental plant, such as Zhuozheng Garden, Xi Garden, Liu Garden, Yu Garden, etc. Besides, we can use many small-sized ornamental bamboos to make bonsi, such as Fodu Bamboo, Cui Bamboo, Fengwei Bamboo, etc. By combining 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 ornamental value. Bamboo's ecological and environmental functions are catching people's eyes daily as more and more attentions are 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 have all form unique tourism advantages and promote the local economy's steady 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, which is just based on the idea of eco-tourism.

Existing Problems

Despite tremendous 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:

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 does 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.

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 over 400 bamboo products factories, 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 blind 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.

Inconsistent regulation of the bamboo industry and market building's lagging behind.

The majority of them are scattered in remote mountainous areas. There is a lack of information and technology, ineffective macroscopic administration by the government. At the same time, some regions add high tax to bamboo, the highest even reaches 20% of the sale price, some region's protectionism even protects poverty and lagging behind. All these no doubt limit bamboo industry's development and farmers' enthusiasm; hence, it is hard to cope with daily changing market.

The Prospective of China's Bamboo Industry

Bamboo is one of the 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 we can 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 without foreseeing thinking and long-term planning. Now I'd like to address its prospect:

2. 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.

2.1 Tasks and Targets of Bamboo Industry Development

Intensifying the strength of cultivating new resources and implementing "Two restructuring and one breakthrough" on the base of protecting the present bamboo resources. One restructuring is bamboo processing. We should 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 themselves. 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 Nanotechnology in bamboo industry. (e.g. bamboo charcoal and active charcoal's nanomaterials).

2.2. Main Measures of Bamboo Industry Development

2.2.1 Setting up Macroscopic Guidelines and Streamlining Management Administration

One is bamboo forests' 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 shoots' 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.

2.2.2 Setting 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.

2.2.3 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 should also 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 entrusted 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's 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 18000m2. 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.

To become the information dealing center of bamboo resources, technology, achievements and person with ability

To become the international economic and technical exchange and trade center;

To become bamboo products' analysis, inspection, quality control and evaluation center;

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 it has contributed a lot in sino-indian's projects such as setting up factories etc.

2.2.4 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 in 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.

2.2.5 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, ornamental forest and paper-pulp forest. We should upgrade bamboo products' quality and add their value, develop the well-selling products based on the market changing, and open the two markets both at home and abroad.

2.2.6 To Upgrade the Whole Bamboo Industry's Level by S. & T.

We should 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.

To disseminate the newest technology;

To explore new systems which fit for the market economy.

To increase the input and develop bamboo forests.

To fully bring out the function of the bamboo association and other bamboo research institutes

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Chapter 4 China's Bamboo Development and Establishment of Recycling Economy

Totally, there are over 1250 bamboo species, 150 genera, and 20 million ha. bamboo area in the world, among which, there are more than 500 species, 39 genera and 4.83 million ha. bamboo forest in China, or about 1/3 of the world total respectively. China is reputed as a "Bamboo Kingdom". China not only is a big country in bamboo resources, but also has already accumulated rich experiences in bamboo's research, exploitation, production, and management, etc. China is in an advanced position of the world in many aspects of bamboo. Marked achievements have been scored in bamboo integrated processing and utilization in an industrialization scale, especially bamboo plywood, bamboo flooring, bamboo mats and bamboo shoot. which is playing active and important roles in poverty alleviation for well-being, women in development and improvement of ecological environment. China's bamboo sector is growing into a booming and sun rising industry streamlined from cultivation, integrate processing into export, and becoming a pillar of the agricultural economy. The total production value of bamboo sector in China in 2005 is over US$ 8 billion. Bamboo has been playing an increasingly important role on forest sustainable development and replacing wood with bamboo thanks to its unique harmonious features of ecological social and economic benefits.

Bamboo is one of the key components of forestry and it has unique cultivation, processing and utilization system .China's forestry development level is relatively low, but bamboo is in a advanced position in the world.

1 An Outline of China's Bamboo Industry

1.1 Bamboo Development Phrases and Stages

1.1.1 Natural Development and Primitive Utilization

China has the earliest history of bamboo usage in the world. "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.

1.1.2Orderly Development and General Usage

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. 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.

2 Great Achievement in Bamboo Development

2.1 Bamboo Forest Area Increases Quickly and Its Quality has been Much Raised.

Bamboo is 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.

2.2 Overall Development of Bamboo Resources Cultivation and Quality

Average output value per ha of Phyllostachys praecox shoot is USD 22,500 in China. Bamboo has become one of main pillar industry for rural farmers for poverty alleviation and well-off in southern China, and women in development.

2.3 Great Achievements in Scientific and Technical Research and Its Wide Application

0ver 500 invention patent in state and provincial-level for bamboo cultivation and utilization by the end of the ninthfiveyear national plan

More investments from government and private enterprises

Research methods from only physical and chemical ways to physical-chemical-biological and comprehensive methods.

Industry	Item	Figure	Ratio	Conclusion
Forestry	Area	175 million ha	1	Production value of bamboo is 3 times higher than forest
	Total production value	USD 75 billion	1	
	Production value per ha	USD 450	1	
Bamboo	Bamboo area	4.83million ha	1/36	
	Total production value	USD 6 billion	1/13	
	Unit production value per ha	USD 1250	3	

2.4 Continuous Upgrading in Bamboo Processing and Comprehensive Utilization

Transfer of China’s bamboo industry from traditional to modern industry, bamboo sustainable development of bamboo processing and utilization

Production scale enlarging, quality improving , management level bettering, big progress in intensive processing of bamboo products , bamboo application expanding , a new sun-shining industry forming from bamboo cultivation to processing and domestic and international marketing

Year	>1 million Yuan	>5 million Yuan	> 10 million Yuan	>50 million Yuan	>100 million Yuna
2001	>2300	>380	>27	>9	0
2004	>3000	Around 1000	Around 300	Around 30	Around 10

2.5 There are over 1000 kinds of bamboo products which is classified into 10 product series

No. 1 of 10 series of bamboo products

Bamboo boards (floor, decoration panel, lamination board, concrete forming board, truck floor)

Bamboo lamination board used as fir-proof ceiling in Madrid airport, Spain

Bamboo corridor in Europe

Bamboo floor

No. 2 of 10 series of bamboo products: **Bamboo furniture (dismantled)**

No. 3 of 10 series of bamboo products: Bamboo rotary-cutting veneer and its dying and bleaching

No. 4 of 10 series of bamboo products: Bamboo shoot, its derived products (including its extracts for other products

No. 5 of 10 series of bamboo products: Bamboo charcoal, active charcoal, vinegar for medicine, health-care products, plant growth regulator)

No. 6 of 10 series of bamboo products: Bamboo extraction flavoid and its products

No. 7 of 10 series of bamboo products: Bamboo fiber, fabric made through physical method

No. 8 of 10 series of bamboo products: Bamboo high-molecule composite new material


No. 9 of 10 series of bamboo products: Equipment for bamboo active charcoal


No. 10 of 10 series of bamboo products: **Bamboo arts and handicrafts**

2.6 Expansion of Domestic and International Market

Market has been developed from Japan, South Korea to others including USA and European countries. The export value expanded to USD800 million in the recent year compared to USD100million.The bamboo market has expanded from the domestic market to the both of domestic and international ones.

2.7 More Benefits Brought by the Rapid Growth of Bamboo Industry

As shown in statistics, bamboo production value in 2003 was over 30 million yuan, among which half is from processing industry. And the export value reached USD800 million, which showed a high-speed development tendency. Take Zhejiang Province for example, its bamboo production value was 13 million yuan, and it becomes a pillar industry contributed to a richer life for farmers living in mountainous areas. Zhejiang province’s total bamboo forest area is only 1/8 of the nation’s total, but its production value and export value occupies 1/3.

Due to its unique biological characteristics, bamboo plays a big role in environment protection and ecology with great potential. It can hold the water resources, reserve the soil , prevent sand storm, adjust climate, purify the air, reduce the noises and provide the shelter to other plants, hence, it is a very important plant for improving the environment in China.

Beside, it is an excellent plant for landscaping . Bamboo is not only good looking in shape, but also attributed with spiritual meanings. Just like the wine culture and tea culture formed during the long history of China, bamboo culture is an important component of Chinese culture and has become a common ornamental plant for urban landscaping.

3 Bamboo Industry Innovation and Establishment of Recycling Economy

Sustainable development is put in the top position for our nation’s economy. One important achievement for China’s macro-strategy research is the point-out of three ecological theories, namely “improving the ecological environment, strengthening the ecological construction and maintaining the ecological security”, which has also become the main request of forestry for social-economy development in China. As one of the most important component of China’s forestry, bamboo has a great potential to make the contribution to this goal and realization of recycling economy in bamboo industry is an approach to it.

Mr. Jiang zeming has clearly pointed out that” Innovation is a Continuous Source of a Nation's Prosperity”. To realize the innovation of bamboo industry, the most urgent and important thing is to change the development concept and idea, otherwise, it is impossible to develop the recycling economy of bamboo industry.

Innovation on development concept and idea

3.1 Concepts and ideas innovation

3.2 Management and operation mechanism innovation

3.3 Policy innovation

3.4 Science and technology innovation

3.5 Management innovation

3.6 It is urgent to establish the recycling economy

3.7 Recycling economy’s system and its implement mode

3.8Present situation and its advantages

After the high speed development since the reforming and opening up policy, some enterprises have finished primitive accumulation and opened up the market both home and abroad.

Some bamboo enterprises has begun to built up the recycling economy.Science development concept has become the powerful energy for bamboo recycling economy and comprehensive innovation provided precondition for recycling economy.

Chapter 5 The 60 year development road of Three Rural Development in new China

This year is the 60th anniversary of the founding of new China. After first 30 years of socialist construction and hard exploration, and the second 30 years of great practice of reform and opening up, China's economic and social development has made remarkable achievements. China is a developing country with peasants in majority of its population. The issues of agriculture, rural areas and peasants has always been the fundamental issue in China's construction and reform development. The three rural development is the main cause of new China’s 60 development. Fruitful explorations have been done in solving the three rural issue, and useful experience and inspiration, which is meaningful to face the three rural issue in new era, needed to be summed up.

1 The Historic Changes in the 60 years’ Development of Three Rural in New China

Ten great leap in the three rural development:

1.1 Peasants have achieved historic leap politically from the oppressed and the exploited to the ownership of the republic country. Chinese peasants have never been more self-confident and with more boundless enthusiasm before.

1.2 The rural economic structure have achieved historic leap from a feudal small-scale peasant economy to a planned economy and to the current socialist market economy. China's rural development system has never been more vibrant and full of vigor before.

1.3 The supply of agricultural products has achieved historic leap from a long-term shortage of supply to the balance of total supply and demand and being surplus in years of plenty. The variety, and quantity of China's agricultural products has never been richer before.

1.4 Agricultural production has achieved historic leap from a traditional small-scale extensive operation to the professional, intensive operation with constantly improving industrial management standards. China's agriculture has never been more intensive and brilliant before.

1.5 The rural industrial structure has achieved historic leap from single self-support to the coordinated development of primary, secondary, and tertiary industry. China's rural economy has never been more colorful and prosperous before.

1.6 The rural ownership structure has achieved historic leap from the feudal private ownership to single public ownership and then to the current collaborative development of multiple socialist ownership. China’ rural production relations has never been advancing with the times and being in line with public opinion like this before.

1.7 The life of peasants has achieved historic leap from lack of wellbeing to the overall well-off. Peasant life in China has never been more well off before.

1.8 The rural society has achieved historic leap from a backward agricultural society to an open and civilized civil society. China's rural society today has never been more civilized and harmonious before.

1.9 The rural grass-roots governance has achieved historic leap from the rule of man to the democratic rule of law. Grass-roots organizations in rural China has never been stronger and serving the people with dedication and integrity like this before.

1.10 The overall quality of peasants has achieved historic leap from the traditional semi-literate and illiterate to literate peasants with a good command of the new technology and operation management. The overall quality of Chinese peasants the their ability to create wealth and doing business has never been growing so fast and advancing with the times before.

2 The Basic Experience in the 60 years' Three Rural Development in New China

10 basic experiences are summarized as follows:

2.1 The China's renaissance should rely on three rural development;

2.2 Pay great attention to three rural when governing.

2.3 People-oriented in three rural development;

2.4 Enhancing three rural development by reform and opening up;

2.5 Enhancing three rural development by coordinating urban and rural development;

2.6 Enhancing three rural development with technology and education;

2.7 Embellishing three rural development with advanced culture;

2.8 Protect three rural development with democratic and legal system;

2.9 Developing three rural harmoniously;

2.10 Developing three rural in realistic and pragmatic way

3 Profound Enlightenment in the 60 years' Three Rural Development in New China

3.1 Correctly handle the relationships between promoting agriculture and enriching peasants

Principles of people-oriented, people-centered should be adhered to and enriching peasants as the priority, enhance the most fundamental interests of broad peasants, achieve a free and comprehensive development of peasants are the foothold in the three rural task, and great attention should be paid to three rural when governing. The idea of rich people makes country strong and strong agriculture makes country prosperous should be firmly established, and peasants' equal civil rights, land rights, and property rights should be effectively protected.

3.2 Correctly handle the relationships between adjustment of agricultural production and development of agricultural productivity.

We should follow the law that agricultural production relationship should adapt to the development requirements of agricultural productivity, and should not spoil things by excessive enthusiasm. The policy of land to the tiller and the management system with combination between household contract management and mutually beneficial co-operation operation must be adhered.

We must take the new agricultural modernization road which features cost-effective, product security, feature-rich, resource-saving, environment-friendly, technology-intensive, and giving full play to the human resource advantages.

3.3 Correctly handle the relationships between the invisible hand of the market and the visible hand of government.

Three rural development must be done through market-oriented reform. We must uphold the the basic role played by market mechanism in three rural development, and the government' role in policy support and legal protection when we are developing socialist market economy. Peasants should be encouraged to innovate, create market and wealth and the invisible hand of government must always make up for the deficiency of market and provide strong support to the three rural development.

3.4 Correctly handle the relationships between the urban and rural development.

Industry and agriculture, urban and rural areas, peasants and city dwellers must be interdependent and jointly promote each other. We must avoid splitting development of urban and rural areas and promote the open exchange of urban and rural areas. We must implement strategy of coordinating urban and rural development, get rid of the dual structure of splitted urban-rural areas. The new industrialization and urbanization, and new countryside construction should be carried out together as two drives. The long term mechanism of promoting the agriculture through industry and cities aiding rural areas must be established to create a new pattern of integration of development in urban and rural areas.

3.5 Correctly handle the relationships between respecting wishes of peasants and the education and guidance to peasants.

The wishes of peasants are the expression of their fundamental interests. The most important aspect in respecting the wishes of peasants is avoid executive orders and compulsive behavior, and protect peasants' enthusiasm and creativity. The system of democratic self-government in rural areas, and continuously improve the democratic election, democratic decision-making, democratic management and democratic supervision must be established in order to respect the wishes of the peasants. At the same time, we should consider the importance and necessity in reinforcing education to peasants, and continuously improve the overall quality of the peasant by education, training and model demonstration and strive to cultivate new peasants who are educated, skilled, civilized and understand cooperation and management. We should be dedicated to building public service-oriented government and public service-oriented grass-roots organizations.

3.6 Correctly handle the relationships between some areas and some people getting rich before others and common prosperity.

We should clearly recognize the objective laws that some areas and some people getting rich before others is decided by the uneven social and economic development and disparity in population quality. In order to create more social and economic wealth and common prosperity, some areas and some people getting rich before others and capable and talented people should play a full part in the development. At the same time, we must stress that the common prosperity is the purposes and ideals of the Communists, and advocate rich former leads latter, and improve the secondary and tertiary distribution of national income. We should be clear in mind that common prosperity is not average wealth, and simultaneously rich, and even distribution should not be implemented.

3.7 Correctly handle the relationships between the construction of material civilization and spiritual civilization.

The law of construction of two civilizations together and improve each other should be followed and construction of spiritual civilization and soft power of culture should be given full play in order to provide spiritual power to construction of material civilization in rural areas. Meanwhile, we should be clear that construction of spiritual civilization itself is the one part of the construction of overall well-being, and only by increasing the material standard of living and enriching the cultural life of the peasants at the same time can enable peasants to truly enjoy a happy and harmonious happy life.

3.8 Correctly handle the relationships between the transformation of nature and follow the laws of ecology .

In order to develop agricultural productivity in rural areas, we need to give full play to people's subjective initiative, and strive to transform nature, form higher social productive forces and achieve sustainable development. But all the natural transformation of production activities must follow the laws of nature and ecology as a precondition and avoid being eager for quick success and instant benefit, being disobedient to the objective law. The harmonious development between man and nature should be coordinated, and the development road of development of production development, affluent life and sound eco-civilization should be taken.

3.9 Correctly handle the relationships between the bottom-up innovation and top-down leadership and deployment.

In the three rural development, we must respect the pioneering spirit of the peasants, and insist the guideline of from the masses, to the masses. We should be good at summing up and promoting the advanced experience and successful model created by the grass roots peasants and encourage peasants with inspiring development goals. There is no end to development and innovative reform. and inspire the masses. Should adhere to the development of an open-ended, endless innovation so we need to push forward reform and innovation constantly. Peasants' opinion should be set as the criterion to check whether the reform and policies are good or not.

3.10 Correctly handle the relationships between the main role of the peasant and the leading role of party government.

The fundamental driving force should be giving full play to peasants and mobilize their creativity and entrepreneurial enthusiasm to create wealth. We must take road of market-oriented and agricultural industrialization and urbanization of rural areas. We should bring the government leading role into play fully, and give guidance and encouragement to the mail role played by peasants, but the peasants main role should not be replaced. At the same time, we must distinguish between the functions "two roles" played in different areas. in the production and operation areas, the peasant masses should play the main role, while in the public services, the government must play a leading role.

4 The New Challenges of the Three Rural Development in New Era

Ten pressing issues summed up need to be addressed:

4.1 Agricultural development is facing numerous challenges, the transformation of traditional agriculture, construction of modern agriculture is extremely urgent.

Now we are facing low demand for agricultural products, lower prices of agricultural products, agricultural labor productivity, the contribution rate of science and technology, and market competitiveness is low, a small scale production oriented, sideline production oriented, labor aging, fluctuations in production and sales, eco-environmental degradation, and difficulties of income increase. The change of traditional agriculture, transformation in ways of agricultural development, and speeding up transformation and upgrading of agriculture is very urgent.

4.2 The transfer of rural labor employment is getting more difficult, and open up multi-channel employment opportunities for peasants is very urgent.

Now we are have reduced demand for migrant workers, the number of jobless migrant workers returning home is increasing. Wage increase in income is more difficult, and the problem of increasing of rural surplus labor force and lack of labor jobs is very serious.

4.3 Barriers exist in front of the property income increase of peasants, and the policy of creation of peasant land, real estate, capital appreciation is very serious.

At present, peasants are collectively owned land assets, peasants real estate, currency assets are now being restrained by the land system, property rights system, financial system policies, and it is difficult to activate capital appreciation, and the majority of peasants have no chance to access stock and property markets. The chance of increasing the property income for the peasants is still very narrow.

4.4 The process in urbanization in rural areas is slow, and speeding up the citizen transformation of peasants who work or do business is very urgent.

Nationally, there are more than 200 million peasants who work or do business, and two thirds of the rural labor force in Zhejiang have transferred to the secondary and tertiary industries, but most of these peasants are "amphibious" population, the citizenship process among rural areas is clearly lagging behind the industrialization and urbanization process, and it has become an important factor in restricting the economic and social transformation and upgrading and expanding domestic demand.

4.5 Rural infrastructure and public service system is backward, and achieving equalization of basic public services in urban and rural areas is very urgent.

Rural traffic, water and power supply, communications infrastructures and public services are lagging behind. Education, health, culture, social security and public service system are backward. Hard efforts need to be done in order to give young people access to education, give patients access to good medicines, and let old people be looked after properly .

4.6 Layout of villages and houses are scattered, construction of new communities in countryside and rural areas and improving the living environment is very urgent.

Scattered houses and villages, simple and rough houses which is compatible with small-scale peasant economy are incompatible with mode of production and changes of peasant lifestyle. Livestock breeding with mixed people and livestock style and the in a factory-style home manufacture workshop with the style of former shop and back factory is making a worse influence on rural environment, and is seriously hampering the efficiency of public service coverage and the improvement of living standard of peasants.

4.7 The rural labor mobility is accelerating, unstable factors are increasing, and building a harmonious society in rural areas is very urgent.

A large number of rural young adults are going out for work, and migrant workers in cities are increasing. The social security situation is facing challenges, the task of fighting against evil forces and illegal religious is very tough. But the battle and cohesion effectiveness of grassroots organizations is not strong, so the building of an equal society in rural areas and democracy and legal system should be strengthened.

4.8 The task of strengthening the building of spiritual civilization and improving of the overall quality of the peasants is difficult, and enhancing the soft power of rural development is very urgent.

Cultural construction in rural areas, mass cultural activities is not yet popular, and the task of building of spiritual civilization will be a heavy work. Peasants' educational attainments need to raised, and the innovation spirit needs to be further promoted, as society atmosphere need to be purified and stereotypes need to be get rid of and harmonious village atmosphere need to be created with efforts.

4.9 The widening income gap among peasants has not yet been under control, speeding up of the income increase in the less developed villages and low-income households is very urgent.

the income gap between urban and rural areas, and among different regions and peasants groups are still widening, and less developed areas are facing more difficulties. And the task of leading low-income households to better life is extremely difficult. The poverty-relief work of adopting measures according to local conditions and family's needs in order to help the low-income households become better off remains to be further innovation.

4.10 The constraints to scientifically developing by the urban-rural dual economic and social structure is more apparent and accelerating the urban-rural comprehensive reform, and innovation of construction mode of a new socialist countryside is very urgent.

Rural economic and social transformation and upgrading are making more demands of getting away the urban-rural dual economic and social structures and institutional obstacles. However, many aspects of urban and rural comprehensive reform are facing many restricts from the original system, regulations, and policies, and the task of emancipating the mind is still very difficult . understanding of the law of the building of new socialist countryside need to be deepened, and systematic summary need to be done based on the experience of building new countryside in recent years. Insufficient investment in new rural construction, unclear ideas, and not enough participation among peasants very acute problems.

5 Grasp the New Opportunities of Three Rural Development in the New Era.

Ten new opportunities of three rural development in new era:

5.1 China has entered a new era of scientific development. The scientific development concept has provided the correct strategical guiding ideology for three rural development, and the Party's Third Plenary Session of Seventeenth Central Committee has given the right direction for the next step in three rural development.

5.2 China's economy has stepped into the track of the socialist market economy, the role of market mechanism in promotion of three rural development and the role of government in protection and regulation of three rural development will be further strengthened.

5.3 China has stepped into the new stage of industry helping agriculture and cities aiding rural areas. New industrialization and urbanization process is accelerated and it will boost and stimulate the three rural development, and the non-agricultural labor force will increase and the changing rate of peasants to citizens will accelerate.

5.4 China has established a new way of coordinating urban and rural development and a new task of building a new socialist countryside. Two drive mechanism of new cities and new rural construction will be further strengthened, and a more enthusiastic atmosphere will be created.

5.5 China's comprehensive national strength is significantly increased, and it is time to have industry support agriculture and urban aid rural areas. More public finances would be given to the three rural development and public services will accelerate to cover the rural areas.

5.6 China's economic development is under the change from the investment and external demand pulled to consumption and domestic demand, and this transformation of macro-economic strategy will provide a more favorable social environment for three rural development.

5.7 China has entered a critical moment of accelerating the transformation of traditional agriculture and develop agricultural modernization with Chinese characteristics, is bound to enter a new stage of agricultural practices transformation and modern agriculture construction.

5.8 China's urban and rural comprehensive reform has been launched, breakthrough of urban-rural dual economic and social structure is expected to speed up, the momentum of three rural development reform will continue to grow.

5.9 The peasant masses awareness of doing business and making wealth, and quality and ability of peasants is increasing continually, and a new wave of doing business and making wealth among peasants is emerging with vitality.

5.10 The party's leadership of the three rural development is being strengthened continuously. 60 years of development has provided us with a wealth of both positive and negative experience. The increasing level of guidance to the three rural development by leaders at every level has provided a powerful political safeguard to the three rural development in the new era.

6 New measures of scientific implementation of three rural development in the new era.

There are ten measures:

6.1 The planning of urban and rural integration

According to objective of the integration of economic and social development in urban and rural areas, we need an overall plan of the new cities and new countryside in a comprehensive manner and coordinate the distribution of productive forces, distribution of population, and construction of cities and rural areas. We focus on the nodes of central cities, central towns, and central villages in the layout of the integration of urban and rural. Coordinates the overall planning of counties, land use, and infrastructure construction planning, and improve the accumulation of rural population and factors of production and create the new pattern of economic and social development in urban and rural areas.

6.2 Developing a new eco-efficient agriculture

China is now changing traditional agriculture, and developing agricultural modernization with Chinese characteristics, the work of speeding the transformation of traditional agriculture and construction of highly efficient modern agriculture should be done. With the basic conditions of big country with small agriculture, large population with small land, highly efficient ecological agriculture should be the practice model, and we should follow the high-yield, high-quality, efficient, safe, ecological requirements, and develop the new agricultural modernization which is economic, efficient and environmentally friendly, safe in products, feature-rich, technology-intensive, and with full play of human resources.

Specifically, in order to develop efficient ecological modern agriculture. First, we should set the new development direction of making high-quality agriculture in industrial structure and precision agriculture in technical architecture. Second, we should strengthen the new agriculture development mechanism of innovation in agricultural system, technology creation and culture, and making wealth by able peasants. Third, it requires the integrated use of administrative means, economic means, education means, legal means to establish and improve a new development of modern agriculture protection.

In other words, according to the general ideas of "four precision agriculture", "four innovation mechanism", "four protection means", we will implement the new strategy of "building strong agriculture by innovation", and speed up the transformation of traditional agriculture and construction of modern agriculture.

6.3 Cultivating, concentration and development of new towns.

County is the main area for coordinating the urban and rural development, and construction of new countryside. Building big and strong counties and towns is a good way to realize the transformation of agriculture economy centered, and industry economy centered to urban economy centered and form the combination of towns groups and industry groups. Rural population need to concentrate in counties and central towns, and rural industry need to concentrate in industrial areas, commercial industry need to focus on urban areas, and agricultural land need to concentrate on large-scale agriculture organization. Reform of the land system, the household registration system, employment system and social security system need to speed up. , off-site replacement of housing land in other areas will be carried out. Encourage replace the housing land and old building with urban houses and enhance the "four concentration" and changing of peasants to citizens.

6.4 Building clean and tidy new communities

In line with idea of overall urban and rural construction planning and integration of urban and rural construction, the traditional scattered villages layout should soon be changed. Converge the housing of villages and different villages and make good plan of central village communities. Make these central villages based new communities constructions as a strategic focus in deepening “10000 Village Model” project.

Central villages based new communities constructions is a good way of building a modern communities with integration of urban and rural areas, and it will narrowing the rural-urban difference and improve the level of construction of new rural areas, and let the peasants enjoy modern life together. Construction of infrastructure with integration of urban and rural areas, and construction of public service should be based on the central villages. Center village public services should include community planning, community education, community health, community culture, community cleaning, community greening, community welfare, community employment and other integrated services.

In accordance with the guideline of one village, one special industry, the central village should be guided to follow the way of green development and its own characteristics. Combine the development of agriculture with distinctive local characteristics with construction of green villages, combine the improvement of industry with distinctive local characteristics and improvement of living environment together. The building of new communities in central village should not only keep the rural pastoral scenery, beautiful environment, local history and culture, but also introduce modern public service system, and achieve the perfect combination of tradition and modernity, the formation of a new style of modern rural landscape and make the beautiful garden that the public are interested in and peasants are proud of.

6.5 Foster a new system of public service

Promote on a full scale the system building of new rural cooperative, the new agricultural insurance, agricultural education in accordance with the equalization of basic public services in urban and rural areas. It is required to give all peasants access to education, give patients access to good medicines, and let old people be looked after properly and improve the rural relief system. Further increase the poverty alleviation and push the projects of low-income households to prosperity and a better life, and narrow the income gap between peasants, and between different regions, and achieve the target of making low-income households in less developed regions to be prosperity and a better life.

6.6 Advocate the new trend of civilization and harmony

It is a important measure of construction harmonious society to strengthen the building of spiritual civilization in rural areas and rural cultural development, prosperity of cultural undertakings in rural areas, and enhance the soft power of rural culture. Give full play to culture in the building of a harmonious society, and carry out the healthy and happy sports and recreational activities to enhance harmonious relations between the peasant masses, and create a civilized, harmonious and happy living environment.

Combine the moral construction and democratic legal system together, and develop together with the leadership style and moral construction of rural cadres. Not only should we improve the moral standards of the peasant masses, help more peasants get the proper use of the democratic rights so that rights protection can be realized according to law, but also pay special attention to improving the moral standards and democracy and legal awareness of cadres at all levels, especially those department and officials who dealing directly with peasants.

6.7 Advocate the new spirit of innovation and making wealth.

Make new upsurge of innovation and making wealth among peasants and advocate the new spirit of innovation and making wealth, and create a good environment of making more peasants making wealth in the wider urban and rural industrial development space. Improve the mechanism of letting new business by capable people drive more peasants to change to different industries, and promote the division of jobs and industries among peasants. Actively expand the multiple functions of agriculture and rural industries, lengthening the industry chain, expand employment and chance of making business, promote the specialization, intensification, entrepreneurialism and industrialization of agricultural and rural economy.

6.8 Foster the new peasants with all-round development.

Innovate the training and education method and mechanisms, popularize vocational education, community education, continuing education and increase the cultural and technological quality of peasants, and cultivate various types of high-quality professionals, skillful workers and entrepreneurs. Further accelerate free of charge vocational education in rural areas, and let the rural youth who can not enjoy the high school and college education have the access to higher vocational and technical education, and fundamentally eliminate the possibility of low quality migrant workers, and eradicate the causes of poverty and backwardness in rural areas. Skills training for rural laborers need to develop toward specialization, professional training.

Focus on the building of a learning society in the rural areas, and promote lifelong learning. All levels of Radio and TV colleges, correspondence university, further education colleges, community colleges, adult education should all focus on rural areas, and particular attention should be paid to education on peasants' civilized quality. All types of schools must open courses for education of peasants' civilized quality, and make an significant improvement in peasants cultural awareness, technological and moral quality.

6.9 Deepen the new reform of urban and rural areas

Three rural issues in the new era should be addressed by the drive of reform, and a new wave of emancipation of the mind in order to break the system barriers.It is necessary to promote the urban and rural comprehensive reform, promote the reform in economic, political, social, and cultural aspects, break the shackles of a number of old ideas, and give peasants free and comprehensive development with vast space and equal rights, promote the reforms of whole land system, household registration system , employment system, social security system, property system, property rights system, financial system, and promote optimal allocation of land, population, human resources, capital, technology and other production elements in urban and rural areas.

6.10 Build a new team to better serve the people.

First, it is needed to transform government functions, and build a public service-oriented government and public service a team of civil servant who serve people; Second, consolidate the rural foundation by building public service-oriented rural grassroots organizations, and create political organization protection for social equity and justice in rural areas and the building of a harmonious society in rural areas. Build grass-roots party organizations, the villagers self-governance organizations, and village collective economic organizations with combat effectiveness, and foster a team of new countryside construction who has the ability to take the lead to make wealth and has the dedication of lead other people to get rich.

Chapter 6 Systematic Analysis on Quick Development of Bamboo Industry in Zhejiang Province - A Case Study for Successful Development Approach of China's Booming Bamboo Industry

Being fastest growing, short harvest, renewable, sustainable and versatile use, bamboo is worldwide recognized as one of 2 top non-timber forestry products, and has unique harmony of economic, social and ecological benefits. It is highly linked to human being's livelihood, plays increasingly important roles in rural social-economy development and ecological environment protection.

China is globally acknowledged as "Kingdom of Bamboo" for its excellent achievements in bamboo. It has rich bamboo resources, i.e. 500 species, 39 genera and an area of 5 million ha, about 1/3 of the world total, respectively (ZHANG Xinping,2003). After 4-decade painstaking efforts, China's bamboo sector has grown into a booming and sun rising industry streamlined from cultivation, integrated processing to export, and has become a pillar of agricultural economy. In 2006, China's total bamboo production value is over US$ 6 billion with an export value of US$ 600 million （JIANG Zehui，2002；JIANG Zehui，2006）

Bamboo is widely grown in Asia, Africa, Latin America and the Pacific Regions, with 1 250 species, 150 genera, and an area of 17 million ha. But those treasonable and rich resources have not been explored well. The authors have investigated many countries of 5 continents on bamboo, and are also in charge of conducting 21 international bamboo technology training workshops in China funded by the Chinese government and international organizations, in which over 600 trainees of 62 countries are well trained. Through those activities, the authors are deeply impressed by their firm determination to explore bamboo, and their strong expectation to know China's successful experience and secret of bamboo development so that they can help their bamboo development, but they usually attribute China's bamboo achievements to technology role, and neglect other more important factors which hinders them from deep and right understanding of China's bamboo.

This article is a case study of Zhejiang bamboo development, and makes all-sided and detailed analysis on its successful development experience so as to provide significant references and instructions for bamboo development for other countries.

1 Outline of Bamboo Industry Development in Zhejiang Province

Zhejiang Province is well recognized as the first bamboo province in China. "If you want to know world's bamboo, please look at China's bamboo; if you want to know China's bamboo, please look at Zhejiang's bamboo", which is a vivid and precise description of Zhejiang bamboo. Zhejiang has a bamboo forest area of 0.78 million ha, in which Moso bamboo (*Phyllostachys pubescens*) forest is 0.6 million ha, or around 1/6 of the China's total bamboo forest area, but it had an annual bamboo production value of US$ 2.3 billion in 2006, around 1/3 of the China's total(Figure 1), in which US$ 300 million from export. It has 4 838 bamboo processing enterprises, in which 4 enterprises have an annual production value of over US$ 13 million, 17 ones over US$ 6.5 million. Zhejiang Province produces over 3 000 varieties of 10 line products . Bamboo resources have been quickly expanded from 1989 to 2004, and bamboo plantation area has increased by 22.5%, 19.7 % and 4.7 % for each 5 years respectively, and Moso culm stock had increased by 41.18 %, 25.32% and 45.32%, respectively (Figure 2). The primary, secondary and tertiary industries are developing harmoniously (Figure 3). Bamboo industry has become one of main farmers income resources and agricultural pillars. In Zhejiang, 34 counties have an annual bamboo production value of over US$ 12.8 million, in which Anji county's is over US$ 641million(.Weng Fujin , ZHU Yunjie, LOU Yuntai.,2004)

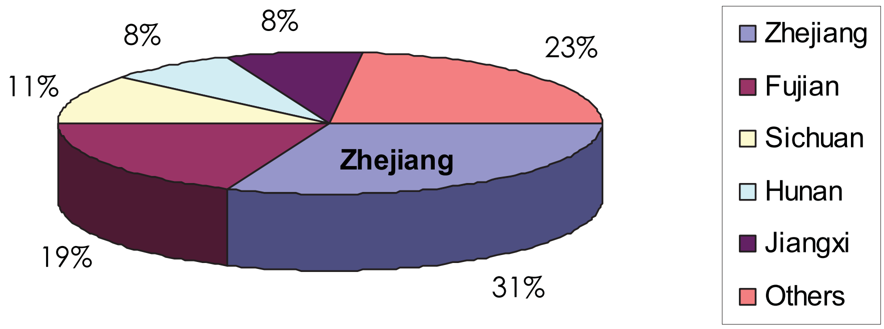

Fig. 1 Bamboo industry value distribution of different provinces in China

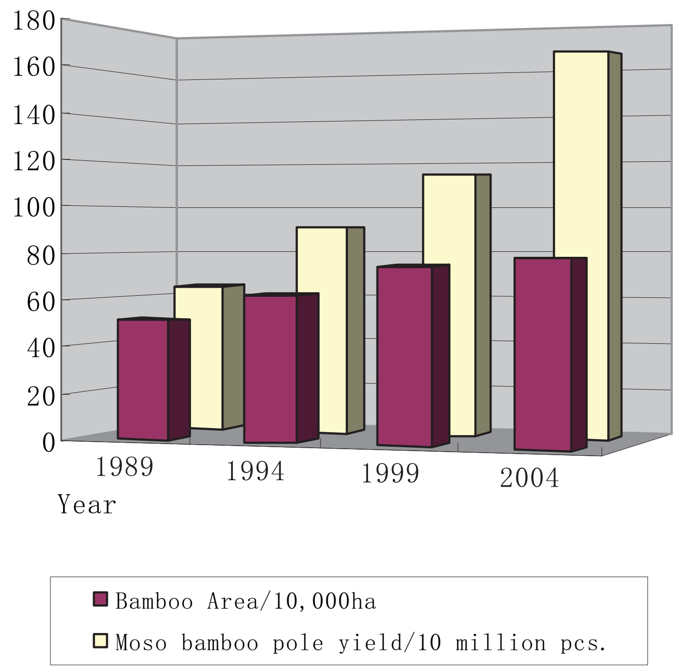

Fig. 2 Quick increase of bamboo forest area and Moso bamboo culm yield from 1989 to 2004 in Zhejiang

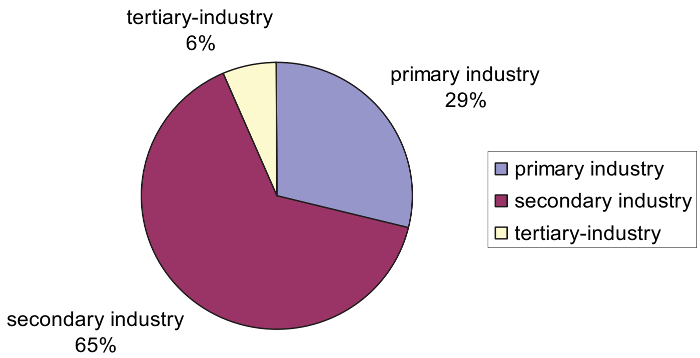

Figure 3. Composition of total bamboo industry value of USD 2.3 billion in 2006 in Zhejiang

2 Main Analysis on Quick Development of Bamboo Industry in Zhejiang

It is acknowledged that the below factors make main contributions to the great success of Zhejiang bamboo industry.

2.1 Quick Progress and Updating of Bamboo Technology Provides a Strong Back-up for Bamboo Industry Development

It is in Zhejiang province that the famous research institutes concerning bamboo are located, e.g. the Subtropical Forestry Institute of CAF, China National Bamboo Research Center, Zhejiang Academy of Forestry, Zhejiang Forestry College. They are the most dynamic in Research & Development (R & D) of bamboo in China, and therefore they have brought about a lot of benefits and contributions to Zhejiang bamboo development. The wide application of the following advanced cultivation technologies has markedly improved productivity and quality of bamboo forest: classified management technology of bamboo forest, improvement technology of low-yield and low-benefit bamboo forest, and high-yield, high-value directional cultivation technology of bamboo forest, water irrigation and balance fertilization, counter-season cultivation of "early bamboo"(*Phyllostachys praecox*) by mulching, which can produce amazing economic benefits as high as US$ 77 000 per ha.,directional and high-yield cultivation for 3 kinds of shoot (spring shoot, summer shoot and winter shoot) greatly increases production, quality and output value of fresh shoot.

Primary and basic R & D of new technology and new product is done by concerted cooperation between institutions and enterprises, further improvement of new product and market access is undertaken by interaction cooperation between manufacturers and importers of developed countries. Therefore by such a cycle from research institutions, manufacturers to markets, new products are accepted by markets, and new technologies are matured, and more such art-of-the-state technologies are quickly disseminating among all the bamboo enterprises by the mechanism of so called "Bamboo Industry Zone", so that the whole bamboo processing industry can be simultaneously promoted. In recent 2 decades, the following technologies have played key role in making the bamboo industrialization shifting from the traditional way featured with simple, cottage handicraft-level and low added value to the modern one with complicate, modern industry-level and high added value. Bamboo culm harvesting method, bamboo timber bleaching, preservation and drying, bamboo timber carbonization, manufacturing technologies of bamboo floor (solid bamboo floor, bamboo and wood composite floor, reinforced bamboo floor), bamboo veneer, bamboo building plywood, bamboo mats(square bamboo mat, strip bamboo mat), bamboo shuttle and carpet, sliced bamboo shoot by vacuum packing, bamboo charcoal and vinegar, bamboo fiber and fabric, bamboo leave flavoid-derived health-care products, etc. It could be concluded that the majority of those major bamboo technologies in China could be originated from, or related with Zhejiang province. It is the major reason why Zhejiang's bamboo industry development is so fast, and takes the first position in China.

Therefore, bamboo cultivation technology progress can ensure sustainable provision of raw bamboo material in a high yield and high quality, and advanced bamboo processing technology can guarantee production of high value-added and high quality products so as to enhance its economic benefits, greatly drive bamboo cultivation since high demands for raw material can result in the increase of its purchase price. As a result, the whole bamboo sector is initiated from bamboo technology progress.

2.2 Various Governmental Supports Promotes Orderly and Harmonious Development of Bamboo Sector

2.2.1 Favorable Policies Ensuring Sound Development of Bamboo Industry

Government intervention to promote bamboo sector development could be generally classified into 3 steps in the development sequence. From late 1970s to early 1980s, China had made rural system reform, and the rural production system had been shifted from the unified collective management to Household Responsibility System (HRS), which can greatly promote farmers' bamboo production. Meanwhile, bamboo product marketing system had also been shifted from the state monopoly which does not allow farmers to sell their bamboo, to the free market in which farmers can sell their bamboo at their own will. More township and village enterprises were booming, and some of them started bamboo processing. As a result, preliminary and simple bamboo processing industry started and developed. In the middle 1990s, 3-stabilization policy including "Stabilization of mountain and forest property", "Stabilization of self-processed mountain property", and "Stabilization of household responsibility system" was issued by the central government, which has further strengthened farmers' determination of developing bamboo plantation since they did not have enough confidence with long-term investment in bamboo plantation considering possible change of properties of mountain and forest. Therefore, quantity and quality of bamboo forest resources have been greatly improved. In 2006, China's government made another far-reaching forestry system reform, that is forest property reform. Of course, the reform includes bamboo, and it renders farmers not only with the right of management in which farmers have been empowered in the previous HRS, but also with the right of ownership which allows farmers to transfer, transact or circulate as a property, so that the huge fixed assets of bamboo resources are activated, therefore, more and more people show bigger and bigger enthusiasm for developing bamboo plantation since it is indeed a very profitable investment. Therefore bamboo plantation has got another big momentum and opportunity to fly.

Sundry kinds of taxes and fees imposed on bamboo farmers as a fund-pooling means for developing bamboo before have been exempted since 2001, including agricultural special product tax of 6%-16 %, afforestation fund of around 0.5 RMB/Yuan per bamboo pole, forest construction fee and forest resource compensation fee, which makes farmers have more incomes from bamboo planting, therefore they are highly motivated to develop bamboo plantation and supply more bamboo poles to factories for high-valued processing. Different provisions of incentive subsidiary of fund, fertilizer have also been made by government to encourage farmers to establish new bamboo plantation and improve existing low-yield and low-value bamboo plantation.

In order to encourage export, China's government has promulgated a set of export tax refunding systems for bamboo products, based on the principle "the higher the products' added value is, the more the tax is refunding", e.g. only 5% for raw bamboo pole, and 12% for bamboo floor. It is to spur up bamboo enterprises to make much more intensive processing of bamboo resources to produce much higher added value, and also limited bamboo resources are ushered to developing high value-added products.

2.2.2 Strengthening Bamboo Plantation and Expanding Bamboo Resources for Sustainable Supply of Raw Bamboo Material for Processing

In the 9th National Five–Year Planning (1996~2000), special funds were earmarked by Zhejiang provincial government to support the implementation of 3 big construction projects of bamboo plantation bases, i.e. 1 million mu (Mu is a Chinese area unit, 1 ha= 15 mu) of high-yield Moso bamboo plantation, 1 millon mu of Moso plantation for shoot and timber, and 1 million mu of the improvement of low-yield bamboo forest. In the 10th National Five Year Planning (2001~2005), construction and improvement of bamboo forest bases were listed as one of priorities in agricultural planting structure adjustment of the province, and thus bamboo forest management level has been raised to a great degree by extending new cultivation technology, water irrigation. What should be stressed is that more investment has been earmarked for better developing bamboo road networks in several key bamboo production counties /cities by provincial government in order to reduce harvesting and transportation costs of bamboo timber , which brings farmers more benefits. Therefore, areas, productivity and quality of bamboo forest have been very much increasing to meet high demand of bamboo processing for raw bamboo material. It is said that " Bamboo Spring " is approaching in Zhejiang.

2.2.3 Facilitating Formation and Development of "Dragon-head" Bamboo Enterprises to Play Much More Important Role in Example-setting and Promotion

Dragon-head bamboo processing enterprises are always connected both with markets as up-stream and with hundreds of thousands of farmers as down-stream, therefore, they play a key role in promoting bamboo industry development. Eighteen bamboo enterprises representing different fields of bamboo processing and different areas have been selected out as provincial-class "dragon-head enterprise", therefore they can get favorable and special support and assistance from government in fund, loan, and land purchase, etc. in order to enhance their capacity, technology and export for playing much bigger driving role in the whole bamboo industry in Zhejiang.

2.3 Good bamboo Management Models between Bamboo Cultivation and Processing and Sale to Ensure Balanced Development

At present, Zhejiang Provincial Bamboo Industry Association is set up with 5 chapters, i.e. bamboo plywood chapter, bamboo floor chapter, bamboo shoot chapter, bamboo charcoal chapter and bamboo article chapter. Meanwhile, there are 70 bamboo industry associations with 5,834 members, 52 bamboo cooperatives with 6,145 members in Zhejiang. Each main bamboo county has set up such association and cooperative. Regarding cooperative, it has 2 kinds of organization form: "Dragon-head enterprise + cooperatives + farmers", "markets + farmers", e.g. Northern Zhejiang Moso Bamboo Market has 402 "bamboo management households", and connects 62,000 farmer households, spurs on development of bamboo plantation "Cooperatives+ farmers"; "Dragon-head enterprise + bamboo processing farmers", e.g. Deqin Monganshan Bamboo Plywood Factory places purchase orders of semi-finished bamboo products to farmers to meet their finished product production needs, which connects 22,000 bamboo farmers, absorbs over 5,000 farmers, consumes over 11 million bamboo poles per year, drives development of bamboo plantation bases of 53,000 ha distributed all over Zhejiang Province(WANG Shudong, 2004.).

Association is a good bridge among government, enterprises and farmers, and plays an important role in protecting rational benefits of bamboo farmers and production enthusiasm, ensuring enterprise low costs raw material and stable supply, and promoting sound development of bamboo industry as a whole. A share-holding financing firm which provides a financial loan service for bamboo enterprises with help of Zhejiang Provincial Bamboo Industry Association is set up.

2.4 Special Scio-economic and Humanitarian Advantages and Conditions

2.4.1 Developed and Convenient Transportation Facilitates Bamboo Export

Located in China's eastern coastal areas, Zhejiang is one of the most economic developing provinces in China, and ranks the 3rd in export value in China. Its transportation network is very developed: wherever you want to go, you can be over there by driving within 4 h, and 2 h to Shanghai which is the biggest commercial city in China; Nangbo sea port of Zhejiang ranks the 3rd in China. All the unique geographical location and good infrastructure conditions play a firm physical foundation for bamboo export, and promote bamboo industry development since bamboo export takes a leading role in driving the development of whole bamboo industry.

2.4.2 Export and Private-enterprise Culture Promotes Quick Growth of Bamboo Processing Industry

Zhejiang is scarce in natural resources, and small in land area, therefore it has to take a road of developing "export-oriented and value-added industry invigorated by more dynamic and flexible economic policies and systems. After 3-decade efforts, now most of the enterprises in Zhejiang are highly connected with import /export businesses, and the total export value is ranked the 3 rd position in China. It has formed an "export culture" which has made a deep impact on Zhejiang entrepreneurs. The private economy is extremely booming, and ranks the first in China, with economic contribution over "half a sky", or over 50 % of the provincial total GDP

(YE Donglei, ZHU You jun. 2006). Therefore Zhejiang is growing one of the most economic developing provinces in China.

Composition of bamboo enterprises in Zhejiang is nearly 100 % private, whether from inside China or outside China as joint-venture or sole-funded, but none from government

As cultivated and influenced by "export culture", bamboo entrepreneurs have known how the export will bring about, and how to better engage in export business; meanwhile, they can get a quick enhancement of business management by absorbing and updating their advanced management technology as they do transaction and interaction with the developed countries, e.g. USA, EU, Japan, etc., to which they export bamboo products, but the importers of developed countries usually have a very serious quality and service requirement for exporters. Now the general level of China's bamboo flooring manufacture and quality can approach to the highest level of the world wood floor level in many aspects after 2-decade efforts, it is an excellent result of exposure and export of China's bamboo floor to the developed countries.

2.4.3 "Bamboo Industry Zone" and "Bamboo Economy Block"

There are 4 838 bamboo timber processing factories in Zhejiang, but their distribution is mainly restricted in the western and northern Zhejiang . They produce 10 lines of very similar products , i.e. bamboo floor, bamboo plywood, bamboo curtain/carpet, bamboo shoot, etc., so they look like a big "Bamboo Industry Zone", which has formed a whole chain from bamboo plantation, transportation, semi-finished processing by farmers, finished processing by factories, supply of subsidiary materials to export. Indeed, Bamboo Industry Zone creates a "Bamboo Economy Block" which consists of the primary industry —bamboo plantation for supply bamboo poles, the secondary industry—production of different semi-finished and finished bamboo products, manufacture of bamboo machines, processing of subsidiary materials, and the tertiary industry—financial, technical and trade service, bamboo ecological tourism. Inside the zone, there are several saline advantages: (a) Production enterprises could/can share technologies by learning from each other, or even by "stealing", therefore the technologies are updated and improved very quickly as a whole; (b) Prices of products are reduced since all the purchase price of raw and subsidiary materials, service, etc. is lower as a "wholesale price", not a "retail price "; (c) Quality of products is much higher. Each enterprise faces a very serious competition from many similar enterprises nearby, so it has to take painstaking efforts to enhance its product quality, reduce its price, otherwise, it would not be survived further; (d) More business opportunities have occurred. More customers come to the Zone to do business for its much better price and quality, more selection of suppliers, and much easier exploration of new products. All the above-mentioned advantages are hard to be found outside the Zone where bamboo enterprises are quite less.

2.4.4 Excellent Talents of Bamboo Grown up under Unique Humanitarian Environments

Bamboo in Zhejiang has a history of over 5 000 years, people have accumulated very rich experiences of bamboo cultivation and processing, therefore bamboo has been already rooted deeply in their mind, which is a good working foundation for bamboo. Chinese people are very famous for their "cleverness, diligence, and talent/capacity/intelligence". That "The richer people are, the harder they work" has become a fashion which is called as "A Spirit of Zhejiang". At present, bamboo industry is still a combination of handcraft and semi-mechanization, so the labors it needs should be not only quite intelligent, but also hard and diligent. Therefore, it is in Zhejiang where people are extremely excellent and qualified for bamboo development. In fact, the majority of bamboo's entrepreneurs were farmers before, but and very motivated to start up township and village enterprises since China opening up to the outside world in 1980s. It is the unique social and culture foundation in Zhejiang that promotes bamboo rapid development in Zhejiang.

2.5 Quick Expansion of International and Domestic Bamboo Market Stimulates and Drives Bamboo Industry Development

In recent 2 decades, international and domestic markets of bamboo products are expanding very quickly, especially since 2000. Over 90% of bamboo flooring made in Zhejiang is for export to international market with an annual increase of 20% thanks to its excellent and unique quality and environment-protection. Over 80% of bamboo curtain and carpet are for export to USA, EU, Japan, etc. for its fine designing, unique function. Bamboo shoot market is expanded not only in Japan, which is a traditional main importer, but also in USA, EU, where people do not like to eat bamboo shoot, but now start to enjoy it for its rich nutrient and slimming function. Bamboo fiber and fabric, bamboo charcoal, bamboo construction Plywood, which have very high added value are showing a strong tendency of export. Bamboo mat is amazingly growing in domestic market, e.g. if each household in China has one bamboo mat, how much big it is. Bamboo shoot market is traditionally restricted in Southern China, but now comes across the Yangtze River to Northern China.

The reason why bamboo product markets can be developed quickly is as below: decreasing supply of wood products due to serious depletion of wood resources, and increasing demand for wood products since people prefer natural and environment-harmonious commodities than artificial synthetic ones. Therefore the gap between supply and demand is widening, and it is bamboo that can well fill up this gap because bamboo can replace wood in many uses, and bamboo can even exceed wood in some uses because of its unique characteristics.

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Chapter 7 Bamboo and Rattan Products Coding System and Import & Export Data Analysis

Since INBAR became the International Commodity Body(ICB) of CFC in 2000, we have paid more attention to the international trade in bamboo and rattan products by observing the trends in relevant product categories. We make import & export data analysis of bamboo and rattan products on the basis of UN COMTRADE Statistics with the following HS codes:

140110 Bamboos used primarily for plaiting (BAMBO)

140120 Rattan used primarily for plaiting (RATAN)

140190 Vegetable materials nes, used primarily for plaiting (OVPMT)

460110 Plaits and products of plaiting materials (PLATE)

460120 Mats, matting and screens, vegetable plaiting material (PPMAT)

460191 Plaited vegetable material articles not mats or screen (PNMAT)

460210 Basketwork, wickerwork products of vegetable material (BSKWK)

940150 Seats of cane, osier, bamboo-or similar materials (SEATC)

940380 Furniture of cane, materials nes (FURNC)

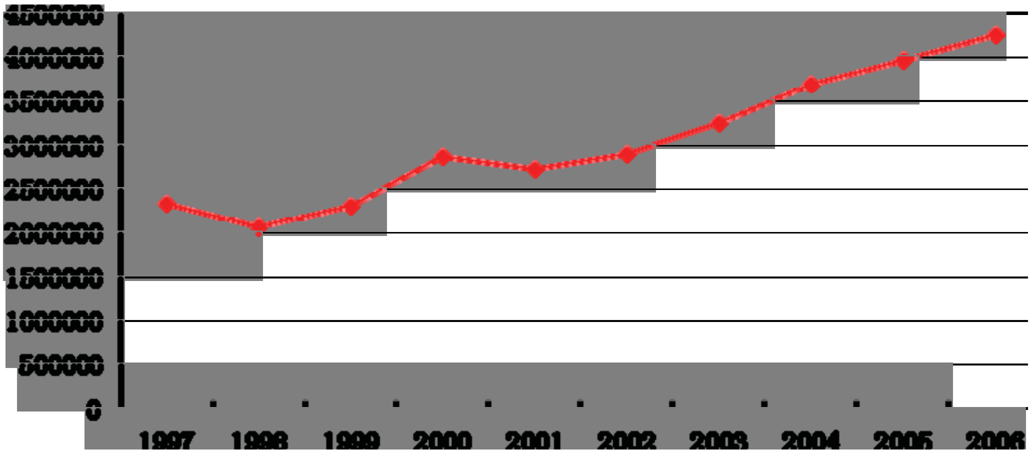
International trade statistics of bamboo and rattan materials and products has been showed non-even increase during 15 years period (see table 1).

Table 1World Export Statistics of Bambooand Rattan Materials & Products from 1992-2006

($1000)

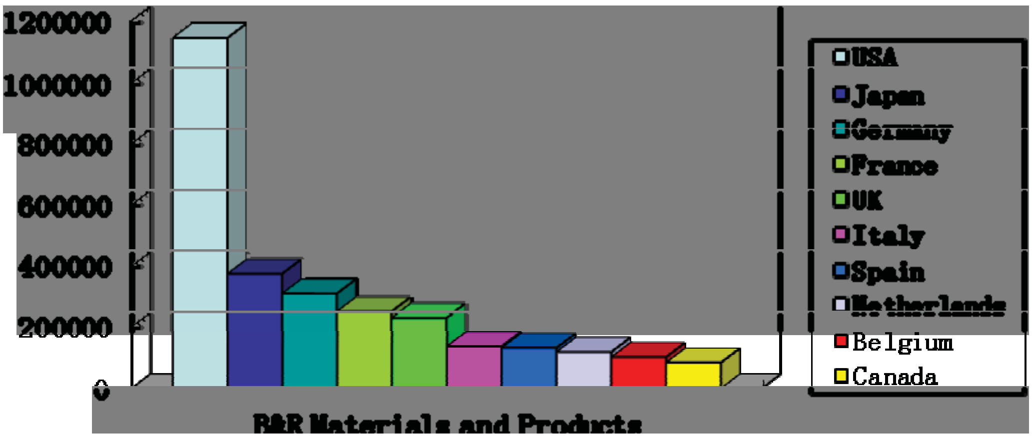
Year	Value	Year	Value	Year	Value
1992	1,967,887	1997	2,331,834	2002	2,898,023
1993	1,881,389	1998	2,060,119	2003	3,240,762
1994	2,336,723	1999	2,306,347	2004	3,697,118
1995	2,641,150	2000	2,878,188	2005	3,973,387
1996	2,541,906	2001	2,726,193	2006	4,261,484

The UN COMTRADE data indicated the import value of B&R product was $4,112 million and export value of B&R product was $4,261 million in 2006. The total export value of bamboo and rattan products in 2006 has been increased by 217% in comparison with that of 1992. From the following graph, we can see non-even increase of B& R products in ten years running (please see graph 1).



Graph 1 World Trade Analysis of BR Products During the 10 Years Period ($1000)

Major Markets for B&R Materials and Products in 2006 were USA, Japan, Germany, France, UK, Italy, Spain, Netherlands, Belgium and Canada (see graph 2).



Graph 2 Major Importers for B&R Materials and Products in 2006 ($1000)

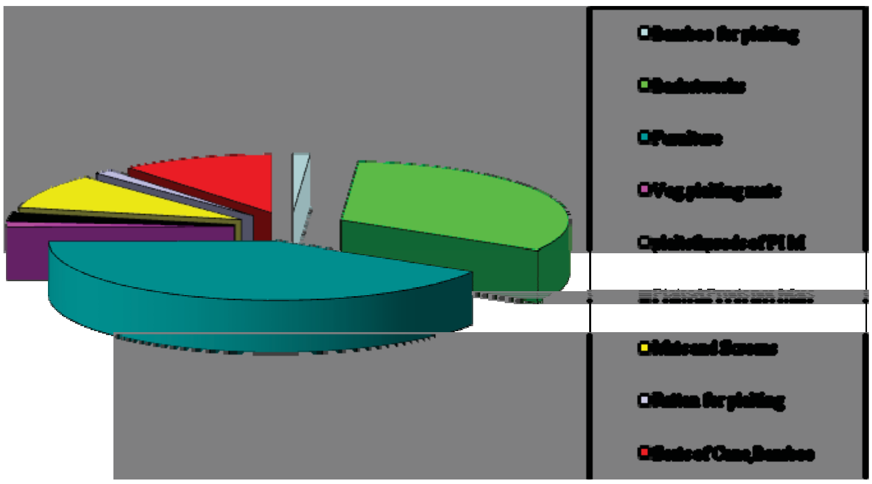
Among EU member countries, Italy, Germany, Spain, Belgium and Netherlands (see table 2) were also the major exporters of top ten exporting countries in the world for bamboo and rattan materials and products in 2006.

Table 2 Major Exporter of B&R Materials and Products in 2006

Main Exporters for B&R	Export Value in 2006 ($1000)
China	1,748,201

Main Exporters for B&R	Export Value in 2006 ($1000)
Indonesia	432,833
Italy	420,898
Viet Nam	207,286
Philippines	164,225
Germany	121,903
Spain	121,344
USA	111,839
Belgium	87,882
Netherlands	87,491

We also do some analysis based on individual products (see graph 3) of bamboo and rattan from Harmonized Commodity Description and Coding System:



Graph 3 World Export Value of Bamboo and Rattan Products Breakdown by Products

From the abovementioned graph, we know clearly the main products of B&R are mats and screens, seats of cane and bamboo, basketworks and furniture.

With the support of FAO, ITTO, EFI and Chinese government-Chinese Custom Administration, World Customs Organization approved the proposal submitted by INBAR to add 14 new HS codes for B&R products in 2003. The newly added codes are as follows:

200591 - Vegetables, Bamboo shoots

440210 - Roundwood, Charcoal, Bamboo

440921 -Wood continuously shaped non-coniferous, of bamboo

441210 - Plywood, Bamboo

460121 - Mats, & screens, of bamboo

460122 - Mats, & screens, of rattan

460192 - Plaits, Plaited Prods, of bamboo

460193 - Plaits, Plaited Prods, of rattan

460211 - Basketwork etc., of bamboo

460212 - Basketwork etc., of rattan

470630 - Other Fibre Pulp, of bamboo

482361 - Articles of Paper, Bamboo

940151 - Seats of bamboo & rattan

940381 - Furniture of bamboo & rattan

For the first time, INBAR made it possible to have import and export statistics data on bamboo shoots, bamboo flooring, bamboo pulp and paper, bamboo-based panels and boards, as well as bamboo charcoal. All the new codes became effective in 2007. These new codes have been much facilitated the international trade in bamboo and rattan products, removed some tax barriers and improved the collection and analysis of trade statistics.

We have developed bamboo and rattan trade database online on INBAR's website which can be processed by bamboo experts, government officials, business people who are interested in this area.

Since INBAR is the sole international organization focusing entirely on development issues related to bamboo and rattan – the two important non-timber forest resources with great economic potentials for environmental conservation, poverty eradication and industrial development. We hope both our efforts in coding system and import & export data analysis would help INBAR member states to further develop their bamboo and rattan industries in their own countries.

Chapter 8 Bamboo Research in China

1 Brief History

China has the earliest history of bamboo usage in the world. There is some unearthed bamboo weaving relics of 5000-6000 years discovered at the Banpo village, Xian City, and of the Neolithic Stone Age in Zhejiang. Bamboo was used for bamboo arrow, and books in Shang Dynasty, for palace building in Han Dynasty, for pulping and paper-making in Jin Dynasty. It is very understandable that scientific research on bamboo is connected with bamboo usage to a large extent, it proves some bamboo researches had been initiated since ancient times, even in Jin Dynasty, e.g. a special book---Bamboo was written by (AD 265-316), in which 61 species/varieties of bamboo were recorded in details, including biological characteristic descriptions and cultivation techniques, 34 of which have been used so far. But bamboo's research of real significance has not embarked on until the latest 1920's or 1930's, and it has been proceeding synchronously with development step of China's bamboo industry which can be phased out in the below 3 stages:

Stage 1: Initial stage from 1920 to 1949 (before the founding of People's Republic of China)

Nearly all research activities were restrained within bamboo's species identification, classification, and their resource distribution, and inventory.

Stage 2: Slow-speed development stage from 1949 to 1970

Emphasis were widely placed on bamboo research which, besides continuous research on bamboo flora, extended into comprehensive cultivation techniques of harvest bamboo stand, such as biological characteristics of some important cash bamboo, bamboo cultivation techniques, bamboo pest control, bamboo forest management, large-scale bamboo introduction in which a great success of introduction/transplanting of the southern Moso (*Phyllostachys pubesces*) to the northern Yellow River Valley was typically symbolized.

Stage 3: High-speed development stage since 1970's

More attention has been focused on bamboo research work, in which some of them have been listed as state-level or province-level key projects, and their research scopes have been expanded into various aspects of both cultivation and bamboo processing, integrate utilization, such as harvest-yield, orientation and multi-purpose cultivation of bamboo stand, counter-season cultivation of *Phyllostachys praecox* for shoot purpose, bamboo bio-diversity, and ex situ. and in situ. Protection, genetic breeding and improvement, further exploitation of various bamboo-based plywood, bamboo integrate processing and utilization, bamboo socio-economy, meanwhile some international cooperative projects have been commenced with International Canadian Research & Development (IDRC), United Nations Development Program (UNDP), etc.

Now present researches of bamboo in China are briefed in the following four Parts: Research Capacities/Institutions; Research Achievements; and Recommendations for the Future Research Priority.

2 Research Capacities/Institutions

Despite of several research institutions engaged in research of bamboo in as early as 1950's, they are restrained only in some Universities or state Institutes, such as Nanjing University, Chinese Academy of Science, etc., in a rather narrow range of research subjects in which overwhelming majorities are confined in bamboo taxonomy, identification, classification, and bamboo resources inventory, etc.. A breakthrough progress, especially in the sense of contributions and impetus to production with large scale and economic benefits, has not trigged until 1970's, and it is calculated that there are totally more than 100 institutions/organizations of state, provincial, and county levels, and over 1000 high-qualified bamboo researches with senior, medium and preliminary academic titles who work in research institutes, universities/colleges, enterprises, among which the following are prestigious and has large scope, research characteristics: Chinese Academy of Forestry (the Subtropical Forestry Research Institute in Zhejiang, the Bamboo Information Center in Beijing, the Tropical Forestry Research Institute in Guangzhou,), the Chinese Academy of Science (Nanjing Botanical Research Institute, Kunming Botanical Research Institute, Beijing Botanical Research Institute), Nanjing Forestry University, Zhejiang Forestry College, South west Forestry College, Central South Forestry University, Sichuan Forestry School, Nanjing University, Beijing University, Hangzhou University, Xiaming University, and so on; some of provincial Forestry Research Institutes of major bamboo-grown areas, such as in Zhejiang. Guangdong, Jiangxi, Fujiang, Hunan, Guangxi, Sichuan;, meanwhile including some other research institutes/universities/colleges in the field of agriculture, food, building. They have played a very important role in enhancing bamboo's research, production, but we should know, they are in a very scattered state in facilities, personnel, programs, funds, so it seems to be very difficult to play a bigger integrated role. In this context, on one hand, the booming China's bamboo industry development objectively urges more progresses of bamboo's sciences and technology to invigorate bamboo industry, on another hand, in order to play a more integrated role of bamboo science & technology in prompting China's bamboo industry development as a whole, it proves to be, not only feasible, but also very necessary, to integrate and share all available research resources and capacities scattered all over the country, based on those conditions, the Chinese Government ---- the original Commission of Science and Technology, the Ministry of Forestry decided and approved to set up China National Bamboo Research Center (CBRC) in Hangzhou, Zhejiang Province in as early as 1988. By several-year efforts, a multi-functional Headquarters which has a construction area of 15,000 square meters, a total ground area of 1.7 hectare and a total investment of USD 7 millions has been close to completion. Some of well-known bamboo experts are transferred to CBRC to start their work. In a word, it is entering into a normal and rapid growth track. CBRC is entrusted with 3 missions by the Chinese Governments:

-----Undertaking, organizing, coordinating major bamboo projects of research and development, national and worldwide;

-----Engaging in foreign economic and technical exchange and cooperation in area of bamboo, including personnel training, project contracting, technical consultation, etc., and

-----Evolving into China Bamboo Industry Group to be acted as a locomotive and backbone of China's bamboo industry to promote its development into a higher level as a whole.

Another very far-reaching event in the world bamboo cycle is the founding of the Headquarter of International Network for Bamboo and Rattan (INBAR) in Beijing in November, 1997. For more understanding, some briefings on INBAR are given as follows:

What is INBAR

INBAR was created by the International Development Research (IDRC) of Canada in 1993 to consolidate the information of bamboo and rattan research network operating for over a decade through various individual projects funded by the Center in Asia. In 1994, the UN, the International Fund for Agricultural Development (IFAD), joined hands with a grant to strengthen the socio-economic and post-harvest technology programs. The International Plant Genetic Resources Institute (IPGRI) supports the activities of INBAR's Bio-diversity, Genetic Resources and Conservation program under a Japanese Government grant. In November 6, 1997, INBAR officially came into being with the signing of the INBAR Establishment Agreement in Beijing. The 9 Signatories included the Governments of Bangladesh, Canada, China, Indonesia, Myanmar, Nepal, Peru, the Philippines, and Tanzania. Its three-tiered governance structure is: A Council, comprised of representatives of the signatory countries, is the highest body and provides overall guidance and oversight to the organization, A Board of Trustees, comprised of individuals selected on the basis of their qualifications and expertise, is the major decision-making body of INAR; and A Secretariat, which is the major operational body. INBAR's Mission is to improve the well-being of small-scale products and users of bamboo and rattan within the context of a sustainable bamboo and rattan resource base by consolidating, coordinating and supporting strategic research. It provides a framework for cooperative research on shared problems.

Besides, there are two national non-governmental bamboo bodies in China which play a very important role in coordinating, prompting and accelerating bamboo research, development, and technical dissemination. One is China Bamboo Industry Association (CBIA) affiliated with the State Administration of Forestry, mainly for the administrational coordination and management of the whole bamboo industry at a macroscopic level, and offers consultation for policy-making; another is China Bamboo Society (CBS) annexed with the Chinese Forestry Society (CFS), mainly for bamboo academic purposes. They both have branched out chapters in some southern major bamboo-grown provinces/autonomous regions.

3. Scientific Research Achievements

3.1 On China's Bamboo Classification and Flora

Through several-decade efforts by many Chinese scientists since 1930's on bamboo classification, a complete set of theories has been established to date, including some endeavors of new classification methods by bio-chemistry, mathematics. Nearly all Chinese bamboo resources have been clearly inventoried. The Flora of Republican Popularize Sincere come into publication in 1988, which induces 37 genera and 515 species, but some new genera and species have been discovered since 1988, on and off. So far, it is commonly recognized that there are totally 49 genera and about 500 species in China, despite some, even acute disputes among different schools. In 1994, the Chinese Bamboo Compendium was also published in Chinese and English versions. Detailed research and observation have been made on biological and phonological characteristics of some important timber and shoot species so as to lay down a good base for scientific cultivation. Protection and bio-diversity of bamboo have been well undertaken, many bamboo botanical gardens of various sizes have been set up nationwide, among which the important representatives are as follows: Zhejiang Anji Bamboo Botanical Garden which occupies 17 ha., and collects more than 300 species, Fujiang Zhangzhou Bamboo Botanical Garden has over 60 ha., and collects more than 350 species, and Bamboo Botanical Gardens affiliated with Nanjing Forestry University, Southwest Forestry College, Forestry Research Institutes of Zhejiang, Guangdong Sichuan provinces, Guangxi autonomous region.

3.2 China's Bamboo Forest Division

China's bamboo forests division has been completed as into 4 regions with 4 sub-regions. They are:

(1) Sub-alpine bamboo forest region.

(2) Monopodial bamboo forest region.

- (a) Rainy sub-region.
- (b) Irrigation sub-region.

(3) Mixed bamboo forest region.

(4) Sympodial bamboo forest region.

- (a) Southeast monsoon sub-region.
- (b) Southwest monsoon sub-region.

3.3 On Expansion of Bamboo Forest Area

Biological and ecological traits of some leading bamboo species have been studied, so that their bamboo ecological afforestation adapatibility are well solved. A good solution of bamboo propagation reduces bamboo afforestation costs by a big margin, such as by seeding of *Phyllostacys pubescens*, or by culm-burying, internode-burying, by cutting-burying, by secondary branch burying. Bamboo introduction tests have been conducted covering more than 100 species. What is most far-reaching is "Bamboo Transplantation from the South to North" has been successfully undertaken, or bamboo could be well afforested in the Yellow River valley, which enlarge bamboo growing areas.

3.4 Pests Control

Proven by survey that damaged bamboo insects amount to 280 genera and over 600 species, among which 200 species or so have been studied, including their life histories, natural enemies, control methods. Totally, more that 180 papers are published. Bamboo insects and diseases have nearly been kept under control, no serious bamboo pests has been brought about.

3.5 On Basic Researches on Bamboo Physiology, Biochemistry, Anatomy, and Ecology

Since 1980's, a big progress has been scored in the research of bamboo physiology and biochemistry, such as growth and differentiation, flowering mechanism, photosynthesis, on-year and off-year mechanism, mineral element nutrition, phyto-hormones, enzyme, all those have put down a good theoretical bases for harvest cultivation. On photosynthesis, it proves bamboo photosynthesis is belonged to the type of C3 plant, points out a theory of "Leaf Area Index". On general high plants, are one of major reasons why bamboo grows at unimaginable fast speed, and the dynamic balance of IAA, GA3 and ABA content play an important role in bamboo's off-year and on-year phenomenon. On mineral element nutrition, *Phyllostachys pubescen*s contains 11 normal elements (N, P, K, Na, S, Fe, Ca, Mg, Zn, Cu, and 8 trace elements (Co, Ni, Pb, Mo, Cr, V, Al, Ti), Nutrient element absorption is made not only in root, leaf which is commonly recognized, but also in bamboo cavity which opens a new path of rapid and efficient take-in nutrients. Anatomies have been studied on more than 100 species of bamboo, mostly for monopodial behavior, e.g. quantity and distribution of vascular bundles. Even by means of carbonated sampling method, observation, analysis, measurement and photo-taking are conducted by scanning electronic microscope on their microscopic and ultra-microscopic structures of those bamboo belonged to 33 genera, 71 species, as per their vascular bundle characteristics, a bamboo timber index table is listed out. Bamboo biomass, bamboo litter dynamic and decomposition, water and nutrition element cycle and balance in Moso bamboo stands.

3.6 On Some Basic Physic-mechanical and Chemical Properties of Bamboo Timber

Determination of physi-mechanical and chemical properties has been made on majorities of the important bamboo species in China, and so has measurement of cellulose, semi-cellulose, lignin contents for 50-60 bamboo species for pulping and paper, and analysis of combustion value on over 70 bamboo species.

3.7 On Integrate Research on Harvest-Yield Cultivation Techniques

A complete set of bamboo propagation techniques has been summed up, including by mother bamboo transplanting, by seedling, or by rhizome-laying, cutting-laying, internode-laying, even by tissue culture, also for bamboo afforestation, including planting density, season, method, tending, fertilizing, irrigation, reclamation, bamboo-remaining ratio, etc. Especially for Moso stand, a mathematics model of bamboo growth, and a set of theory of bamboo bump-harvest structure were established so that the yield can be predicted in a scientific base. Bamboo cultivation in China can be phased out 3 stages:

Stage 1: Low-yield bamboo stand improvement since 1950's;

Stage 2: Harvest-yield bamboo stand cultivation since 1970's; and

Stage 3: Bump-yield, high-profit orientation cultivation of bamboo stand since later 1980. So a full set of low-yield improvement and harvest-yield cultivation techniques are summed up, and it greatly enhances China's bamboo development. So far, harvest-yield bamboo forest accounts for 10% of the total bamboo forest area, middle-yield one 30%, and majorities of them are, therefore, low-yield, and are left to be improved. Previous Moso yield standard before is 22.5-30 tons/ha, 2 years for harvest timber stand, 15 tons/ha. 2 year for middle-yield timber stand, but in the latest decade, the research targets have been greatly enhanced, not only in timber yield alone, but also timber and shoot yield so as to reach much higher economic benefits, they are: harvest-yield standards of timber and shoot stands are 20 tons/ha. 2 years and 30 tons/ha, 2 years for timber, 1.6 tons/ha, 2years and 3 tons/ha. 2 years for shoot, in a scale of 1,000 ha. and 100 ha. respectively. Counter-season cultivation of elite edible shoot small-diameter bamboo which *Phyllostachys praecox* is most typical and important, it is to increase soil temperature, moisture by covering ground with bamboo leaf, straw, or other bamboo leftovers in winter, so as to make it shooting much earlier until later winter or around Chinese traditional Spring Festival, as a result, selling at a very good price. At present, it is very successful and popular in Zhejiang for its extremely high economic benefits which could reach to USD 5,000/mu. In recent years, in order to supply market with fresh bamboo shoot all over the year, some researches have been paid on rational arrangement and mix-up of each bamboo species with different shooting period.

3.8 On Breeding and Hybrid

Bamboo breeding in China has been started 20 years ago, but focused only on sympodial bamboo. Based on researches on biological and anatomical features of bamboo flowering, pollen, cell chromosome, etc., hybridization of sympodial bamboo and bamboo between species and genera have been done to obtain high-yield, good-quality hybrids and clones for timber, paper, and shoot. A complete set of hybridization expertise are well mastered, including parent selection, pollen preparations, optimal fertilization positions and time, light regulation, pets control, and multiplication of hybrid. Breeding have been tried among 4 general and 7 species, as a consequence, 4 best hybrids, *Dedrocalamopsis oldhamii, Dedrocalamus brandistii, Bambusa pervariabilis x Dedrocalamus latiflorus*, etc., are obtained featured with rapid growth, good culm form, high long-fiber content, delicious shoot taste, strong disease-resistance, etc., and more, thanks for a good overcoming of technical problems in tissue culture, bamboo rooting rate in tube reaches over 90%, transplanting rate does 70% on average, and 93.3% at peak, so those fine hybrids can be multiplied in a fast way. So far, they have been grown in several provinces with a total area of about 660 ha. 2 bamboo species have been found flowering in vitro, i.e. Dendrocalamus latiflorus, Bambusa pervariabilis x Dendrocalamus latiforus which shows a rare and good chance for breeding by a sexual way. It proves well that there are a tremendous range of variation in many bamboo qualitative and quantitative traits among, not only seedling, but also clones, especially for Dendrocalamus lstiflorus, that ushers in a rather possibility of selecting clones from generations.

3.9 On Bamboo Timber Processing

It is one of biggest achievements in Chinese bamboo circle, and an era-dividing symbolic of striding of china’s bamboo industry from traditional cottage industry into industrialized and modern one, and plays a very important role as a locomotive to prompting bamboo siliviculture, and take the whole bamboo industry to a high level. They are mainly as follows:

(a) Bamboo-based boards, including floorings and decorative panels

A complete set of production technology for the production of bamboo artificial boards are becoming more and more perfect and mature after research and practice of over 10 years, including material preparations, preservation, production technologies (all kinds of best working parameters), glue, after-finishing etc. As per different diameter grade of bamboo, large, medium and small, they have been developed into tens of bamboo artificial boards, and in a industrialization-scale production, such as Plybamboo (Bamboo mat plybamboo, bamboo strip lamination plybamboo, Bamboo building model plybamboo), Bamboo Particle Board, Bamboo Wood Composite Board, Bamboo Flooring (bleached and carbonized), Bamboo decorative Panel (Bamboo spinning-cut veneer, etc)., besides, researches on reinforced bamboo, Bamboo fiber board, Bamboo wood composite flooring, etc., have got a big progress, too..

(b) Bamboo furniture

Novelty bamboo furniture produced by modern technology, instead of past traditional handicraft skill, are appearing, such as rocket-chair, conference table, various office furniture.

3.10 On Bamboo Shoot Processing

Analyses and measurements have been made on various nutrient components such as sugar, protein, fat, vitamin, mineral element, trace elements, 17 free amino acids and their occupied proportion in important shoot bamboo species, e.g. Pyllostachys pubesens, Ph.Iridescens, Ph.vivax, Ph.praecox. Ph.dulctis, Ph.nuda. Dendrocalamospsis oldhami, D. Latiflorus, D. becheyanus var. pubescens, D. beecheyanus, etc. Bamboo shoot, nearly without pollution, with high protein, low fat, high edible fiber, rich amino acid and mineral elements, is proven to be one of very fine vegetables, in particular, Moso shoot contains trace Se element (0.058-2.65 ug/g) which functions well in anti-cancer, and health-care.

In the past, the overwhelming majorities of bamboo shoot are processed into dried shoot by means of traditional, but outdated processing expertise, except for a small proportion used for fresh eating. Since 1980, research and exploitation have been tried on the production of canned shoot, flavored shoot, boiled shoot preservation, soft packaged shoot, etc. To broaden their market supply, raise up their addition value to a great extent, as a result, it gives a very vital impetus to the normal and rapid growth of bamboo shoot industry.

(a) Boiled shoot preservation

In traditional preservations, Salt preservation know-how is top effective, widely used in practice, and has been using in some places in China so far. But since later 1970’s, much efforts have been focused on fresh shoot preservation, by physical and chemical methods, for example, Vacuum package, U1tra-sonic sterilization, Low-temperature storage, Sulfur preservation, etc., despite some effectiveness, more or less, however, they are not satisfactory in practical production, either not feasible in costs, production facilities, or not ideal preservation results, etc., therefore at last, they had to be abandoned. Instead since 1980’s, another way has been replaced, and now widely used hanks for simple, effective, economic, and feasible, that is boiled shoot chemical preservation by taking modern, toxic-free preservative of potassium sorbate in an acid condition. Its handle capacity is very large so that it can process fresh shoot into preservative shoot for further processing, in bamboo shoot peak which is extremely narrow.

(b) Flavored and soft packaged shoot

Fresh or preservative shoot can further be processed into various flavored products with can or soft package, e.g. Pickled vegetable shoot, Chili shoot, Roasted shoot, Mushroom shoot, etc, which are fashionable in recent years, and caters people needs in various taste.

3.11 On Bamboo Chemical Utilization Outlets

As compared with bamboo physical utilization, its chemical outlets are in a pre-mature stage, and have not got some progress until the recent decade, mainly in the 3 aspects:

Extraction of bamboo xylose, other poly-saccharines, and their high-tech products of ultra-filter membrane and film production made of bamboo triacetate have been successful at a pilot scale, but they should be perfected if they are in a production scale.

Bamboo leaf extraction. There is a long history of bamboo leaf usage for medical and edible purpose, but a technical breakthrough has not been made until the latest 5 years, which has proven bamboo leaf contains a lot of flavonid, and other biologically active substances which contents are much higher as compared with *Gingbo biloba* leaf. They behave well in ant-oxidation, anti-aging, reduction of blood fat and chloral, and have a wide range of usage in food, beverage, medicine, and cosmetic, etc. So far, a trial production in a scale of 200 tons flvonid/year has been started in Zhejiang, and their products will be put into marketing soon.

Various bamboo-juice products. Bamboo juice contains very rich nutrients and unique flavors and has been processed into various products, such as, bamboo juice wine, bear, beverage, even bamboo juice flavored, etc.

(d). In 2002, “Green Bamboo fabric Technology (GBFT)” was greatly succeeded in China to produce our very fine and soft bamboo fiber from fresh raw bamboo pole without addition of chemicals during its production process. Now it has been in a commercial production. It could be considered as a great fiber revolution. Bamboo fibers are (1) longer and more pliable than other fibers such as cotton; (2). Hollow inside (3). Adjustable in unit fiber length, so its fabric is featured with (1). Cooler in summer and warmer in winter since its hollow structure isolate air like a “vacuum” layer. (2) strong and quick in water absorption and good at anti-bacterium, anti-odor, anti-mildew which make it perfect for fabrics for different uses, esp. for sports, underwear, stock, beddings, etc., (3). Flexible, rigid, shrink-proof, crease-free, refreshable, high-density, lustrous which appear superior. (4). well-dyed, high color fixing, well-abrasion, wearable, easy for washing, and (5). Protecting your skin from ultraviolet radiation damage

3.12 On Bamboo Processing Machine

Since the China’s implementation of reforming and opening-up policy towards outsides in 1979, a great deal of bamboo processing machines have been introduced form Taiwan and foreign countries, and it is since that time that China has embarked on the research and development of bamboo machines of ourselves own, and with great achievement. It shows by statistics that quantity of bamboo machine factory in china reaches 100, with over 1200 types of machines involving raw bamboo processing, bamboo flooring production, machine-woven bamboo mat, bamboo chopsticks/toothpick, plybamboo/bamboo particle board production, etc.

3.13 On Bamboo as a Food for Panda

Bamboo species that panda likes to eat cover 10 genera and 47 species involving sympodial, monopodial, or from temperature, subtropical to alpine bamboo species. Probes have been made on bamboo flowering impacts on panda inhabits and survival, and on measures to curb bamboo flowering.

3.14 On Bamboo Socio-economy

It seems to be rather weak, fragile, and very little, only the below 3 aspects have the research been touched:

(a) China's bamboo socio-economic outlines;

(b) Bamboo market and policy, and

(c) Comparison research of bamboo industry in different management, social backgrounds, economies, and markets

4 Recommendations for Future Bamboo Research and Development

4.1 Some Principles to Focus on a Outlining Research and Development Strategies

To establish a sustainable bamboo industry is an non-stop objective, all the R & D. Activity must be proceeded in context of sustainable development of bamboo, and avail itself in biodiversity protection, and bamboo resource sustainability.

Bamboo research and development strategy should be in conformity of the state social-economical and forestry development strategies, and feasibility of supporting by the state;

It should be harmonious with ecological, socio-economic benefits, and not totally at the cost of environmental pollution and destruction, and linked with cottage economic improvement, poverty alleviation, employment enhancement, etc.

Some fundamental researches should be highlighted, such as bio-diversity protection and its rational exploitation.

A special attention should be paid to technical transfer, dissemination, and information service set-up.

4.2 Proposed Research Priorities

They should follow the targets of China's bamboo industry development towards 2010, which are: to complete low-yield bamboo stand improvement of an area of 3.1 million ha., and new planting of an area of 1.2 million ha., raising of annual Moso culm yield to 800 million pieces, annual sundry bamboo yield to 24 million tons, annual fresh shoot yield to 3.2 million tons, annual bamboo output value to USD 290 million, annual export value to USE 800 million, or double over the index at present.

(1) Bamboo resource assessment and protection

(a) Research on bamboo resources survey method. No special bamboo resource inventory method has been promulgated, and only following general forest inventory one, so it is worthy to find out a set of inventory method just suitable for bamboo, and better used together with application of GIS and other methods so as to identify resource distribution and storage accessible for exploitation.

(b) Research on set-up of bamboo resources monitoring system. A simple, feasible monitoring and evaluating system of bamboo resources should be set up to master dynamic change of the state bamboo resources.

(c) Research on management strategies of bamboo resources. Good recommendations need to be offered to guidance bamboo industry development, make a better cycle between bamboo consumption and production.

(2) Bamboo bio-diversity protection and rational exploitation utilization

China is the richest bamboo bio-diversity country in the world, to better protecting them is a precious contribution to China, and the world, as well.

Considering a very scattering distribution range of bamboo resources, complicated topography, both in situ. and ex. Situ. should be focused, one feasible way is to designate some state or provincial natural protection areas as bamboo ward-off and monitoring areas. In situ. protection, perfection is proposed of Anji and Zhangzhou Bamboo Botanical Gardens for monopodial bamboo, and establishment of a sympodial bamboo botanical Gardens for monopodial bamboo, and establishment of a sympodial bamboo botanical garden in Yunnan, or even of alpine bamboo botanical garden, is necessary.

Rational exploitation and utilization. Majority of 500-plus bamboo species in China have not been used well, only about 100 species of them come into usage, even so, much less for real commercial purposes. Therefore, more research should be made on those bamboo resources which are very rich, but neglected, in area of ecological adaptability, growth biomass, propagation traits timber quality, shoot nutrients, etc. So as to tap their big potentials.

(3) Research on bio-diversity of fine bamboo genes

It is very fragile and week in area of genetic diversity, and even blank in molecular biology *Phyllostachys pubescens. Ph. praecox, Dendrocalamus Istiflorus* which have the biggest cultivated area, highest economic value show big variation of characteristics among species, in other words, there is a big possibility of bamboo breeding.

(4) Research on bamboo genetic improvement

Selection of fine clone line and provenance by bio-techniques.

Research on bamboo flower mechanism and regulation method.

Research on sympodial bamboo breeding. It should aim at

------ Shoot species of high nutrition and good taste;

------ Pulping species of high fiber content;

------ Oriental species.

(5) Research on sustainable management model of high-benefit bamboo plantation

High-yield and high-benefit ecological model of bamboo plantation and its orientation intensive cultivation techniques Research should be made in the following aspects in sympodial and monopodial bamboo stands :

----- Evaluation on tolerated capacity of bamboo stands soil site, and productivity

Maintenance techniques of high-yield and high-benefit bamboo stand.

----- Dynamic model of bamboo stand growth; and

----- Biological fertilizers.

Stability recovery and maintenance of long-term productivity of Moso plantation. Considering the tendency of site tolerated capacity decreasing, long-term productivity stability destruction of pure Moso plantation caused by ultra-short-term and intensified cutting, the below research seems very necessary:

----- Techniques for recovery and maintenance of existing low-yield and degraded bamboo stand;

----- Assessment and regulation techniques of long-term site productivity of harvest bamboo stand, and

----- Utilization of beneficial techniques of long-term site productivity of harvest bamboo stand, and

Biological control techniques of bamboo pests. Biological control method should be more emphasized than chemical pesticide method which has been so common before, but much disadvantage, especially in environmental pollution.

(6) Exploitation and utilization of natural bamboo resources.

(7) Feasibility study of alpine bamboo resource exploitation and usage

There exists a great sea of natural bamboo forest in sub-alpine areas of the Southwest China, which is estimated to be over 100 million ha. *Fargesia* are being predominated but without any exploitation because it is in poverty-hit areas. Research should encompass: ecological features and functions of bamboo forest, nutrition and usable value of bamboo shoot, ecological impact if exploited properly.

(8) Bamboo timber processing techniques and bamboo integration utilization

Further research should be targeted at bamboo composite material processing, high preservation and anti-cracking of bamboo timber, large-diameter sympodial bamboo processing and bamboo product standard certification.

Research on techniques of high-efficiency, low-toxic, and high-preservation. To extend bamboo timber usage span, and prevent attack by insect, disease, and crack, it is very necessary to research out some chemical pesticides of high-efficiency, low-toxic and corresponding treatment expertise.

Novelty bamboo composite material exploitation. To transform the present status which processing technologies are simple, varieties of products are less, and expand usage scope of bamboo timber, improve qualities, and reduce production costs, a research and development are urged on the exploitation of new bamboo composite materials and focused on the below aspects:

----- Composite material of bamboo with other materials, such as wood, inorganic or organic fillings;

----- Structural designing of bamboo composite materials;

----- Now production technologies for all kinds of end products made from bamboo composite materials; and

---- Technological perfection of staple bamboo products.

Quality assessment and certification of staple bamboo products. Nowadays, this kind of work seems nearly vacuum, but very urgent to enhance and stabilize bamboo product quality as a whole, and make China's bamboo industry into a sound and sustainable track.

(9) Bamboo shoot

Some problems which we are facing in bamboo shoot industry are uncertainty of bamboo shoot resources, not a good solution of fresh shoot preservation, out-dated processing technologies of bamboo shoot, the below researches are necessary:

Overall inventory and evaluation of nationwide bamboo shoot resources, including, distribution, areas, yield, etc.;

Effective preservative techniques of edible fresh bamboo shoot;

Technical research on new technologies of bamboo shoot production, and

Quality control and certification of staple bamboo shoot products.

(10) Bamboo pulping and paper-making

CTMP technology of bamboo chemical hot ground pulp;

Pollution control expertise of bamboo pulping and paper-making, and

Selection of fine pulp bamboo species and corresponding cultivation techniques.

(11) Bamboo activated charcoal

It is envisaged that bamboo charcoal and bamboo activated charcoal have a very promising prospective, and a wide usage in environmental beautifying, soil improvement, medicine, food, water purification, etc. Their research should emphasize on technology and equipment of their scale production.

(12) Bamboo leaf extraction

It opens a new path of further and high value-added utilization of bamboo and shows a very bright prospective. The research priorities are:

Chemical analysis of effective elements of main bamboo specie, and feasibility study of their exploitation;

Control measures for bamboo leaf flavonids and other intermediate products during production; and

Bamboo flavonids as food anti-oxidant.

(13) Bamboo socio-economy

Research on small-scale bamboo enterprise role in local economic development and employment, esp. for woman. Bamboo is reputed as "poor timber", indeed, most of the bamboo is scattered in poverty-hit and mountainous areas, bamboo is playing a rather important role and one of the main approaches in developing local economy, providing employment, esp. for woman, so how to sum up experiences, and disseminate them to peasants seems very important. Research contents are encompassed:

----- Ownership and organization structures and benefit sharing of bamboo enterprises participated by peasants;

----- Favorable policies to encourage peasant initiatives, and

-----Technical service system, including bamboo production, processing and marketing

Research bamboo levy imposition. Twice levy is imposed to bamboo producer and manager in bamboo production, and more with product addition taxi, besides, producer and manager have to pay various kinds of fees, a big problem is over-burden of bamboo levy, but on another hand, governmental tax departments complain difficulty of tax-imposition, and serious tax-evasion, so it become a bottleneck of hindering sustainable and sound development of bamboo industry, therefore, research is very vital to harmonize them:

---- Impacts of recent tax-imposition system on China's bamboo development;

----- In-depth analysis on levy compositions and charged bases, and contrast between bamboo levy and other products; and

----- Rational adjustment of existing levy standards.

Research on management model of bamboo processing industry. A transformation of China' bamboo industry has been scored from traditional, handicraft and small-scale production to bigger-scale, modern one since 1980's, but it can not denied that most of those enterprises are derided from township-owned, village-owned, or private enterprises which are usually featured with small production scale, uncertainty of product quality, bad market competition capacity because of being in short of fund, talented manpower, technology. So, how to set up a bamboo production and management model which adapts socialist market in context of different socio-economic conditions becomes a rather important. Research thrusts are:

----- Internal and external analysis of different management models;

----- Beneficial analysis and role in improving cottage economy and enhancing woman employment and social status different management model, and

----- Proposals for policy of sustainable development of bamboo processing industry.

(14) Set-up of technical dissemination system

To perfect technical education and training and dissemination system seems rather necessary to improve qualification of China's bamboo personnel, and ensure proper application of research achievement.

(a) Personnel training. We have to strengthen bamboo education in forestry colleges, schools located in bamboo-grown provinces, and hold various kinds of bamboo training courses to bamboo growers. Enterprises in regular and irregular cases need to improve their capacities.

(b) Publications. We need to publish all kinds of technical publications, brochures, handbooks to disseminate bamboo techniques, expertise, know-how to bamboo peasants, enterprises, and perfect the Journal of Bamboo Research sponsored by

China National Bamboo Research Center, if possible with English version for convenience of international exchange.

(c) International technical service, consultation, transfers of bamboo.

China's bamboo research and development is on the advanced position in the world, so much focus should be paid on conducting international technical cooperation and exchange of bamboo so as to disseminate China's bamboo expertise, know-how to other bamboo-grown countries which are desired so much, it is also a contribution of China to the development of world bamboo industry.

Chapter 9 Booming Bamboo Industry in Zhejiang Province

Located in the Southeast coast of China and close to Shanghai, Zhejiang Province has very convenient transportation and obvious regional advantages. Hangzhou, Capital city of Zhejiang Province and one and half hour's journey away from Shanghai, is well known for its picturesque "West Lake" and reputed as "Paradise of the Earth". Hangzhou has a population of 45 million and its GDP ranks the fourth among the Chinese cities. With a total area of 101.8 thousand km^2, Zhejiang Province has 70% mountainous and hilly area, 10% water and river area, and 20% farmland. The forest cover rate in Zhejiang Province is 59.4%.

Featured with fast growing, short growth cycle, great potential in exploration and utilization, environment protection and sustainable management, bamboo is very popular with people. Zhejiang Province is one of the key bamboo distribution areas and has very long history in bamboo cultivation and utilization. Particularly in recent years, high attention has been paid to bamboo sector by the governments of Zhejiang Province at all levels. By means of establishing bamboo demonstration, supporting dragon-head enterprises, promote processing of bamboo sector, exploring market, bamboo forest area in Zhejiang province is consciously extended and its economic value being increasingly raised. Bamboo industry is playing an increasingly important role in agriculture and rural economy. Although Zhejiang's bamboo forest area only occupies 1/6 of the China's bamboo recourses in total, its production turnout accounts for 1/3. Therefore, people are saying: "Visit China you will know the bamboo in the world while visiting Anji you will know the bamboo in China".

1. Outline of Zhejiang's Bamboo Development

1.1 Bamboo Forest

Presently, Zhejiang Province has bamboo forest 800,000 ha totally, among which Moso forest and bamboo forest for shoots occupy 630,000 ha and 170,000 ha respectively. Almost every county and city has its bamboo recourses. 15 counties with bamboo areas above 13.300 ha add up to 4,167,000 ha totally, occupying 88.3% of the total Zhejiang's bamboo forest recourses. As the county with the biggest bamboo forest areas, Anji County has bamboo forest areas of 667,000 ha and occupies 1/10 of the Zhejiang's total. Moso is the main bamboo species in Anji and its total forest area is up to 50,000 ha. Lin'an County comes in second. Its bamboo forest area is up to 58,000 ha, among which bamboo shoot forest area (mainly phyllostachys praecox) has 353,000 ha. Presently, a phyllostachys praecox industry has come into being there and its forest farming turnout reaches 450,000,000 Yuan. 11 counties or cities with bamboo forest area above 20,000 ha are as below: Anji County, Lin'an County, Longquan County, Fuyang County, Jujiang County, Yuhang County, Zhuji County, Longyou County, Deqing County, QingYuan County, SuiCang County.

1.2 Bamboo Products and Bamboo Processing Industry

Currently, Zhejiang Province yields 148,000,000 pieces of bamboo timber and processes 148,000,000 pieces respectively. Totally there are 2,572 bamboo manufacturing enterprises in Zhejiang Province and more than 3,000 bamboo products has been explored out and manufactured, including bamboo shoots, bamboo daily-used crafts, bamboo handicraft, bamboo plywood, bamboo flooring, bamboo furniture, bamboo charcoal, bamboo fiber, bamboo pulp and paper-making etc. It produces 300,000 m3 of plywood, 2,500,000 m3 of bamboo shoots, 1,400,000 tons of bamboo shoots and 10,200 tons of bamboo charcoal annually.

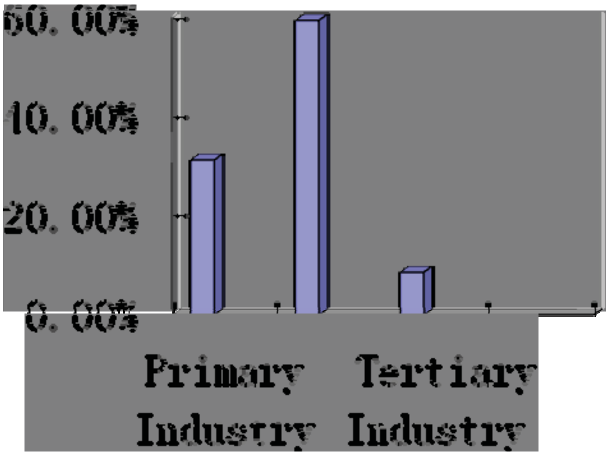
1.3 Bamboo Industrial Economy

Total output of Bamboo industry in Zhejiang province is 11.475 billion Yuan, including primary industry, secondary industry and tertiary industry with 683 billion Yuan, 6.805 billion Yuan, 0.975 billion Yuan respectively and the percentage of each is 32%, 5.9%, 8.5% respectively.

2. The Characteristics of the Development of Bamboo Industry

2.1 Upgrade of Bamboo Status

With the extension of bamboo cultivation areas and increase of its economic value, bamboo industry has become the pillar of agricultural and rural economy.



Bamboo industry has become the pillar of Agricultural and rural economy, and the main income source for local farmers in Zhejiang Province. 24 Counties/ Cities' bamboo industry production turnout is over 100 million

Table 1. Increase statistics of Zhejiang bamboo recourses from 1989 to 2002

Year	1989	1994	1999	2002
Cultural area (Ten thousand hectares)	50.98	62.45	74.75	80.00
Number of bamboo (Hundred million pieces)	6.46	9.12	11.43	13.17

2.2 Management System's Innovation and the Continuous Enhancement of Industry's Organizational Development.

The growth of bamboo processing makes short supply of bamboo timber and shoot, and raises their prices up. Application of techniques of improving low-yield bamboo stand into high-yield one, earlier shooting by ground covering, "one bamboo and three shoot" renders economic benefits of bamboo plantation markedly, and farmers' bamboo planting initiative is raised greatly. In the recent decade, newly-planted bamboo plantation is increased by 20,000 ha. per year in Zhejiang. For example, 1/ 3 of farmers' income and fiscal resources in Anji come from bamboo industry. The income of bamboo shoots alone in Lin'an in 2003 is over RMB 340,000,000 Yuan, or 25 % of the total (RMB 5362) from the bamboo. One farmer in Lin'an plant 0.1 ha of phyllostachys praecox plantation, and its output is RMB 41,500 Yuan per mu (1 ha=15 mu).

2.3 New Products Coming out, Processing Scale Expanding, and Processing Technology Enhancing

In recent year, bamboo fiber, bamboo fabric, bamboo flavoid health-care products, bamboo curtain, bamboo charcoal, bamboo-wood composite floor, bamboo veneer decoration panel, etc are put into marketing, which greatly broadens bamboo application scopes, and increase bamboo processing added value, e.g. with increasing by 10 times and 5 times for bamboo fiber and bamboo charcoal.

Export-oriented bamboo enterprises are booming. On the one hand, bamboo product markets in Zhejiang are mainly outside China and Zhejiang, and export production value is over USD 200,000,000. On another hand, local supply of raw material is short although Zhejinag is a big bamboo province.

2.4 To Fit the Tendency of Internationalization, Profession, Socialization, More and More Organizations Are Been Explored

One is "dragonhead enterprises + professional cooperative institute + farmer". E.g. Zhuji city's GuangYu Bamboo & Wood Professional cooperative institute was set up by a key forestry enterprise of Zhejiang province --- Zhuji City Guangyu Bamboo Industry Co., Ltd. There are 62 members in it, who are from Zhuji, Fuyang, Shaoxing etc., which all are very rich in bamboo resources. It stipulates product production quality standard, use the same registered brand, sales together, and profit re-allocates. It will organize technical guide, consultation, training, and exchange to offer production technology and management information, etc. The second one is "market + farmer". E.g. there are 402 bamboo products manufacturers and 23,300 ha of bamboo plantation bases in North Zhejiang province. The third one is "dragon-head enterprises + farmer (processing ones)". E.g. Deqing Moganshan Bamboo Plywood Co., Ltd. will buy fixed farmers' semi-products through signing a purchasing contract, which has absorbed more than 5,000 laborers with an annual Moso consumption of more than 1,100 culms and has promoted more than 53,300 ha bamboo plantations' development. Besides, there are other forms like "professional cooperative institute + farmer", etc.

3 Main Measures Taken

3.1 Strengthening the Construction of Bamboo Plantation Demonstration and Increasing the Bamboo Recourses

During the “9th five years”, Zhejiang Province has carried out three bamboo demonstration construction projects, which were to establish 66.7million ha of high-yielding moso plantation, 66.7 million ha of moso plantation both for bamboo shoot and bamboo timber, and moderate 66.7 ha of low yielding bamboo forest into high-yielding ones. A particular turnover capital is arranged for supporting the above three projects. During “the 10th five years”, Zhejiang Province has made efforts to develop bamboo forest demonstrations’ cultivation so as to modify the planting structure in agriculture and develop characteristic forest demonstration. By means of publicizing new technologies and investing on frustration of transportation and irrigations, we have greatly improved the bamboo demonstrations’ management level from extensive one to intensive one.

3.2 Supporting the Dragon-Headed Enterprises and Promoting the Development of Bamboo Timber and Bamboo Shoot’s Processing

Dragon-headed enterprises are the bridge and linkage connecting changeable market and thousands of scatted farmers. It is playing an important role in marketing, guiding production, solving sales problems, extending and demonstrating forestry technologies, promoting bamboo production into a intensive way; improving its added value; pushing leading regional products’ development; creating famous forest products with large scale, improving forest products’ marketing competition, combining the industrial chains in production, processing and sales etc., leading the farmers to manufacture products standardly and professionally, improving its forestry’s management and industrialization level, improving the forest value and raising farmers’ income etc.18 leading bamboo timber and bamboo shoot enterprises, including Dazhuang bamboo flooring factory, Zhejiang Songyou factory, Guanyu bamboo factory, were listed as the provincial key dragon-headed enterprises supported and cultivated by Zhejiang Province. A particular supporting capital was arranged for leading enterprises to expand their production scale, innovate and apply to new technology and develop new products. By the above means, we finally push these enterprises to realize the goals of expansion and improvement, which means to further expend their management scale, upgrade their equipment and innovation capability, improve their management level, enhance their marketing competitiveness, increase their export for earning more foreign currency and promote the development of farmers through base construction. Take Zhejiang Tenglong Bamboo Industrial Co., Ltd for example, its number of production line is increased from 3 to 7, and annual production capacity is up to 25,000 cubic meter, 36 rough-processing manufacturers are set up, and with an employment of 2500, and farmer income per capita is increased by RMB 350 Yuan.

3.3 More attention has been paid to the construction of association and professional economy cooperation organization standard

As an important middleman in socialist market economy system, association functions very well in coordination of market majority interests and promotion of market resource allocation. We have taken the following actions for this:

Strengthening the construction of association's organizational institution by setting up Zhejiang Bamboo Industry Association with 158 members, and there are 5 sub-branches, namely bamboo plywood, bamboo flooring, bamboo shoots, bamboo charcoal and bamboo daily products in order to work more effectively. Meanwhile, there are 22 bamboo products associations with 1969 members. Currently, almost every bamboo high-yielding county has set up bamboo industry association.

Try to create better and suitable environment for associations' development. Associations' construction should be of China's characteristic, but due to our basic national situation, associations cannot grow and develop quickly without governmental support such as line planning, line administration, brand products promotion, backbone enterprises introduction, and stipulation of line standardization etc. Meanwhile, government will give economic support to associations in activity organizing.

Promote association's function through coordination and guiding, particularly its function in line service, line coordination, line self-discipline, etc. to guarantee the majorities' interests and promote the whole line's healthy development. Besides, we emphasized on introducing and supporting the development of forestry professional economy cooperation organization, and made efforts on exploring a new mode of forestry industrialization management organization, which is "association + dragon-head enterprises + professional + economy cooperation organization + farmer".

(4) Promote bamboo industry based on science and technology. We should explore new products by combing R. & D. and practices. Bamboo concrete board, bamboo veneer, bamboo vinegar, bamboo fiber and bamboo charcoal, which are together explored by Dazhuang Bamboo flooring Co., Ltd., Nanfang Bamboo & Wood Products Co., Ltd., Wenzhao Bamboo Charcoal Co., Ltd., Zhejiang Forestry Bureau, Zhejiang Forestry Institute, Subtropical Forestry Research Institute of China Forestry Academy, and Bamboo Timber Research Institute of Nanjing Forestry University, have been put into market successfully, resulting in the widening of bamboo timber processing field and promotion of resources' added value. Forest products enterprises' technology reform should be intensified and their technical equipments' level should be promoted. E. g. Hangzhou Dazhuang Bamboo Flooring Co., Ltd. 's technical innovation project has introduced the most advanced digital-controlled processing equipment to produce bamboo products, which has greatly enhanced the bamboo products' level, resource utilization ratio and products' market competitiveness of Zhejiang province. To disseminate standardized production, we have made out provincial- and county- level standardizations successively for harmless bamboo shoot, bamboo flooring etc. and strengthen the dissemination of standardized production. And 5 brands have been entitled Zhejiang Famous Brand Products, which are MGS bamboo plywood, Dazhuang bamboo flooring, Shuangqiang bamboo chopsticks, Shanyaer *P. Proecox* shoot, Guoshi dry bamboo shoot

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Chapter 10 Forestry Economy Development in Zhejiang Province

Zhejiang province is located in the eastern of China. The area is only 1.06% of China, which is one of the small size provinces in China. Zhejiang province has a population of 46.47 million people. The GDP per capita in Zhejiang was US$4553（US$1700 in China ）in 2007. Annual per capita disposable income of urban households and per capita farmer's income were US$2341(US$ 1346 in China) and US$ 936(US$460 in China), respectively.

Zhejiang has 90 counties, which 51 counties belong to mountain areas. The area of forestland is 70.4% of total area and the forest coverage is 60.5%.

1 Overview of Forest Resources in Zhejiang Province

Forest resource is the basis of forestry development. There were increasing trend over time as followings: ①forestland area increased from 5.7555 million ha in 1983 to 6.6797 million ha in 2004, the rate of per year is 0.7116%; ②forest area increased from 3.7247 million ha in 1983 to 5.8442 million ha in 2004, the rate of per year is 2.1682%; ③forest volume increased from 100.2453 million m3 in 1983 to 193.8293 million m3 in 2004, the rate of per year is 3.1896%; ④forest coverage increased from 39.6% in 1983 to 60.5% in 2004, the rate of per year is 2.0358%; Following is the comparison of related criteria between Zhejiang and vicinage provinces

Table1 Comparison of forest coverage among vicinage provinces

Year	China	Zhejiang	Jiangsu	Fujian
1989	12.98	43	3.76	50.6
1994	13.92	50.8	4.02	41.18
1999	16.55	54.4	4.51	60.52
increasing rate of per year	1.025	1.024	1.018	1.020

Note：http://sdinfo.forestry.ac.cn/000new/index.cfm (following is same)

Table 1 show that the forest coverage in Zhejiang is more than in Jiangsu and is less than in Fujian

Table2 Comparison of forestland usage rate among vicinage provinces（%）

Year	China	Zhejiang	Jiangsu	Fujian
1989	——	0.71	0.63	0.56
1994		0.81	0.65	0.69
1999	0.60	0.88	0.78	0.82

Table 2 show that the forestland usage rate in Zhejiang is most high in all three provinces

Table3 Comparison of forest area and volume per capita among vicinage provinces

(hm2/person、m3/person)

year	China		Zhejiang		Jiangsu		Fujian	
	area	volume	area	volume	area	volume	area	volume
1989	0.1	7.59	0.099	1.36	0.006	2.151	0.18	4.74
1994	0.12	9.08	0.10	2.23	0.006	0.118	0.197	10.32
1999	0.13	9.42	0.12	2.6	0.007	0.12	0.22	11

Table 3 show that the forest area and volume per capita in Zhejiang is more than in Jiangsu and is less than in Fujian, which are less than average level of China

Table4 Comparison of forest volume per ha among vicinage provinces

($x10^4m^3/hm^2$)

year	China	Zhejiang	Jiangsu	Fujian
1989	72.8	21.83	17.81	52.73
1994	74.81	21.62	19.71	52.32
1999	70.91	21.51	18.72	49.62

Table 4 show that the forest volume per ha in Zhejiang is more than in Jiangsu and is less than in Fujian, which are less than average level of China

Table 5 Comparative of cash forest resources among vicinage provinces

year		Zhejiang	Jiangsu	Fujian
1989	area(10 thousand hm2)	70.66	14.54	56.58
	% of forest area (%)	17.5%	37.7%	11.3%
1994	area(10 thousand hm2)	90.61	12.16	79.14
	% of forest area (%)	20.7%	45.5%	12.9%
1999	area(10 thousand hm2)	109.95	22.26	103.44
	% of forest area (%)	21.3%	48.1%	14.1%

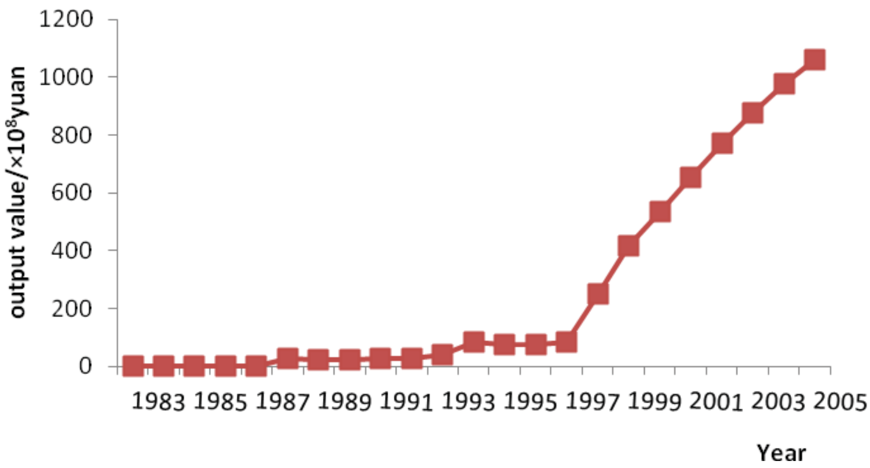
Table 5 show that the cash forest resources in Zhejiang is obvious more than in Jiangsu and Fujian.

In the word, there are obvious advantages in usage of forestland, cash forest etc. While there are obvious disadvantages in forest resource per capita and forest quality.

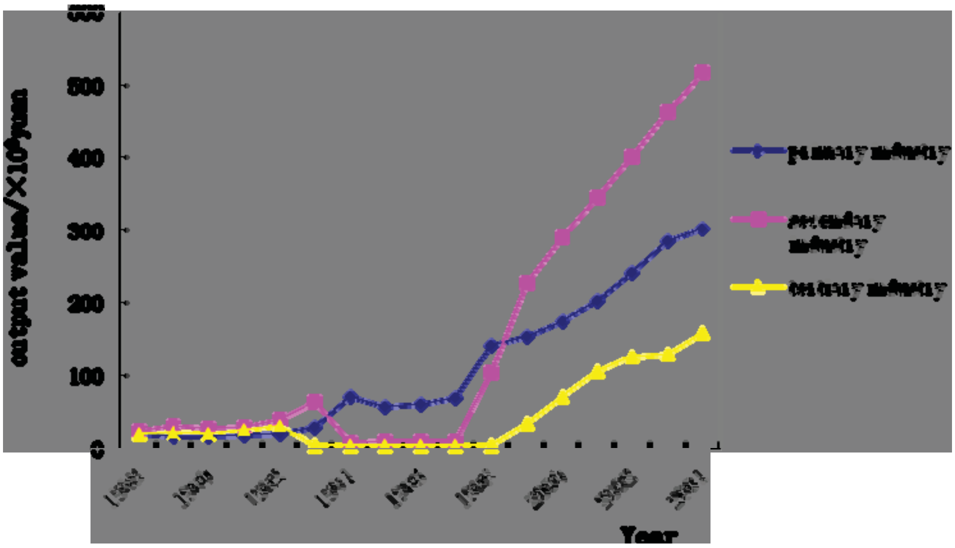
2 The Development of Forestry Industry in Zhejiang Province

2.1 The Status of Forestry Industry in Zhejiang Province

The total value of forestry industry in Zhejiang Province in 2007 was 119.404 billion RMB, which head the list of all provinces in China. There are 90 counties in Zhejiang, in which , there are 41 counties that forestry value is more than 1 billion yuan, there are 16 counties that forestry value is more than 2 billion yuan. 50% farmer' income in forestry key counties such as Linan, Anji county come from forestry. Zhejiang is only pilot provinces of forestry modernization in China.



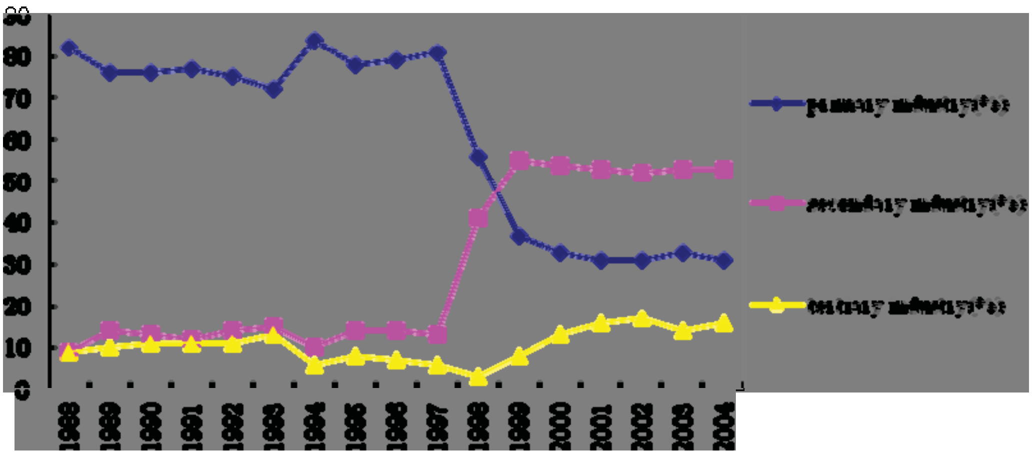
Graph 1 The change of three forestry industrial sectors



Graph 2 The change of three forestry industrial sectors

Graph 2 shows that the primary industrial sectors are increased, which depended on the development of regional special forestry industry . The second industrial sectors are obviously increased, which depended on the development of bamboo and timber manufacture based in the regional and resource advantages. The tertiary industrial sectors are increased, which depended on the development of forest tourism.

2.2 The Characteristics of Forestry Industry in Zhejiang Province



Graph 4 The chang of forestry industry structure

The structure of forestry industry changed from low to high level.

②The local special industry developed rapidly as following: The first is that the development of local special forestry industry based on the forest resources such as bamboo industry and local dried and fruit industry;The second is that the development of local special forestry industry based on the regional advantages such as bamboo-timber manufacturing and forest tourism

3 Overview of Bamboo Industry in Zhejiang Province

China is very famous as bamboo in the world, While Zhejiang is very famous as bamboo in China . The total value of bamboo industry was 23 billion in 2007，which occupied 30% of total value in China。Bamboo industry in Zhejiang included the primary，secondary and tertiary industry , which formed a good circulation industry chain. The bamboo forest area and it’s value in Zhejiang account for 1/6 and 1/3 of China, respectively. There are five counties named “Bamboo Counties in China” and they are Anjie, Linan, Deqin, Longyou, Yuhang. More than 1 million farmers benefit from the development of bamboo industry.

3.1 The Primary Bamboo Industry

The area and volume of bamboo forest in Zhejiang is 7.83 million ha and 120 million branch, which account for 16% and 10% that of China ,respectively. The government of Zhejiang province has been paid more attention to the construction of Modern Bamboo Science and Technology Garden.

Table 5 Facts of Model Bamboo Science and Technology Garden(MBSTG) in Zhejiang Province hm^2

	Core area	**demonstration area**	**radiation area**
Anjie MBSTG	320	2000	6667
Suichang MBSTG	280	1400	3333
Shaoxin MBSTG	100	1333	3333
Ruian MBSTG	187	853	2333
Yuhang MBSTG	80	667	2000

Economy benefit of MBSTG is as following：①Improving the forestland output per ha；②Increasing the farmer’s income from bamboo forest；③Shorten the capital pay-off time。

3.2 The Secondary Industrial Sector

The No. of bamboo-timber manufacturing enterprise is 4838, and the quantities of bamboo timber per year are 317 t, of which the quantities of floor board account for 73% of China. The development bamboo industry in Zhejiang depended on bamboo resource and market outside. 40% of Mao bamboo and 60% of bamboo shoots come from other provinces. At the same time, the products of bamboo export to foreign countries and can get 300 millions foreign exchange every year.

3.3 The Tertiary Industrial Sector

Bamboo forest tourism based on the households Developed rapidly. The value of the third bamboo industry was 1000 millions yuan.

4 The Development of Non-timber Forest Product and Increasing Farmer's Income in Rural areas: Lin'an as Case Study

Zhejiang is the most advanced province in NTFPs. Based on the local advantage, the mountain counties in Zhejiang developed and improved the traditional forestry industry. In the same time, they cultivated and enlarged the local special industry. Therefore, they set up a stable basis of new rural construction and accumulate rich experience in the increasing farmer income.

4.1 Fact of Lin'an County

Lin'an is located in the northwest of Zhejiang province. Total land area is 3126.8 km2, in which hills and mountains area is 86.14%. The population is 526.4 thousand. Per capita net income of farmers and per capita disposable income of urban residents are RMB 8852 and 18 159 RMB, respectively.

4.2 Forest Resource and Forestry Industry in Lin'an

The total forestry production value was increased from 510 million Yuan in 1989 to 4.753 billion yuan in 2007. The rural per capita income was increased from 1153 Yuan to 8852 Yuan, among which forestry income was increased from 14% to 45%.

Forest coverage was increased from 4.9% in 1989 to 7.55% in 2007, the volume of forest was increased from 4,860,000 m3 to 8,300,000 m3.The volume per hectare was increased from 26.2 to 39.1, the percentage of broad-leaf trees were increased from 19% to 27%.

4.3 Development Non-timber Forest Products(NTFPs) in Lin'an

In the early 1990s, the main income sources of rural population in Lin'an were timber, fuelwood, charcoal. Over exploration resulted in decreasing of the forest volume and serious water and soil erosion. In the late 1990s, government paid more attention to NTFPs so that the main sources of income of rural population were shifted from the timber products to NTFPs.

Timber production value was reduced from 80 million Yuan in 1989 to 50 million Yuan in 2007, the percentage of timber production value in the total forestry was reduced from 50% to 6.2%. While the production value of NTFPs was increased from 430 million Yuan to 4.3 trillion Yuan, the percentage increased from 50% to 90.1%.

(1) Development of NTFPs—— Bamboo industry

In 2007, the total bamboo production value of Lin'an was 2.63 billion Yuan. In the year, the production of fresh bamboo shoots reached 259,000 tons, values 602 million Yuan;bamboo farmer households takes about 60% of the total number of farmer households, more than 260,000 people worked in the processing and sales of bamboo shoots.

(2) Development of NTFPs—— Hickory industry

Production value of hickory was 1.44 billion Yuan, farmer households engaged in hickory tree cultivation took 35% of the total number of households, more than 7000 people worked in the sector.

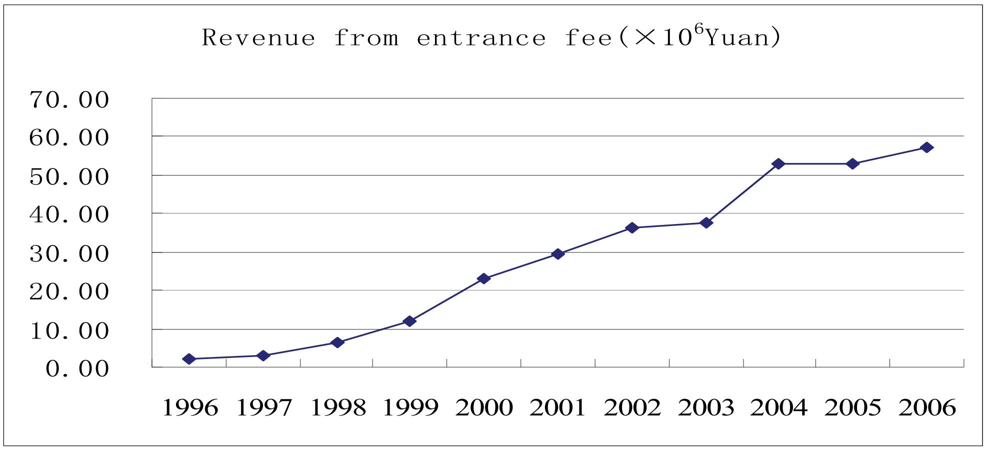
(3) Development of NTFPs—— others

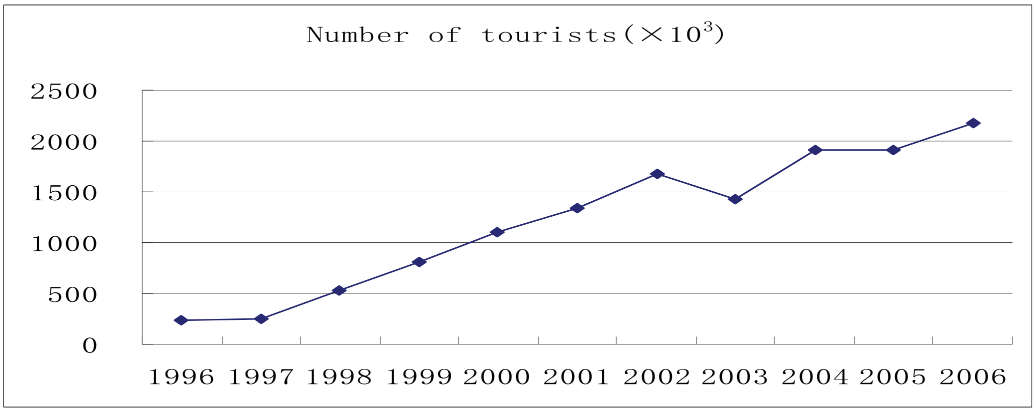
Other NTFPs including Chestnut, Cornus officinalis Sieb. et Zucc, Torreya grandis Fort., Theaceae Adinandra Jack, the production value was 247 million Yuan, people employed in the sector reached 13,000.

(4)Development of NTFPs—— Eco-tourism

Based on the Taihu Lake , eco-tourism in Lin'an developed rapidly, Linan has become an important tourist targets in the Yangtze River Delta. Farm-stay now has 7564 beds in 410 farmer households in 44 villages. In 2007, the Farm-stay in Lin'an received more than 500,000 tourists.

Graph 5 Entrance fees and number of tourists 1996-2006





Resource: Lin'an statistics yearbook 1997-2007

In a word, the development of special forestry industry, which based on the non-timber resources, reduced the dependent on the timber resources. Following is the correlation analysis between timber fall and farmer income per capita（1984-2003）.It shows that it is negative significant between timber fall and farmer income per capita

Table 6 Descriptive Statistics

	Mean	Std. Deviation	N
timber fall	102390.20	41979.54996	20
farmer income per capita	3003.10	1790.01396	20

Table 7 Correlations Matrix

		WF	FI
timber fall (WF)	Pearson Correlation	1	-.808(**)
	Sig. (2-tailed)	.	.000
	N	20	20
farmer income per capita (FI)	Pearson Correlation	-.808(**)	1
	Sig. (2-tailed)	.000	.
	N	20	20

** Correlation is significant at 0.01 level (2-tailed).

5 The Driving Force of Forestry Economy in Zhejiang Province: Tenure Rreform

In China, there are 10 provinces where the collective forest ownership (accounts for 57% of the total forestland) is dominated. Collective forest property in southern China has experienced different reform stages: ① Land reform in early 1950s; ② primary cooperation in mid-1950s;③ high-level cooperation & people’s communes from late 1950s to 1970s;④ “three stabilizations” in early 1980s (HRS) .After that, some southern provinces kept the same policy and others made adjustments.

In Zhejiang Province, the collective forestland area is 95% of total forestland area, which is more than that in Fujian (66%) and in Jiangsu Province(86%).The Process of Forestland Tenure Reform are as following:

5.1 The forestry “three stabilizations” period

The tenure reform began in 1981. Zhejiang initiated reform rather early and kept the same policy , which made Zhejiang possessed rich valuable experience. The forestland areas managed by farmers accounted for 76% of collective forestland in 1986.

5.2 The marketing period of forest-land use right

The transference of forest-land began in the middle and late of 1990's.the transference of forest-land is growing popular and the cooperative organization in forestry area is being developed.

5.3 The New Reforms of forestland tenure

The new reform began in 2003, Zhejiang, Fujian , Jiangxi and Liaoning were assigned as new reform pilot area.

(1)Characteristics of the New Reforms

◇ Privatization of collective forestland include in three aspects. First is to continue and extend the use right of household-management-forestland. Second is to redistribute the forestland in a more equal manner to the farmers. Third is to transfer the collective forestland to households in various ways.

◇ Variety of forestland management

The transfer of the forestland among different households, individuals and enterprises by different methods, e.g. leaseholder agreement； contract ； auction

◇ Compensation is made to villages for using collective forestland

◇ The government takes additional measures to promote the new reform. e.g reducing tax； adjusting logging policies etc.

(2) Types of the New Reforms

There are three different types of the new reforms. First is continuity in privatization of collective forestland tenure .e.g. Zhejiang—extended by 50 to 2055. Second is reformation in Privatization of Collective Forestland Tenure. e.g. Fujian transfer the collective to household

Third is adjustment and improvement in privatization of collective forestland tenure. e.g. Jiangxi adjust unreasonable forestland allocation.

Zhejiang finished the major task of the new reform and took the lead in doing forestland tenure in China and got better effect.

Chapter 11 Government's Role in the Bamboo Industry of Anji County

1. The General Situation

Anji County, the "Bamboo County of China", is located in the northwestern part of Zhejiang, 70 kilometers to Hangzhou, and 230 kilometers to Shanghai. Anji County covers an area of 1,886 square kilometers, 70 % for low mountainous land (mostly under 500 m. a.s.l), 20 percent for plain cropland and 10 % for water surface. The population of the county is 450,000. With the sub-tropical monsoon climate, the average annual rainfall of Anji County is 1,400 mm, and the annual temperature is 15℃, and the GDP per capita of the county is about 1,600 USD, twice the national average but only intermediate level among the counties or county-level administrations in Zhejiang.

For thousands of years, Anji has been characterized with and thereby famous for bamboo. Bamboo woven utensils in 4,700 years ago were unearthed in the county and the rich growth of bamboo in Anji area was recorded in a number of historical documentations. Now the county has about 1.98 million mu forest land, the forest coverage is about 70 %; and the area of bamboo (*P. herterocycla* or Moso bamboo for 78% and 22% for miscellaneous species) is about one million mu. Biologically, the bamboo in Anji falls into 6 families and 43 species. The standing bamboo stock reaches 0.13 billion culms, the average stand density of 178 culms per mu, the annual commercial production reaches 20 million culms, and the bamboo industrial production value about RMB 3.5 billion Yuan (2002), all ranking the first among all the bamboo- growing counties in the country. It is in this very reason that in 1996 Ministry of Forestry, especially in the site visit, with the autograph of Premier Li Peng, Anji county was officially awarded the tile of "The Bamboo County of China", along with other titles like Model County of Afforestation, Model County of Forestry Technology, Model County of Bamboo Industrial Development etc.

The role of the government can be seen in three different development stages of the bamboo industry in the county: resource cultivation, value addition by processing and tourism.

2 Cultivation of the Bamboo Resources

2.1 Political Attention from the Higher Administration as an Opportunity

It is crystal clear that bamboo means of the livelihood of the county and attention from the governmental level has been taken as an opportunity for the growth and activation of the bamboo industry here.

At the central governmental level, a number of leaders have visited Anji on site to give encouragement and instructions. Accordingly, the provincial administration, including the governors and the line agency authorities took Anji as the afforestation and economic growth demonstration site. Their presence at the county was widely reported and this not only spurred enthusiasm of the local people but also let the county government have a sound political foundation to obtain material support of the related administration. For example, the Director General of the Provincial Department of Forestry Mr. Chen came to Anji for eight continuous springs on Tree Planting Day and he himself initiated a High-Benefit Moso Bamboo Demonstration Base sized 800 mu at Gangkou Township of Anji.

And the county level administration thereby had an opportunity to mobilize the bamboo farmers, especially to improve their field operation level by new production technologies. For example, traditional bamboo timber is the dominant commodity of the farmers, but for years bamboo timber and bamboo shoots have been equally emphasized and the value-addition processing has been greatly pushed forward.

2.2 Appropriate Planning and Orientating Policies from the County Government

---Since the 1980s, a number of county-level policies have been promulgated, i.e., The Instructions to Quicken Bamboo Resource Cultivation, The Development Plan of the Bamboo Resources in Anji County, The Winter Bamboo Shoots Development Plan of Anji etc., so as to enhance and increase the bamboo reserves.

---In 1993, the county adopted the strategy of “dual highs (high quality, high benefit)” to expand the bamboo reserve through technological adoption. For 6 years continuously, RMB 40 million Yuan had been put with widespread participation of the farmers and the county, township and village administration, and consequently 55,000 mu timber-and-bamboo shoot producing land was cultivated and the 236,000 mu low production bamboo land was improved.

---Compared with Moso bamboo *(Phyllostachys heterocycla var pubescens*), the Early–gardening ZaoYuan bamboo (*P. praecox or P. propinqua)* is much more profitable in bamboo shoot production because of its earlier and longer shoot-harvesting feature. By 1999, the 0.3 million mu early-gardening bamboo was cultivated in Anji.

2.3 Stabilization of the Bamboo Land Tenure Relationship

There is a Chinese line goes, “No permanent asset, no permanent effort”. As early as 1983, as the result of the national agricultural reform initiatives, the mountainous land was contracted to the individual household at the Household Group (the sub-village administration) average basis with the duration of 20 years, which was a historic shift from the planned economy times. However, as the duration ends, it was found out that such contracting, because of its different practice from the planned economy measurers, had not been carried out to very high satisfaction of the farmers. To this end, the county administration reacted quickly to extend the contracting for another 30 years, and related legal procedures plus support polices were carried out seriously and in detail. This move comforted the farmers so they are now very willing to put additional effort in bamboo resource maintenance and cultivation.

2.4 Technological Service, Training, Extension and Research

--- The county Forestry Bureau made immense efforts to improve the technological level of the farmers: helping with the planning and design, site problem identification and solution, supply of information and materials (seedlings, fertilizer, pesticides), and financial assistance (low-interest micro-credit etc.).

--- Training by demonstration. The improved technological measures will not be fully understood and accepted until the farmers see with their eyes and are taught to act in their own field. To this end, a number of Technological Demonstrations Bases (national and provincial level,) were established with governmental financing for training and education of the farmers, from as early as the 1950s. These places have also been sites for millions of domestic and international visitors to the bamboo industry of Anji.

---Research. At the county level, the government has helped establish the bamboo research institute, the bamboo technological station, the bamboo botanical garden, and the bamboo museum etc. In addition, domestic universities and research institutes like Chinese Academy of Forestry, Zhejiang Forestry Institute, Nanjing Forestry University, Zhejiang Forestry Academy have been sponsored to do a lot of field studies in Anji. Plenty of state/ provincial level research achievements were made and applied, and many effective reformative measures have been adopted to encourage the researchers to push forward the studies and the technological use in the field.

3 Value Addition by Bamboo Processing

Resource is one side and benefit is the other side. Anji government and the people quickly realize the resource advantage will not exist at all until it is transferred into a commodity advantage. In 1979 Anji Canned Food Factory successfully produced boiled bamboo shoot for export to Japan, so much less bamboo came to be marketed at a low price. The past 20 years is the booming time of bamboo product processing, mainly the bamboo mat, bamboo floorboard and bamboo art crafts. And Anji has also become the major producer of bamboo processing machines of the country.

--- The county government helped the processing first by establishing industrial parks, which means production bases where the investors and producers can enjoy many preferable policies and special governmental services. While many of these overseas and domestic investors made money, the nearby farmers were employed and many farmers established "household workshops" to produce semi-products or parts for the investors' mills.

---- The county government gave particular attention to those enterprises that adopt "high-techs" to carry out the bamboo processing: the Bamboo Liquid (a kind of medicine to cure coughs and tracheitis), the Bamboo Flavone (a cardio- medicine to lower the blood pressure, blood fat level) etc.

4 Bamboo Tourism: the Invisible Value of Bamboo

Bamboo is an important aspect of Chinese culture therefore Anji should make use of it in economic development. But this is not fully realized until the late 1990s. The county government follows the provincial summoning of "establishing Eco-Zhejiang", which was decided by civil surveys and legal procedures that Anji should be positioned as an Ecological County: ecological economy, ecological culture and ecological human residence. To create ecological culture, bamboo forest parks, bamboo museum, bamboo culture festivals etc. were highly pushed through direct governmental involvement. In this process, by opening restaurants, selling folk art crafts and bamboo food, managing household hotels etc. the living condition of farmers are bettering than ever before.

5 Conclusion and the Future

China is a public ownership dominated country, and the flexible options like separation of land / resource ownership right, management right and benefit right beginning from the 1980s significantly released the productivity of the rural area. This is the macro-factor. Relevantly, at the grass-roots level, like the county level, the market economy does not run as it is in other international economies, so effective “political and technological push” is necessary in the orientation stage.

The challenges exist for Anji, especially with the globalization process, like WTO entry and the growing competition of the bamboo industry in the country. Anji needs to review its current status and growth history systematically but with global eyesight to identify a “road map” for sustainable development, especially by adding expertise, by upgrading the production quality level, and socially by looking more closely at the farmers’ wishes.

Chapter 12 Bamboo Industry in Deqing County, Zhejiang Province in China

Deqing County is located in northern part of Zhejiang Province, in the Taihu Lake Basin of eastern China, with a range in east altitude 110 46’~120 42’, north latitude 30 26’~30 42’. The county has 947 square kilometers of land, 54.75 kilometers in east-west and 29.75 kilometers in north-south, in which the forestry land accounts to 400 square kilometers. It has a population of 420,000 in 21 townships. The county is in hilly area, composed of 40% mountainous or hilly land, 50% farming land and 10% water area, its western part is in the branch of Tianmushan Mountain and its eastern part is in a plain with a lot of streams and rivers.

1 Brief Introduction of Bamboo Industry in Deqing

As one of the traditionally managed forest resources, there were about 200,000 mu of bamboo forests in the county in the early 1980s. At that time, the management of bamboo forests was extensive and consequently the plantation productivity was low, where the yearly output of Moso (*Phyllostachys pubescens*) timber, other small-size bamboo culms and shoots were 3 million culms, 1,510 tons and 9,276 tons respectively, mainly because of lack of support of the advanced science and techniques and finance. Meanwhile, the shoots and timber for processing were initially with a low output value amounting to RMB 18.5 million Yuan. Poor development on bamboo resources partly resulted in poor rural economy at that time. In 1986, for instance, the average income per capita in rural area in the county was only RMB 679 Yuan, which was 12.2% lower than the average income of the whole county. In a few places, the farmers even didn’t have enough food.

Since the 1980s, with the policy of reform and opening up has been carried out, the demand for bamboo products has become large with the economic development. As a result, the price of bamboo products rose. On the other hand, farmer’s enthusiasm on production was stimulated by the market policies. In this background, the plan to develop economy in mountainous regions was put forward and implemented by Deqing Government. From a successful practice we can find that the development of bamboo industry can help farmers achieve significant economic benefit in short term, while ecological and social benefits will be achieved coordinately. Based on this, a strategy on mountainous economy development-‘To exploit the potential in mountainous lands to develop forests with emphasis on bamboo resources was put forward. As a result, to develop bamboo resources as a priority has been treated as a major practice in forestry to develop economy in the mountainous areas.

To plan and guide bamboo industry, a strategy on primary, secondary and tertiary sections to develop bamboo industry was made out by the county government, where the primary, secondary and tertiary sections of bamboo industry mean development of bamboo resources, establishment of the processing industry of bamboo shoots, timber and bamboo product market, respectively. With a decade’s efforts, bamboo industry has been developed as a backbone economy in the mountainous areas in the county. Based on the development of the bamboo industry, the forestry and all other aspects of economy in the areas have been greatly improved. As a result, the county was in the list of the top 100 counties in economy in China and was reputed as one of the most comfortable counties in Zhejiang Province.

2 Current Status of the Bamboo Industry in the County

In recent ten years, the bamboo industry has been greatly developed as a priority in the forestry section, where the bamboo plantation area has been raised from 200,000 mu in 1986 to 300,000 mu in 2003 and the output of bamboo industry has been raised from 18,500,000 Yuan to 1,400,000,000 Yuan.

2.1 Primary Section of Bamboo Industry --- Bamboo Resource development

In the management of bamboo resources, the county government encouraged to adopt new advanced management techniques by the cooperation with national and provincial research institutions. A series of high-yield techniques and extension network have been established in the county. High-yield techniques have been applied in management by categories. In management of Moso bamboo plantations, the high-yield techniques such as fertilizing without soil loosening, plantations cultivating for shoots and culms and even-year plantation maintenance were adopted; in the management of small-size bamboo species, the high-yield techniques, such as deeply loosening soil and leaving shoots growing for culms reasonably have been adopted; in the management of the plantations of *Phyllostachys praecox*, comprehensive high-yield techniques such as covering land in winter have been adopted.

In the establishment of new plantations, the adoption of planting one-year culms in rainy season and densely planting techniques has promoted the survival rate of planted bamboos and achieved output 3-4 years earlier than other usual techniques. The yield of bamboo plantation has been greatly increased by the high-yield management practices such as loosening soil deeply, adding a layer of soil, reasonable fertilizing, and preventing pests and diseases. For example, the shoot output of *Ph. praecox* plantations has been increased from 250 kg/mu to 1,000 kg/mu, in some cases, the maximum amounts to 2,500 kg/mu. In Moso plantations, the yield of culms and edible shoots has been increased from 900 kg and 35 kg/mu in every two years to 1,000 kg and 400 kg/mu in every two years. Some new harvesting techniques such as thinning shoots and harvesting culms in a round year instead of only in autumn and winter has replaced the traditional harvesting techniques such as ‘leaving all shoots growing for new culms’ and ‘harvesting culms over 7-year-old only’, so that the harvesting cycle has been shortened to reduce the waste of shoot and culm resources.

In a recent survey, those advanced techniques on high-yield cultivation have been widely applied in the county, where the high-yield techniques on *Ph. praecox*, Moso plantation and other small-size species have been applied in 85% areas of the whole bamboo regions in the county respectively.

So far, there are lots of bamboo products from the rich bamboo resources in the county, where the main products are culms and edible shoots, accompanied with other products such as bamboo branches for brush-making, culm sheathes, bamboo leaves, bamboo roots, and bamboo rhizomes.

The species to produce culms for timber in the county include *Ph. pubescens* (Moso bamboo), *Ph. glauca, Ph. augusta, Ph. iridencens, Pleioblastus amarus*, and others. In the county, the yearly culm output of Moso bamboo amounts to 4.8 million culms and yearly culm output of small-size species bamboo is 8,300 tons. Among the edible shoot products, the main productive species are *Ph. praecox*, Moso bamboo and some other wild bamboo species, in which the yearly shoot output of *Ph. praecox* amounts to 75,000 tons, Moso shoot 10,000 tons and other wild species 1,000 tons. The yearly branches for brush-making amount to 8,900 tons.

As the data in 2002, the yearly output value of the primary sections of bamboo industry, i.e. bamboo resources, is RMB 320 million Yuan, accounting 22.9% of the total in the county.

2.2 The Secondary Section of Bamboo Industry ---- Processing section of bamboo products

The processing industry is an important step to achieve the commercial value of the bamboo resources. Bamboo processing industry used to be small-scale household factories, in which only simple and low-quality products could be produced with low economic benefits in the county in the past. For this reason, several large-scale processing enterprises with advanced processing techniques have been established, all of which have become the leading processing enterprises to utilize the bamboo resources largely. On the other hand, different kinds of enterprises, which were invested as the state-owned or private-owned, have been established.

Until now, there are more than 60 processing enterprises in the county, producing 7 categories and over 400 kinds of products such as tools, furniture, stationery, foods, medicines, handicrafts, and construction materials, where the yearly bamboo consumption amounts to 8 million of Moso culms and 8,000 tons of culms of small-size species and 23,000 tons of bamboo shoots, which accounts for 166.7%, 96.4% and 230% of total yearly yield in the whole county respectively.

So far, there are 8 large-scale processing enterprises which lead the bamboo processing industry in the county, and they are classified as follows:

Shoot processing**:** there are 3 leading enterprises with 40 million RMB Yuan of fixed assets, which consumes 18,000 tons of Moso bamboo shoots every year and their output value amounts to RMB 60 million Yuan.

Timber processing: there are 2 leading enterprises with RMB 80 million Yuan of fixed assets, which consumed 8 million of culms every year and their output value amounts to 220 million RMB Yuan.

Handicrafts making: there are 3 leading enterprises with RMB 40 million Yuan of fixed assets, which processed 2,000 tons of small-size culms and 1 million Moso culms every year and their output value amounts to 50 million RMB Yuan.

According to the data in 2002, the yearly output value of secondary sections of bamboo industry, i.e. bamboo processing, was RMB 860 million Yuan, accounting the 61.4% of the total bamboo industry in the county, among which it makes foreign exchange of 14 million US dollars from exporting.

2.3 The Tertiary Section of Bamboo Industry --- Bamboo market, sale and bamboo cultural activity

The tertiary section of bamboo industry includes establishment of market, sale and bamboo cultural activities such as bamboo tourism.

(1) Market establishment

The markets of bamboo products were established to promote sale in terms of the products. A big market with systematic equipment in 20 hectares of land was established based on former Wukang Bamboo and Wood Sale Station, which becomes the biggest market for bamboo products in Zhejiang province. The market has a yearly commercial deal of 20 million Moso bamboo culms, which amounts to 25% of the total deals in the province, where the currency flow is RMB 230 million Yuan. In Shangbai Town of the county, an edible shoot market was established in 1.8 hectares, where the yearly deal of shoots amounts to 15,000 tons with RMB 80 million Yuan of currency flow. Moreover, several small markets were formed around the shoot market.

(2) Establishment of the sale systems

To promote the sale of bamboo products, local government took some favorable policies to encourage commercial institutions and bamboo farmers to establish the sale systems. So far, about 500 institutions and individuals with 3,000 businessmen have been involved in the sale systems for bamboo products, where the annual deal in sale amounts to RMB 300 million Yuan.

(3) Bamboo cultural tourism

The national scenic spot Moganshan Mountain is well-known for its vast bamboo forests called ‘bamboo sea’, it is located in Deqing county. A bamboo cultural tourism, with bamboo-view, resort, entertainment, holiday, has attracted many tourists from home and abroad. So far, the scenic spot has attracted 200,000 tourists and tourism income amounts to RMB 70 million Yuan every year.

According to the data in 2002, the yearly income of the tertiary sections of the bamboo industry, i.e. bamboo product sale and tourism, is RMB 220 million Yuan, accounting to 15.7% of the total bamboo industry in the county.

3 Evaluation of The Bamboo Industry

Guided by the policy and strategy to develop the bamboo industry as a priority, the social economy in the mountainous areas in the county has been greatly promoted.

3.1 Bamboo Industry Has Become a Backbone of the Rural Economy in Mountainous Areas in the County

(1) Bamboo industry has become a major industry in mountainous areas

In the county, bamboo forests account for 45% of the total forests. The development of bamboo industry has produced many employment chances. So far, totally 42,000 laborers are working in bamboo industry, among which 35,000 people work in cultivation of the bamboo resources, 2,000 in sale markets, and 5,000 in processing section, which is distributed in 79.2% of all households and amounts 35% of the total population in the bamboo growing area. As a result, the bamboo industry has become the main income sources for the people.

(2) Bamboo processing is an advantageous industry in the private enterprises

The rich bamboo resources supply raw materials for the industry in the private enterprises. Until now, bamboo industry has become an advantageous part in rural areas. For instance, there are 28 enterprises in Fatou Town, among which 24 enterprises are in the processing industry whose yearly output value amounts to RMB 320 million Yuan, which amounts 86.4% of the total output.

3.2 Bamboo industry brings great income for the farmers

Income from bamboo industry has become a major source for the farmers. As a result, many farmers alleviate their poverty and are living a comfortable life by developing bamboo products. Before the bamboo industry was developed in Shangbai Town, for example, the income per capita was 44.5%, lower than the average in the county. So far, the income per capita in town has amounted to the average of the county, in which the income from bamboo products amounts 64% of the total income. In the town, households with the yearly income of RMB 10,000 Yuan are more than 1,800. Another example is in Fatou Town, where there are over 300 households out of the total 480 households, have a yearly income of RMB 10,000 Yuan from the bamboo products.

Chapter 13 The Bamboo Industry of Lin'an County: Problems in bamboo shoot processing and utilization and the solutions

1 Overview of the bamboo industry in Lin'an county

Lin'an County is located in Tianmu Mountain, northwest Zhejiang Province at 118°51′-119°59′ east longitude and 29°56′-30°26′ north latitude. The county has a total area of 3 126km^2 and a population of 500,000 with a forest coverage rate of 71.3%, the total forestland area in the county adds up to 260,000 ha, of which bamboo forests take up 52,000 ha. The County is reputed as a "Bamboo Homeland of China". The annual income per capita of the farmers in 1988 was RMB 4,199 Yuan. Since the 1980s, the county started planting bamboo on the hill and mountain slopes, focusing on planting the "three bamboo species"-vegetable bamboo, Moso bamboo (*Phyllostachys heterocycala var. pubescens*) and shoot bamboo, as well as on the joint development of the "three industries". These measures helped Lin'an to increase its bamboo forest area from 29,000 ha to 52,000 ha. As a result, the gross yield of bamboo shoots grew from 2,000 tons to 80,000 tons, and the bamboo-generated gross yield of bamboo shoots grew from 2,000 tons to 80,000 tons, and the bamboo-generated gross output value increased from 20 million Yuan to 650 million Yuan. Bamboo has become the primary industry of the rural areas of Lin'an county as well as the "goose that lays golden eggs", contributing significantly to rural poverty alleviation.

1.1 Bamboo Resources of Lin'an County

There are 63 bamboo species belonging to 11 genera in Lin'an county. Areas and distribution of the bamboo species are described below.

1.1.1 Moso Bamboo

The area of Moso bamboo forests in Lin'an county is about 20,000 ha, on which 40.4 million bamboo culms are grown, yielding 10,000 tons of fresh bamboo shoots annualy. This bamboo species is mostly distributed on the low mountains, where 4,000 ha of high-yield bamboos are planted to produce bamboo timber and shoots.

1.1.2 Vegetable Bamboo

"Vegetable bamboo" is the general title for *Phyllostachys praecox* and *Ph. prominers* species that produce edible bamboo shoots. Vegetable bamboo forests area in Lin'an is totally 14,000 ha, and are mostly planted on the low hills and gentle mountain slopes, especially in the dry farmlands around the farmhouses. The annual yield of vegetable bamboo is 76,540 tons. With the extensive application of the early-shooting and high-yield technology for *Phyllostachys praecox,* the annual output value reached 270 million Yuan, the unit production up to 46.5 tons/ha and the unit output value up to 825,000 Yuan/ha. In 1997, the average annual income of the 6,500 farmer households in Lin'an from bamboo was over 10,000 Yuan, among which 70 households earned over 50,000 Yuan and 4 households earned as high as 100,000 Yuan.

1.1.3 Shoot Bamboo

"Shoot bamboo" is the general term employed for small-diameter bamboo species such as *P. nuda, P. iridescens, P. yiamuensis and P. acuta.* These species spread over an area of 15,000 ha in the county, mainly on steep mountain slopes at an elevation of about 600m above sea level, particularly in the remote mountainous areas. Annual yield adds up to 17,380 tons, which can be processed to produce 1,738 tons of dried shoots.

1.2 Development of Bamboo Processing

In Lin'an, there are 130,000 farmer households, 60% of which are directly engaged in bamboo growing. They have built 46 shoot-processing factories and over 100 bamboo timber factories. The bamboo timber factories are now producing 508 bamboo products in 10 types, including panels, threads, mattresses, knit-ware, chopsticks, meat skewers, toothpicks, toys and scaffold plates. The annual output of bamboo plywood panel has now reached 500,000m^2. About 100 mattress production lines are producing over 5.4 million m^2 of Bamboo culms.

1.3 Development of Markets for Bamboo Products

In the 1990s, 11 large markets for selling the bamboo shoot products were built in Gaohong and Hengtang townships of the county, where over 5,000 people, mostly farmers, market their bamboo shoot and timber products. In Pudong New District of Shanghai, Hengda-Tianmushan Bamboo Shoot Market was established, there parts of the products are exported to the international markets.

1.4 Establishment of Service Networks

Lin'an County has developed a strong scientific and technological foundation for developing the bamboo industry as well as service networks. Service stations and substations have been established in Lin'an, and service posts have been set up in 39 townships. The Bamboo Shoot Research Institute and Bamboo Shoot Development and Research Institute have been set up. An association of the bamboo shoot processing enterprises has been established in the county and bamboo associations have been set up in 11 townships. These service networks provide consultation services to the Party Committees and local government, as well as the bamboo industry related to pre-production, production and post-production.

2 Bamboo Shoot Processing and Utilization

2.1 An analysis of the Current Situation

Bamboo shoots produced in Lin'an are mostly processed into three categories of products: boiled shoots (canned), dried shoots and preserved shoots.

2.1.1 Boiled Shoots

Raw materials used for this product include bamboo shoots of Moso and *Ph.vivax*. As *Phyllostachys praecox* shoots fetch a high price, they are sold as unprocessed fresh shoots. However, in the last two years when the price of *P.praecox* shoots dropped below 1.4 Yuan/kg, some factories started processing the shoots into the boiled products. Lin'an was among the municipalities and counties in China that first processed canned boiled shoots. The first bamboo shoot processing factory was built in 1979 and put into operation in 1980. In the same year, 113 tons of canned bamboo shoots (packed with their juice) were produced. Export of the product had brought in foreign exchange revenue of US$66,600.

The technical process for producing the boiled shoots is as follows: raw material cleaning→ boiling→ cooling → sorting → rinsing → anning → adding juice→ can sealing → sterilizing → cooling→ storage. By 1988, there were 9 factories in Lin'an County, including the Lin'an Canned Food Factory that produced canned products are using Moso bamboo shoots. The gross output of these factories added up to 5,221.66 tons, and the foreign exchange earnings amounted to US$ 16.956 million. By 1998, the producers of canned boiled shoots had increased to 46 factories, and the output had reached 690,000 cans (12 500 tons). Among the products, 546,000 cans were made with Moso bamboo shoots and 152, 000 cans by using *Ph.vivax* bamboo shoots. The export volume reached 9,000 tons, bringing about foreign exchange earnings of US$ 45 million. Earlier, most locally grown Moso bamboo shoots were used for processing. At present, raw materials are largely purchased from outside the county. In 1998, 80% of the raw Moso bamboo shoots processed in Lin'an came from Fujian and Jiangxi Provinces.

With the expansion of vegetable bamboo growing area in Lin'an, fine processing of *Ph.vivax* bamboo shoots also developed rapidly. After some surveys in 1994, Mr. Zhang Fengchao from Taiwan established the first boiled bamboo shoot processing factory in Yangling township of Lin'an, which focused on production by using *Ph.vivax* bamboo shoots. The factory produced a series of soft-packaged shoot products that found favor with customers. By continuously introducing new equipment and up-to-date technology, more new shoot products were developed, and the bamboo shoot processing in Lin'an reached a new level. Guided by this initiative, the number of enterprises manufacturing boiled shoot products increased from 4 in 1994 to 26 in 1998. The gross processing capacity of these enterprises amounted to 220,000 tons, and the net value of their fixed assets increased from 1 million Yuan in 1994 to 43 million Yuan in 1998. The annual processing capacity also increased from 1,300 tons in 1994 to 11,730 tons in 1998, the sales income reached 52.15 million Yuan. In the field of boiled shoot processing, 22 enterprises produced 4,783 tons of *Ph.vivax* products, netting a sales income of 17.5 million Yuan. Nine enterprises switched over from rough processing to fine processing, and developed over 10 series of delicious shoot products. The products were packed in small packages, soft packages or cans, which boosted their value by 1.5 to 2 folds. The technological process (fine processing) now adopted for making boiled shoot products is as follows: boiling shoots→ rinsing → chopping → compress dewatering →flavoring → weighing → packing → selecting →adding edible oil →vacuum sealing → pressurized sterilization → drying → quality control → exterior packing → sealing → storage. The refined processing technology provided by Mr. Zhang Fengchao not only ensured preservation of the freshness of raw materials, but also tackled the problems of producing packed shoots and ready-to-eat shredded shoots. The technology has covered the complete process of production, from handing of raw shoots and preservation of freshness of the shoots to producing small packaged shoots and ready-to-eat shredded shoots without using any preservatives and antioxidation chemicals. The technology is ideal for fine processing and thus effectively enhances the product quality.

2.1.2 Dried Bamboo Shoots

'Tianmu' dried bamboo shoot is the special product of Lin'an county. It is produced by using the small-diameter shoots picked from bamboos such as the *Phyllostachys nuea, P. iridescens, P, yiamuensis* and *P.acuta.* According to the *Annals of Lin'an County,* Tianmu bamboo shoots were favored by people of South China in the Zhenged and Jiajing containing rich nutrients. The Tianmu dried bamboo shoots have a delicious taste and contain rich nutrients. The product is therefore widely used as an appetizer (*The Economic Herald* of Hongkong once praised Tianmu dried bamboo shoot as "the number one delicious food in the world"). The best of Tianmu shoot is the tender shoot sprouts. The technology is also the earliest to appear in the market. The "Top Tianmu sprouts" produced in Sankou and Shanggan areas are picked and processed when the sprouts are extremely tender, and are probably the most delicious among the shoot products.

In 1997, 3,000 tons of dried bamboo shoots were produced in Lin'an County, of which 1,738 tons were processed using local shoots. The gross output value amounted to 26.07 million Yuan, which was 1.9 times that of 1993. The Xitianmu Township produced 1,100 tons of dried shoots in 1997, at an output value of 8.16 million Yuan. In Lin'an, most farmers in the bamboo shoot-producing areas are good at making traditional shoot products. However, there are only 12 large processing enterprises in the entire county. Recently, another brand called Tianmu Zhijian was developed by the Lin'an Tianmushan Green Food Co., Ltd. The company took a refined technology to process the dried shoot and developed a tasty ready-to-eat dried shoot product, multi-flavor dried shoots and local-flavor dried shoots. Key steps of the technological process for producing such items are given below: peeling of shoots → rinsing → boiling → dehydration → sterilization → compress dewatering →bake dewatering →squeeze dewatering →re-bake dewatering → semi-product storage → sorting → packing → marketing. An alternative route after "re-bake watering" is: fine cutting → flavoring →baking → storage → sorting → packing → marketing.

With the development of the dried shoot processing industry, besides purchasing raw shoots and producing dried shoots within Lin'an, the shoot-processing farmers and factories began to preliminarily process or purchase raw bamboo shoots in other areas of Zhejiang and in the neighboring provinces such as Hunan, Hubei, Aihui, Jiangxi, Fujian, Sichuan, Guizhou and Shanxi. According to Lin'an farmers:"Where there is bamboo, there are Lin'an folks". Many farmers in the shoot-producing areas did not know that small-diameter bamboo shoots are edible and their processing can earn money. Most of these farmers live in areas such as Shennongjia of Hubei Province and the Hanshui River watershed, which are poverty-stricken areas though shoot bamboos are extensively grown there. With assistance from the Lin'an shoot-processing farmers, the local farmers increased their income. They began to realize that tapping the shoot resources is an ideal way for poverty alleviation. In 1997, Lin'an became China's largest market for trading dried bamboo shoot products. At the same time, over 1,000 people, majority of them were farmers, were engaged in bamboo shoot grading activities, and their bamboo shoot products dominated markets in Jingxi, Zhejiang and Shanghai. Only in Xitianmu Township, each of the 100 plus bamboo shoot traders were annually marketing over 5 tons of dried bamboo shoot products, and three of them were each selling over 50 tons of dried bamboo shoot products.

2.1.3 Preserved Bamboo Shoots

Preserved shoot is one of the primary bamboo shoot products. The processing method is of low cost. After rinsing, the preserved shoots are even more delicious than the canned shoots, and become an excellent raw material for producing snack foods that sell well in the markets. Because the technology is good for factory production, it is widely applied in the primary processing of bamboo shoots. The technology is also welcome among the farmer households as shoots can be easily preserved for future use when they cannot be sold on time or the price is too low. In 1997, over 200 tons of shoots were preserved in Lin'an. The technology for processing preserved bamboo shoots is as follows: peeling of shoots → rinsing → boiling → dehydration → sterilization → loading into containers → addition of salt between shoot layers → compressing → sealing.

After rinsing, preserved bamboo shoots can be fine-processed or directly marketed. As long as the seal is intact and the containers do not leak, the product will retain its good quality for over one year.

2.2 Experiences in the Development of Bamboo Shoot Processing Industry

(1) Persistence in democratic decision-making and emphasis on processing. To bring about a better life to farmers living in the mountainous areas and to find a breakthrough for developing the rural economy, after discussions and scientific and technological verifications, the Party Committee and People's Government of Lin'an county concluded that felling trees for timber sale would cause fatal harm to the economy of the mountainous areas. They also realized that Lin'an has eight outstanding advantages-excellent geographical locations, and bamboo industry would bring about remarkable economic, ecological and social well-being. Based on this thought, the municipal leaders decided to focus on developing the bamboo industry as the tool for developing the rural economy. By joining forces from all social sectors, Lin'an began to newly plant 660 ha of bamboos each year from 1996, while the output of bamboo shoots also substantially increased each year. Because of the increasing bamboo plantations, the output of bamboo shoots increases rapidly. The harvesting of most bamboo shoots during April-May created marketing difficulties. To solve this problem, the municipal Party Committee and government drafted the strategy of "prioritizing bamboo production, making efforts to speed up product circulation, focusing on processing, and seeking coordinated development", and the strategy of "building bamboo production bases on the mountains, constructing factories down the mountains, and exploring markets outside the mountains". The new guideline of "optimizing the primary industry, deepening the secondary industry, strengthening the tertiary industry and industrializing the bamboo industry" was also promulgated. Preferential policies were formulated and implemented to help develop the bamboo processing industry, and efforts were made to establish bamboo shoot processing as the leading industry.

(2)Setting up of Association of Bamboo Shoot Processing Enterprises and promoting the healthy development of shoot processing enterprises. The Association of Bamboo Shoot Processing Enterprises is a trade association formed through the voluntary participation of shoot processing enterprises. In the two years since its establishment, the Association followed the principle of "strengthening the enterprises and prioritizing services", and made its goal to boost the overall strength of the membership enterprises. Through good coordination and services, the Association has endeavored to build up links between the processing enterprises, served as the bridge between the enterprises and the government, and vigorously promoted competition among the enterprises and the healthy development of the bamboo shoot processing industry. In the last two years, the Association has provided all-round services to the enterprises in the following six areas: Offering coordination to promote cooperation; Information access to boost development; Helping marketing to promote product circulation; Carrying out inspections to enhance management; Publicizing investigations to upgrade services; and Organizing study tours to facilitate the improvement of work performance.

Through the improved services in the last two years, the Association has helped bring about new prospect to the bamboo shoot processing industry in Lin'an County, while maintaining order in the industry. Unequal competition among enterprises has been greatly curbed while the fair competition nurtured. These measures have greatly promoted the healthy development of the bamboo shoot processing industry in Lin'an County.

(3)Taking markets as the guide, making science and technology as the support, and upgrading the level of enterprise management and product quality. To ensure success of the bamboo shoot industry of Lin'an County, it was essential to gain recognition of the customers and boost the competitiveness of the products. To achieve these goals, both the municipal leaders and the processing enterprises have gained a full understanding that production must be guided by market demands, and that the science and technology input to the products development deserves the highest priority. Since 1992, when Mr. Zhang Fengchao established Yihua Company, Luo Chunying, Director of the Bamboo shoot Development Institute of Lin'an County, insisted on developing new shoot products and upgrading the product quality. Up to now, Mr. Luo has developed 12 new shoot products, among which 7 have become patented products of China and won in 1994 the gold medal for new products awarded by the State Commission of Science and Technology and the Award for Developing New products issued by the People's Government of Lin'an County. In 1995, these products were nominated as the "consumers' Trustworthy Products of China" and "Provincial Quality Products". In the same year, the Chinese Gourmet and Nutrition Committee listed the products as the first group of "Recommended Products", while Zhejiang Province has named the products as "designated tourist products".

To upgrade the quality of bamboo shoot products and to enhance the management level, the Association invited experts and technicians from the Municipal Technology Supervision Bureau and Public Health and Disease Prevention Center to teach the members the specifications for food products and regulations for food hygiene. Some factories have developed cooperation with the Food Department of Zhejiang University and Zhejiang Academy of Agricultural Sciences, and invited experts and professors from these institutions to serve as technical advisors.

Based on the market demand, Lin'an Canned Food Co., Ltd. of Hangzhou City has introduced modern Japanese equipment, such as thread-cutting, slicing and vacuum-packing machines. Such measures have significantly upgraded the product quality. Lin'an Tianmushan Green Food Co., Ltd. and Simake Food Co., Ltd. of Hangzhou City produces top-quality products, which have won gold medals at the International Bamboo Exposition(sponsored by the 1999 China International Bamboo

Culture Festival), and the products were nominated as the “Designated products” at the 1999 China Agriculture Exposition.

2.3 Current Problems in the Bamboo Shoot Processing Industry

Most bamboo shoot processing enterprises are small-scale, and the competition is largely price-based. In Lin’an County, most bamboo shoot processing enterprises are small and use simple equipment. Among them, 41 enterprises can process only 200 tons on the average. Owing to their small scale, low capitalization, shortage of cash flow and inadequate scientific and technical staff, such enterprises base competition on product prices. They compete against each other by cutting prices and buying raw materials at reduced prices. In other words, these enterprises fail to compete by upgrading quality of the products and creating quality brands.

Technology for retaining the freshness of bamboo shoots is lacking. Development of the market-oriented economy calls for higher quality products, and the customers demand that preserved shoot products retain, as much as possible, the juiciness and taste. Regretfully, the enterprises have not yet fully mastered freshness preservation technology, and a considerable gap still exists between the processed products and customer demands. Large cities like Shanghai have formulated strict regulations to restrict bamboo shoots with skins entering the cities, thus necessitating that the shoots to be preserved by other means. Enterprises in Lin’an are still adopting the out-dated technology adopted in 1995 by Yihua Company for producing boiled shoot products. Owing to the lack of technological breakthroughs, products made by the old technology can hardly meet the requirements of the customers.

Markets are to be expanded for selling the shoot products. Yield of the vegetable bamboo shoots has increased from 1,400 tons in 1983 to 76,000 tons at present, a 50-fold increase. As the bamboo shoot trade brings about considerable profits, many neighboring counties and municipalities are also vigorously developing shoot processing industry. The shoot products of Lin’an are mostly sold in the domestic markets in Jiangsu, Hangzhou and Shanghai areas, and exported only to Japan. The small-sized market can hardly accommodate the drastically increasing production capacity, resulting in serious glut of shoot products.

Inadequate information leads to blind production. As mentioned earlier, most shoot producing enterprises are small ones, and employ out-dated means and equipment for information access. This has led to poor information dissemination, and many enterprises expect the customers are aware of the products by themselves. Many shoot producing farmers do not show market-oriented awareness, and produce their products blindly. In 1998, a few farmers made good profits by producing preserved shoots, that led to a big rush of preserved shoot production in the following year, resulting in serious over-production and market glut. Consequently, many farmers had to sell their products at reduced prices.

3 Main Considerations for Developing Shoot Processing Industry

3.1 Strategic Objectives

It is planned to grow 1 million mu (approximately 15 mu equals 1 ha) of bamboo forests and raise the gross output value generated by the bamboo industry to 1.5 billion Yuan by 2010. By 2005, it is expected that five enterprises will be established, each having an output value of 10 million Yuan from shoot processing, while the gross output value of the shoot processing industry would be boosted to 200 million Yuan. By 2010, it is expected that the strategic objective of increasing the gross output value of the shoot processing industry to RMB 400 million Yuan would be achieved and shoot-producing group companies can be formed.

3.2 Major Measures Required

We need to nurture the leading enterprises of shoot producing industry. The leading enterprises play a vital role in the industrialization of the shoot producing industry. Presently, the shoot producing enterprises are mostly small ones. Although number of the leading enterprises in the shoot processing industry have established branded quality products, they should be further developed to help them adapt to the development trends of the existing shoot production bases and to meet Lin'an' rural economic development objectives. Governments at all levels must prioritize their support for promoting the industrialization of bamboo shoot processing, as well as the nurturing of the leading shoot-processing enterprises. New and improved policies may be adopted to provide these enterprises with high-quality services in funding, credit, taxation and land using, and to establish an insurance cover for them. The leading enterprises must be guided to sign production and sales contracts with the farmers or production bases to gradually forge closer ties and integrate them into the system to share profits and losses. The leading enterprises must also be guided to create quality brand products, and those enterprises that create famous brands should be rewarded, paving the way for market expansion and technology upgrading.

Strengthening trade management, and promoting healthy competition among the shoot-processing enterprises. Ordered and equitable trade competition is the fundamental requirement of a market-oriented economy. To reach this goal, the bamboo shoot processing trade must have its own intermediary organization, such as the trade union. As mentioned earlier, Lin'an County established the Association of Bamboo Shoot Processing Enterprises to address the chaotic competition among the shoot-processing enterprises that seriously hindered the healthy development of the shoot-processing industry. After its establishment, the Association has repeatedly called meetings to coordinate the activities of the enterprises to curb unhealthy competition and to promote ordered competition under a contract. One of the important clauses of the contract sets forth support prices for products of the same grade. Although some preliminary achievements have been made by Lin'an County in strengthening the trade management, a lot has to be done in the future. The regulations need to be further improved and perfected to strengthen the supervision on implementation of the trade codes and regulations. It is advisable that relevant state departments cooperate and establish the All-China Association of the Bamboo Shoot Processing Enterprises, which would take the responsibility of managing the shoot processing trade. By promoting ordered and reasonable competition, the credibility and export volume of Chinese bamboo shoot products in the international markets could be enhanced and the industrialization of the bamboo shoot processing promoted.

Continuing to introduce and train personnel for the food processing industry, and stepping up the development of new technologies and new products. It is suggested that forestry research institutes, universities and colleges at respective levels step up their efforts in studying the bamboo shoot processing technologies, and upgrade the level of bamboo shoot processing through innovations. Meanwhile, selected forest industry personnel must be sent to food departments of relevant universities or colleges for further training. With these measures, the forestry technicians would be able to master shoot processing technologies. Apart from introducing talented personnel, the enterprises must also vigorously train their existing workers. They must establish quality brands making use of scientific and technological advancements. Moreover, the products should have better packaging with distinctive features and printed with standardized language to attract the consumers.

The channels for selling bamboo shoot products need to be further increased. Presently, Chinese bamboo shoot products are exported mostly to Japan. It is important to diversify the export markets by penetrating the European and American countries. The shoot producing enterprises must step up their refined processing, and develop products that would sell well in the European and American markets. According to the national plan for forest industry development, bamboo shoot products would reach 4.0464 million tons by 2010 owing to the rapid development of the bamboo shoot production bases. It would be logical to sell much of the bamboo shoot products in the domestic markets. Unfortunately, people of many Chinese provinces or regions are not used to eating bamboo shoots, and many are not even aware of the different shoot products. Therefore, it is necessary to aggressively publicize the different shoot products. The shoot processing enterprises must also improve their marketing methods. For example, they should not only sell products but also teach the customers how to cook the shoot products. Such measures would go a long way in establishing a healthy bamboo shoot processing industry.

Chapter 14 Bamboo Sector Development Policy and its Implementation in Anji

There are totally 953 ha state-owned bamboo forest in the county, which occupies 1.4% of the whole county's bamboo forest. Previously, those bamboo forests were mostly managed by state-owned forest plantation. And it is contracted to forest plantation staff or the farmers nearby to manage since 1990. The management mode in the village since the 1950s has always been collective management, unified sale and unified allotment by the village's production team. It is not until 1981 that the whole county started up a project, namely, mountain and forest rights fixation, self-reserved mountain allocation, forestry production responsibility system (PRS) implementation. Therefore, the whole county had set up PRS with the main mode of farmers' family contracted management (FCM). In the whole countryside, the bamboo forests are collectively owned by the villages and each villager groups reach 56,184 ha (842766 mu). Among these, 43,503 ha (652552 mu) are Moso bamboo forest, which occupies 84.1% of the whole bamboo forest's area, and 3,467 ha (52005 mu) belongs to the farmer's self-reserved bamboo forests. From 1984 to 2001, the collectively owned mountainous areas where single farmers planted bamboo forest through contracts with the forests' rights reserved to the farmers reached 6,234 ha (93,509mu). Therefore, the bamboo forest area, which is managed by single farmers, reaches 14.5% of the whole. The main steps of a contracted management are listed as below:

a. Government officials will come and determine the mountains and areas, then hand out forest right certificates to villager groups (5,488 certificates in the whole county up to now).

b. Each villager group will organize to examine the standing bamboo resource, area, boundary, standing area class, standing bamboo amounts and then calculate the total amount of the grownup bamboo timber.

c. Calculate each family's grain ration (laborer's status of the family), and select members based on both the grain ration and laborer's status equally to participate in the villager group's resource allocation, then make out every family's contract basic number.

d. Organize meeting with all the farmers to have a democratic discussion, and then decide each farmer's contracted area and place. In some villages, part of the bamboo forest will be reserved to the village collectively through farmers' meeting. The income from these bamboo forests will be used as the expenditure of some non-profit projects.

The duration of the first round contracted management is 15 years (some villages extended to 20 years). According to the statistics in 1984, the bamboo forest belonging to the collective in the whole county was 39,800 ha (597000 mu), 90% of the collectively owned bamboo forest was managed by farmers through contract. There were 8,800 ha of middle and small diameter bamboo forest 68.9% of which was contracted to the farmers. With the implementation and fulfillment of the contract policy, 98% of the bamboo forest will be managed by the farmers (including some workers and private manufacturers) through contract in the near future, except some tourist spots, state-owned bamboo forests, county- and village-owned bamboo forests.

Bamboo forest contracted management has promoted the farmers' production initiatives. Farmers strengthened management on bamboo forests and increased their investment too. Therefore, both bamboo forest's economic benefit and yielding are promoted and many high-yielding and high-benefit plantations have emerged. To stabilize the bamboo forest production, in 2001, the county government sent many of its officials to the villages to undertake a project of stabilization and extension of bamboo forest contract responsibility system.

Up to September, 2001, there had been 28,930 and 8,077 farmers whose contracts expired and unexpired. Among them, 28,188 and 7,943 farmers resigned to extend their contract duration respectively, which occupied 97.4% and 98.3% respectively. The resigned contract duration is for 30 years (up to 2031). For the problems such as big differences between farmers' contract area and bamboo standing amount caused by family member change and forest land confiscation etc., the solution of "contracted bamboo forest remain unchanged and profit made out of those land should be re-allocated" is adopted to balance it. (e.g. To some families with large contracted bamboo forest areas, if the number of their family members decreases, their contracted areas remain unchanged within the contract duration, but they are required to hand in part of their profit earned from their extra bamboo forest land to the villager group. And the villager group will allocate the corresponding profit to those farmers for compensation for those farmers' family member increases, thus their bamboo forest area per person decrease.) Meanwhile, farmers are permitted to transfer or re-contract their bamboo forest to the others based on the principle of "freewill and compensation". But both sides need to sign a contract and hand it in to the village community for their file.

Bamboo forest cultivation supporting policy and its implementation

To increase its bamboo forest resource and raise the quality, Anji County has always attached great importance to bamboo forest cultivation and management. Besides governmental guide, scientific and technical demonstration and stipulation of some regulations to protect bamboo shoot and timber locally, the government has always been giving economic support to bamboo forest cultivation since 1991.

Farmers and others who contract mountainous land to plant bamboo forest and if they reach the forestry department technical standard after checking, they will receive a subsidiary of 1,200—1,500 RMB Yuan per ha.

Farmers disseminate "low-yielding bamboo forest rebuilding technology" and if they reach the technical standard of the forestry department in the checking, they will receive a subsidiary of 450 RMB Yuan per ha.

Farmers grow bamboo forest for both shoot and timber use and if they reach the forestry department technical standard after checking, they will receive a subsidiary of 750 RMB Yuan per ha.

Farmers undertake the project of establishing high-yielding and high-benefit bamboo shoot and timber forest layout by forestry department and if they reach the technical standard of the forestry department after checking, they will receive a subsidiary of 750—1,500 RMB Yuan per ha.

If the bamboo forest is listed in the county's or village's scientific and technical demonstration forest, the county, township or village will allocate a subsidiary of 750 RMB Yuan per ha to the farmers at the first 1---3 years.

If the bamboo forest is destroyed by the pest, those farmers who have benefited are responsible for dealing with it. For some paroxysmal pests, the government will coordinate and allocate certain subsidiary for the pesticide.

Bamboo forest cutting regulation

Selective cutting is the exclusive way for bamboo cutting in Anji County. Only 5-year-old and above Moso bamboo is allowed to be cut. This is the same to most of the middle and small diameter bamboos.

Cutting duration is from Sep. 15 to March in the next year. Besides, the forestry bureau will carry out some "waxberry red" Moso bamboo cutting plans in July.

The cutting amount is regulated: restricted cutting is implemented in cutting Moso bamboo. Except those bamboos in the self-reserved land and some around the residence, farmers need to apply for a cutting license to cut Moso bamboo from state owned, collective owned bamboo forest and also cutting from their contracted bamboo forest, self-reserved mountainous area forest with diameter of over 5 cm.

Each township's Moso cutting plan is first stipulated by the forestry bureau of the county, and then handed in to the county government for approval. After approval, the plan will be executed. The township will allocate the cutting task to its villages according to the distribution of bamboo resources. Then the village will allocate the cutting task to farmers according to their contracted bamboo forest area by poster. Cutting plan of the middle-and-small-diameter bamboo is drawn up by each township, which should be sent to the county's forestry bureau for their file, and then be allocated to each village and each village will allocate the cutting amount to farmers according to their contracted area.

The cutting plan is stipulated based on forestry bureau staffs' on-spot survey. Every year, the forestry bureau will send its staff to those bamboo shoot villages to survey the new bamboo shoots' and bamboo timber's yielding. There are 2 kinds of pilots: fixed ones (provincial- and county-level) and the temporarily selected ones. The intended cutting amount is 90% of this year's total bamboo timber yielding principally. Middle and small diameter bamboos' timber yielding is surveyed by the township's forestry station and is required to send to the forestry bureau for their file. The cutting amount almost equals to the bamboo timber amount. Recently, Anji county's Moso cutting amount is restricted to 18.5 million culms per year in which middle-and small-diameter bamboos' is 60000—70000 ton.

Regulation on bamboo sale, processing and transportation

Moso bamboo, no matter of middle-and small-diameter and their by-products are sold through multi-channels. Whoever obtains the business license and bamboo and wood manufacturing license is allowed to take up the business of sale and processing. Those units who want to purchase bamboo are only required to make a registration at the village where they intend to purchase bamboo culms by presenting the above 2 licenses.

For transportation, if the bamboo timber and its products are to be transported out of the county but inside Zhejiang province, only the Zhejiang Province Timber

Transportation License is needed. If they are to be transported to the other provinces, only a Trans-province Timber Transportation License is needed. Transportation license can be applied at the county's license transaction center or every township's and village's forestry stations or those license transaction spots near the timber examination stations. In real practice, Moso bamboo, middle-and small-diameter bamboos' out-of-township or village transportation license can be obtained in the local township or village by presenting a village certificate. The input to the county can be applied to get a local license just by showing their transportation license. License must go with the cargo, one license for one vehicle and is valid from the beginning to the end of the trip. The vehicle should accept the timber examination stations' examination along the road. If the license is valid, then the vehicle can continue the trip. Otherwise, it must re-transact the license will be fined and confiscated.

Bamboo tax collection policy and its collection method

(1) Tax collection standard: government will collect a special forestry products tax of 8-16% from the farmers and bamboo processing plants. The tax is calculated as 15 RMB Yuan per 50kg. To lighten the burden of the bamboo farmers and bamboo processing plants, this tax has been cancelled since 2000. But if the output bamboo culms and their products are sent to other places in the province, a bamboo forest cultivation tax must be collected, and a forest resource compensation tax is collected when output bamboo culms and its products are sent to other provinces. The details are listed as below:

Table I: Anji County's bamboo products forest cultivation fund collection and its quarantine standard reference.

type	Item	SpecificationUnit	Tax collection standard (Yuan /50kg) Forest cultivation Fund	Forest area build fee	Forest resource compensation tax	Remarks
Moso	Big Moso	Diameter>=7cm	0.48Yuan/culm	0.05 Yuan/culm	0.18 Yuan/culm	
	Small Moso	Diameter 5-6cm	0.24 Yuan/culm	0.05 Yuan/culm	0.09 Yuan/culm	
By-products	Inferior small Moso	50kg	12x6%	0.5		Dia.=<4cm
	Middle & small diameter Moso	50kg	12x6%	0.5		All
	Waste materials	50kg	12x6%			
	Bamboo tips	50kg	6x6%			Processed
	Old branches	50kg	6x6%			Processed
	Broom	Pcs.	0.03Yuan/pcs.			All sizes

Table Ⅱ: Bamboo plants quarantine fee collection standard reference

Item / Type	unit	Collection standard (Yuan)	Tax collection start point (Yuan)	remarks
Moso and its products	Culm	0.02	1.00	
Middle & small diameter bamboo tips	50 kg	0.05	1.00	
Broom	Pcs.	0.005	0.5	
Bamboo sheath	50 kg	0.02	0.5	

(2) The standard of bamboo products timber consumption depreciation

Zhejiang province bamboo products timber consumption depreciation standard will be executed when the bamboo products are transported:

a. For the bamboo products are mainly made from the green surface of the bamboo culms, such as the old-fashioned mats, cage, handicrafts etc., and every 50kg can be converted from 15 bamboo culms.

b. For the bamboo products mainly made from the yellow surface of the bamboo culms, every 50 kg can be converted from 6 bamboo culms. The bamboo products include bamboo strips, bamboo curtain, cushion, and dustpan, incense stick, etc.

c. For the bamboo products and semi products mainly made from the raw bamboo culms, every 50 kg can be converted from 5 bamboo culms. These products include scaffold, ladder, bed, chair, bench, closet etc.

d. For the refined bamboo products made from both the first green layer and the second layer of bamboo culms, every 50 kg can be converted from 10 bamboo culms. The products include chopsticks, toothpick, round strip curtain, pillow, bamboo steamer etc.

e. The following products should be divided into wet and dry 2 types so as to be converted from the consumption depreciation of standard bamboo culms:

① Bamboo strip made mats: the wet one should be converted from 10 bamboo culms while the dry one 20.

② Mah-jong mat: the wet one can be converted from 10 culms while the dry one should be 15 culms.

③ Bamboo flooring strips: the wet one can be converted from 6 culms while the dry one should be 15 culms.

f. Bamboo slices:

20 bamboo slices with a width of 4.5 cm and length of 200cm are converted from 1 standard culm.

15 bamboo slices with a width of 4.5 cm and length of 300cm are converted from 1 standard culm.

10 bamboo slices with a width of 4.5 cm and length of 400cm can be converted from 1 standard culm.

g. Bamboo culm: 4 pieces of culms with the central circum length of 24 cm and length of 240 cm are converted into 1 standard culm.

h. Bamboo charcoal: 300kg bamboo charcoal can be converted from 100 standard bamboo culms.

Notes:

1. Standard bamboo refers to those raw bamboo culms with the length of 0.25 m and weight of 16.5 kg.

2. The rate of the charcoal's finished products is about 18%.

3. Raw bamboo culm transportation will be calculated according to the exact culm number.

(3) Forest cultivation fund and forest area building fee are collected on the base of the basic number. Based on the bamboo yielding villages, the county government will notify every township or village for the previous 4-year forestry cultivation fund collected from the restricted cutting tax and bamboo by-products tax of Moso bamboo. 80% of the 4 years' average number will be treated as the basic number for this year's tax collection. The county forestry bureau will allocate it to every township and village. For those whose tax collections reach the basic number, 20% will be given back to them for bamboo industry development, 80% will be given to the county forestry bureau among which 15% of the remaining 80% will be turned into the provincial forestry bureau and 5% of the remaining 80% will be handed in to prefecture forestry bureau for whole county's forestry production and policy administration. This expenditure will be supervised by its superior and will be overseen by the county's financial department and audit department.

Forestry police team setup and its administration, forestry policy

According to the items listed in *Forest Law* and some other forest protection regulations, the county forestry bureau should set up a forestry policy administration office and forestry resource administration office to take charge of the whole county's forestry policy administration, which mainly includes forestry right administration, cutting and transportation administration, management and processing administration, forestry administration and fine administration, etc. To carry out the anti-criminal actions to protect the forest resources, forest security which consists of forestry police office, forest police team and 4 forest police stations was set up in 1985. It is led by the county's forestry bureau and police bureau. Forest police station has acquired the right of forestry administration fine.

To intensify bamboo and wood regulation and standardize tax collection, our county has set up bamboo and wood examination station and examination spots along the main road to other counties or provinces according to *Forest Law*. To facilitate administration, bamboo forest patrol team has also been set up.

In townships' or villages' forestry stations, there is the forestry policy staff, ticket administration staff, etc. In those key bamboo and wood villages, forest protection team has been set up to assist the villages to manage their forest.